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Jaganath Sankaran

ABSTRACT
American policy makers have insisted that the purpose of recent US missile-defense efforts is limited to defending the United States against rogue states and that these defenses do not weaken strategic stability by threatening the Russian or Chinese nuclear deterrent. However, despite this insistence, the United States appears to be assembling the technological building blocks of a national missile defense that may have the capability to be quickly reconfigured against Russia or China. Using the theoretical framework of "technology creep," this article examines the reasons for the disconnect between the stated US doctrine and the pursuit of advanced technologies that significantly expand the capabilities of US missile defense. The article concludes by recommending a rethinking of the logic and purpose of US limited missile defense to avert a renewed nuclear-arms race.

KEYWORDS
missile defense; strategic stability; technology creep

Strategic nuclear stability emerged as a core organizing concept during the Cold War to stabilize the bilateral nuclear confronation between the United States and the Soviet Union. The logic of strategic stability required each of the two countries to have a very high degree of confidence in its ability to absorb a nuclear first strike from the other and still be able to strike back with overwhelming force and cause assured destruction.[1] The confidence in the ability to retaliate with overwhelming force even after suffering a nuclear attack was expected to lead to first-strike stability—that is, a situation in which neither of the two powers felt a need to initiate a nuclear war purely because it feared nuclear annihilation if it chose to wait. In reality, however, the prospect of a technological surprise undermining strategic stability was a constant worry for both countries. While several over-the-horizon technological capabilities influenced perceptions of the robustness of strategic stability during the Cold War, advances in homeland missile-defense technologies had a particuarly significant influence on these perceptions.[2] As a result, the United States and the Soviet Union

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[1] Elbridge Colby, "Defining Strategic Stability: Reconciling Stability and Deterrence," in Elbridge A. Colby and Michael A. Gerson, eds., *Strategic Stability: Contending Interpretations* (Carlisle Barracks, PA: US Army War College Press, 2013), p. 48, <https://apps.dtic.mil/sti/pdfs/ADA572928.pdf>.
[2] For instance, as early as 1957, the Gaither Committee report, foreshadowing the effects of technological advances in missile-defense technologies, declared that any "temporary technical advance (such as high-certainty missile defense against ballistic missiles) could give either nation the ability to come near to annihilating the other." The report further postulated that there would be no end to the "technical moves and counter-moves" as national missile

entered into a bilateral treaty, the 1972 Anti-Ballistic Missile Treaty, and pursued other measures to reassure each other that any homeland missile-defense efforts would not radically weaken strategic stability.

As in the Cold War, the fear of advances in US homeland missile defense has recently permeated Russian and Chinese decision making. In 2011, Russian President Dmitry Medvedev declared in a speech at the G8 summit that a "new arms race will begin" unless an agreement in reached on the scale and scope of US missile-defense efforts.[3] President Medvedev was reacting to the planned emplacement of US missile-defense systems in Romania and Poland as part of the European Phased Adaptive Approach defense system.[4] In 2016, President Vladimir Putin offered a detailed critique of several US missile defense initiatives at the St. Petersburg International Economic Forum.[5] He warned that Russia would respond with new offensive nuclear arms to restore the strategic balance of power. Chinese leaders have expressed similar concerns. In 2016, reacting to the US decision to deploy the Terminal High Altitude Area Defense (THAAD) missile-defense system to South Korea, Chinese officials and analysts vehemently complained that it undermined China's reasonable national-security concerns and weakened strategic stability.[6] In July 2019, Putin and Chinese President Xi Jinping released a joint statement accusing the United States of reprising a Cold War mindset and asked for the cessation of "unrestricted development of the global anti-missile system" to avert a renewed nuclear-arms race.[7] The message was reiterated in 2022 in a joint statement issued by the two leaders.[8]

Russia and China contend that the contemporary expansion in the mission, goals, and technological capabilities of US missile defense exceeds the operational needs of defending against North Korea or Iran. Furthermore, as noted above, Russia and China argue that these advances compromise the viability of their nuclear deterrents and therefore weaken strategic stability. Recognizing the interrelationship between homeland missile defense and strategic stability, the United States has strived to reassure Russia and China by repeatedly proclaiming that current and planned limited missile-defense capabilities do not undermine the strategic stability between the United States and Russia or the United States and China. For example, in the 2019 Ballistic Missile Defense Review, the Trump administration argued that the "United States relies on deterrence to protect against large and technically sophisticated

defense emerged. See Security Resources Panel of the Science Advisory Committee, "Deterrence & Survival in the Nuclear Age," November 7, 1957), p. 17, <https://nsarchive2.gwu.edu/NSAEBB/NSAEBB139/nitze02.pdf>.

3 Jaganath Sankaran, *The United States' European Phased Adaptive Approach Missile Defense System: Defending against Iranian Threats without Diluting the Russian Deterrent* (Santa Monica, CA: RAND, 2015), p. 5, <https://www.rand.org/pubs/research_reports/RR957.html>.

4 A more detailed analysis of the political and technical debates on the European Phased Adaptive Approach missile-defense system can be found in Sankaran, *The United States' European Phased Adaptive Approach*.

5 *YouTube*, "Putin Speaks to USA Press: 2016 International Economic Forum," St. Petersburg, 2016, <https://www.youtube.com/watch?v=ald8pXk0Jho>.

6 Jaganath Sankaran and Bryan Fearey, "Missile Defense and Strategic Stability: Terminal High Altitude Area Defense (THAAD) in South Korea," *Contemporary Security Policy*, Vol. 38, No. 3 (February 6, 2017), pp. 322, 329–30, <https://doi.org/10.1080/13523260.2017.1280744>.

7 Ministry of Foreign Affairs of the People's Republic of China, "Assistant Foreign Minister Zhang Jun Publishes a Signed Article on Jointly Strengthening Global Strategic Stability between China and Russia," June 12, 2019, <https://www.fmprc.gov.cn/mfa_eng/wjdt_665385/zyjh_665391/201906/t20190614_678745.html>.

8 Office of the President of Russia, "Joint Statement of the Russian Federation and the People's Republic of China on the International Relations Entering a New Era and the Global Sustainable Development," February 4, 2022, <http://www.en.kremlin.ru/supplement/5770>.

Russian and Chinese intercontinental ballistic missile threats to the US homeland."[9] The Fiscal Year (FY) 2020 National Defense Authorization Act similarly notes that the United States will maintain a homeland missile-defense system to defend US territory against the "threat posed by rogue states" but will depend on its nuclear deterrent "to address more sophisticated and larger quantity near-peer intercontinental missile threats to the homeland."[10] Similarly, the 2022 US Missile Defense Review explicitly states that "the United States will continue to rely on strategic deterrence" and the threat of mutual assured destruction as its policy toward Russia and China while staying ahead of "North Korean missile threats to the homeland."[11] The Trump administration's 2018 Nuclear Posture Review and the 2017 National Security Strategy made similar assertions.[12]

The Ballistic Missile Defense Review and the Nuclear Posture Review of the Obama administration forcefully argued for preserving strategic stability with Russia and China. Furthermore, these documents proclaimed that US missile-defense efforts would not alter the balance of nuclear deterrence with Russia and China.[13] These doctrinal commitments were enshrined in the 2010 New Strategic Arms Reduction Treaty (New START), which recognized the existence of the crucial "interrelationship between strategic offense arms and strategic defensive arms."[14]

Simultaneously, however, unconstrained US technological experimentation over several decades has generated the ability to engineer and deploy the components of a missile-defense system that might achieve a surprise breakthrough in strategic missile defense against Russia and China. Since 2001, the United States has spent more than $67 billion to produce the technological breakthroughs necessary to field a limited national missile-defense system, the Ground-Based Midcourse Defense (GMD).[15] The sustained pursuit of GMD and other missile-defense systems has resulted in a massive, technologically advanced architecture of sensors, platforms, and interceptors.

For instance, the SPY-6(V)1 radar has turned out better than expected and is almost 100 times more sensitive than the system it is replacing, the SPY-1 radar.[16] Such

[9] US Department of Defense, "2019 Missile Defense Review," Office of the Secretary of Defense, p. iii, <https://media.defense.gov/2019/Jan/17/2002080666/-1/-1/1/2019-MISSILE-DEFENSE-REVIEW.PDF>.

[10] US Congress, S. 1790, National Defense Authorization Act for Fiscal Year 2020, 116th Cong., 1st sess., January 3, 2019, p. 584, <https://www.congress.gov/bill/116th-congress/senate-bill/1790/text>.

[11] US Department of Defense, "2022 Missile Defense Review," Office of the Secretary of Defense, 2022, p. 5, <https://apps.dtic.mil/sti/trecms/pdf/AD1183539.pdf>.

[12] Office of the Secretary of Defense, *Nuclear Posture Review* (Washington, DC: US 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>; White House, *National Security Strategy of the United States of America* (Washington, DC: White House, 2017), p. 8, <https://trumpwhitehouse.archives.gov/wp-content/uploads/2017/12/NSS-Final-12-18-2017-0905.pdf>.

[13] US Department of Defense, "Ballistic Missile Defense Review Report," 2010, p. 34; US Department of Defense, "Nuclear Posture Review Report," 2010, pp. 4, 29.

