Defending the United States

Revisiting National Missile Defense against North Korea

Jaganath Sankaran and Steve Fetter

U.S. policymakers have long feared the emergence of a North Korean intercontinental ballistic missile (ICBM) threat. In 1998, the congressionally mandated bipartisan Commission to Assess the Ballistic Missile Threat to the United States, known as the Rumsfeld Commission, argued that North Korea was devoting an "extraordinary level of resources" to obtain ballistic missiles to threaten and coerce the United States, suggesting that North Korea could acquire ICBM capability within five years of deciding to do so.[1] North Korea made intermittent and limited progress in its nuclear and missile program since the Rumsfeld Commission, but these programs accelerated after Kim Jong Un came to power in 2011.[2] In 2016 and 2017, North Korea conducted three nuclear tests, the last of which had a yield that exceeded 100 kilotons.[3] In 2017, North Korea test-launched two ICBMs: the Hwasong-14 and Hwasong-15. The director of the U.S. Department of Defense's Missile Defense Agency (MDA), Lieutenant General Samuel Greaves, testified that the Hwasong-14 has the range to target North America, and the Hwasong-15 can target the continental

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1. Donald H. Rumsfeld et al., *Report of the Commission to Assess the Ballistic Missile Threat to the United States* (Washington, D.C.: Government Printing Office [GPO], July 1998), https://fas.org/irp/threat/missile/rumsfeld/toc.htm.
2. For details on the progression of the North Korean nuclear and missile programs in the 2000s, see Daniel A. Pinkston, *The North Korean Ballistic Missile Program* (Carlisle, Pa.: Strategic Studies Institute, U.S. Army War College, February 2008); and Jaganath Sankaran, "Missile Defenses and Strategic Stability in Asia: Evidence from Simulations," *Journal of East Asian Studies*, Vol. 20, No. 3 (November 2020), pp. 3–7, https://doi.org/10.1017/jea.2020.10.
3. Kelsey Davenport, "Chronology of U.S.-North Korean Nuclear and Missile Diplomacy," *Arms Control Association*, July 2020, https://www.armscontrol.org/factsheets/dprkchron. There is some evidence that North Korea has been able to miniaturize a nuclear device for missile delivery. See Nicola Smith, "North Korea Likely Has Miniature Nuclear Warheads, UN Report Finds," *Telegraph*, August 4, 2020, https://www.telegraph.co.uk/news/2020/08/04/north-korea-likely-has-miniature-nuclear-warheads-un-report/; and Jack Kim, "North Korea Can Put Nuclear Warhead on Mid-Range Missile—South," Reuters, April 5, 2016, https://in.reuters.com/article/uk-northkorea-nuclear-idUKKCN0X21FI.

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United States.[4] After two years of accelerated strategic weapons testing, Kim Jong Un, in his 2018 New Year's address, declared that North Korea now possesses "a powerful and reliable war deterrent" capable of countering any U.S. nuclear threats.[5]

North Korea's nuclear and missile programs have been the primary motivation for longstanding U.S. national missile defense efforts. Beginning in the late-1990s, the United States developed at extraordinary cost a national missile defense architecture, the Ground-based Midcourse Defense (GMD) system, to deny North Korea the ability to use or threaten to use ICBMs to coerce the United States and its allies.[6] The GMD system is the only deployed missile defense system devoted to defending the U.S. homeland. The GMD system's interceptors are deployed in the United States, with forty interceptors at Fort Greely, Alaska, and four at Vandenberg Air Force Base in California.[7] In the event of a North Korean ICBM launch, space-based sensors will begin tracking it within seconds. Ground-based radars, located worldwide, will continue tracking the ICBM after its rocket motor burns out and the warhead is released. The radars will guide the interceptors to a predicted intercept point. As the interceptor nears the predicted intercept point, a kill vehicle is expected to identify, home in on, and collide with the missile warhead while it is coasting in space toward the target.

More than twenty years after it was first developed, the GMD system remains limited and unproven. Notably, the MDA has not demonstrated GMD's ability to defeat countermeasures that are technologically simple and economically trivial compared with the effort needed to develop nuclear-armed ICBMs.[8] The GMD system has repeatedly suffered technical setbacks,

4. Senate Hearing 116-AS29, FY20 Priorities for Missile Defense and Defeat Programs, before the Subcomm. on Strategic Forces, 116th Cong., May 8, 2019 (Statement of Lt. Gen. Samuel Greaves, USAF, Director, Missile Defense Agency), p. 5. In 2017, North Korea demonstrated a limited ability to launch solid-propellant medium-range ballistic missiles, which, if scaled up to intercontinental ranges, would enable North Korea, in principle, to prepare and launch ICBMs within minutes. See Senate Hearing, Worldwide threats, before the Comm. on Armed Services, April 29, 2021 (statement of Lieutenant General Scott Berrier, U.S. Army, Director, Defense Intelligence Agency), p. 22, https://www.armed-services.senate.gov/hearings/worldwide-threats.
5. Kim Jong Un, "Kim Jong Un's 2018 New Year's Address," *National Committee on North Korea*, January 1, 2018, https://www.ncnk.org/node/1427.
6. The GMD system ranks fourth among the seventy-eight most expensive major defense programs. See United States Government Accountability Office [GAO], "Missile Defense: The Warfighter and Decision Makers Would Benefit from Better Communication about the System's Capabilities and Limitations" (Washington, D.C.: GAO, May 2018), p. 70, https://www.gao.gov/assets/gao-18-324.pdf.
7. U.S. Department of Defense, *2019 Missile Defense Review* (Washington, D.C.: U.S. Department of Defense, 2019), p. x.
8. Richard L. Garwin, "Holes in the Missile Shield," *Scientific American*, Vol. 291, No. 5 (November 2004), p. 77, https://www.jstor.org/stable/26060765.

critical program cancellations, large cost increases, and significant delays.[9] Since its inception, moreover, the multitude of interceptor kill vehicle designs that have been proposed have all been unreliable. Most recently, in August 2019, the Department of Defense terminated the Redesigned Kill Vehicle (RKV) program because design problems were so "significant as to be either insurmountable or cost-prohibitive to correct."[10] The RKV program had been at the center of the MDA's effort to improve the GMD system's ability to deal with the growing North Korean threat.

This article seeks to explain why the GMD system is faltering despite immense funding, and why it has been so poorly executed. We trace the system's failings to its rushed deployment by the George W. Bush administration. Specifically, we argue that three causal factors—the perception of North Korea as an imminent foreign threat, domestic politics, and technological hubris—enabled the Bush administration to ignore warnings about technological immaturity and discard concerns over strategic stability.

Notwithstanding its limitations, the pursuit of the GMD system has persistently provoked a strong response from Russia and China.[11] The Bush administration, claiming Russia was no longer a strategic adversary, argued that strategic stability was a Cold War construct that was no longer relevant. The administration claimed that the United States should no longer be bound by legacy arms control agreements. As Secretary of State Colin Powell noted in a 2002 congressional testimony, the U.S. message to Russia on nuclear arms reductions and national missile defense was, "This is where we are going. We are going there unilaterally. Come with us or not. Stay where you are or not . . . you can do whatever you think you have to do for your security."[12] In pursuing national missile defense, the Bush administration presumed that any offsetting counter-nuclear armament by Russia and China would not affect U.S. security and strategy.[13] While these presumptions may have been plausi-

9. GAO, "Missile Defense: Observations on Ground-Based Midcourse Defense Acquisition Challenges and Potential Contract Strategy Changes" (Washington, D.C.: GAO, October 21, 2020), p. 1, https://www.gao.gov/assets/gao-21-135r.pdf.
10. Jen Judson, "Pentagon Terminates Program for Redesigned Kill Vehicle, Preps for New Competition," *Defense News*, August 21, 2019, https://www.defensenews.com/pentagon/2019/08/21/dod-tanks-redesigned-kill-vehicle-program-for-homeland-defense-interceptor/.
11. U.S. Department of Defense, "Layered Homeland Missile Defense: A Strategy for Defending the United States" (Washington, D.C.: U.S. Department of Defense, June 22, 2020), p. 3, https://media.defense.gov/2020/Jun/22/2002319425/-1/-1/1/LAYERED-HOMELAND-MISSILE-DEFENSE-FINAL.PDF.
12. Senate Hearing 107–622, Treaty on Strategic Offensive Reduction: The Moscow Treaty, Day 1, before the Comm. on Foreign Relations, 107th Cong., 2d sess., July 9, 2002 (statement of Hon. Colin L. Powell, Secretary of State), p. 10, https://www.govinfo.gov/content/pkg/CHRG-107shrg81339/pdf/CHRG-107shrg81339.pdf.
13. Ibid.

ble at that time, they can no longer guide U.S. strategy in the current "era of strategic competition."[14]

Ballistic missile defense is now the foremost source of contestation in U.S.-Russia and U.S.-China strategic stability conversations. In a 2019 joint statement, Russian President Vladimir Putin and Chinese President Xi Jinping declared that the unrestricted development of national missile defense by the United States threatens strategic stability.[15] Putin has justified developing several new strategic weapon systems as a measure to defeat U.S. missile defenses, which he has claimed could neutralize the vital components of Russian nuclear deterrent forces.[16] Chinese leaders have made similar arguments justifying their nuclear weapons programs as a response to U.S. missile defenses. These changes in Russian and Chinese nuclear postures are now of profound concern to U.S. security and are weakening support for sustaining the 2011 New Strategic Arms Reduction Treaty (New START) and other arms control measures that provide a way to avert nuclear arms racing.[17]

Countering North Korean ICBMs without compromising stability with Russia and China is challenging. Diplomatic efforts have so far failed to limit the North Korean threat, and the prospects for North Korean disarmament are dim. The United States is not prepared to rely entirely on the threat of devastating retaliation to deter North Korea; thus, the United States has emphasized missile defenses. We offer an alternative missile defense architecture, an airborne boost-phase intercept (BPI) system, as a potential and more sensible way to defend against North Korean ICBMs. Such a system would have no capability against Russian and Chinese ICBMs, thus minimizing strategic stability concerns. A variety of recent technological advances—such as long-endurance Unmanned Aerial Vehicles (UAVs), high-performance rocket motors, and improvements in missile-tracking sensors—may make airborne BPI feasible against current liquid-fueled North Korean ICBMs. Against hypothetical solid-fueled North Korean ICBMs, airborne BPI defenses can be effective in in-

14. Berrier Statement, April 29, 2021, p. 2. In this testimony, Lt. Gen. Berrier stated that Russia is an "existential threat," and China was "a major security challenge and remains a long-term strategic competitor."
15. Assistant Foreign Minister Zhang Jun, "Working Together to Maintain Global Strategic Stability and Promote World Peace and Development," Ministry of Foreign Affairs People's Republic of China, June 12, 2019, https://www.fmprc.gov.cn/mfa_eng/wjdt_665385/zyjh_665391/t1672187.shtml.
16. Vladimir Putin, "Presidential Address to the Federal Assembly," speech at the Manezh Central Exhibition Hall in Moscow, March 1, 2018, *President of Russia*, http://en.kremlin.ru/events/president/news/56957.
17. Joseph R. Biden Jr., "Interim National Security Strategic Guidance" (Washington, D.C.: White House, March 2021), p. 13, https://www.whitehouse.gov/wp-content/uploads/2021/03/NSC-1v2.pdf; and Joseph R. Detrani, "The New START Extension Lacks Critical Points for Strategic Stability," *Hill*, July 8, 2021, https://thehill.com/opinion/national-security/561774-the-new-start-extension-lacks-critical-points-for-strategic.

tercepting several missile trajectories launched from the eastern and central regions of North Korea. Airborne BPI defenses would not be able to intercept solid-fueled launches from the northwestern region of North Korea, but this limitation could be overcome with Chinese cooperation.

This article is organized as follows. In the first section, we review debates over U.S. national missile defense, including its influence on the concept of strategic stability. In the second section, we outline a framework for understanding the rush to deploy national missile defense in the 1990s. In the third section, we explore how that rush to deployment has undermined national missile defense efforts in the long-term, detailing the programmatic failures and conceptual flaws plaguing the GMD effort. The fourth section reviews Russian and Chinese claims that U.S. ballistic missile defense threatens bilateral strategic stability, drives their nuclear modernization efforts, and imperils future arms control. In the fifth section, we examine alternatives to the GMD system and detail recent technological advances that suggest the viability of airborne BPI systems against North Korean ICBMs. Finally, we conclude with recommendations to meaningfully realign national missile defense efforts to address current and future threats to U.S. security, including establishing a bipartisan presidential commission.

National Missile Defense and Strategic Stability

Two important aspects of the contemporary debates over national missile defense and strategic stability have roots in the Cold War. The heated debates in the 1950s and 1960s, detailed below, led to the realization in the United States that the deployment of national missile defenses could undermine the ability of offensive forces that survived a first strike to penetrate the defense, giving an incentive for both sides to initiate nuclear war in a crisis. In addition, the deployment of defenses could provoke a nuclear arms race, as both sides increased their offensive forces to ensure penetration of the adversary's missile defense system.[18] To avert such a crisis and arms race instability, the United States, and eventually the Soviet Union, accepted that negotiated limits on national missile defense were essential to preserve stability in U.S.-Soviet nuclear deterrence.

