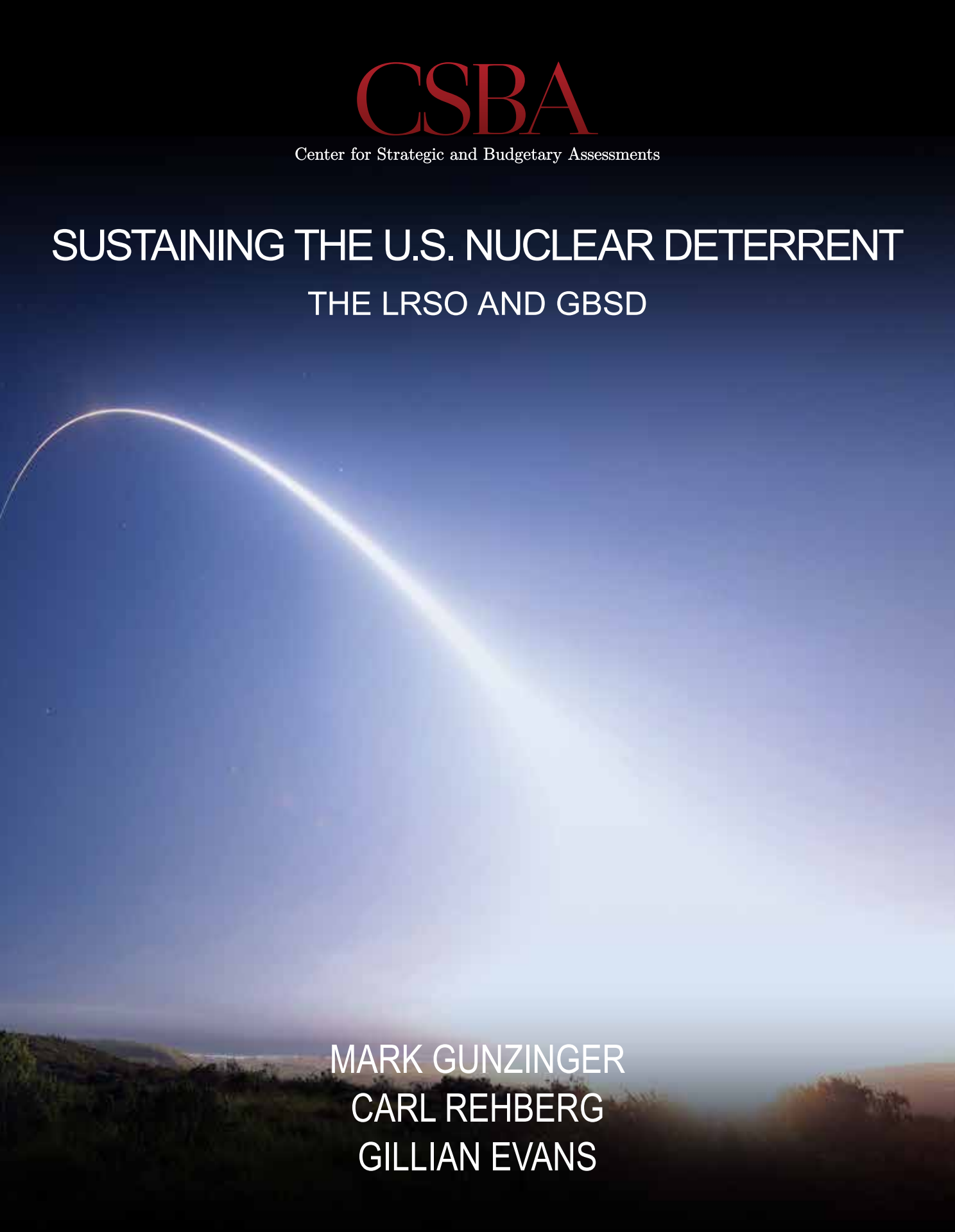

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THE LRSO AND GBSD

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The Center for Strategic and Budgetary Assessments is an independent, nonpartisan policy research institute established to promote innovative thinking and debate about national security strategy and investment options. CSBA's analysis focuses on key questions related to existing and emerging threats to U.S. national security, and its goal is to enable policymakers to make informed decisions on matters of strategy, security policy, and resource allocation.

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Cover Graphic: An unarmed Minuteman III intercontinental ballistic missile launches during an operational test at Vandenberg Air Force Base, CA on February 25, 2016. U.S. Air Force photo by Senior Airman Kyla Gifford.

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Executive Summary

The ability to launch a retaliatory strike in response to a nuclear aggressor has long underpinned the strategic deterrence posture of the United States. Since the 1960s, a complementary set of capabilities known as the nuclear triad has enabled this strategy. The United States developed this triad of intercontinental ballistic missiles (ICBM), long-range bombers, and nuclear ballistic missile submarines (SSBN) during the Cold War primarily to deter nuclear attacks by the Soviet Union. The U.S. ICBM force of approximately 400 Minuteman III missiles deployed to underground launch silos located in five states continues to provide the capability to respond rapidly to a nuclear first strike on the United States.[1] Dispersing this force across such a large area makes it more difficult for an enemy to launch a preemptive nuclear strike with high confidence that it will destroy all operational U.S. ICBMs. The U.S. nuclear-capable bomber force, which now consists of B-52Hs and B-2s, is the most visible and flexible leg of the triad and is survivable once generated.[2] During a crisis or conflict, these bombers could be used to signal U.S. resolve, disperse to distant locations to avoid a potential attack, and hold at risk a wide variety of targets. The Navy's fleet of *Ohio*-class SSBNs, which can sortie and disperse at sea, is the most survivable leg of the triad and provides the redundancy that helps assure the United States has a second-strike capability.

Although the Soviet Union is a relic of the past, the continued threat of nuclear attack by a great power or a rogue state is a major reason why every U.S. administration since the end of the Cold War has validated the need to maintain a safe, secure, and credible triad. Russia maintains a stockpile of approximately 4,300 nuclear warheads and continues to adhere to military doctrine that indicates in might be willing to use nuclear weapons to coerce an

1 "The term 'deployed ICBM' means an ICBM that is contained in or on a deployed launcher of ICBMs." See The Treaty between the United States of America and the Russian Federation on Further Reduction and Limitation of Strategic Arms, signed in Moscow on January 3, 1993, p. 4, available at https://www.state.gov/documents/organization/140047.pdf.

2 The Air Force is developing a new B-21 "Raider" stealth bomber that will be nuclear capable. B-21s should begin to join the force in the mid-2020s timeframe.

adversary and prevail in a conventional conflict.[3] Both Russia and China are funding multiple programs to modernize their nuclear arsenals, and the proliferation of nuclear weapon and missile technologies has allowed North Korea to fast-track the development of an offensive nuclear capability. Today, a total of nine states have nuclear weapons, and it is possible that additional aspirants, such as Iran, could field nuclear weapons in the not-too-distant future.[4] To deter these threats and promote stability in an increasingly uncertain security environment, the United States will continue to need a triad that provides "flexible, adaptable, and resilient" capabilities and forces.[5]

Looking Ahead, Not Back

All Nuclear Posture Reviews (NPR) completed by the Department of Defense (DoD) since the end of the Cold War validated the need to sustain the U.S. triad.[6] Until recently, however, post-Cold War U.S. administrations have chosen to reduce the size of the triad and cancel, delay, or truncate triad modernization programs, including programs to replace its now nearly 50-year-old Minuteman IIIs and 35-year-old AGM-86B air-launched cruise missiles (ALCM). This is reflected in the funding allocated to DoD's "Strategic Forces" investment portfolio (see Figure 1). Strategic Forces funding accounted for approximately 22 percent of DoD's annual Total Obligation Authority (TOA) in 1962 and averaged about 9.6 percent per year until the end of the Cold War. The portfolio's TOA share decreased to an average of about 2.4 percent from FY 1992 through FY 2017, a level that was barely sufficient to fund upgrades and programs to extend the operational lives of aging triad weapon systems.

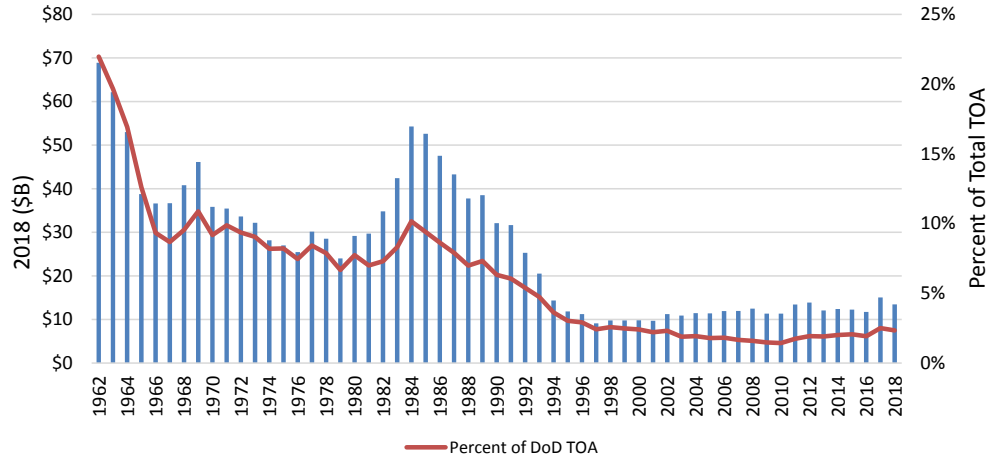
3 Robert Work, Deputy Secretary of Defense, and Admiral James Winnefeld, Vice Chairman of the Joint Chiefs of Staff, Statement to the Committee on Armed Services, U.S. House of Representatives, June 25, 2015, p. 4, available at http://docs.house.gov/meetings/AS/AS00/20150625/103669/HHRG-114-AS00-Wstate-WinnefeldJrUSNJ-20150625.pdf/. According to Nikolai Sokov, "The doctrine introduced the notion of de-escalation—a strategy envisioning the threat of a limited nuclear strike that would force an opponent to accept a return to the status quo ante. Such a threat is envisioned as deterring the United States and its allies from involvement in conflicts in which Russia has an important stake, and in this sense is essentially defensive." Nikolai N. Sokov, "Why Russia Calls A Limited Nuclear Strike 'De-Escalation'," *Bulletin of the Atomic Scientists,* March 13, 2014, available at https://thebulletin.org/why-russia-calls-limited-nuclear-strike-de-escalation. Also see Hans M. Kristensen and Robert S. Norris, "Russian Nuclear Forces, 2017," *Bulletin of the Atomic Scientists,* February 28, 2017.

4 "Nuclear Notebook," *Bulletin of the Atomic Scientists*, available at http://thebulletin.org/nuclear-notebook-multimedia.

5 Office of the Secretary of Defense (OSD), *Nuclear Posture Review 2018* (Washington, DC: DoD, February 2018), p. vi.

6 The 2010 Nuclear Posture Review (NPR) affirmed that "retaining all three Triad legs will best maintain strategic stability at reasonable cost, while hedging against potential technical problems or vulnerabilities." OSD, *Nuclear Posture Review Report* (Washington, DC: DoD, April 2010), p. 21, available at https://www.defense.gov/Portals/1/features/defenseReviews/NPR/2010_Nuclear_Posture_Review_Report.pdf. After the U.S. Senate ratified the New START Treaty, President Obama stated that he intended to "modernize or replace the triad of strategic nuclear delivery systems: a heavy bomber and air-launched cruise missile, an ICBM, and a nuclear-powered ballistic missile submarine (SSBN) and SLBM." The White House, "Message from the President on the New START Treaty," February 2, 2011, available at https://obamawhitehouse.archives.gov/the-press-office/2011/02/02/message-president-new-start-treaty-0.

FIGURE 1: FUNDING FOR DOD'S STRATEGIC FORCES INCLUDING MODERNIZATION[7]



There is no shortage of critics, studies, and reports that have questioned the need to modernize the U.S. triad. Skeptics tend to focus on the expense of maintaining and modernizing the U.S. triad as well as the inherent threat posed by the existence of nuclear weapons. So-called "global zero" advocates support creating a substantially leaner U.S. nuclear force or eliminating one or more legs of the triad.[8] Barack Obama, George Shultz, William Perry, and others have endorsed the global zero aspirational goal of eliminating all nuclear weapons. Perry, in particular, has been a strong advocate for retiring all U.S. ICBMs and not funding a replacement for the ALCM.[9]

The tendency of many of these critics, however, has been to view triad modernization through the lens of the immediate post-Cold War period, a time when there were few credible threats to America's ability to project military power. Today's operational environment is very

7 Office of the Under Secretary of Defense (OUSD) (Comptroller), *National Defense Budget Estimates for FY 2018, FY 2018 Greenbook* (Washington, DC: DoD, June 2017), Tables 6-4 and 6-5, available at http://comptroller.defense.gov/Portals/45/Documents/defbudget/fy2018/FY18_Green_Book.pdf.

8 Janne E. Nolan, *An Elusive Consensus: Nuclear Weapons and American Security After the Cold War* (Washington, DC: The Brookings Institution, 1999). A good portion of this book covers the debate during the 1994 NPR on reducing the U.S. triad. Also see General Accounting Office, *The U.S. Nuclear Triad* (Washington, DC: GAO, June 10, 1993). More recent studies advocating the reduction of U.S. nuclear forces include the Global Zero U.S. Nuclear Policy Commission, *Global Zero U.S. Nuclear Policy Commission Report: Modernizing U.S. Nuclear Strategy, Force Structure and Posture* (Washington, DC: Global Zero, May 2012), available at https://www.globalzero.org/files/gz_us_nuclear_policy_commission_report.pdf; and Barry Blechman and Russell Rumbaugh, *Protecting US Security by Minimizing the Role of Nuclear Weapons: A New US Nuclear Policy* (Washington, DC: The Stimson Center, May 2015), available at https://www.stimson.org/sites/default/files/file-attachments/ProjectAtom_051315%20%281%29.pdf.

9 "First and foremost, the United States can safely phase out its land-based intercontinental ballistic missile force, a key facet of Cold War nuclear policy. Retiring the ICBMs would save considerable costs, but it isn't only budgets that would benefit. These missiles are some of the most dangerous weapons in the world." William J. Perry, "Why It's Safe to Scrap America's ICBMs," *New York Times*, September 30, 2016, available at https://www.nytimes.com/2016/09/30/opinion/why-its-safe-to-scrap-americas-icbms.html. An International Institute for Strategic Studies (IISS) Adelphi series report by Dr. James Doyle also calls for a much smaller triad or dyad. James. E. Doyle, *Renewing America's Nuclear Arsenal: Options for the 21st Century,* IISS Adelphia Paper (New York: Routledge, 2017).

different than the one that existed shortly after the fall of the Soviet Union. Although national security experts acknowledge that the proliferation of nuclear technologies, precision guidance systems, missile technologies, and other modern military systems threatens DoD's future ability to project power, they generally do so in the context of how they will affect conventional military operations. Advanced integrated air defense systems (IADS) and other anti-access and area-denial (A2/AD) capabilities designed to constrain the U.S. military's freedom of action also threaten the survivability—and ultimately the credibility—of triad weapon systems that were designed for Cold War threat environments.

DoD has funded several life extension programs to keep ALCMs in the force until around 2030. However, it is unlikely that programs focused on addressing the ALCM's availability and sustainability issues have significantly improved its ability to survive in future threat environments. Absent the development of a new standoff attack weapon with greater ability to penetrate future air defenses fielded by Russia, China, and increasingly other potential aggressors, non-stealth B-52s that now make up the majority of the nuclear-capable U.S. bomber force will not be able to credibly threaten a number of targets. While stealth bombers can penetrate defended airspace, the small number of stealth bombers currently in the inventory (20 B-2s) limits the number of targets they can hold at risk, at least until the next-generation stealth B-21 begins to join the force in the mid-2020s. Moreover, as air defenses continue to improve, low-observable strike platforms may need to launch attacks against some targets from standoff distances that exceed the very short ranges of gravity bombs. Consequently, the failure to modernize the air breathing leg of the triad, to include its weapons and its bomber aircraft, would erode the credibility of the U.S. strategic deterrence posture.[10]

DoD has also funded multiple programs to sustain its Minuteman III ICBMs beyond their original ten-year planned service life. Completed programs have upgraded the maintainability and reliability of the Minuteman III's guidance system and replaced its solid propellant and post-boost propulsion components. Ongoing initiatives include the ICBM Fuze Modernization Program.

Despite these upgrade and sustainment programs, there are critical Minuteman III capabilities that cannot be sustained much past the year 2030. For example, Minuteman III electronics updated by the completed Guidance Replacement Program begin to age out in 2032. The propellant used in the Minuteman's three stages also begins to age out in the late 2020s, and many of the ICBM's first and second stages, which have had their solid fuel washed out and re-poured once before, are not viable candidates to undergo this process a second time. Experts across the Air Force and defense industry believe issues related to extending

10 James MacStravic posed this concern as a major strategic choice during testimony to Congress: "Our choice is between modernizing those forces or watching a slow and unacceptable degradation in our ability to deter adversaries who present existential threats to our nation." James MacStravic, performing the duties of the Under Secretary of Defense for Acquisition, Technology and Logistics, "Fiscal Year 2018 Budget Request for Nuclear Forces," testimony before the Strategic Forces Subcommittee, Senate Armed Services Committee, June 7, 2017, p. 3, available at https://www.armed-services.senate.gov/imo/media/doc/Macstravic_06-07-17.pdf.

Minuteman III solid rocket motors are so significant that they undercut the viability of doing so and could increase the risk that the size of the U.S. ICBM force will dip below minimum operational requirements. Component age-out is a major reason why the Air Force has requested funding to develop and field a replacement for the Minuteman III.

Report Purpose and Scope

This report assesses a number of arguments that have been made against replacing the ALCM and the Minuteman III. A previous CSBA report, *The Future of America's Strategic Nuclear Deterrent,* recommended DoD and Congress support critical triad modernization programs and forgo reductions in the size of its nuclear forces below the ceiling created by the New Strategic Arms Reduction Treaty (START).[11] A second CSBA report, *The Cost of U.S. Nuclear Forces: From BCA to Bow Wave and Beyond,* assessed costs associated with modernizing the triad.[12] The report's analysis reveals that although triad modernization program costs are projected to grow significantly, then decline as the "bow wave" of new weapon system procurement tails off, their total cost will remain a small percentage of DoD's overall budget. Building on both assessments, this report first addresses A2/AD complexes that increasingly threaten the ability of U.S. guided weapons, including cruise and ballistic missiles, to reach their designated targets. It then assesses the need to replace ALCMs and Minuteman III ICBMs with modern weapons systems. The report concludes that maintaining a credible triad will require funding for programs that will replace the Air Force's aging and increasingly obsolete ALCMs and ICBMs with capabilities that will meet requirements well into the future.

The following sections take the form of recommendations for planning and developing a future triad that is credible, flexible, and able to operate in future threat environments. Specific weapon system recommendations are limited to the two most recent triad modernization programs, the Long-Range Standoff weapon (LRSO) and Ground Based Strategic Deterrent (GBSD). This limited scope is not intended to diminish the importance of procuring a new stealth bomber for nuclear and conventional missions or funding a replacement for the Navy's *Ohio*-class SSBNs. Both are critically needed.

Recommendation: Plan for Multipolar Strategic Competitions

Most current U.S. triad capabilities were developed for a Cold War threat environment that was dramatically different than the one that national leaders face today. Over the last two decades, Russia and China have sought to expand their global influence and diminish confidence in the United States as a security guarantor in their respective regions. In support of

11 Evan Braden Montgomery, *The Future of America's Strategic Nuclear Deterrent* (Washington, DC: Center for Strategic and Budgetary Assessments, 2013), pp. i–iii, 26.

12 Todd Harrison and Evan Braden Montgomery, *The Cost of U.S. Nuclear Forces: From BCA to Bow Wave and Beyond* (Washington, DC: Center for Strategic and Budgetary Assessments, 2015), available at http://csbaonline.org/uploads/documents/CSBA-NCS_Resize_FINAL_WEB.pdf.

these strategic objectives, China and Russia (and other potential adversaries) have invested heavily in conventional offensive and defensive weapons to offset the U.S. military's ability to project power. These countervailing capabilities include offensive guided weapons, which can be used to attack U.S. regional bases and forces, and increasingly advanced air and missile defenses. They are also evidence of a "salvo competition" dynamic in which adversaries continuously seek to gain advantages by improving their capabilities to attack with precision and defend against precision strikes. A previous CSBA report, *Sustaining America's Precision Strike Advantage,* assessed new operating concepts and capabilities that could sustain the U.S. military's conventional precision strike competitive advantage against great powers and other adversaries with advanced air and missile defenses.[13] The following chapters use the same salvo competition concept as a framework to identify the challenges to U.S. *nuclear* strike capabilities created by the spread of advanced air and missile defenses, and then assess requirements to modernize the triad in light of these challenges.

Multipolar great power competition includes actions to strengthen strategic nuclear deterrence postures. Russia and China are both engaged in modernizing their respective nuclear arsenals. Sustaining a credible nuclear-capable force to assure U.S. allies and meet America's extended deterrence commitments is part of the great power competition dynamic. According to DoD, maintaining a credible U.S. nuclear force, including dual-capable weapons systems, enables most U.S. allies to abstain from developing their own nuclear weapons.[14]

Long-term competition with Russia and China should inform DoD's force planning

Future U.S. forces and capability portfolios, including weapon systems needed to sustain strategic deterrence and meet extended deterrence commitments, should be sized and shaped for threats posed by China as well as Russia. Force planning scenarios used by DoD to assess its future requirements should incorporate operating concepts to deter a great power competitor's use of nuclear weapons, including non-strategic nuclear weapons. Russia's national security strategy and military doctrine indicate that it could threaten to use or even employ nuclear weapons to change the course of a conventional conflict.[15]

13 Mark Gunzinger and Bryan Clark, *Sustaining America's Precision Strike Advantage* (Washington, DC: Center for Strategic and Budgetary Assessments, 2015). Available at http://csbaonline.org/research/publications/sustaining-americas-precision-strike-advantage.

14 OSD, *Nuclear Posture Review 2018*, p. viii.

15 "Over the past decade, Russia has made nuclear weapons a predominant element of its national security strategy and military doctrine." Matthew Kroenig, The Renewed Russian Nuclear Threat and NATO Nuclear Deterrence Posture (Washington, DC: Atlantic Council, February 2016), p. 1, available at http://www.matthewkroenig.com/Kroenig_Russian_Nuclear_Threat.pdf. Also see Nikolai Sokov, "Russia's Nuclear Doctrine," NTI Issue Brief, August 2004; and Dmitry Adamsky, "If War Comes Tomorrow: Russian Thinking About 'Regional Nuclear Deterrence'," *The Journal of Slavic Military Studies* 27, no. 1, 2014, pp. 169–177.

