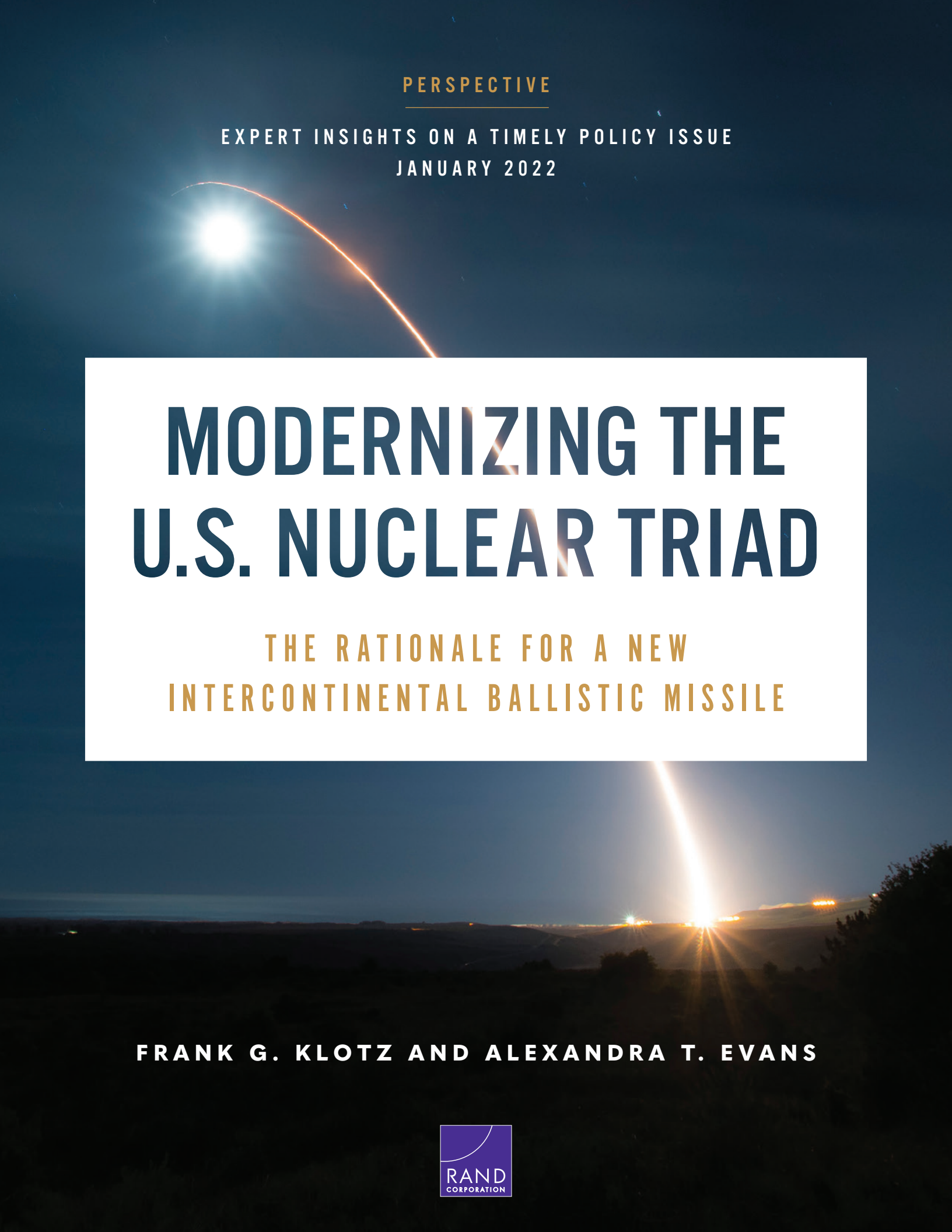

PERSPECTIVE

EXPERT INSIGHTS ON A TIMELY POLICY ISSUE

JANUARY 2022

MODERNIZING THE U.S. NUCLEAR TRIAD

THE RATIONALE FOR A NEW INTERCONTINENTAL BALLISTIC MISSILE

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About This Perspective

Since the late 1950s, the United States has fielded a Triad consisting of air-, sea-, and land-based nuclear delivery systems. After multiple decades of service, major components of all three legs are now nearing the end of their scheduled service lives. Several nuclear modernization programs are well underway, but the decision to replace the aging Minuteman III intercontinental ballistic missile (ICBM) with a new system, called the Ground-Based Strategic Deterrent (GBSD), has catalyzed a debate over the role of nuclear weapons in U.S. national security policy and the composition and costs of the U.S. nuclear arsenal.

This Perspective presents an overview of the principal arguments publicly advanced for and against continuing the GBSD program of record. Intended to assist U.S. Air Force officials, it presents an overview of the role of the Triad in U.S. nuclear weapons policy, a survey of the current strategic landscape, and an outline of the major nuclear modernization programs of record, in addition to describing and assessing the major points of disagreement related to fielding a new ICBM.

This research was conducted within RAND Project AIR FORCE's Strategy and Doctrine Program. This Perspective represents the views of the authors.

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Overview

Shortly after taking office, the Biden administration announced that it would review the nation's nuclear weapons and arms control policies as part of an integrated approach to deterrence across several domains. In a shift from past practice, however, the Nuclear Posture Review (NPR) will be "nested" within the administration's forthcoming National Defense Strategy, expected to be released in early 2022.[1] The White House foreshadowed its basic themes on nuclear policy in its March 2021 interim strategic guidance on national security, in which it pledged to "take steps to reduce the role of nuclear weapons in our national security strategy, while ensuring our strategic deterrent remains safe, secure, and effective and that our extended deterrence commitments to our allies remain strong and credible." In the same document, the Biden administration also expressed a desire to "head off costly arms races," "pursue new arms control arrangements," and "re-establish [U.S.] credibility as a leader in arms control."[2]

The task for the NPR, which began in July 2021, will be to outline a course to achieve these objectives. This undoubtedly will include decisions on the size and composition of the U.S. nuclear deterrent force. For the past six decades, the United States has maintained a Triad of long-range nuclear delivery systems, including nuclear-capable bomber aircraft, intercontinental ballistic missiles (ICBMs), and nuclear-powered submarines armed with submarine-launched ballistic missiles (SLBMs). Beginning with the Obama administration and continuing through the Trump administration, the United States has pursued multiple programs of record to modernize all three legs of the existing Triad, including fielding a new class of ballistic missile submarines (SSBNs), a new bomber, a new version of the nuclear-armed air-launched cruise missile (ALCM), and a new ICBM. These investments represent the first sustained efforts to replace U.S. strategic nuclear delivery systems since the end of the Cold War more than 30 years ago.

These nuclear modernization programs have enjoyed broad, bipartisan support over the past decade. Nevertheless, some members of the U.S. Congress have expressed reservations about the initiatives' cost and necessity, particularly in light of the financial strain caused by the COVID-19 pandemic.[3] Likewise, several well-established nongovernmental organizations (NGOs) within the arms control community have argued that funding can and should be scaled back. Various options to reduce costs have been floated, but the program of record most often cited as a candidate for suspension or outright cancellation is the new ICBM, known as the Ground-Based Strategic Deterrent (or GBSD).[4] The fate of GBSD—and the Triad—will depend not only on the outcome of the Biden administration's NPR but also on the degree of continuing support for the current modernization programs within the congressional committees that exercise jurisdiction over the U.S. Department of Defense (DoD) and the U.S. Department of Energy's National Nuclear Security Administration (NNSA).

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[1] U.S. House of Representatives, Committee on Armed Services, Strategic Forces Subcommittee, "Statement by Melissa Dalton, Acting Assistant Secretary of Defense for Strategy, Plans, and Capabilities, Office of the Secretary of Defense, Before the 117th Congress," Washington, D.C., June 10, 2021b, p. 5.

[2] Joseph R. Biden, Jr., *Interim National Security Strategic Guidance*, Washington, D.C.: White House, March 2021, p. 13.

[3] For examples of the scrutiny applied to GBSD, see Office of Senator Ed Markey, "Senator Markey, Rep. Khanna Introduce the 'Investing in Vaccines Before Missiles (ICBM) Act,'" press release, Washington, D.C., March 26, 2021a; and Office of Senator Edward Markey, "Senator Markey and Rep. Blumenauer Announce Legislation to Cut $73 Billion from Bloated Nuclear Weapons Budget," press release, May 24, 2021b.

[4] For illustrative examples of advocacy by NGOs against GBSD, see Kingston Reif and Alicia Sanders-Zakre, *U.S. Nuclear Excess: Understanding the Costs, Risks, and Alternatives*, Washington, D.C.: Arms Control Association, April 2019; David Wright, William D. Hartung, and Lisbeth Gronlund, *Rethinking Land-Based Nuclear Missiles: Sensible Risk-Reduction Practices for US ICBMs*, Cambridge, Mass.: Union of Concerned Scientists, June 2020; George Perkovich and Pranay Vaddi, *Proportionate Deterrence: A Model Nuclear Posture Review*, Washington, D.C.: Carnegie Endowment for International Peace, 2021. Additional critiques of the current Triad modernization plan are cited later in this Perspective.

U.S. nuclear policymakers have repeatedly asserted that the survivability of U.S. nuclear forces can best be ensured by maintaining a diverse array of nuclear delivery systems.

As the service responsible for two of the three legs of the Triad, the Air Force has important equities in any decisions affecting U.S. nuclear policy and related modernization programs.[5] As in the past, Air Force leaders undoubtedly will be called on to provide advice on these topics during interagency deliberations on the NPR and in congressional testimony on defense spending. This Perspective is intended to assist them in preparing for this role by describing the choices that have shaped the U.S. nuclear force posture in the past, the major questions and disagreements informing the current debate over nuclear modernization, and the significance of the decisions that will be made over the next several months. It begins with an overview of the Triad's role in U.S. nuclear weapons policy, including the rationale advanced by successive presidential administrations for retaining each of its three legs. Next, it discusses the current strategic landscape and outlines the United States' major nuclear modernization efforts. Because much of the debate on modernization is focused on GBSD, special attention is devoted to actions regarding the ICBM force taken since the end of the Cold War, including the 2014 decision to develop a new land-based missile system to replace the aging Minuteman III ICBMs. This Perspective then identifies and explains the principal arguments publicly advanced for proceeding with or suspending the GBSD program.

This Perspective is based on an extensive review of publicly available data and analyses, official government documents, and statements by senior military and civilian officials on nuclear modernization. Although certain aspects of this topic can only be discussed in a classified setting—and more analysis on specific aspects of the current programs, noted in the sections below, may be warranted—the issue is too important to limit the conversation to closed forums. This Perspective, therefore, seeks to provide a single, concise, and readily accessible document that explains the rationale for modernizing the Triad and identifies the key arguments for and against fielding a new ICBM.

The Triad in U.S. Nuclear Weapons Policy

Despite changes in U.S. nuclear posture, doctrine, and technology over the past 75 years, several core aspects of U.S nuclear policy have endured.[6] The first is the belief that the fundamental purpose of nuclear weapons is to deter nuclear attacks on the United States, its military forces, and its allies. The second is the calcula-

[5] The Department of the Air Force (DAF) now consists of two separate services: the U.S. Air Force and the U.S. Space Force. The use of the term *Air Force* in this Perspective refers to the former and not the latter.

[6] Franklin C. Miller, "American Nuclear Deterrence Policy: What Is It and How Is It Implemented?" in Adam B. Lowther, ed., *Guide to Nuclear Deterrence in the Age of Great-Power Competition*, Bossier City, La.: Louisiana Tech Research Institute, 2020, pp. 23–35. Miller dealt extensively with nuclear policy during his 31-year U.S. government career, which included senior positions in DoD and on the National Security Council staff. For a comprehensive history of the origins and evolution of U.S. nuclear strategy, see Lawrence Freedman and Jeffrey Michaels, *The Evolution of Nuclear Strategy*, 4th ed., New York: Palgrave Macmillan, 2019.

tion that the United States can best deter aggression and achieve strategic stability by maintaining nuclear forces capable of surviving a nuclear attack and retaliating in a way that denies the attacker its objectives and imposes devastating consequences in the process. Similarly, U.S. strategists have long held that decreasing an adversary's confidence in its ability to decapitate U.S. nuclear forces reduces the incentive to launch a first strike in a crisis or conflict. Lastly, U.S. nuclear policymakers have repeatedly asserted that the survivability of U.S. nuclear forces can best be ensured by maintaining a mix of nuclear delivery systems, each of which complements the others' attributes and compensates for any vulnerabilities or technical failures of the others.[7]

This latter concept underlies the United States' decision to develop and maintain a mix of nuclear forces operating in the air, on land, and at sea. The Triad, as it is commonly known, became a central feature of U.S. nuclear weapons policy when the United States began to field its first operational ICBMs and SSBNs in the late 1950s and early 1960s.[8] Interservice competition for shares of the nuclear deterrence mission contributed to the diversification of U.S. strategic forces, but that outcome also reflected concerns over the increasing vulnerability of U.S. nuclear forces, which, at the time, were composed almost entirely of bomber aircraft.[9] The development of the hydrogen bomb, coupled with improvements in the range, precision, and quantity of Soviet missile systems, weakened U.S. strategists' confidence in the bomber force's ability to survive a preemptive first strike, thereby undermining a fundamental precept for maintaining deterrence. This concern led to calls for more-secure, survivable nuclear forces—including their associated command, control, and communications systems—to ensure the ability to respond to a nuclear attack under all circumstances and provide the President with a wider variety of options for doing so.[10]

Throughout the Cold War, the United States continuously updated all three components of the Triad by designing, developing, and deploying successive generations of nuclear-capable bombers, ICBMs, and nuclear-powered submarines armed with SLBMs (see Figure 1). Each new delivery system represented significant improvements over its predecessor in terms of capabilities, safety, and security. At the same time, the United States also steadily added to the number and types of weapons in the U.S. nuclear arsenal, ultimately reaching a peak of 31,255 warheads by 1969 (Figure 2).[11]

The end of the Cold War presaged a significant reduction in the number and types of U.S. nuclear delivery systems and their associated warheads. The United States negotiated a series of bilateral nuclear arms control agreements with the Soviet Union that placed limits on both countries' forces, including the elimination

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[7] For recent official statements on this point, see Office of the Secretary of Defense, *Nuclear Posture Review Report*, Washington, D.C.: U.S. Department of Defense, April 2010, p. 22; and Office of the Secretary of Defense, *Nuclear Posture Review*, Washington, D.C.: U.S. Department of Defense, February 2018, p. 43.

[8] The first U.S. ICBM, the liquid-fueled Atlas D, went alert on October 31, 1959 (see Stewart M. Powell, "The Day of the Atlas," *Air Force Magazine*, October 2009, p. 60). For a brief history of the decision to acquire ICBMs and SLBMs, see Robert L. Perry, "The Ballistic Missile Decisions," Santa Monica, Calif.: RAND Corporation, P-3687, October 1967. For a wider discussion of U.S. strategic debates during this period, see Freedman and Michaels, 2019, pp. 193–211.

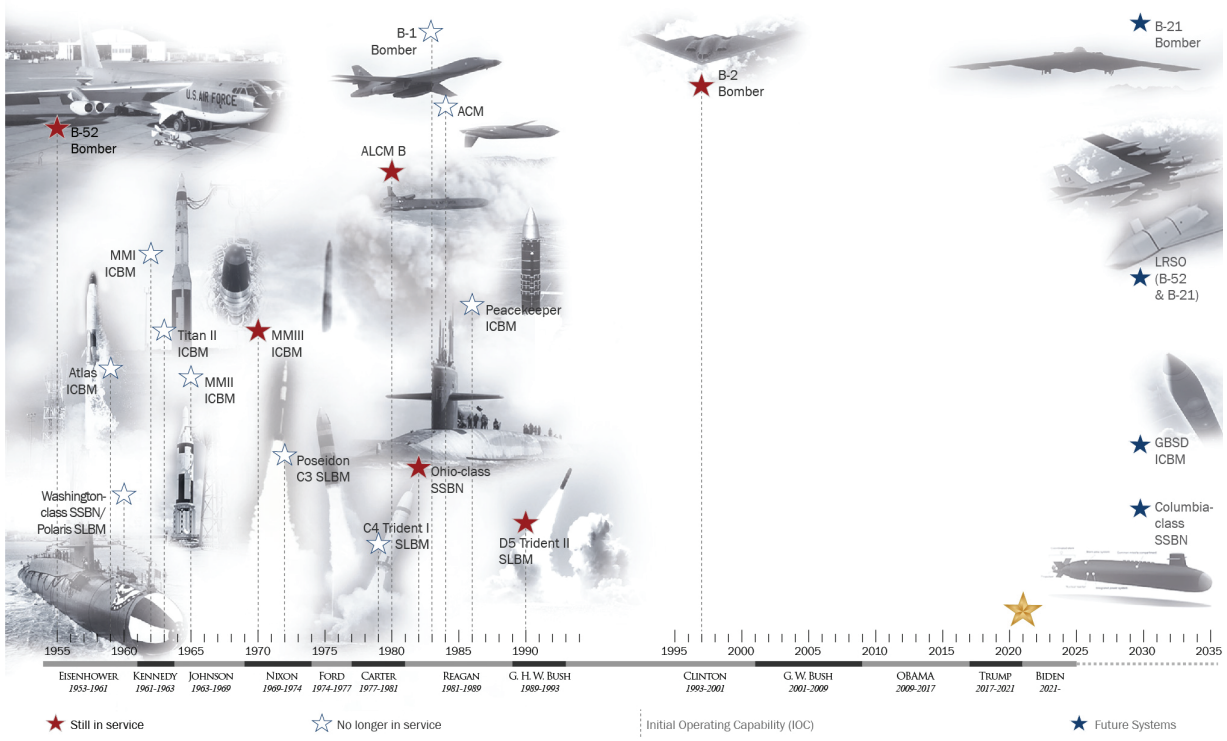
[9] For two early but still insightful discussions of the role of institutional and bureaucratic politics in nuclear innovation, see Michael H. Armacost, *The Politics of Weapons Innovation: The Thor-Jupiter Controversy*, New York: Columbia University Press, 1969; and Harvey M. Sapolsky, *Polaris System Development: Bureaucratic and Programmatic Success in Government*, Cambridge, Mass.: Harvard University Press, 1972. For a more-recent study, see chapters two through four in Fred Kaplan, *The Bomb: Presidents, Generals, and the Secret History of Nuclear War*, New York: Simon & Schuster, 2020.

[10] The seminal work on the strategic implications of and response to a possible Soviet surprise nuclear attack is Albert Wohlstetter, "The Delicate Balance of Terror," Santa Monica, Calif.: RAND Corporation, P-1472, 1958. See also Freedman and Michaels, 2019, pp. 169–178, 206–208.

[11] U.S. Department of Energy, *Fiscal Year 2020 Stockpile Stewardship and Management Plan—Biennial Plan Summary, Report to Congress*, Washington, D.C., July 2019b, p. 1-4; and U.S. Department of Energy, "Transparency in the U.S. Nuclear Weapons Stockpile," fact sheet, October 2021b.