In 1955, the U.S. Army started work on the prototype Nike-Zeus missile defense system to achieve nationwide defense against the Soviet Union.[19] While

18. John D. Steinbruner, "National Security and the Concept of Strategic Stability," *Journal of Conflict Resolution*, Vol. 22, No. 3 (September 1978), p. 413, https://www.jstor.org/stable/173725.
19. U.S. Congress Office of Technology Assessment, "Ballistic Missile Defense Then and Now," *Ballistic Missile Defense Technologies* (Washington, D.C.: GPO, 1985), p. 45.

the army wanted to deploy the system, the Dwight D. Eisenhower administration was unconvinced about its performance. The project acquired urgency after the Sputnik launch in 1957.[20] In 1958, the army was authorized to develop the Nike-Zeus system as a damage-limitation measure against Soviet missiles.[21] This system relied on mechanically steered radars and a relatively slow interceptor missile that had to be launched while the warhead was still far out in space. The system was highly susceptible to decoys and saturation missile attacks.[22] These limitations, and the belief that the Soviets would offset the missile defense system with more offensive forces, led Secretary of Defense Robert McNamara to veto the system's deployment.[23]

The technical weaknesses of the Nike-Zeus system led to the development of the Nike-X missile defense system in 1961. This newer system employed a high-speed terminal-defense interceptor, Sprint, to work around the warhead-decoy discrimination problem.[24] It also incorporated electronic scanning radars that mitigated the offense's ability to saturate the defense. Secretary McNamara, however, remained skeptical. His objections to national missile defense stemmed from research conducted as early as 1962 in the Pentagon's Systems Analysis Office exploring two variants of Nike-X deployment and their effects on strategic stability. The analysis concluded that in either case the Soviets would be driven to respond to Nike-X deployment because the Soviets would otherwise lose their deterrent against the United States.[25] The Soviet Union had both the technological capability and the economic capacity to respond in several ways, "including adding [Multiple Independent Reentry Vehicles] MIRV's and penetration aids, adding sea-launched ballistic missiles (SLBM's) or a mobile ICBM, adding a higher payload missile, or some combination of these responses."[26] Any such Soviet response would trigger U.S. deployment of additional offensive and defensive systems. Summarizing the arms race cycle that would unfold, the System

20. Alain C. Enthoven and Wayne K. Smith, *How Much Is Enough? Shaping the Defense Program, 1961–1969* (Santa Monica, Calif.: RAND, 2005), p. 184.
21. David N. Schwartz, "Past and Present: The Historical Legacy," in Ashton B. Carter and David N. Schwartz, eds., *Ballistic Missile Defense* (Washington, D.C.: Brookings Institution Press, 1984), p. 332.
22. Enthoven and Smith, *How Much Is Enough?* pp. 170, 185.
23. Schwartz, "Past and Present: The Historical Legacy," pp. 333–335.
24. Enthoven and Smith, *How Much Is Enough?* p. 186.
25. In a March 1967 testimony to Congress, Secretary McNamara stated, "it is a virtual certainty that the Soviets will act to maintain their deterrent which casts such grave doubts on the advisability of our deploying the Nike X system." See U.S. Congress Office of Technology Assessment, "Ballistic Missile Defense Then and Now," p. 46.
26. Enthoven and Smith, *How Much Is Enough?* p. 188.

Analysis Office warned that the deployment of Nike-X would provide no security benefit and would lead both sides into an arms race.[27]

The armed forces did not accept the System Analysis Office's conclusions, arguing that the Soviet Union did not size its nuclear arsenal using the criteria applied by civilian analysts at the Pentagon.[28] They claimed that the Soviet Union relied on a nuclear warfighting strategy rather than the U.S. preference for punitive nuclear retaliation. The armed forces also contended that the Soviet Union could not afford to respond to all U.S. deployments.[29]

By late 1966, evidence of the Soviet Union's deployment of its Galosh missile defense system increased pressure on the Lyndon B. Johnson administration to deploy the Nike-X system. In an extraordinary meeting at the White House on January 23, 1967, Secretary McNamara assembled, along with the Joint Chiefs of Staff, all past and current Special Assistants to the President for Science and Technology and all past and current directors of defense research and engineering to advise President Johnson on the desirability of a national missile defense system.[30] President Johnson reportedly inquired if such a system would work against the Soviet Union, to which the overwhelming answer was "no."[31] President Johnson was convinced to delay deploying the Nike-X system, a decision that would soon be altered by developments in U.S. domestic politics.

In February 1967, the Republican National Committee published a monograph entitled *The Missile Defense Question: Is LBJ Right?*, which argued strongly for deploying the Nike-X system against the Soviet nuclear threat.[32] For Johnson, the monograph's reference to his decision to defer the deployment of Nike-X was a ploy to influence the 1968 election.[33] In a compromise, Johnson requested money in the 1968 fiscal year budget to procure long lead time subsystems for Nike-X and made this funding contingent on efforts to negotiate missile defense limits with the Soviet Union.[34] Unable to persuade the

27. Alain Enthoven and Wayne Smith note that this conclusion remains robust under any reasonable range of assumptions and nuclear exchange calculations. Enthoven and Smith, *How Much Is Enough?* pp. 187–188.
28. Schwartz, "Past and Present," p. 337.
29. Ibid.
30. Ernest J. Yanarella, *The Missile Defense Controversy: Strategy, Technology, and Politics, 1955–1972* (Lexington: University Press of Kentucky, 1977), p. 124.
31. Ibid.; Herbert F. York, "Military Technology and National Security," *Scientific American*, Vol. 221, No. 2 (August 1969), p. 18, https://www.jstor.org/stable/24926434; and Schwartz, "Past and Present," p. 338.
32. Yanarella, *The Missile Defense Controversy*, p. 125.
33. Ibid.
34. Schwartz, "Past and Present," p. 337; and U.S. Congress Office of Technology Assessment, "Ballistic Missile Defense Then and Now," p. 46.

Soviets on missile defense arms control, President Johnson moved to fund a scaled-down Nike-X system named Sentinel in 1968.[35]

After its own review, in 1969 the Richard M. Nixon administration agreed with the Johnson administration's position that it was desirable to limit national missile defense. In March 1969, President Nixon also announced the decision to deploy the Safeguard missile defense system to defend Minuteman ICBM sites rather than the Sentinel system that focused on national defense.[36] President Nixon emphasized that "there is no way that we can adequately defend our cities without an unacceptable loss of life."[37] He noted that deploying a national missile defense system would provoke an offensive nuclear arms buildup by the Soviet Union, fostering crisis and arms race instability.[38] He stressed that he wanted an even more scaled-down system with "no provocation which might deter arms talks" with the Soviet Union.[39] By May 1971, the United States and the Soviet Union reached an agreement on limiting missile defenses. The Anti-Ballistic Missile (ABM) Treaty was signed in May 1972, banning national missile defense systems and limiting each country to 100 interceptors for the defense of an individual region (i.e., the national capital or an ICBM field). The ABM Treaty paved the way for the first agreed limitation on offensive arms. For a decade, both states refrained from any significant missile defense deployments.

In January 1983, President Ronald Reagan established a Commission on Strategic Forces, known as the Scowcroft Commission, and charged it with examining the future of ICBM forces. Two months later, Reagan surprised defense analysts by announcing the Strategic Defense Initiative (SDI), a program aiming to build a national missile defense shield over the United States. This was met with widespread skepticism over the ability to deliver what the SDI promised. In April 1983, the Scowcroft Commission noted that prevailing technological capabilities did not provide a viable pathway to deploy national missile defense anytime soon.[40] In a 1985 address to the Philadelphia World Affairs Council, Paul Nitze, President Reagan's special advisor on arms control, clarified that if technology were eventually to permit such a defense, it

35. Schwartz, "Past and Present," p. 339.
36. Richard Nixon, "The President's News Conference: Deployment of the Anti-ballistic Missile System," news conference, White House, March 14, 1969, *American Presidency Project*, https://www.presidency.ucsb.edu/documents/the-presidents-news-conference-153.
37. Ibid.
38. Ibid.
39. Ibid.
40. President's Commission on Strategic Forces, *Report of the President's Commission on Strategic Forces* (Washington, D.C.: White House, April 1983), p. 9, http://web.mit.edu/chemistry/deutch/policy/1983-ReportPresCommStrategic.pdf.

would be deployed in a cooperative effort with the Soviet Union.[41] Nitze identified two criteria to evaluate the feasibility of SDI deployment.[42] The first required that the defensive systems be survivable, or that the defenses should not themselves be attractive targets for a first strike. The second criterion required that the defensive systems be cost-effective at the margin. In other words, deploying the defensive systems should not trigger an adversary to expand its offensive arsenal, which would foster arms race instability. Without meeting both these criteria, Nitze said, there would be no deployment of SDI.[43]

Until 2001, every U.S. administration since 1968 had acknowledged the importance of strategic stability and the need for balance between offensive and defensive capabilities. President George W. Bush broke with this consensus in a May 2001 speech at the National Defense University, in which he argued that "Cold War deterrence is no longer enough" to deter so-called rogue states such as North Korea.[44] President Bush and his advisors declared that future nuclear arms control would be accomplished outside of the Cold War–era framework, abandoning the primacy of strategic stability as an organizing concept.[45] In December 2001, the president announced his decision to withdraw from the ABM Treaty and to immediately pursue the GMD system.[46]

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41. Paul H. Nitze, "On the Road to a More Stable Peace," address before the Philadelphia World Affairs Council, Pennsylvania, February 20, 1985 (Washington, D.C.: U.S. Department of State, Bureau of Public Affairs, 1985), pp. 1, 3.
42. Ibid., p. 2. Nitze's criteria were not immediately accepted by the Reagan administration. See Nancy W. Gallagher, "Congress and Missile Defense," in Catherine McArdle Kelleher and Peter Dombrowski, eds., *Regional Missile Defense from a Global Perspective* (Stanford, Calif.: Stanford University Press, 2015), p. 87.
43. Nitze, "On the Road to a More Stable Peace," p. 2.
44. George W. Bush, "Remarks by the President to Students and Faculty at National Defense University," Fort Lesley J. McNair, Washington, D.C., May 1, 2001, *White House*, https://georgewbush-whitehouse.archives.gov/news/releases/2001/05/20010501-10.html. An excellent theoretical exploration of the impact of national missile defense on nuclear deterrence is Robert Powell, "Nuclear Deterrence Theory, Nuclear Proliferation, and National Missile Defense," *International Security*, Vol. 27, No. 4 (Spring 2003), pp. 86–118, https://doi.org/10.1162/016228803321951108.
45. Powell Statement, July 9, 2002, pp. 6–7.
46. Terence Neilan, "Bush Pulls Out of ABM Treaty; Putin Calls Move a Mistake," *New York Times*, December 13, 2001, https://www.nytimes.com/2001/12/13/international/bush-pulls-out-of-abm-treaty-putin-calls-move-a-mistake.html. In 2007, the Bush administration also proceeded to develop plans to deploy a European version of the GMD system aimed at dealing with future Iranian ICBMs. See Karen Travers, "Bush to Putin: 'Cold War Is Over,'" *ABC News*, June 6, 2007, https://abcnews.go.com/GMA/story?id=3245434. President Barack Obama, however, in an attempt to reassure Russia, altered these plans and deployed a version called the European Phased Adaptive Approach (EPAA) missile defense system. The EPAA system was based on the less capable SM-3 interceptors. See Jaganath Sankaran, *The United States' European Phased Adaptive Approach Missile Defense System: Defending against Iranian Missile Threats without Diluting the Russian Deterrent* (Santa Monica, Calif.: RAND, 2015), https://www.rand.org/pubs/research_reports/RR957.html; and Jaganath Sankaran, "Missile Defense against Iran without Threatening Russia," *Arms Control Association*, November 2013, https://www.armscontrol.org/act/2013-11/missile-defense-against-iran-without-threatening-russia#5.

The Rush to Deploy: The Genesis of the GMD System

The GMD system is the only deployed missile defense system devoted to defending the U.S. homeland. The GMD system, however, was not the result of a rigorous design, test, and validation process that explored a range of alternatives. All major defense programs require that any new technologies and designs have been validated before developing a prototype. Program managers must show that the chosen prototype design has been rigorously tested and has met all technical expectations set by the military end user, and they must demonstrate the prototype's ability to meet cost and schedule targets before beginning production and deployment. Furthermore, throughout this process, an acquisition program is subject to stringent independent oversight on cost and quality control.[47] In contrast, the GMD system was an unvalidated architecture that the George W. Bush administration cobbled together from previous experimental missile defense systems and hastily pushed forward.[48]

In early 2001, Lt. Gen. Ronald Kadish, then director of the MDA, advised Secretary of Defense Donald Rumsfeld that the GMD system "provided the earliest opportunity and probably the only option" that was feasible within the next decade.[49] But he also acknowledged that it had substantial technical uncertainties.[50] Yet, by 2004, the Bush administration had brought the GMD system to operational status, employing an acquisition process that was criticized as "buy first, think later."[51] In doing so, the Bush administration circumvented the political and technological scrutiny that is usually required for major weapons development projects. We detail below three factors—imminent foreign threat, domestic politics, and technological hubris—that explain how the Bush administration obtained the political sanction to rush the GMD system into deployment.[52]

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47. GAO, "Missile Defense: Opportunities Exist to Reduce Acquisition Risk and Improve Reporting on System Capabilities" (Washington, D.C.: GAO, May 2015), p. 6–10, https://www.gao.gov/assets/gao-15-345.pdf; and GAO, "Missile Defense: Delivery Delays Provide Opportunity for Increased Testing to Better Understand Capability" (Washington, D.C.: GAO, June 2019), p. 5, https://www.gao.gov/products/gao-19-387.
48. Anthony H. Cordesman, *Strategic Threats and National Missile Defenses: Defending the U.S. Homeland* (Westport, Conn.: Praeger, Center for Strategic and International Studies [CSIS], 2002), p. 13.
49. Bradley Graham, *Hit to Kill: The New Battle over Shielding America from Missile Attack* (New York: Public Affairs, 2001), pp. 360–361.
50. Ibid., pp. 60–61.
51. Wade Boese, "Pentagon Outlines Missile Defense Plans to Congress," *Arms Control Today*, Vol. 32, No. 3 (April 2002), pp. 24–25, https://www.jstor.org/stable/23626512.
52. The framework used in this article shares similarities to other theories developed to study how major defense program acquisitions succeed. See Harvey M. Sapolsky, "Success and Its Secrets," in *The Polaris System Development: Bureaucratic and Programmatic Success in Government*, reprint ed.