[14] US Department of State, "New START: Treaty Text," n.d., <https://2009-2017.state.gov/t/avc/newstart/c44126.htm>.

[15] The GMD system is the fourth most expensive weapons-acquisition program in US history. See United States Government Accountability Office, "Missile Defense: The Warfighter and Decision Makers Would Benefit from Better Communication about the System's Capabilities and Limitations," May 2018, p. 77, <https://www.gao.gov/assets/gao-18-324.pdf>. If the missile-defense enterprise is considered to include the GMD system, THAAD system, Aegis BMD, Patriot terminal defenses, and other programs developed in cooperation with Israel, the cost of the entire program reaches approximately $165 billion. See Justin Doubleday, "Ballistic Missile Defense Program Costs Rise to $164.9 Billion," *Inside the Pentagon*, August 10, 2017, pp. 3-4, <https://www.jstor.org/stable/90011585>. For details on more recent budgetary allocations to various US missile defense programs, see Jaganath Sankaran, "The Delusions and Dangers of Missile Defense," *Arms Control Today*, September 2023, <https://www.armscontrol.org/act/2023-09/features/delusions-dangers-missile-defense>.

[16] Jason Sherman, "Navy Determines SPY-6 Radar Three Times Stronger than Original Requirement," *Inside the Navy*, Vol. 32, No. 18 (May 6, 2019), <https://www.jstor.org/stable/26643355?seq=1>.

performance gains in the tracking range of the radar sensors that are now being installed on certain ships will significantly expand the ballistic-missile-defense (BMD) capabilities of each of these ships. While initially designed for regional missile defense, these BMD-capable ships armed with SM-3 interceptors are now being considered for homeland-defense missions, blurring the line between regional and homeland missile defense.[17]

Highlighting this point, Greg Thielmann—who served for three decades in the US government, including as director of the Office of Strategic, Proliferation, and Military Affairs in the State Department's Bureau of Intelligence and Research—wrote in 2020 that, when Russian officials initially expressed concerns over the capability of the SM-3 interceptors to intercept Russian intercontinental ballistic missiles (ICBMs), "US officials ridiculed Russian expressions of concern" and insisted that the interceptors' "velocity and location would make such interceptions impossible. Now, the very same interceptors are scheduled to be tested against ICBM targets."[18] Additionally, the US Missile Defense Agency (MDA) could soon acquire as many as 50 BMD-capable ships and several SM-3 IIA missile-defense interceptors to emplace on these ships.[19] These acquisitions would sharply expand the number of US interceptors for homeland defense beyond the minimal number of GMD interceptors envisioned for defense against rogue threats.[20]

To adversaries employing a worst-case estimation, the several emerging American technological capabilities will appear highly destabilizing. Russian and Chinese experts and policy makers have to take into account the possibility that these advances in a multitude of sensors, platforms, and interceptors could morph into a potent threat to their nuclear deterrents. It is implausible that the United States would tolerate the same state of affairs if Russia or China—the designated near-peer adversaries in the new great-power competition—were to pursue similar missile-defense efforts.

Indeed, the United States was unwilling to tolerate a much less technologically advanced Soviet missile-defense system in the 1960s. The fear of weapons not yet built but capable of near-perfect defense was the baseline for US nuclear-war planning. During the early years of the Cold War, many US analysts believed that the Soviets would capitalize on technological gains in missile defense and strike first if a favorable situation emerged.[21] Secretary of Defense Robert McNamara, speaking about American fears of a Soviet technological breakthrough in missile defense in 1967, observed that it did not make "much difference what the evidence indicates … because

[17] US Department of Defense, "2019 Missile Defense Review," Office of the Secretary of Defense, 2019, pp. XIII–XIV, <https://media.defense.gov/2019/Jan/17/2002080666/-1/-1/1/2019-MISSILE-DEFENSE-REVIEW.PDF>.

[18] Greg Thielmann, "Increasing Nuclear Threats through Strategic Missile Defense," Center for International & Security Studies at Maryland (CISSM), School of Public Policy, University of Maryland, July 2020, p. 14, <https://cissm.umd.edu/research-impact/publications/increasing-nuclear-threats-through-strategic-missile-defense>.

[19] Ronald O'Rourke, "Navy Aegis Ballistic Missile Defense (BMD) Program: Background and Issues for Congress," CRS Report RL33745, Congressional Research Service (CRS), July 24, 2024, pp. 7, 14, <https://sgp.fas.org/crs/weapons/RL33745.pdf>; George N. Lewis, "Update to 'How Many SM-3 Block IIA Missiles?'" *Mostlymissiledefense*, May 20, 2018, <https://mostlymissiledefense.com/2018/05/20/update-to-how-many-sm-3-block-iia-missiles-may-20-2018/>.

[20] US Department of Defense, Missile Defense Agency, "ELEMENTS: Ground-Based Midcourse Defense (GMD)," updated December 9, 2024, <https://www.mda.mil/system/gmd.html>.

[21] Sayre Stevens observes that irresolvable uncertainties in political intentions permitted both the pessimist and the sanguine analyst to make viable arguments. He writes that the "questions to be asked involve not only the characteristics and capabilities of the deployed Soviet BMD systems, but also Soviet intentions in developing new ones and Soviet plans for ultimately deploying them." See Sayre Stevens, "The Soviet BMD Program," in Ashton B. Carter and David N. Schwartz, eds., *Ballistic Missile Defense* (Washington, DC: Brookings Institution Press, 1984), p. 184.

I believe we must assume for planning [purposes]" that even limited defense systems could at some future point emerge as a highly capable homeland defense.[22]

Throughout the 1960s, US nuclear-war planners used a threat metric of "greater than expected" in their planning to offset any future Soviet technical breakthroughs in missile defense. The Department of Defense formulated and used this metric to characterize a Soviet homeland missile defense that was more robust than predicted by the high-end estimates of US National Intelligence Estimates.[23] The metric fueled a destabilizing buildup in US nuclear forces, with a particular emphasis on being able to defeat future Soviet missile defenses. John Foster, the Pentagon's director of defense research and engineering, testified in 1968 that the US government had acquired multiple independently targetable re-entry vehicles to make sure it stayed ahead of "whatever [the Soviets] do of the possible things that we can imagine they might do."[24] Similarly, Alain Enthoven and Wayne Smith noted that, by the late 1960s, the Department of Defense threat metric of "greater than expected" resulted in the amassing of an excessive nuclear-weapons arsenal that could destroy 50 percent of the Soviet population and 80 percent of Soviet industry in a nuclear war, even though the Department of Defense had determined that destroying 20 percent of the Soviet population and 50 percent of its industry would be sufficient for deterrence.[25]

The US response to early Soviet missile-defense efforts should provide important lessons for current American policy makers. A lesson from the 1960s is that the fragility of strategic stability and the fear of technological breakthroughs require substantial limits on strategic missile defense to avert a nuclear arms race.[26] While US policy makers seem committed to such limits, the increasing capabilities in deployed and planned missile-defense systems present a very different impression. In essence, the belief in the congruity between the doctrine governing US missile-defense efforts and the country's manifest capabilities is a matter of firmly held assumption rather than a matter of fact.

Why do US missile-defense acquisitions stand in stark contrast to the doctrinal commitments made by the United States? The article argues that the disconnect between US doctrine and emerging technological capabilities is a result of

22 Text of McNamara Press Conference (US Information Service), April 3, 1967, quoted in Lawrence Freedman, *US Intelligence and the Soviet Strategic Threat*, 2nd ed. (Princeton, NJ: Princeton University Press, 1986), p. 96.

23 Alain C. Enthoven and Wayne K. Smith, *How Much Is Enough? Shaping the Defense Program 1961–1969*, 2nd ed. (Santa Monica, CA: RAND, 2005), p. 178. See also John Newhouse, *Cold Dawn: The Story of SALT* (New York: Pergamon-Brassey's International Defense, 1989), p. 72.

24 Senate Hearing, *Status of U.S. Strategic Power*, Hearings before the Preparedness Investigating Subcommittee of the Committee on Armed Services—Part I, 90th Cong., 2nd Sess., April 23, 1968 (Statement of Dr. John S. Foster, Jr., Director of Defense Research and Engineering, Department of Defense), p. 110.

25 Enthoven and Smith, *How Much Is Enough?*, pp. 177–78. The destruction of 20 percent of the Soviet population and 50 percent of Soviet industry was accepted as sufficient to ensure "unacceptable damage." The acceptance emerged from the fact that any further small increases in destruction would require enormous increases in nuclear forces and cost. See Enthoven and Smith, p. 208. See also Graham T. Allison and Frederic A. Morris, "Armaments and Arms Control: Exploring the Determinants of Military Weapons," *Daedalus*, Vol. 104, No. 3 (Summer 1975), p. 104; Statement of Secretary of Defense Robert S. McNamara before the Senate Armed Services Committee on the Fiscal Year 1969–73 Defense Program and the 1968 Defense Budget, January 1968, pp. 57–58.