China's nuclear forces should not be considered as a "lesser included case"

The size and mix of capabilities in the future U.S. triad should support a range of flexible options to deter or respond to nuclear aggression by China as well as Russia. During the Cold War and for much of the post-Cold War period, U.S. planning and resource priorities for the triad were based mainly on deterring a Russian nuclear strike. However, there is mounting evidence that China is modernizing its nuclear forces and acquiring new variants of ballistic and cruise missiles that are nuclear capable or dual capable, such as the DF-26 intermediate-range ballistic missile (IRBM) and the new DF-41 road-mobile ICBM.[16] Future U.S. arms limitation initiatives should address China's growing nuclear weapons portfolio and ambitions, as well as the key technologies, manufacturing systems, and other capabilities exported by Russia and China that could lead to the further proliferation of nuclear weapons to other actors.

Assess capabilities needed for future threat environments

DoD should assess the effectiveness of its triad in future threat environments. Increasingly capable IADS with active and passive sensors, electronic warfare systems, directed energy weapons, GPS denial capabilities, and other defenses could significantly decrease the probability that U.S. guided weapons—conventional and nuclear—will arrive at their designated targets. Continuing to rely on decades-old ICBMs and nuclear cruise missiles that will not be effective in future threat environments will eventually erode the credibility of the U.S. triad.

Leverage triad modernization to help revitalize the U.S. defense industrial base

Developing a new ICBM and LRSO would help revitalize associated U.S. industrial bases. This should be a national priority.[17] The ICBM industrial base is linked to the broader industry that develops and manufactures solid rocket motors, guidance systems, and other components for surface-to-air and surface-to-surface weapons. Similarly, the development and production of an LRSO could help sustain the industrial base that provides the U.S. military with next-generation conventional air-to-air, air-to-ground, and other munitions needed for future salvo competitions.

16 The DF-26, first seen in public during a 2015 parade in Beijing, is likely based on China's DF-21D. The DF-26 may be an anti-ship as well as a land attack weapon. "China: Strategic Weapon Assessments," *Jane's Sentinel Security Assessment: China And Northeast Asia*, updated April 17, 2017, available at https://janes.ihs.com/Janes/Display/jswsa399-jsws. The DF-41, currently in testing, will be a road-mobile and silo-based ICBM with MIRV capability. Some reports indicate that it will have a range of 12,000 to 15,000 km, which would make it China's longest-range ICBM. See "Dong Feng 41 (DF-41/CSS-X-20)," *MissileThreat*, CSIS Missile Defense Project, available at https://missilethreat.csis.org/missile/df-41/#enref-518-3; and OSD, *Military and Security Developments Involving the People's Republic of China 2017*, Annual Report to Congress (Washington, DC: DoD, May 15, 2017), p. 31, available at https://www.defense.gov/Portals/1/Documents/pubs/2017_China_Military_Power_Report.PDF.

17 The *2017 National Security Strategy* stressed this point: "We will modernize our nuclear enterprise to ensure that we have the scientific, engineering, and manufacturing capabilities necessary to retain an effective and safe nuclear Triad and respond to future national security threats." *National Security Strategy 2017* (Washington, DC: The White House, 2017) p. 30

Recommendation: Plan for Replacing the AGM-86B ALCM

The ALCM, whose service life has been extended far beyond its planned retirement date, will soon be unable to penetrate advanced IADS to strike their targets. Even with increased funding, the availability, survivability, and reliability of the ALCM inventory will be uncertain. Without a capable nuclear standoff attack capability, the U.S. strategic bomber force will have to rely on using very short-range gravity bombs to attack defended targets. This could reduce the ability of the air-breathing leg of the triad to attack targets defended by advanced IADS.

The LRSO also represents a cost-imposing capability that will complicate adversaries' efforts to develop defenses against U.S. precision strikes. Unlike ballistic missiles that have a more predictable flight path, a bomber force can attack from multiple vectors. To counter these attacks, adversaries would have to develop and procure more advanced and greater numbers of defensive systems and other countermeasures. This could divert an enemy's funding and other resources away from competing military priorities, including the procurement of additional offensive capabilities. The development of the B-1 had this effect during the Cold War; it caused the Soviet Union to divert significant resources to develop defenses against U.S. penetrating aircraft capable of low-altitude, supersonic flight.[18]

Fully resource the LRSO program to replace the ALCM as planned

The continuing proliferation of increasingly advanced air and missile defenses underscores the need to maintain a U.S. bomber force that has a diverse range of strike capabilities, including the ability to launch nuclear weapons from outside the most lethal contested areas. The ability to strike from standoff ranges into contested areas will be lost when the ALCM is no longer capable of penetrating threat environments.[19] Fully funding the LRSO program will help avoid delays to developing and fielding the ALCM's replacement.

18 Gordon Barrass discusses the impact of U.S. investments in high-end capabilities on the U.S.-Soviet strategic competition: "Although the contract for 100 B-1s was not signed until 1982, the concept of a low-flying supersonic bomber played into Soviet fears, and the Soviet air defense forces leapt to the bait. The Soviets spent billions developing the MiG-25, new surface-to-air-missiles, and radar to counter the threat. The strategists in the Pentagon were pleased to see Soviet money spent this way, rather than on more offensive weapons." See Gordon S. Barrass, "Competitive Strategy During the Cold War," in Thomas Mahnken, ed., *Competitive Strategies for the 21st Century: Theory, History and Practice* (Stanford, CA: Stanford University Press, 2012), p. 78.

19 "The Long-Range Standoff (LRSO) Weapon will replace the ALCM and sustain the ability to penetrate advancing air defenses." Robert Scher, "The U.S. Nuclear Modernization Program," DoD briefing, slide 11, available at https://2009-2017.state.gov/documents/organization/263731.pdf. Also see Office of the Undersecretary of Defense for Acquisition, Technology, and Logistics (OUSD [AT&L]), *Report to Congress on the Number of Long-Range Standoff Weapons as Specified by Section 1657 of the National Defense Authorization Act for Fiscal Year 2016* (Washington, DC: DoD, March 2016), pp. 1–3, available at https://www.ucsusa.org/sites/default/files/attach/2016/04/FY16-LRSO-cost-reporting-requirement.pdf?_ga=2.10700477.864310662.1517093440-828786151.1511191845.

Assess operating concepts for using the LRSO to support extended and tailored deterrence

The U.S. has lost a great deal of its capacity for carrying out its extended deterrence commitments in the event deterrence fails, including the Navy's nuclear Tomahawk Land Attack Missile (TLAM-N), which was retired in 2013. This, in turn, has undermined the U.S. ability to reassure its allies. The 2018 NPR recognized this shortfall and recommended a study and analysis of alternatives for a new sea-launched cruise missile.[20] Cruise missiles with nuclear warheads and dual-capable fighters remain important capabilities for meeting America's extended deterrence commitments. DoD should also develop operating concepts for using the LRSO as a flexible deterrent option that complements this sea-based capability.

Recommendation: Plan for Replacing the Minuteman III

The U.S. land-based ICBM force provides a capability to immediately respond to a major nuclear strike against the United States. Its size and distribution across a large area improves its survivability against an enemy's first strike. It also acts as a "missile sink" that greatly increases the number of targets an enemy would have to expend weapons against in a first strike. It is also considered by many to be the most cost-effective leg of the triad. A recent DoD assessment concluded that annual operations and support funding required for its Minuteman III force was about $1.4 billion per year, compared to $3.8 billion for the *Ohio*-class SSBN force and about $1.8 billion for 20 B-2s and 40 B-52s.[21] These attributes compliment capabilities provided by other legs of the triad and strengthen the U.S. deterrence posture as a whole. If the capabilities and size of the land-based ICBM force were allowed to diminish to the extent that the U.S. triad was a *de facto* dyad, adversaries would need much fewer weapons to attack other U.S. nuclear forces that were not generated or dispersed.

The Minuteman III was never intended to remain in the operational force well into the 21st century. Despite a series of modernization and life extension programs, the weapon system's age, key components whose service lives cannot be extended, and obsolete technologies will degrade its reliability and sustainability. Moreover, DoD has concluded that additional investments to extend the Minuteman III are unlikely to keep enough missiles in the force to meet U.S. requirements for operationally deployed ICBMs much past 2030.[22] Over time, these shortfalls will undercut the credibility of the U.S. strategic triad, which is reliant on an ICBM

20 The 2018 NPR report also states that "in the near-term, the United States will modify a small number of existing SLBM warheads to provide a low-yield option." OSD, *Nuclear Posture Review 2018* (Washington, DC: DoD, February 2018), p. 52.

21 Roger W. Burg, *America's Nuclear Backbone: The Value of ICBMs and the New Ground-based Strategic Deterrent* (Arlington, VA: Mitchel Institute, 2017), p. 31.

22 U.S. Air Force, *Cost Comparison of Extending the Life of the Minuteman III Intercontinental Ballistic Missile to Replacing it with a Ground-Based Strategic Deterrent*, Report to Congress (Washington, DC: U.S. Air Force, July 2016), pp. 4–6, available at https://insidedefense.com/sites/insidedefense.com/files/documents/oct2016/10132016_mm3.pdf. According to the 2018 NPR, "A series of life extension programs have kept Minuteman III viable, but component aging and inventory attrition are rapidly driving it to the end of its sustainability . . . The Minuteman III service life cannot be extended further." OSD, *Nuclear Posture Review 2018*, p. 46.

force to deter aggressors from crossing the nuclear threshold and to provide a rapid response capability should deterrence fail.

Fully resource the GBSD program to replace the Minuteman III force

Sustaining the land-based leg of the triad as a reliable deterrent will require the Air Force to replace the Minuteman III—and do so expeditiously. Further extending and modernizing a number of critical Minuteman III components is not feasible, and the resources needed to do so would fund the development and procurement of its replacement, the GBSD.

Continue the on-time development, procurement, and fielding of the GBSD force

According to the New START Treaty between the United States and Russia, "Each side can retain no more than 700 deployed ICBMs, deployed SLBMs [submarine-launched ballistic missiles], and deployed heavy bombers equipped to carry nuclear armaments."[23] The United States has chosen to operationally deploy 400 Minuteman IIIs to underground silos and retain an additional 50 empty (or non-deployed) ICBM silos. To meet these requirements past 2030, DoD should develop and field the GBSD as planned. Due to periodic test launch requirements and aging missile components that cannot be replaced or undergo life extension, the total remaining Minuteman III inventory will not support a force of 400 operationally deployed missiles much past 2030. In other words, a delay in the GBSD program created by insufficient funding or other for other reasons would equate to a unilateral decision to reduce the size of the U.S. ICBM force. This could have a destabilizing effect, since it could lead a great power aggressor to believe that it could allocate a greater number of its nuclear weapons toward attacking the small number of remaining U.S. bomber bases and SSBN facilities.

Design the GBSD to hedge against uncertainty

Modifying Minuteman IIIs to carry a single warhead reduced the U.S. ability to quickly increase the number of U.S. operationally deployed warheads in the event that Russia decides to break out from the New START Treaty's limitations or China unexpectedly increases the size of its nuclear force.[24] Ensuring the GBSD has the ability to quickly change its payload

23 The treaty between the United States and Russia "limits each side to no more than 800 deployed and nondeployed land-based ICBM and SLBM launchers and deployed and nondeployed heavy bombers equipped to carry nuclear armaments. Within that total, each side can retain no more than 700 deployed ICBMs, deployed SLBMs, and deployed heavy bombers equipped to carry nuclear armaments. The treaty also limits each side to no more than 1,550 deployed warheads; those are the actual number of warheads on deployed ICBMs and SLBMs, and one warhead for each deployed heavy bomber." Amy Woolf, *The New Start Treaty: Central Limits and Key Provisions* (Washington, DC: Congressional Research Service, October 5, 2017), summary, available at https://fas.org/sgp/crs/nuke/R41219.pdf.

24 As summarized later in this report, Russia retains a large number of theater nuclear weapons and has developed a ground-launched cruise missile that violates the INF Treaty. There is also considerable uncertainty and debate over China's nuclear weapons doctrine and the size of its nuclear weapons inventory.

configuration would help restore this strategic flexibility and provide a hedge against unforeseen changes in an adversary's nuclear weapons strategy and posture.[25]

25 This is addressed by DoD's latest NPR: "Given the increasing prominence of nuclear weapons in potential adversaries' defense policies and strategies of Russia and China, and the uncertainties of the future threat environment, particularly from illicit North Korean nuclear and missile programs, U.S. nuclear capabilities and the ability to quickly modify those capabilities are essential to mitigate or overcome risk." OSD, *Nuclear Posture Review 2018*, p. 24.

Introduction

An Older and Smaller U.S. Triad

The U.S. bomber force

The air-breathing leg of the U.S. triad consists of B-52H and B-2 bombers capable of delivering nuclear weapons. The B-52 is a non-stealth bomber designed in the 1950s primarily to support the strategic deterrence mission. The Air Force has retired all but 75 of the more than 700 B-52s it procured through the early 1960s. To meet New Start Treaty limitations, DoD chose to keep only 46 of these bombers capable of delivering nuclear weapons. Twenty B-2 stealth bombers are the only U.S. long-range strike aircraft capable of penetrating areas defended by advanced air defenses. The Air Force is currently developing the B-21 stealth bomber, which should begin to join the force in the mid-2020s, to maintain its ability to strike globally in contested threat environments well into the future. B-1B bombers, which also remain in the Air Force's active inventory, were de-certified for nuclear missions in 1994 and now support completely conventional missions.[26]

FIGURE 2: AGM-86B ALCM

A right side view of an AGM-86 ALCM in flight on January 11, 1980. U.S. Air Force photo.

26 "B-1B Lancer," U.S. Air Force fact sheet, updated December 16, 2015, available at http://www.af.mil/About-Us/Fact-Sheets/Display/Article/104500/b-1b-lancer/.

The Air Force has a variety of nuclear gravity weapons that can be carried by its nuclear-capable aircraft. According to unclassified sources, there may be approximately 510 B83 and B61 gravity weapons now in the U.S. inventory. The B83, which is the "largest bomb remaining" in the operational nuclear gravity bomb inventory, may be retired in the 2020s.[27] A life extension program will replace four existing B61 variants with a single weapon called the B61 Mod 12 that will have new and refurbished components, as well as a tail kit to improve its accuracy. According to the National Nuclear Security Administration, B-2s; dual-capable F-15E and F-16C/D fighters; and, in the future, B-21s and dual-capable F-35 fighters will be certified to carry B61 Mod 12 bombs.[28]

The Air Force began to develop the AGM-86B ALCM in the 1970s to improve the B-52's ability to strike targets that were defended by air-to-air interceptor aircraft and surface-to-air missiles (SAM). Initially fielded in 1982 with a projected service life of 10 years, the ALCM is a subsonic, long-range cruise missile designed to evade Soviet-era airborne and ground-based defenses. Concern over the weapon's ability to survive increasingly lethal Soviet air defenses caused the Air Force to initiate a program to replace its ALCMs shortly after they first became operational in the early 1980s. The resulting AGM-129 Advanced Cruise Missile (ACM) had stealth coatings, forward-swept wings, and other design features to improve its ability to penetrate contested areas.

FIGURE 3: AGM-129 ACM

U.S. Air Force photo.

Due to the end of the Cold War and for other reasons, DoD terminated ACM production early, did not replace its ALCMs, and eventually retired all ACMs before the end of their service life. Thirty-five years after ALCMs were first fielded, DoD is ready to replace them with a new cruise missile called the Long-Range Standoff weapon. According to the Air Force, the LRSO

27 Amy F. Woolf, *U.S. Strategic Nuclear Forces: Background, Developments, and Issues* (Washington, DC: Congressional Research Service, August 8, 2017), p. 30, available at https://fas.org/sgp/crs/nuke/RL33640.pdf.

28 "B61-12 Life Extension Program," National Nuclear Security Administration, available at https://nnsa.energy.gov/sites/default/files/nnsa/factsheet/b61-12_lep.pdf.

will have the ability to penetrate advanced IADS, operate in GPS-denied environments, and hold high value targets at risk from significant standoff ranges.[29]

The U.S. ICBM force

The Air Force's first operational ICBM, the liquid-fueled Atlas missile, was deployed in October 1959. In the early 1960s, the Air Force began replacing its liquid-fueled ICBMs with more reliable and easier to maintain solid-fueled Minuteman I and Minuteman II missiles. The third variant in the Minuteman series, the Minuteman III, was designed in the 1960s and fielded in the 1970s. The more modern Peacekeeper ICBM, which became operational during the Reagan administration, was equipped with upgraded guidance and propulsion systems and had sufficient payload capacity to carry up to ten multiple independent reentry vehicles (MIRV). DoD retired its Peacekeepers in 2005 to comply with the terms of START II, leaving the Minuteman III as the only operational land-based ICBM in the U.S. triad.[30] Forty-seven years after Minuteman IIIs were deployed, DoD is ready to replace them with a new ICBM called the Ground Based Strategic Deterrent. The GBSD is expected to meet its initial operational capability threshold by 2029, reach full operational capability in 2036, and remain in service until the mid-2070s.

The U.S. SSBN force

The Navy's 14 *Ohio*-class SSBNs were originally equipped with 24 tubes that can launch SLBMs. To meet New START II Treaty limitations, the Navy modified its SSBNs to carry up to 20 Trident II D-5 missiles. SSBNs will account for over 70 percent of the U.S. triad's deployed warheads permitted by the New START Treaty.[31] The Navy is developing a new SSBN to replace its *Ohio*-class boats before they reach the end of their service lives in the 2030s. A 2017 Government Accountability Office report estimated a program to acquire 12 *Columbia*-class SSBN-826s will cost approximately $100 billion in FY 2017 dollars.[32]

Complying with arms limitation agreements

Over a 30-year period beginning in the 1960s, DoD sized its SSBN, bomber, and ICBM forces primarily to deter a massive nuclear attack by the Soviet Union. The latter two legs of the triad

29 MacStravic, "Fiscal Year 2018 Budget Request for Nuclear Forces," p. 6.

30 Minuteman III missiles are deployed to underground silos located around Malmstrom AFB, Montana; Minot AFB, North Dakota; and F.E. Warren AFB, Wyoming.

31 Montgomery, *The Future of America's Strategic Nuclear Deterrent*, pp. 7–12.

32 Government Accountability Office (GAO), *Defense Acquisitions: Assessments of Selected Weapon Programs* (Washington, DC: GAO, March 2017), p. 117. The report estimated the program unit cost of each *Columbia*-class SSBN will be approximately $8.35 billion in FY 2017 dollars.

reached a high of 1,850 bombers in 1959 and 1,054 ICBMs in the late 1960s.[33] Since the end of the Cold War, a series of arms control agreements signed by the United States and Russia placed limits on their nuclear weapon launchers and warheads (see Table 1).

TABLE 1: POST-COLD WAR TREATY LIMITATIONS[34]

	1991 Strategic Arms Reduction Treaty (START I)	2003 Strategic Offensive Reductions Treaty (SORT)	2010 New START Treaty
Aggregate Delivery Vehicles	1,600	N/A	700 deployed 800 including non-deployed
Aggregate Warheads	6,000	1,700–2,200 deployed	1,550 deployed, strategic
ICBMs	Specified limits on some ICBMs[35]	N/A	N/A
ICBM Warheads	4,900 combined with SLBM warheads	N/A	N/A
SLBM Warheads	4,900 combined with ICBM warheads	N/A	N/A
Heavy Bombers	Counting rules: • Specified limits on ALCM bombers[36] • 1 non-ALCM bomber = 1 nuclear warhead	N/A	Counting rules: • 1 heavy bomber = 1 nuclear warhead
Implementation Deadline	December 5, 2001	No deadline; SORT entered into force on June 1, 2003	February 5, 2018

33 Robert S. Norris and Hans M. Kristensen, "Nuclear Notebook: U.S. and Soviet/Russian intercontinental ballistic missiles, 1959-2008," *Bulletin of the Atomic Scientists*, January/February 2009; and Robert S. Norris, Steven M. Kosiak, and Stephen I. Schwartz, "Deploying the Bomb," in Stephen I. Schwartz, ed., *Atomic Audit the Costs and Consequences of U.S. Nuclear Weapons since 1940* (Washington, DC: The Brookings Institute, 1998), p. 112.

34 "START I at a Glance," Arms Control Association, updated July 2017, available at https://www.armscontrol.org/factsheets/start1; "Strategic Offensive Reductions Treaty," Nuclear Threat Initiative, updated October 2011, available at http://www.nti.org/learn/treaties-and-regimes/strategic-offensive-reductions-treaty-sort/; and "New Start at a Glance," Arms Control Association, updated August 2012, available at https://www.armscontrol.org/factsheets/NewSTART.

35 START I established a limit of 154 heavy ICBMs and no more than 1,540 warheads for heavy ICBMs. Heavy ICBMs were defined as ICBMs with a launch weight of over 106 tons or a throw-weight over 4,350 kg. Only the Soviet Union possessed heavy ICBMs. START I also established a maximum of 1,100 warheads for mobile ICBMs, and banned new ballistic missiles with more than 10 warheads. "Treaty between the United States of America and the Union of Soviet Socialist Republics on Strategic Offensive Reductions (START I)," Nuclear Threat Initiative, updated October 26, 2011, available at http://www.nti.org/learn/treaties-and-regimes/treaties-between-united-states-america-and-union-soviet-socialist-republics-strategic-offensive-reductions-start-i-start-ii/.

36 United States: maximum of 20 ALCMs per bomber; the first 150 bombers count as carrying only 10 ALCMs each. Soviet Union: maximum 16 air-launched cruise missiles per bomber; the first 180 bombers count as carrying only 8 cruise missiles each.

DoD's nuclear force structure complies with the New START Treaty (see Table 2).[37] The treaty does not affect inventories of non-strategic nuclear weapons, which are also known as theater nuclear weapons. Russia has a distinct numerical advantage in theater nuclear weapons over the United States.