IMMINENT FOREIGN THREAT: NORTH KOREA

A broad political consensus on the North Korean missile threat to the United States had already emerged in the mid-1990s. In a 1994 executive order, President Bill Clinton declared a "national emergency" to address the "unusual and extraordinary" threat posed to the United States by the proliferation of weapons of mass destruction and their means of delivery to rogue states like North Korea.[53] In a 1996 speech, Secretary of Defense William J. Perry reiterated the rogue state threat and argued for the "need to be ready" to deploy a national missile defense system.[54]

Two events in 1998 pushed the North Korean threat further into the political limelight and provided new impetus for national missile defense. In July 1998, the Rumsfeld Commission warned that North Korea could acquire ICBMs within five years, claiming that the prevailing geopolitical environment provided North Korea easier access to the technology, materials, and expertise necessary to develop ICBMs.[55] The findings of the Rumsfeld Commission upended previous intelligence estimates that attached a much longer timeline to North Korean missile ambitions.[56] The report suggested that while such missiles may not match the reliability and accuracy of U.S. systems, they could be deployed at a faster pace.[57] Speaker of the House Newt Gingrich called the commission's findings "the most important [national security] warning" since the Cold War, and he declared the immediate need to pursue a national missile defense system.[58]

(Cambridge, Mass.: Harvard University Press, 2013); and Thomas L. McNaugher, *New Weapons, Old Politics: America's Military Procurement Muddle* (Washington, D.C.: Brookings Institution Press, 1989).

53. William J. Clinton, "Executive Order 12938: Proliferation of Weapons of Mass Destruction" (Washington, D.C.: White House, November 14, 1994), https://www.archives.gov/files/federal-register/executive-orders/pdf/12938.pdf.

54. William J. Perry, "Secretary of Defense Speech: Protecting the Nation Through Ballistic Missile Defense. Prepared Remarks Defense Secretary William J. Perry, George Washington University, Washington," U.S. Department of Defense, April 18, 1996, https://web.archive.org/web/20130715085136/http://www.defense.gov/speeches/speech.aspx?speechid=956.

55. Rumsfeld et al., *Report of the Commission to Assess the Ballistic Missile Threat*.

56. See Graham, *Hit to Kill*, pp. 50–51.

57. Rumsfeld et al., *Report of the Commission to Assess the Ballistic Missile Threat*. Similarly, Robert D. Walpole testified in 2000 that weaker countries trying to deter, constrain, and harm the United States do not need to deploy ICBMs "in large numbers" and the ICBMs "need not be accurate or reliable." He suggested that the strategic value of such ICBMs "is derived primarily from the threat of their use, not the near certain outcome of such use." See Senate Hearing 106-671, The National Intelligence Estimate on the Ballistic Missile Threat to the United States, before the Subcomm. on International Security, Proliferation, and Federal Services of the Comm. on Governmental Affairs, 106th Cong., 2nd sess., February 9, 2000 (statement of Robert D. Walpole, National Intelligence Officer for Strategic and Nuclear Programs, National Intelligence Council), p. 7, https://www.govinfo.gov/content/pkg/CHRG-106shrg63638/pdf/CHRG-106shrg63638.pdf.

58. Graham, *Hit to Kill*, p. 48.

A few weeks later, North Korea launched the Taepodong-1. According to a Defense Intelligence Agency (DIA) officer, the U.S. intelligence community was surprised by the North Korean attempt to launch a multiple-stage rocket.[59] Republican proponents of national missile defense portrayed the Taepodong-1 launch as validation of the Rumsfeld Commission's findings.[60] These events prompted the Clinton administration to start experimental testing of interceptors; simultaneously, the administration opened a dialogue with Russia on amending the ABM Treaty to accommodate deploying a limited national missile defense system.[61]

DOMESTIC POLITICS

The Republican Party's 1994 midterm election manifesto, *Contract with America*, crafted by Newt Gingrich, declared that "it shall be the policy of the United States to deploy at the earliest possible moment an antiballistic missile system."[62] When the Republican Party won control of both houses of Congress in the midterm elections, it immediately demanded a commitment to missile defenses. The provisions on missile defense in *Contract with America* were then used against President Clinton in the 1996 election.[63] Bob Dole, President Clinton's Republican challenger in the election, characterized Clinton's cautious approach to missile defense as "one of the most shortsighted, irresponsible and potentially catastrophic policies in history."[64] Similar to President Johnson's strategy in 1967, President Clinton announced his own missile defense plan (known as the 3+3 plan) to deflate Republican pressure.[65] Members of the Clinton administration admitted that the plan was heavy on rhetoric and weak on technical feasibility.[66]

In 2001, the George W. Bush administration came into office convinced that it was more urgent to address the North Korean threat than Russia's position

59. Cordesman, *Strategic Threats and National Missile Defenses*, p. 122.
60. Graham, *Hit to Kill*, p. 61.
61. Andrew Futter, *Ballistic Missile Defence and US National Security Policy: Normalisation and Acceptance after the Cold War* (New York: Routledge, 2015), pp. 89–90.
62. Newt Gingrich, "Republican Contract with America" (Washington, D.C.: U.S. House of Representatives, September 27, 1994), https://web.archive.org/web/19990427174200/http://www.house.gov/house/Contract/CONTRACT.html.
63. Futter, *Ballistic Missile Defence and US National Security Policy*, p. 57.
64. Katharine Q. Seelye, "Dole Tries to Talk about Jobs, but Tobacco Keeps Intruding," *New York Times*, June 19, 1996, https://www.nytimes.com/1996/06/19/us/dole-tries-to-talk-about-jobs-but-tobacco-keeps-intruding.html.
65. The 3+3 plan, outlined in 1996, supported the development and demonstration of a national missile defense (NMD) system by three years, or by the year 2000. At that point, depending on the evolution of the North Korean threat and viability of the NMD system, a decision would be made for deployment in three years, or by the year 2003. Futter, *Ballistic Missile Defence and US National Security Policy*, p. 63.
66. Futter, *Ballistic Missile Defence and US National Security Policy*, pp. 72–73.

on the ABM Treaty. During his campaign, Bush had characterized North Korea as an imminent threat to U.S. national security.[67] He had promised, if elected, to immediately build national missile defense.[68] The September 11, 2001, terrorist attacks added a sense of vulnerability that further paved the way for an early deployment decision.[69] In the immediate aftermath of the attacks, Democrats, usually missile defense skeptics, were less willing to oppose a president on a matter of national security.[70]

In December 2001, President George W. Bush announced his decision to withdraw from the ABM Treaty. A year later, he signed a National Security Presidential Directive stipulating deployment of missile defenses within two years.[71] In 2004, the Bush administration declared that a limited national missile defense system was operational with five deployed interceptors.[72] In standard weapons acquisition procedures, the military typically presents its requirements and performance expectations for responding to a well-defined threat. But the Bush administration reversed this process when it decided to rapidly engineer a national missile defense system. In 2001, Kadish declared at a news conference, ". . . we're going to provide the military decision-makers and users what we can produce and ask them a very simple question—'We can do this technically; is this good enough for you to use?'"[73] He argued that "instead of working very hard, very high risk, trying to meet a [warfighter] requirement," the initial effort was aimed at putting something in place as soon as possible.[74]

TECHNOLOGICAL HUBRIS

Over the years, various proponents have referenced the United States' unique ability to technologically innovate as justification for the George W. Bush administration's rush to deploy missile defenses. These proponents have argued

67. George W. Bush, "A Period of Consequences," speech at The Citadel, South Carolina, September 23, 1999, http://www3.citadel.edu/pao/addresses/pres_bush.html. See also George W. Bush, "President Bush Speech on Missile Defence, May 1, 2001," speech at National Defense University, Washington, D.C., *Federation of American Scientists*, https://fas.org/nuke/control/abmt/news/010501bush.html.
68. Cordesman, *Strategic Threats and National Missile Defenses*, p. 3.
69. For details on how the September 11, 2001 attacks altered the calculus on national missile defense, see Futter, *Ballistic Missile Defence and US National Security Policy*, pp. 102–107.
70. Ibid.
71. The White House, "National Security Presidential Directive 23," December 16, 2002, *Federation of American Scientists*, https://fas.org/irp/offdocs/nspd/nspd-23.htm.
72. MDA, "Missile Defense: The First Seventy Years" (Washington, D.C.: U.S. Department of Defense, August 8, 2013), pp. 16–17, https://www.mda.mil/global/documents/pdf/first70.pdf.
73. Columba Peoples, *Justifying Ballistic Missile Defence: Technology, Security, and Culture* (New York: Cambridge University Press, 2010), p. 201.
74. Ibid.

that prior U.S. technological achievements demonstrated that the many challenges in building a national missile defense could be surmounted in a few years.[75] When early tests of the GMD system contradicted this optimism, proponents dismissed the failures as temporary setbacks. In August 2001, for instance, Rumsfeld stated that test failures did not undermine the case for national missile defense.[76] Responding to allegations that a GMD test had used a beacon to guide the interceptor to its quarry (i.e., the target missile's warhead), he reasoned that any setbacks would be corrected swiftly and argued that opponents of missile defense were unfairly critical.[77] Rumsfeld pointed to the CORONA program that failed eleven times before its eventual success, and he invoked the legacy of the Wright brothers who had failed several times before flying their first airplane.[78] In testimony to the U.S. Senate, Deputy Secretary of Defense Paul Wolfowitz argued that "there isn't a single major technological development in human history that didn't proceed with a process of trial and error, including many of our most successful weapons systems . . . Yet, from these failures and from the successes came some of the most effective capabilities we have ever fielded."[79] The George W. Bush administration portrayed these test failures as a natural part of a development process that would inevitably result in an effective system. Writing in 1969, Herbert York, who served as the first director of Defense Research and Engineering, pointed to the logical flaw in such false analogies:

> We find that some say: 'You can't tell me that if we can put a man on the moon, we can't build an ABM.' Others say: 'That's what Oppenheimer told us about the hydrogen bomb.' These two statements contain the same basic error. They are examples of success in a contest between technology and nature, whereas the ABM issues involves a contest between two technologies: offensive weapons and penetration aids versus defensive weapons and discrimination techniques. These analogies would be more pertinent if, in the first case, someone were to jerk the moon away just before the astronauts landed, or if, in the second case, nature were to keep changing the nuclear-reaction probabili-

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75. Peoples, *Justifying Ballistic Missile Defence*, pp. 3, 4, 192.
76. Donald H. Rumsfeld, interview with Conan Nolan, Secretary Rumsfeld Interview with *KNBC-TV Los Angeles*, U.S. Department of Defense, August 14, 2001, http://www.tep-online.info/laku/usa/whitehou/dod/14082001.htm.
77. Ibid.
78. Ibid. See also York, "Military Technology and National Security," p. 23. The CORONA program was America's first satellite photoreconnaissance system. National Reconnaissance Office, "CORONA," https://www.nro.gov/History-and-Studies/Center-for-the-Study-of-National-Reconnaissance/The-CORONA-Program/.
79. Senate Hearing 107-355, Department of Defense Authorization for Appropriations for Fiscal Year 2002, before the Comm. on Armed Services, 117th Cong., 1st sess., July 12, 2001 (statement of Hon. Paul D. Wolfowitz, Deputy Secretary of Defense), p. 443, https://www.govinfo.gov/content/pkg/CHRG-107shrg75346/pdf/CHRG-107shrg75346.pdf.

ties all during the development of hydrogen bomb and once again after it was deployed.[80]

While celebrating past technological successes, proponents of national missile defense refused to acknowledge the rigor and discipline required to successfully field a technologically sophisticated weapons system, despite warnings against rushing to deployment. For example, a 1997 U.S. Government Accountability Office (GAO) report noted that there had been very few "hit-to-kill" intercept tests and an even smaller number of successful trials. The report argued that these tests did not demonstrate the viability of missile defense.[81] In 1998, the Report of the Panel on Reducing Risk in Ballistic Missile Defense Flight Test Programs, known as the Welch Panel report, warned that the national missile defense efforts were "marred by poor planning, insufficient testing, and political pressure" and called the planned deployment schedule a "rush to failure."[82] In August 2000, a National Missile Defense Deployment Readiness Review conducted by the director of the Department of Defense's Operational Test and Evaluation Office stated that given the limited and inadequate testing undertaken so far, "no one can reliably predict that the NMD system will perform" effectively under stressing real-world conditions.[83]

Ignoring these warnings, the Bush administration proceeded to accelerate the program in December 2001. Since then, the MDA has continuously been mandated to meet unrealistic presidentially mandated schedules in one way or another.[84] Ironically, the rush to meet politically determined deadlines has led to a recurrent series of delays and cancellations over the last twenty years.