26 During the Cold War years, these limits on strategic missile defense were verifiably enforced through legally binding treaties. While Moscow continues to insist on legally binding "military-technical" guarantees similar to Cold War-era arms-control treaties, US decision makers have argued that politically binding guarantees are sufficient to reassure Russia and China. See Sankaran, *The United States' European Phased Adaptive Approach*, pp. 5–6. An analysis of whether such politically binding guarantees can be effective is beyond the scope of the article.

"technological creep"—that is, the pursuit of advanced technologies without an appropriate awareness of their destabilizing strategic implications.

The rest of this article is organized as follows: The next section lays out the logic of the technological-creep framework and develops two hypotheses. The first hypothesis states that the development and acquisition of advanced weapons that can provide surprising operational capabilities can occur through technological creep if the decision makers do not pay rigorous attention to its destabilizing strategic implications. The second hypothesis argues that external threats will be used to justify the pursuit of such technological capabilities. The two subsequent sections employ these hypotheses to understand the logic behind the development and acquisition of US missile-defense subsystems that can threaten the viability of Russian and Chinese nuclear deterrence against the United States. The article concludes by recommending a rethinking of the logic and purpose of American missile defense and a diplomatic effort to contain and reduce the North Korean threat.

Technological creep and strategic stability

For the purposes of this article, "technological creep" refers to the development and acquisition of weapons with newer and more advanced technological functionality that results in surprisingly powerful operational capabilities. A distinguishing feature of technological creep is the absence of a priori debate and evaluation by policy makers of the impact on strategic stability of these development and acquisition efforts.[27] Technological creep is primarily driven by the bargaining between bureaucrats, the armed forces, project managers, and systems engineers, all motivated by their parochial interests rather than by purely strategic geopolitical considerations.[28]

Policy makers often are unable to anticipate and constrain technological creep. The qualitative aspects of weapons systems are rarely shaped in detail by policy makers' conscious efforts.[29] Such decisions are often left to weapons designers and developers. Herbert York, who served as the first director of defense research and engineering and in several other crucial policy-making roles, suggested more than three decades ago that the scientific enterprise in the United States "generates more ideas and inventions of all kinds, including ever more powerful and exotic means of mass destruction. In short, the root of the problem is not maliciousness, but rather a sort of technological exuberance that has overwhelmed the other factors that go into the making of overall national policy."[30]

Policy makers, particularly in the United States, also prefer to simultaneously allow the pursuit of multiple avenues of research and development in matters of military technology, believing that this will help them retain as many future alternatives as

[27] Lawrence Freedman, "The Persistence of Technological Enthusiasm: The Technological Input into U.S. Strategic Arms Policy," *Millennium*, Vol. 5, No. 2 (1976), p. 155, <https://doi.org/10.1177/03058298760050020601>.

[28] Deborah Shapley, "Technology Creep and the Arms Race: Two Future Arms Control Problems," *Science*, Vol. 202, No. 4365 (October 20, 1978), p. 289; Deborah Shapley, "Arms Control as a Regulator of Military Technology," *Daedalus* Vol. 109, No. 1 (Winter 1980), p. 148.

[29] Shapley, "Arms Control as a Regulator," p. 148.

[30] Herbert F. York, *The Advisors: Oppenheimer, Teller, and the Superbomb* (Stanford, CA: Stanford University Press, 1989), p. xiii.

possible.[31] Policy makers fear that unilaterally constraining military technological pursuits may cede an advantage to a technologically sophisticated adversary willing to exploit it for geopolitical gains.[32] This, in turn, endows bureaucrats, the armed forces, weapons engineers and scientists, and related bureaucracies with an ability to pursue weapons technology "for its own sweet sake."[33]

Technological creep initially manifests in marginal performance gains. Over time, these marginal gains accumulate to produce improved and powerful operational characteristics in a weapons system. As a result, a level of weapons-system performance previously seen as infeasible becomes technologically viable and can quickly progress to threaten strategic stability.[34] For instance, technological creep in varied fields of study—such as electronics, materials science, and intertial navigation—converged to produce "absolute accuracy" of US ICBMs in the 1980s, challenging extant doctrine and fostering a sense of strategic vulnerability for the Soviets.[35] In the United States, the evolution of increasing missile accuracy was neither an inevitable result of technological progression nor a product of policy makers' mandate to scientists. Instead, a complex process of collaboration between "ambitious, energetic technologists, laboratories and corporations, and political and military leaders" was socially constructed and sustained by enterprising individuals in an attempt to advance their agenda.[36]

Charles Stark Draper, the director of the Massachusetts Institute of Technology (MIT) Instrumentation Laboratory, was invested in engineering highly precise inertial-navigation systems. For several decades, Draper and the laboratory were committed to developing the technological means to increase "the accuracy of inertial guidance and navigation by predominantly incremental means."[37] Draper was also generally seen as a talented innovator capable of convincing even a skeptic of the merits of pursuing incremental improvements in inertial navigation. Draper and his scientific collaborators were not particularly interested in making US ballistic missiles more accurate and would "have been just as happy making civil air inertial navigators more

[31] Warner R. Schilling, "Scientists, Foreign Policy, and Politics," *American Political Science Review*, Vol. 56, No. 2 (June 1962), p. 290. Matthew Evangelista made a similar argument, writing, "When there is an abundance of resources and little central control, technical ideas for new weapons tend to flourish. … The proliferation of innovative ideas is enhanced by two factors: the willingness of private firms to undertake research at their own expense (much of which is later reimbursed) and the reluctance of higher political authorities to restrict an R&D program whose potential is still uncertain." Matthew Evangelista, *Innovation and the Arms Race: How the United States and the Soviet Union Develop New Military Technologies* (Ithaca, NY: Cornell University Press, 1988), pp. 53–54. See also Michael A. Armacost, *The Politics of Weapons Innovation: The Thor-Jupiter Controversy* (New York: Columbia University Press, 1969), pp. 256–57; Freedman, "The Persistence of Technological Enthusiasm," pp. 155–56.

[32] Freedman, "The Persistence of Technological Enthusiasm," p. 162; John Newhouse, *War and Peace in the Nuclear Age* (New York: Alfred A. Knopf, 1989), p. 223.

[33] Schilling, "Scientists, Foreign Policy, and Politics," pp. 293–94. John S. Foster, Jr., the director of defense research and engineering in the Department of Defense, made a similar argument in a 1967 speech: "By what mechanism does our society select the goals and opportunities which our research and development community will pursue? … many are pursued because they are possible or because they are exciting." See Ralph E. Lapp, *Arms Beyond Doubt: The Tyranny of Weapons Technology* (New York: Cowles, 1970), pp. 22–23.

[34] Shapley, "Arms Control as a Regulator," p. 145.

[35] See Deborah Shapley, "Technology Creep and the Arms Race: A World of Absolute Accuracy," *Science*, Vol. 201, No. 29 (September 1978), p. 1192. See also Deborah Shapley, "Technology Creep and the Arms Race: ICBM Problem a Sleeper," *Science*, Vol. 201, No. 4361 (September 22, 1978), pp. 1102–05; Shapley, "Technology Creep and the Arms Race."

[36] Donald MacKenzie, *Inventing Accuracy: A Historical Sociology of Nuclear Missile Guidance* (Cambridge, MA: MIT Press, 1993), p. 3.

[37] MacKenzie, *Inventing Accuracy*, p. 386.

accurate."[38] However, the US Air Force, for various organizational and strategic reasons, was the only agency amenable to financially supporting the pursuit of inertial navigation technologies to significantly increase the accuracy of missiles for counterforce missions—that is, missions that targeted Soviet nuclear forces rather than populations. The goals of the US Air Force were supported by analysts who believed that, irrespective of American choices, the Soviets would acquire highly accurate missiles. Therefore, according to this thinking, the United States should do all it could to avoid lagging behind the Soviets.[39] The confluence of these factors was critical for the emergence of highly accurate ICBMs. Equally critical was the lack of a concerted a priori effort by senior policy makers to understand the impact of the technology on strategic stability or to control the progression of the technology. Ultimately, the advent of these technologically advanced weapons led to perceptions by the Soviets that they were vulnerable to a nuclear first strike and thus weakened strategic stability between the United States and the Soviet Union.