FIGURE 1

U.S. Nuclear Modernization, 1955–2035



SOURCE: Office of the Deputy Assistant Secretary of Defense for Nuclear Matters, *Nuclear Matters Handbook 2020*, Washington, D.C., 2020, p. 6.

NOTES: The chart depicts the dates for the first deployment of new weapons systems; it does not show subsequent deployments of the same system or upgrades and service life extensions to a particular system. ACM = advanced cruise missile.

of all intermediate-range nuclear forces.[12] As the Soviet Union was breaking up, the U.S. government took additional measures to limit its own nuclear force posture by eliminating strategic bomber alerts; ending the practice of deploying nuclear weapons on surface ships, attack submarines, and land-based naval aircraft; withdrawing all ground-launched weapons deployed overseas; and canceling several ongoing nuclear modernization programs.[13] The trend continued through the 2000s, as U.S.-Russian nuclear arms control negotiations produced agreements that further constrained both countries' strategic nuclear delivery systems.[14]

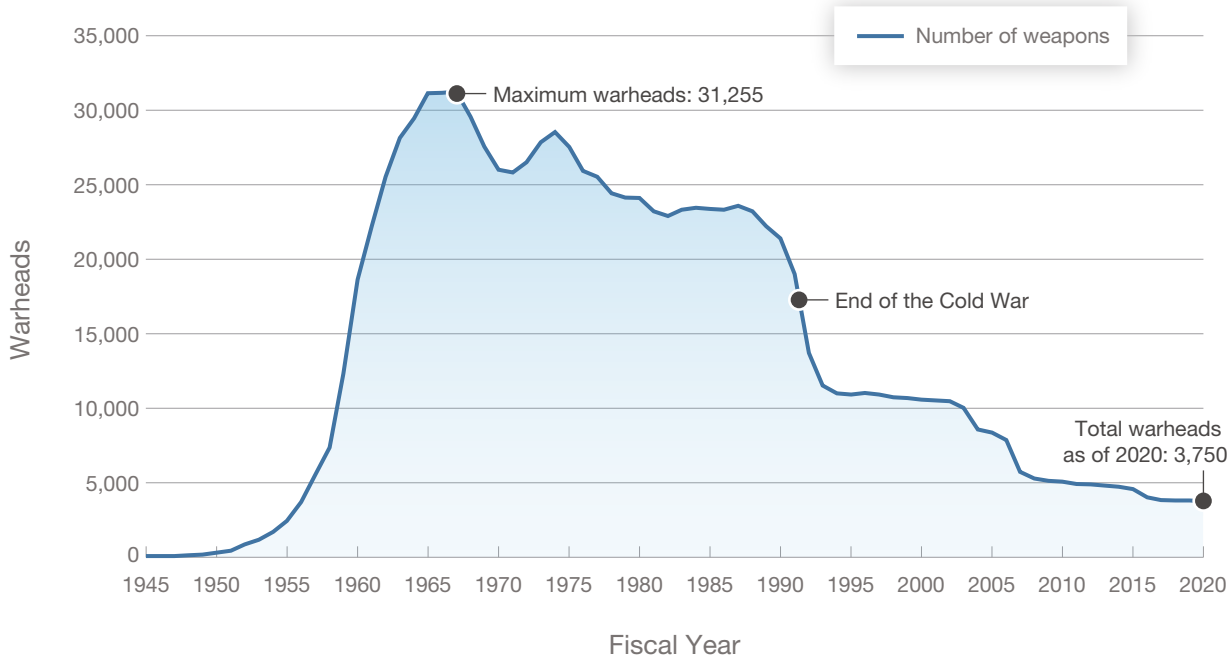
Even with significant reductions in the number and type of U.S. nuclear forces after the end of the Cold War, successive presidential administrations—both Democrats and Republicans—have chosen to retain

[12] For a history of these bilateral arms control agreements, see Matthew J. Ambrose, *The Control Agenda: A History of the Strategic Arms Limitation Talks*, Ithaca, N.Y.: Cornell University Press, 2018; and James G. Wilson, *The Triumph of Improvisation: Gorbachev's Adaptability, Reagan's Engagement, and the End of the Cold War*, Ithaca, N.Y.: Cornell University Press, 2014.

[13] The Soviet Union also made reciprocal unilateral reductions, though uncertainty remains regarding the full extent of the measures they took (see Susan J. Koch, *The Presidential Nuclear Initiatives of 1991–1992*, Washington, D.C.: National Defense University Press, September 2012). The U.S. programs that were canceled included the development of the small ICBM and further production of the B-2 bomber, the Peacekeeper ICBM, the AGM-129A ACM, and the W88 warhead for SLBMs (George H. W. Bush, "Address Before a Joint Session of the Congress on the State of the Union," George H. W. Bush Library and Museum, National Archives, January 28, 1992).

[14] See endnote 2 in Frank G. Klotz, *The Military Case for Extending the New START Agreement*, Santa Monica, Calif.: RAND Corporation, PE-350-AF, 2020, p. 22.

FIGURE 2
Size of the U.S. Nuclear Weapons Stockpile, 1945–2020



SOURCE: U.S. Department of Energy, October 2021b.
NOTE: The figure depicts active and inactive warheads. Approximately 2,000 additional nuclear warheads are retired and awaiting dismantlement.

the Triad.[15] Every NPR conducted since the practice began in 1993 has concluded that maintaining a mix of delivery systems, each possessing different characteristics and attributes, enhances strategic stability by ensuring that no adversary can (or believes it can) conduct a successful disarming first strike and thereby eliminate the United States' ability to respond to a nuclear attack. The redundancy inherent in the Triad is also described as a means to hedge against unforeseen technical issues, guaranteeing that the United States retains the ability to conduct nuclear operations even if one or more delivery systems becomes unavailable for a period of time. Finally, maintaining a variety of systems with different operational capabilities (including range, flight profiles, and weapons yields), it has been argued, enables the United States to tailor its strategies for deterring strategic attack, assuring allies, and achieving objectives should deterrence fail.[16]

Although the Biden administration has not yet completed its review of nuclear weapons policy, statements by senior Pentagon officials have indicated continued support for the Triad. In testimony before the Senate Armed Services Committee in June 2021, Secretary of Defense Lloyd Austin remarked that he was "absolutely committed to the modernization of the triad" and noted that the President's budget request for fiscal year (FY) 2022 dedicated $28 billion to that effort. In the same hearing, GEN Mark Milley, the Chairman of the Joint Chiefs of Staff, stated that "recapitalization of the nuclear triad is the number one priority." He

[15] Office of the Deputy Assistant Secretary of Defense for Nuclear Matters, 2020, p. 23.

[16] Office of the Secretary of Defense, 2010, pp. 20, 22; Office of the Secretary of Defense, 2018, pp. 42–43. The full reports on the findings of earlier NPRs are not publicly available. For unclassified summaries of these reviews, see DoD, *Annual Report to the President and the Congress*, Washington, D.C., February 1995, pp. 10–11; and DoD, "Special Briefing on the Nuclear Posture Review," Washington, D.C., January 9, 2002.

also added, "It is critical that we have the air, sea, and land components of that triad in order to maintain the security of the United States going forward."[17]

The Changing Strategic Landscape

Statements by senior Biden administration officials suggest that they share their predecessors' view that modernizing the Triad is a necessary response to changes in the international environment. If the prospect of a nuclear conflict waned in the years following the collapse of the Soviet Union, the recent deterioration of U.S. relations with Russia and China has refocused attention on the potential threat posed by nuclear-armed adversaries and the continued need to ensure a safe, secure, and reliable nuclear force.[18] The Biden administration's interim strategic guidance underscores this point, noting that "[b]oth Beijing and Moscow have invested heavily in efforts meant to check U.S. strengths and prevent us from defending our interests and allies around the world."[19] Subsequent testimonies by Pentagon officials indicate that these efforts include "expanding and modernizing their nuclear capabilities to achieve strategic and potentially escalatory effects."[20]

U.S. nuclear weapons policy, including the size and composition of the U.S. deterrent force, must now take into account not one but two major power rivals, each armed with an increasingly diverse and growing array of nuclear capabilities. Russian nuclear forces continue to pose an existential threat to the United States and its allies. As senior military leaders have stated, China can no longer be considered "a lesser included case" in U.S. calculations of the number and types of nuclear forces required to maintain deterrence.[21]

Russia

Nuclear weapons have played a central role in Soviet/Russian military doctrine since the 1950s.[22] According to the U.S. Intelligence Community, the Russian government today views its strategic and nonstrategic nuclear forces as essential to maintaining deterrence, securing the country's territorial integrity, and achieving its goals in the event of conflict involving the United States and NATO forces. Moreover, Russia reserves the right to use nuclear weapons first in a conflict to achieve those objectives.[23] A previous analysis by RAND

[17] U.S. Senate, Committee on Senate Armed Services, "Hearing to Receive Testimony on the Department of Defense Budget Posture in Review of the Defense Authorization Request for Fiscal Year 2022," Washington, D.C., June 10, 2021g, pp. 60 and 90.

[18] See statements by Undersecretary of Defense for Policy Colin Kahl as quoted in C. Todd Lopez, "Nuclear Posture Review, National Defense Strategy Will Be Thoroughly Integrated," *DOD News*, June 25, 2021.

[19] Biden, 2021, pp. 7–8.

[20] U.S. Senate, Committee on Armed Services, Subcommittee on Strategic Forces, "Statement of Leonor Tomero, Deputy Assistant Secretary of Defense for Nuclear and Missile Defense Before the 117th Congress," Washington, D.C., May 12, 2021d, p. 2.

[21] See U.S. Senate, Committee in Armed Services, "Statement of Charles A. Richard, Commander, United States Strategic Forces, Before the Senate Committee on Armed Services," Washington, D.C., April 20, 2021d, p. 6. For historical contrast, see statement from Gen. David C. Jones, former Chairman of the Joint Chiefs of Staff, in U.S. Senate, *Threat Assessment, Military Strategy, and Defense Planning: Hearings Before the Committee on Armed Services*, Vol. 4, Washington, D.C.: U.S. Government Printing Office, 1992, p. 102.

[22] For discussions on the evolution of Russian nuclear doctrine during and since the Cold War, see James T. Quinlivan and Olga Oliker, *Nuclear Deterrence in Europe: Russian Approaches to a New Environment and Implications for the United States*, Santa Monica, Calif.: RAND Corporation, MG-1075-AF, 2011; and chapters 27, 35, and 42 in Freedman and Michaels, 2019.

[23] Office of the Director of National Intelligence, *Annual Threat Assessment of the U.S. Intelligence Community*, Washington, D.C., April 9, 2021, p. 10; Defense Intelligence Agency (DIA), *Russia Military Power: Building a Military to Support Great Power Aspirations*, 2017, p. 22.

U.S. nuclear weapons policy, including the size and composition of the U.S. deterrent force, must now take into account not one but two major power rivals, each armed with a growing array of nuclear capabilities.

researchers suggests that Moscow likely would consider or threaten nuclear responses to nonnuclear attacks that it perceived as grave threats to its territorial integrity and sovereignty, continuity of government, or the viability of its strategic nuclear deterrent.[24] Although there is no indication that Russia would deliberately seek a large-scale conflict, "[d]eepening distrust" of the United States and its allies has characterized recent Russian security guidance and could color decisionmaking in a crisis.[25]

For the foreseeable future, Russia will remain the largest and most capable nuclear-armed rival to the United States as it continues to expand and modernize its strategic and nonstrategic nuclear weapons capabilities. Indeed, the country already has made substantial progress toward upgrading or replacing Soviet-era systems. Although U.S. officials might differ with Russian President Vladimir Putin's claim that more than 88 percent of Russian nuclear weapons and equipment will be modernized by the end of 2021, they generally concede that the country's efforts to upgrade or replace its Soviet-era systems are well advanced.[26] ADM Charles A. Richard, commander of U.S. Strategic Command (STRATCOM), recently testified that Russia is "strengthening its overall combat potential with an imposing array of modernization efforts and novel programs designed to ensure a retaliatory strike capability by all three triad legs."[27]

Russia's ICBM force holds a privileged position within the Russian military. It continues to provide the bulk of the country's strategic nuclear capabilities, which reportedly consist of 318 missiles, more than half of which carry more than one warhead.[28] A new heavy ICBM (the *Sarmat*) is slated to begin replacing the aging SS-18 in the early 2020s. Additionally, Russia continues to swap out its older SS-19 and SS-25 ICBMs for newer SS-27 Mod 1 and Mod 2 ICBMs in fixed silos and on mobile launchers. Russia has also modified a few of its remaining SS-19 ICBMs to carry a hypersonic glide vehicle (known as *Avangard*), some of which, according to Putin, are "[s]tanding on combat duty" already.[29]

The Russian Navy's fleet of ten SSBNs is also undergoing significant modernization. The aging Delta III and IV submarines are being replaced by the more-capable *Borei*-class submarine, armed with the new *Bulava*

[24] Scott Boston and Dara Massicot, *The Russian Way of War: A Primer*, Santa Monica, Calif.: RAND Corporation, PE-231-A, 2017.

[25] Dara Massicot, "Anticipating a New Russian Military Doctrine in 2020: What It Might Contain and Why It Matters," *War on the Rocks*, September 9, 2019.

[26] U.S. Office of the Director of National Intelligence, 2021, p. 10; President of Russia, "Presidential Address to the Federal Assembly," Moscow, transcript, April 21, 2021.

[27] U.S. Senate, Committee in Armed Services, 2021d, p. 9.

[28] Keith Crane, Olga Oliker, and Brian Nichiporuk, *Trends in Russia's Armed Forces: An Overview of Budgets and Capabilities*, Santa Monica, Calif.: RAND Corporation, RR-2573-AF, 2019, pp. 47, 50; Amy F. Woolf, *Russia's Nuclear Weapons: Doctrine, Forces, and Modernization*, Washington, D.C.: Congressional Research Service, R45861, July 20, 2020a, p. 15.

[29] U.S. Senate, Committee on Foreign Relations, "Statement of Honorable David J. Trachtenberg Deputy Under Secretary of Defense for Policy on the State of Arms Control with Russia," Washington, D.C., May 15, 2019, p. 3; Crane, Oliker, and Nichiporuk, 2019, pp. 47–48, 50–51; Woolf, 2020a, p. 15; and President of Russia, 2021.

SLBM. Three of the new boats are in service; the remaining vessels are scheduled for delivery by 2027.[30] As for its long-range, nuclear-capable bomber force, the Russians reportedly plan to field a stealthier version of the Tu-160 and start serial production of a next-generation bomber, the PAK-DA, by the end of the decade.[31]

At the same time, Putin and other Russian senior officials have publicly touted the development of "novel" or "exotic" long-range nuclear delivery systems that lie outside the traditional concept of a strategic nuclear triad. These include a maneuverable air-launched ballistic missile (*Kinzhal*), a long-range nuclear-powered cruise missile (*Burevestnik*), and a nuclear-powered underwater autonomous vehicle (*Poseidon*).[32] Various motives have been attributed to the Russian pursuit of these capabilities, the most likely being an abiding concern about penetrating increasingly sophisticated U.S. air and missile defenses.[33] It is worth noting that none of these new systems is covered by the 2010 Treaty on Measures for the Further Reduction and Limitation of Strategic Offensive Arms, commonly referred to as New START, which was recently extended until February 2026. This has led some U.S. senior military leaders to argue that these new systems should be addressed in any future nuclear arms control arrangements.[34]

Finally, Russia is investing in new air and missile defenses to augment existing capabilities. In recent years, its air defense forces have introduced advanced systems like the S-400—capable of engaging manned and unmanned aircraft, as well as cruise and ballistic missiles—in addition to the Pantsir-S1/M fielded point-defense systems.[35] In July 2021, the Ministry of Defense of the Russian Federation released a video reportedly depicting a successful test campaign of its long-delayed S-500 air defense system, which is designed to counter an array of aerial threats, including ballistic missiles and manned aircraft, at a maximum range of 600 kilometers.[36] Once ready for service, the S-500 is expected to replace the A-135 anti-ballistic missile system deployed around Moscow.[37] The DIA assesses that Russian defense systems are designed to support integration "around a central command structure" that will "promote the interaction of all air defense forces and weapons."[38] Against this background, Russia's unannounced November 2021 direct-ascent anti-satellite missile test, which destroyed one of its own satellites and created at least 1,500 trackable pieces of debris, "demonstrates that Russia continues to pursue counterspace weapon systems that undermine strategic stability," as U.S. Army GEN James Dickinson, U.S. Space Command commander, cautioned.[39]

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[30] Crane, Oliker, and Nichiporuk, 2019, p. 23, 48–49; Woolf, 2020a, pp. 15–16.

[31] Woolf, 2020a, p. 17.

[32] U.S. Senate, Committee on Foreign Relations, 2019, p. 3; and Jill Hruby, *Russia's New Nuclear Delivery Systems: An Open-Source Technical Review*, Washington, D.C.: Nuclear Threat Initiative, November 2019. Russia is also developing a novel short-range hypersonic cruise missile, known as *Tsirkon*. Although Russian officials have not described the system officially as a nuclear-capable missile, public statements suggest it might be deployed with a nuclear payload. For a description of this system, see Hruby, 2019, pp. 21–25.

[33] DIA, 2017, p. 48; Austin Long, "Red Glare: The Origins and Implications of Russia's 'New' Nuclear Weapons," *War on the Rocks*, March 26, 2018; and Edward Geist and Dara Massicot, "Understanding Putin's Nuclear 'Superweapons,'" *SAIS Review of International Affairs*, Vol. 39, No. 2, Summer–Fall 2019, pp. 103–117.

[34] Klotz, 2020, p. 16; David Vergun, "General Notes Value, Limitations of New START Treaty," *DOD News*, February 26, 2021.

[35] DIA, 2017, p. 80; Missile Defense Project, "S-400 Triumf," Center for Strategic and International Studies, last updated July 6, 2021; and Crane, Oliker, and Nichiporuk, 2019, pp. 38–39.

[36] DIA, 2017, p. 80.

[37] Thomas Newdick, "This Is Our First View Of Russia's New S-500 Air Defense System In Action," *The Drive*, July 20, 2021.

[38] DIA, 2017, p. 33.

[39] U.S. Space Command Public Affairs Office, "Russian Direct-Ascent Anti-Satellite Missile Test Creates Significant, Long-Lasting Space Debris," press release, Peterson Space Force Base, Colo., November 15, 2021.