The Failed Experiment of the GMD System

After twenty years of dedicated effort and unconstrained funding, the GMD system's readiness is still in doubt. As of June 2021, the GMD system has been

80. York, "Military Technology and National Security," p. 23. See also Scott D. Sagan, "Sagan Responds to Waltz" in Scott D. Sagan and Kenneth N. Waltz, eds., *The Spread of Nuclear Weapons: A Debate Renewed* (New York: W.W. Norton, 2003), pp. 177–179.

81. GAO, "National Missile Defense: Schedule and Technical Risks Represent Significant Development Challenges" (Washington, D.C.: GAO, December 1997), pp. 5, 7, https://www.gao.gov/products/nsiad-98-28.

82. Graham, *Hit to Kill*, p. 28.

83. Director of Operational Test and Evaluation, "Report in Support of National Missile Defense Deployment Readiness Review" (Washington, D.C.: Office of Operational Test and Evaluation, U.S. Department of Defense, August 10, 2000), p. 42, http://www.bits.de/NRANEU/BMD/documents/coylereport.pdf.

84. House Hearing, FY21 Priorities for Missile Defense and Missile Defeat Programs, before the Subcomm. on Strategic Forces, March 12, 2020 (statement of Christina T. Chaplain, GAO), https://www.gao.gov/assets/gao-20-490t-highlights.pdf.

flight-tested twenty times.[85] Even under idealized test conditions, however, only about 50 percent of the attempts to intercept targets have succeeded.[86] Furthermore, the first ten tests (with five successful intercepts) were conducted using prototype interceptors or other surrogates that may not reflect the abilities of the deployed interceptors. The initial flight tests were conducted with cued information rather than information from the network of sensors that would track an incoming North Korean ICBM.[87] Several flight tests were timed to occur in the daytime and in favorable weather, thereby avoiding the uncertainty of real-world conditions.[88] Given these factors, the ability of the GMD system to now offer reliable defense against North Korean ICBMs has caused even the Joint Staff and other warfighters to question the system's practical utility.[89] In addition to these shortcomings, debilitating programmatic failures and conceptual flaws have yet to be resolved.

PROGRAMMATIC FAILURES: THE PERPETUAL SEARCH FOR A KILL VEHICLE

The GMD program has yet to field a reliable kill vehicle. The first kill vehicle, the CE-I, was deployed in 2004—three years before its first flight test.[90] Similarly, the CE-II kill vehicle was deployed more than five years before its first flight test.[91] The decision to deploy these kill vehicles as an operational system before testing not only weakened the GMD system's reliability but also led to costly retrofits and delays.[92] The MDA has since acknowledged that the CE-I and CE-II kill vehicle designs were "costly to produce and sustain and re-

85. MDA, "Fact Sheet: Ballistic Missile Defense Intercept Flight Test Record" (Fort Belvoir, Va.: MDA, 2021), p. 1, https://www.mda.mil/global/documents/pdf/testrecord.pdf.
86. Ibid. Other U.S. regional missile defense efforts have been significantly more successful in intercepting target ballistic missiles in flight tests. The Aegis BMD has a flight test success rate of approximately 81 percent. The THAAD system, after some early missteps, has registered a 100 percent flight test success rate. See Ibid., pp. 2–3. Among other things, these better results indicate the efficiency of a systems development process that is unhindered by political mandates.
87. Grego, Lewis, and Wright, *Shielded from Oversight*, pp. 30–31. Some corrective actions have recently occurred. In March 2019, MDA conducted its first salvo flight test of the GMD system, "firing a CE-II Block I-equipped interceptor followed by a CE-II-equipped interceptor." See GAO, "Missile Defense: Delivery Delays Provide Opportunity for Increased Testing to Better Understand Capability," p. 58.
88. Grego, Lewis, and Wright, *Shielded from Oversight*, p. 30.
89. GAO, "Missile Defense: Further Collaboration with the Intelligence Community Would Help MDA Keep Pace with Emerging Threats" (Washington, D.C.: GAO, December 2019), pp. 28–29, https://www.gao.gov/products/gao-20-177.
90. Grego, Lewis, and Wright, *Shielded from Oversight*, p. 20.
91. Ibid., p. 22.
92. For instance, the CE-II kill vehicle program cost increased from $236 million to $1.981 billion to "resolve the test failures and implement a retrofit program." The reason for the increase is attributed to moving "forward with producing and fielding interceptors before completing its flight test program." See GAO, "Missile Defense: Opportunities Exist to Reduce Acquisition Risk and Improve Reporting on System Capabilities," p. 10.

quire the warfighter to fire more interceptors to overcome anticipated in-flight reliability failures."[93]

In 2014, Frank Kendall, Undersecretary of Defense for Acquisition, Technology, and Logistics, said the existing CE-I and CE-II kill vehicles were plagued by "bad engineering" because "there was a rush" to get something out.[94] He advocated for the development of a new and more reliable kill vehicle. In 2014, the MDA began the Redesigned Kill Vehicle (RKV) program to replace CE-I and CE-II kill vehicles.[95]

Learning from past mistakes, the MDA initially adopted a robust development and deployment plan for the RKV program that included rigorous testing and evaluation.[96] But in October 2017, in response to North Korean ICBM tests, these weapons acquisition best practices were abandoned. The MDA was tasked with accelerating the RKV program by "concurrently performing development and production and reducing the number of necessary flight tests" to increase the number of deployed interceptors from forty-four to sixty-four by 2023.[97] The altered deployment schedule forced the contractor to hire several new personnel to work on the project and to use "commercial off-the-shelf hardware and re-use Aegis SM-3 Block IIA components," both of which compromised reliability.[98] By 2018, the RKV program was over budget and behind schedule, prompting the Department of Defense to terminate the RKV program in August 2019 after determining that its design flaws were too severe to be fixed quickly or cheaply.[99] Without an operable RKV, the plan to increase the number of interceptors to sixty-four by 2023 is infeasible.[100] Moreover, the GMD system will continue to operate with CE-I and CE-II kill vehicles, further eroding confidence in its effectiveness in real-world conditions.[101]

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93. Ibid., p. 23.
94. Andrea Shalal, "Pentagon Plans Work on New Missile Defense Interceptor," Reuters, February 25, 2014, https://www.reuters.com/article/us-usa-budget-missile/pentagon-plans-work-on-new-missile-defense-interceptor-idUSBREA1P03F20140226.
95. GAO, "Missile Defense: Opportunities Exist to Reduce Acquisition Risk and Improve Reporting on System Capabilities," p. 24.
96. GAO, "Missile Defense: The Warfighter and Decision Makers Would Benefit from Better Communication about the System's Capabilities and Limitations," pp. 72–73.
97. Ibid.
98. GAO, "Missile Defense: Delivery Delays Provide Opportunity for Increased Testing to Better Understand Capability," pp. 17, 18, 61.
99. Judson, "Pentagon Terminates Program for Redesigned Kill Vehicle."
100. GAO, "Missile Defense: Delivery Delays Provide Opportunity for Increased Testing to Better Understand Capability," p. 18.
101. Currently, the GMD system consists of twenty interceptors armed with the CE-I kill vehicle, sixteen interceptors armed with the CE-II kill vehicle, and eight interceptors armed with the CE-II Block I kill vehicle. See GAO, "Missile Defense: Fiscal Year 2020 Delivery and Testing Progressed, but Annual Goals Unmet" (Washington, D.C.: GAO, April 2021), p. 4, https://www.gao.gov/products/gao-21-314.

We find that these failures are a result of the decisions to rush to field the GMD system. The Bush administration empowered the MDA to independently define system requirements, review its performance, and establish and cancel programs without external review.[102] The MDA was also exempted from standard reporting and oversight on the program's technological progress and cost increases.[103] These exceptions allowed the MDA to circumvent rigorous knowledge-based acquisition processes that otherwise might have averted many of the deficiencies that now plague the efforts to develop a kill vehicle.[104] The next iteration of a kill vehicle, the Next-Generation Interceptor (NGI), is estimated to cost $18 billion and is not expected to be ready until the late 2020s.[105] Even if a high-reliability interceptor eventually emerges from the NGI program, it must overcome the enduring conceptual flaw of the GMD system: the countermeasures challenge.

CONCEPTUAL FLAW: THE COUNTERMEASURES CHALLENGE

Like all midcourse defense systems, the GMD system is vulnerable to countermeasures.[106] This vulnerability of midcourse missile defense systems has long been well understood. Former Secretary of Defense James Schlesinger, recounting the U.S. reaction to Soviet missile defense deployments in the 1960s, writes that the Soviet deployment provoked extensive research to defeat the Soviet defenses.[107] In a short time, the United States had developed a variety of countermeasures to confuse, deceive, and evade Soviet missile defenses.[108] A high-altitude nuclear detonation is a particularly effective countermeasure.[109] In the case of the GMD system, North Korea could detonate a warhead just outside the range of GMD interceptors, warheads could be designed to deto-

102. Grego, Lewis, and Wright, *Shielded from Oversight*, p. 10.
103. For more details, see GAO, "Missile Defense: Fiscal Year 2020 Delivery and Testing Progressed, but Annual Goals Unmet," pp. 5–6.
104. GAO, "Missile Defense: Observations on Ground-Based Midcourse Defense Acquisition Challenges and Potential Contract Strategy Changes," p. 6.
105. Jen Judson, "Next-Gen Intercontinental Ballistic Missile Interceptor Estimated Cost? Nearly $18B," *Defense News*, April 27, 2021, https://www.defensenews.com/pentagon/2021/04/27/next-gen-intercontinental-ballistic-missile-interceptor-estimated-to-cost-nearly-18-billion/.
106. Andrew M. Sessler et al., *Countermeasures: A Technical Evaluation of the Operational Effectiveness of the Planned US National Missile Defense System* (Cambridge, Mass.: Union of Concerned Scientists and MIT Security Studies Program, 2019), https://www.ucsusa.org/sites/default/files/2019-09/countermeasures.pdf.
107. James R. Schlesinger, "Rhetoric and Realities in the Star Wars Debate," *International Security*, Vol. 10, No. 1 (Summer 1985), p. 3, https://doi.org/10.2307/2538787.
108. Hans A. Bethe, "Countermeasures to ABM Systems," in Abram Chayes and Jerome B. Wiesner, eds., *ABM: An Evaluation of the Decision to Deploy an Antiballistic Missile System* (New York: Harper and Row, 1969), p. 130; and York, "Military Technology and National Security," p. 18.
109. Charles L. Glaser and Steve Fetter, "Should the United States Reject MAD? Damage Limitation and U.S. Nuclear Strategy toward China," *International Security*, Vol. 41, No. 1 (Summer 2016), p. 77, https://doi.org/10.1162/ISEC_a_00248.

nate upon interceptor impact, or an intercept could lead to a nuclear detonation of a warhead that is not one-point safe.[110] In all these three instances, the resulting nuclear explosion would ionize a large volume of space, making accurate radar tracking of follow-on warheads impractical.[111]

Decoys remain a major, if not insurmountable, countermeasure to the GMD system. Decoys such as lightweight balloons follow the same flight path as missile warheads in the vacuum of space, making it difficult to distinguish between decoy and warhead using only their trajectories. Moreover, hiding a warhead inside a balloon (i.e., an anti-simulation decoy) is an effective countermeasure. As Richard Garwin writes, "it may be very costly and difficult to make decoys which resemble in all observable respects real warheads in space, but it becomes a lot easier if the warhead is first modified or enclosed in a balloon so that it looks like a cheap decoy."[112] A 2010 study by the scientific advisory group, JASON, conducted at the request of the U.S. Congress, concluded that "given a reasonable amount of time, money, initiative, and expertise, the offense can (in principle) field countermeasures that the defense cannot handle at any reasonable marginal cost."[113]

There is no evidence to indicate that the GMD system has overcome this challenge. Additionally, a 2019 GAO report found that a "culture exists within the [missile defense] agency that generally tolerates the use of [threat] models that have not been sufficiently vetted" and the agency "is too willing to accept the associated risk."[114] The report further noted that the MDA restricts the DIA's "insight into and input on" developing accurate threat models, even though it is uniquely capable of assisting the MDA.[115] Given these limitations, analysts question the GMD system's ability to respond to countermeasures,

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110. One-point safety is a required criterion in U.S. nuclear weapons manufacturing. A nuclear weapon is considered one-point safe if, "when the high explosive (HE) is initiated and detonated at any single point, the probability of producing a nuclear yield exceeding 4 pounds of trinitrotoluene (TNT) equivalent is less than one in 10^6." Assistant to the Secretary of Defense for Nuclear and Chemical and Biological Defense Programs, *DoD Nuclear Weapon System Safety Program Manual* (Washington, D.C.: U.S. Department of Defense, December 1996), p. 9, https://www.hsdl.org/?view&did=501.

111. This phenomenon is detailed in Hans A. Bethe, "Countermeasures to ABM Systems," pp. 135–142.

112. Richard L. Garwin, "Enforcing BMD against a Determined Adversary?" in Bhupendra Jasani, ed., *Space Weapons and International Security* (New York: Oxford University Press, 1987), pp. 71–84.