This history of the maturation of highly accurate ICBMs during the Cold War suggests that technological decisions about weapons do not occur in a vacuum; instead, these decisons are a function of the bureaucratic and political bargaining processes among various agencies and actors.[40] The history speaks to the need to identify and incorporate all the factors that might simultaneously influence technological creep in the development and acquisition of advanced weapons systems.[41] Technocratic initiative by weapons scientists is the first stage in weapons acquisition.[42] However, technocrats cannot operate "as an autonomous force"; they must seek broader political support and recruit allies to support their preferred course of action.[43] A coalition of actors formed to further a particular weapons program must match the technical capabilities of the weapons system to an external national-security threat.[44] Once a politically influential coalition has been formed, the claimed rationale for the weapon system is difficult to challenge.[45]

Technological creep in US missile defense

Since the mid-1980s, a linear progression of constantly improving US missile-defense capabilities is readily apparent. For states designated as adversaries of the United States, the decades-long steady progression of capabilities appears intolerably

[38] MacKenzie, p. 390.
[39] MacKenzie, p. 388.
[40] James A. Kurth, "A Widening Gyre: The Logic of American Weapons Procurement," *Public Policy*, Vol. 19, No. 3 (Summer 1971), pp. 374–76. Kurth notes that, in attempting to develop a logical handle on how US weapons acquisitions happen, scholars have produced a "cluster of competing explanations, a thicket of theories" that often obscures the understanding of the making of these acquisition decisions. See Kurth, "A Widening Gyre," p. 373. He notes that these competing theories lead to a posteriori overdetermination, yet in some cases suffer a priori underdetermination.
[41] Kurth, "A Widening Gyre," pp. 395–404.
[42] Evangelista, *Innovation and the Arms Race*, p. 53.
[43] Evangelista, p. 64.
[44] Evangelista, p. 64.
[45] Evangelista notes that, in seeking high-level endorsement and public and congressional support to secure "full funding" for large-scale production and deployment, promoters of a weapons system need to justify their programs. However, he writes that, "because promoters of the new weapon have already amassed considerable support" through bureaucratic maneuvering and bargaining, the "rationales for producing the system need not have much grounding in reality." See Evangelista, p. 67.

threatening, particularly when the scope of the threat is determined using a worst-case methodology—for instance, something similar to the "greater than expected" threat metric detailed above.

Such worst-case assessments were a standard feature of US defense planning during the Cold War. Caspar Weinberger, President Ronald Reagan's secretary of defense, acknowledged this point: "You should always use a worst-case analysis in this business. You can't afford to be wrong. In the end, we won the Cold War, and if we won by too much, if it was overkill, so be it."[46] Today, as a renewed strategic competition takes hold and states grow increasingly distrustful of each other's intentions, Russia and China have employed similar worst-case assessments of future US missile defense. In February 2022, Putin and Xi argued in a joint statement that the US missile-defense system was an attempt to build a capacity for "disarming strikes" and called for the elimination of "unrestricted development of global anti-ballistic missile defense (ABM) system."[47] Acknowledging but disagreeing with these concerns, the 2022 US Department of Defense report on China's military and security developments notes that "PRC [People's Republic of China] leaders are concerned that Washington could achieve a breakthrough development in system effectiveness or deployment scale that negates Beijing's ballistic missile arsenal."[48] Russia and China have also developed and tested hypersonic weapons, anti-satellite (ASAT) weapons, and a fractional orbital bombardment system (FOBS) to defeat US missile defense.[49]

Technology creep in platforms and interceptors

A crucial factor that may drive Russia and Chinese worst-case assumptions is the growing capabilities of US missile-defense platforms and interceptors. Responding to criticism that it has not fully exploited the potential of the Ground-Based Interceptor (GBI) of the GMD system, the MDA, in a September 2021 flight trial, tested the ability of the GBI to engage in shoot-look-shoot tactics.[50] With this capability, operators of missile-defense systems can fire a single interceptor against an incoming threat missile, wait to see whether it is successful in eliminating the threat, and then launch a second interceptor only if the first one fails. Without such an ability, two or more interceptors will have to be launched simultaneously to ensure a higher probability of destroying the incoming missile. Therefore, a shoot-look-shoot tactic provides "greater flexibility" in how interceptors can be used and reduces the number of interceptors needed to destroy a target missile.[51] Such a capability might provide a

[46] Tim Weiner, "Military Accused of Lies over Arms," *New York Times*, June 28, 1993, <https://www.nytimes.com/1993/06/28/us/military-accused-of-lies-over-arms.html>.
[47] Office of the President of Russia, "Joint Statement of the Russian Federation and the People's Republic of China."
[48] US Department of Defense, "Military and Security Developments," p. 159.
[49] US Department of Defense, p. 98; Jill Hruby, *Russia's New Nuclear Weapon Delivery Systems: An Open-Source Technical Review* (Washington, DC: Nuclear Threat Initiative, 2019), pp. 14–35.
[50] Robin Hughes, "MDA Demonstrates Selectable Stage Booster for GBI," *Janes*, September 16, 2021, <https://www.janes.com/osint-insights/defence-news/weapons/mda-demonstrates-selectable-stage-booster-for-gbi>; Jen Judson, "Missile Defense Agency Successfully Tests New Booster for Homeland Missile Defense System," *Defense News*, September 12, 2021, <https://www.defensenews.com/2021/09/12/missile-defense-agency-successfully-tests-new-booster-for-homeland-missile-defense-system/>.
[51] Judson, "Missile Defense Agency Successfully Tests New Booster."

potent advantage to US missile defense if there were a large increase in the number of GMD interceptors.

Similarly, the ability to employ multiple kill vehicles in each GMD interceptor, as envisioned for the Next Generation Interceptor (NGI), would give US missile defenses the ability to expand the capabilities of the GMD system quickly.[52] The attempt to develop multiple-kill-vehicle technology has been persistent. The MDA undertook a program to develop such technology between 2004 and 2009 at a cost of $700 million.[53] Secretary of Defense Robert Gates canceled the program in 2009, saying that the multiple-kill-vehicle program was "designed to deal with a more complex threat that would have come potentially from either China or Russia" and was not needed against the limited threats posed by Iran or North Korea.[54] However, the program was restarted in 2015 and is now expected to be integrated into the NGI. While the technology has proven elusive so far, for Russian and Chinese analysts, persistent US pursuit of multiple-kill-vehicle technology may require them to presume its eventual maturation.

US posture-review documents reiterate that the GMD system is the only deployed national missile-defense system. However, as detailed below, the distinction between theater defense and homeland missile-defense systems has been constantly eroded since the late 1990s.[55] In 2009, the Obama administration began the deployment of Standard Missile-3 (SM-3) interceptors in Romania and later in Poland as part of the European Phased Adaptive Approach.[56] These interceptors are capable of velocities greater than 3 kilometers per second (km/s). That number represents an agreed threshold—developed during negotiations between the United States and Russia in the mid-1990s—between a theater missile-defense system and a homeland defense system.[57] A second important criterion that emerged from the US–Russian demarcation efforts stipulated that testing of the interceptors cannot be performed against target missiles with ranges exceeding 3,500 kilometers and a velocity of 5 km/s over any part of their trajectory.[58]

52 House Hearing, *FY24 Budget Request for Missile Defense and Missile Defense Programs*, House Armed Services Committee, Strategic Forces Subcommittee, 118th Cong., April 18, 2023, Statement of Vice Admiral Jon A. Hill, US Navy, director, Missile Defense Agency (hereafter "Jon Hill budget testimony"), p. 7, <https://armedservices.house.gov/sites/evo-subsites/republicans-armedservices.house.gov/files/mda_fy24_written_statement_hasc%20md_md%20hearing[39]%20(2).pdf>. See also Wes Rumbaugh, "A New Generation of Homeland Missile Defense Interceptors," Center for Strategic and International Studies, <November 12, 2019, https://www.csis.org/analysis/new-generation-homeland-missile-defense-interceptors>; Missile Defense Advocacy Alliance, "Multi-Object Kill Vehicle (MOKV)," n.d., <https://missiledefenseadvocacy.org/defense-systems/multiple-kill-vehicle-mkv/>.

53 Arms Control Association, "Missile Defense Systems at a Glance," August 2019, <https://www.armscontrol.org/factsheets/missiledefenseataglance>.

54 Jim Wolf, "U.S. Missile-Defense Salvage Operations under Way," *Reuters*, June 9, 2009, <https://www.reuters.com/article/us-arms-usa-missiles-sb-idUSTRE5584HS20090609/>.

55 See, for instance, CRS, "Anti-Ballistic Missile Treaty Demarcation and Succession Agreements: Background and Issues," CRS Report 98-496, April 27, 2000, <https://crsreports.congress.gov/product/pdf/RL/98-496/2>; Lisbeth Gronlund, George Lewis, Theodore Postol, and David Wright, "Highly Capable Theater Missile Defenses and the ABM Treaty," *Arms Control Today*, Vol. 24, No. 3 (April 1994), pp. 3–8; National Institute for Public Policy, "Proliferation, Potential TMD Roles, Demarcation, and ABM Treaty Compatibility," National Institute for Public Policy, September 1994, <https://apps.dtic.mil/sti/tr/pdf/ADA344594.pdf>.

56 When forward deployed in Poland and Romania, these interceptors cannot intercept the plurality of Russian ICBM trajectories. See Sankaran, *The United States' European Phased Adaptive Approach*. However, if these interceptors are repurposed and deployed in the United States or in the Atlantic and Pacific Oceans near the US coast, they may have homeland defense capabilities.