TABLE 2: 2018 PLANNED U.S. STRATEGIC NUCLEAR FORCES UNDER THE NEW START TREATY[38]

	Total Launchers[39]	Deployed Launchers	Warheads
Minuteman III ICBMs	454	400	400
Trident II SSBNs	280	240	1,090
B-52H Bombers	47	41	41
B-2 Bombers	19	19	19
Total	**800**	**700**	**1,550**

Report Organization

This report assesses planned modernization programs that will replace the Air Force's aging AGM-86B ALCM and Minuteman III weapon systems. Chapter 1, "Shaping Future Triad Requirements," begins by summarizing the increasingly advanced air and missile defenses of China, Russia, and other U.S. adversaries that threaten the U.S. military's ability to conduct strike operations in regions critical to the nation's security. Chapter 2, "ALCM Modernization and the LRSO," assesses the survivability and sustainability of the AGM-86B ALCM, as well as other factors related to its future viability. It concludes that an ALCM replacement will help to ensure the U.S. bomber force will continue to have the capability to attack strategic targets over global ranges well into the future. Chapter 3, "Minuteman Modernization and the GBSD" assesses the sustainability, future deterrence potential, and cost of sustaining Minuteman IIIs compared to replacing them with a new ICBM. It concludes that DoD should replace the Minuteman III with a new GBSD weapon system that will maintain a credible ICBM force into the 2070s.

37 It is important to note the New START Treaty's limitations will not be in effect past 2021 unless the United States and Russia both agree to extend it to 2026. The U.S. State Department periodically releases a fact sheet on "New START Treaty Aggregate Numbers of Strategic Offensive Arms" for the United States and Russia. The fact sheet dated January 12, 2018 reports that Russia had 1,561 and the United States had 1,393 "warheads on deployed ICBMs, on deployed SLBMs, and nuclear warheads counted for deployed heavy bombers." See https://www.state.gov/documents/organization/277683.pdf.

38 Woolf, *The New Start Treaty*, p. 20. Note: the actual U.S. warhead count is higher, since bombers are counted as a single warhead regardless of their weapons loadout under the New START Treaty. Bombers are allowed to carry nuclear cruise missiles and/or gravity bombs.

39 This column assumes the Air Force will maintain 450 silos, of which 50 will be empty and on warm standby. It also assumes the Navy retains 14 Trident submarines, with two in overhaul, and each Trident will have 20 deployed launchers.

CHAPTER 1

Shaping Future Triad Requirements

Over the last two decades, the governments of Russia and China have sought to expand their global influence and diminish confidence in the United States as a security guarantor in their respective regions.[40] Both are modernizing their military forces in support of their revisionist strategies, which includes nuclear weapon systems that China and Russia perceive as critical to their status as great powers.[41] At the same time, regional powers such as North Korea and Iran are extending their military's reach and acquiring capabilities that could be used to coerce their neighbors and undermine the U.S. ability to assure its allies and partners. This chapter addresses the A2/AD systems fielded by China and Russia, and to an extent Iran and North Korea that are eroding the credibility of America's deterrence posture. It begins by summarizing advanced air and missile defenses that are designed to prevent U.S. strike platforms and weapons from reaching their designated targets. Previous CSBA reports have assessed how emerging salvo competition challenges should shape the U.S. military's future conventional strike and missile defense capabilities.[42] Similarly, the emergence and proliferation of A2/AD systems designed to degrade the effectiveness of U.S. conventional strike systems should influence requirements for modernizing the triad. This chapter then addresses Russia's and China's nuclear force modernization initiatives. China's investments to improve and enlarge its

40 General Joe Dunford recently remarked that the U.S. military's competitive advantage over its great power competitors has eroded "in the last 10 or 15 years . . . and it's no longer as decisive as it was some years ago." Jim Garamone, "Dunford: U.S. Military Advantage Over Russia, China Eroding," DoD News, November 16, 2017, available at https://www.defense.gov/News/Article/Article/1374168/dunford-us-military-advantage-over-russia-china-eroding/.

41 "Russia today continues to put a large share of its national resources into nuclear weapons programs, equating great power status with nuclear capability which may exceed that of the rest of the world combined." Mark B. Schneider, "Escalate to De-escalate," *Proceedings*, February 2017, available at https://www.usni.org/magazines/proceedings/2017-02/escalate-de-escalate.

42 See Gunzinger and Clark, *Sustaining America's Precision Strike Advantage*; and Mark Gunzinger and Bryan Clark, *Winning the Salvo Competition: Rebalancing America's Air and Missile Defenses* (Washington, DC: Center for Strategic and Budgetary Assessments, 2016).

nuclear and dual-capable forces reinforces the need for the United States to develop a better understanding of what is needed to deter nuclear threats in the era of multipolar great power competition. A modernized triad with a diverse set of capabilities would provide a hedge against uncertainty and the potential that Russia and China's nuclear programs could rapidly increase their respective nuclear forces and capabilities.[43]

Shaping Future Triad Requirements: Increasingly Advanced Air and Missile Defenses

In the aftermath of the Cold War, DoD planners assumed that conventional air and missile attacks on U.S. regional bases and forces either would not occur or, if they did, could easily be countered by limited active and passive defenses. The proliferation of precision-guided munition (PGM) technologies has undermined this and other optimistic assumptions around which DoD sized and shaped its forces and capabilities in the 1990s. Over the last two decades, adversaries have studied the American way of war and developed a variety of conventional and nuclear capabilities to offset the U.S. military's advantages. Russia and China both possess maturing A2/AD networks that include increasingly advanced air and missile defenses. Although North Korea's and Iran's A2/AD capabilities are less sophisticated, both continue to enhance their resilience against strike systems.

As addressed in a previous CSBA report, the combination of an enemy's active and passive defenses could significantly decrease the probability that U.S. guided weapons, including non-stealthy cruise missiles and other PGMs, will reach their designated target aimpoints.[44] Although assessments usually focus on how these increasingly challenging defensive complexes will affect U.S. conventional strike operations, they should also consider how they might change requirements for future triad capabilities. The next several pages briefly characterize the air and missile defenses of China, Russia, Iran, and North Korea.

China's air and missile defense complex

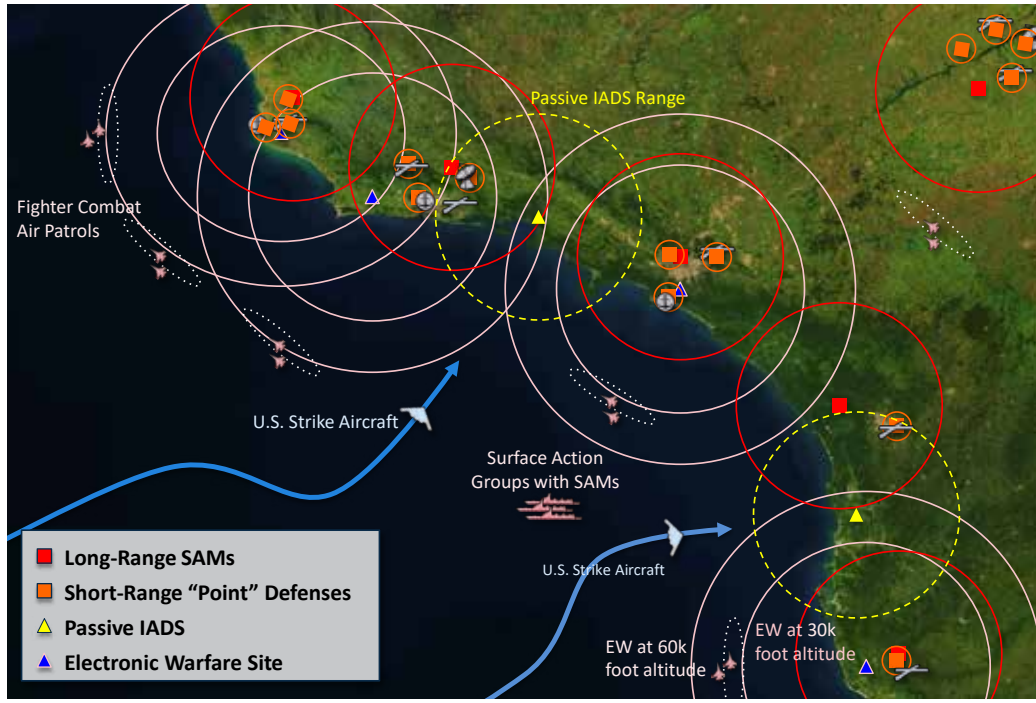
China is in the third decade of its development of an A2/AD complex in the Western Pacific that is intended to restrict the U.S. military's access and freedom of action in the region. Major elements of China's A2/AD network include complexes of overlapping active and passive early warning and target-tracking sensors, SAM batteries, increasingly advanced interceptor

43 "The goal of preventing nuclear war is so crucial that it is better to hedge with flexible, diverse, and overlapping capabilities rather than risk the failure of deterrence due to unknown or unpredictable developments or otherwise having too few or the wrong types of nuclear forces needed to deter." Keith B. Payne, "Why US Nuclear Force Numbers Matter," *Strategic Studies Quarterly*, Summer 2016, p. 15, available at www.airuniversity.af.mil/Portals/10/SSQ/documents/Volume-10_Issue-2/Payne.pdf.

44 For examples of how decreased PGM "probability of arrival" values created by an enemy's active and passive air and missile defenses could offset the U.S. military's precision strike advantage, see Gunzinger and Clark, *Sustaining America's Precision Strike Advantage*.

aircraft, hardened facilities to protect people and assets, and a network of over 3,000 miles of underground tunnels.

FIGURE 4: ILLUSTRATION OF A NOTIONAL OVERLAPPING AND NETWORKED IADS



Advanced SAM systems. Russia has exported weapon systems and technologies to China that accelerated the efforts of the People's Liberation Army (PLA) to field state-of-the-art air and missile defenses. China has fielded operational battalions of the Russian-sourced S-300PMU1/2 SAM system and signed a contract to acquire six Russian S-400 battalions.45 According to media reports, Russia delivered its first shipment of S-400s to China in January 2018.46 S-400s deployed to the coast of mainland China could range all of Taiwan and the Senkaku islands near Japan.47 Chinese engineers have also successfully reverse-engineered foreign systems, including the S-300 and the U.S. PAC-3, to field indigenous land-based HQ-9 and sea-based HHQ-9 SAMs. HQ-9 variants have active electronically scanned array radars and could, according to some sources, "engage six targets simultaneously out to 120 miles at

45 OSD, *Military and Security Developments Involving the People's Republic of China 2017*, p. 29; and U.S.-China Economic and Security Review Commission (USCC), *2017 Report to Congress* (Washington, DC: U.S. Government Publishing Office, November 2017), p. 210.

46 "Russia begins delivery of S-400 missile systems to China," *Tass*, January 18, 2018, available at http://tass.com/defense/985601.

47 "China: Air Force," *IHS Jane's World Air Forces,* updated January 10, 2018, available at https://janes.ihs.com/Janes/Display/1319011#.

altitudes up to 90,000 feet."48 Non-stealthy U.S. aircraft and weapons would find it extremely difficult to reach targets in areas that are defended by these advanced systems.

FIGURE 5: HQ-9 LAND-BASED SAM

Chinese HongQi 9 (HQ-9) launcher during China's 60th anniversary parade on October 1, 2009. Photo by Jian Kang, available for use under the Creative Commons Attribution 3.0 Unported license.

Underground facilities. China's underground tunnel complexes are another element of its missile defense architecture. The effectiveness of coalition airstrikes during Operation Desert Storm in 1991 and Operation Allied Force in 1999 helped convince China that it should continue to develop underground facilities (UGF) to protect its command and control systems, nuclear forces, and other forces and critical infrastructure.49 China's extensive network of hardened UGFs, which has been called the "Second Great Wall," consists of approximately 3,000 miles of tunnels. China's aggressive UGF program has also led to speculation that it may be using these facilities, together with other denial and deception practices, to conceal the true size of its nuclear

48 Dave Majumdar, "Flash Point: America's Lethal F-22 vs. China's Fiery HQ-9," *The National Interest*, February 8, 2016, available at http://nationalinterest.org/blog/the-buzz/flash-point-americas-lethal-f-22-vs-chinas-fiery-hq-9-15246.

49 "China began to update and to expand its military UGF program in the mid- to late-1980s. This modernization effort took on a renewed urgency following China's observation of U.S. and coalition air operations during the 1991 Gulf War and their use in OPERATION ALLIED FORCE. These military campaigns convinced China that it needed to build more survivable, deeply buried facilities, resulting in the PLA's widespread UGF construction effort over the past fifteen years." OSD, *Military and Security Developments Involving the People's Republic of China 2017*, p. 61.

forces.[50] Despite repeated efforts, the Department of Defense has been unable to engage China in a productive discussion about its nuclear force posture.

Ballistic missile defenses. To date, China has not placed the same degree of emphasis on deploying defenses against ballistic missiles. Some analysts have reported that "China's ballistic missile defense program appears closely linked to its anti-satellite program," which includes test shots of its SC-19 direct-ascent interceptor.[51] This is supported by a 2017 DoD report to Congress that said China is "developing its indigenous HQ-19 to provide the basis for a ballistic missile defense capability."[52] IHS Jane's has reported the PLA Air Force (PLAAF) may acquire a Russian S-500 SAM system that is capable of intercepting intermediate-range ballistic missiles and possibly ICBMs and SLBMs.[53]

Russia's air and missile defense capabilities

During the Cold War, the Soviet Union fielded the world's most sophisticated air defenses. After the collapse of the Soviet Union, Moscow continued to invest in programs to develop more advanced IADS to defeat enemy strike aircraft and weapons of all classes, including weapon systems with stealth characteristics.54 Russia has since fielded numerous state-of-art

50 "Most public assessments conclude that the PLA maintains a relatively limited number of nuclear weapons, perhaps around 250 warheads." Mark Stokes, *China's Future Nuclear Force Infrastructure: A Notional Breakout Scenario*, draft report (Arlington, VA: Project 2049 Institute, February 21, 2014), available at http://www.npolicy.org/article_file/Stokes_-_CHINA_NUCLEAR_EXPANSION_SCENARIO.pdf. For instance, OSD concluded that "China's nuclear arsenal currently consists of approximately 75–100 ICBMs, including the silo-based CSS-4 Mod 2 (DF-5A) and Mod 3(DF-5B); the solid-fueled, road-mobile CSS-10 Mod 1 and Mod 2 (DF-31 and DF-31A); and the more-limited-range CSS-3 (DF-4)." This land-based arsenal is complemented by China's SSBN force. OSD, *Military and Security Developments Involving the People's Republic of China 2017*, pp. 60, 95. Other assessments speculate China's nuclear weapons inventory may be much larger. Based on an assessment of China's production of fissionable materials, a former commander of Russia's Strategic Rocket Forces estimated that "China's nuclear arsenal may consist of 1,600–1,800 nuclear warheads. Of those, about 800–900 might be available for operational deployment, whilst the rest may be kept in storage as reserve or await dismantling and recycling after the expiration of their service lifetime." Victor Yesin, "China's Nuclear Capability," in Alesksey Arbatov, Vladimir Dvorkin, and Sergey Oznobishchev, eds., *Prospects for China's Participation in Nuclear Arms Limitations* (Moscow: Institute of World Economy and International Relations, Russian Academy of Sciences, 2012), p. 26, available at https://www.files.ethz.ch/isn/155166/12031_EN.pdf.

51 Charles D. Ferguson and Bruce W. MacDonald, *Nuclear Dynamics in a Multipolar Strategic Ballistic Missile Defense World* (Washington, DC: Federation of American Scientists, July 2017), p.25, available at https://fas.org/wp-content/uploads/media/Nuclear-Dynamics-In-A-Multipolar-Strategic-Ballistic-Missile-Defense-World.pdf.

52 OSD, *Military and Security Developments Involving the People's Republic of China 2017*, p. 28.

53 "China: Air Force," *IHS Jane's World Air Forces*.

54 "Russia employs what is considered to be among the very best of modern military integrated air defense systems. Historically, Russia has been a leader in developing technologically advanced detection and engagement elements. During the 1990s, Russia largely maintained its research and development programs for air defense equipment. During this period, Russia purchased very few of these systems for domestic use. However, the State Armaments Program of 2015, and the subsequent 2020 plan, significantly enhanced support for the purchase and employment of the newest and most capable air defense equipment including radar, surface to air missiles, command and control, and electronic warfare equipment." Defense Intelligence Agency (DIA), *Russia Military Power: Building A Military to Support Great Power Aspirations* (Washington, DC: DIA, 2017), p. 62.

SAMs, including its mobile S-300 and S-400 long-range interceptors, for homeland defense and for export.[55]

FIGURE 6: S-400 ANTI-AIRCRAFT SYSTEM

S-400 Triumf air defence system transporter erector launcher. Photo by Vitaliy Kuzmin, available for use under the Creative Commons Attribution-Share Alike 4.0 International licence.

Russia is developing a new ballistic missile defense system with nuclear- and conventional-capable interceptors to protect Moscow and surrounding areas.[56] It will soon begin to field a new S-500 anti-ballistic missile defense system that may be, in some respects, roughly comparable to the U.S. Terminal High Altitude Area Defense (THAAD) system.[57] Unlike THAAD, the S-500 is also designed to detect, track, and intercept aircraft.

Russia's plans for more widespread deployment of its ballistic missile defense capabilities remain unclear. It is likely that Russia will continue to deploy defenses around Moscow and invest in advanced hard and deeply buried underground facilities to protect its nuclear command and control leadership and infrastructure.[58] Russia has yet to forward-deploy networked sensors and other components that would be needed to create wide-area defenses against ballistic missiles. The Russian government may consider a more comprehensive ballistic missile defense to be a lower priority at this time than its other planned investments in advanced weapon systems.

55 Russia has exported S-300s to Iran and S-400s to China, and it has deployed S-400s to Syria. Franz-Stefan Gady, "Iran: Russian-made S-300 Air Defense Systems Placed on 'Combat Duty'," *The Diplomat,* July 11, 2017, available at https://thediplomat.com/2017/07/iran-russian-made-s-300-air-defense-missile-systems-placed-on-combat-duty/.

56 Ferguson and MacDonald, *Nuclear Dynamics*, pp. 23–24.

57 Ibid. Russian officials have indicated that the S-500 will enter service as early as 2020. Nicholas Fiorenza, "Army-2017: S-500 to enter service in 2020," *IHS Jane's Defence Weekly,* August 22, 2017, available at https://janes.ihs.com/Janes/Display/FG_630849-JDW.

58 Bill Gertz, "Russia Building New Underground Command Posts," *Washington Free Beacon,* August 15, 2016, available at http://freebeacon.com/national- security/russia-building-new-underground-nuclear-command-posts/.

Iran's air and missile defense capabilities

Iran seeks to develop an A2/AD "umbrella" that spans much of the Persian Gulf region. This umbrella now includes multiple types of ballistic missiles; unconventional forces and non-state actor proxies; maritime exclusion weapons such as mines, anti-ship cruise missiles (ASCM), and fast attack craft; and air defense systems.[59] These capabilities support Iran's hybrid A2/AD strategy that mixes advanced technology with unconventional and proxy forces to deter foreign militaries from intervening in the Persian Gulf region.[60]

Iran has prioritized investments to improve its air defenses over developing a more capable air force. These defenses primarily consist of Russian-built SA-2, SA-5, and SA-15 SAMs, a number of which protect Iran's nuclear facilities at Isfahan, Bushehr, and other high-value facilities.[61] Iran acquired Russia's S-300 in 2016, which significantly improved the quality of its defenses. It is also an example of how Russia uses exports of its advanced weapon systems to further erode the U.S. ability to assure its allies and deter aggression.

North Korea's A2/AD capabilities

North Korea's ballistic missiles are the backbone of its A2/AD strategy, which is immature relative to China and Russia's A2/AD complexes. In addition to its ability to launch mass artillery attacks on South Korea, North Korea has several hundred short-range ballistic missiles (SRBM) and medium-range ballistic missiles (MRBM) that are capable of attacking targets across the Korean peninsula and reaching areas of Japan; a large special operations force; an increasingly capable cyber force; and small conventional submarines.[62] North Korea has created extensive networks of underground facilities and taken other hardening measures to protect its key assets and capabilities, and it continues to invest in active defenses against enemy air forces. In addition to its fleet of approximately 1,300 military aircraft, which primarily consists of older Soviet models, North Korea has fielded a dense network of anti-aircraft artillery and early generation SAMs. More recently, it has developed an indigenous road-mobile SAM system called the KN-06, with a phased array radar and other capabilities that appear similar to Russia's S-300 and China's HQ-9/FT-2000.[63]

59 Mark Gunzinger and Chris Dougherty, *Outside-In: Operating from Range to Defeat Iran's Anti-Access and Area-Denial Threats* (Washington, DC: Center for Strategic and Budgetary Assessments, 2011), pp. 21–24.

60 For a more complete description of Iran's A2/AD strategy and weapon systems, see Gunzinger and Dougherty, *Outside-In*.

61 Gunzinger and Dougherty, *Outside-In*, p. 29.

62 OSD, *Military and Security Developments Involving the Democratic People's Republic of Korea* (Washington, DC: DoD, 2015), pp. 1–14.

63 "KN-06 at a Glance," *CSIS Missile Defense Project*, updated September 8, 2017, available at https://missilethreat.csis.org/missile/kn-06/.

FIGURE 7: NORTH KOREAN KN-06 SAM

A Pon'gae-5 on North Korea Victory Day, July 26, 2013. Photo by Stefan Krasowski, available for use under the Creative Commons Attribution 2.0 Generic license.

Shaping Future Triad Requirements: Hedging Against Uncertainty

In salvo competitions, each opponent seeks to gain advantages over time by improving its ability to strike with precision and to defend against strikes with precision. Although this dynamic is usually discussed in the context of conventional operations, it also applies more broadly to strategic deterrence. As summarized in the remainder of this chapter, Russia and China apparently understand this; both continue to develop a diverse set of increasingly advanced nuclear weapons and delivery systems to bolster their great power status. Whereas the United States has moved away from a ballistic missile force equipped with MIRVs, Russia and China have increased their inventories of MIRV- and MaRV-capable weapons and fielded road-mobile or rail-mobile ICBMs. DoD made the decision to de-MIRV its ICBMs during the 2010 Nuclear Posture Review, even though it was clear that Russia and China were continuing to develop more advanced ballistic missiles with MIRV capabilities.[64] Over time, this could create a growing strategic imbalance that weakens crisis stability by causing a great power adversary to conclude it may have a sufficient warhead advantage to launch a disabling first strike against the United States. A U.S. ICBM force with single warheads also increases the potential that Russia could quickly break out of the New START Treaty's limitations and China could develop an inventory of operational nuclear weapons at parity or near parity with the U.S. triad.