China

Historically, China has maintained a much smaller nuclear force than either the United States or Russia for the purpose of deterring nuclear coercion and retaliating in the event of a nuclear attack. Beijing has repeatedly declared a policy of no first use, maintaining that it would employ nuclear weapons only in response to a nuclear strike on Chinese territory and that it would not use, or threaten to use, nuclear force against a non-nuclear weapon state or in nuclear weapon–free zones. However, public writings by Chinese military officers have introduced ambiguities over the conditions in which the country might use nuclear weapons preemptively, such as to avoid the prospect of a conventional attack that threatened the survival of the regime or its nuclear deterrent.[40] The difficulty of predicting Chinese intentions was underscored during a 2020 congressional hearing, in which Admiral Richard told the Senate Committee on Armed Services, "[w]e have very little to go on in terms of how they interpret" their policy of no first use.[41]

This uncertainty has deepened amid new evidence that China is rapidly increasing the number and diversity of its strategic missiles and warheads—a shift that could portend, some observers suggest, alterations in Chinese nuclear doctrine and policy.[42] The U.S. Intelligence Community has assessed that Beijing is pursuing the "most rapid expansion and platform diversification of its nuclear arsenal in its history, intending to at least double the size of its nuclear stockpile during the next decade and to field a nuclear triad."[43] In a related vein, then–Vice Chairman of the U.S. Joint Chiefs of Staff Gen John E. Hyten characterized China as the "fastest growing nuclear power in the world . . . building, at a percentage level, more new nuclear weapons than anybody on the planet."[44] According to publicly available DoD projections, China may have up to 700 deliverable nuclear weapons by 2027, and at least 1,000 warheads by 2030—numbers "exceeding the pace and size the DoD projected in 2020."[45]

Compared with Russia, China likely will still possess fewer nuclear weapons that can threaten the U.S. homeland for the foreseeable future. It is, however, improving and expanding the capabilities of its ICBM force, including the deployment of the road-mobile and multi-warhead DF-41.[46] Additionally, various nongovernmental analysts have recently reported that China is in the process of constructing as many as 250 or more underground silos for long-range missiles. When asked about these reports, General Hyten publicly

[40] Office of the Secretary of Defense, *Military and Security Developments Involving the People's Republic of China 2021*, Washington, D.C.: U.S. Department of Defense, November 3, 2021, pp. 90–91.

[41] Testimony from ADM Charles A. Richard, U.S. Navy, Commander, STRATCOM, as transcribed in U.S. Senate, Committee on Armed Services, "Hearing to Receive Testimony on United States Northern Command and United States Strategic Command in Review of the Defense Authorization Request for Fiscal Year 2021 and the Future Years Defense Program," Washington, D.C., February 13, 2020a, p. 61. For a discussion of the factors that could inspire a change in policy in China, see Fiona S. Cunningham and M. Taylor Fravel, "Assuring Assured Retaliation: China's Nuclear Posture and U.S.-China Strategic Stability," *International Security*, Vol. 40, No. 2, Fall 2015.

[42] Eric Heginbotham, Michael S. Chase, Jacob L. Heim, Bonny Lin, Mark R. Cozad, Lyle J. Morris, Christopher P. Twomey, Forrest E. Morgan, Michael Nixon, Cristina L. Garafola, and Samuel K. Berkowitz, *China's Evolving Nuclear Deterrent: Major Drivers and Issues for the United States*, Santa Monica, Calif.: RAND Corporation, RR-1628-AF, 2017. For a discussion of the strategic, political, and organizational factors motivating the Chinese modernization program, see Fiona S. Cunningham, "Cooperation Under Asymmetry? The Future of US-China Nuclear Relations," *Washington Quarterly*, Vol. 44, No. 2, 2021.

[43] Office of the Director of National Intelligence, 2021, p. 7.

[44] As quoted in Vergun, 2021.

[45] Office of the Secretary of Defense, 2021, p. 90.

[46] Office of the Secretary of Defense, 2021, pp. 61–62.

In contrast to Russia and China, the United States deferred modernization of its nuclear forces in the decades after the Cold War period.

stated "you now see hundreds and hundreds of fixed silos coming in . . . there's no limit on what China can put in those silos."[47]

China has also completed construction of six second-generation SSBNs, each armed with 12 JL-2 SLBMs, which allow it to maintain a continuous at-sea presence. It reportedly is developing an even more capable class of submarines and SLBMs that would enable it to target the United States from littoral waters, and could have up to eight SSBNs by 2030.[48] Moreover, China publicly revealed its first nuclear-capable, air-to-air refuelable bomber (a derivative of its H-6 family of bombers) in October 2019, and reportedly is developing a nuclear-capable ballistic missile that could be launched from the new aircraft.[49] Finally, DoD officials have highlighted China's announcement that it is developing a new, stealthy nuclear-capable strategic bomber.[50]

Through its recent development of a nuclear capable air-launched ballistic missile and improvements to its ground and sea-based nuclear capabilities, China may already possess a "nascent" Triad, according to a 2021 DoD assessment.[51] All of these developments have led STRATCOM to conclude that China is "on trajectory to be a strategic nuclear peer by the end of the decade."[52]

Like Russia, China has also made substantial investments in its air and missile defenses. Over the past two decades, China has built one of the world's largest arsenals of long-range surface-to-air missile defense systems, integrating domestically produced and Russian-made systems like S-400s and S-300s.[53] Beijing reportedly is testing an anti-ballistic missile system that can intercept intermediate-range projectiles mid-course and is developing a variety of anti-satellite weapons.[54] Many of these systems have multiple applications, including to deter, deny, or degrade the United States' ability to project conventional forces and intervene in a conflict near its borders.

[47] Brookings Institution, "Webinar: A Conversation with Vice Chairman of the Joint Chiefs of Staff General John E. Hyten," transcript, Washington, D.C.: September 13, 2021. For a summary of the various nongovernmental reports, see Shannon Bugos and Julia Masterson, "New Chinese Missile Silo Fields Discovered," Arms Control Association, September 2021.

[48] Office of the Secretary of Defense, 2021, p. 49.

[49] Office of the Secretary of Defense, 2021, pp. 91–92.

[50] Office of the Secretary of Defense, 2021, p. 56.

[51] Office of the Secretary of Defense, 2021, pp. vi, 90–92.

[52] ADM Charles A. Richard, remarks presented at International Security at the Nuclear Nexus Conference, Day 1, Washington, D.C.: Center for Strategic and International Studies, October 21, 2020b; ADM Charles A. Richard, transcript of interview with Dave Deptula, July 30, 2020a; Office of the Secretary of Defense, 2018, p. 11. This assessment marks a significance shift since the 2010 NPR, which identified Russia as "America's only peer in the area of nuclear weapons capabilities" (Office of the Secretary of Defense, 2010, p. iv).

[53] Office of the Secretary of Defense, 2021, p. 57; Office of the Secretary of Defense, *Missile Defense Review*, Washington, D.C.: U.S. Department of Defense, 2019, p. v.

[54] Office of the Secretary of Defense, 2021, pp. 67–68, 86; Joseph Trevithick, "China Claims It Has Conducted a New Mid-course Intercept Anti-Ballistic Missile Test," *The Drive*, February 4, 2021.

Current Programs to Modernize the U.S. Nuclear Triad

In contrast to Russia and China, the United States deferred modernization of its nuclear forces in the decades after the Cold War. Rather than designing, developing, and deploying new delivery systems, both the Clinton and George W. Bush administrations chose to live off earlier investments and extend the service life of existing capabilities. As a result, the United States has not procured any nuclear-capable missiles or bombers since the last B-2 was delivered to Whiteman Air Force Base (AFB), Missouri, in 1997—24 years ago.

That policy began to change under the Obama administration. In 2010, DoD released the public version of the NPR report, which recognized that all three legs of the Triad were nearing the end of their service lives and outlined plans to prepare modernization options. The Navy was directed to begin technology development for an eventual replacement of its *Ohio*-class SSBNs, the first of which was scheduled for retirement in 2027.[55] Likewise, the Air Force was to begin a formal assessment of alternatives to determine "whether (and if so) how" to replace the nuclear-capable ALCM, carried by the B-52, which was expected to reach the end of its service life "later in the next decade."[56] No mention was made of replacing either the B-52H or the B-2 with a new nuclear-capable bomber, an option the Air Force had begun exploring as early as 2004.[57] Finally, the report announced that DoD would begin an initial study of possible alternatives to the Minuteman III and affirmed that ongoing programs to extend the ICBM's service life until 2030 would continue.[58]

These modernization initiatives gained momentum over the latter half of 2010, when a rancorous, largely partisan debate erupted in Washington regarding ratification of the U.S.-Russian New START nuclear arms control agreement that had been signed in April of that year. As part of an effort to ensure Senate approval to ratify the treaty, the Obama administration struck a "grand bargain" with Republicans by agreeing to devote more resources to the modernization of all three legs of the Triad, as well as the nuclear weapons laboratories and production facilities owned by NNSA.[59] Ultimately, the Senate voted 71–26 to give its consent to New START's ratification, with the added stipulation that the President would need to certify the intent "to modernize or replace the triad of strategic nuclear delivery systems" before the treaty entered into force.[60] Subsequent legislation required the President to certify annually in writing the administration's commitment to modernizing and replacing strategic delivery systems.[61]

The 2010 NPR and the New START ratification debate ultimately led to formal programs of record to modernize all three legs of the Triad by fielding a new class of SSBNs, a new bomber, a new version of the nuclear-armed ALCM, and a new ICBM. These programs of record continue to this day; their current status

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55 Office of the Secretary of Defense, 2010, p. 23.

56 Office of the Secretary of Defense, 2010, p. 24.

57 Jeremiah Gertler, *Air Force B-21 Raider Long-Range Strike Bomber*, Washington, D.C.: Congressional Research Service, R44463, updated July 7, 2021, pp. 1–2.

58 Office of the Secretary of Defense, 2010, p. 23.

59 In November 2010, DoD updated an earlier report to Congress on its nuclear force structure plans to provide more detail on timelines, milestones, and initial cost estimates. It also forecast increased spending levels for modernization of all legs of the Triad and for the nuclear weapons complex owned by NNSA. (See DoD, "November 2010 Update to the National Defense Authorization Act of FY2010, Section 1251 Report, New START Treaty Framework and Nuclear Force Structure Plans," Washington, D.C., November 17, 2010). For a firsthand account of the "grand bargain" to ratify New START, see Rose Gottemoeller, *Negotiating the New START Treaty*, Amherst, N.Y.: Cambria Press, 2021, pp. 144, 150–151, 160, 163–164, and 182–183. Gottemoeller was the chief U.S. negotiator for the New START agreement.

60 U.S. Department of the State, Bureau of Arms Control, Verification, and Compliance, "New START Treaty: Resolution of Advice and Consent to Ratification," December 22, 2010.

61 U.S. Code, Title 10, Section 495, Strategic Delivery Systems, in effect as of January 16, 2014.

is discussed in following sections. Because the political spotlight is currently focused on GBSD, additional details on its origins are provided.

However, two caveats are in order. First, in addition to modernizing the Triad's nuclear delivery systems, DoD is also pursuing improvements to the nation's nuclear command, control, and communications (NC3) systems, a multifaceted effort that will have implications for the technical specifications of existing and new bomber, submarine, and missile systems. Likewise, NNSA is upgrading and modernizing its nuclear weapons laboratories and production facilities to ensure its ability to develop and deliver the types and number of nuclear warheads associated with each leg of the Triad. A full discussion of these efforts is beyond the scope of this Perspective, but suggestions for additional reading are provided in the footnotes. Second, the Trump administration's 2018 NPR called for adding "supplements" to the existing programs of record, including "to 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-launch cruise missile (SLCM)."[62] NNSA executed the first of these supplements as the W76-2 modification program, and completed warhead production and delivery to the Navy in FY 2020.[63] The SLCM initiative has not yet become a program of record, and its fate is still uncertain.[64] Neither the W76-2 nor the SLCM is discussed in detail here.

The Sea Leg

The sea leg of the Triad currently consists of 14 *Ohio*-class SSBNs, each capable of launching 20 Trident II D5 missiles armed with either W76 or W88 nuclear warheads.[65] At any one time, at least two submarines are being overhauled and are not available for nuclear deterrence operations. The oldest *Ohio*-class boat still in service was commissioned in October 1984; the youngest in 1997. The submarines were originally designed to operate for 30 years but were later certified by the Navy for a 42-year service life, longer than any previous class of submarines.[66] Having already once pushed back the projected date for retiring the *Ohio*-class boats, the Navy insists that it is not technically feasible to do so again.[67] Virtually no one disputes this assessment.

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[62] Office of the Secretary of Defense, 2018, p. 54.

[63] U.S. Department of Energy, *Fiscal Year 2021 Stockpile Stewardship and Management Plan—Biennial Plan Summary, Report to Congress*, Washington, D.C., December 2020, p. 5-28.

[64] John M. Doyle, "Acting SECNAV Says Memo Doesn't Mean He's Canceling Nuclear Sea-Launched Cruise Missile," *Seapower Magazine*, June 16, 2021.

[65] Eighteen *Ohio*-class boats were built and commissioned originally. Four of them were subsequently converted and assigned non-nuclear and special forces roles. Additionally, the *Ohio*-class submarines were designed with 24 missile launch tubes. To reduce the overall level of strategic nuclear forces and conform to the New START treaty's ceilings on deployed long-range delivery systems, the United States decided to render four launch tubes on each of the remaining submarines incapable of launching ballistic missiles (see U.S. Department of Energy and U.S. Department of the Navy, *The United States Naval Nuclear Propulsion Program 2020*, Washington, D.C., July 2020, p. 7).

[66] Ronald O'Rourke, *Navy Columbia (SSBN-826) Class Ballistic Missile Submarine Program: Background and Issues for Congress*, Washington, D.C.: Congressional Research Service, R41129, updated February 26, 2020; and U.S. Government Accountability Office, *Nuclear Triad: DOD and DOE Face Challenges Mitigating Risks to U.S. Deterrence Efforts*, Washington, D.C., May 2021, p. 11.

[67] In November 2020, the Navy announced that it was exploring options to extend the life of *Ohio*-class SSBNs to mitigate the risks of a possible delay in the production and deployment of future *Columbia*-class submarines. Senior Navy officials, however, have cautioned that the program might buy a few additional years but cannot offset the urgent need for recapitalization (Megan Eckstein, "Navy May Extend Life of Ohio SSBNs to Provide Cushion for Introduction of Columbia-Class," *USNI News*, November 16, 2020).

As noted earlier, the decision to pursue a replacement to the *Ohio*-class submarine was made in 2010, with official DoD approval to proceed with a program of record secured in January 2017.[68] The new submarines, now officially known as the *Columbia*-class, will incorporate electric drive propulsion and a life-of-the-ship nuclear reactor core to eliminate the requirement for midlife refueling, a process that in the past has taken submarines out of operation for as long as 40 months.[69] For this reason, the Navy concluded that it can meet operational requirements with 12 SSBNs, two fewer than the current fleet of 14. The *Ohio*-class submarines will begin retiring in 2027, with the remaining 13 boats leaving service at roughly one-year intervals. The lead *Columbia*-class submarine is scheduled to be delivered in 2028 and, after testing and sea trials, to conduct its first deterrent patrol in 2031. The fleet is expected to remain in operation until the 2080s.[70]

Each of the new *Columbia*-class SSBNs will be able to launch 16 SLBMs, four fewer than the current *Ohio*-class. This change was based in part on the assumption that the multi-decade reduction in U.S. nuclear delivery systems is unlikely to be suddenly and dramatically reversed. The Navy plans to continue using the Trident II D5 SLBM, which just completed the first phase of a D5 life extension program, on the new boats. For the longer term, the Navy is pursuing a second phase of a D5 life extension program. The first of the so-called D5LE2 missiles are scheduled to be delivered by 2039, in time to be fitted on the ninth *Columbia*-class submarine. Eventually the entire fleet will be armed with D5LE2 missiles, which will support the *Columbia*-class program through the life of the submarine.[71]

As for the warheads associated with the D5, NNSA completed the W76-1 life extension program in 2018 and more recently delivered a few W76-2s, the low-yield variant of the warhead, to the Navy. The agency is making alterations to the W88 warhead to ensure its continued effectiveness, completing the first production unit in early July 2021.[72] Finally, the Navy and NNSA have initiated the W93/Mk7 program to address future Navy requirements. According to a senior U.S. Navy official, the W93/Mk7 will "rebalance the stockpile of W76 and W88s and meet STRATCOM requirements."[73] The budget and schedule for the W93/Mk7 have yet to be determined.

The Air Leg

The air leg of the Triad consists of two nuclear-capable, long-range heavy bombers: the B-52H Stratofortress and the B-2 Spirit (often referred to as the stealth bomber). Both aircraft can deliver conventional muni-

[68] O'Rourke, 2020, p. 33.

[69] U.S. Department of Energy and U.S. Department of the Navy, 2020, p. 53; U.S. Government Accountability Office, 2021, pp. 20–21.

[70] O'Rourke, 2020, p. 39.

[71] U.S. Senate, Committee on Armed Services, Subcommittee on Strategic Forces, "Statement of Andrew T. Walter, Deputy Assistant Secretary of Defense for Nuclear Matters," Washington, D.C., May 12, 2021b, p. 6; U.S. Senate, Committee on Armed Services, Subcommittee on Strategic Forces, "Statement of Vice Admiral Johnny R. Wolfe, Jr., USN, Director, Strategic Systems Programs Before the Subcommittee on Strategic Forces of the Senate Armed Services Committee on FY 2022 Budget Request for Nuclear Forces and Atomic Energy Defense Activities," Washington, D.C., May 12, 2021c, p. 20; Megan Eckstein, "Navy Beginning Tech Study to Extend Trident Nuclear Missile into the 2080s," *USNI News*, November 14, 2019; and John Grady, "Wolfe: Modernized Trident Missiles Require Rigorous Testing as Navy Builds Columbia-Class," *USNI News*, January 15, 2021.

[72] U.S. Department of Energy, 2020, pp. 2-6 and 2-7; U.S. Department of Energy, "NNSA Completes First Production Unit of W88 Alteration 370," webpage, July 13, 2021a.

[73] U.S. Senate, Committee on Armed Services, Subcommittee on Strategic Forces, 2021c, p. 20. The W93 program apparently has implications beyond the future needs of the Navy. As one senior DoD official testified in May 2021, the program also "provides the opportunity for aligning . . . and collaborating" with the United Kingdom's Continuous at Sea Deterrent (see U.S. Senate, Committee on Armed Services, Subcommittee on Strategic Forces, 2021b, p. 6).

tions in addition to their nuclear mission, and they have played significant roles in U.S. military operations throughout the post–Cold War era.[74] In its nuclear role, the B-52H employs the AGM-86B ALCM armed with a W80-1 warhead, which enables the B-52H to launch its nuclear weapons at standoff distances from its assigned targets. Because the B-2 is considered more capable of penetrating enemy air defenses, it is designated to carry two types of gravity bombs (the B61 and the B83) in its nuclear role.[75]

Both bombers are showing the effects of age. The newest B-52H rolled off the production line in 1962 and will be at least 90 years old before it is retired in 2050.[76] To ensure that it can continue to perform its varied missions, the Air Force plans to upgrade several subsystems on the aircraft, such as equipping it with new engines, modernizing its radar capabilities, and increasing its capacity to carry conventional munitions.[77] The younger B-2, which was designed using 1980s technology and was first delivered to Whiteman AFB in late 1993, also requires periodic upgrades to its subsystems. The materials and processes used to maintain its stealth characteristics are costly and labor-intensive, and more-effective technology and techniques have since been developed. The Air Force originally planned to procure 132 B-2s but ended the program in 1992 after buying only 21 of them as part of the George H. W. Bush administration's decision to terminate several Cold War nuclear programs following the collapse of the Soviet Union.[78] The B-2's highly effective performance in conventional conflicts over the past two decades has largely dispelled any concerns over its continued relevance, and there is now widespread agreement that additional stealthy bombers are needed to meet future nuclear and conventional operational requirements.[79]

The program to modernize the air leg of the Triad consists of two major efforts: the AGM-181 Long-Range Standoff Weapon (LRSO) nuclear cruise missile program, and the B-21 Raider bomber. Because the Air Force has decided to keep the B-52 in service for at least another 30 years, it has determined that there is a continuing requirement for the aircraft to have a standoff nuclear delivery capability. But the current ALCM, which was first deployed in 1980, is increasingly difficult to sustain, as are the test and handling equipment required for maintenance. Accordingly, the Air Force received formal approval in 2016 to proceed with a replacement, the AGM-181 LRSO.[80] In the meantime, NNSA is conducting a program to extend the service life of the W80-1 warhead currently associated with the ALCM to enable its use on the LRSO. The completion of the first production unit of the updated warhead, known as the W80-4, is scheduled for 2025, approximately five years before the first LRSO is due to be deployed.[81]

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[74] The combination of mass, precision, and range made possible by arming these bombers with modern conventional munitions constitutes one of the most significant developments in the history of U.S. airpower. The authors are indebted to David Ochmanek of RAND for this observation. See also Benjamin S. Lambeth, *The Transformation of American Air Power*, Ithaca, N.Y.: Cornell University Press, 2000, pp. 164–167.