57 CRS, "Anti-Ballistic Missile Treaty Demarcation and Succession Agreements," pp. 10–19.

58 CRS, pp. 10–19.

More recently, the second criterion separating theater and homeland missile defense has been completely abandoned. Reacting to advances in North Korean ballistic missiles, the FY 2018 National Defense Authorization Act directed the MDA to test the technological feasibility of the SM-3 Block IIA interceptor to defeat an ICBM threat.[59] The SM-3 IIA interceptors were initially designed to defend against medium- and intermediate-range ballistic missiles.[60] The 2019 Missile Defense Review, prepared by the Trump administration, highlighted the potential for SM-3 Block IIA interceptors deployed on BMD-capable ships to provide an additional underlayer to the GMD system and shoot down incoming missiles that might be missed by that system. The review claimed that these ships, which are deployed across the world for different missions, could be "moved into position quickly" in a crisis to defend the US homeland.[61]

In Flight Test Mission 44 (FTM-44), on November 16, 2020, the MDA employed a BMD-capable ship to launch an SM-3 IIA interceptor and intercept an ICBM-range missile.[62] After the test, the director of the MDA, Vice Admiral Jon Hill, declared that, despite significant uncertainty in the trajectory of the target, the interceptor executed a high-divert maneuver to intercept the target.[63] His statement indicates that SM-3 IIA interceptors are inherently capable of providing homeland missile defense.[64]

The use of SM-3 IIA interceptors for homeland defense against ICBMs may now be de facto US policy. In June 2021, Deputy Secretary of Defense Kathleen Hicks reportedly authorized moving 11 SM-3 IIA interceptors from research to deployment after the success of FTM-44.[65]

Before the flight test, Hill stated, "If we succeed with Aegis, then we'll go right down the path with THAAD."[66] Such a networked missile-defense system—that is, one that

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59 CRS, "Navy Aegis Ballistic Missile Defense (BMD) Program: Background and Issues for Congress," CRS Report RL33745, updated April 1, 2022, p. 12, <https://crsreports.congress.gov/product/pdf/RL/RL33745/235>.

60 Richard R. Burgess, "MDA Considering Navy's Aegis System for Homeland Missile Defense," *Seapower*, August 18, 2020, <https://seapowermagazine.org/mda-considering-navys-aegis-system-for-homeland-missile-defense/>.

61 US Department of Defense, "2019 Missile Defense Review," pp. XIII–XIV.

62 Megan Eckstein, "MDA to Use Destroyer USS John Finn for Defense-of-Hawaii Missile Intercept Test," *USNI News*, August 5, 2020, <https://news.usni.org/2020/08/05/mda-to-use-destroyer-uss-john-finn-for-defense-of-hawaii-missile-intercept-test>; CRS, "Navy Aegis Ballistic Missile Defense (BMD) Program," p. 12.

63 Megan Eckstein, "MDA: Test of DDG, Standard Missile-3 IIA a Good Start, but More Work Needed on Homeland Defense Mission," *USNI News*, May 13, 2021, <https://news.usni.org/2021/05/13/mda-test-of-ddg-standard-missile-3-iia-a-good-start-but-more-work-needed-on-homeland-defense-mission>.

64 Some caution is necessary in judging the capabilities of the SM-3 IIA. Components of the SM-3 Block IIA were implicated in the failures of the Redesigned Kill Vehicle program. See Jaganath Sankaran and Steve Fetter, "Defending the United States: Revisiting National Missile Defense against North Korea," *International Security*, Vol. 46, No. 3 (Winter 2021), p. 67. It may be the case that the test demonstrates much less than is touted by proponents of missile defense. However, such details do not seem to alter significantly analyst perceptions in Russia and China, much as limitations and faults in Soviet missile defense did not alter the drive to make worst-case evaluations in the United States in the 1960s. See Tong Zhao, "Managing the Impact of Missile Defense on U.S.–China Strategic Stability," in Tong Zhao and Dmitry Stefanovich, *Missile Defense and the Strategic Relationship among the United States, Russia, and China* (Cambridge, MA: American Academy of Arts & Sciences, 2023), pp. 15–17, <https://www.amacad.org/publication/missile-defense-and-strategic-relationship-among-united-states-russia-and-china>.

65 Anthony Capaccio, "U.S. Navy Ships Close to Getting Interceptors that Could Stop an ICBM," *Bloomberg*, June 22, 2021, <https://www.bloomberg.com/news/articles/2021-06-22/navy-ships-close-to-getting-interceptors-that-could-stop-an-icbm#xj4y7vzkg>.

66 Jen Judson, "Missile Defense Agency Director Lays out Hurdles in Path to Layered Homeland Missile Defense," *Defense News*, August 18, 2020, <https://www.defensenews.com/digital-show-dailies/2020/08/18/missile-defense-agency-director-lays-out-hurdles-in-path-to-layered-homeland-missile-defense/>. See also Jen Judson, "Congress Makes Moves to Fund Additional Terminal-Phase Missile Defense Battery," *Defense News*, November 10, 2020, <https://www.defensenews.com/pentagon/2020/11/10/congress-makes-moves-to-fund-additional-terminal-phase-missile-defense-battery/>. The THAAD system could offer limited terminal defense against high-value small-area assets; the

includes a homeland defense shield buttressed by a shoot-look-shoot GMD system, SM-3 IIA interceptors as an underlayer, and THAAD interceptors for terminal defense—cannot reasonably be claimed to be limited. Such a multilayered missile defense is likely to be viewed as highly destabilizing and as catalyzing an arms race. Each of these missile-defense systems, in its individual capacity, may have originated as an effort to develop viable defense against limited threats from rogue states. However, if integrated and repurposed for comprehensive strategic defense, the number of interceptors and opportunities for interception could provide a significant capability for strategic defense against Russian and Chinese missiles. It is not unreasonable for Russia and China to suggest that these efforts foretell the possibility of a rapid breakout in US strategic defense.[67] In joint statements issued in 2019 and 2022, leaders of Russia and China have characterized US missile defense as posing a threat to their deterrents and provoking an arms race.[68]

The flight test of the SM-3 IIA discussed above portends further technological advances. The technological skills learned in testing the SM-3 IIA against ICBM targets could revive interest in a more capable SM-3 IIB interceptor. In 2013, the Obama administration scrapped plans for an SM-3 IIB interceptor with higher burnout velocity.[69] However, the decision was not universally embraced. In 2016, congressional missile-defense proponents requested that the MDA director provide a briefing on concept development for future upgrades "through an evolved and iterative variant, for example, an SM-3 IIA + ."[70] Such higher-burnout variants would provide the United States with a more powerful interceptor.

Limited publicly available data suggest that the MDA may have plans to acquire a significant arsenal of SM-3 IIA interceptors. A 2021 Congressional Research Service (CRS) report projected the US Navy to have acquired 50 SM-3 IIA interceptors by FY 2025.[71] Updates to the CRS report do not mention the total number of interceptors in the MDA inventory. However, the most recent update of the CRS report (as of the writing of this article) indicates plans to acquire 12 SM-3 IIA interceptors each year from FY 2025 through FY 2029.[72] These interceptors could be deployed on a

system is designed to be deployable on C-17 aircraft. See Sankaran and Fearey, "Missile Defense and Strategic Stability."

[67] The US strategic community had similar worries about the ability of the Soviets to quickly expand their missile-defense capabilities and surprise the United States. In the late 1970s, the US delegation to the ABM Treaty negotiations feared that the Soviets might secretly upgrade their air-defense SAMs into ABM interceptors while eluding detection by US intelligence. See Herbert Scoville, Jr., "Upgrading Soviet SAM," *New Republic*, October 9, 1971, p. 19. With the goal of avoiding such a possibility, the United States strenuously negotiated strict limits on Soviet experiments with air-defense and missile-defense interceptors as part of the 1972 ABM Treaty. The ABM Treaty was designed to avert such a possibility. Article VI of the ABM Treaty required that interceptors other than permitted ABM interceptors not be given the ability "to counter strategic ballistic missiles" and the parties were not permitted "to test them in an ABM mode." See Treaty between the United States of America and the Union of Soviet Socialist Republics on the Limitations of Anti-Ballistic Missile Systems, May 26, 1972, <https://2009-2017.state.gov/t/avc/trty/101888.htm#text>.

[68] See Ministry of Foreign Affairs of the People's Republic of China, "Assistant Foreign Minister Zhang Jun Publishes a Signed Article on Jointly Strengthening Global Strategic Stability between China and Russia"; Office of the President of Russia, "Joint Statement of the Russian Federation and the People's Republic of China."

[69] Sankaran, *The United States' European Phased Adaptive Approach*, p. 6.

[70] Justin Doubleday, "Missile Defense Agency Not Pursuing Follow-on to SM-3 Block IIA Interceptor," *Inside Missile Defense*, Vol. 22, No. 22 (October 26, 2016), <https://www.jstor.org/stable/e24789477>, pp. 1, 6.

[71] Ronald O'Rourke, "Navy Aegis Ballistic Missile Defense (BMD) Program: Background and Issues for Congress," CRS Report RL33745 (February 25, 2021), p. 11, <https://crsreports.congress.gov/product/pdf/RL/RL33745/221>.