64 In the interest of improving strategic stability, the 2010 NPR concluded that U.S. ICBMs should be modified to carry single warheads. "The United States will 'deMIRV' all deployed ICBMs, so that each Minuteman III ICBM has only one nuclear warhead. (A 'MIRVed' ballistic missile carries Multiple Independently-targetable Reentry Vehicles (MIRVs). 'DeMIRVing' will reduce each missile to a single warhead.) This step will enhance the stability of the nuclear balance by reducing the incentives for either side to strike first." OSD, *Nuclear Posture Review Report* (2010), p. 23.

Russia's Nuclear Force Modernization

Since the turn of the century, Russia has funded an extensive military modernization agenda known as the "New Look Program," which aims "to change the Russian military from a Cold War-style mobilization force to a more ready, modern, and professional military to respond to 21st century conflicts."[65] Prospects for Russia's military modernization plans rely partly on the health of its economy. Russia has failed to diversify its economy, resolve its dependence on commodity prices, or mitigate other major structural economic issues. Although budget constraints may circumscribe Russia's future military investments,[66] it continues to prioritize modernizing its nuclear forces over other investments. The pace of Russia's nuclear modernization program could create future opportunities for breakout and develop a much larger inventory of operationally deployed nuclear weapons and delivery systems.[67]

Russia's nuclear doctrine

Although recent U.S. administrations deemphasized the role of nuclear weapons in national strategy, nuclear weapons have retained a preeminent position in Russia's security planning since the end of the Cold War.[68] Russia continues to rely on its nuclear arsenal to deter conventional attacks and regularly conducts large-scale nuclear exercises.[69] Russian military leaders have indicated they might threaten to use or actually employ non-strategic nuclear forces to change the course of a conventional conflict.[70] Some defense analysts argue that the U.S. military's limited non-strategic nuclear portfolio, which now consists of a small number of gravity weapons that can be delivered by dual-capable fighters stationed in Europe, may increase the potential for Russia to employ a tactical nuclear strike against NATO forces.[71]

Russia's ICBM force

Russia's Strategic Rocket Forces, which is comprised of three missile armies, 12 divisions, and 40 regiments, is equipped with over 300 ICBMs that can carry more than 1,000 warheads. Russia had replaced more than half of its Soviet-era ICBMs with modernized systems by 2015,

65 DIA, *Russia Military Power,* pp. 12–13.

66 Russia cut its overall defense expenditures by 30 percent between 2016 and 2017. Ibid., p. xx.

67 "Russia's strategic nuclear modernization has increased, and will continue to increase its warhead delivery capability, and provides Russian with the ability to rapidly expand its deployed warhead numbers." OSD, *Nuclear Posture Review 2018,* p. 9.

68 Matthew Kroenig, *The Renewed Russian Nuclear Threat and NATO Nuclear Deterrence Posture* (Washington, DC: Atlantic Council, February 2016), p. 2.

69 Eric Heginbotham et al., *China's Evolving Nuclear Deterrent: Major Drivers and Issues for the United States* (Santa Monica, CA: RAND Corporation, 2017), pp. 3–4.

70 Kroenig, *The Renewed Russian Nuclear Threat,* p. 2. DoD's 2018 NPR concluded, "These mistaken perceptions increase the prospect for dangerous miscalculation and escalation." OSD, *Nuclear Posture Review 2018*, p. 8.

71 Kroenig, *The Renewed Russian Nuclear Threat,* pp. 2–4; and Christopher S. Chivvis, Andrew Radin, Dara Massicot, and Clinton Bruce Reach, *Strengthening Strategic Stability with Russia* (Santa Monica, CA: RAND Corporation, 2017), pp. 1–2.

and it should replace its remaining missiles in the early 2020s.[72] Recent modernization activities include replacing its legacy SS-19s and SS-25s with the SS-27 and its numerous variants and acquiring the RS-28 "Sarmat" ICBM, which should begin to deploy in 2020. Nicknamed the "country killer," the RS-28 can carry 10 to 16 reentry vehicles with capabilities to evade ballistic missile defenses or 24 hypersonic glide vehicles (HGV).[73] Future HGVs launched into flight by ballistic missiles, and possibly other vehicles, will fly at high speeds (greater than Mach 5), have trajectories that are lower than typical ballistic missile profiles, and will be able to maneuver. This combination of capabilities will make them very difficult to intercept.[74] According to the U.S. Missile Defense Agency, both Russia and China claim they have successfully launched HGV test vehicles.[75]

Unlike the U.S. ICBM silo-based force, Russia has fielded silo-based and road-mobile ICBMs, and it may be developing a rail-mobile version of its SS-27.[76] All of Russia's mobile ICBMs should be MIRV capable by the early 2020s.[77] In contrast to the United States, which decided to modify its Minuteman IIIs to carry a single warhead, MIRV-capable ICBMs give Russia the ability to quickly increase the number of its operational warheads.

Russia's ballistic missile submarines

Russia's fleet includes three *Delta II*-, six *Delta IV*-, and three *Borei*-class SSBNs[78] that can each carry 16 SLBMs. Although military spending cuts caused in part by declining oil revenues may slow Russia's modernization of its blue water navy, it has dedicated a stable funding stream to support its SSBN modernization plans.[79] Russia will field eight new *Borei II*-class boats by the 2020s, which will have the capacity to carry additional warheads. DoD has

72 "As of 2015, modernized systems only made up 56% of the missile force. They are scheduled to reach 100% by 2022." DIA, *Russia Military Power*, p. 76. See also and Hans M. Kristensen, "Russian Nuclear Forces: Buildup or Modernization?" *Russia Matters*, September 14, 2017, available at https://www.russiamatters.org/analysis/russian-nuclear-forces-buildup-or-modernization.

73 Hans M. Kristensen and Robert S. Norris, "Russian Nuclear Forces, 2016," *Bulletin of the Atomic Scientists* 72, no. 3, April 15, 2016, p. 129.

74 National Air and Space Intelligence Center (NASIC), *Ballistic and Cruise Missile Threat 2017 Annual Report* (Wright-Patterson Air Force Base, OH: U.S. Air Force, June, 2017), pp. 3, 8, available at http://www.nasic.af.mil/Portals/19/images/Fact%20Sheet%20Images/2017%20Ballistic%20and%20Cruise%20Missile%20Threat_Final_small.pdf?ver=2017-07-21-083234-343.

75 Vice Admiral J.D. Syring, Director, Missile Defense Agency, Statement Before the Subcommittee on Strategic Forces, House Armed Service Committee, June 7, 2017, p. 2, available at https://www.mda.mil/global/documents/pdf/FY18_WrittenStatement_HASC_SFS.PDF; and NASIC, *Ballistic and Cruise Missile Threat 2017 Annual Report*, pp. 26, 38.

76 The exact status of a rail-mobile SS-27 program is uncertain. "A rail-based version of the SS-27 Mod. 2, known in Russia as Barguzin, has been reported to be in early design development. But this program may have been delayed or even canceled because of Russia's financial crisis." Kristensen and Norris, "Russian Nuclear Forces, 2016," p. 26.

77 "RS-28 Sarmat (SS-X-30 Satan II)," *CSIS Missile Defense Project*, May 27, 2017, available at https://missilethreat.csis.org/missile/rs-28-sarmat/.

78 DIA, *Russia Military Power,* p. 30.

79 "Russia Scuttles Its Grand Maritime Dreams," *Stratfor Worldview,* June 23, 2017, available at https://www.stratfor.com/analysis/russia-scuttles-its-grand-maritime-dreams.

confirmed that Russia is also developing a new nuclear torpedo that is also nuclear powered and has intercontinental range.[80] According to some reports, this weapon, which has been called the "Kanyon," may be capable of loitering undersea for some period of time before being remotely directed to attack coastal targets. Collectively, Russia's new undersea capabilities are clear indicators of the strategic importance Russia places on increasing the flexibility and diversity of its nuclear triad.

Russia's heavy bombers and air-launched cruise missiles

Russia has a force of about 120 bombers, of which 50 may count against the New START Treaty's heavy bomber limitations. Modernization programs will sustain Russia's Tu-160 and Tu-95MS Bear H bombers through 2030. Russia is developing a nuclear-capable stealth bomber that may be operational in the mid-2020s.[81] In addition to carrying gravity weapons, Russia's bombers can launch cruise missiles that improve their ability to strike while remaining outside the lethal radius of enemy air defenses. Russia's new Kh-102 nuclear-capable cruise missile and its conventional counterpart, the Kh-101, can be launched from standoff ranges.[82] The Kh-102 will likely replace Russia's older AS-15 ALCMs and AS-16 short-range attack missiles. Russia is pursuing new supersonic and hypersonic cruise missiles to further improve the ability of its bombers to strike deep into contested areas.[83]

FIGURE 8: RUSSIAN TU-160 BOMBER

Photo by Kirill Naumenko, available for use under the Creative Commons Attribution-Share Alike 3.0 Unported license.

80 "Russia is also developing at least two new intercontinental range systems, a hypersonic glide vehicle, and a new intercontinental, nuclear-armed, nuclear-powered, undersea autonomous torpedo." OSD, *Nuclear Posture Review 2018*, p. 9.

81 "Russia: Air Force," *IHS Jane's Sentinel Security Assessment—Russia and the CIS,* updated September 27, 2017, available at https://janes.ihs.com/Janes/Display/jwafa228-cis.

82 DIA, *Russia Military Power,* p. 25; and "Kh-101/Kh-102," *GlobalSecurity.org*, January 1, 2017, available at http://www.globalsecurity.org/wmd/world/russia/kh-101.htm.

83 Franz-Stefan Gady, "India Fires Nuclear-capable Cruise Missile from Fighter Jet," *The Diplomat*, November 2, 2017, available at https://thediplomat.com/2017/11/india-test-fires-nuclear-capable-cruise-missile-from-fighter-jet/.

Russia's non-strategic nuclear forces

Russia has at least 2,000 operationally available non-strategic nuclear warheads that can be delivered by air, sea, and ground platforms,[84] and it is developing multiple dual-capable systems that are not limited by the New START Treaty.[85] Russian doctrine indicates it may have integrated the use of nuclear weapons into its war plans. The fact that Russia periodically threatens to use nuclear weapons "against U.S. forces and allies in Europe"[86] suggests this doctrine may be grounded in reality.

It should be noted that the United States maintains a force of non-strategic warheads (deployed and non-deployed) that is significantly smaller and much less diverse than Russia's force. Since the retirement of the Navy's TLAM-N, DoD's non-strategic nuclear forces consist of a small number of dual-capable fighter aircraft that can deliver nuclear gravity weapons. This disparity in the numbers and types of non-strategic nuclear weapons has given Russia a significant advantage over the United States and its allies.[87]

Russia's Intermediate-Range Nuclear Forces (INF) Treaty breaches

According to the U.S. Government, Moscow has developed nuclear-capable missiles that contravene the INF Treaty which bans all land-based nuclear and conventional ballistic missiles and cruise missiles with ranges between 500 and 5,500 km. In 2011, the Obama Administration concluded that a particular Russian ground-launched cruise missile (GLCM) constituted a clear-cut violation of the treaty.[88] There are indications that Russia has operationally deployed one or more battalions of these GLCMs, which are thought to be SSC-8s.[89]

84 OSD, *Nuclear Posture Review 2018*, p. 53.

85 Evan Braden Montgomery, *Extended Deterrence in the Second Nuclear Age: Geopolitics, Proliferation, and the Future of U.S. Security Commitments* (Washington, DC: Center for Strategic and Budgetary Assessments, 2016), p. 21; and Kristensen and Norris, "Russian Nuclear Forces, 2016," pp. 127–132.

86 According to General Paul Selva, Russia "is not only modernizing its strategic nuclear triad and developing new nonstrategic weapons, but remains in violation of its Intermediate Range Nuclear Forces Treaty obligations and has threatened nuclear use against U.S. forces and allies in Europe." General Paul Selva, USAF, Vice Chairman of the Joint Chiefs of Staff, "Military Assessment of Nuclear Weapons Requirements," statement before the House Armed Services Committee, March 8, 2017, p. 4, available at http://docs.house.gov/meetings/AS/AS00/20170308/105640/HHRG-115-AS00-Wstate-SelvaUSAFP-20170308.pdf.

87 OSD, *Nuclear Posture Review 2018*, p. 53.

88 State Department reports submitted to the U.S. Congress in 2014, 2015, and 2016 cited Russia's violations. See Amy F. Woolf, *Russian Compliance with The Intermediate Range Nuclear Forces (INF) Treaty: Background and Issues for Congress* (Washington, DC: Congressional Research Service, March 15, 2017).

89 Michael R. Gordon, "Russia Deploys Missile, Violating Treaty and Challenging Trump," *New York Times,* February 14, 2017, available at https://www.nytimes.com/2017/02/14/world/europe/russia-cruise-missile-arms-control-treaty.html?mcubz=3.

China's Nuclear Force Modernization

China's nuclear doctrine and strategic priorities

China's "minimum deterrent" nuclear doctrine calls for developing and sustaining a force that provides it with a second-strike capability. Although this is consistent with China's declared no first use policy,[90] it is unclear what kind of force China actually believes will constitute a minimum deterrent in the future.[91] It is clear, however, that China considers it necessary to continue a robust set of programs to develop increasingly capable SSBNs; road-mobile ICBMs; and MaRV, MIRV, and HGV nuclear weapons. These investments have led a growing number of analysts to speculate that China's nuclear strategy may be evolving.[92]

China's missile forces

China has invested significant resources in land-based conventional and nuclear missile capabilities for which the United States has little or no counter since the United States is precluded from developing them by legally-binding treaty requirements.[93] The PLA can now launch multiple salvos of ballistic missiles and cruise missiles against U.S. forces and facilities that are located "as far away as Guam and the so-called second island chain."[94] These salvos would present major operational challenges to U.S. forces that continue to depend on using local bases to project power into the Western Pacific.[95] Although most of China's ballistic missiles

90 Hans M. Kristensen and Robert S. Norris, "Chinese Nuclear Forces, 2016," *Bulletin of the Atomic Scientists* 72, no. 4, June 13, 2016, p. 209.

91 Eric Heginbotham, Michael Chase, and others argue China's minimum deterrence doctrine is more akin to nuclear sufficiency, which means "lean and effective forces with assured retaliation" capability. Eric Heginbotham et al., *China's Evolving Nuclear Deterrent: Major Drivers and Issues for the United States* (Santa Monica, CA: RAND Corporation, 2017), pp. 15–20. The 2018 NPR reiterates DoD's long-standing concern that China's "lack of transparency regarding the scope and scale of its nuclear modernization program raises questions regarding its future intent." OSD, *Nuclear Posture Review 2018,* p 11.

92 RAND has reported that China is likely to accelerate its investments in new nuclear weapon systems that could give it additional response options. Heginbotham et al., *China's Evolving Nuclear Deterrent,* p. xi. According to DoD, "The PLARF, renamed from the PLA Second Artillery Force (PLASAF) and formally established as a service, trains, equips, and operates China's land-based nuclear and conventional missiles. In 2016, it advanced long-term modernization plans to enhance its 'strategic deterrence capability,' a theme President Xi echoed during a visit to PLARF headquarters in September 2016. The service is developing and testing several new variants of missiles, forming additional missile units, retiring or upgrading older missile systems; and developing methods to counter ballistic missile defenses." OSD, *Military and Security Developments Involving the People's Republic of China 2017*, p. 31. See also, Dean Cheng, *Evolving Chinese Thinking About Deterrence: The Nuclear Dimension* (Washington, DC: Heritage Foundation, August 2017), available at http://www.heritage.org/asia/report/evolving-chinese-thinking-about-deterrence-the-nuclear-dimension.

93 Admiral Harry B. Harris estimated that 90 percent of China's land-based missile forces may fall into categories prohibited by the INF Treaty. Lucas Tomlinson, "Treaty Restrictions Giving China Huge Missile Advantage Over US, Admiral Warns," *Fox News Politics*, April 28, 2017, available at http://www.foxnews.com/politics/2017/04/28/treaty-restrictions-giving-china-huge-missile-advantage-over-us-admiral-warns.html.

94 Admiral Harry B. Harris, Commander U.S. Pacific Command, "U.S. Pacific Command Posture," statement before the House Armed Services Committee, April 26, 2017, available at http://docs.house.gov/meetings/AS/AS00/20170426/105870/HHRG-115-AS00-Wstate-HarrisH-20170426.PDF.

95 Gunzinger and Clark, *Winning the Salvo Competition*, p. 2.

and cruise missiles are likely conventional, it is difficult to distinguish which variants are conventional, nuclear, or dual capable. The People's Liberation Army Rocket Force (PLARF) does not maintain separate organizations for its nuclear and conventional missile forces, complicating efforts to determine their nature.[96]

Conventional SRBMs constitute the majority of China's missile arsenal, although there are indications that its DF-15 (CSS-6) may be nuclear capable.[97] China, which has not signed the INF Treaty, also possesses a variety of MRBMs and IRBMs, of which several variants may be nuclear capable. Its DF-26 IRBM, which became operational in 2016, may have a maximum range of 2,500 nm and "reportedly is capable of nuclear and conventional strikes against ground targets, and conventional strikes against naval targets."[98] Several reports estimate that China has approximately 150 land-based nuclear ballistic missiles, of which 50 to 75 are ICBMs.[99] China has unveiled a new DF-31AG ICBM that is road mobile and MIRV capable,[100] and its new DF-41 ICBM could be silo-based, road-mobile, rail-mobile, and has the capacity to deliver 6 to10 MIRVs per missile on targets located anywhere in the world.[101] The DF-41 was tested just days before President Trump made his first trip to China, and may be deployed in 2018.[102] Some of China's ICBM variants could soon carry HGVs.[103] Taken together, China's missile programs may eventually give it a land-based nuclear weapons inventory that is significantly larger and more capable than it is today.

China's SLBMs

Although China's SSBNs are qualitatively inferior compared to U.S. and Russian SSBNs, they are on the path toward becoming a credible leg of its strategic deterrent force. The People's Liberation Army Navy (PLAN) operates four Type 094 *Jin*-class SSBNs and has a fifth under construction. China's SSBNs carry JL–2 SLBMs that have a maximum range of 8,000 km and may carry MIRVs or a single nuclear warhead.[104] These weapon systems provide China with "the ability to conduct a nuclear strike from the sea and, perhaps more importantly . . . the potential for a

96 Heginbotham et al., *China's Evolving Nuclear Deterrent,* p. xii.

97 Kristensen and Norris, "Chinese Nuclear Forces, 2016," p. 208.

98 USCC, *2017 Report to Congress*, p. 212.

99 Kristensen and Norris, "Chinese Nuclear Forces, 2016," p. 206. Multiple unclassified sources indicate that China now has about 200 to 300 nuclear warheads and 75 to 150 ICBMs. See, for example, OSD, *Military and Security Developments Involving the People's Republic of China 2017*, p. 95.

100 Bill Gertz, "China's New Long-Range Missile," *Washington Times,* August 9, 2017, available at http://www.washingtontimes.com/news/2017/aug/9/inside-the-ring-chinas-new-long-range-missile/.

101 USCC, *2017 Report to Congress*, pp. 211–212.

102 Bill Gertz, "China Confirms Test of Powerful DF-41 Intercontinental Ballistic Missile," *Washington Times,* December 6, 2017, available at https://www.washingtontimes.com/news/2017/dec/6/china-confirms-df-41-missile-test/.

103 NASIC, *Ballistic and Cruise Missile Threat 2017 Annual Report*, p. 8

104 "China Test Fires JL-2 SLBM," *IHS Jane's Missiles and Rockets*, July 8, 2015, available at https://janes.ihs.com/Janes/Display/jmr01498-jmr-2005.

survivable second strike capability should it suffer a first strike on land."[105] Since *Jin*-class SSBNs are noisy, and therefore detectable by anti-submarine warfare sensors, it is believed that China will invest in a next-generation SSBN (Type 096) and a new SLBM (JL-3).[106]

China's heavy bombers

It is unclear if PLAAF and PLAN Naval Aviation H-6 bombers, which are modified Soviet Tu-16s, can deliver nuclear weapons. China used H-6 bombers for nuclear tests between 1965 and 1979, and Kristensen and Norris assess that "a small portion of China's H-6 intermediate-range bombers may have a secondary nuclear mission."[107] The Air Force Global Strike Command believes that China's CJ-20 long-range cruise missiles can deliver nuclear warheads as well as conventional payloads.[108] Although H-6K bombers could not reach targets located within the continental United States without multiple aerial refuelings, a long-range, nuclear-capable CJ-20 would significantly increase the flexibility of China's nuclear weapons portfolio. In 2017, a modified H-6 bomber was photographed for the first time with a refueling probe mounted on its nose.[109]

FIGURE 9: ARTIST DEPICTION OF AN H-6N BOMBER WITH A NOSE-MOUNTED REFUELING PROBE

One in a series of artist depictions of the H-6N from Global New Military dated December, 2017, available via http://www.shixunwang.net/article/i1512611465324001/. Captured satellite images of the aircraft are also available at this source.

105 USCC, *2016 Report to Congress*, pp. 214–215.

106 According to OSD, "China's four operational JIN-class SSBNs represent China's first credible, sea-based nuclear deterrent. China's next-generation Type 096 SSBN, will likely begin construction in the early-2020s, and reportedly will be armed with the JL-3, a follow-on SLBM." OSD, *Military and Security Developments Involving the People's Republic of China 2017*, p. 24. Also see Renny Babiarz, "China's Nuclear Submarine Force," *China Brief* 17, no. 10, July 21, 2017, available at https://jamestown.org/program/chinas-nuclear-submarine-force/.

107 Kristensen and Norris, "Chinese Nuclear Forces, 2016," pp. 205–211.

108 "Strategic Weapon Systems," *IHS Jane's Sentinel Security Assessment—China and Northeast Asia*, April 7, 2017, available at https://janes.ihs.com/Janes/Display/cnaa015-cna.

109 Richard D. Fischer, Jr., "Chinese Xian H-6K With Refuelling Probe Suggests New Missions," *Jane's Defence Weekly*, August 18, 2017, available at http://www.janes.com/article/73182/chinese-xian-h-6k-with-refuelling-probe-suggests-new-missions.