[75] U.S. Department of Energy, 2020, p. 1-3.

[76] Marcelle Size Knaack, *Encyclopedia of U.S. Air Force Aircraft and Missile Systems,* Volume II*, Post-World War Two Bombers, 1945-1973*, Washington, D.C.: Office of Air Force History, 1988, p. 288; John A. Tirpak, "USAF Releases B-52 Engine Replacement RFP, Award Expected July 2021," *Air Force Magazine*, May 20, 2020.

[77] U.S. Senate, Committee on Armed Services, Subcommittee on Strategic Forces, "Statement of General Timothy M. Ray, Commander, Air Force Global Strike Command," Washington, D.C., May 12, 2021e, pp. 7–8.

[78] Gertler, 2021, p. 10; Bush, 1992.

[79] David A. Deptula and Douglas A. Birkey, *Building the Future Bomber America Needs: The Bomber Re-Vector*, Washington, D.C.: Mitchell Institute for Aerospace Studies, September 2018, p. 20.

[80] Leigh Giangreco, "USAF Reaches Milestone A on Nuclear Cruise Missile," *FlightGlobal*, July 29, 2016.

[81] U.S. Department of Energy, 2020, p. i; John A. Tirpak, "New Nuclear Missile Ahead of Schedule for Next Development Phase," *Air Force Magazine*, January 15, 2021a; and U.S. Senate, Committee on Armed Services, Subcommittee on Strategic Forces, 2021e, pp. 14–15.

Over the past half century, almost every major component of the Minuteman III ICBM has undergone a series of upgrades and life extension programs.

Additionally, the Air Force plans to replace the B-2 bomber (as well as the B-1 bomber, which no longer has a nuclear role) with the B-21 Raider. Because the B-21 is managed as a highly classified program, public information regarding its design and capabilities is limited. Like the B-2, the new B-21 bomber will have both a nuclear and a conventional role.[82] Air Force officials recently announced the first flight of the aircraft would take place in mid-2022, with delivery of the first operational aircraft to host bases scheduled for the mid-2020s.[83] The Air Force has officially committed to buying 100 new bombers, although senior Air Force officials have publicly cited the need for more aircraft.[84]

The Land Leg

The land leg of the Triad currently consists of 400 Minuteman III ICBMs, each armed with either a single W78 or a single W87 warhead. Operational missiles are deployed in below-ground launch facilities, commonly referred to as *missile silos*. At the moment, there is a total of 450 silos, equally divided among three Air Force Bases: Malmstrom AFB, Montana; Minot AFB, North Dakota; and F.E. Warren AFB, Wyoming (whose missile field also stretches into the neighboring states of Nebraska and Colorado). At each base, the Minuteman IIIs are allocated to one of three squadrons that are each responsible for five dispersed underground launch control centers (LCCs) capable of monitoring and sending launch commands to all 50 missile silos in that squadron. Two officers crew each LCC on a 24-hour, seven-days-per-week basis. The missiles are continuously on alert and can be launched within minutes of an order to do so.[85]

The Minuteman III missiles were first fielded in 1970 to replace 550 of the 1,000 older Minuteman missiles then in service. At the time, the Minuteman III represented a significant technical advance in ICBM capabilities. Unlike the Minuteman IIs and the Titan IIs that were armed with only a single warhead, the Minuteman IIIs were capable of carrying up to three multiple independently targetable reentry vehicles (MIRVs), increasing the number of Soviet targets that the United States could hold at risk and improving the odds of defeating Soviet missile defenses. In the mid-1980s, 50 of the Minuteman III missile silos at F.E. Warren AFB were converted for use by the new Peacekeeper ICBM, each of which could carry up to ten warheads.

[82] U.S. Air Force, "B-21 Raider," fact sheet, July 6, 2021.

[83] John A. Tirpak, "The Raider Comes Out of the Black," *Air Force Magazine*, February 19, 2021b.

[84] For example, the commander of Global Strike Command has publicly testified that at least 100 B-21 Raiders are needed "to support the nuclear triad, deter aggression, fight and win in a contested environment, and replace our aging B-1 and B-2 bombers" and "many more B-21s could be used to mitigate risks" (see U.S. Senate, Committee on Armed Services, Subcommittee on Strategic Forces, 2021e, p. 13; and Deptula and Birkey, 2018). More recently, Secretary of the Air Force Frank Kendall stated during his confirmation hearing that 145 aircraft would be a "reasonable" target (see U.S. Senate, Committee on Armed Services, "Hearing to Consider the Nomination of Frank Kendall III to Be Secretary of the Air Force, Heidi Shyu to Be Under Secretary of Defense for Research and Engineering, and Susana Blume to Be Director of Cost Assessment and Program Evaluation," Washington, D.C., May 25, 2021f, p. 116).

[85] U.S. Air Force, "LGM-30G Minuteman III," fact sheet, undated; U.S. Government Accountability Office, May 2021, p. 8.

In short, from the early 1960s through the 1980s, the United States deployed a series of ICBM types of increasing capability while maintaining a constant total of 1,054 ICBMs throughout this period.[86]

As the Cold War drew to a close, the number of U.S. ICBMs and deployed warheads were reduced through unilateral decisions by the U.S. government and bilateral arms control agreements with the Soviet Union and its successor state, the Russian Federation. The last of the Titan IIs were retired in May 1987 after two deadly accidents revealed obsolescence and safety concerns.[87] Following the signing of the START I Treaty in 1991 and the Presidential Nuclear Initiatives of that same year, the United States began deactivating all of the 450 Minuteman IIs, completing the task by 1995.[88] The next year, the George H. W. Bush administration halted further production of the Peacekeeper ICBM and canceled the Air Force program to develop a smaller, road-mobile ICBM, dubbed the "Small ICBM" or "Midgetman."[89]

The START II Treaty (which was signed in January 1993 but never entered into force) and the subsequent 2002 Moscow Treaty presaged even further reductions. All 50 Peacekeeper ICBMs were retired between 2003 and 2005. Additionally, the number of warheads loaded on a portion of the Minuteman IIIs was reduced to one, which was accomplished, in part, by installing the Peacekeeper's more modern but larger W87 warheads on some of the Minuteman IIIs. In 2006, the George W. Bush administration decided to reduce the number of Minuteman IIIs from 500 to 450, following a major review of U.S. defense requirements to "fight the long war" in Afghanistan and Iraq.[90]

In 2010, the Obama administration announced that the United States would "deMIRV" all remaining Minuteman IIIs still armed with multiple warheads so that every ICBM would henceforth have only one nuclear warhead.[91] It subsequently chose to reduce the number of deployed Minuteman IIIs from 450 to 400 to meet the new, lower limits on delivery systems and warheads mandated by the 2010 New START agreement. In response to strong congressional pressure, however, the administration also decided to maintain the remaining 50 empty silos in a warm status.[92] As a result, the United States now possesses 50 more silos than deployed missiles. The composition of the ICBM leg of the Triad has not changed since.[93]

Deferring a Decision to Replace the Minuteman III

Over the past half century, several major components of the Minuteman III system have been upgraded or had their service lives extended. During the 1980s, the Air Force launched a campaign (called Rivet MILE) to repair and sustain the physical infrastructure and ground equipment associated with the missile silos and LCCs, which had originally been constructed for the deployment of Minuteman I and II in the 1960s. It

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86 James C. Ruerhmund, Jr., and Christopher J. Bowie, "Arsenal of Airpower: USAF Aircraft Inventory, 1950–2009," Washington, D.C.: Mitchell Institute for Aerospace Studies, November 2020, pp. 17–25. For two outstanding works on the history of U.S. ICBMs, and the Minuteman in particular, see David N. Spires, *On Alert: An Operational History of the United States Air Force Intercontinental Ballistic Missile System, 1945-2011*, Colorado Springs, Colo.: Air Force Space Command, 2012; and Neil Sheehan, *A Fiery Peace in a Cold War: Bernard Schriever and the Ultimate Weapon*, New York: Random House, 2009.

87 See Eric Schlosser's account in *Command and Control: Nuclear Weapons, the Damascus Accident, and the Illusion of Safety*, New York: Penguin Press, 2013.

88 Spires, 2012, p. 169; Koch, 2012, pp. 169–171.

89 Bush, 1992.

90 DoD, *Quadrennial Defense Review Report*, Washington, D.C., February 6, 2006, p. 50.

91 Office of the Secretary of Defense, 2010, p. 23.

92 DoD, *Report on Plan to Implement the Nuclear Force Reductions, Limitations, and Verification and Transparency Measures Contained in the New START Treaty Specified in Section 1042 of the National Defense Authorization Act for Fiscal Year 2012*, Washington, D.C., April 8, 2014.

93 Mark Gunziger, Carl Rehberg, and Gillian Evans, *Sustaining the U.S. Nuclear Deterrent: The LRSO and GBSD*, Washington, D.C.: Center for Strategic and Budgetary Assessments, 2018, pp. 41–42.

also modified the missile's command and control system to support faster targeting from the LCCs (called REACT). The decisions to cancel the Small ICBM program and to retire the Peacekeeper in the early 1990s meant that the Minuteman III would be the only ICBM in the U.S. strategic nuclear arsenal for some time to come. More needed to be done to ensure that the missile, which had already far exceeded its original ten-year design life, remained reliable and on alert. Potentially serious effects of aging already were apparent; for instance, periodic inspections revealed that the solid propellent fuel used in all three stages of the missile was displaying signs of hardening, cracking, and debonding from the motor casing liner.[94]

The Air Force accordingly shifted its focus from designing, developing, and deploying successive generations of new ICBMs to maintaining and refurbishing its existing inventory.[95] After Secretary of Defense Richard Cheney directed the Air Force to "upgrade and extend Minuteman III service life" in 1992, the service initiated major programs to remanufacture the solid propellent motors in all three stages of the missile; update the missile's guidance system; refurbish the post-boost vehicle or "fourth stage" (officially known as the propulsion system rocket engine); and upgrade command, control, and communications systems, as well as security and ground support equipment (see Table 1).[96] All of the programs were described as efforts to keep the Minuteman III in operation *until 2020*.

Yet even as these life extension programs were underway, Air Force officials wrestled with the issue of how best to sustain the land-based leg of the Triad over the longer term. In 2001, the George W. Bush administration directed the Air Force to start the process of defining the requirements for future ICBM force while continuing its programs to extend the service life of Minuteman III.[97] The ICBM Systems Program Office at Hill AFB, Utah subsequently conducted an analysis of alternatives (AoA) for sustaining the ICBM force *beyond 2020*. Because of other demands on the defense budget, the review team recommended continuing to refurbish the Minuteman III's hardware as needed, and incorporating incremental upgrades rather than beginning the development of a replacement ICBM at that time. Air Force Space Command, then responsible for the ICBM force, agreed that the approach would keep the system viable through 2030, as Congress had mandated in the FY 2007 National Defense Authorization Act (NDAA). At the same time, Air Force Space Command also suggested that the Air Force should nevertheless begin considering a replacement to Minuteman III given the time required to design, develop, and deploy a new missile system *by 2030*.[98]

The Air Force did not begin reviewing alternatives until after the new Obama administration gave the go-ahead in its 2010 NPR. In addition to announcing that all Minuteman IIIs would be de-MIRVed, the NPR also stated that "studies to inform" a decision on a follow-on ICBM "are needed now."[99] As part of this effort, the Air Force requested that RAND researchers evaluate prospective ICBM design, basing, and employment options. Although a public report was not published until 2014, the RAND study team recommended at the end of FY 2011 that the Air Force's AoA should include consideration of incremental modernization and sus-

94 Spires, 2012, p. 173.

95 Spires, 2012, pp. 172–182.

96 These programs are described in detail in Spires, 2012, pp. 174–182; and Amy F. Woolf, *U.S. Strategic Nuclear Forces: Background, Developments, and Issues*, Washington, D.C.: Congressional Research Service, RL33640, updated December 10, 2020b, pp. 13–15.

97 As quoted in Air Force Space Command, *Strategic Master Plan FY04 and Beyond*, Peterson Air Force Base, Colo.: U.S. Air Force, November 5, 2002, p. 13. Unlike the subsequent 2010 and 2018 NPRs, the report on the 2002 NPR was never publicly released. However, the Pentagon did issue an unclassified executive summary signed by Secretary of Defense Donald Rumsfeld. Then–Assistant Secretary of Defense J. D. Crouch also provided an unclassified briefing on the NPR's findings and recommendations (see DoD, 2002).

98 Spires, 2012, p. 187; Woolf, 2020b, pp. 17–18; and Gunziger, Rehberg, and Evans, 2018, pp. 43–44.

99 Office of the Secretary of Defense, 2010, p. 23.

TABLE 1
Major Minuteman III Service Life Extension Programs, 2000–2013

Program	FY Start	FY End
Guidance Replacement Program (GRP)	1998	2009
Propulsion Replacement Program (PRP)	1999	2013
Propulsion System Rocket Engine (PSRE) Life Extension Program	2004	2012
Safety Enhanced Reentry Vehicle	2004	2012
REACT Service Life Extension Program	2002	2006
Environmental Control System (ECS) Service Life Extension Program	2006	2012
Minuteman Minimum Essential Emergency Communications Network (MEECN) Program	2002	2005
ICBM Security Modernization Program	2005	2013
ICBM Cryptology Update	2007	2009

SOURCE: Spires, 2012, pp. 174–182; Woolf, 2020b, pp. 13–15.

tainment of Minuteman III alongside the costs of developing a replacement system. The authors cautioned, however, that "new challenges may call for capabilities beyond what Minuteman currently delivers."[100]

Concurrently, Air Force Global Strike Command, which had assumed responsibility for the ICBM mission, began a capabilities-based assessment of a future ICBM system in January 2011. The following year, the Air Force started a new AoA for the future of the ICBM force. Completed in 2014, this AoA confirmed that an ICBM replacement program was necessary to meet current and future operational requirements beyond 2030. As subsequently described by Gen Robin Rand, then–commander of Air Force Global Strike Command, the Air Force's analysis determined that further life extensions would "cost more than full system recapitalization, and would not address warfighting capability gaps validated by the Joint Requirements Oversight Council."[101] Drawing upon these conclusions, DoD decided to proceed with the development of a new ICBM, dubbed the Ground-Based Strategic Deterrent.[102]

[100] Lauren Caston, Robert S. Leonard, Christopher A. Mouton, Chad J. R. Ohlandt, Craig Moore, Raymond E. Conley, and Glenn Buchan, *The Future of the U.S. Intercontinental Ballistic Missile Force*, Santa Monica, Calif.: RAND Corporation, MG-1210-AF, 2014, pp. 115–118.

[101] Gen Robin Rand as quoted in response to member questions in U.S. House of Representatives, Committee on Armed Services, Subcommittee on Strategic Forces, "Fiscal Year 2018 Priorities for Nuclear Forces and Atomic Energy Defense Activities," Washington, D.C.: U.S. Government Publishing Office, May 25, 2017. For a similar summary of the RAND study team's findings, see the responses of General Hyten and Gen Paul J. Selva to questions submitted by members during and after a 2017 hearing (U.S. House of Representatives, Committee on Armed Services, "Hearing on Military Assessment of Nuclear Deterrence Requirements," Washington, D.C.: U.S. Government Publishing Office, March 8, 2017).

[102] The current practice of referring to the new ICBM as the *Ground-Based Strategic Deterrent* will change in early 2022. Per the FY 2022 NDAA, the Secretary of the Air Force, in coordination with the Under Secretary of Defense for Acquisition and Sustainment, is required to establish a "mission-design series popular name" to replace GBSD. This convention is consistent with past ICBM programs, such as the Minuteman and the Peacekeeper (see Section 1638 in U.S. House of Representatives, Committee on Rules, *Rules Committee Print 117-21: National Defense Authorization Act for Fiscal Year 2022*, Washington, D.C., December 7, 2021).

The GBSD Program

At this point, the program for a replacement ICBM entered into the formal DoD acquisition process (see Figure 3).[103] On August 23, 2016, the Air Force received Defense Acquisition System "Milestone A" approval for its replacement ICBM program following a determination by the then–Under Secretary of Defense for Acquisition, Technology and Logistics, Frank Kendall, that its acquisition plan was "structured to reduce risk, balance design and requirement trades, and ensure affordable program execution."[104] The announcement allowed the program to enter the Technology Maturation and Risk Reduction (TMRR) phase, and in August 2017, the Air Force awarded TMRR contracts to Boeing and Northrop Grumman.[105] Before completion of the contract, however, Boeing withdrew from competition for the next-phase Engineering, Manufacturing, and Development (EMD) contract, citing concerns that Northrop Grumman's acquisition of solid rocket motor manufacturer Orbital ATK granted the company a pricing advantage.[106] The Air Force did not respond to a subsequent Boeing request to compel the creation of a joint team, and in September 2020, it awarded the $13.3 billion contract to Northrop Grumman, the only remaining bidder.[107]

To date, Northrop Grumman reportedly is on pace to complete the eight-year EMD phase—which includes weapon system design, qualification, test and evaluation, and nuclear certification—on schedule. The company's design plan passed review in November 2020, clearing the way to begin transitioning ownership of program data to the government.[108] In late April 2021, Northrop Grumman completed its integrated baseline review, which established a cost and schedule baseline and mitigation plans for identified risks, also on schedule.[109] The first test flight of GBSD is forecasted for December 2023.[110]

The Air Force plans to deliver the first production unit of the GBSD "at the earliest feasible date and reach initial operational capability in fiscal year 2029."[111] The new ICBMs will be deployed in the same missile silos currently used by the Minuteman IIIs they are replacing, so the GBSD program also entails significant upgrades to portions of the existing infrastructure.[112] To meet STRATCOM requirements for on-alert ICBMs, the Air Force expects to continue operating Minuteman IIIs as they are being replaced, lending additional complexity to the already challenging task of transitioning between weapon systems.[113]

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[103] Department of Defense Instruction 5000.02, "Operation of the Defense Acquisition System," Washington, D.C.: U.S. Department of Defense, updated August 10, 2017.