[72] O'Rourke, "Navy Aegis Ballistic Missile Defense (BMD) Program," July 24, 2024, p. 13.

significant number of BMD-capable ships. Rear Admiral Douglas L. Williams, the acting director of the MDA, testified on December 7, 2023, that there were 49 BMD-capable ships and that the number was expected to reach 69 in FY 2030.[73] Additionally, these ships have become increasingly sophisticated. In the last few years, they have been provided with "engage on remote" (EOR) missile-defense capability, which enables them to use data from tracking sensors that do not reside within the ship.[74] In 2018, the MDA, in one of its flight tests, demonstrated the EOR capability.[75] Subsequently, in 2019, the MDA upgraded several ships to perform EOR missile-defense operations.[76] These upgrades enable the ships to simultaneously use tracking cues from satellites, THAAD X-band radars, and other external sensors to guide the interceptors.[77] Using the EOR capability, the SM-3 IIA interceptors can intercept a target missile at a far greater distance. MDA Director Hill has testified that the EOR capability provided "a seven-fold increase" in the area covered by missile-defense ships compared with relying on ship-based sensors.[78]

Technology creep in sensors

The technological evolution in the performance of interceptors and platforms is further reinforced by a separate dedicated effort to advance the state-of-the-art sensors supporting missile-defense missions. For instance, the 2022 Missile Defense Review advocated a global architecture of sensors that seamlessly transitions "from theater-level threats to homeland defense."[79] Such an effort, however, is already long-standing.

The SPY-6(V)1 radar, also known as the Air and Missile Defense Radar (AMDR), offers an illustrative example of recent spectacular advances in sensor technologies.[80] The SPY-6(V)1 radar has been installed on the first of the US Navy's BMD-capable Flight III *Arleigh Burke*-class destroyers, which was commissioned in June 2023.[81] The

[73] House Hearing, *Regional Missile Defense Assets: Assessing COCOM and Allied Demand for Capabilities*, 118th Cong., 1st Sess., December 7, 2023 (Statement of Rear Admiral Douglas L. Wiliams, Director (Acting), Missile Defense Agency, House Armed Services Committee, Strategic Forces Subcommittee), p. 2, 6, <https://www.congress.gov/118/meeting/house/116678/witnesses/HHRG-118-AS29-Wstate-WilliamsD-20231207.pdf>.

[74] The technological effort to seed the Aegis-equipped BMD-capable ships with a launch-on-remote and engage-on-remote (EOR) capability has been a decade-long effort. See National Research Council of the National Academies, *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, DC: National Academies Press, 2012), <https://nap.nationalacademies.org/catalog/13189/making-sense-of-ballistic-missile-defense-an-assessment-of-concepts>, p. 77.

[75] Jason Sherman, "After MDA Demonstrates 7x Increase in Defended Area, Raytheon Pitching for Older SM-3s," *Inside Defense*, April 1, 2020, <https://insidedefense.com/daily-news/after-mda-demonstrates-7x-increase-defended-area-raytheon-pitching-eor-older-sm-3s>.

[76] Sherman, "After MDA Demonstrates 7x Increase."

[77] Sherman. These upgrades will enable all the variants of the SM-3 interceptors to perform EOR missile defense intercepts.

[78] Sherman.

[79] US Department of Defense, "2022 Missile Defense Review," p. 8. The document pays particular attention to space-based sensors, arguing that "resilient space-based infrared, radar, and associated data transport systems will be critical" to the future of missile-defense efforts. See US Department of Defense, pp. 8–9.

[80] The AMDR will replace the current S-band Aegis SPY-1 radar on BMD-capable ships. It consists of the large four-faced S-band AMDR-S and the smaller X-band AMDR-X radars. See Laura Grego, George N. Lewis, and David Wright, "Appendix 10: Sensors," in *Shielded from Oversight: The Disastrous Approach to Strategic Missile Defense* (Cambridge, MA: Union of Concerned Scientists, 2016), p. 7.

[81] See Mallory Shelbourne, "Navy Takes Delivery of First Flight III Destroyer Jack H. Lucas," *USNI News*, June 27, 2023, <https://news.usni.org/2023/06/27/navy-takes-delivery-of-first-flight-iii-destroyer-jack-h-lucas>. It should be noted that the US Navy is also replacing the existing radars on the approximately 46 Flight II *Arleigh Burke*-class destroyers with a scaled-down version of the SPY-6(V)1 radars, giving the radars on the destroyers 30 times more

radar will be installed on the approximately 15 Flight III *Arleigh Burke*-class destroyers that the Navy is scheduled to procure by 2027.[82] As noted above, the SPY-6(V)1 originally had a programmatic requirement for a sensor to be 30 times more sensitive than the current SPY-1 radar deployed on the BMD-capable ships.[83] However, the SPY-6(V)1 radar has turned out better than expected and is "nearly 100 times more sensitive" than the SPY-1 radar.[84] In other words, the SPY-6(V)1 could track objects with similar signatures at approximately three times the range of the SPY-1 radar.[85]

A threefold increase in the tracking range of the organic radar sensors of the BMD-capable ships, coupled with the EOR capability, significantly expands the missile-defense capabilities of these platforms.[86] The increasing number of BMD-capable ships

sensitivity. See Sherman, "Navy Determines SPY-6 Radar Three Times Stronger." While the SPY-6(V)1 slated to be deployed on the Flight III destroyers will be composed of four antenna faces, each with 37 radar modular assembles, the version slated to replace the radars on the Flight II destroyers will be composed of 24 radar modular assemblies. See Sherman; Richard R. Burgess, "With SPY-6, Navy Has Radar to Match the Range of Its Missiles," *Seapower*, April 1, 2022, <https://seapowermagazine.org/with-spy-6-navy-has-radar-to-match-the-range-of-its-missiles/>.

82 Shelbourne, "Navy Takes Delivery of First Flight III Destroyer."

83 Sherman, "Navy Determines SPY-6 Radar Three Times Stronger."

84 Sherman. These performance gains emerge from advances in material-science technology, particularly gallium nitride (GaN) semiconductors. GaN is capable of operating at higher voltages than other materials. The new AMDR radar replaces older vacuum-tube transmitters with GaN solid-state transmitters, SOLSTx, which can provide orders-of-magnitude improvements in performance. The SOLSTx transmitter, manufactured with GaN semiconductor materials, requires much less cooling, thereby reducing the power demand while increasing efficiency and range. Furthermore, GaN SOLSTx transmitters offer better adaptive digital beamforming and faster frequency switching and have proved to be more long-lasting and reliable by a factor of 10, increasing the mean time between failures to 50,000 hours. See Edward J. Walsh, "Naval Systems—Solid-State Technology Promises Gains for Aegis," *Proceedings* (US Naval Institute), Vol. 142, No. 8 (August 2016), p. 1362; Dave Sammut and Chantelle Craig, "The Rise and Rise of Gallium," *Chemistry in Australia*, August 2018, <https://dcstechnical.com.au/wp-content/uploads/2018/07/Chemistry-in-Australia-46-July-Aug-2018.pdf>, pp. 20–23; ni (National Instruments Corp.), "4 Game-Changing Underlying Technologies for Advanced Radar," September 21, 2022, <https://www.ni.com/en-us/solutions/aerospace-defense/radar-electronic-warfare-sigint/4-game-changing-underlying-technologies-for-advanced-radar.html>; David W. Runton, Brian Trabert, Jeffrey B. Shealy, and Ramakrishna Vetury, "History of GaN," *IEEE Microwave Magazine*, Vol. 14, no. 3 (May 2013), pp. 82–93. GaN radars may also be cost effective. See Garrett Reim, "Raytheon Unveils Compact, Half-Priced Gallium Nitride AESA Radar," *Flight Global*, September 23, 2021, <https://www.flightglobal.com/fixed-wing/raytheon-unveils-compact-half-priced-gallium-nitride-aesa-radar/145611.article>.

85 The maximum range of a radar is determined by the following equation:

$$R_{max}^4 = \frac{P_{av} G A \rho_a \sigma \, n \, E_i(n) \, F^4 \, e^{-2\alpha \boldsymbol{R}_{max}}}{(4\pi)^2 \, kT_0 F_n \, (B\tau) f_p \left(\frac{S}{N}\right)_1 L_f L_s}$$

For details on the equation, see Sankaran and Fearey, "Missile Defense and Strategic Stability," p. 341. However, since we are dealing with relative sensitivity, we can write,

$$\text{Relative sensitivity} = \frac{[R_{max}^4]_{SPY\,6}}{[R_{max}^4]_{SPY\,1}}$$

where R_{max} is the maximum range of the radar

$$[R_{max}^4]_{SPY\,6} = \text{Relative sensitivity} \times [R_{max}^4]_{SPY\,1}$$

$$[R_{max}^4]_{SPY\,6} = (\sim 100) \times [R_{max}^4]_{SPY\,1}$$

$$[R_{max}]_{SPY\,6} = (\sim \sqrt[4]{100}) \times [R_{max}]_{SPY\,1}$$

$$R_{max\ SPY\,6} = (\sim 3.2) \times [R_{max}]_{SPY\,1}$$

86 However, the S-Band SPY-6(V)1 radar is not ideally suited to discriminate decoys and other countermeasures from the ICBM warhead. X-band radars are better suited to this task. However, fusing data from the SBX sea-based radar could

armed with these radars and the SM-3 IIA interceptors could provide a capacity to create a dense second layer of homeland defense, augmenting the GMD system. Furthermore, as noted earlier, the 2019 Missile Defense Review has already suggested the possibility of BMD-capable ships being used to defend the US homeland in a crisis.[87]

US advances in missile-defense radars have progressed alongside technological gains in space-based tracking of missiles and accurate cueing of interceptors to the predicted intercept point.[88] Since the 2000s, the MDA has expended considerable effort to increase the efficiency of sensors used in such space-based tracking and cueing.[89] For instance, recent research-and-development (R&D) efforts have been focused on developing an even more high-performance array of semiconductor chips that are used in space-based sensors.[90] Additionally, the Space Development Agency (SDA), established in 2019, aims to develop a seven-layer National Defense Space Architecture consisting of constellations of 550 satellites for global coverage.[91]

SDA's tracking layer is advertised as providing "indications, warning, tracking, and targeting" of missiles, including hypersonic missiles.[92] SDA has also indicated it plans to develop and launch an eight-satellite Wide Field of View (WFOV) architecture.[93] The first WFOV satellite was launched on July 1, 2022.[94] These WFOV satellites are expected to provide cueing data for other sensors, including the MDA's planned Hypersonic and Ballistic Tracking Space Sensor (HBTSS).[95] The MDA is also exploring birth-to-death tracking and discrimination as part of the HBTSS and the

offset limitation of the organic S-Band SPY-6(V)1 radars slated to be installed on BMD-capable ships. See National Research Council of the National Academies, *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, DC: National Academies Press, 2012), pp. 117, 132–37.