In September 2016, PLAAF commander General Ma confirmed that China is developing a new "H-X" (or H-20) bomber. The H-X is expected to be a nuclear-capable strategic bomber with stealth characteristics, an unrefueled range of approximately 9,000 km, and the capacity to carry 20 metric tons of munitions. The H-X could be operational in the mid-2020s.[110]

Summary

Many of DoD's major weapons systems, including the majority of its current combat air forces, were developed in 1970s and 1980s. For a variety of reasons, including a persistent lack of funding for modernization programs, the desire to realize a defense budget "peace dividend" after the Cold War, and the need to support multiple overseas contingency operations after 2001, DoD continued to rely on weapon systems that were designed for permissive operational environments. This includes many of DoD's triad weapon systems such as the B-52 bomber, the AGM-86B ALCM, and the Minuteman III.

Over the last two decades, China, Russia, and other adversaries have invested heavily in capabilities to offset the U.S. military's strike platforms and weapons. Networks of advanced kinetic air and missile defenses combined with electronic warfare and cyber capabilities are intended to degrade the U.S. military's ability to conduct conventional *and* nuclear strikes. In response, DoD is pursuing new conventional weapons systems and is requesting funding to develop and procure triad capabilities that can operate in more challenging threat environments.[111]

China's and Russia's defense investments indicate they believe their nuclear forces and modernization programs are essential to their status as great powers. Both are developing new stealth bombers, multiple variants of ICBMs that are mobile and can be launched from fixed sites, cruise missiles that are nuclear capable or dual capable, hardened infrastructure, and other capabilities that could give them advantages in future salvo competitions. A diverse, modernized U.S. triad would create a more robust hedge against the potential that great power competitors' nuclear modernization programs could result in strategic or technological breakouts.[112] Conversely, should the United States choose to forego modernizing its triad, it could lead to a strategic imbalance that might cause a great power adversary to conclude that the United States could be subdued or coerced by the threat of nuclear weapons use in a crisis.

110 Andreas Rupprecht, "The PLA Air Force's 'Silver-Bullet' Bomber Force," *China Brief* 17, no. 10, July 21, 2017, available at https://jamestown.org/program/the-pla-air-forces-silver-bullet-bomber-force/.

111 "The President directed DoD to ensure that the U.S. nuclear deterrent is modern, robust, flexible, resilient, ready, and appropriately tailored to deter 21st century threats. Each of these characteristics contributes to the effectiveness of our deterrence strategy." Robert Soofer, Deputy Assistant Secretary of Defense (Nuclear and Missile Defense), "The President's Fiscal Year 2018 Budget Request for Nuclear Forces and Atomic Energy Defense Activities," statement before the Subcommittee on Strategic Forces for the Senate Armed Services Committee, June 7, 2017, available at https://www.armed-services.senate.gov/imo/media/doc/Soofer_06-07-17.pdf.

112 Some analysts have summarized factors that could lead China to engage in a "race to parity" with the United States, by increasing their inventories of nuclear weapons and nuclear weapons delivery vehicles. See Stokes, *China's Future Nuclear Force Infrastructure*.

The remainder of this report assesses the need to for DoD to invest in modernized nuclear systems with the operational flexibility to meet these and other challenges. Chapter 2 focuses on issues related to replacing the ALCM with a new nuclear-capable cruise missile that can penetrate future threat environments. Chapter 3 addresses the feasibility and cost of further extending the aging Minuteman III's service life relative to developing the GBSD, its replacement.

CHAPTER 2

ALCM Modernization and the LRSO

The AGM-86B ALCM is the only nuclear cruise missile in the U.S. military's weapons inventory.[113] The ALCM, which also has conventional AGM-86C/D variants, is a single-warhead, subsonic missile that can reach targets over long ranges.[114] Although it was designed in the mid-1970s to have a planned service life of ten years, life extension programs are expected to keep ALCMs in the active inventory until approximately 2030. The U.S. retains approximately 550 ALCMs in its inventory, all of which are carried by nuclear-capable B-52 bombers.[115] This chapter begins by summarizing attributes of the U.S. nuclear-capable bomber force, the development of the ALCM, and DoD's previous attempt to replace the ALCM with a more capable weapon. It then assesses the ALCM's survivability, its sustainability, and other issues that have caused the Air Force to request funding for the LRSO program, which will develop and acquire a new cruise missile to replace the ALCM. Chapter 2 concludes that the future battlespace will require a replacement for the ALCM, a system that was designed in an era when there were few threats capable of challenging its ability to penetrate enemy airspace.

113 The Navy's only nuclear-capable cruise missile, the sea-launched Tomahawk Land Attack Missile-Nuclear (TLAM-N), was retired by the Obama administration.

114 "AGM-86B/C/D Missiles Factsheet," U.S. Air Force, May 24, 2010, available at http://www.af.mil/About-Us/Fact-Sheets/Display/Article/104612/agm-86bcd-missiles/.

115 Robin Rand, General, Commander, Air Force Global Strike Command, "Department of Defense Nuclear Acquisition Programs and the Nuclear Doctrine," statement before the Subcommittee on Strategic Forces, Senate Armed Services Committee, June 7, 2017, p. 8, available at https://www.armed-services.senate.gov/imo/media/doc/Rand_06-07-17.pdf; and "AGM-86 ALCM/CALCM," *IHS Jane's Strategic Weapons Systems*, updated October 4, 2017, available at https://janes.ihs.com/Janes/Display/jalw3062-jalw.

The Air-Breathing Leg of the Triad

Since the dawn of the nuclear age, bombers have been the foundation of the U.S. strategic deterrence posture. B-52H bombers, which have been operational since the early 1960s, will likely remain in the force for decades. The Air Force's 20 B-2s are the world's only operational, stealthy, "penetrating" bomber force. B-2s will soon be joined by B-21s that will be capable of penetrating future threat environments.[116] These forces have unique capability attributes that complement other legs of the triad. Bombers can be generated and placed on nuclear alert status, then dispersed to remote airfields if necessary to send signals in a crisis. Unlike ICBMs and SLBMs, bombers can be launched and recalled without delivering their nuclear payloads. Long flight times required for airstrikes over intercontinental distances increase this flexibility relative to ballistic missiles that may reach their targets in 30 minutes or less after launch. Bombers with human crews are also capable of modifying their mission profiles to avoid threats detected in flight, changing targets as required, or determining if weapons should be withheld. In combination, a bomber force capable of conducting standoff and penetrating attacks greatly complicates a competitor's defensive challenges. An exclusively standoff-strike bomber force, on the other hand, would permit potential adversaries to optimize their air defenses to defeat U.S. cruise and ballistic missiles.

The Air-Launched Cruise Missile

During the 1970s, the Air Force sought capabilities to improve the survivability of its B-52 force against enemy air defenses. A proposed Subsonic Cruise Armed Decoy (SCAD) program was intended to develop unarmed decoys capable of mimicking an inflight B-52's radar signature to confuse Soviet anti-aircraft defenses.[117] Although disagreements over the need for the SCAD led to its termination in 1973, the Air Force's interest in developing a standoff attack capability for its strategic bombers continued to grow as the effectiveness of the Soviet Union's air defenses improved.[118] In August 1973, the Air Force received funding to develop the ALCM. Boeing produced approximately 1,715 ALCM missiles for the Air Force between 1979 and 1987.[119]

116 For a recent report on the B-21 program, see Jeremiah Gertler, *Air Force B-21 Raider Long-Range Strike Bomber* (Washington, DC: Congressional Research Service, June 7, 2017) p. 1, available at https://fas.org/sgp/crs/weapons/R44463.pdf. According to DoD, "Delays in the B-21 bomber program or associated bomber weapons would reduce the ability of our strategic forces to penetrate adversary air defenses, limit the diversity of our response options, and compromise our ability to send the visible deterrence and assurance signals for which strategic bombers are particularly well suited." OSD, *Nuclear Posture Review 2018*, p. 51.

117 Ron Huisken, "The History of Modern Cruise Missile Programs," in Richard K. Betts, ed., *Cruise Missiles: Technology, Strategy, Politics* (Washington, DC: Brookings Institution, 1981), p. 84.

118 E. H. Conrow, G.K. Smith, and A.A. Barbour, *The Joint Cruise Missiles Project: An Acquisition History* (Santa Monica, CA: RAND Corporation, August 1982), p. 4, available at http://www.dtic.mil/dtic/tr/fulltext/u2/a140985.pdf; and Will Saetren, *Ghosts of the Cold War: Rethinking the Need for a New Nuclear Cruise Missile* (Washington, DC: Ploughshares Fund, April 2016), p. 5.

119 "AGM-86 ALCM/CALCM," *IHS Jane's Strategic Weapons Systems*; and Greg Goebel, *US Cruise Missiles*, Kindle edition (Amazon Kindle Direct, 2015), location 443.

B-52s initially carried six ALCMs externally on each wing. They were later modified to carry a Common Strategic Rotary Launcher in its internal weapons bay that allowed them to carry another eight ALCMs.[120] Countering salvos of B-52-launched ALCMs would require the Soviet Union to develop defenses capable of detecting low-flying cruise missiles attacking from multiple azimuths. In other words, ALCMs provided the United States with a formidable advantage in the early years of the precision strike salvo competition.

In 1986, work began to convert some AGM-86Bs to a conventional AGM-86C variant known as the Conventional Air-Launched Cruise Missile (CALCM). Instead of the ALCM-B's terrain contour-matching guidance system, the CALCM uses a GPS-aided inertial navigation system for guidance.[121] The weapon carries a 2,000-pound blast/fragmentation warhead that is effective against large, fixed targets such as SAM sites. The public became aware of the weapon's existence after B-52s from Barksdale Air Force Base in Louisiana launched 35 CALCMs on the first night of the Operation Desert Storm air campaign.[122] The Air Force developed a final AGM-86D CALCM variant with a penetrating warhead in the early 2000s for use against hardened targets.[123] Although an Air Force fact sheet published in 2010 indicated there were less than 300 AGM-86C/D missiles in the inventory, the current quantity is not publicly available.[124]

Initial attempt to replace ALCMs: The Advanced Cruise Missile

Concerned the ALCM would lose its ability to penetrate increasingly lethal Soviet air defenses, the Air Force initiated development of the ACM in 1982. Specifications for the ACM included greater range and accuracy compared to the ALCM,[125] low radar cross section, stealth coatings, forward-swept wings, and a reduced infrared signature to increase its ability to avoid detection by enemy sensors. The ACM never replaced the ALCM as planned, partially due to bad timing. The ACM entered into production just after the Cold War ended,[126] and the George H.W. Bush administration reduced the ACM's total production to 460 missiles.[127] ACMs were

120 "AGM-86 ALCM/CALCM," *IHS Jane's Strategic Weapons Systems.*

121 "AGM-86B/C/D Missiles Factsheet," U.S. Air Force.

122 "It is understood that 35 AGM-86C missiles were launched from B-52 aircraft during the 1990-91 Gulf War. In 1996, 16 were launched against targets in Iraq, with 90 more fired against Iraq in December 1998. The Balkans War in 1999 saw about 230 AGM-86C missiles fired against targets in Serbia and Kosovo. In the 2003 Gulf War, 153 AGM-86C/D missiles were used against targets in Iraq." "AGM-86 ALCM/CALCM," *IHS Jane's Air-Launched Weapons,* updated October 4, 2017, available at https://janes.ihs.com/Janes/Display/jalw3062-jalw.

123 "AGM-86 ALCM/CALCM," *IHS Jane's Strategic Weapons Systems.*

124 "AGM-86B/C/D Missiles Factsheet," U.S. Air Force.

125 "AGM-129 Advanced Cruise Missile (ACM)," *IHS Jane's Air-Launched Weapons*, October 6, 2016, available at https://janes.ihs.com/Janes/Display/jalw3067-jalw.

126 "AGM-129A Advanced Cruise Missile Fact Sheet," U.S. Air Force, available at http://www.af.mil/About-Us/Fact-Sheets/Display/Article/104543/agm-129a-advanced-cruise-missile/.

127 In 2007, the Air Force had an inventory of over 1,100 ALCMs and approximately 400 ACMs. Woolf, *U.S. Strategic Nuclear Forces*, p. 34.

subsequently retired from the force in 2012, leaving the aging ALCM the only nuclear-capable air-launched standoff weapon in the U.S. inventory.[128]

ALCM reliability and availability

The ALCM faces numerous reliability issues that life extension programs may not be able to fully address. DoD testimony during a February 2015 HASC Strategic Forces Subcommittee hearing offers one of the more revealing glimpses into these issues; according to Brian McKeon, the then Principal Deputy Under Secretary of Defense for Policy, "Sustaining the ALCM is becoming increasingly difficult, and its reliability in the next decade is not assured even with substantial investment. The ALCM's service lifetime has already been extended more than two decades beyond the ten years that were originally planned."[129] The ALCM will continue to undergo service life extensions to update its telemetry, encryption, and flight termination components. It is unlikely that these Service Life Extension Programs (SLEP) will significantly improve the ALCM's ability to penetrate future threat environments.

The remaining ALCM inventory may be pressed to meet availability requirements toward the end of its service life. Similar to the Minuteman III, periodic flight tests of the ALCM help ensure it remains a reliable weapon system.[130] This testing and other attrition could reduce the ALCM inventory below the number that would be needed to fully load-out all remaining nuclear-capable B-52s before ALCMs are replaced by LRSOs.[131]

The Long-Range Standoff missile program

To address these shortfalls, the 2010 NPR required the Air Force to conduct "an assessment of alternatives to inform decisions in FY 2012 about whether and (if so) how to replace the current air-launched cruise missile, which will reach the end of its service life later in the next

128 "AGM-86B/C/D Missiles Factsheet," U.S. Air Force.

129 Brian McKeon, Principal Deputy Under Secretary of Defense for Policy, "National Defense Authorization Act for Fiscal Year 2016," testimony before the House Committee on Armed Services, February 26, 2015, p.72, available at https://www.gpo.gov/fdsys/pkg/CHRG-114hhrg94101/pdf/CHRG-114hhrg94101.pdf.

130 ALCM tests have been "conducted under Air Force Global Strike Command's Nuclear Weapon System Evaluation Program, part of the Air Force's ongoing effort to test weapons systems in training missions and prepare aircrews for future mission requirements." Leah Bryant, "Air-launched Cruise Missile Passes Tests," *Air Force News Service*, January 21, 2017, available at http://www.af.mil/News/Article-Display/Article/1055470/air-launched-cruise-missile-passes-tests/. Approximately five ALCM flight tests are conducted annually. "AGM-86 ALCM/CALCM," *IHS Jane's Air-Launched Weapons*.

131 If approximately 550 ALCMs remain in inventory in 2017, and there are approximately nine ground/flight tests flown per year, 460 ALCMs will remain in the inventory by 2027. The B-52H can carry a maximum of 20 ALCMs. A total of 460 ALCMs would only allow 23 B-52Hs to carry the full load of ALCMs. Alternatively, 38 B-52Hs could carry either 12 ALCMs with a few spares, or eight ALCMs internally with a significant number of weapons left over.

decade."[132] After the Joint Requirements Oversight Council validated the results of the analysis of alternatives (AoA), the Air Force initiated a program to develop and procure the LRSO to replace the ALCM.[133]

According to DoD, LRSOs will be capable of penetrating the future threat environment to hold targets at risk. Unlike the AGM-86B, which can only be launched by B-52s, the LRSO will be compatible with multiple U.S. bombers.[134] The Air Force is leading development of the LRSO and is responsible for its aircraft integration, logistics, and ensuring it meets reliability and availability requirements. The Department of Energy is responsible for the W80-4 nuclear warhead life extension program that will develop the LRSO's nuclear warhead.[135] Similar to the ALCM program, the Air Force could eventually request funding to develop a conventional LRSO variant.[136]

The Air Force originally planned to award a contract to develop the LRSO in FY 2013, but delayed that decision,[137] and the FY 2015 President's Budget deferred funding LRSO development until FY 2018. Concerned the LRSO could be further delayed, Congress approved language in the FY 2014 National Defense Authorization Act requiring the LRSO to achieve IOC prior to the ALCM's retirement.[138] Congress also directed the National Nuclear Security Administration (NNSA) to deliver its first production W-80 warhead in 2025 in time to support the LRSO program's schedule. In August 2017, the Air Force awarded Technology Maturation and Risk Reduction (TMRR) contracts for $900 million each to the Lockheed Martin Corporation and the Raytheon Company to mature LRSO design concepts, prove

132 OSD, *Nuclear Posture Review Report* (2010), p. 24. "The LRSO is the replacement for the aging ALCM, which will have significant capability gaps beginning late this decade and worsening through the next. Replacement of the ALCM was identified by OSD in a 2007 Program Decision Memorandum and reiterated in the 2010 NPR, the Airborne Strategic Deterrence Capability Based Assessment, and the Initial Capability Document." Stephen W. Wilson, Lieutenant General, Commander, Air Force Global Strike Command, "Status of Air Force Nuclear and Strategic Systems," statement before the Subcommittee for Strategic Forces, Senate Armed Services Committee, April 22, 2015, available at https://www.armed-services.senate.gov/imo/media/doc/Wilson_04-22-15.pdf.

133 "The existing ALCM is already 30 years beyond its original designed lifetime and its viability cannot be ensured beyond the next decade." Scher, "The U.S. Nuclear Modernization Program," slide 11. The first missile is expected to be completed in 2026. Woolf, *U.S. Strategic Nuclear Forces*, p. 35.

134 The 2018 NPR supports sustaining these capabilities: "The replacement for the aging ALCM—the LRSO—is a modern air-launched cruise missile. The LRSO program will maintain into the future our bomber capability to deliver stand-off weapons that can penetrate and survive advanced integrated air defense systems, thus holding targets at risk anywhere on Earth." OSD, *Nuclear Posture Review 2018,* p. 50.

135 OSD, *Nuclear Posture Review 2018*, p. 61.

136 Stephen W. Wilson, Lieutenant General, Commander, Air Force Global Strike Command, "Status of Air Force Nuclear and Strategic Systems," statement before the Subcommittee for Strategic Forces, Senate Armed Services Committee, April 22, 2015.

137 Jon Hemmerdinger, "USAF Delays LRSO Again, This Time by Three Years," *FlightGlobal.com,* March 13, 2014, available at https://www.flightglobal.com/news/articles/usaf-delays-lrso-again-this-time-by-three-years-396997/.

138 *National Defense Authorization Act for Fiscal Year 2014*, Public Law 113-66, 113th Congress, December 26, 2013, p. 521, available at https://www.congress.gov/113/plaws/publ66/PLAW-113publ66.pdf.

developmental technologies, and demonstrate reliability of key components.[139] The program's TMRR phase will conclude with a competitive down-select to a single prime contractor for the program's Engineering and Manufacturing Development (EMD) phase.[140]

Cruise Missiles and the Changing Threat Environment

For over 75 years, the United States has possessed a unique, unmatched ability to conduct long-range strikes. Since the end of World War II, U.S. penetrating long-range strike aircraft and cruise missiles have included the B-47, B-52, FB-111, B-1B, B-2, ALCM, and ACM.[141] These capabilities—especially the aircraft and weapons capable of low altitude flight and later equipped with stealth technologies—have driven U.S. adversaries to invest resources in defensive weapon systems, partly at the expense of procuring offensive capabilities.[142] The Soviet Union has fielded thousands of SAMs, numerous early warning and fire-control radar systems, tens of thousands of air-defense artillery systems, and at least 15 different major aircraft, many of which were single-purpose interceptors, to defend its airspace.[143]

DoD conducted tests in the late 1970s to assess the ability of cruise missiles to penetrate Soviet defenses. Because development of the Navy's Tomahawk missile was ahead of the ALCM-B at the time, DoD used Tomahawks to evaluate their ability to penetrate against U.S. systems and captured Soviet equipment. The tests concluded that existing Soviet defenses would be ineffective against U.S. cruise missiles.[144] DoD also concluded these missiles had a significant potential to impose costs on the Soviets, since the missiles would remain effective even if the Soviet Union invested $90 to $100 billion over a five- to ten-year period in new defenses.[145]

The proliferation of more advanced A2/AD systems has profoundly reshaped the threat environment since the ALCM and Tomahawk were first developed and tested.[146] The number of countries with advanced IADS continues to increase, as are adversary investments in

139 "USAF Awards Contracts for New Nuclear Missile to Lockheed, Raytheon," *Air Force News Service*, August 23, 2017, available at http://www.af.mil/News/Article-Display/Article/1287616/usaf-awards-contracts-for-new-nuclear-missile-to-lockheed-raytheon/.

140 Ibid.

141 See Mark A. Gunzinger, *Sustaining America's Advantage in Long-Range Strike* (Washington, DC: Center for Strategic and Budgetary Assessments, 2010).

142 Mahnken, ed., *Competitive Strategies For the 21st Century*, pp. 34–37; and Andrew Krepinevich, Simon Chin, and Todd Harrison, *Strategy in Austerity* (Washington, DC: Center for Strategic and Budgetary Assessments, 2012), p. xi.

143 Mahnken, ed., *Competitive Strategies For the 21st Century*, pp. 77–78, 106–120; Randall A. Greenwalt et al., *Historical Examples of Competitive Strategies* (Greenwood Village, CO: Science Applications International Corporation [SAIC], March 23, 1991), p. 2.45, a report prepared for the Competitive Strategies Office, OSD; and Kenneth Ekman, *Winning the Peace Through Cost Imposition* (Washington, DC: Brookings, 2014), p. 6.

144 Kenneth P. Werrell, *The Evolution of the Cruise Missile (Maxwell Air Force Base, AL: Air University Press, September 1985)*, p. 120.

145 Ibid.

146 See Gunzinger and Clark, *Winning the Salvo Competition*.

hardening measures, electronic warfare systems including directed energy weapons, advanced cyber capabilities, and other means to degrade U.S. strike operations. As a cruise missile designed for the threat environment of the 1970s, it is unlikely that the ALCM will have adequate stealth characteristics, features that harden it against non-kinetic attacks, and other survivability attributes needed to penetrate future missile defenses. Unlike the ALCM, the LRSO will be designed to penetrate and strike targets in these challenging threat environments. In other words, the development of next generation cruise missiles, including the LRSO, is a classic example of the next cycle in the ongoing competition between advances in precision strike technologies and their countervailing air and missile defense systems.

Considering Several Arguments Against the LRSO

Common arguments against procuring the LRSO can be loosely grouped into three main themes: nuclear-armed cruise missiles are destabilizing,[147] the LRSO would be a redundant capability, or the LRSO program is too expensive.[148] This section assesses each of these arguments.