[104] Air Force Global Strike Command, Public Affairs Office, "AF Reaches First Milestone in Acquisition of New ICBM," September 1, 2016. Frank Kendall later became the Biden administration's Secretary of the Air Force on July 28, 2021.

[105] Lockheed Martin Strategic and Missile Defense Systems also submitted a proposal but did not protest the award decision (see Valerie Insinna, "Boeing, Northrop Move Forward on Next-Gen ICBM Program; Lockheed Out," *Defense News*, August 21, 2017).

[106] Valerie Insinna, "Boeing Drops from Next-Generation ICBM Competition," *Defense News*, July 25, 2019b.

[107] John A. Tirpak, "Boeing Rebuffed in Bid to Partner with Northrop Grumman on New ICBM," *Air Force Magazine*, September 13, 2019. Northrop's partners include Aerojet Rocketdyne, Bechtel, BRPH, Clark Construction, Collins Aerospace, General Dynamics, Honeywell, Kratos, L3Harris, Lockheed Martin, Parsons, and Textron Systems.

[108] Sandra Erwin, "Northrop Grumman Clears First Design Review of Next-Generation ICBM," *Space News*, February 16, 2021b.

[109] Brian W. Everstine, "GBSD Passes Integrated Baseline Review, on Pace for IOC in 2029," *Air Force Magazine*, April 7, 2021b.

[110] Statement from Lt Gen James Dawkins as transcribed in U.S. House, Committee on Armed Services, Subcommittee on Strategic Forces, June 9, 2021a.

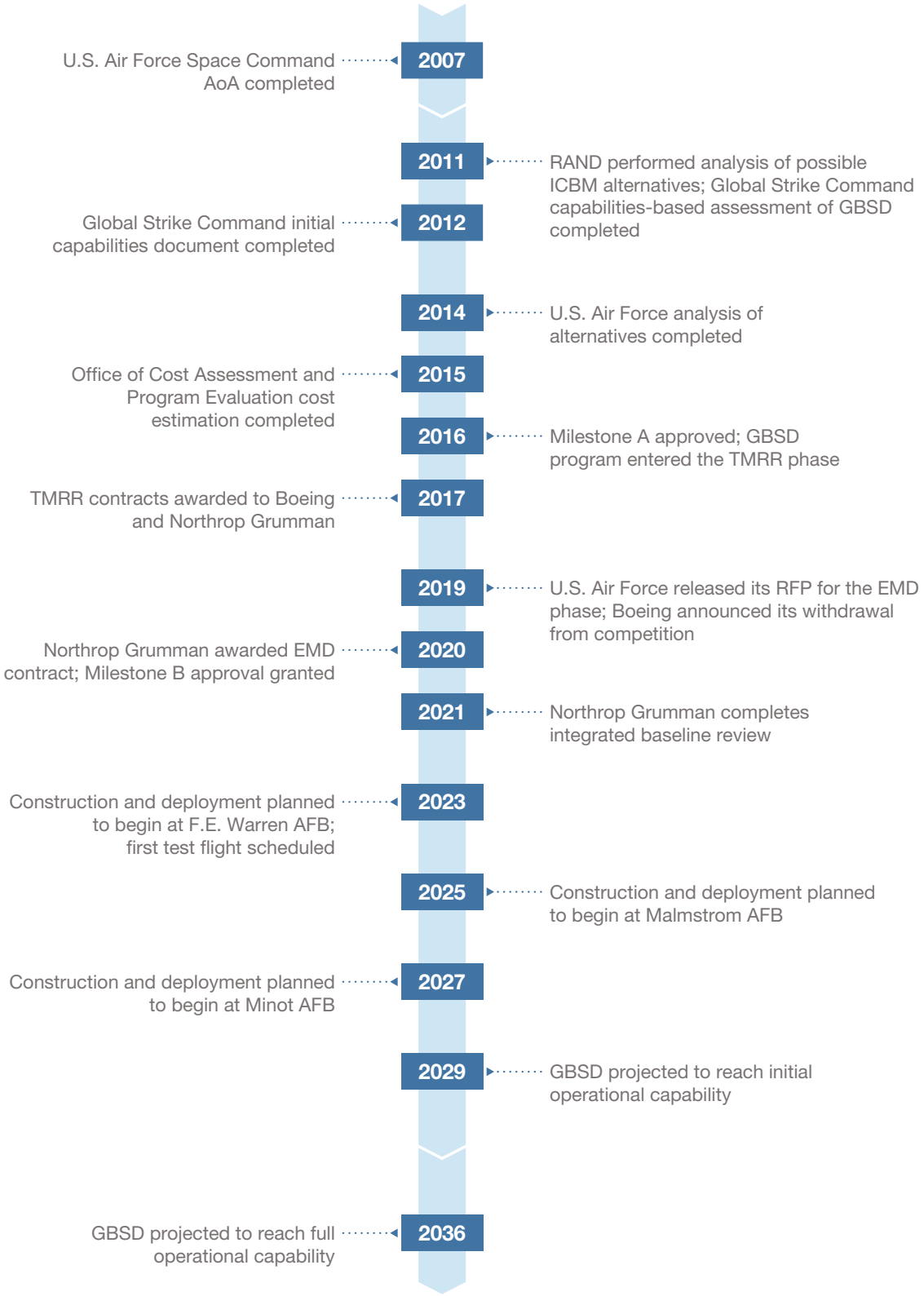
[111] U.S. Government Accountability Office, May 2021, p. 26.

[112] Office of the Secretary of Defense, 2018, pp. 49–50.

[113] U.S. Government Accountability Office, May 2021, pp. 27–28.

FIGURE 3

Timeline of the ICBM Modernization Program



The new ICBM—like the Minuteman III missile it will replace—is not expected to be MIRVed. Today, each Minuteman III is deployed with either a single W78 warhead or a W87 warhead.[114] The United States first deployed the W78 in 1979, and, in response to the 2010 NPR, NNSA began in June 2012 to study the feasibility and design options for conducting a life extension program for W78 that would also make it interoperable with both the Air Force's and Navy's ballistic missiles.[115] That program was paused in 2014, however, in part because of interservice disagreements over the approach. The 2018 NPR directed NNSA to restart the program "in order to support fielding on GBSD by 2030."[116]

The following year, NNSA announced that the W78 would be replaced with a modification of the existing W87 warhead design, part of an effort henceforth known as the W87-1 modification program.[117] The decision to opt for a modified version of the W87 reflects NNSA's long-held objective to enhance safety and security by using insensitive high explosives in all ICBM warheads and, at the same time, to draw on known designs to avoid the need to conduct explosive nuclear testing as part of the development process.[118] NNSA has informed Congress that it intends to use newly manufactured plutonium pits in the W87-1, although this will be affected by the progress of the agency's ongoing effort to re-establish a viable plutonium pit production capability.[119] According to the Congressional Research Service, budget documents provided to the Congress indicate that the existing W87 warhead will also be "qualified and deployed onto the GBSD," which will help cover any gaps between the first fielding of the new ICBM in 2028 and the first deployment of the W87-1 in 2030. This arrangement will also afford the Air Force some flexibility if development of the W87-1 is delayed.[120]

The GBSD is slated to achieve full operational capability by 2036. Defense acquisition officials readily admit that the schedule is "aggressive and compressed." They maintain, however, that improvements in digital engineering, combined with a competitive and multi-year TMRR phase, have decreased the likelihood of

[114] U.S. Department of Energy, *Fiscal Year 2020 Stockpile Steward and Management Plan – Biennial Plan Summary*, Washington, D.C., December 2020, p. 1-3; and U.S. Department of Energy, "W87-1 Modification Program," fact sheet, March 2019a.

[115] Office of the Secretary of Defense, 2010, p. 39.

[116] Office of the Secretary of Defense, 2018, p. 61.

[117] U.S. Department of Energy, 2019a.

[118] U.S. Government Accountability Office, *Nuclear Weapons: Should NNSA Further Develop Costs, Schedule, and Risk Information for the W87-1 Warhead Program*, Washington, D.C., GAO-20-703, September 2020b, pp. 8–10.

[119] A plutonium pit is an essential component of every nuclear weapon. During the Cold War, the United States produced roughly 1,000 pits a year at the Rocky Flats Plant near Denver, Colorado. That facility was shut down in 1992 following concerns about safety, compliance with environmental rules, and the Bush administration's decision to cease further production of the W88 warhead. Los Alamos National Laboratory (LANL), which performs much of the scientific work related to plutonium, subsequently manufactured 29 replacement pits for the W88 warhead between 2007 and 2011. Congress has mandated that NNSA develop the capability to manufacture 80 pits per year by 2030. NNSA developed plans to meet this objective by repurposing facilities at LANL to produce 30 pits per year and to develop a parallel capability to produce 50 pits per year at the Department of Energy's Savannah River Site in South Carolina by repurposing facilities originally under construction for the cancelled Mixed Oxide Fuel Fabrication Facility program. In June 2021, Charles Verdon, the then–acting NNSA administrator, publicly confirmed that NNSA would not be able to meet the 80-pit requirement by 2030 because of forecasted delays in construction at the Savannah River site. See Marisa Sandoval, "Pit Perfect: LANL Meets Plutonium Pit Production Goal," *National Security Science*, No. 3, October 2011; National Nuclear Security Administration, "Joint Statement from Ellen Lord and Lisa E. Gordon-Hagerty on Recapitalization of Plutonium Pit Production," May 10, 2018; and U.S. House of Representatives, Committee on Armed Services, Subcommittee on Strategic Forces, "Hearing on Fiscal Year 2022 Budget Request for Nuclear Forces and Atomic Energy Defense," Washington, D.C., June 9, 2021a, p. 27.

[120] Woolf, 2020b, pp. 21–23.

design or production delays and associated cost increases.[121] Even so, many major defense acquisition programs experience delays as a result of funding or technical challenges, among other potential issues.[122] The multifaceted nature of the GBSD program—which includes development of the missile; upgrades to existing real property, infrastructure, and NC3 systems; and modification of an existing warhead—suggests that some speed bumps may be encountered along the way. GBSD's timely progress to date is a credit to the Air Force's new approach to engineering and program management, but the real possibility of schedule delays, which almost invariably drive up costs, should temper expectations.

Arguments for a New ICBM

As a result of decisions made after the end of the Cold War, the United States currently depends on only one land-based delivery system, which was originally fielded a half century ago to operate for a ten-year service life. Despite continued support for the Triad, programs to replace the Minuteman III were deliberately and repeatedly deferred in favor of extending the aging missile's service life until the Obama administration decided to develop and deploy a new ICBM after extensive study of alternatives. In the judgment of senior defense officials and military officers, replacing the Minuteman III with GBSD is essential to maintaining a viable land-based strategic deterrent. The three most-common explanations for why delivery of a new ICBM starting in 2030 is needed are described below.

Further Life Extension Is Neither Feasible nor Cost-Effective

The first and perhaps most compelling argument advanced for fielding a new ICBM is that it is no longer technically feasible nor cost-effective to continue extending the service life of the Minuteman III.[123] By 2030, it will have been 20 years or longer since the solid-rocket motors, guidance sets, and propulsion rocket system engines in the fleet were replaced or refurbished. Those subsystems continue to age, as do other components that have never been updated. Likewise, the facilities and infrastructure associated with the Minuteman III—most of which were constructed or installed in the early 1960s with the deployment of the Minuteman I and II—are exhibiting serious aging issues. Corrosion, water intrusion, collapsed conduits, misaligned doors, and bulging walls are prevalent; at one installation, an LCC could only be reached by a temporary pully system after an elevator component broke and the replacement was delayed by several months.[124] According to the Air Force's Minuteman III systems directorate, corrosion on launch and closure doors already "prevents us

[121] Testimony of Gen Arnold W. Bunch, Jr., as transcribed in STRATCOM, "House Armed Services Subcommittee on Strategic Forces Holds Hearing on Fiscal Year 2020 Budget Request for Defense Nuclear Activities," April 3, 2019. See also U.S. Government Accountability Office, May 2021a, pp. 26–29; Sandra Erwin, "HASC Chairman: Single-Contractor Bid for New ICBM Is 'Troubling,'" *Space News*, October 24, 2019b; and John Harper, "Next-Gen Nuclear Missile Viewed as Pathfinder," *National Defense Magazine*, December 4, 2020.

[122] See, for example, U.S. Government Accountability Office, *Weapon Systems Annual Assessment: Updated Program Oversight Approach Needed*, Washington, D.C., GAO-21-222, June 2021b.

[123] Testimony of ADM Charles A. Richard as transcribed in U.S. Senate, Committee on Armed Services, "To Receive Testimony on United States Strategic Command and United States Space Command in Review of the Defense Authorization Request for Fiscal Year 2022 and the Future Years Defense Program," Washington, D.C., April 20, 2021e.

[124] U.S. Government Accountability Office, *Defense Nuclear Enterprise: Systems Face Sustainment Challenges, and Actions Are Needed to Effectively Monitor Efforts to Improve the Enterprise*, Washington, D.C., GAO-20-296, March 2020a, pp. 25–26; Tara Copp, "U.S. Nuclear Weapons Are Aging Quickly. With Few Spare Parts, How Long Can They Last?" McClatchy, March 29, 2021.

from being able to close the blast doors and lock [them] appropriately. And you can only scrape away the rust and take away layers so many times before you're putting the crews at risk for potential hardness concerns."[125]

The effects of this age-related degradation are unpredictable. Maj Gen Anthony W. Genatempo, director of the Air Force Nuclear Weapons Center, has expressed particular concern about the possibility that 60-year-old heating, ventilation, and air conditioning systems could fail, an event that "would take a missile offline for an unknown amount of time as it is fixed."[126] Additionally, much of the specialized and unique gear required to maintain the missiles on alert (e.g., vehicles, handling equipment, diagnostic test sets, and cables) is simply worn out. As a result, missile maintenance technicians routinely take two or three sets of a critical piece of equipment to the field to ensure that they will have at least one unit that works.

Extending the service life of Minuteman III yet again would require finding or producing the pieces and parts needed to refurbish or replace aging components and equipment. This is far easier said than done. Design choices made when Minuteman III was first developed limit the possibility of inserting redesigned components that might be easier to manufacture. Instead, maintainers generally must replace worn components with identical items to ensure proper form, fit, and function. But manufacturing replacement parts and the associated maintenance equipment and test sets would require the Air Force to recreate an industrial base that has atrophied beyond recognition. The production lines for the Minuteman III weapon system shut down decades ago; many of the original manufacturers of critical components in the missile have since closed or moved onto other lines of business.[127] As a result, the Air Force does not have a source for approximately 330 of the parts that are required to sustain the propulsion system alone.[128]

Even if the Air Force chose to incentivize commercial enterprises to manufacture specialized components, formidable challenges would remain. Designs and blueprints would have to be resurrected and recertified, new vendors (and subvendors) would have to be qualified, new assembly lines would have to be built, new technicians would have to be trained, and the end products would have to be rigorously tested to ensure that they meet specifications. Although the Air Force is searching for vendors to produce obsolete parts to sustain the Minuteman III until 2030 as planned, Air Force officials have cautioned that they expect 40 percent to 50 percent of the requests will go unfilled.[129] And it is by no means a foregone conclusion that every willing and approved vendor will ultimately be up to the task. During the Propulsion Replacement Program, for instance, one of the subcontractors slated to produce solid fuel experienced serious quality control issues, including an explosion that destroyed one of its facilities. Even though the employees of the company had the right "recipe" for the material, they had not reacquired the "art" of manufacturing it—such as knowing to use mallets made of rubber rather than steel when working around vats filled with the ingredients for solid fuel.[130]

Given these conditions, Air Force officials maintain that continuing to extend the life of the Minuteman III would entail many of the same costs of designing, developing, and fielding a new ICBM—but with none of the advantages of incorporating 21st century technology. The Air Force's 2014 AoA, subsequently verified by an

[125] John A. Tirpak, "New GBSD Will Fly in 2023; No Margin Left for Minuteman," *Air Force Magazine*, June 14, 2021d.

[126] Tirpak, 2021d.

[127] U.S. Government Accountability Office, 2020, p. 43; Copp, 2021; "An Interview with Major General Michael J. Lutton, Commander, Twentieth Air Force, Air Force Global Strike Command," transcript of interview with Michaela Dodge, *Information Series: Conversations on National Security*, No. 487, April 27, 2021, pp. 3–4.

[128] U.S. Senate, Committee on Armed Services, Subcommittee on Strategic Forces, 2021e, p. 29.

[129] U.S. Senate, Committee on Armed Services, Subcommittee on Strategic Forces, "To Receive Testimony on the Department of Defense Budget Posture for Nuclear Forces in Review of the Defense Authorization Request for Fiscal Year 2022 and the Future Years Defense Program," Washington, D.C., May 12, 2021f, p. 29.

[130] Spires, 2012, p. 175.

Office of the Secretary of Defense Cost Assessment and Program Evaluation sufficiency review, concluded that the estimated cost for a baseline service life extension program would be $1.1 billion more than the 50-year life-cycle cost of an alternative modernized missile.[131] As General Hyten, then–STRATCOM commander, summarized in 2017: "You will have ended up replacing just about everything on the missile, which will cost you more [than GBSD]."[132] Noting that the estimated cost of extending the Minuteman III continues to climb, then–Commander of Air Force Global Strike Command Gen Timothy Ray stated as recently as May 2021 that refurbishment would cost $38 billion more than developing a new ICBM.[133]

Some observers have expressed concern about the Air Force's public description of its cost estimates, noting that acquisition and lifetime costs of major programs often exceed projections.[134] However, statements by the House Armed Services Committee Chairman, Rep. Adam Smith (D-Wash.), who previously expressed skepticism of the GBSD program, indicate that evidence presented in private consultations has convinced him that extension would be, in his words, "actually more expensive than building the GBSD."[135] Independent analysis by the Congressional Budget Office released in May 2021 did not report evidence of significant cost overruns, noting that increases in estimated costs from a previous assessment are "mostly the result of the current estimate starting and ending two years later than the period used for the 2019 estimate."[136] Nevertheless, more transparency regarding the potential risks and a detailed discussion of the Air Force's cost estimate methodology would help to promote greater confidence in its assessment.

New Capabilities Are Required to Respond to a Changing Strategic Environment

Even if it were technically feasible and cost-effective to further extend the life of the Minuteman III, senior defense officials question whether the existing system can meet the requirements for deterrence in the decades ahead. The Minuteman III was originally designed in the 1960s to conduct a specific operational

[131] Gen Robin Rand's response to member questions as quoted in U.S. House of Representatives, Committee on Armed Services, Subcommittee on Strategic Forces, 2017. According to General Hyten, the AoA "determined the entire Minuteman weapon system, to include the command and control infrastructure, requires modernization beginning in 2028 and concluded executing the GBSD program is more cost-effective than an additional Minuteman life extension" (see General Hyten's response to questions submitted by members after the 2017 hearing as quoted in U.S. House of Representatives, Committee on Armed Services, 2017). Chairman of the Joint Chiefs of Staff General Selva offered a similar summary of the report's findings at the same hearing, telling the House committee that the AoA determined that the costs of continued life extension of the Minuteman III were "equivalent if not prohibitive."