113. JASON, "MDA Discrimination," Unclassified Summary (McLean, Va.: MITRE, August 3, 2010), p. 3, https://fas.org/irp/agency/dod/jason/mda-dis.pdf. JASON is an independent scientific advisory group established in the 1960s to provide classified and unclassified analysis to various agencies of the U.S. government. A list of reports authored by JASON can be found at Federation of American Scientists (FAS), "JASON Defense Advisory Panel Reports," undated, https://irp.fas.org/agency/dod/jason/.

114. GAO, "Missile Defense: Further Collaboration with the Intelligence Community Would Help MDA Keep Pace with Emerging Threats," p. 35.

115. Ibid., pp. 24, 25, 30.

unexpected launch scenarios, or incomplete sensor data during an actual North Korean attack.[116]

Based on available evidence, we argue that there is no lasting technical solution to the countermeasures challenge.[117] North Korea might have access to Russian or Chinese countermeasures, which are technologically mature and are designed to breach the GMD system.[118] Additionally, as long as it is easier to refine countermeasures than to update the GMD system, any GMD system refinements are unlikely to overcome this enduring conceptual flaw.

The Geopolitical Cost of National Missile Defense

Despite its programmatic failures and vulnerability to countermeasures, national missile defense is at the core of strategic stability concerns in U.S.-Russia and U.S.-China relations. U.S. leaders have insisted that national missile defense is essential to address North Korean ballistic missile threats to the continental United States. U.S. administrations have also consistently argued that these defenses could not alter the strategic stability with Russia or China and their intended purpose is not to do so. The 2020 National Defense Authorization Act, for instance, states that the United States relies on nuclear deterrence "to address more sophisticated and larger quantity near-peer intercontinental missile threats to the homeland."[119] Similarly, the 2019 Ballistic

116. Grego, Lewis, and Wright, *Shielded from Oversight*, pp. 30–31. See also Institute for Defense Analyses (IDA), "IDA's Response to Questions on the 'Independent Review and Assessment of the Ground-Based Midcourse Defense System,'" *IDA*, April 11, 2012, pp. 1, 4.
117. Advances in sensors may offer short-term reprieve. A 2012 National Academies study argued that X-band radars and interceptor optical sensors offered some hope that "in the near term," there is a "reasonable chance" that the United States could stay ahead of the countermeasures challenge. See National Research Council, *Making Sense of Ballistic Missile Defense: An Assessment of Concepts and Systems for U.S. Boost-Phase Missile Defense in Comparison to Other Alternatives* (Washington, D.C.: National Academies Press, 2012), p. 10. The Space Development Agency is building the Hypersonic and Ballistic Tracking Space Sensor (HBTSS). HBTSS, like the Space Tracking and Surveillance System (STSS), is advertised as capable of birth-to-death tracking from space. See Nathan Strout, "After More than a Decade, Agency to Retire Experimental Missile Warning Satellites," *C4ISRNET*, May 13, 2021, https://www.c4isrnet.com/battlefield-tech/space/2021/05/13/after-more-than-a-decade-agency-to-retire-experimental-missile-warning-satellites/. The 2012 National Academies study argued, however, that such space-based sensors would contribute "little if anything to midcourse discrimination." See National Research Council, *Making Sense of Ballistic Missile Defense*, p. 16.
118. A 1999 National Intelligence Estimate assessed that Russia and China may sell numerous countermeasures technologies to North Korea. See National Intelligence Council, "Foreign Missile Developments and the Ballistic Missile Threat to the United States through 2015" (Washington, D.C.: National Intelligence Council, September 1999), p. 16, https://www.dni.gov/files/documents/Foreign%20Missile%20Developments_1999.pdf. This assessment still seems valid.
119. United States Congress S. 1790, National Defense Authorization Act for Fiscal Year 2020, 116th Cong., 1st sess., January 3, 2019, p. 584, https://www.congress.gov/116/bills/s1790/BILLS-116s1790enr.pdf.

Missile Defense Review conducted by the Donald Trump administration states that the "United States relies on deterrence to protect against large and technically sophisticated Russian and Chinese intercontinental ballistic missile threats to the U.S. homeland."[120] The *Nuclear Posture Review* and the *National Security Strategy* released by the Trump administration made similar assertions.[121] The *Ballistic Missile Defense Review* and the *Nuclear Posture Review* conducted under the Barack Obama administration in 2010 declared that preserving strategic stability with Russia and China was an important goal.[122] U.S. policymakers have pointed out that Russia's deployed strategic weapons can easily defeat the comparatively limited number of GMD interceptors.[123] Similarly, a 2012 report drafted by an International Security Advisory Board of the U.S. State Department notes that China is "determined to maintain a credible nuclear deterrent regardless of U.S. choices and will almost certainly have the necessary financial and technological resources to continue to do so. Accordingly, mutual nuclear vulnerability should be considered a fact of life for both sides."[124] Despite these facts, Russia and China have remained deeply skeptical about the limited scope of U.S. homeland missile defense.

In the next two subsections, we explore Russia's and China's respective arguments about how U.S. national missile defense diminishes their nuclear deterrent, and we summarize several weapons' modernization initiatives that both states claim are driven by U.S. missile defenses.

RUSSIA ON U.S. NATIONAL MISSILE DEFENSE

Russian leaders have consistently linked increases in their nuclear arsenal to U.S. missile defenses. In the 1990s, during negotiations on amending the ABM Treaty, Russians vehemently argued that a national missile defense system

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120. U.S. Department of Defense, *2019 Missile Defense Review*, p. iii.
121. Office of the Secretary of Defense, *Nuclear Posture Review* (Washington, D.C.: U.S. Department of Defense, 2018), pp. 30–32, 33, https://media.defense.gov/2018/Feb/02/2001872886/-1/-1/1/2018-NUCLEAR-POSTURE-REVIEW-FINAL-REPORT.PDF; and White House, *National Security Strategy of the United States of America* (Washington, D.C.: White House, December 2017), p. 8, https://trumpwhitehouse.archives.gov/wp-content/uploads/2017/12/NSS-Final-12-18-2017-0905.pdf.
122. U.S. Department of Defense, *Ballistic Missile Defense Review Report* (Washington, D.C.: U.S. Department of Defense, February 2010), p. 34, https://dod.defense.gov/Portals/1/features/defenseReviews/BMDR/BMDR_as_of_26JAN10_0630_for_web.pdf; and U.S. Department of Defense, *Nuclear Posture Review Report* (Washington, D.C.: U.S. Department of Defense, April 2010), pp. 4, 29, https://dod.defense.gov/Portals/1/features/defenseReviews/NPR/2010_Nuclear_Posture_Review_Report.pdf.
123. U.S. Department of Defense, "Layered Homeland Missile Defense: A Strategy for Defending the United States," p. 3.
124. International Security Advisory Board, "Report on Maintaining U.S.-China Strategic Stability" (Washington, D.C.: U.S. Department of State, 2012), p. 3, https://2009-2017.state.gov/documents/organization/200473.pdf.

once deployed could not be meaningfully limited without arms control agreements.[125] They threatened asymmetrical response to thwart any perceived dangers to the Russian nuclear deterrent.[126] Strobe Talbott, President Clinton's chief negotiator, writes that Russians worried that once the architecture was in place, it could be expanded significantly within a short period.[127] He recounts that the Russians, basing their position on a worst-case scenario, calculated that the United States may be able to use precision weaponry to disable 90 percent of the Russian deterrent.[128] Even a limited missile defense system could then intercept the nuclear forces that might survive a U.S. first strike. Talbott writes that while the Russians acknowledged nuclear war was unthinkable, they also believed the combination of missile defenses and highly capable nuclear forces would "leave them vulnerable to nuclear intimidation in a political crisis."[129]

These concerns have persisted. Russian military analysts regularly write about a future war in which a massive air-missile strike campaign could be mounted against Russia's nuclear deterrent, using U.S. and NATO high-precision conventional weapons.[130] U.S. missile defense would further degrade Russia's retaliatory potential, leaving Russia vulnerable to coercion.[131] Although elements within Russia's military-industrial complex often exaggerate these fears, several Russian analysts have raised concerns about U.S. technological dominance facilitating a coordinated high-precision aerospace strike that theoretically could overcome limited Russian defenses.[132]

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125. Strobe Talbott, "Unfinished Business: Russia and Missile Defense under Clinton," *Arms Control Today*, June 2002, https://www.armscontrol.org/act/2002-06/features/unfinished-business-russia-missile-defense-under-clinton.
126. Ibid.
127. Ibid.
128. Ibid.
129. Ibid.
130. Igor Morozov, Baushev Sergey, and Kaminsky Oleg, "Kosmos i kharakter sovremennykh voyennykh deystviy" [Space and the nature of modern military operations], *Vozdushno-Kosmicheskaya Oborona* [Aerospace Defense], August 11, 2009, http://www.vko.ru/koncepcii/kosmos-i-harakter-sovremennyh-voennyh-deystviy.
131. "Kommentariy Departamenta Informatsii i Pechati MID Rossii v Svyazi s Novym «Obzorom Politiki SSHA v Sfere PRO»—Novosti—Ministerstvo Inostrannykh Del Rossiyskoy Federatsii" [Commentary by the department of information and press of the Russian foreign ministry in connection with the new 'review of U.S. missile defense policy'], *Ministry of Foreign Affairs of the Russian Federation*, January 18, 2019, https://www.mid.ru/ru/foreign_policy/news/-/asset_publisher/cKNonkJE02Bw/content/id/3479839.
132. Some Russian analysts have noted that the threat of a technologically advanced, high-precision aerospace campaign is "eagerly embraced as a new and fascinating domain of seemingly endless competition with a worthy counterpart" to justify large defense budgets for Russia's military-industrial complex. See Alexey Arbatov, Vladimir Dvorkin, and Petr Topychkanov, "Entanglement as a New Security Threat: A Russian Perspective," in James M. Acton, ed., *Entanglement: Chinese and Russian Perspectives on Non-nuclear Weapons and Nuclear Risks* (Washington, D.C.: Carnegie Endowment for International Peace, 2017), pp. 17, 30.

In his March 2018 presidential address to the Russian Federal Assembly, Putin claimed that U.S. national missile defense "will result in the complete devaluation of Russia's nuclear" deterrence forces.[133] He argued that while the number of nuclear delivery vehicles and weapons is being reduced bilaterally, the United States is unilaterally pursuing several ballistic missile defense systems.[134] Putin outlined the development of several new Russian strategic nuclear weapon systems to counter U.S. missile defenses, including the Sarmat heavy ICBM equipped with hypersonic warheads.[135] He argued that the increased range of the Sarmat ICBM would also allow attacks from the southern hemisphere to avoid U.S. missile defense radars and interceptors deployed in Alaska and other parts of the northern hemisphere. President Putin discussed several other delivery systems—including the Avangard hypersonic boost-glide vehicle, the Kinzhal air-launched hypersonic missile, the Tsirkon hypersonic cruise missile, the Poseidon nuclear-powered torpedo, and the Burevestnik nuclear-powered cruise missile. We find that the common element among these systems is that their technological features would make little or no sense apart from their determination to evade and defeat missile defenses.

Russia also uses U.S. missile defenses to justify other actions. For instance, in 2018, when President Trump charged Russia with violating the 1987 Intermediate-Range Nuclear Forces (INF) Treaty, Russian Deputy Foreign Minister Sergey Ryabkov countered that the U.S. deployment of the Mk-41 ground-based Aegis Ashore missile defense system in Europe was a violation of the INF Treaty.[136] Similarly, Russian analysts claim that Russia's pursuit of anti-satellite weapons is a way to pressure the United States to undertake serious talks on missile defense.[137]

CHINA ON U.S. NATIONAL MISSILE DEFENSE

Many Chinese analysts discount the need for missile defenses to defeat the North Korean threat to the United States and argue that China's strategic missiles are the real target of the GMD system.[138] U.S. reassurances that its missile defenses are not intended to neutralize the Chinese strategic deterrent are not

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133. Putin, "Presidential Address to the Federal Assembly," 2018.
134. Ibid.
135. Jill Hruby, "Russia's New Nuclear Weapon Delivery Systems: An Open-Source Technical Review" (Washington, D.C.: Nuclear Threat Initiative, November 2019), https://media.nti.org/documents/NTI-Hruby_FINAL.PDF.
136. "Russia Slams US Aegis Ashore Missile Deployment in Europe as Direct Breach of INF Treaty," *TASS: Russian News Agency*, November 26, 2018, https://tass.com/politics/1032585.
137. Alexei Arbatov and Vladimir Dvorkin, eds., *Outer Space: Weapons, Diplomacy, and Security* (Washington, D.C.: Carnegie Endowment for International Peace, 2010), p. xi.
138. Tong Zhao, "Narrowing the U.S.-China Gap on Missile Defense: How to Help Forestall a Nuclear Arms Race" (Washington, D.C.: Carnegie Endowment for International Peace, 2020), p. 36.

seen as an accurate reflection of U.S. plans by Chinese experts, who argue that U.S. promises of restraint are ephemeral and easily revoked, as evidenced by the unilateral withdrawal from the ABM Treaty.[139] Chinese experts often note that while the system being deployed now may be limited, it could be repurposed quickly and easily to target China's second-strike capability.[140] According to Chinese experts, logistical and technological limitations rather than coherent policy choices to preserve strategic stability with China are what drive the deployment patterns of U.S. missile defenses.[141]