87 US Department of Defense, "2019 Missile Defense Review," pp. XIII–XIV.

88 The MDA has a long history of pursuing advanced research on low-earth-orbit space-based sensors. See National Research Council of the National Academies, *Making Sense of Ballistic Missile Defense,* pp. 89, 119, 217.

89 Office of the Director of Defense Science and Engineering Department of Defense, *Defense Science and Technology Success Stories* (Washington, DC: Department of Defense, 2007), p. 116, <https://apps.dtic.mil/sti/citations/ADA568949>; E.P.G. Smith, A.M. Gallagher, T.J. Kostrzewa, M.L. Brest, R.W. Graham, C.L. Kuzen, E.T. Hughes, et al., "Large Format HgCdTe Focal Plane Arrays for Dual-Band Long-Wavelength Infrared Detection," *Physica Status Solidi*, Vol. 7, No. 10 (2010), pp. 2522–25.

90 These strained-layer-superlattice (SLS) focal-plane arrays are being developed to surpass the signal-to-noise ratio of mercury cadmium telluride (HgCdTe) arrays by a factor of 10 while also reducing relative weight and power consumption. See Department of Defense, *Department of Defense Fiscal Year (FY) 2012 Budget Estimates. Missile Defense Agency, Justification Book, Vol. 2, Research, Development, Test & Evaluation, Defense-Wide* (Washington, DC, 2011), pp. 120–23, <https://comptroller.defense.gov/Portals/45/Documents/defbudget/fy2012/budget_justification/pdfs/03_RDT_and_E/MDA.pdf>; Meimei Z. Tidrow, Lucy Zheng, Hank Barcikowski, James Wells, and Leslie Aitcheson, "Manufacture of Sb-Based Type II Strained Layer Superlattice Focal Plane Arrays," paper delivered at the CS MANTECH Conference, Tampa, Florida, May 18-21, 2009, <https://citeseerx.ist.psu.edu/document?repid=rep1&type=pdf&doi=5ffd11926e6e04cffcd3394a6debcb5a352d175a>.

91 Kelley M. Sayler, "Hypersonic Missile Defense: Issues for Congress," In Focus IF11623, CRS, October 3, 2022, p. 1, <https://crsreports.congress.gov/product/pdf/IF/IF11623/7>. The seven layers consist of a data-tracking and transport layer, a custody layer for targeting of mobile ground assets, a battle-management layer to provide space-based command and control, a navigation layer for alternate GPS, a deterrence layer for space-based space surveillance, and a support layer to facilitate satellite operations.

92 Sayler, "Hypersonic Missile Defense," p. 1.

93 Sayler, p. 1.

94 Sandra Erwin, "ULA's Atlas 5 Launches U.S. Space Force Experimental Missile-Warning Satellite," *Space News*, July 1, 2022, <https://spacenews.com/ulas-atlas-5-launches-u-s-space-force-experimental-missile-warning-satellite/>.

95 Sayler, "Hypersonic Missile Defense," p. 1; Sandra Erwin, "Space Force to Activate Sensor on Wide-Field-of-View Missile Warning Satellite," *Space News*, October 24, 2022, <https://spacenews.com/space-force-to-activate-sensor-on-wide-field-of-view-missile-warning-satellite/>.

Discriminating Space Sensor program.[96] All these space sensors will, in all probability, support and enhance homeland defense against strategic threats.

Perpetual threat and politics of missile defense

The several US efforts in missile defense described above have occurred in a permissive political environment that has discounted the fragility of strategic stability and amplified the threat of rogue states posing an intolerable nuclear risk to the United States. The threat of irrational leaders who cannot be deterred has been the linchpin in the argument for developing and building national missile-defense technologies for several decades.

In the mid-1980s, the US government allocated enormous effort and resources to the Strategic Defense Initiative (SDI), a national missile-defense program. President Reagan, justifying the need for SDI, explained to Soviet leader Mikhail Gorbachev at the 1986 Reykjavik summit that there might be a "madman like Hitler" who might build and use nuclear weapons in the future.[97] In another conversation during the summit, President Reagan cited Muammar Qaddafi, the Libyan leader, as an unpredictable madman willing to use nuclear weapons. Reagan said to Gorbachev, "We are both civilized countries and civilized people … [but] if a madman wanted to use such weapons; take Qaddafi; if he had them he would certainly have used them."[98]

Reagan also stated that the United States was willing to share any missile-defense system that proved technologically feasible as a way to convey reassurance to the Soviet Union.[99] While publicly available declassified documents indicate that Reagan was genuinely committed to the idea of sharing SDI technologies with the Soviets, members of his Cabinet were less enthusiastic.[100] Additionally, the Soviets did not believe that the United States would share such advanced defense technologies. According to a State Department record of the meeting, Gorbachev responded to Reagan by saying that

> he could not take the President seriously; speaking frankly. The United States was unwilling to give the Soviets oil drilling equipment, automatic machinery, even milk factories. For the United States to give the products of high technology would be a second American Revolution, and it would not happen. It was better to be realistic. This was more reliable.[101]

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96 US Department of Defense, "MDA, SDA Announce Upcoming Launch of the Hypersonic and Ballistic Tracking Space Sensor and Tranche 0 Satellites," February 14, 2024, <https://www.defense.gov/News/Releases/Release/Article/3676902/mda-sda-announce-upcoming-launch-of-the-hypersonic-and-ballistic-tracking-space/>. See also Jon Hill budget testimony, p. 3.

97 Jason Saltoun-Ebin, ed., *The Reagan Files: The Untold Story of Reagan's Top-Secret Efforts to Win the Cold War* (CreateSpace, 2010), p. 337.

98 US Department of State, Memorandum of Conversation [between Reagan and Gorbachev at the Reykjavik summit], October 11, 1986 (3:30 p.m. – 5:40 p.m.), <https://nsarchive2.gwu.edu/NSAEBB/NSAEBB203/Document11.pdf>, p. 13.

99 Reagan's offer implicitly presumes the enduring viability of perfect technological defense against strategic missiles. Such perfect defense may be possible for a limited period. However, maintaining it indefinitely in a world of constantly evolving technological capabilities is highly unlikely. The prospect of perfect defense decaying into imperfect defense raises several difficult questions for strategic stability. A detailed treatment of these issues can be found in Charles L. Glaser, *Analyzing Strategic Nuclear Policy* (Princeton, NJ: Princeton University Press, 1990), pp. 103–32.

100 Saltoun-Ebin, *The Reagan File*s, pp. 302, 385, 386.

101 US Department of State, Memorandum of Conversation, October 11, 1986, pp. 14–15.

Reagan, in an earlier conversation with Gorbachev at the Reykjavik summit, had argued,

> If SDI research is successful, it will make possible the elimination of nuclear weapons. We are accused of wanting a first strike capability, but we are proposing a treaty which would require the elimination of ballistic missiles before SDI is deployed, therefore a first strike would be impossible.[102]

The Soviets did not accept these arguments and threatened to respond asymmetrically to any unilateral US efforts on missile defense. In a December 1985 letter to Reagan, Gorbachev wrote that, while he believed the president personally had no intention of using SDI against the Soviet Union, the Soviet leadership had to evaluate SDI "not in accordance with intentions, but in accordance with the potential capabilities which may be attained as a result of the development of these weapons."[103] Seen in this light, the SDI shield was necessary only for "a country which is preparing for a first (disarming) strike."[104] Reiterating these arguments to Reagan at Reykjavik, Gorbachev warned that the Soviet Union would respond by increasing its strategic nuclear arsenal, developing means to neutralize SDI, building space weapons, and deploying a territorial ABM system.[105]

In the early 2000s, after the end of the Cold War, the George W. Bush administration recast the madman argument to advocate for the GMD system against rogue states. In Senate testimony, Undersecretary of Defense for Policy Douglas Feith remarked that, "if Saddam Hussein had the ability to strike a Western capital with a nuclear weapon, would he really be deterred by the prospect of a US nuclear strike that would kill millions of Iraqis? Is he that concerned about his people?"[106] Iraq, Iran, and North Korea were designated as rogue states that could not be deterred by prevailing doctrines.[107] Feith proceeded to argue that the United States no longer remained in an adversarial relationship with Russia and claimed the proposed limited GMD system would not affect Russia's strategic deterrent.[108] Predictably, Russia did not accept either the rationale for the GMD system or the argument that it would not have an impact on the Russian deterrent. Russia and China have protested against

102 Saltoun-Ebin, *The Reagan Files*, p. 338.

103 US Department of State, Division of Language Services (Translation), Letter from Soviet General Secretary Mikhail Gorbachev to President Ronald Reagan, December 24, 1985, <https://www.reaganlibrary.gov/public/2022-09/40-749-198135-040-008-2018.pdf>, p. 2.