[132] Sydney J. Freedberg, Jr., "New ICBM Cheaper Than Upgraded Minuteman: Boeing on GBSD," *Breaking Defense*, August 2, 2017. Although he praised the "very innovative" efforts to reverse engineer components during a visit to Minot AFB, STRATCOM Commander ADM Richard shared a similar conclusion with reporters, cautioning that "another service life extension is "certainly past the point of being cost-effective and approaching the point where you can't do it at all" (Copp, 2021). This message is consistent with earlier warnings from then–Under Secretary of Defense for Acquisition and Sustainment Ellen M. Lord in 2019 Senate testimony (see U.S. Senate, Committee on Armed Services, Subcommittee on Strategic Forces, "Hearing to Receive Testimony on U.S. Nuclear Weapons Policy, Programs, and Strategy in Review of the Defense Authorization Request for Fiscal Year 2020 and the Future Years Defense Program," Washington, D.C., May 1, 2019a).

[133] U.S. Senate, Committee on Armed Services, Subcommittee on Strategic Forces, 2021b, pp. 28, 43–44. During House Subcommittee on Strategic Forces hearings, General Dawkins, U.S. Air Force Deputy Chief of Staff for Strategic Deterrence and Nuclear Integration, noted that the initial AoA (completed in 2014) had an estimated cost benefit of $5 billion. That amount has grown since then because the cost to extend the life of the Minuteman III has increased (see U.S. House, Committee on Armed Services, Subcommittee on Strategic Forces, 2021a).

[134] For example, the Air Force's F-35 Joint Strike Fighter program has exceeded its original budget estimate by 30 percent as of May 2020 (see Jeremiah Gertler, *F-35 Joint Strike Fighter (JSF) Program*, Washington, D.C.: Congressional Research Service, RL30563, updated May 27, 2020).

[135] Meredith Roaten, "JUST IN: HASC Chairman Says Congress Won't 'Kill' GBSD Program," *National Defense*, June 29, 2021.

[136] Congressional Budget Office, *Projected Costs of U.S. Nuclear Forces, 2021 to 2030*, Washington, D.C., May 2021.

The number and types of targets that U.S. nuclear forces might need to hold at risk to deter an adversary's use of nuclear weapons are changing—and can be expected to continue to change in complex and unpredictable ways.

mission in the event deterrence failed. It was to deliver up to three warheads of a given weight, from bases in the continental United States, in a straight-line ballistic trajectory, with sufficient range and accuracy to strike targets in the Soviet Union, while facing only modest anti-ballistic missile defenses. Given China's substantially smaller nuclear force, U.S. strategists considered it to be a lesser included case in calculating the requirements for the U.S. deterrence posture. As a result, the need to hold strategic targets in China at risk was not a driving factor in the design and development of the Minuteman series of ICBMs.

The United States confronts a very different strategic environment today. The global nuclear balance is shifting as both Russia and China continue to modernize, diversify, and expand their respective nuclear arsenals and other adversaries pursue nuclear-related activities.[137] As previously discussed, Russia has elevated the role of nuclear weapons in its defense strategy, and Pentagon reports suggest that China also might be doing so.[138] Despite international sanctions, North Korea continues to advance its nuclear and missile programs and could field delivery systems capable of conducting nuclear strikes against the U.S. homeland. Its emphasis on mobility and survivability (the latter illustrated by a robust underground facility program) introduces daunting targeting challenges.[139] Iran's long-term nuclear ambitions are uncertain, but recent enrichment activities indicate that it continues to surmount technological barriers to building a weapon.[140] In short, the number and types of targets that U.S. nuclear forces might need to hold at risk to deter an adversary's use of nuclear weapons in a crisis or conflict are changing—and can be expected to continue to change in complex and unpredictable ways over the next several decades.[141]

At the same time, senior U.S. military leaders stress the need to ensure that the ICBM force will continue to be effective in the face of emerging and future threats, including improved air and missile defenses and new cyber challenges.[142] Although U.S. defense officials emphasize that the Minuteman III is able to fulfill its mission, the system is anticipated to have "increasing difficulty penetrating future adversary defenses," according to the 2018 NPR.[143] Responding to a question on the possibility of extending the missiles' life again, Admiral Richard warned: "I need a weapon that can fly and make it to the target. Minuteman III is

[137] For an overview of changes in global nuclear warhead inventories since 1991, see Thomas G. Mahnken, Evan Braden Montgomery, and Jacob Cohn, "Assessing the Changing Nuclear Balance," *SAIS Review of International Affairs*, Vol. 39, No. 2, Summer–Fall 2019, pp. 29–34.

[138] Office of the Secretary of Defense, 2020, pp. 85–92.

[139] Mary Beth D. Nikitin, *North Korea's Nuclear Weapons and Missile Programs*, Washington, D.C.: Congressional Research Service, IF10472, updated April 14, 2021.

[140] Office of the Director of National Intelligence, 2021, p. 14.

[141] Rebecca Hersman, "Wormhole Escalation in the New Nuclear Age," *Texas National Security Review*, Vol. 3, No. 3, Summer 2020, pp. 99–109.

[142] U.S. Senate, Committee on Armed Services, Subcommittee on Strategic Forces, 2021b, pp. 12, 40–41; U.S. Senate, Committee on Armed Services, Subcommittee on Strategic Forces, 2021e, pp. 30–31.

[143] Office of the Secretary of Defense, 2018, p. 46.

increasingly challenged in its ability to do that." He highlighted the improvement in potential adversaries' cyber capabilities, stating "[t]here is almost no possibility of an upgrade on that relative to the threat."[144] Similarly, Deputy Assistant Secretary of Defense for Nuclear Matters Drew Walter has stated that "cybersecurity is a paramount priority and requirement" for the new ICBM.[145]

Accordingly, senior military officials have made clear that a comprehensive overhaul of the U.S. ICBM force is needed to increase targeting flexibility; to mitigate improvements in adversary missile defenses; and to strengthen defenses against cyberattacks that could undermine the system's responsiveness and degrade communication in a crisis.[146] Although the exact nature of the improvements has not been described publicly, the GBSD program includes new missile and guidance systems, launch facilities, command centers, and test and integration facilities, as well as modifications to ensure alignment with enterprisewide improvements of NC3 systems.[147] Moreover, the GBSD Mission Defense Team includes a dedicated cybersecurity component tasked with integrating cyber requirements throughout the system design—a stark contrast to the Minuteman III, which was first developed and fielded before the invention of the internet and which senior defense officials have cautioned can no longer be retrofitted to meet evolving cyber threats.[148]

To maintain its advantage in a changing nuclear landscape, the Air Force also requires a system that can be adapted quickly and relatively cheaply to meet new or unforeseen challenges. Predictions of the course of technological change often fall short, and it is difficult to anticipate the nature of the challenges the United States might confront over GBSD's reported 50-year life cycle.[149] Accordingly, GBSD will use a modular design and open system standard that lower the barriers to incorporating future technologies into the system.[150] To guide this effort, the Air Force has developed a "multi-decadal roadmap" to ensure that the new system is sufficiently flexible to support upgrading and replacing specific components without redesigning the entire weapon system.[151]

A New ICBM Will Reduce the Cost of Doing Business

One lesser understood advantage of deploying a new ICBM cited by the Air Force is that it offers the opportunity to obviate the labor-intensive and time-consuming maintenance procedures required to sustain the

[144] "Senate Armed Services Committee Holds Hearing on Fiscal 2022 Defense Authorization for US Strategic and Space Command," transcript, ProQuest, April 20, 2021.

[145] U.S. Senate, Committee on Armed Services, Subcommittee on Strategic Forces, 2021b, p. 41.

[146] U.S. Office of the Secretary of Defense, 2018, p. 46; "Senate Armed Services Committee Holds Hearing on Fiscal 2022 Defense Authorization for US Strategic and Space Command," 2021; Office of the Secretary of Defense, Nuclear and Missile Defense Policy, "The Importance of the Nuclear Triad," November 2020; U.S. Senate, Committee on Armed Services, Subcommittee on Strategic Forces, 2021e, pp. 30–31, 41.

[147] Don Snyder, Sherill Lingel, George Nacouzi, Brian Dolan, Jake McKeon, John Speed Meyers, Kurt Klein, and Thomas Hamilton, *Managing Nuclear Modernization Challenges for the U.S. Air Force: A Mission-Centric Approach*, Santa Monica, Calif.: RAND Corporation, RR-3178-AF, 2019.

[148] Office of the Secretary of Defense, Director, Operational Test and Evaluation, "FY20 Air Force Programs: Ground Based Strategic Deterrent (GBSD)," Washington, D.C., undated; "Senate Armed Services Committee Holds Hearing on Fiscal 2022 Defense Authorization for U.S. Strategic and Space Command," 2021.

[149] For a historical perspective on the difficulty of forecasting nuclear dynamics, see Francis J. Gavin, "Same as It Ever Was: Nuclear Alarmism, Proliferation, and the Cold War," *International Security*, Vol. 34, No. 3, 2009, pp. 7–37.

[150] U.S. Senate, Committee on Armed Services, Subcommittee on Strategic Forces, 2021e, pp. 31 and 70.

[151] Stew Magnuson, "Air Force on a Long Road to Replace Minuteman III," *National Defense Magazine*, July 23, 2017. As Lt Gen Richard Clark, former Deputy Chief of Staff, Strategic Deterrence and Nuclear Integration, explained at an event hosted by the Mitchell Institute for Aerospace Studies: "As we bring the system online, we will ensure that we have the ability to roll different technologies in" (Harper, 2020).

existing Minuteman III system. If an individual component fails on an aircraft, it is often possible for maintenance technicians to gain direct access to that component to either repair or replace it on site. But when a fault occurs in a major subsystem of the Minuteman III (e.g., the rocket motors or the missile guidance set), it often cannot be repaired in place. Instead, the entire subsystem must be removed from the missile silo, transported back to the main operating base, and then shipped to a depot for repair. To remove large subsystems from the missile silo, missile maintenance personnel must first push back the 110-ton launch closure door that covers the top of the silo and then hoist out of the silo as many of the subsystems stacked upon each other as necessary to reach the subsystem in need of repair.[152] These same steps must then be carried out in reverse order to install a replacement subsystem and return the missile to alert status. In addition to the associated labor costs, this cumbersome process requires additional security measures because the launcher closure door has been opened. Even in a best-case scenario where the aging handling equipment functions properly and the notoriously cold northern-tier winter weather does not delay missile maintenance activities, the entire process could take several days or even longer.[153]

Public reports of GBSD's modular design suggest that it would allow for routine maintenance to be performed without having to open the launcher closure door or to remove major segments of the missile from its silo. Instead, maintenance technicians would be able to gain direct access to many of the individual components within larger subsystems to repair or replace them within the silo.[154] According to Air Force leaders, this would result in more cost-effective and secure maintenance. As General Ray, a former commander of the Air Force Global Strike Command, testified in 2019: "The security requirements [with GBSD] will change dramatically: There will be fewer convoys on the roads, fewer open launcher configurations, fewer defenders needed to guard the site during maintenance."[155] He later told reporters that "the value proposition that I'm looking at is a two-thirds reduction in the number of times we have to go and open the site. There's a two-thirds reduction in the number of times we have to go and put convoys on the road."[156]

Moreover, Air Force leaders emphasize that the combination of a modular design and open system architecture will contribute additional cost savings over the GBSD's 50-year life cycle. The incorporation of enhanced diagnostics and predictive analysis systems will improve supply integration and reduce the time between failure and component replacement.[157] In contrast to many other programs, the Air Force will control the intellectual property of the system, including the underlying source code, allowing it to solicit bids from multiple competitors for future upgrades.[158] As General Ray testified, "the Air Force will save money on maintenance, operations, and in personnel. . . . GBSD [is] simpler and more affordable to sustain than any of its predecessors."[159]

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[152] U.S. Senate, Committee on Armed Services, Subcommittee on Strategic Forces, 2021e, pp. 29–30.

[153] U.S. Senate, Committee on Armed Services, Subcommittee on Strategic Forces, 2021e, p. 29; "An Interview with Major General Michael J. Lutton . . . ," 2021, pp. 3–4.

[154] Benji Johnson, *Defense Primer: Ground Based Strategic Deterrent (GBSD) Capabilities*, Washington, D.C.: Congressional Research Service, IF11681, updated November 10, 2020, p. 3.

[155] U.S. Senate, Committee on Armed Services, Subcommittee on Strategic Forces, "FY20 Posture for Department of Defense Nuclear Forces," Washington, D.C., May 1, 2019b.

[156] As quoted in Valerie Insinna, "The Cost of a New ICBM Is Going Up. Here's Why the US Air Force Isn't Concerned," *Defense News*, April 17, 2019a.

[157] "An Interview with Major General Michael J. Lutton . . . ," 2021, p. 4.

[158] Johnson, 2020, p. 2. For an additional discussion of the open systems architecture, see Wilson Brissett, "Replacing Minuteman," *Air Force Magazine*, December 21, 2017.

[159] U.S. Senate, Committee on Armed Services, Subcommittee on Strategic Forces, 2019b.

U.S. military leadership has stated that recapitalization of the ICBM force can no longer be deferred without sacrificing performance and incurring additional costs.

Objections to the GBSD Program

Although the current nuclear modernization programs continue to enjoy bipartisan support, some members of Congress and NGOs have expressed misgivings about continued funding for the GBSD program. A challenging fiscal environment, competing policy priorities, and an uncertain arms control climate have led to disagreements about the size and composition of the national defense budget and have renewed long-standing calls by some observers to review the role of ICBMs in the U.S. nuclear arsenal.[160] Common objections to the GBSD program can be grouped into four categories: (1) the potential cost savings associated with suspending the GBSD program in favor of further extending the life of the Minuteman III; (2) the continued relevance of ICBMs in the current security environment; (3) the relative efficacy of transitioning from a nuclear triad to a dyad; and (4) the risk of miscalculation or accidental launch associated with the ICBM. Notably, the last three concerns are rooted in general opposition to maintaining an ICBM force, although advocates differ on whether the United States should reduce or eliminate its land-based missile arsenal altogether. Only the first argument pertains specifically to the GBSD program.

Is Extending the Life of Minuteman III a More Cost-Effective Option?

Operating, maintaining, and modernizing ICBM forces is projected to cost $82 billion between 2021 and 2030, according to the Congressional Budget Office.[161] Even before the COVID-19 response caused a sharp uptick in federal spending, some congressional members had expressed concerns over the cost of replacing Minuteman III, arguing that the money would be better spent on other DoD modernization priorities or non-defense programs.[162] Although the Biden administration has indicated that it supports continued funding of the current programs to modernize the U.S. nuclear enterprise, opponents have called for a suspension

[160] Bryan Bender, "Air Force Prepares for Budget Battle over Nuclear Weapons," *Politico*, February 11, 2021. These budgetary concerns predated the COVID-19 emergency; in 2017, the Congressional Budget Office cautioned that funding nuclear modernization would be "challenging" because of caps established in the Budget Control Act of 2011, rising entitlement costs, and growing interest on the national debt, among other pressures (Congressional Budget Office, *Approaches for Managing the Costs of U.S. Nuclear Forces, 2017 to 2046*, Washington, D.C., October 2017, pp. 9–10). For a discussion of modernization resources and the Biden administration's discretionary funding request for FY 2022, see Stacie Pettyjohn and Becca Wasser, *Making Sense of Cents: Parsing the U.S. Department of Defense's FY 2022 Budget Request*, Washington, D.C.: Center for New American Security, May 6, 2021.

[161] Press reports have emphasized that this total is approximately $21 billion more than the Congressional Budget Office's 2019 estimate. However, the Congressional Budget Office notes that the "increases in estimated costs are mostly the result of the current estimate starting and ending two years later than the period used for the 2019 estimate," rather than a substantial and unanticipated increase in development costs. As long anticipated, this latter period encompasses the most-expensive phase of developing, producing, and fielding a new ICBM (Congressional Budget Office, 2021, p. 10). For the earlier projection, see Congressional Budget Office, *Projected Costs of U.S. Nuclear Forces, 2019 to 2028*, Washington, D.C., January 2019, p. 3.

[162] Rebecca Kheel, "Lawmakers Gird for Spending Battle over Nuclear Weapons," *The Hill*, March 7, 2021. Several NGOs have rallied behind the call to freeze or redirect funds allocated for the GBSD program. See, for example, William D. Hartung, "The New ICBM Is a Legacy System, and Should Be Cancelled," *Defense News*, March 12, 2021.

of further development of the new ICBM in favor of continued efforts to extend the service life of the existing Minuteman III system.[163]

The arguments proffered by critics of the GBSD program provide no specific evidence to support the contention that another life extension would be a more cost-effective option for meeting current or anticipated operational requirements. Proponents for delaying modernization often point to 2019 testimony by General Clark that appears at first glance to suggest that the Air Force had determined further refurbishment was technically possible. A closer examination of the context of his remarks, however, reveals that General Clark made only passing reference to the viability of another life extension and deferred technical questions to an accompanying officer, Gen Arnold W. Bunch, Jr., who stated clearly that military leadership "do not believe we would be able to meet" current warfighter requirements without modernization.[164] This assessment is consistent with repeated statements by U.S. military leaders that recapitalization can no longer be deferred without sacrificing performance and incurring additional costs.[165] "That thing is so old that in some cases the drawings don't exist anymore," Admiral Richard told a January 2021 virtual conference audience, stating unequivocally: "You cannot life extend the Minuteman [III]."[166]

Moreover, senior defense officials insist that a life extension program would not provide the substantial cost savings required to justify the risk of technical failure or the inability to meet military requirements. Advocates for extending the life of the current missile system often cite the previously mentioned RAND study team's finding that "incremental modernization and sustainment of the current Minuteman III force is a cost-effective alternative that should be considered" within the Air Force's AoA.[167] Using data collected in 2011, the study was intended as a preliminary assessment and did not examine the cost of nonmissile components or account for sensitive survivability and cybersecurity considerations—factors that inform the final cost of both sustaining the current system and developing a replacement. Similarly, the authors also cautioned that their assessment did not account for the "costs and risks involved in pursuing incremental

[163] Edward Markey and Ro Khanna, letter to President Joseph R. Biden, March 3, 2021. For a related argument to pause the GBSD program, see James M. Acton, "Future Defense Spending: Nuclear Modernization: Testimony Before the House of Representatives, Appropriations Committee, Subcommittee on Defense," Washington, D.C., March 23, 2021, pp. 6–7.

[164] Testimony of General Bunch, Military Deputy, Office of the Assistant Secretary of the Air Force for Acquisition as quoted in U.S. House of Representatives, Committee on Armed Services, Subcommittee on Strategic Forces, "Hearing on Fiscal Year 2020 Priorities for Department of Defense Nuclear Activities," Washington, D.C., March 28, 2019. This confirms earlier testimony by General Hyten, who was the then–STRATCOM commander, that "any further delays and/or cancellations will result in the loss of deterrent capabilities and failure to meet our strategic objectives and extended deterrent commitments causing adversaries, allies and partners to doubt the credibility of the U.S. deterrent" (as quoted in U.S. House of Representatives, Committee on Armed Services, 2017, p. 96).