Cruise missiles are "destabilizing"

Some LRSO detractors consider nuclear-armed ALCMs to be destabilizing. According to former Secretary of Defense William Perry, "because they can be launched without warning and come in both nuclear and conventional variants, cruise missiles are a uniquely destabilizing type of weapon."[149]

The reality is there is little evidence that ALCMs were destabilizing during the Cold War. In fact, bombers equipped with nuclear cruise missiles and gravity bombs may have been and remain the *most* stabilizing element of the U.S. triad. Due to their visibility, ability to be recalled after launch, and longer flight times relative to ballistic missiles, bombers are considered particularly effective means for stabilizing crises.[150] In a future crisis, the United

147 Kingston Reif, "Cruise Control: Why the United States Should Not Buy a New Nuclear Air-Launched Cruise Missile," *War on the Rocks*, March 16, 2016, available at https://warontherocks.com/2016/03/cruise-control-why-the-u-s-should-not-buy-a-new-nuclear-air-launched-cruise-missile/.

148 For example, see Kingston Reif, "Overkill: The Case Against a New Nuclear Air-Launched Cruise Missile," *Issue Briefs*, Arms Control Association, October 19, 2015, available at https://www.armscontrol.org/Issue-Briefs/2015-10-19/Overkill-The-Case-Against-a-New-Nuclear-Air-Launched-Cruise-Missile.

149 William J. Perry and Andy Weber, "Mr. President, Kill the New Cruise Missile," *Washington Post*, October 15, 2015, available at https://www.washingtonpost.com/opinions/mr-president-kill-the-new-cruise-missile/2015/10/15/e3e2807c-6ecd-11e5-9bfe-e59f5e244f92_story.html?utm_term=.4641ea302d91. Perry was a proponent of the ALCM as DoD's Undersecretary of Defense for Research and Engineering in the late 1970s. Also see Hans M. Kristensen, "The Nuclear Cruise Missile Mission," *Strategic Security* blog, Federation of American Scientists, October 20, 2015, available at https://fas.org/blogs/security/2015/10/lrso-mission/.

150 John Mecklin, "Rose Gottemoeller on the NPT Review Conference, Russian Saber Rattling, and More," *Bulletin of the Atomic Scientists*, May 14, 2015, available at https://thebulletin.org/rose-gottemoeller-npt-review-conference-russian-saber-rattling-and-more8317. Also see Forrest E. Morgan, *Crisis Stability and Long-Range Strike: A Comparative Analysis of Fighters, Bombers, and Missiles* (Santa Monica, CA: RAND Corporation, 2013), pp. xv–xxiii.

States could signal its resolve and strengthen its deterrence posture by uploading bombers with nuclear cruise missiles and gravity weapons, and if necessary, disperse them to distant airfields to increase their survivability.

China's and Russia's acquisition of modern, dual-capable ALCMs suggest they are not concerned with their potential to destabilize the nuclear balance. Russia's Kh-102 cruise missile is a nuclear-armed variant of its Kh-101 conventional land-attack cruise missile,[151] and a 2013 U.S. Air Force Global Strike Command briefing listed China's CJ-20 air-launched land-attack cruise missile as nuclear capable.[152]

There is a major issue related to the U.S. military's future triad that *could* be destabilizing. Should Russia and China develop the capability to prevent B-52s and other bombers from launching effective standoff nuclear attacks, then the United States would lose a significant means to signal its resolve and manage crises. As the 2008 Schlesinger Commission concluded, "ALCMs provide the B-52 with a stand-off capability allowing the bomber to deliver nuclear weapons without having to penetrate air defenses of a potential adversary. If this stand-off capability is allowed to disappear, then the ability to signal strategic capability through the generation and dispersal of B-52s will be compromised."[153] Although B-2s and future B-21s will still have the ability to employ nuclear gravity weapons against targets located in contested areas, continued advances in air defenses will increase the risk to bombers attempting to penetrate close enough to launch these short-range weapons against some defended targets.

The LRSO is a "redundant" capability

Some critics have argued that a new nuclear cruise missile would be a redundant capability given the Air Force's program to develop a new stealth bomber.[154] In light of China and Russia's continued efforts to field more advanced IADS, the LRSO will *complement* stealth bombers, not act as substitutes. Despite advances in low-observable technologies and aircraft designs, improvements in stealth countermeasures mean that the survivability of stealth aircraft and penetrating cruise missiles will eventually erode over their operational lives. Similar to the B-2, continued investments to upgrade the B-21 with new stealth-related technologies over time will help ensure it remains an effective penetrator. However, having the

151 "Kh-101, Kh-102," *Jane's Air-Launched Weapons*, updated September 28, 2017, available at https://janes.ihs.com/Janes/Display/jalw3712-jalw.

152 Kristensen and Norris, *Chinese Nuclear Forces 2016*, p. 210.

153 Secretary of Defense Task Force on DoD Nuclear Weapons Management, *Phase II: Review of the DoD Nuclear Missions* (Arlington, VA: DoD, December 2008), p. 25, available at https://www.defense.gov/Portals/1/Documents/pubs/PhaseIIReportFinal.pdf. Forrest Morgan also notes that cruise missiles "strengthen the deterrent and reinforce structural stability." Morgan, *Crisis Stability and Long-Range Strike*, p. 37; and Forrest E. Morgan, phone conversation and email with Carl Rehberg, November 2017.

154 For instance, see Steven Pifer, "Cancel the Long Range Strike Missile," *The National Interest,* June 26, 2017, available at http://nationalinterest.org/feature/cancel-the-long-range-standoff-missile-21322.

capability to launch strikes using penetrating cruise missiles while remaining outside the most lethal radius of advanced air defenses would increase the survivability and operational flexibility of stealth bombers. The LRSO will also give non-stealth bombers such as the B-52, which will be in the Air Force's inventory for many decades to come, the ability to hold strategic targets at risk while remaining outside the range of air defenses.[155]

LRSOs could also be an important means to reinforce the U.S. ability to meet its extended deterrence commitments. After the end of the Cold War, the United States maintained a small number of non-strategic nuclear weapons in Europe that could be delivered by NATO dual-capable fighter aircraft and removed all of its non-strategic nuclear weapons from the Pacific except for nuclear cruise missiles carried by *Los Angeles*-class attack submarines. All of the Navy's remaining TLAM-N weapons were retired in 2013, which reduced options available for the United States to communicate its intent and resolve to its allies and potential adversaries in a crisis. Until the 2018 NPR, DoD did not have a plan to develop weapons that could replace the TLAM-N.[156] The LRSO could provide another extended deterrence option for the United States.

The LRSO will be "too expensive"

Some LRSO detractors have asserted the weapon system will cost too much or the program should be delayed to help fund other needed military modernization programs.[157]

Although the LRSO will not be inexpensive, its program will cost a small fraction of the $94 billion the Pentagon has projected it will spend on the triad between FY 2016 and FY 2020, and about 0.06 percent of DoD's total projected spending over the same period.[158] DoD's April 2016 LRSO Milestone A Acquisition Decision Memo directed the Air Force to fund the program to the Service Cost Position of $9.7 billion for about 1,000 missiles.[159] This cost is consistent with other publicly available government estimates for the missile and its nuclear warheads (see Table 3).

155 "Beginning in 1982, our B-52H bombers were equipped with ALCMs in response to steady advances in adversary air defense systems. Armed with ALCMs, the B-52H can stay outside adversary air defenses and remain effective. The ALCM, however, is now more than 25 years past its design life and faces continuously improving adversary air defense systems. Life extension programs (LEPs) are underway to ensure the ALCM can be maintained until its replacement, the Long-Range Stand-Off (LRSO) cruise missile, becomes available." OSD, *Nuclear Posture Review 2018,* p. 47.

156 "With the retirement of the TLAM-N following the 2010 NPR, the United States relies almost exclusively on its strategic nuclear capabilities for nuclear deterrence and the assurance of allies in the region. . . . The United States will modify a small number of existing SLBM warheads to provide a low-yield option, and in the longer term, pursue a modern nuclear-armed sea-launched cruise missile." OSD, *Nuclear Posture Review 2018,* pp. 37, 54.

157 See Aaron Mehta, "Senators Urge Obama To Cancel Nuclear Cruise Missile," *Defense News*, July 21, 2016, available at https://www.defensenews.com/congress/2016/07/21/senators-urge-obama-to-cancel-nuclear-cruise-missile/; and "The New Nuclear-Armed Cruise Missile Unneeded and Destabilizing," factsheet, Union of Concerned Scientists, February 2016, available at https://www.ucsusa.org/sites/default/files/attach/2016/02/UCS-LRSO-fact-sheet.pdf.

158 OUSD (AT&L), *Report to Congress on the Number of Long-Range Standoff Weapons as Specified by Section 1657 of the National Defense Authorization Act for Fiscal Year 2016*, pp. 1–3.

159 This includes total development and procurement costs for about 1,000 missiles.

TABLE 3: LRSO MISSILE AND WARHEAD COST ESTIMATES[160]

	Missile Cost Estimate	W-80-4 LEP Nuclear Warhead	Total Estimated Cost
Air Force 2016 Acquisition Decision Memorandum	$9.7 B for about 1,000 missiles	NNSA bears cost	$9.7 B[161] for missiles only
National Nuclear Security Administration		$7 B to $10 B for 500 warheads	$7 B to $10 B for nuclear warheads
Congressional Research Service[162]	$10.8 B		$10.8 B for missiles only
Congressional Budget Office[163]	$13 B	$7 B to $10 B	$23 B for missiles and warheads

Moreover, the official Program Acquisition Unit Cost (PAUC) estimate for the LRSO is consistent with the ALCM's PAUC and significantly lower than the ACM's PAUC due to the ACM's truncated production run (see Table 4).[164]

160 In addition to estimates listed in Table 2, the Federation of Atomic Scientists estimates the LRSO will cost $20–30 billion. Hans M. Kristensen, "Forget LRSO; JASSM-ER Can Do the Job," *Strategic Security* blog, Federation of American Scientists, December 16, 2015, available at https://fas.org/blogs/security/2015/12/lrso-jassm/. Another independent estimate suggested the LRSO could cost $9.0 billion for missiles and $7.0 to 9.5 billion for its nuclear warheads. Kingston Reif, "U.S. Nuclear Modernization Programs: Fact Sheets & Briefs," Arms Control Association, January 2018. Steven Pifer from the Brookings Institution estimated the LRSO will cost $15–30 billion. This range is due to a 50 percent confidence level in the estimate. Steven Pifer, "Cancel the Long-Range Standoff Missile," *Order from Chaos* blog, Brookings Institution, July 28, 2017, available at https://www.brookings.edu/blog/order-from-chaos/2017/06/28/cancel-the-long-range-standoff-missile.

161 This is the Air Force cost position as of April 2016. The NNSA, which is part of the Department of Energy, is responsible for the W80-4 warhead Life Extension Program (LEP).

162 Woolf, *U.S. Strategic Nuclear Forces,* pp. 34–36.

163 Congressional Budget Office (CBO), *Approaches for Managing the Costs of U.S. Nuclear Forces, 2017 to 2046* (Washington, DC: CBO, October 2017). Derived CBO numbers are $23 billion (in then-year dollars) for RDT&E and production of both the cruise missile and the W-80 warhead. RDT&E and production estimates for the W-80 warhead range from $7 to 10 billion, delivering an estimate of roughly $13 billion for the LRSO without the warhead. The CBO estimated that sustainment costs through 2046 for the LRSO could be approximately another $5 billion.

164 Program Unit Acquisition Costs (PUAC) includes RDT&E and procurement in its average cost. Average Procurement Unit Cost (APUC) only includes procurement divided by the number or articles acquired. PUAC is generally considered a more transparent way to present costs, especially for systems that require significant RDT&E.

TABLE 4: CRUISE MISSILE PROGRAM ACQUISITION UNIT COST COMPARISON

Missile Type (Quantity Procured)	Program Base Year	Then-Year $	FY 2018 $	PAUC
ALCM (1,765 missiles)	1977	$4.1 B	$13.64 B	$7.7 M[165]
ACM (460 missiles)	1983	$3.8 B	$8.23 B	$17.9 M[166]
LRSO (about 1,000 missiles)	2016	$9.7 B	$8.27 B	$8.1 M[167]

This is a small price to pay to help ensure the bomber leg of the triad has the ability to launch standoff strikes well into the future in addition to conducting direct attacks with B61-12 gravity bombs.

Not included in these estimates, of course, is an accounting of what it might cost Russia, China, Iran, and North Korea to invest in missile defenses to try to counter LRSOs, which can be launched by U.S. bombers from multiple azimuths of attack. Unlike ballistic missiles that have more predictable flight paths, long-range, air refuellable bombers can maneuver to attack targets with standoff and gravity nuclear weapons from many different vectors. The combination of multi-axis air strikes and ballistic missiles that can be launched from the land and sea could compel great power competitors to increase their investments in technologically complex and expensive defensive systems. In the words of the Air Force's Vice Chief of Staff, the LRSO will present "a very daunting challenge for any adversary" and support "a cost-imposing strategy."[168]

165 Office of the Assistant Secretary of Defense (OASD) (Comptroller), "SAR Program Acquisition Cost Summary as of December 31, 1985," April 7, 1986, available at https://www.acq.osd.mil/ara/sar/1985-DEC-SARSUMTAB.pdf. This estimate does not include costs for the conventional CALCMs. Spiral development & procurement of AGM-86C/D weapons occurred after the ALCM program was complete. That historical data is not available in open source literature.

166 OUSD (AT&L), "Selected Acquisition Report (SAR) Summary Tables as of December 31, 1992," June 7, 1993, available at https://www.acq.osd.mil/ara/sar/1992-DEC-SARSUMTAB.pdf.

167 CSBA used RDT&E program costs from the FY 2017 President's Budget and General Robin Rand's testimony on FY 2022 RDT&E to develop a notional LRSO cost estimate profile in FY 2018 dollars. See "Exhibit R-2, RDT&E Budget Item Justification: PB 2017 Air Force," in U.S. Air Force, *Department of Defense Fiscal Year (FY) 2017 President's Budget Submission: Research, Development, Test & Evaluation, Air Force,* Air Force Justification Book vol. 2 (Washington, DC: U.S. Air Force, February 2016), available at http://www.dtic.mil/descriptivesum/Y2017/AirForce/stamped/U_0604932F_5_PB_2017.pdf; and Robin Rand, General, Commander, Air Force Global Strike Command, "Department of Defense Nuclear Acquisition Programs and the Nuclear Doctrine," statement before the Subcommittee on Strategic Forces, Senate Armed Services Committee, June 7, 2017.

168 Wilson Brissett, "LRSO is a Cost-Imposing, Cost-Saving Strategy," *Air Force Magazine,* May 26, 2017, available at http://www.airforcemag.com/DRArchive/Pages/2017/May%202017/May%2026%202017/LRSO-is-a-Cost-Imposing,-Cost-Saving-Strategy.aspx.

Summary

The ALCM is a 1970s-era cruise missile that has exceeded its intended service life and will not be able to penetrate future threat environments.[169] As summarized by the comparison in Table 5, developing a replacement for the ALCM would help ensure the air-breathing leg of triad remains an effective and cost-imposing deterrent force.

Without the LRSO, the U.S. bomber force will eventually lose its ability to launch nuclear strikes from standoff ranges. The alternative would require bombers to penetrate close enough to targets to release very short-range nuclear gravity weapons. Having the ability to strike from outside the most lethal ranges of future advanced air defense systems will increase the probability that U.S. bombers will be able to launch their weapons. In summary, replacing the aging ALCM with the LRSO will give the United States a capability it needs to keep pace with great power competitors that are developing and fielding multiple cruise missile variants that are, or may soon be, nuclear capable. The alternative of delaying the ALCM's replacement would give China and Russia the opportunity to gain significant advantages in the salvo competition.

169 "A nuclear air-launched cruise missile contributes significantly to every element of U.S. nuclear strategy and is therefore an essential component of our future nuclear capability. . . . The AGM-86 Air Launched Cruise Missile, initially fielded in 1982, is well beyond its intended service life. The Department has undertaken several Service Life Extension Programs to sustain ALCM, but they are not sufficient to meet long term operational requirements." Colin Clark, "VCJCS Selva Says US Must Not Let Robots Decide Who Dies; Supports LRSO," *Breaking Defense*, July 18, 2017, available at https://breakingdefense.com/2017/07/vcjcs-selva-us-must-not-let-robots-decide-who-dies-supports-lrso/.

TABLE 5: ALCM AND LRSO COMPARISON

	AGM-86B ALCM	LRSO
Ability to penetrate future threat environments	• Will not meet this requirement[170]	• Will meet this requirement
Navigation and targeting	• Limitations of ALCM terrain contour-matching guidance system, challenges of operating in a degraded or denied GPS environment	• Potential for more autonomous, self-contained navigation systems and improved targeting capabilities
Cost imposition potential	• IADS will be increasingly effective against non-stealthy cruise missiles.	• Could induce China and Russia to upgrade/modernize their IADS
Impact on strategic deterrence	• ALCM-only could undermine the credibility of the current bomber force beyond 2030.	• Would help maintain the credibility of the bomber leg of the triad • Still need to procure the B-21 stealth bomber
Potential to support extended deterrence		• Could support extended and tailored deterrence commitments
Impact on crisis stability	• Would weaken a key means of signaling resolve in crises	• Would help maintain the future viability of B-52s, which can be used to signal in crises
Conventional strike potential	• Limited inventory of CALCMs	• Potential to develop a conventional variant that carries a variety of payloads
Risks associated with additional ALCM service life extensions	• SLEPs problematic in the 2020s, key components will likely age-out after 2030	
Potential cost of additional service life extensions	• After 2030, ALCM SLEPs are no longer cost effective.[171] • Already planned SLEPs cannot be avoided even if the LRSO program is accelerated.	• LRSO cost estimates are similar to the ALCM and less than the ACM.

Red = excessive risk or won't meet requirements
Yellow = increased cost compared to the LRSO
Green = meets requirements, best option.

170 "ALCM is already well beyond its originally planned end of life and also was not designed to penetrate state-of-the-art air defenses in the 2020s or beyond." Dennis Evans and Jonathan Schwalbe, *The Long-Range Standoff (LRSO) Cruise Missile and its Role in Future Nuclear Forces* (Washington, DC: Johns Hopkins Applied Physics Laboratory, 2017), p. 4.

171 According to an internal Air Force document, "ALCM designed in 1970s and fielded in the 1980s. Currently undergoing three service life extensions but parts/technology outdated—no longer cost effective to maintain past 2030." Air Force Global Strike Command, "Air Force Global Strike Command Priority Programs," Version 11, November 2016, p.2. For more information, see U.S. Congress, *Fiscal Year 2017 Budget Request for Department of Defense Nuclear Forces,* transcript of hearing before the House Armed Services Committee held March 2, 2016 (Washington, DC: U.S. Government Publishing Office, 2017), p. 102; and Evans and Schwalbe, *The Long-Range Standoff (LRSO) Cruise Missile and its Role in Future Nuclear Forces,* p. 11.

CHAPTER 3

Minuteman III Modernization and the GBSD

The U.S. ICBM force has long been a visible symbol of the U.S. commitment to maintaining a ready strategic deterrent. This chapter begins by summarizing the attributes of U.S. ICBMs and the history of the Minuteman III. Originally designed to have a ten-year service life, a series of modernization and life extension programs have allowed the third Minuteman variant, the Minuteman III, to remain operational since it was first deployed in the 1970s.[172] Chapter 3 then assesses the future deterrence potential, sustainability, and cost of extending Minuteman IIIs compared to replacing them with GBSDs designed for future threat environments. Chapter 3 concludes, as has every Nuclear Posture Review since the end of the Cold War, that an ICBM force should remain a part of the U.S. strategic deterrence posture. It also concludes that the Minuteman III's age and technological obsolescence are eroding its reliability; the feasibility of further extending and modernizing critical Minuteman III components is questionable at best; and the resources needed to further extend its life would be more wisely used to develop a replacement that meets future requirements.

The Land-Based Leg of the Triad: ICBMs

The U.S. land-based ICBM force is the most responsive leg of the triad. The Air Force maintains its operationally deployed Minuteman III missiles at a very high state of readiness, ensuring that they remain on continuous alert in peacetime. Unlike strategic bombers, ICBMs can strike targets over global ranges within tens of minutes after launch. The U.S. ICBM force is also highly dispersed, which creates a large number of targets for an enemy contemplating a first strike on the United States. The size of the ICBM force and its dispersion would

172 The LGM-30G Minuteman III is the world's oldest ICBM still in service. Russia's oldest ICBM became operational in 1988, while China's oldest ICBM was operational in 1980.

"make a disarming strike extraordinarily difficult and extremely costly for any adversary."[173] By contrast, the Air Force maintains its nuclear-capable bombers at three bases, and there are two home ports for the Navy's *Ohio*-class SSBNs.[174] The U.S. ICBM force is also the least expensive leg of the triad to maintain since its annual operations and sustainment costs are about one-third the cost of the Navy's SSBN force and at least 20 percent less than the bomber leg of the triad.[175]

History and evolution of Minuteman ICBMs

Throughout the 1950s, the U.S. military and defense industrial base worked on developing reliable solid fuel rocket motors that would improve the safety and the launch response times of DoD's ballistic missiles. Contemporary liquid-fueled ICBMs were difficult to deploy, expensive to maintain, and had to be fueled above ground before they could be launched.[176] By 1957, a preliminary design for a relatively small, low-maintenance solid fuel ICBM that could be fired at a moment's notice was briefed to senior DoD leaders.[177] Supported by Congress, which was also concerned with the emergence of a potential U.S.-Soviet ICBM missile gap, DoD developed the solid fuel Minuteman IA, which became operational in 1962 just prior to the Cuban missile crisis.[178] The development of upgraded Minuteman variants continued through the 1960s. By the spring of 1967, there were 800 Minuteman IBs and 200 Minuteman IIs in the U.S. inventory.[179]

The three-stage Minuteman III, which entered its development phase in the mid-1960s, was the world's first MIRV-capable ICBM. Minuteman IIIs were deployed to Minuteman II underground silos. At the time of the Minuteman III's development, the United States was in a competition with the Soviet Union to expand and improve their respective ICBM arsenals. This competition motivated both countries to innovate and improve their ICBM programs continuously, which was a factor in determining the Minuteman III's planned ten-year service life.

173 Selva, "Military Assessment of Nuclear Weapons Requirements," p. 5.

174 B-52Hs are stationed at Minot AFB, North Dakota and Barksdale AFB, Louisiana. All B-2 bombers are stationed at Whiteman AFB, Missouri. The Navy's *Ohio*-class SSBNs are homeported at Bangor, Washington and at Kings Bay, Georgia.