Chinese analysts warn that U.S. missile defense deployments will provoke a nuclear arms race.[142] Chinese leaders posit an expansion in China's nuclear arms and postures, including the possibility of placing its nuclear forces under a launch-on-warning high alert system, as a possible response to U.S. missile defenses.[143] Indeed, as noted in the *Economist* in July 2021, the recent construction of hundreds of new missile silos may be part of this response.[144] Baohui Zhang takes this analysis a step further by suggesting that China's anti-satellite capabilities should target U.S. early-warning satellites, which play a vital role in missile defense efforts.[145]

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139. Lora Saalman, "The China Factor," in Alexei Arbatov and Vladimir Dvorkin, eds., *Missile Defense: Confrontation and Cooperation*, trans. Natalia Bubnova (Moscow: Carnegie Moscow Center, 2013), pp. 233, 242, https://www.files.ethz.ch/isn/163188/Missile_Defense_book_eng_fin2013 .pdf.
140. Lora Saalman, *China and the U.S. Nuclear Posture Review* (Beijing: Carnegie-Tsinghua Center for Global Policy, 2011), p. 24, https://carnegieendowment.org/files/china_posture_review.pdf; and Zhao, "Narrowing the U.S.-China Gap on Missile Defense," p. 18.
141. Ralph Cossa, Brad Glosserman, and Matt Pottinger, "Progress Despite Disagreements: The Sixth China-US Strategic Dialogue on Strategic Nuclear Dynamics," *Issues & Insights*, Vol. 12, No. 5 (November 2011), pp. 12, 30, 36, https://csis-website-prod.s3.amazonaws.com/s3fs-public/legacy_files/files/publication/issuesinsights_vol12no05.pdf.
142. Christopher P. Twomey et al., "The U.S.-China Strategic Dialogue: Phase IX Report" (Monterey, Calif.: Naval Postgraduate School, December 2016), p. 5, https://www.hsdl.org/?abstract&did=799076. Often Chinese opposition to U.S. missile defenses also reflect other geopolitical goals. Tong Zhao suggests that Beijing views its regional conventional missiles as "foundational to its national security" and fears that any attempts to shield regional U.S. and allied forces from China's conventional missiles will embolden the United States and its allies in a regional conflict. See Zhao, "Narrowing the U.S.-China Gap on Missile Defense," pp. 24–25. A review of Chinese regional missile capabilities and U.S. and allied regional missile defense counter-efforts can be found in Jaganath Sankaran, "Missile Wars in the Asia Pacific: The Threat of Chinese Regional Missiles and U.S.-Allied Missile Defense Response," *Asian Security*, Vol. 17, No. 1 (2021), pp. 25–45, https://doi.org/10.1080/14799855.2020.1769069; and Jaganath Sankaran, "Missile Defenses and Strategic Stability in Asia: Evidence from Simulations," *Journal of East Asian Studies*, Vol. 20, No. 3 (November 2020), pp. 485–508, https://doi.org/10.1017/jea.2020.10.
143. Office of the Secretary of Defense, "Annual Report to Congress: Military and Security Developments Involving the People's Republic of China 2019" (Washington, D.C.: Department of Defense, 2019), p. 67, https://media.defense.gov/2019/May/02/2002127082/-1/-1/1/2019_CHINA_MILITARY_POWER_REPORT.pdf.
144. "China Is Rapidly Building New Nuclear-Missile Silos," *Economist*, July 31, 2021, https://www.economist.com/china/2021/07/31/china-is-rapidly-building-new-nuclear-missile-silos.
145. Baohui Zhang, "The Security Dilemma in the U.S.-China Military Space Relationship: The Prospects for Arms Control," *Asian Survey*, Vol. 51, No. 2 (March/April 2011), p. 321, https://

How to Counter North Korea while Preserving Strategic Stability

The growing North Korean nuclear arsenal is a threat to U.S. national security.[146] As our evidence shows, the GMD system seems unable to offer a reliable defense. Bipartisan consensus in the United States rejects relying solely on diplomacy or deterrence against North Korea. Diplomatic engagement with North Korea is, at best, expected to lead to incremental steps toward limited reductions in North Korean capabilities.[147] We believe deterrence is still the only way to prevent unconventional means of nuclear weapon delivery (e.g., launching short-range missiles from surface ships near the U.S. coast or smuggling weapons into a U.S. city). In a militarized crisis, however, North Korea is expected to threaten an ICBM nuclear attack on the United States to try to bargain for a favorable outcome.[148] Against such threats, U.S. policy places considerable weight on national missile defense.

We suggest that an airborne BPI missile defense system is a sensible alternative to the GMD system. Airborne BPI systems could defend the United States against current North Korean ICBMs without imposing an undue burden on strategic stability concerns associated with midcourse defenses. Airborne BPI systems would be designed to intercept North Korean ICBMs within minutes after launch, before an adversary can deploy decoys, thereby avoiding the conceptual flaw that afflicts the GMD system.[149] But airborne BPI is infeasible against Russia or China because of the countries' expansive geographies and effective air defenses. Additionally, airborne BPI missile defenses are unable to defend against several possible locations of Russian or Chinese submarine-launched ballistic missiles (SLBMs). In the remainder of this article, we examine the concept's viability given recent technological innovations.

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doi.org/10.1525/as.2011.51.2.311. For a review of Chinese anti-satellite capabilities, see Jaganath Sankaran, "Limits of the Chinese Antisatellite Threats to the United States," *Strategic Studies Quarterly* (Winter 2014), pp. 20–47, https://www.airuniversity.af.edu/Portals/10/SSQ/documents/Volume-08_Issue-4/Sankaran.pdf.

146. U.S. Department of Defense, *2019 Missile Defense Review*, p. iv.

147. Victor Cha, "The Biden-Moon Summit: Rejuvenating and Modernizing the Alliance," *CSIS*, May 19, 2021, https://www.csis.org/analysis/biden-moon-summit-rejuvenating-and-modernizing-alliance.

148. Charles L. Glaser and Steve Fetter, "National Missile Defense and the Future of U.S. Nuclear Weapons Policy," *International Security*, Vol. 26, No. 1 (Summer 2001), p. 54, https://doi.org/10.1162/016228801753212859.

149. Some forms of countermeasures, such as salvo launches and deliberate boost-phase trajectory maneuvers, complicate boost-phase defenses. But they are much more costly and complicated to execute than midcourse decoys. David K. Barton et al., "Report of the American Physical Society Study Group on Boost-Phase Intercept Systems for National Missile Defense: Scientific and Technical Issues," *Reviews of Modern Physics*, Vol. 76, No. 3 (July–September 2004), pp. 145–153, https://doi.org/10.1103/RevModPhys.76.S1.

AIRBORNE BPI DEFENSES

The idea of boost-phase missile defense is not new. Space-based boost-phase missile defense efforts have been suggested as far back as the 1950s.[150] After the Cold War, attention shifted to limited ground-based and airborne boost-phase missile defense systems. For example, Garwin proposed a cooperative missile defense architecture that would utilize hit-to-kill interceptors stationed in Russia or near North Korea's coast.[151] In a 2000 *Foreign Policy* article, John Deutch, Harold Brown, and John P. White argued for developing naval platforms that could host boost-phase interceptors with significant capability against North Korea, noting that such a solution would be more responsive to Russian concerns.[152] Many other studies have debated the possibilities and merits of land-based and airborne boost-phase missile defenses.[153] Yet, research and experimentation on boost-phase systems have been haphazard and uncoordinated.[154]

We evaluate how a variety of recent technological advances may affect the ability of airborne interceptors to kinematically reach a boosting North Korean ICBM. Kinematic reach indicates the ability of airborne interceptors to arrive in the same region of space occupied by the North Korean missile at the same

150. See Donald R. Baucom, "The Rise and Fall of Brilliant Pebbles 1," in Jeremy Black and Jeffrey Charleston, eds., *United States Military History: 1865 to the Present Day* (London: Routledge, 2006); and Keith B. Payne, *Missile Defense in the 21st Century: Protection against Limited Threats* (New York: Routledge, 1991).

151. Richard L. Garwin, "Berkeley Physics Graduation Speech," Berkeley, California, May 19, 2000, *Federation of American Scientists*, https://fas.org/rlg/000519-berkeley.htm. Charles Glaser and Steve Fetter propose a similar architecture. See Glaser and Fetter, "National Missile Defense and the Future of U.S. Nuclear Weapons Policy," p. 53.

152. John Deutch, Harold Brown, and John P. White, "National Missile Defense: Is There Another Way?" *Foreign Policy*, Summer 2000, pp. 92, 98–99.

153. A very detailed study on boost-phase missile defenses is Barton et al., "Report of the American Physical Society Study Group on Boost-Phase Intercept Systems for National Missile Defense." Dissenting views against this study can be found in Richard L. Garwin, "Boost-Phase Missile Defense Debate Continues," *Physics Today*, July 2004, https://physicstoday.scitation.org/doi/full/10.1063/1.4796588; and Dean Wilkening, "Boost-Phase Missile Defense Debate Continues," *Physics Today*, July 2004, https://physicstoday.scitation.org/doi/pdf/10.1063/1.1784286. See also Dean A. Wilkening, "Airborne Boost-Phase Ballistic Missile Defense," *Science & Global Security*, Vol. 12, Nos. 1–2 (2004), pp. 1–67; and Congressional Budget Office (CBO), *Alternatives for Boost-Phase Missile Defense* (Washington, D.C.: CBO, July 2004), https://www.cbo.gov/sites/default/files/108th-congress-2003-2004/reports/07-22-missiledefense.pdf. Both Dean Wilkening and the CBO study were optimistic about boost-phase missile defense. Other prominent studies on boost-phase missile defense include F.S. Nyland, "Exploring Boost Phase Intercept Concepts for Theater Missile Defense" (Washington, D.C.: U.S. Arms Control and Disarmament Agency, November 1995); and David R. Vaughan, Jeffrey A. Isaacson, and Joel S. Kvitky, *Airborne Intercept: Boost- and Ascent-Phase Options and Issues* (Santa Monica, Calif.: RAND, 1996), https://www.rand.org/pubs/monograph_reports/MR772.html.

154. A review of recent experimental work on boost-phase missile defenses can be found in Jaganath Sankaran and Steve Fetter, "Reexamining Homeland Missile Defense against North Korea," *Washington Quarterly*, Vol. 43, No. 3 (2020), pp. 47–62, https://doi.org/10.1080/0163660X.2020.1813400.

point in time, after which a kill vehicle takes over and performs a hit-to-kill collision with the quarry.[155] The interceptor basing area plots discussed below indicate the kinematic reach of airborne BPI systems. There are two steps involved in developing the interceptor basing area plots. First, a planar (head-on) engagement between the ICBM and the interceptor is modeled. Then, using the interceptor ground range in a planar engagement as the radius, a circle is drawn centered on the ground intercept point. The circle represents interceptor basing areas for non-planar engagements.[156]

We examine advances in two subsystems—launch platforms and interceptors—to determine variation in the performance of an airborne BPI system. These two subsystems are the most crucial to understanding the performance, and potential, of an airborne BPI system.[157]

A SURVEY OF RECENT TECHNOLOGICAL ADVANCES

Several technological advances have occurred with launch platforms. Long-endurance UAVs armed with interceptors can theoretically loiter for a day while stationed outside North Korean airspace.[158] James Goodby and Theodore Postol have proposed using the big-wing variant of the MQ-9 Reaper (Predator-B) UAV to execute airborne boost-phase intercepts of North Korean ICBMs. They note that the long-endurance Predator-B UAV may be able to loiter at 15 kilometers altitude for twenty-four hours, carrying 1,350 kilograms of interceptor payload.[159] The Reaper UAV offers a baseline to examine the viability of airborne BPI systems.

Our preliminary examination of the North Korean air defense network indi-

155. A more accurate technical simulation would require detailed modeling of the endgame of the interception. While kinematic reach does not always imply successful interception, it does indicate the ability of the combination of airborne platform and interceptors modeled to possess the means to get the kill vehicle close enough to the quarry to attempt interception, which is a principal requirement of any viable airborne BPI system.

156. For details on the process, see Barton et al., "Report of the American Physical Society Study Group on Boost-Phase Intercept Systems for National Missile Defense," pp. 55–60.

157. Other technical parameters, however, also influence the performance of a BPI missile defense system. For instance, the plume-to-hardbody handover problem is a challenge in BPI. See CBO, "Alternatives for Boost-Phase Missile Defense," p. 51. We leave exploration of other technical parameters to future work.

158. See Garrett Reim, "General Atomics Unveils 'Ultra-long Endurance' Replacement for MQ-9 Reaper," *FlightGobal*, September 14, 2020, https://www.flightglobal.com/military-uavs/general-atomics-unveils-ultra-long-endurance-replacement-for-mq-9-reaper/140162.article.