[165] See, for example, the joint statement of Ellen Lord and Admiral Richard as quoted in U.S. Senate, Committee on Armed Services, "Joint Statement of the Honorable Ellen M. Lord, Under Secretary of Defense for Acquisition and Sustainment and Admiral Charles A. Richard, Commander, U.S. Strategic Command: Hearing to Receive Testimony on Matters Relating to the Budget of the National Nuclear Security Administration," Washington, D.C., September 17, 2020b; testimony of Lord as quoted in U.S. Senate, Committee on Armed Services, Subcommittee on Strategic Forces, 2019; testimony of General Hyten and David J. Trachtenberg (Deputy Under Secretary of Defense for Policy) as quoted in U.S. House of Representatives, Committee on Armed Services, Subcommittee on Strategic Forces, 2019; Sandra Erwin, "Head of U.S. Strategic Command Blasts GBSD Critics: 'Minuteman III Cannot Be Life-Extended,'" *SpaceNews*, January 5, 2021a; U.S. Senate, Committee on Armed Services, Subcommittee on Strategic Forces, 2021e, pp. 26–28, 43.

[166] Erwin, 2021a. Admiral Richard repeated the warning in more recent testimony before the Senate Committee on Armed Services (see "Senate Armed Services Committee Holds Hearing on Fiscal 2022 Defense Authorization for US Strategic and Space Command," 2021).

[167] Caston et al., 2014, p. 115.

modernization beyond 2030."[168] The RAND study, therefore, was not intended to forecast the relative cost of replacement versus life-sustainment over the full life of GBSD.[169]

Although an independent evaluation of the cost projections is outside the scope of this work, evidence made publicly available to date suggests that multiple analyses conducted by different stakeholders since 2014 have reached the same conclusion: that developing and deploying a new ICBM will cost substantially less than extending the service life of the Minuteman III. Moreover, GBSD's modular design will decrease the cost of day-to-day maintenance by minimizing labor and security requirements while enabling incremental modernization. "Our estimates are in the billions of savings over the lifespan of the weapon," General Ray told reporters in 2019.[170] In contrast, even delaying GBSD for several years would force the Air Force to expend an additional $6 billion to $8 billion to develop, manufacture, test, and certify replacement components for the Minuteman III during this period.[171]

In short, both replacing and extending the Minuteman III will require the Air Force to incur substantial costs. Delays or complications, either in the GBSD program or in related programs like the W87-1 program, could also narrow the cost difference between the two options. However, using the currently available evidence, the prospect of extending the life of Minuteman III instead of investing in a modern replacement appears analogous to the predicament many car owners face in deciding whether to keep their older vehicle or trade it in for a newer model. At some point, the cost of parts and labor to keep the old car running while forgoing the safety features, fuel economy, and improved maintainability of a newer model become greater than the cost of buying a new car.

Even if continued refurbishment were possible, Air Force officials maintain that the window of opportunity to implement this option has already closed. As General Ray testified to the Senate Subcommittee on Strategic Forces, any program to refurbish existing missiles' propulsion systems, rocket engines, guidance sets, and boosters could take several years to design, test, develop, and implement. Presuming engineers could have found a feasible solution that met all current and anticipated requirements, the Air Force would have needed to initiate the program in 2015 or 2016 to ensure continued functionality beyond the 2030 retirement schedule. As a result, "you actually are out of time," General Ray explained. "You will buy a gap, a significant gap, in ICBM capability if you were to go backwards now."[172]

As with any major modernization program, supporting GBSD will require DoD to accept trade-offs in readiness, force structure, and other acquisition priorities.[173] Nonetheless, U.S. military leadership maintains that the ICBM replacement program is an affordable and necessary expense that will provide cost savings over the life of the program. Continued delays cannot be undertaken without incurring the risk that Minuteman III might become unsustainable before a replacement program can be completed. Lt Gen Thomas A. Bussiere, deputy commander of STRATCOM, summarized the problem bluntly during a February 2021

[168] Caston et al., 2014, p. 115.

[169] Freedberg, 2017; Todd Harrison, *Options for the Ground-Based Leg of the Nuclear Triad*, Washington, D.C.: Center for Strategic and International Studies, September 2017, pp. 11–13.

[170] Insinna, 2019a.

[171] Dave Deptula, "Five Persistent Misconceptions About Modernizing the U.S. ICBM Force," *Forbes*, December 22, 2020.

[172] U.S. Senate, Committee on Armed Services, Subcommittee on Strategic Forces, 2021e, p. 27. For a similar argument, see the response from General Dawkins as quoted in U.S. House, Committee on Armed Services, Subcommittee on Strategic Forces, 2021.

[173] Theresa Hitchens, "2021: Air Force's Nuke Mod Efforts Service's Biggest Challenge," *Breaking Defense*, December 28, 2020; and Steven Pifer, "How COVID-19 Might Affect US Nuclear Weapons and Planning," *Order from Chaos*, Brookings Institution blog, May 18, 2020.

address to the Air Force Association's virtual Aerospace Warfare Symposium: "It's really a choice of replacing [ICBMs] or losing them."[174]

Are ICBMs Still Relevant in the 21st Century?

A related camp of GBSD opponents have called for the United States to rethink the value of maintaining a large number of nuclear-capable delivery systems deployed in fixed silos. As noted earlier, ICBMs were initially developed to deter a massive Soviet surprise attack intended to disarm the United States and raise the prospect of its destruction or capitulation.[175] Mitigating this risk required a survivable force that could hold numerous and varied Soviet targets at risk and be launched within minutes of warning. Such a force would confront the Soviets or any other adversary contemplating a first strike on the United States or its allies with an unattractive choice: either expend hundreds of its missiles to destroy hundreds of U.S. ICBMs in widely dispersed, hardened silos or face the prospect of an unpalatably costly counterattack on its homeland.

Fears of such a bolt-from-the-blue attack have diminished since the end of the Cold War, however.[176] As a result, some analysts question the continued utility of maintaining a land-based system that they view as ill-suited for use in regional conflicts and whose role in responding to new forms of cyber, information, and irregular operations is unclear at best. Adherents of this school of thought acknowledge that a future conflict in Europe or Asia could lead an enemy to detonate low-yield tactical nuclear weapons in an effort to stave off battlefield defeat, but they dispute the notion that any rational leader would contemplate a counterforce strike on the U.S. homeland and maintain that limited use of nuclear weapons would not necessarily escalate to the large-scale nuclear exchanges that the ICBM force, armed with high-yield warheads, was designed to address.[177] These critics disagree over whether the United States should sustain a limited number of Minuteman IIIs or eliminate its ICBM force altogether, but they do agree that money would be better spent on either ensuring sufficient conventional forces to deter or prevail in a limited conflict, or bolstering nondefense programs.

That the strategic environment has changed since the United States fielded its first ICBMs in the late-1950s and early 1960s is indisputable. Strategists today confront a more complex international landscape in which power is defused, the number of nuclear states has grown, and new technologies and tactics challenge traditional theories of deterrence and crisis escalation.[178] Nonetheless, the fundamental purpose for which ground-based nuclear delivery systems were designed—to deter an attack on the United States or its allies by decreasing an adversary's confidence in its capacity to successfully carry out a disarming first strike—remains urgent so long as other states maintain the ability to execute nuclear attacks on the U.S. homeland. The diminished risk of a bolt-from-the-blue attack, in part, serves as suggestive evidence of the credibility of U.S. nuclear forces to date. Continued erosion of U.S. capabilities could undermine deterrence stability by

[174] John A. Tirpak, "New Threats Demand Nuclear Modernization," *Air Force Magazine*, March 2, 2021c. For more information, see the testimony of General Clark as quoted in U.S. House of Representatives, Committee on Armed Services, Subcommittee on Strategic Forces, 2019.

[175] For an articulation of this fear, see Wohlstetter, 1958.

[176] For a brief discussion of the shift in emphasis, see Timothy P. McDonnell, "Bolts from the Blue, Monsters Under the Bed, and the Pursuit of Absolute Security," *War on the Rocks*, October 17, 2017.

[177] Garrett Hinck and Pranay Vaddi, "Setting a Course Away from the Intercontinental Ballistic Missile," *War on the Rocks*, February 16, 2021.

[178] For a discussion of emerging shifts in the strategic environment and their consequences for nuclear dynamics, see Hersman, 2020, pp. 99–109.

creating a perception of U.S. vulnerability that could embolden adversaries and increase the difficult challenge of preventing the onset of crises and managing the risk of escalation.[179]

This prospect is additionally concerning because Russia is no longer the only country capable of holding U.S.-based targets at risk. As noted earlier, the United States now faces two strategic competitors that have modernized their nuclear arsenals in what STRATCOM has described as an attempt to outpace U.S. forces and mitigate U.S. defenses.[180] Russia, in particular, has demonstrated a willingness to take greater risks in challenging U.S. interests in recent years and is expected to soon field new nuclear capabilities that would "enable strikes from virtually any vector due to its extreme range and endurance," according to recent U.S. Northern Command statements.[181] In a demonstration of increased confidence, Russian military activity near Alaska reached its highest level since the end of the Cold War in 2020.[182]

Are Bombers and Submarines Sufficient for Deterrence?

Impressed by continuing technological improvements in the sea-based leg of the Triad, a small group of academics and NGOs have proposed that the United States reduce or eliminate its ground-based delivery systems as part of an eventual transition to a dyad consisting of bombers and SSBNs armed with SLBMs.[183] Advocates of this approach maintain that sea-launched weapons provide similar or superior capabilities at a lower cost than ground-based systems, while avoiding the use-it-or-lose-it constraint that they claim characterizes the more-vulnerable, silo-based missiles.[184] Like ICBMs, SLBMs possess the intercontinental range, readiness levels, accuracy, and speed required to hold targets across Eurasia at risk and, depending on location at the time of launch, can reach targets in approximately the same time as land-based systems. Enhancements developed over recent decades have improved the SLBM force's capacity to destroy hard targets and, according to proponents for deprioritizing the ICBM force, decreased the need for land-based missiles as effective counterforce weapons.[185] Unlike silo-based ICBMs, however, submarines' mobility allows SLBMs to

[179] On the role of effective counterforce in mitigating nuclear arsenal vulnerability, see Keir A. Lieber and Daryl G. Press, "The New Era of Counterforce: Technological Change and the Future of Nuclear Deterrence," *International Security*, Vol. 41, No. 4, Spring 2017.

[180] David Vergun, "Stratcom Commander: DOD on Track to Face 2 Peer Nuclear-Capable Competitors," *DOD News*, September 14, 2020. For similar discussions of the challenges associated with Russian and Chinese improvements, see U.S. Senate, Committee on Armed Services, Subcommittee on Strategic Forces, 2021e, pp. 16–17, 46.

[181] Gen Glen VanHerck, "NORAD-USNORTHCOM Commander's House Armed Services Committee Statement," transcript, Washington, D.C., April 14, 2021.

[182] In written testimony submitted to the U.S. Senate Committee on Armed Services, Gen Glen VanHerck, Commander of U.S. Northern Command and the North American Aerospace Defense Command, stated that "NORAD responded to more Russian military flights off the coast of Alaska than we've seen in any year since the end of the Cold War." Recent Russian military exercises have included "rehears[ing] potential strikes" on the U.S. homeland with "multiple flights of heavy bombers, anti-submarine aircraft, and intelligence collection platforms near Alaska" (see Mallory Shelbourne, "NORAD: Russians Stay in Airspace 'for Hours' During Flight Operations Near Alaska," *USNI News*, March 31, 2021).

[183] For variations of this argument, see Matt Korda, *Siloed Thinking: A Closer Look at the Ground-Based Deterrent*, Washington, D.C.: Federation of American Scientists, 2021; Kingston Reif, "Why the New ICBM Contract Is a Bad Deal," *Defense News*, September 21, 2020; Benjamin H. Friedman, Christopher A. Preble, and Matt Fay, *The End of Overkill? Reassessing U.S. Nuclear Weapons Policy*, Washington, D.C.: CATO Institute, September 24, 2013; Wright, Hartung, and Gronlund, 2020, pp. 1, 5; Steven Fetter and Kingston Reif, "A Cheaper Nuclear Sponge," *War on the Rocks*, October 18, 2019.

[184] Because SSBNs are "virtually undetectable" when on patrol, successive NPRs have asserted that the sea-based deterrent force is the "most survivable leg of the triad" (Office of the Secretary of Defense, 2018, pp. 44–45; Office of the Secretary of Defense, 2010, p. 22).

[185] For a general discussion of improvements in SLBM targeting, see Lieber and Press, 2017, pp. 20–21, 25–27. For the argument that SLBMs' increased counterforce capability could enable replacement of ICBMs, see Friedman, Preble, and Fay, 2013,

Continued delays cannot be undertaken without incurring the risk that Minuteman III might become unsustainable before a replacement program can be completed.

launch from numerous and unseen locations, opening new flight trajectories and circumventing the targeting challenges arising from the current ICBM posture. Considering these attributes, some analysts contend that ICBMs provide insufficient contributions to deterrence to justify modernization or even retention.

Yet advocates for an alternative dyadic posture downplay the importance of redundancy in preserving strategic stability. The elimination of ICBMs would simplify an adversary's targeting calculus and introduce the possibility of a smaller—but still devastating—counterforce attack. As noted earlier, the need to destroy a large and distributed network of ground-based missiles would force an attacker to expend either an infeasible or undesirable percentage of its arsenal. If the U.S. ICBM force were eliminated, however, an adversary would need to attack fewer targets to significantly diminish the U.S. ability to retaliate, particularly if carried out before the United States had had an opportunity to increase the overall readiness of its nuclear forces.[186] As General Hyten has noted, the remaining targets would be vulnerable to both nuclear and conventional attacks—the latter of which could be more difficult to attribute and, in turn, more attractive to an adversary willing to test the escalation threshold.[187] This scenario could appear to make a disarming first-strike more plausible while allowing an adversary to retain a greater number of warheads to "destroy additional US cities or hold back for a threatened 'third strike' in an attempt to deter U.S. retaliation."[188]

Maintaining a varied nuclear force is also necessary to prepare for the event of unanticipated failures or technological breakthroughs that could impede the capacity to respond to a threat quickly, weaken current U.S. capabilities, or change the nature of the threat.[189] Because U.S. heavy bombers are no longer on alert, the United States leans most heavily on the sea- and land-based legs of the Triad on a day-to-day basis. If ICBMs were eliminated, it would be forced to rely on SSBNs alone—at the risk that a technical malfunction, cyberattack, or other failure could leave the United States vulnerable for several days, if not longer, while it scrambled to restore its bombers to alert status.[190] Proponents of a submarine-based force discount this possibility, asserting that because no adversary to date has developed the technology or tactics required to track and threaten SSBNs on patrol "the survivability of the [sea-based leg] is unlikely to change, even decades into

particularly pp. 11, 13, 16–17.

[186] Patrick Tucker, "Hyten: US Must Broaden Its Strategic Deterrence Concept—and Keep Its ICBMs," *Defense One*, February 26, 2021b.

[187] Statement by General Hyten as cited in Tucker, 2021b. See also David J. Trachtenberg, Michaela Dodge, and Amy Joseph, eds., transcript of interview with U.S. Air Force (Ret.) Gen. Larry D. Welch, *Information Series: Conversations on National Security*, No. 496, July 14, 2021, p. 4.

[188] Matthew Kroenig, Mark J. Massa, and Christian Trotti, *The Downsides of Downsizing: Why the United States Needs Four Hundred ICBMs*, Washington, D.C.: Atlantic Council, March 29, 2021, p. 3.

[189] For a discussion of the Triad's role in hedging against unforeseen events, see Richard, 2020a; U.S. Office of the Secretary of Defense, 2018, pp. 14, 38–40.

[190] Eric S. Edelman and Franklin C. Miller, "America's Nuclear Missiles Need Major Modernization," *The Bulwark*, April 9, 2021.

the future."[191] But past failure is not a guarantee of future inability, and the United States could be surprised, as it has been before, by a game-changing innovation, particularly one that emerges in the private sector.[192]

U.S. competitors continue to invest in anti-submarines capabilities, perhaps buoyed by signs that advances in sensing, computing, acoustics, and electronic communications have lowered traditional technical barriers.[193] Dramatic advances in computer processing capacity and miniaturization, for instance, have already surmounted one barrier to real-time oceanographic modeling, introducing the possibility that the improvement in detection techniques may outpace parallel improvements in quieting.[194] Even if the ability to track and threaten SSBNs remains out of reach, enhanced anti-submarine technologies and undersea platforms could still contest nuclear submarines' access and introduce new targeting challenges. Although the exact consequences for submarine warfare are unknowable, the potential implications for strategic stability suggest the United States should maintain a robust hedge against a sudden breakthrough, a point that the Obama administration's NPR emphasized.[195]

Whether the strategic bomber force alone could provide sufficient insurance against unanticipated challenges to the submarine force is a matter of debate.[196] Recent improvements in Russian and Chinese anti-access and air-denial capabilities may impede their ability to reach adversary targets.[197] Likewise, advances in adversary cruise and ballistic missiles could endanger the survivability of aircraft on the ground.[198] That a dyadic posture would allow adversaries to concentrate efforts on devising ways to threaten U.S. aircraft and SSBNs compounds the challenge.[199] The problem is not only whether U.S. forces could destroy adversary targets in the event of a conflict but also whether the decreased credibility of U.S. capabilities might undermine deterrence, diminish allies' confidence, encourage malign activities, and increase the prospect of escalation.

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[191] Korda, 2021, p. 9.

[192] On the difficulty of predicting the development or effects of high-impact technologies, see Ron Lehman, "'Sputnik-Like' Events: Responding to Technological Surprise," in Zachary S. Davis and Michael Nacht, eds., *Strategic Latency: Red, White, and Blue Managing the National and International Security Consequences of Disruptive Technologies*, Livermore, Calif.: Lawrence Livermore National Laboratory, Center for Global Security Research, February 2018, pp. 33–51; and C. Wes Spain, "Curious Incidents: Dogs That Haven't Barked," in Zachary S. Davis and Michael Nacht, eds., *Strategic Latency: Red, White, and Blue Managing the National and International Security Consequences of Disruptive Technologies*, Livermore, Calif.: Lawrence Livermore National Laboratory, Center for Global Security Research, February 2018, pp. 52–70.

[193] Ari Kattan, "Emerging Submarine Detection Technologies and Implications for Strategic Stability," in Sarah Minot Asrar, ed., *On the Horizon: A Collection of Papers from the Next Generation*, Washington, D.C.: Center for Strategic and International Studies, 2019, pp. 62–71; John R. Harvey, "Modernizing the U.S. Nuclear Arsenal—The Road to 2030 and Beyond," in Brad Roberts, ed., *Fit for Purpose? The U.S. Strategic Posture in 2030 and Beyond*, Livermore, Calif.: Lawrence Livermore National Laboratory, Center for Global Security Research, October 2020, p. 23; Lieber and Press, 2017, pp. 36–37.