175 C. Donald Alston, *Deterrence and the ICBM: A Practitioner's Perspective*, An Open Letter to the Commander-in-Chief (Vienna, VA: The Potomac Foundation, 2017), pp. 6–9. See also Burg, *America's Nuclear Backbone: The Value of ICBMs and the New Ground Based Strategic Deterrent*.

176 Thomas G. Mahnken, *Technology and the Way of War Since 1945* (New York: Columbia University Press, 2008), pp. 35–39, 47–50; and John C. Lonnquest and David F. Winkler, *To Defend and Deter: The Legacy of the United States Cold War Missile Program*, illustrated edition (Bodega Bay, CA: Hole in the Head Press, 2014), p. 73.

177 Lonnquest and Winkler, *To Defend and Deter*, p. 73.

178 David Spires, *On Alert: An Operational History of the United States Air Force Intercontinental Ballistic Missile (ICBM) Program, 1945–2011* (Colorado Springs, CO: Air Force Space Command [AFSPC], 2012), p. 137. Minuteman missiles required only 20 percent of the construction costs and 10 percent of the annual sustainment costs of Titan and Atlas liquid-fueled missiles. Ibid., p. 150.

179 Ibid., p. 152.

Since the Minuteman III's deployment[180]

The pace of ICBM modernization began to slow in the 1970s due in part to a series of arms control agreements between the United States and Soviet Union, including the 1972 Anti-Ballistic Missile Treaty and SALT I.[181] The MX Peacekeeper missile, which was capable of carrying ten reentry vehicles (RV), was designed in the 1970s and early 1980s to replace the Minuteman III. The MX was originally intended to be a mobile system to reduce the U.S. reliance on fixed-site ICBMs that were increasingly vulnerable to Soviet attacks. Cost concerns, however, reduced the size and scope of the Peacekeeper program.[182] Ultimately, the Air Force procured 50 silo-based Peacekeepers without their originally planned mobile capability.

FIGURE 10: MX PEACEKEEPER TEST LAUNCH

Test launch of LGM-118 Peacekeeper Intercontinental ballistic missile on November 26, 2002. U.S. Air Force photo.

180 For more background, see Mahnken, *Technology and the Way of War Since 1945*, pp. 72–79.

181 The size of the U.S. ICBM inventory, which peaked in 1967 at 1,000 Minuteman and 54 Titan missiles, began to decline in 1982. James C. Ruehrmund Jr. and Christopher Bowie, *The Arsenal of Airpower: USAF Aircraft Inventory 1950–2009* (Washington, DC: Mitchell Institute, 2010), p. 15.

182 The mobile MX Peacekeeper Missile was designed to replace the Minuteman III missiles and offset U.S. reliance on silo-based ICBMs. The original Peacekeeper plan had multiple missiles (200) in numerous protective shelters (4,600). Concern over increased nuclear weapons investments and other issues, however, reduced the size and scope of the Peacekeeper program, limiting acquisition to 50 silo-based missiles without its originally planned mobile capability. The Peacekeepers were only deployed between 1986 and 2005. Since its retirement, the Minuteman III has remained the only U.S. in-service ICBM. Spires, *On Alert*, pp. 189–218.

The START II Treaty between the United States and Russia limiting MIRV-capable missile systems further undercut the need for Peacekeepers and contributed to the decision to retire them early.[183] As a result, the Minuteman III has been the only U.S. ICBM in the triad since 2005. Assuming the GBSD schedule is not delayed, some Minuteman IIIs will remain operationally deployed until the mid-2030s.

The Minuteman III today

Minuteman III ICBMs are three-stage, solid-fuel missiles that include a missile guidance set (NS-50 Guidance), a Propulsion System Rocket Engine (PSRE), and an RV that houses a warhead. The PSRE is a small, liquid-fueled stage that provides power for final velocity and direction adjustments before a Minuteman III's RV is deployed into its ballistic arc. These RVs lack a terminal guidance system; when released from the missile body, they follow ballistic arcs like artillery shells.[184] Although the Minuteman III originally carried three RVs with nuclear warheads, all Minuteman IIIs are now single-warhead systems.[185] The United States made the decision to download Minuteman IIIs to a single warhead after signing the START II Treaty with Russia. In spite of Russia declaring START II null and void in 2002,[186] the 2010 NPR decided the Air Force should physically modify some Minuteman IIIs so they could not be easily reconfigured to carry more than one warhead.[187]

The U.S. ICBM force also includes 450 launch facilities (missile silos), 45 launch control centers, and command and control infrastructure. The retirement of 50 Minuteman IIIs between 2007 and 2008 reduced the number of U.S. ICBMs on alert from 500 to 450. This reduction was influenced by the Strategic Offensive Reductions Treaty and decisions made during the U.S. 2005 Base Realignment and Closure process. The United States further reduced its operationally deployed weapons and launchers to comply with the 2010 New

183 Due to the Soviet Union's invasion of Afghanistan, Congress did not ratify the SALT II Treaty, which placed a limit on MIRV systems and new land-based ICBM launchers. Details on the SALT II Treaty are available at https://www.state.gov/t/isn/5195.htm. The START Treaty was fully implemented by 2001 prior to the Peacekeeper's retirement in 2005. Details on the START Treaty are available at https://www.armscontrol.org/factsheets/start1.

184 "Current RVs have no terminal guidance system: once released from the missile, they follow ballistic arcs in much the same manner as artillery shells." Jeff Schaff, *Future Ballistic Missile Requirements: A First Look* (Colorado Springs, CO: U.S. Air Force, 2000), p. 2, available at http://www.dtic.mil/dtic/tr/fulltext/u2/a386554.pdf.

185 Woolf, *U.S. Strategic Nuclear Forces*, pp. 12–13; and Jean Rowell, "Last Malmstrom ICBM reconfigured under treaty," *Great Falls Tribune,* June 18, 2014, available at http://www.greatfallstribune.com/story/news/local/2014/06/18/last-malmstrom-icbm-reconfigured-treaty/10773351/.

186 "Treaty between the United States of America and the Union of Soviet Socialist Republics on Strategic Offensive Reductions (START II)," Nuclear Threat Initiative, updated October 26, 2011, available at http://www.nti.org/learn/treaties-and-regimes/treaty-between-united-states-america-and-union-soviet-socialist-republics-strategic-offensive-reductions-start-ii/.

187 According to the 2010 NPR, "All U.S. ICBMs will be 'de-MIRVed' to a single warhead each to increase stability. Some ability to 'upload' non-deployed nuclear weapons on existing delivery vehicles should be retained as a hedge against technical or geopolitical surprise. Preference will be given to upload capacity for bombers and strategic submarines." OSD, *Nuclear Posture Review Report* (2010), p. 25. The Minuteman III can carry either the W-78/Mk12A warhead/RV combination or the W-87/Mk21 warhead/RV combination. Minuteman IIIs could be re-MIRVed with the W-78/Mk12A.

START Treaty, which superseded the SORT. Four hundred Minuteman III launchers and their associated missiles now remain in an "operationally deployed" status, and 50 additional launchers are in a "non-deployed" status without operational missiles.[188] Because the United States maintains a single ICBM weapon system, its ICBM force is at higher risk of suffering future technological or operational failures compared to great power competitors that are continuously developing multiple ICBM variants that are rail- or road-mobile and can be stored in hardened underground facilities when not deployed.

Replacing the Minuteman III

First Attempt: The Land-Based Strategic Deterrent

In 2001, DoD directed the Air Force to "extend the life of the Minuteman III until 2020, while beginning the requirements process for the next-generation ICBM."[189] In 2003, the Air Force Space Command's Strategic Master Plan called for life extension programs to sustain Minuteman III through 2020 and the development of a new Land-Based Strategic Deterrent (LBSD) that would reach initial operating capability in 2018.[190] From 2004 to 2005, the Air Force conducted an AoA to assess the desired accuracy, range, lethality, mission responsiveness and flexibility, enhanced C4, security, and ownership cost for a LBSD with alternative rail-mobile and road-mobile basing modes.[191] The AoA also assessed a baseline scenario with a series of SLEP options that would keep Minuteman IIIs in service. AoA results released in 2006 concluded that "The baseline [Minuteman III] system, while very capable today and a successful deterrent for the Cold War, does not meet the post-2018 warfighter requirements."[192] Due to competing priorities that left insufficient funding to pursue an ICBM replacement at the time, the Air Force chose to accept risk and incrementally fund programs to modernize and extend Minuteman IIIs. This decision was supported by the AFSPC

188 New START has limitations of 700 deployed ICBMs, deployed SLBMs, and deployed bombers. There is no requirement on the mix. The U.S. has chosen this mix, but it can change. "New START," U.S. Department of State, available at https://www.state.gov/t/avc/newstart/. An additional four Minuteman III launchers are held in reserve for testing. The Air Force is required to continually monitor and maintain its non-deployed missiles sites. It is important to note that future U.S. requirements might exceed 400 operationally deployed ICBMs, which would increase total inventory requirements.

189 Schaff, *Future Ballistic Missile Requirements*, p. 1. The 2001 NPR directed the Air Force to extend the life of the Minuteman III until 2020 and begin the process to replace it. AFSPC, *Strategic Master Plan FY04 and Beyond* (Peterson Air Force Base, CO: AFSPC, November 5, 2002), p. 13, available at https://nukewatch.org/importantdocs/resources/Final004SMP.pdf.

190 The plan also called for the modernization of the Air Force's nuclear support infrastructure, to include communication networks, mobile command and control center, and helicopter and security programs. AFSPC, *Strategic Master Plan FY06 and Beyond* (Peterson Air Force Base, CO: AFSPC, October 1, 2003), p. 28, available at http://www.wslfweb.org/docs/Final%2006%20SMP--Signed!v1.pdf.

191 AFSPC/A5M Deterrence and Strike Division, "Land-Based Strategic Deterrent (LBSD) Analysis of Alternatives (AoA)and Concept Refinement," October 7, 2004. This is an unclassified summary of the AoA provided by AFGSC and not available to the general public. See also "Air Force Lays Out Post-2020 Modernization Priorities for ICBMs," *Satellite Today*, July 10, 2006, available at http://www.satellitetoday.com/uncategorized/2006/07/10/air-force-lays-out-post-2020-modernization-priorities-for-icbms/.

192 Ibid.

commander, who stated that this "incremental approach was the 'preferred course' given the difficult challenge of acquiring funding for a new ICBM during a 'global war on terror' and a country focused on two major conventional wars."[193]

A second major Air Force study conducted in the same timeframe concluded that although the Minuteman III could be sustained until 2030, additional research was needed to assess the cost of extending the service life of its aging components. This study likely influenced the 2007 NDAA language that required the Air Force to keep Minuteman IIIs in service until 2030 instead of 2020. Several years later, the Commander of the Air Force's Global Strike Command testified, "In response to Congressional direction, the Air Force is currently exploring the steps necessary to sustain the Minuteman III until 2030. Projections can and have been made about the potential service life of the motors and other hardware after undergoing the current upgrade programs; but, *it's still too early to say with confidence just how long the Minuteman weapon system will be serviceable* [emphasis added]."[194] After additional analysis, the Air Force determined that the cost of extending the service life of its Minuteman IIIs to 2030 would be greater than originally expected, and some of the weapon system's key components were not viable candidates for the SLEPs that would keep them in service past 2030. As a result of this analysis and the 2014 GBSD AoA, the Air Force determined it should replace its Minuteman IIIs with a new ICBM weapon system that "would meet current and expected threats."[195]

GBSD emerges as the Minuteman III replacement

Shortly after the Air Force Global Strike Command was established in 2009, it completed an ICBM Master Plan that stated "large-scale investment beginning in 2020 would be necessary to sustain Minuteman III through 2030. These modernization efforts must support both sustainment though 2030 and recapitalization for a Minuteman Follow-on after 2030."[196] The FY 2018 President's Budget requested full funding for the GBSD program. On August 23, 2017, the Air Force announced Northrop Grumman would receive $328.6 million and Boeing would receive $349.2 million to continue into the TMRR phase of the GBSD program.[197] After

193 Ibid.

194 Frank G. Klotz, Lieutenant General, Commander Air Force Global Strike Command, "Strategic Forces Programs in Review of the Defense Authorization Request for Fiscal Year 2011 and the Future Years Defense Programs," statement before the Strategic Forces Subcommittee, Senate Armed Services Committee, March 17, 2010, p. 9, available at www.nti.org/media/pdfs/off_us_congress_senate_16.pdf?_=1316627912.

195 U.S. Air Force, *Cost Comparison of Extending the Life of the Minuteman III Intercontinental Ballistic Missile to Replacing it with a Ground-Based Strategic Deterrent*, p. 4; and Woolf, *U.S. Strategic Nuclear Forces,* p. 16.

196 U.S. Air Force Fellow (name redacted), *U.S. Air Force Intercontinental Ballistic Missile Sustainment, Modernization, and Recapitalization: Background and Issues for Congress* (Washington, DC: Congressional Research Service, June 24, 2015), available at https://www.everycrsreport.com/files/20150624_R44103_9f80f15092b83b44c9439bbdef749a41afbe0736.pdf; and Jeffrey F. Smith, *ICBM Master Plan* (Barksdale Air Force Base, LA: AFGSC, October 2010).

197 Mike Stone, "U.S. Air Force Awards Contracts to Boeing, Northrop for ICBM Replacement," *Reuters,* August 21, 2017, available at https://www.reuters.com/article/us-boeing-pentagon-gbsd/u-s-air-force-awards-contracts-to-boeing-northrop-for-icbm-replacement-idUSKCN1B12H3.

TMRR is completed in 2020, one prime contractor will likely be selected to continue into the GBSD program's EMD phase which could cost about $15 billion. Production of 642 missiles would start circa 2025, finish in 2040, and cost about $32 billion in then-year dollars. The new missile force is expected to reach its initial operational capability threshold by 2029, full operational capability in 2036, and remain in service until the mid-2070s. In addition to the new missiles, the GBSD force will include a modernized command and control infrastructure with enhanced secure communications, including refurbished underground launch control centers (LCC) and launch facilities (LF). These modifications and upgrades are part of an integrated GBSD program, which should reduce costs and improve the security of the ICBM force.

Considering Several Arguments Against the GBSD

The U.S. ICBM force is "too vulnerable"

Similar to conventional salvo competitions, the development of increasingly accurate, multiple warhead ICBMs and SLBMs have led some to question the value of sustaining a U.S. ICBM force. As early as the 1970s, the Soviet Union's development of high throw-weight, MIRVed ICBMs with improved guidance systems caused concern that Moscow could erroneously conclude it had gained the ability to "inflict a major blow against the U.S. nuclear arsenal and still have sufficient weapons left to absorb an American retaliation and launch a counter-reprisal."[198] However, launching a preemptive strike to defeat the hundreds of ICBMs in the U.S. Cold War inventory would have required such a massive effort that an adversary was likely to conclude that it was not feasible.

Despite improvements in Russia's and China's precision strike capabilities, the U.S. silo-based ICBM force still poses a major targeting challenge to an enemy contemplating a first strike. Destroying the Air Force's 450 ICBM silos and 45 launch control centers that are hardened and dispersed over a very large area would require an enemy to launch a massive attack. For illustrative purposes, a great power adversary would need to launch two nuclear warheads with a 90 percent probability of kill against each U.S. ICBM silo in order to achieve a high level of confidence of success; this would require over 1,000 highly accurate, long-range weapons.[199] Diminishing the size of the ICBM leg of the triad would be destabilizing, since a great power

198 Montgomery, *The Future of America's Strategic Nuclear Deterrent*, p. 23. These concerns were captured in a 1977 paper by Colin Gray: "With the deployment of a generation of high throw-weight MIRV-equipped ICBM (with a circular error probable that must be presumed already to be around 0–25 nautical miles or better), the Soviet Union is acquiring the means to eliminate the American fixed-site ICBM force." Colin Gray, *The Future of Land-Based Missile Forces*, Adelphi Paper No. 140 (London: International Institute for Strategic Studies, Winter 1977), p. 4.

199 Lauren Caston et al., *The Future of the U.S. Intercontinental Ballistic Missile Force* (Santa Monica, CA: RAND Corporation, 2014), pp. 30–35, available at https://www.rand.org/content/dam/rand/pubs/monographs/MG1200/MG1210/RAND_MG1210.pdf.

adversary might erroneously conclude that it could successfully launch a preemptive strike in a crisis against a smaller number of U.S. bomber bases and SSBN facilities.[200]

It is likely that the value of the Minuteman III force as a "missile sink" for an enemy first strike will diminish as it becomes increasingly unreliable over time. Significant doubts over the viability of Minuteman IIIs as effective weapon systems could cause an adversary to believe that it could reallocate some of its weapons to other elements of the U.S. triad in a first-strike scenario. From this perspective, replacing Minuteman IIIs with GBSDs that are designed to remain in the force until 2075 could improve the survivability of the U.S. triad as a whole.

Other measures that would help improve the U.S. position in the nuclear salvo competition include maintaining a larger number of "non-deployed" silos without ICBMs. This would increase the number of targets an enemy would have to attack. Over time, the United States could also increase the capacity of its active defenses against ballistic missile strikes, and it could eventually deploy relocatable (road- or rail-mobile) ICBMs if necessary. However, post-Cold War DoD analyses have concluded that the cost to acquire a mobile ICBM force, its operating expenses, and other factors such as access to large, secure areas, make it an impractical choice.[201] For instance, the 2006 LBSD AoA concluded that options for a rail- or road-mobile ICBM would cost an additional $29.4 billion and $41.2 billion (in FY 2012 dollars), respectively, compared to deploying a new ICBM to Minuteman III launch facilities.[202]

A Minuteman III force will "meet future requirements"

The Minuteman III has been extended far past its planned ten-year service life. Even if it were possible to extend the Minuteman III force past 2030, it would remain a capability that was originally designed for a 1970s missile defense environment that lacked advanced IADS, cyber threats, electronic warfare (EW) systems such as high-power microwave counter-electronics

200 According to DoD's Defense Science Board Task Force on Nuclear Deterrence, the possession of "significant numbers of ICBMs denies any adversary the benefits of a limited attack. Without the ICBM, surprise attacks against a handful of bomber bases and SSBN facilities, with plausible deniability, could drastically alter the correlation of forces." OUSD (AT&L), *Report of the Defense Science Board Task Force on Nuclear Deterrence* (Washington, DC: DoD, October 1998), p. 14, available at http://www.dtic.mil/get-tr-doc/pdf?AD=ADA433328. Evan Montgomery discusses these dynamics in *The Future of America's Strategic Nuclear Deterrent*, p. 22.

201 DoD first approved a mobile basing mode for an ICBM, the Minuteman I, in 1961. This mode was cancelled just a few months after it received initial funding. President Kennedy's March 28, 1961 special message to Congress recommended it "defer the currently funded three mobile Minuteman squadrons and replace them with three underground squadrons." Steven A. Pomeroy, *An Untaken Road: Strategy, Technology and The Hidden History of America's Mobile ICBMs* (Annapolis, MD: Naval Institute Press, 2016), p. 96.

202 Trevor Flint, *Land-Based Strategic Deterrent Analysis of Alternatives: Final Report* (Peterson Air Force Base, CO: AFSPC, April 28, 2006). This is an unclassified report provided by AFGSC and not available to the general public.

weapons, and other advanced defenses.[203] Similar to the earlier LBSD analysis of alternatives, the 2014 GBSD AoA concluded that Minuteman IIIs will not meet future requirements.[204] Although details on the GBSD's specific operational requirements are not available to the public, a 2004 Air Force Space Command summary of the LBSD concept stated it would require "better accuracy, higher reliability, and very importantly, designed-in flexibility and adaptability that allow the force provider to react to new requirements in an uncertain future."[205] DoD's 2018 NPR report is more direct, stating Minuteman IIIs will lose their ability to penetrate future defenses over time.[206] The Minuteman III's ability to meet these requirements may be the most significant factor behind the Air Force's decision to proceed with the GBSD: "A final determination to support a replacement system was made because a replacement GBSD capability would meet current and expected threats."[207]

A Minuteman III force "is sustainable"

The Air Force has gone to extraordinary lengths to extend the operational life of its Minuteman IIIs beyond their original ten-year timeframe. Table 6 lists most major Minuteman III modernization and SLEP programs that have been completed or are ongoing and the probable longevity of their modifications.

203 "High power microwave weapons generate very high power, short-duration pulses of electromagnetic energy at discrete frequencies using waveforms that are designed to damage sensitive electronic components such as a PGM's guidance, seeker, or control systems. HPM pulses can interfere with or cause damage by inducing a current in a targeted circuit that exceeds the circuit's rating, causing it to overheat and fail, similar to blowing a fuse. Because HPM beams attack specific elements such as input/output boards or amplifiers located inside threats such as PGMs, they are less affected by heat shielding on a missile's exterior." Gunzinger and Clark, *Winning the Salvo Competition*, p. 43.

204 U.S. Air Force, *Cost Comparison of Extending the Life of the Minuteman III Intercontinental Ballistic Missile to Replacing it with a Ground-Based Strategic Deterrent*, p. 6.

205 AFSPC/A5M Deterrence and Strike Division, "Land-Based Strategic Deterrent Analysis of Alternatives," p. 3.

206 "The Minuteman III service life cannot be extended further. In addition, Minuteman III will have increasing difficulty penetrating future adversary defenses." OSD, *Nuclear Posture Review 2018*, p. 46.

207 U.S. Air Force, *Cost Comparison of Extending the Life of the Minuteman III Intercontinental Ballistic Missile to Replacing it with a Ground-Based Strategic Deterrent*, p. 4.