159. James E. Goodby and Theodore A. Postol, "A New Boost-Phase Missile Defense System—and Its Diplomatic Uses in the North Korean Dispute," *Bulletin of the Atomic Scientists*, Vol. 74, No. 4 (2018), p. 211, https://doi.org/10.1080/00963402.2018.1486578. A Department of Defense report on the regular version MQ-9 Reaper notes that it can operate at 50,000 feet with an external payload of 3,000 pounds for a duration of fourteen hours. See Director of Operational Test and Evaluation, "FY 2017 Annual Report: MQ-9 Reaper Armed Unmanned Aircraft System (UAS)" (Washington, D.C.: Office of Operational Test and Evaluation, U.S. Department of Defense, January 2018), p. 269, https://www.dote.osd.mil/Portals/97/pub/reports/FY2017/af/2017mq9reaperuas.pdf?ver=2019-

cates that these UAVs may be safely stationed in the Sea of Japan. Several of North Korea's air defense assets are Soviet equipment from the 1960s and 1970s.[160] North Korea possesses some radar systems that might track UAVs operating at a more considerable distance outside their airspace.[161] But its air defense interceptors have much shorter ranges.[162] Except for the SA-5 Gammon air defense system, most of the other systems in the North Korean inventory have an intercept range of less than 50 kilometers.[163] The SA-5 Gammon (i.e., the S-200) air defense system has the longest interceptor range (150–300 kilometers). Whether North Korea has enough SA-5 batteries to defend the entire coastline effectively, however, is unclear. Additionally, SA-5 systems may be vulnerable to electronic countermeasures because they depend on relatively unsophisticated mechanical scanning radars.[164] At a standoff distance of 300 kilometers, UAVs could be invulnerable to North Korea's air defense network.

Similarly, the North Korean Air Force may not be able to challenge UAVs operating outside its airspace. While its inventory of fighter aircraft may be large, many of them may be damaged, inactive, or ineffective in combat.[165] Additionally, North Korean aircrews "accumulate less than 30 annual flying hours" and cannot train and maintain proficiency.[166] Without a competent air force, North Korea might not keep the United States and allied fighter aircraft

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08-19-113931-413. The big wing MQ-9 Reaper has demonstrated the ability to fly as long as 37.5 hours. See Tamir Eshel, "Predator B ER Spreads Bigger Wings," *Defense Update*, June 1, 2016, https://defense-update.com/20160601_predator-b-er-spreads-bigger-wings-3.html. Further study is necessary to understand the performance of this UAV and future UAV variants that could be designed for boost-phase missile defense missions.

160. John Reed, "What Do North Korea's Air Defenses Look Like?" *Foreign Policy*, April 1, 2013, https://foreignpolicy.com/2013/04/01/what-do-north-koreas-air-defenses-look-like/.

161. North Korea's Soviet P-14 radar has an approximate range of 600 kilometers. It may also have other radar systems with a range of 200 to 300 kilometers. Additionally, it seems that North Korea has acquired phased array radars that make it possible to track multiple targets simultaneously. See Terence Roehrig, "The Abilities—and Limits—of North Korean Early Warning," *Bulletin of the Atomic Scientists*, November 27, 2017, https://thebulletin.org/2017/11/the-abilities-and-limits-of-north-korean-early-warning/.

162. Some of North Korea's air defense interceptors are SA-2 Guideline, SA-6 Gainful, SA-3 Goa, SA-13 Gopher, SA-16 Gimlets, SA-4 Ganef, SA-5 Gammon, and SA-17 Gadfly. See Reed, "What Do North Korea's Air Defenses Look Like?"

163. It is possible that North Korea's KN-06 may have ranges up to 150 kilometers. See Missile Threat, "KN-06 (Pon'gae-5)," *CSIS Missile Defense Project*, July 31, 2021, https://missilethreat.csis.org/missile/kn-06/.

164. Richard L. Garwin and Theodore A. Postol, "Airborne Patrol to Destroy DPRK ICBMs in Powered Flight" (Cambridge: Massachusetts Institute of Technology Science, Technology, and National Security Working Group, November 27–29, 2017), pp. 44–52, https://fas.org/rlg/airborne.pdf.

165. Haena Jo, "Flying against the Odds: North Korea's Air Force," *Military Balance Blog*, International Institute for Strategic Studies, February 10, 2020, https://www.iiss.org/blogs/military-balance/2020/02/north-korea-air-force.

166. Ibid.

at a far enough distance to prevent Suppression of Enemy Air Defense (SEAD) operations against its air defense forces.

Given these factors, we use 100 kilometers as the minimum standoff distance for UAVs conducting BPI missile defense patrols to perform our calculations. If SEAD aircraft and air defense escort patrols are brought into the mission, however, it may be possible to operate closer to the North Korean coast. As future UAVs acquire deep penetration and combat capabilities, the ability to perform boost-phase missile defense against North Korea might increase.

In the case of interceptors, several innovations in rocket motor manufacturing may have created new opportunities. Garwin and Postol note that advances in lightweight and small motor casing, high fuel-to-payload mass fractions, improved thrust vector control capabilities, and high exhaust velocities have made it possible to develop boost-phase interceptors that a UAV can carry. Drawing from existing rocket motors, such as the ASAS 13-30V, the STAR 37FMV, and the STAR 12GV, they propose a 5 kilometer per second airborne interceptor weighing approximately 500 kilograms and equipped with a 43-kilogram kill vehicle capable of generating 2 kilometer per second divert velocity.[167] While kill vehicle designs with mass less than 50 kilograms were proposed in the 1990s, it is only recently that advances in material science and manufacturing may have made them feasible.[168] The calculations performed in this article model a heavier 60 kilogram kill vehicle against the current Hwasong-15 ICBM, and a 50 kilogram kill vehicle against hypothetical solid-fueled ICBMs.

Our analysis starts by examining the performance of an airborne BPI system, assuming a commit time of 65 seconds after launch for liquid-fueled ICBMs and 45 seconds after launch for solid-fueled ICBMs.[169] Commit time is the time needed to determine a firing solution for the interceptor after the

167. Richard L. Garwin and Theodore A. Postol, "Technical Refinements in Design Features of the Airborne Patrol against North Korean ICBMs" (Cambridge: Massachusetts Institute of Technology Science, Technology, and National Security Working Group, May 10, 2018), pp. 4–5, https://fas.org/rlg/refine.pdf. For details on the technical parameters for these rocket motors, see Northrop Grumman, "Propulsion Products Catalog" (Falls Church, Va.: Northrop Grumman, April 5, 2016), pp. 75, 96, 118, https://www.northropgrumman.com/wp-content/uploads/NG-Propulsion-Products-Catalog.pdf. Further engineering evaluations are needed to validate these designs.

168. Wilkening, "Airborne Boost-Phase Ballistic Missile Defense," p. 20; and CBO, "Alternatives for Boost-Phase Missile Defense," p. 24. A survey of interceptors that have demonstrated boost-phase missile defense capabilities can be found in Sankaran and Fetter, "Reexamining Homeland Missile Defense against North Korea," pp. 55–56. The PAC-3 missile that is the basis for one of these interceptors has demonstrated a dual-pulse solid rocket motor that can switch thrust on and off. "Lockheed Martin's PAC-3 MSE reaches major milestone during successful flight tests," November 15, 2021, https://news.lockheedmartin.com/2021-11-15-lockheed-martins-pac-3-mse-reaches-major-milestones-during-successful-flight-tests.

169. Commit time values were determined on the basis of Barton et al., "Report of the American

ICBM launch. Postol has argued that interceptors can be committed against liquid-fueled ICBMs as early as 50 seconds after launch. He notes that at 50 seconds, an ICBM should reach an altitude of approximately 12 kilometers and should be above the cloud cover and visible to the Space Based Infrared System missile-tracking satellites, therefore providing enough data to commit an interceptor.[170]

evaluating airborne bpi missile defense system against icbm targets

Using the parameters discussed above, we performed calculations to test the airborne BPI missile defense system's performance against two ICBM targets: the liquid-fuel Hwasong-15 that North Korea tested in 2017; and a hypothetical solid-fuel ICBM that North Korea might develop in the future.[171] We modeled three North Korean launch sites to assess the airborne BPI system's robustness. The first launch site, near Wonsan, is located on the eastern coast of North Korea. The second site is in the central part of North Korea near Chagang, approximately 157 kilometers from the east coast. The third site is in the northwestern part of North Korea near Chunggangup, approximately 240 kilometers from the east coast (see online appendix).

Figure 1 shows flight trajectories of a Hwasong-15 launched from the site near Chunggangup. The figure shows the trajectories of missiles targeting several U.S. cities. Figure 1 also indicates the impact point of the trajectories if the thrust is terminated early by a successful boost-phase intercept. Figure 1 shows that if intercept occurs less than 270 seconds after the launch of a Hwasong-15 ICBM, no debris will fall on U.S. territory.

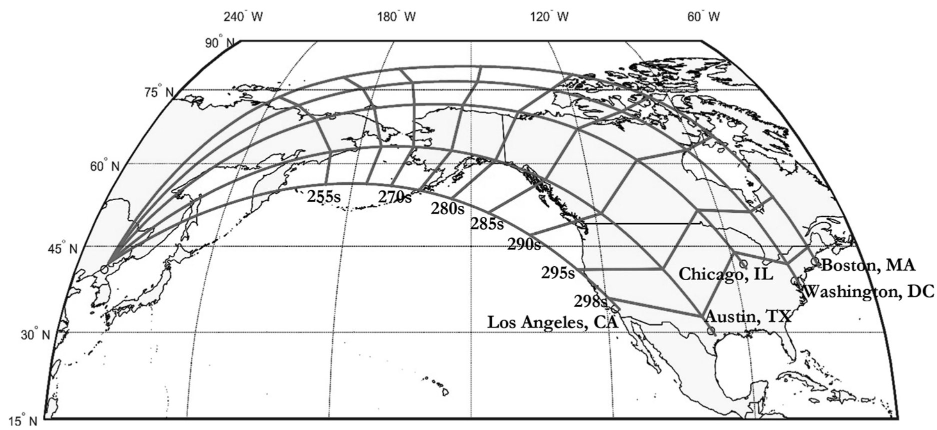
The top image in figure 2 shows the available interceptor basing areas for an engagement between a 5 kilometer per second airborne BPI and the Hwasong-15 ICBM launched from the eastern part of North Korea heading to-

Physical Society Study Group on Boost-Phase Intercept Systems for National Missile Defense," p. S23.

170. Theodore A. Postol, "North Korean Ballistic Missiles and US Missile Defense," *Physics & Society*, April 2018, p. 23. Other aircraft and ships that are equipped with modern sensors may augment satellite detection capabilities. See Sankaran and Fetter, "Reexamining Homeland Missile Defense against North Korea," pp. 54–55; and Edward J. Walsh, "New Air-Missile Defense Radar," *Proceedings*, June 2020, p. 89.

171. The parameters of the Hwasong-15 ICBM were derived from Postol, "North Korean Ballistic Missiles and US Missile Defense," pp. 16, 20. Postol models the Hwasong-15 with a total boost-phase time of 299 seconds. The appendix also illustrates the performance for a Hwasong-15 modeled with a total boost-phase time of 290 seconds. Even with the reduced boost-phase time, airborne BPI remains viable. But there is a slight degradation in performance for the challenging case of launches from the northwestern part of North Korea (near Chunggangup) toward Boston. The parameters of the model solid-fueled ICBM were derived from the model S1 ICBM detailed in Barton et al., "Report of the American Physical Society Study Group on Boost-Phase Intercept Systems for National Missile Defense," p. 265.

Figure 1. North Korean Hwasong-15 ICBM Trajectories Targeting the United States



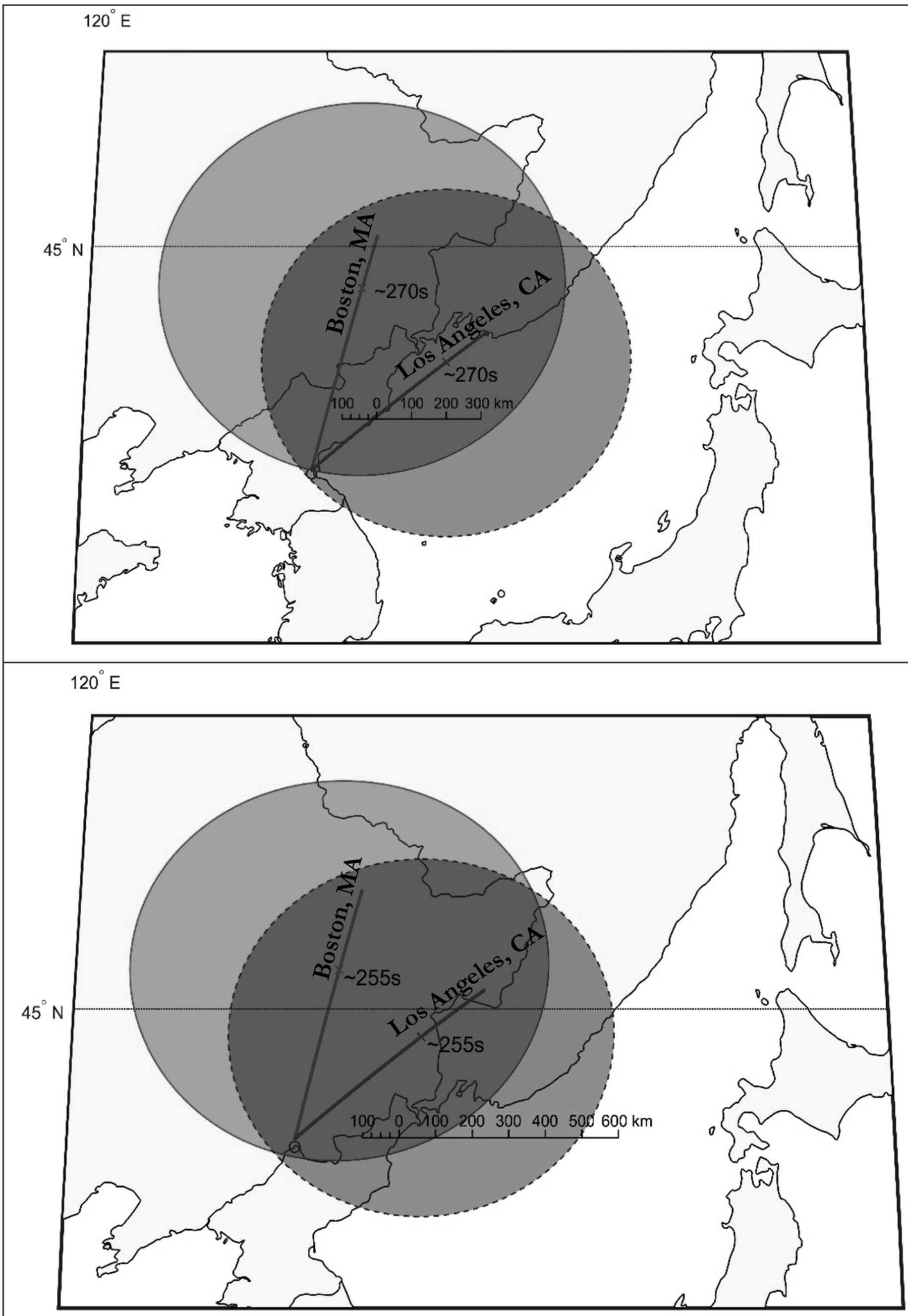
NOTE: The launch site for this ICBM is from the northwestern launch site near Chunggangup. The time contours across the trajectories denote the impact point of the missile payload if interception occurs at that time in the missile's boost-phase.