[194] Bryan Clark, *The Emerging Era in Undersea Warfare*, Washington, D.C.: Center for Strategic and Budgetary Assessments, 2015, p. 10.

[195] Office of the Secretary of Defense, 2010, p. 23.

[196] For more information on the argument for a bomber-based "nuclear reserve hedge force," see Bruce G. Blair, Jessica Sleight, and Emma Claire Foley, *The End of Nuclear Warfighting: Moving to a Deterrence-Only Posture*, Washington D.C.: Princeton University Program on Science and Global Security and Global Zero, September 2018, pp. 24 and 107.

[197] For a discussion of improvements in adversary air defenses, see chapters three and five in Terrence Kelly, David C. Gompert, and Duncan Long, *Smarter Power, Stronger Partners,* Volume I*: Exploiting U.S. Advantages to Prevent Aggression*, Santa Monica, Calif.: RAND Corporation, RR-1359-A, 2016.

[198] For a discussion of cruise missile threats to U.S. air bases, see Alan J. Vick, Sean M. Zeigler, Julia Brackup, and John Speed Meyers, *Air Base Defense: Rethinking Army and Air Force Roles and Functions*, Santa Monica, Calif.: RAND Corporation, RR-4368-AF, 2020.

[199] According to U.S. defense officials, eliminating a nuclear leg "would greatly ease adversary attack planning and allow an adversary to concentrate resources and attention on defeating the remaining two legs" (Office of the Secretary of Defense, 2018, p. x).

Do ICBMs Create a Unique Risk of Accidental Launch?

A final common objection to the GBSD program concerns whether maintaining a large number of ICBMs increases the risk of an accidental nuclear exchange. In recent years, several NGOs and prominent retired defense officials, including former Secretary of Defense William Perry and former Vice Chairman of the Joint Chiefs of Staff Gen James Cartwright, have argued for the total elimination of the ICBM force on the grounds that the vulnerability of land-based missiles creates intense pressure on decisionmakers to act on incomplete or possibly inaccurate information. Confronted with evidence of an impending strike, critics assert, the President would have mere minutes to decipher ambiguous and potentially erroneous indicators of an impending attack and decide whether to launch the missiles or risk their destruction.[200] The United States' reliance on ground- and space-based missile warning and communication systems that might be vulnerable to cyberattack or kinetic attack compounds the risk, in these officials' view, of a technical malfunction or human error that could either cause decisionmakers to blunder into a conflict or even, in a worst-case scenario, trigger an accidental launch.[201]

Critics of the ICBM force argue that the risk of an inadvertent or accidental escalation is magnified by the fact that the missiles are kept in a heightened state of readiness that they describe as a hair-trigger alert. Pointing to historical examples of false warnings of incoming attacks, adherents of this school of thought maintain that the responsiveness of ICBMs, combined with the fact that missiles cannot be recalled after launch, introduces an intolerable risk that the United States could—either because of flawed information or as a result of a technical failure in automated systems—initiate an unnecessary but catastrophic attack before the mistake is identified. Only by taking silo-based missile forces off high alert and, ultimately, dismantling the arsenal, they argue, can the United States reduce the risk to an acceptable level.[202]

These arguments conflate the distinction between an unauthorized launch and one based on false warning while overstating the likelihood of both scenarios.[203] Multiple independent reviews have confirmed that the procedures required to initiate nuclear use are extensive and reinforced by an abundance of safeguards. The 2009 Congressional Commission on the Strategic Posture of the United States, co-chaired by former Secretary of Defense Perry, concluded that the hair-trigger metaphor "is simply an erroneous characterization" of the U.S. alert posture, which is "highly stable" and "subject to multiple layers of control, ensuring clear civilian and indeed Presidential decision-making."[204] Since the 1970s, technical developments and refinements to NC3 processes and procedures have added safeguards to existing architecture, including human and technological

[200] For illustrative representations of this argument, see William J. Perry and James E. Cartwright, "Spending Less on Nuclear Weapons Could Actually Make Us Safer," *Washington Post*, November 16, 2017; Blair, Sleight and Foley, 2018, pp. 32–33; William J. Perry and Tom Z. Collina, *The Button: The New Nuclear Arms Race and Presidential Power from Truman to Trump*, Dallas, Tex.: BenBella Books, 2020a, p. 49; William J. Perry and Tom Z. Collina, "Who Can We Trust with the Nuclear Button? No One," *New York Times*, June 22, 2020b; Daryl G. Kimball, "Enough Already: No New ICBMs," *Arms Control Today*, March 2021; Wright, Hartung, and Gronlund, 2020, pp. 8–10, 12–13.

[201] Perkovich and Vaddi, 2021, pp. 64–65; Wright, Hartung, and Gronlund, 2020, p. 5; Perry and Collina, 2020a.

[202] Union of Concerned Scientists, "What Is Hair-Trigger Alert?" October 3, 2014; Blair, Sleight, and Foley, 2018; Wright, Hartung, and Gronlund, 2020, pp. 9–10; Akshai Vikram, *The New Nuclear Arms Race: The Outlook for Avoiding Catastrophe*, San Fransisco, Calif.: Ploughshares Fund, August 2020, pp. 14–15.

[203] The authors borrow this distinction from Trachtenberg, 2021, p. 5.

[204] William J. Perry, James R. Schlesinger, Harry Cartland, John Foster, John Glenn, Morton Halperin, Lee Hamilton, Fred Ikle, Keith Payne, Bruce Tarter, Ellen Williams, and James Woolsey, *America's Strategic Posture: The Final Report of the Congressional Commission on the Strategic Posture of the United States*, Washington, D.C.: United States Institute of Peace Press, 2009, p. 69.

redundancies designed to improve the accuracy and speed of detection systems, avoid over-reliance on a single misleading indicator, and adapt to evolving threats.[205]

Similarly, senior defense officials have disputed the notion that the United States would automatically launch on warning to avoid losing its silo-based missiles.[206] The ICBM's responsiveness ensures that adversaries recognize the United States' ability to respond quickly to an act of aggression, but the diversity, flexibility, and survivability of U.S. conventional and nuclear forces are designed to ensure that "we can always wait," as one former STRATCOM commander has put it.[207] "'Use them or lose them' as a reason to launch on warning is a myth," retired Air Force Chief of Staff Gen Larry Welch recently explained in an interview, "Launch on warning is an operational capability, not a plan. The operational plan is to launch whenever the President makes the decision. Giving the President the widest range of options is the most effective approach to reduce the existential threat for the United States and allies."[208]

In addition to improved reliability, enhancements in indications and warning have in effect expanded the decisionmaking window by allowing for earlier detection of concerning behaviors that could contribute to a nuclear crisis. This in turn provides additional time to collect information, develop a variety of options, and attempt to de-escalate or intervene before the nuclear threshold is crossed. As Gen Kevin Chilton, former STRATCOM commander, has written: "People who described our ICBMs as being on 'hair-trigger' alert either do not know what they are talking about or are intentionally attempting to frighten the uninformed into calling for the de-alerting of the ICBM leg."[209]

Moreover, leaders in the Air Force and STRATCOM have publicly stated that replacing the aging Minuteman III system will contribute additional safeguards that decrease the likelihood of a miscalculation arising from computer failure or misidentification of an incoming object. Although modernization is not a panacea for all cyber threats, the GBSD program reportedly includes improvements in NC3 systems designed to strengthen cyber resiliency, which STRATCOM leaders have identified as a principal NC3 challenge. The results will harden the nuclear infrastructure against malicious attacks that could contribute (purposefully or inadvertently) to false warning indicators. "We will replace what is basically a 60-year-old circuit switch system with a modern cyber-defendable up-to-current-standards command and control system," Admiral Richard told reporters in January 2021, adding: "Just to pace the cyber threat alone, GBSD is a necessary step

[205] Adam Lowther, William Murphy, and Gerald Goodfellow, "Intercontinental Ballistic Missiles Still Matter," *Real Clear Defense*, July 4, 2020. For an overview of U.S. nuclear weapons employment policy and command, control, and communications systems, see Office of the Deputy Assistant Secretary of Defense for Nuclear Matters, 2020, pp. 16–26.

[206] See, for example, the response from Robert Scher, Assistant Secretary of Defense for Strategy, Plans, and Capabilities, in U.S. House of Representatives, Committee on Armed Services, Subcommittee on Strategic Forces, "President Obama's Nuclear Deterrent Modernization Plans and Budgets: The Military Requirements," Washington, D.C., July 14, 2016; the response from General Hyten as quoted in U.S. House of Representatives, Committee on Armed Services, 2017, pp. 96–97; the response from Gen Robert Kehler, former Commander, U.S. Strategic Command, as quoted in U.S. Senate, Committee on Armed Services, Subcommittee on Strategic Forces, "United States Nuclear Deterrence Policy and Strategy," Washington, D.C., April 28, 2021a, pp. 56–57; and the response from General Dawkins as quoted in in U.S. House, Committee on Armed Services, Subcommittee on Strategic Forces, 2021.

[207] Statement of ADM Richard W. Mies, former Commander, U.S. Strategic Command, in U.S. Senate, Committee on Armed Services, "Department of Defense Authorization for Appropriations for Fiscal Year 2002," Senate Hearing 107-355, Part 7, Strategic, Washington, D.C.: U.S. Government Printing Office, April 25, June 26, July 11, and July 25, 2001.

[208] Trachtenberg, 2021, p. 5.

[209] Kevin P. Chilton, "Defending the Record on U.S. Nuclear Deterrence," *Strategic Studies Quarterly*, Vol. 12, No. 1, Spring 2018, p. 15.

forward."[210] Absent such modernization, the continued degradation of aging infrastructure could increase the risk of technical failures or create opportunities for malicious actors to exploit.

Implications for the Air Force

Current political realities suggest that the GBSD program likely will continue to be funded at levels needed to deliver the first new missile before the end of the decade, as envisioned in the approved program of record. As noted earlier, bipartisan support for nuclear modernization, including GBSD, has remained strong even as control of the White House and key committees in both the House and Senate has changed hands several times over the past decade. The Biden administration's first defense spending request proposed increasing the funding for GBSD from $1.4 billion in FY 2021 to $2.6 billion in FY 2022, a figure slightly higher than had been predicted during the final year of the previous administration.[211] Likewise, the Senate's Armed Services Committee version of the FY 2022 NDAA expressed the sense of the Senate that "the continued development of the ground-based strategic deterrent is necessary and in the national security interest of the United States."[212]

That said, Air Force leaders should not take this support for granted. Several prominent NGOs have expressed disappointment at the President's first budget request for nuclear modernization and they continue to urge the administration to defer or adjust the scope and pace of the GBSD program.[213] Additionally, some members of Congress have introduced legislation to pause or cancel development of the GBSD program.[214] Others have indicated that they would support delaying or reducing funding for a new ICBM.[215] Even if they are ultimately unsuccessful in the near term, critics of GBSD will likely continue to press for substantial changes to the existing programs of record during future budget cycles.

As long as the Biden administration and the Congress decide to keep the GBSD program on track, senior Air Force leaders will no doubt be expected to defend the decision in their public statements and congressional testimony. They, therefore, must be prepared to explain both why nuclear deterrence remains a core service mission, and why the Triad and a new ICBM are essential to maintaining a safe, secure, and effective nuclear deterrent force. The Air Force would benefit from being more forthcoming in publicly describing the new capabilities that GBSD is expected to provide, both operationally and in terms of sustaining day-to-day operations over the long term. Admittedly, classification issues present complications in openly discussing

[210] Robert K. Ackerman, "Nuclear C3 Looms Vital to Strategic Modernization," *Signal*, January 7, 2021; Patrick Tucker, "Aging ICBMs Must Be Replaced, not Refurbished, STRATCOM Chief Says," *Defense One*, January 6, 2021a.

[211] U.S. Office of the Under Secretary of Defense (Comptroller)/Chief Financial Officer, *Defense Budget Overview, United States Department of Defense Fiscal Year 2022 Budget Request*, Washington, D.C.: U.S. Department of Defense, May 2021a, p. 2-13 and p. 5-20. The majority of the FY 2022 request ($2.55 billion) is for continued RDT&E with a small amount for procurement ($10.9 million).

[212] U.S. Senate, Committee on Armed Services, "Executive Summary, National Defense Authorization Act, Fiscal Year 2022," July 2021i, p. 30.

[213] For example, Kingston Reif and Shannon Bugos, "Biden's Disappointing First Nuclear Weapons Budget," Arms Control Association, *Issue Briefs*, Vol. 13, No. 4, July 9, 2021.

[214] Matthew Beinart, "Garamendi Introduces Bill to Pause GBSD Development Until 2031," *Defense Daily*, June 30, 2021; Brian Everstine, "Garamendi: Pause GBSD as Other Nuclear Modernization Efforts Proceed," *Air Force Magazine*, May 17, 2021a; Joe Gould, "Next-Gen ICBM Program Survives Defunding Attempt in House Panel," Defense News, July 1, 2020; Office of Senator Edward Markey, 2021b; U.S. Senate Bill 982, Investing in Cures Before Missiles Act of 2021, 117th Congress, 1st session, introduced March 25, 2021; Markey and Khanna, 2021a.

[215] Roaten, 2021.

The Air Force would benefit from being more forthcoming in publicly describing the new capabilities that GBSD is expected to provide, both operationally and in terms of sustaining day-to-day operations over the long term.

the evolving threat environment (including adversaries' missile defense and cyber capabilities) and the ways in which GBSD might mitigate current or future developments. But the arguments currently put forward in defense of GSBD do not convey sufficiently the importance of modernization over proposed alternatives or the potential risks associated with delaying recapitalization. The case for GBSD would undoubtedly be more persuasive if supported by frank discussion by senior DoD and military leaders about the strategic and operational rationale for fielding a new ICBM and a plain-English explanation for why a Triad remains relevant in the 21st century.

Similarly, a more transparent discussion of the cost analysis that informed the decision to replace rather than again extend the service life of Minuteman III is necessary to address concerns expressed by both advocates and critics of the GBSD program. Senior defense officials have publicly stressed that the projected cost savings informed the initial decision in 2014 to proceed with the development of a new ICBM, and they have implied that additional calculations undertaken since then have confirmed the original AoA's findings. However, they have not publicly released information on the breakdown of costs for either extending Minuteman III or fielding a new ICBM. A more-detailed discussion of the methodology employed, paired with more-specific numbers on the program's historical and projected costs, would help to address lawmakers' outstanding questions about the adequacy of existing evaluations and inform the debate over whether an independent assessment on costs is necessary.

In a related vein, Air Force leaders will need to ensure that GBSD program management is properly supported and resourced to meet approved objectives on time and on budget. Toward this end, the Air Force should welcome further analyses by outside experts and organizations to identify areas where additional support may be needed. For instance, past studies by RAND and other federally funded research and development centers identified concerns with ensuring sufficient manpower to sustain existing nuclear weapon systems while also acquiring and fielding new systems.[216] In response, the Secretary of the Air Force directed increases in personnel strength in the program offices associated with its nuclear modernization programs.[217] Similar analyses could help the Air Force to address specific issues as they arise over the course of the GBSD program. Potential areas of inquiry include technical and supply chain challenges, certification, deployment strategy, alternative concepts of operation, physical security, and cybersecurity.

Finally, the Air Force has made impressive strides over the past decade in improving both the reality and the perception of its role as the steward of two of the three legs of the Triad. The Air Force Chief of Staff has forcefully stated on numerous occasions that nuclear deterrence is the service's number one priority, and the continued growth and maturation of Air Force Global Strike Command provides reassuring evidence of the

[216] Don Snyder, Christian Johnson, Parousia Rockstroh, Lance Menthe, Bart E. Bennett, Graph Theoretic Algorithms for the Ground Based Strategic Deterrent Program Prioritization and Scheduling, Santa Monica, Calif.: RAND Corporation, RR-A583-1, 2021; Don Snyder, Sarah A. Nowak, Mahyar A. Amouzegar, Julie Kim, and Richard Mesic, *Sustaining the U.S. Air Force Nuclear Mission*, Santa Monica, Calif.: RAND Corporation, TR-1240-AF, 2013; Snyder et al., 2019.

[217] Department of the Air Force, *Manning and Personnel Optimization for Air Force Global Strike Command and Ground-Based Strategic Deterrent Program, Report to Congressional Committees*, Washington, D.C., December 2020.

strength and resilience of this commitment.[218] After decades focused on sustaining its existing systems, the Air Force deserves credit for the substantial progress it has made toward fielding a new generation of nuclear-capable bombers, ALCMs, and ICBMs. That said, it is worth recalling that the Air Force at one time lost its focus on the nuclear mission and on the airmen who carry it out with serious consequences for the service's reputation and credibility. The technical, managerial, and resource challenges associated with developing and fielding multiple new nuclear systems—while simultaneously continuing to operate and sustain existing systems until they are fully replaced—are daunting. It will require sustained, high-level leadership attention for many years to come to ensure success in this most important endeavor.

[218] Valerie Insinna, "US Air Force Chief's Top Modernization Priorities Aren't What You Think They Are," *Defense News*, November 17, 2020.

Abbreviations

ACM	advanced cruise missile
AFB	Air Force Base
ALCM	air-launched cruise missile
AoA	analysis of alternatives
COVID-19	coronavirus disease 2019
DAF	Department of the Air Force
DIA	Defense Intelligence Agency
DoD	U.S. Department of Defense
EMD	Engineering, Manufacturing, and Development
FY	fiscal year
GBSD	Ground-Based Strategic Deterrent
ICBM	intercontinental ballistic missile
LANL	Los Alamos National Laboratory
LCC	launch control center
LRSO	Long-Range Standoff Weapon
MIRV	multiple independently targetable reentry vehicle
NC3	nuclear command, control, and communications
NDAA	National Defense Authorization Act
NGO	nongovernmental organization
NNSA	National Nuclear Security Administration
NPR	Nuclear Posture Review
SLBM	submarine-launched ballistic missile
SLCM	sea-launched cruise missile
SSBN	ballistic missile submarine
STRATCOM	U.S. Strategic Command
TMRR	Technology Maturation and Risk Reduction

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DIA—*See* Defense Intelligence Agency.

DoD—*See* U.S. Department of Defense.

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ABOUT THIS PERSPECTIVE

Since the late 1950s, the United States has fielded a Triad consisting of air-, sea-, and land-based nuclear delivery systems. After decades of service, major components of all three legs are now nearing the end of their scheduled service lives. Several modernization programs are well underway, but the decision to replace the aging Minuteman III intercontinental ballistic missile (ICBM) with a new system, called the Ground-Based Strategic Deterrent (GBSD), has catalyzed a debate over the role of nuclear weapons in U.S. national security policy and the composition and costs of the U.S. nuclear arsenal.

This Perspective presents an overview of the principal arguments publicly advanced for and against continuing the GBSD program of record. Intended to assist Air Force officials' decisionmaking, it describes the role of the Triad in U.S. nuclear weapons policy, surveys the current strategic landscape, and outlines the major nuclear modernization programs of record, as well as describing and assessing the major objections related to fielding a new ICBM.

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