TABLE 6: MAJOR MINUTEMAN III SLEP/MODIFICATION PROGRAMS[208]

Program Name/Type	Completed or Planned Completion	Approximate Cost (TY$)	Longevity of SLEP
Propulsion System Rocket Engine Program (PSRE)	Completed 2013	$0.2 B	2027
Propulsion Replacement Program (PRP)	Completed 2013	$2.1 B	2028
Guidance Replacement Program (GRP)	Completed 2009	$1.8 B	2032
Rapid Execution and Combat Targeting (REACT) Service Life Extension Program	Completed 2006	$0.2 B	Not available
Safety Enhanced Reentry Vehicle (SERV)	Completed 2012	$0.4 B	Not available
Miscellaneous small programs	Unknown	$2.3 B	Not available
Subtotal for first wave of SLEPs		**$7.0 B**	
Solid Rock Motor Warm Line Program	Only funded in 2013	$76.9 M	Not applicable
ICBM Fuze Modernization for Minuteman III and GBSD	Ongoing, 2027	$410.2 M spent $1.64 B to complete	2060
ICBM Demonstration/Validation Program for Minuteman III and GBSD	Ongoing	$252.3 M through FY 2017 final cost TBD	Not applicable

In the late 1990s, the Air Force initiated a program to upgrade and improve the maintainability and reliability of the Minuteman III's guidance system and a second "Propulsion Replacement Program" to replace its solid propellant.[209] A later program replaced the Minuteman III's post-boost propulsion components. These systems had to be replaced—they could not be repaired since many of the original parts involved were no longer available. Ongoing initiatives include the ICBM Fuze Modernization Program, which is slated to receive funding through at least FY 2022. This program will replace original Minuteman III fuzes that have "long exceeded their original 10-year lifespan" with new fuzes that will also be compatible with a GBSD design.[210]

As highlighted in red in Table 6, it may not be feasible to further extend some Minuteman III components past the indicated years. For example, Minuteman III electronics updated by the Guidance Replacement Program begin to age out in 2032, and many of the guidance system's electronics, including its gyros, cannot be refurbished. Other sections of the guidance system that are based on 1980s-era technologies may not be capable of withstanding modern countermeasures. The propellant used in the missile's three stages also begins to age out in the late 2020s, and many Minuteman III first and second stages, which have had their solid fuel washed out and re-poured once before, cannot undergo this process a second time. Moreover, the Air Force expects there will be a significant attrition of stages during the process. The Minuteman III's third stage solid rocket motor will need to be replaced, since its case is made

208 Woolf, *U.S. Strategic Nuclear Forces,* pp. 10–20.

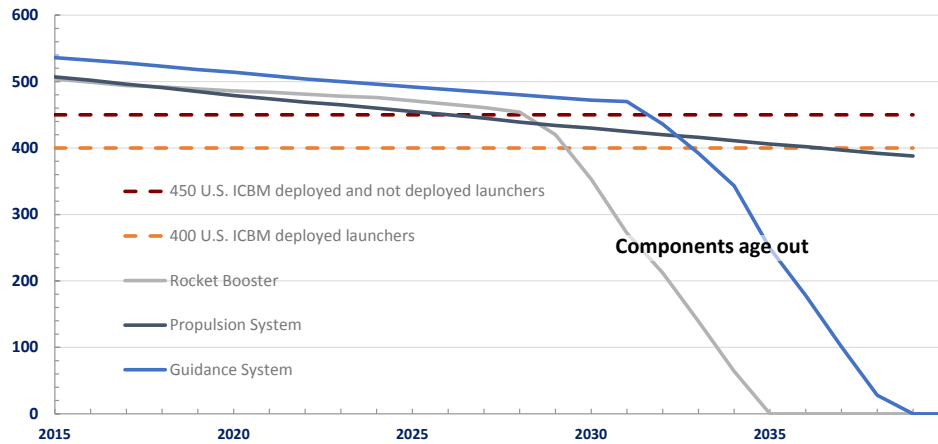
209 Ibid., p. 14.

210 Ibid., p. 15.

of composite materials that cannot be washed out and re-poured. Experts across the Air Force and defense industry believe issues related to extending Minuteman III solid rocket motors are so significant that they undercut the viability of doing so and could increase the risk that the size of the U.S. ICBM force will dip below minimum operational requirements.[211]

The Air Force estimates that shortfalls in critical Minuteman III components will impact its ability to maintain the size of the operationally deployed ICBM force after about 2030 (see Figure 11).

FIGURE 11: PROJECTED DECREASE IN OPERATIONAL MINUTEMAN III MISSILES[212]



The inability to upgrade or repair some major Minuteman III components further highlights the challenges of sustaining the weapon system instead of developing a replacement that takes advantage of modern technologies and materials. A new missile would avoid the risk of a significant force structure reduction that could be caused by aging Minuteman III components. In other words, funding and fielding the GBSD on time would avoid the risk that the size of the U.S. triad will fall below the level needed to sustain America's strategic deterrence posture.

Periodic test launches over the remaining lifespan of the Minuteman III force will also affect its ability to meet operationally deployed ICBM requirements.

211 This information is based on CSBA interviews with Minuteman III subject matter experts in the Air Force and industry.

212 Adapted from Air Force Materiel Command (AFMC), "SPO-Certified Minuteman III Attrition Data," PowerPoint slides, October 25, 2017.

FIGURE 12: MAY 2017 MINUTEMAN III TEST LAUNCH FROM VANDENBURG AFB

An unarmed Minuteman III intercontinental ballistic missile launches during an operational test on May 3, 2017 at Vandenberg Air Force Base, CA. U.S. Air Force photo by 2nd Lt. William Collette.

The Air Force conducts four to five Minuteman III test launches per year to assess the readiness and viability of the fleet. These tests continue to reduce the size of the total Minuteman III inventory year over year, which will eventually affect the Air Force's ability to maintain 400 ICBMs operationally deployed. Alternatively, reducing or delaying test launches could reduce confidence in the reliability of the force. The 2018 NPR concluded much the same: "A series of life extension programs have kept Minuteman III viable, but component aging and inventory attrition are rapidly driving it to the end of its sustainability."[213]

The GBSD will be "too expensive"

Some GBSD skeptics focus on its cost rather than on capabilities needed to meet future requirements. These arguments are countered by official studies that have determined "an integrated replacement to the Minuteman III weapon system was the most cost-effective approach to filling capability gaps."[214] Official estimates of the GBSD's cost, which do not widely diverge, appear to be the result of different assumptions or methodologies. For example, the Air Force based its cost estimates on data extrapolated from previous ICBM programs, while DoD's Office

213 OSD, *Nuclear Posture Review 2018*, p. 46.

214 Robin Rand, General, Commander, Air Force Global Strike Command, "Status of Air Force Nuclear and Global Strike Systems," statement before the Strategic Forces Subcommittee of the House Armed Services Committee, March 2, 2016, available at http://docs.house.gov/meetings/AS/AS29/20160302/104619/HHRG-114-AS29-Wstate-RandR-20160302.pdf.

of Cost Assessment and Program Evaluation determined its estimate in large part by using data from Missile Defense Agency programs such as the Ground-based Midcourse Defense (GMD) program (see Table 7). The GMD was more technologically challenging, and it likely required more new development compared to what is anticipated for the GBSD program, which is taking advantage of mature technologies to reduce cost.[215]

TABLE 7: GBSD PROGRAM COST ESTIMATES

Source of Cost Estimate (in then-year $)	ICBM	Command & Control	Infrastructure	Total
Air Force 2015 estimate[216]	**$48.5 B** $700 M for TMRR $15 B for EMD $32 B for procurement	$6.9 B	$6.9 B	$62.3 B
OSD/Office of Cost Assessment and Program Evaluation	–	–	–	$85 B to $100 B

The cost of weapon systems over time is another major factor in determining their affordability. According to the GBSD AoA, the estimated cost of maintaining a life-extended Minuteman III force is on par with the cost of maintaining a modernized GBSD force (see Table 8).

TABLE 8: TOTAL COSTS ASSOCIATED WITH THE MMIII SLEP AND GBSD SOLUTION BETWEEN FY 2016 AND FY 2075[217]

Option	Notes	Total Cost (FY 2014 $)
Minuteman III SLEP	"Maintaining and extending the life of a system that does not meet capability goals eliminated it as a final candidate solution."	$160.3 B
GBSD in modernized Minuteman III launch facilities		$159.2 B

According to the Air Force's GBSD AoA report to Congress, a replacement for the Minuteman III "has the potential to reduce long-term costs beyond these projections by utilizing a

215 Director, Cost Assessment and Program Evaluation (CAPE), *FY 2016 Annual Report on Cost Assessment Activities* (Washington, DC: DoD, January 2017), pp.28–29, available at http://cdn.defensedaily.com/wp-content/uploads/post_attachment/157333.pdf. The Air Force reported to Congress that CAPE had determined the 2014 GBSD AoA had "complied with their guidance in November 2015." U.S. Air Force, *Cost Comparison of Extending the Life of the Minuteman III Intercontinental Ballistic Missile to Replacing it with a Ground-Based Strategic Deterrent*, p. 5

216 Burg, *America's Nuclear Backbone,* p. 36. These numbers came from the official USAF Acquisition Decision Memorandum (ADM) as required by DoD's Milestone Decision Authority during a Milestone Decision Review.

217 U.S. Air Force, *Cost Comparison of Extending the Life of the Minuteman III Intercontinental Ballistic Missile to Replacing it with a Ground-Based Strategic Deterrent,* p. 7.

modular design, and designing in features to decrease maintenance actions."[218] Therefore, it is likely that a modern GBSD force, when mature, will continue to be the least expensive leg of the triad to operate and sustain.[219] This was reinforced by the commander of the U.S. Strategic Command, who has stated, "Those who have proposed a service-life extension approach haven't seen the numbers. A study found that it would cost more to replace obsolete parts than it would be to build a whole new system."[220]

Another Point to Consider: Potential Benefits to the U.S. Industrial Base

Developing a new ICBM could help revitalize associated industrial bases linked to the broader U.S. industry that develops and manufactures conventional missiles and other precision-guided munitions. Particularly critical for ICBMs is the large solid rocket motor industrial base, which "has not seen any new design work in decades."[221] There are currently two domestic suppliers of solid rocket motors used in DoD's strategic missiles: Orbital ATK and Aerojet Rocketdyne. One concern with the current GBSD plan is that the United States could retain only one solid-rocket motor producer if a single contractor is awarded production for all GBSD stages. There are also special chemicals, energetic materials, and critical subcomponents needed to manufacture missiles that are provided by a sole source or a very limited number of suppliers in the United States or a foreign country.[222]

Summary

While the Minuteman III force will not meet future requirements, the GBSD program is intended to replace it with a new weapon system that will ensure the U.S. ICBM force remains a credible leg of the triad well into the 2070s. Unlike the Minuteman III, a GBSD weapon will be designed to penetrate increasingly advanced complexes of networked kinetic and non-kinetic defenses. Moreover, the Minuteman III's component aging and inventory attrition are eroding its reliability and availability. Over time, these factors will degrade the effectiveness of the U.S. ICBM force and reduce the number of ICBMs that DoD will be able to operationally deploy and sustain. In other words, a decision to forego or significantly delay a Minuteman

218 U.S. Air Force, *Cost Comparison of Extending the Life of the Minuteman III Intercontinental Ballistic Missile to Replacing it with a Ground-Based Strategic Deterrent*, p. 7.

219 A recent DoD assessment concluded annual O&S for the Minuteman III force was about $1.6 billion per year, compared to $3.8 billion for the SSBN force and about $2.0 billion for U.S. bombers (all in FY 2018 dollars). Brian Bradley, "Air Force: GBSD Currently Estimated to Cost $62B," *National Security and Deterrence Monitor*, June 6, 2015, available at https://www.exchangemonitor.com/air-force-gbsd-currently-estimated-to-cost-62b/.

220 Stew Magnuson, "Air Force on a Long Road to Replace Minuteman III," *National Defense Magazine*, July 23, 2017, available at http://www.nationaldefensemagazine.org/articles/2017/7/23/air-force-on-a-long-road-to-replace-minuteman-iii.

221 OUSD (AT&L) and OSD (Manufacturing and Industrial Base Policy [MIBP]), *Fiscal Year 2016 Annual Industrial Capabilities*, report to Congress (Washington, DC: DoD, March 2017), p. 77, available at http://www.businessdefense.gov/Portals/51/Documents/Resources/2016%20AIC%20RTC%2006-27-17%20-%20Public%20Release.pdf?ver=2017-06-30-144825-160.

222 For a short summary of this issue, see Ibid., pp. 76–91.

III replacement would have a destabilizing effect, since a great power aggressor might decide that it could allocate more of its nuclear warheads to attack other strategic targets such as the small number of bomber bases and SSBN facilities the United States now maintains. These risks could be avoided by developing and procuring the GBSD. From a resource perspective, the estimated cost of a life-extended Minuteman III force—which would not meet operational requirements over the long haul—is roughly equivalent with the estimated cost of a more capable GBSD force through 2075.[223] These and other points are summarized in Table 9.

TABLE 9: MINUTEMAN III AND GBSD COMPARISON

	Minuteman III	GBSD and new or refurbished supporting infrastructure
Effectiveness in future threat environments	• Will not meet future requirements	• Will meet future requirements
Risk associated with additional service life extensions	• The age-out of some MMIII components could cause the ICBM inventory to fall below requirements shortly after 2030.[224] • Delaying GBSD IOC could increase risk to the triad as a whole.	• The GBSD program will maintain "a safe, secure, and effective land-based deterrent through 2075."[225]
Cost	• "The Air Force GBSD Analysis of Alternatives (AoA) confirmed the need for Minuteman weapon system recapitalization, concluding the life-cycle costs for a GBSD replacement system were lower than continuing to modernize and life extend the existing Minuteman III capability."[226]	• "A replacement ICBM system is similar in cost to a MMIII life extension program…but will provide the warfighter with a system that meets future Joint Force requirements."[227]
Future life cycle cost reductions	• Little or no potential	• Potential for additional savings than currently projected
Benefits to the U.S. industrial base	• May be some benefits from MMIII life extension/sustainment programs	• Could benefit multiple sectors of the industrial base

Red = excessive risk or won't meet requirements
Yellow = increased cost compared to the GBSD
Green = meets requirements, best option

223 "The Minuteman III service life cannot be extended further [beyond 2030]. In addition, Minuteman III will have increasing difficulty penetrating future adversary defenses." OSD, *Nuclear Posture Review 2018*, p. 28.

224 U.S. Air Force, *Cost Comparison of Extending the Life of the Minuteman III Intercontinental Ballistic Missile to Replacing it with a Ground-Based Strategic Deterrent,* p. 5.

225 Ibid., p. 4.

226 Admiral C. D. Haney, Commander, United States Strategic Command, statement before the Strategic Forces Subcommittee, House Armed Services Committee, July 14, 2016, available at http://docs.house.gov/meetings/AS/AS29/20160714/105199/HHRG-114-AS29-Wstate-HaneyC-20160714.pdf.

227 U.S. Air Force, *Cost Comparison of Extending the Life of the Minuteman III Intercontinental Ballistic Missile to Replacing it with a Ground-Based Strategic Deterrent,* p. 7.

As shown by these comparisons, replacing the Minuteman III is the best option for sustaining the land-based leg of the triad as a strategic deterrent and an operational force in being. Further delaying or foregoing an ICBM replacement program would increase risk that the United States will lose a force that is critical to the credibility of the triad as a whole.

Conclusion

Since the end of the Cold War, there has been significant debate over the need to maintain and modernize all three legs of the U.S. strategic triad. Although the requirement to maintain a triad has endured, until recently replacing its aging weapon systems has taken a back seat to other defense requirements. The *2017 National Security Strategy* and *2018 National Defense Strategy* have made it clear that triad modernization will be a national security priority[228] as the U.S. administration shifts its focus toward planning for long-term great power competition. Maintaining a triad that includes a modernized ICBM force and bombers capable of conducting strikes deep into contested areas will be critical to long-term competitions with China and Russia, which continue to invest in new nuclear weapons and delivery platforms. Toward that end, this report makes the following recommendations:

- **Plan for long-term strategic competitions with great powers.** Contingency planning scenarios used by DoD planners to assess future requirements for new operating concepts, capabilities, and force capacity should address long-term competitions with Russia and China. Russia and China are developing formidable A2/AD complexes with advanced air and missile defenses to counter U.S. precision strikes. DoD's future strike forces and capabilities, including the weapon systems needed to sustain strategic deterrence, should be sized and shaped for the threats posed by Russia and China. DoD's planning scenarios should also include actions and capabilities that would deter an adversary's use of tactical, non-strategic nuclear weapons to coerce the United States and its allies or to regain the initiative in conventional conflicts.

228 "The United States must maintain the credible deterrence and assurance capabilities provided by our nuclear Triad and by U.S. theater nuclear capabilities deployed abroad. Significant investment is needed to maintain a U.S. nuclear arsenal and infrastructure that is able to meet national security threats over the coming decades." *National Security Strategy 2017*, p. 30. "The Department will modernize the nuclear triad—including nuclear command, control, and communications, and supporting infrastructure. Modernization of the nuclear force includes developing options to counter competitors' coercive strategies, predicated on the threatened use of nuclear or strategic non-nuclear attacks." DoD, *Summary of the 2018 National Defense Strategy of The United States of America: Sharpening the American Military's Competitive Edge* (Washington, DC: DoD, January 2018), p. 6, available at https://www.defense.gov/Portals/1/Documents/pubs/2018-National-Defense-Strategy-Summary.pdf.

- **China must no longer be considered a lesser-included case.** During the Cold War and for much of the post-Cold War period, U.S. planning and resource priorities for the triad were based on deterring or responding to Russian nuclear aggression. China continues to aggressively pursue the development and fielding of multiple ballistic missile and cruise missile variants that are nuclear capable or may be dual capable. Future triad modernization priorities should be based on assessments of this multipolar strategic reality. Specifically, the size and mix of capabilities in the U.S. triad should provide a range of options to deter or respond to nuclear aggression by China as well as Russia. Future U.S. arms limitation initiatives should also address China's growing nuclear weapons portfolio and ambitions, as well as key technologies, manufacturing systems, and other capabilities exported by Russia and China.

- **Develop ALCM and Minuteman III replacements that will be effective in future threat environments.** Increasingly capable SAM systems, EW systems including directed energy weapons, GPS-denial capabilities, and other defenses will decrease the probability that U.S. legacy guided weapons—conventional and nuclear—will be able to penetrate and strike their designated targets. Moreover, it is not feasible to upgrade the ALCM and Minuteman III with advanced (and increasingly autonomous) navigation and terminal guidance systems, stealth technologies, and other capabilities that would significantly improve their survivability. These capabilities should be a priority for their replacements.

- **Fully fund the LRSO program to replace the ALCM on time.** The continuing competition between the development of more advanced precision strike weapon systems and the design of air and missile defenses to counter them underscores the need to maintain a U.S. strategic bomber force that has a diverse range of strike capabilities, including cruise missiles that allow them to strike from standoff ranges. This standoff strike capability will be lost when the ALCM is no longer capable of penetrating future threat environments.

- **Develop operating concepts for using the LRSO to support extended and tailored deterrence.** Cruise missiles with nuclear warheads and dual-capable fighters have been important capabilities for meeting America's extended deterrence commitments. The U.S. has lost a great deal of its non-strategic nuclear forces capacity over the last two decades. In addition to new sea-based capabilities identified by the 2018 NPR, DoD should also develop operating concepts for using the LRSO as a flexible deterrent option.

- **Fully fund the GBSD program to replace the Minuteman III.** Sustaining the land-based leg of the triad as a reliable deterrent will require the Air Force to replace the Minuteman III and do so expeditiously. The technical feasibility of further extending and modernizing many Minuteman III components is questionable, and doing so would not result in a weapon system that will meet future requirements.

- **Prioritize the on-time development, procurement, and fielding of the GBSD force.** DoD should develop and field the GBSD as planned. Due to periodic test launch requirements and aging missile components that cannot be life extended or replaced, the total remaining Minuteman III inventory will not support a force posture of 400 operationally deployed ICBMs past 2030.
- **Design the GBSD to hedge against uncertainty.** Modifying Minuteman IIIs to carry a single warhead reduced the flexibility of the United States to quickly increase its number of operationally deployed warheads. Ensuring the GBSD has the capability of quickly accepting modifications to change its payload configuration would help restore this strategic flexibility and provide a hedge against uncertainty.
- **Leverage triad modernization to help revitalize the U.S. munitions industrial base.** Developing a new ICBM and LRSO cruise missile would help revitalize their associated munitions industrial bases. The ICBM industrial base is linked to the broader industry that develops and manufactures rocket motors, guidance systems, and other major components in surface-to-air and surface-to-surface weapons. Investing in the GBSD could help sustain this broader industrial base. Similarly, the development and production of an LRSO cruise missile could help sustain the munitions industrial base that develops and produces air-launched, sea-launched, and surface-to-surface munitions.

In conclusion, investing in replacements for the ALCM and Minuteman III will help ensure the United States maintains a highly capable and reliable force as part of its strategic deterrent posture. This will require a multi-year commitment to funding the LRSO and GBSD programs. The alternative would be to accept the continued erosion of the triad, which will create strategic opportunities for America's great power adversaries.

LIST OF ACRONYMS

A2/AD	anti-access/area denial
ACM	Advanced Cruise Missile
ALCM	air-launched cruise missile
AoA	analysis of alternatives
ASCM	anti-ship cruise missile
CALCM	Conventional Air-Launched Cruise Missile
CSBA	Center for Strategic and Budgetary Assessments
DoD	Department of Defense
EMD	Engineering and Manufacturing Development
EW	electronic warfare
GBSD	Ground Based Strategic Deterrent
GLCM	ground-launched cruise missile
GMD	Ground-based Midcourse Defense
GPS	Global Positioning System
HGV	hypersonic glide vehicle
IADS	integrated air defense system
ICBM	intercontinental ballistic missile
INF	Intermediate-range Nuclear Forces Treaty
IRBM	intermediate-range ballistic missile
LBSD	Land-Based Strategic Deterrent
LCC	launch control center
LEP	Life Extension Program
LF	launch facility
LRSO	Long-Range Standoff weapon
MaRV	maneuverable reentry vehicle
MIRV	multiple independent reentry vehicles
MRBM	medium-range ballistic missile
NATO	North Atlantic Treaty Organization
NNSA	National Nuclear Security Administration
NPR	Nuclear Posture Review
PAC-3	Patriot Advanced Capability-3
PAUC	Program Acquisition Unit Cost
PGM	precision-guided munition
PLA	People's Liberation Army

PLAAF	People's Liberation Army Air Force
PLAN	People's Liberation Army Navy
PLARF	People's Liberation Army Rocket Force
PSRE	Propulsion System Rocket Engine
RV	reentry vehicle
SCAD	Subsonic Cruise Armed Decoy
SLBM	submarine-launched ballistic missile
SLEP	Service Life-Extension Program
SORT	Strategic Offensive Reductions Treaty
SRBM	short-range ballistic missile
SSBN	nuclear ballistic missile submarine
START	Strategic Arms Reduction Treaty
THAAD	Terminal High Altitude Area Defense
TLAM-N	Nuclear Tomahawk Land-Attack Missile
TMRR	Technology Maturation and Risk Reduction
TOA	Total Obligation Authority
UGF	underground facilities

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