ward Boston and Los Angeles, respectively. Boston and Los Angeles are depicted in the figure because they capture the range of launch angles for North Korean ICBMs targeting the continental United States. Missiles heading toward Boston (or other sites in the eastern part of the United States) are the most challenging trajectories because their flight paths bend away from UAVs stationed in the Sea of Japan. The top image indicates that against Hwasong-15 ICBMs launched from the site near Wonsan, UAVs can maintain a distance of 300 kilometers from the North Korean coast and engage the ICBM at or below the 270 seconds threshold needed to prevent debris impact on U.S. territory.

The bottom image in figure 2 shows the basing area plots for the most challenging case for the airborne BPI system—launches from the northwestern part of North Korea, near Chunggangup. Against these launches, intercept is possible at approximately 255 seconds from a UAV stationed 100 kilometers from the North Korean coast.[172] These results were obtained using a 60 kilogram kill vehicle and a commit time of 65 seconds; if, as noted above, lighter kill vehicles or shorter commit times are attainable, the UAVs could have higher standoff distances. These preliminary results indicate that airborne BPI defenses against liquid-fueled Hwasong-15 ICBMs may be feasible.

172. Against ICBMs launched from the central part of North Korea, intercept is possible at approximately 210 seconds after the ICBM launch. At 210 seconds, a UAV can be stationed at 200 kilometers (see online appendix).

Figure 2. Interceptor Basing Area Plots for North Korean Hwasong-15 ICBM



NOTE: The top image plots the interceptor basing area against ICBMs launched from Wonsan, North Korea, and heading toward Boston and Los Angeles, respectively. The bottom image plots the interceptor basing area against ICBMs launched from Chunggangup, North Korea, heading toward Boston and Los Angeles, respectively. In each image, the circle with the dashed line shows the extent of the basing area for ICBMs heading to Los Angeles, and the circle with the solid line shows the extent of the basing area for ICBMs heading to Boston.

Against a hypothetical faster-burning solid-fuel ICBM (with a boost phase of 170 seconds) that North Korea might acquire in the future, the performance of the airborne BPI missile defense system degrades. As shown in the online appendix, against certain trajectories launched from the eastern and central regions of North Korea, defense may be possible while maintaining a standoff distance of 100 kilometers, but not for missiles launched from the northwestern part of North Korea targeting the eastern part of the United States.[173] This result indicates that parts of North Korea may be safe zones for the launch of solid-fuel ICBMs against some U.S. targets. But the ability to intercept missiles from every part of North Korea against every possible target in the United States may be unnecessary. A less-than-perfect defense that covers a significant portion of the country could bolster deterrence, because North Korea would be uncertain about the true capability of the defense. If deterrence fails, we argue that a less-than-perfect but more reliable system could be a better alternative to the GMD system. Future technological advances, such as higher velocity interceptors or UAVs that are stealthy enough to operate inside North Korean airspace, may remove these limitations against eventual solid-fueled North Korean ICBMs.[174]

It is worth noting that boost-phase intercept of solid-fuel ICBMs launched against U.S. targets from North Korean safe zones would be feasible if the UAVs could be stationed in China or Russia, near North Korea's borders. This would, of course, require close military cooperation between the United States and China or Russia. Although the political barriers to such cooperation appear enormous, Russia or China might prefer such cooperation to the unconstrained deployment of U.S. missile defense systems that they believe could threaten their nuclear deterrent.

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173. The results are specific to interception at 145 seconds. While the intercept of the modeled solid-fueled ICBM must occur within 145 seconds of launch to avoid debris impact on U.S. territory, a successful intercept after 145 seconds is still likely to reduce damage, even if debris does fall on U.S. territory. For instance, if intercept occurs 165 seconds after launch (just 5 seconds before the end of boost-phase), debris from an ICBM heading toward Los Angeles, California, or Boston, Massachusetts, would fall in either the Pacific Ocean or the Hudson Bay. Debris from an ICBM heading toward Austin, Texas, would fall approximately thirty-five miles from Cody, Wyoming. While the Austin metropolitan area population is 2.2 million, Cody's population is 10,000. Boost-phase intercept any time before burnout would reduce the loss of life from an attack. We leave exploration of late boost-phase interception to future work.

174. UAVs such as X-47B, Avenger, UCLASS, and Phantom Ray are some examples of technologies under development. See Jeremiah Gertler, "U.S. Unmanned Aerial Systems" (Washington, D.C.: Congressional Research Service, January 3, 2012), https://fas.org/sgp/crs/natsec/R42136.pdf. For a short write-up on the debate unfolding within the United States on the future combat role of UAVs, see Sydney J. Freedberg Jr., "Mabus Sticks with UCLASS Approach (and Unisex Uniforms); Hill Says, Not Enough," *Breaking Defense*, May 20, 2015, https://breakingdefense.com/2015/05/mabus-sticks-with-uclass-approach-unisex-uniforms/.

The limited vulnerability to countermeasures and reduced impact on strategic stability suggest that airborne BPI systems might be a sensible alternative to the GMD system in addressing the North Korean threat.[175] But these advantages need to be prudently managed. As discussed earlier, the GMD system was exempted from several standard weapons acquisition processes and oversight mechanisms that led to its recurrent programmatic failures. Any new airborne BPI effort should be closely monitored and reviewed periodically by external experts to ensure program success.

Conclusion

During the Cold War, the United States and the Soviet Union developed a shared understanding that national missile defense weakened strategic stability. Both superpowers agreed that attempts to establish an effective national missile defense shield by either side would provoke a nuclear arms race and increase first-strike pressures during a crisis. Another lesson from this era was that a complicated and costly midcourse national missile defense system could be defeated by simple and inexpensive countermeasures. These lessons led to the 1972 ABM Treaty, which substantially limited national missile defense and made possible agreed limitations in offensive forces.

In 2001, however, the George W. Bush administration withdrew from the ABM Treaty despite strident objections from Russia and China. The Bush administration argued that Cold War–era arms control arrangements were irrelevant to the emerging threats of the twenty-first century, insisting that nuclear threats from rogue states such as North Korea necessitated the pursuit of national missile defense. Notwithstanding several warnings over technological immaturity, the Bush administration rushed to deploy the GMD system. As we have argued, even after twenty years of dedicated effort, the GMD system is still faltering. It has endured delays, program failures, and excessive cost increases. We have also shown that the GMD effort has failed to produce a reliable kill vehicle. The latitude granted to the MDA has remained in place, however, even as the GMD program has not transitioned to the warfighter.[176] New efforts such as the cruise and hypersonic defense are being undertaken that divert the efforts of the MDA.[177] Furthermore, countermeasures remain a serious, if not insurmountable, challenge to the GMD system's viability.

175. BPI systems may also be cost-competitive. For some details, see Sankaran and Fetter, "Reexamining Homeland Missile Defense against North Korea," p. 53.
176. Over the years, Congress has instituted a few oversight measures for the MDA, removing the carte blanche that it enjoyed in the early 2000s. See GAO, "Missile Defense: Fiscal Year 2020 Delivery and Testing Progressed, but Annual Goals Unmet," pp. 6–7.
177. Chaplain Statement, March 12, 2020, p. 13.

Yet, the pursuit of the GMD system has persistently fueled Russian and Chinese fears over the survivability of their nuclear arsenals. Russian and Chinese policymakers justify several new offensive nuclear weapons programs as both a response to U.S. national missile defense and as a mechanism to reestablish strategic stability. Russian and Chinese weapons programs designed to circumvent U.S. missile defense, such as hypersonic weapons, create new nuclear vulnerabilities for the United States. They are also weakening support for sustaining existing U.S.-Russia bilateral arms control agreements, including the New START Treaty.[178]

We have argued that the GMD system has imposed a high geopolitical cost and is incapable of providing reliable defense against North Korea. Meanwhile, North Korea has substantially improved the capability of its nuclear arsenal, and its ICBMs may soon be able to credibly threaten the U.S. homeland. We believe the United States can effectively deter nuclear attacks by North Korea through the threat of devastating retaliation, but U.S. policymakers have been unwilling to rely exclusively on deterrence. This unwillingness is driven partly by domestic politics and partly by the concerns of U.S. allies, who worry that the United States might not come to their defense if North Korea can credibly threaten to attack U.S. cities.

If the United States is to continue to pursue national missile defense against North Korea, it should adopt an approach that is both more effective against North Korean ICBMs and less likely to weaken strategic stability with Russia and China. This article suggests that an airborne BPI system is a possible alternative to the GMD system. While diplomacy and deterrence can help mitigate North Korean nuclear threats, our analysis indicates that an airborne BPI system could offer effective defense against contemporary North Korean ICBM threats should those efforts fail. BPI systems are less vulnerable to countermeasures and cannot defend against Russian and Chinese ICBMs. Furthermore, we have argued that the effectiveness of a boost-phase defense would be bolstered if interceptors could be based in Russian or Chinese territories or airspaces. Such cooperative missile defenses could form a central component of a grand bargain with Russia and China. It is our recommendation that the United States thoroughly explore the airborne BPI concept, with detailed engineering studies and political analysis, to further understand its advantages and limitations as an alternative to the GMD system.

We have argued that continuing to pursue the GMD system out of political and bureaucratic inertia does not serve the United States' interest. We recommend that a bipartisan presidential commission be instituted to reconsider

178. Biden Jr., "Interim National Security Strategic Guidance," p. 13; and Detrani, "The New START extension."

national missile defense without the biases of the past. The presidential commission should be empowered to critically evaluate all programs and realign efforts to best serve U.S. security. For instance, the special privileges and exemptions afforded to the MDA require careful review and reform.[179] It is also time for the United States to reexamine the goals of the entire missile defense enterprise, which is now at a crossroads. We recommend that missile defenses be examined in the larger context of non-ICBM threats against the United States. Not every threat can be effectively neutralized with defensive weaponry alone. The United States should focus on demonstrating that its commitment to the defense of Japan, South Korea, and other allies in East Asia will not be weakened by North Korean ICBM threats, regardless of whether an effective defense against those threats can be deployed. We also recommend that the United States pursue an array of other confidence-building measures (e.g., political commitments to an upper limit on the quantity and performance of national missile defense assets and reintroducing strategic defense in arms control dialogues) to reassure Russia and China and obtain their diplomatic support to meaningfully constrain North Korea's ability to develop additional strategic weapons systems.[180]

179. A template for such reforms may already exist. In 2020, then deputy secretary of defense David Norquist outlined in a directive several revisions to the MDA charter. The directive recommended that MDA projects be divided into a Technology Development Phase, a Product Development Phase, and a Production Phase. Additionally, in each phase, the directive mandated deeper involvement of the Under Secretary of Defense for Acquisition and Sustainment, Department of Defense Director of Cost Assessment and Program Evaluation, combatant commanders, and the Commander of the U.S. Strategic Forces. See Deputy Secretary of Defense, "Directive-Type Memorandum 20-002—'Missile Defense System Policies and Governance'" (Washington, D.C.: U.S. Department of Defense, March 13, 2020), pp. 12–13, https://www.esd.whs.mil/Portals/54/Documents/DD/issuances/dtm/DTM-20-002.PDF?ver=56eFJM_5vQJOMEdzVOOi6g%3D%3D. The directives do not seem to have been finalized and implemented, however. See CSIS, "Transcript: MDA and the 2022 Budget: Online Event" (Washington, D.C.: CSIS, June 22, 2021), p. 12, https://csis-website-prod.s3.amazonaws.com/s3fs-public/event/210622_Karako_Hill_MDA.pdf?M7FoctizrwzmGla2xvhdNE14wohVU8mi.
180. Discussion of such confidence-building measures can be found in Li Bin, "China's Attitudes toward Missile Defense and Its Limitation," *Bulletin of the Atomic Scientists*, Vol. 74, No. 4 (2018), pp. 246–247, https://doi.org/10.1080/00963402.2018.1486601; and Glaser and Fetter, "National Missile Defense and the Future of U.S. Nuclear Weapons Policy," pp. 80–81.