104 US Department of State, Letter from Soviet General Secretary Mikhail Gorbachev to President Ronald Reagan, p. 2.

105 US Department of State, pp. 2–3.

106 Senate Hearing, The Administration's Missile Defense Program and the ABM Treaty, Hearings before the Committee on Foreign Relations, 107th Cong., 1st Sess., July 24, 2001 (Statement of Hon. Douglas J. Feith, Under Secretary of Defense for Policy, Department of Defense), p. 18. Casting doubt on the logic, Senator Joseph Biden, chairman of the Senate Committee on Foreign Relations, commented that "it is interesting to me that the most certifiable rogue any of us can come up with since Hitler is the guy who sits in Iraq right now, a mad man, as we characterized him, a guy impervious to international concerns, a guy who is only interested in himself. He had the capacity to use a weapon of mass destruction. We know he had biological weapons. We know he had chemical weapons. He did not use them … Now I think that flies in the face, not absolutely, but it flies in the face of the assertion so blatantly made that we know these guys do not yield to deterrence. I find that a preposterous statement." See Senate Hearing, The Administration's Missile Defense Program and the ABM Treaty, p. 64.

107 Sankaran and Fetter, "Defending the United States: Revisiting National Missile Defense against North Korea," *International Security*, Vol. 46, No. 3 (Winter 2021/22), p. 59.

108 He also argued that China was engaged in a rapid modernization of its nuclear deterrent and would continue to be so "whether or not we build missile defenses." See Statement of Hon. Douglas J. Feith, pp. 21–22.

US attempts to build a limited national missile-defense system.[109] For them, prudence required assuming that any limited system is a stalking horse for a more substantial defense.[110]

However, despite the Russian and Chinese protests, US policy makers argued that it was possible to construct a limited national missile-defense system that deters and defends against threats from rogue states while posing no strategic threat to near-peer adversaries. With this belief firmly in place, US policy makers proceeded to endow the MDA with immense power to pursue a broad range of technologies and concepts.[111] A 2006 Government Accountability Office report noted the MDA's "unique flexibility to make changes to its strategy … without necessarily having to seek prior approval from a higher-level [Department of Defense] acquisition executive … the Director [of the MDA], by statute, may decide whether a cost variation is significant enough to be reported to Congress."[112] The MDA still retains most of its independence. In 2020, Deputy Secretary of Defense David Norquist attempted to bring the agency under more oversight.[113] However, Congress halted the implementation of the changes he proposed.[114] As the preceding discussion indicates, the MDA's pursuit of technology has become completely divorced from the strategic geopolitical consequences.

Conclusion

The United States has been engaged in a continuous and persistent R&D effort on missile-defense technologies over the past several decades, which has resulted in several breakthroughs. If worst-case planning is the baseline to determine requirements for strategic deterrence, Russia and China could easily postulate imminent US qualitative and quantitative breakthroughs. Despite repeated assurances at the highest level that its missile-defense efforts are not directed against Russia and China, the United States appears to be slowly accruing the building blocks of a national missile defense that may be reconfigured against near-peer adversaries.

[109] Ministry of Foreign Affairs of the People's Republic of China, "Assistant Foreign Minister Zhang Jun Publishes a Signed Article"; Office of the President of Russia, "Joint Statement of the Russian Federation and the People's Republic of China."

[110] John D. Steinbruner, "NMD and the Wistful Pursuit of Common Sense," *National Security Studies Quarterly*, Vol. 6, No. 3 (Summer 2000), p. 111.

[111] Graham Spinardi, "Ballistic Missile Defence and the Politics of Testing: The Case of the US Ground-Based Midcourse Defence," *Science and Public Policy*, Vol. 35, No. 10 (December 2008), pp. 707–14; Sankaran and Fetter, "Defending the United States," p. 68.

[112] Government Accountability Office, "Defense Acquisitions: Missile Defense Agency Fields Initial Capability but Falls Short of Original Goals," March 15, 2006, p. 4, <https://www.gao.gov/products/gao-06-327>.

[113] Jen Judson, "New Pentagon Directive Will Put Programs on More Solid Ground, Says MDA Boss," *Defense News*, September 10, 2020, <https://www.defensenews.com/smr/defense-news-conference/2020/09/10/missile-defense-agency-director-new-pentagon-directive-will-put-programs-on-more-solid-ground/>; Jason Sherman, "Norquist Gives Services, CAPE, OSD, COCOMs New Leverage in BMD," *Inside Missile Defense*, Vol. 36, No. 36 (September 3, 2020), pp. 1, 4–5.

[114] Jason Sherman, "Norquist's Gambit Last Summer to Rein in MDA Draws an Investigation," *Inside the Pentagon*, Vol. 37, No. 6 (February 11, 2021), pp. 1, 10–11. These changes were laid out in US Department of Defense, "Directive-type Memorandum 20-002 – 'Missile Defense System Policies and Governance'," Office of the Deputy Secretary of Defense, 2020, <https://www.esd.whs.mil/Portals/54/Documents/DD/issuances/dtm/DTM-20-002.PDF?ver=0yQfTQ1VcPiZWos72PzLUw%3D%3D>. However, in an April 2023 written statement submitted to the House Armed Services Committee, Vice Adm. Jon Hill, director of the MDA, noted that the MDA was undertaking a review to update the 2009 acquisition authorities and review the changes suggested in Directive-Type Memorandum 20-002. See Jon Hill budget testimony, p. 1.

In this article, I have used the concept of technology creep to explore the reasons for the apparent differences between the stated doctrine and the actual acquisition of missile-defense technologies. I have outlined and explored two hypotheses: (1) the development and acquisition of advanced weapons can occur through technological creep without rigorous attention to its destabilizing strategic implications, and (2) external threats will be used to justify the pursuit of such technological capabilities. The empirical evidence detailed in the article shows that the development of advanced missile-defense technological capabilities occurs through continuous experimentation and sometimes through unexpected scientific developments. In addition, the analysis demonstrates that fears of threats from rogue-state actors have been employed to insulate the MDA from critical review. The MDA's technological efforts, by design, have not been constrained to avert potential strategic instabilities that can emerge from the maturation of new technologies. In the future, US decision makers need to critically balance the potential gains new technologies can offer for limited defenses against rogue actors, on the one hand, against, on the other hand, the destabilizing effect of such technologies on US relations with Russia and China.

In the immediate aftermath of the Cold War, the focus was primarily on rogue actors such as North Korea, and very limited attention was paid to strategic stability with Russia and China. Such an approach is no longer possible. US decision makers now need to factor in the implications of missile-defense decisions for strategic stability and arms control. The United States has declared the re-emergence of great-power competition. The 2022 Nuclear Posture Review asserts the emergence of two peer nuclear competitors, Russia and China. The review acknowledges "new stresses" on stability and deterrence.[115] In the face of strategic uncertainty and the possibility of technological surprise, Russia and China are likely to endeavor to respond as the United States did in the 1960s. The development and deployment of more-capable missile-defense sensors, platforms, and interceptors is almost certain to heighten Russian and Chinese fears and trigger countermeasures that may lead to a nuclear-arms race.

Some of these countervailing efforts, such as the use of anti-simulation decoys and nuclear precursor bursts to evade missile-defense systems, do not cause strategic vulnerabilities for the United States.[116] However, Russia and China have also embarked upon other countervailing efforts that have raised concerns in the United States. In the last few years, Russia has developed and tested various nuclear-capable weapons systems whose operating principles seem explicitly designed to defeat US homeland missile defense.[117] These weapons include the Avangard hypersonic boost-

115 US Department of Defense, "2022 Nuclear Posture Review," Office of the Secretary of Defense, US Department of Defense, 2022, <https://media.defense.gov/2022/Oct/27/2003103845/-1/-1/1/2022-NATIONAL-DEFENSE-STRATEGY-NPR-MDR.pdf>, p. 4.

116 Anti-simulation decoys defeat a missile defense system by making a warhead appear to be a decoy, which is often easier than the technologically challenging task of making a decoy appear to be a warhead. Nuclear-precursor bursts defeat a missile-defense system by creating blackout conditions for radars, thereby eliminating their ability to discriminate between warheads and decoys. For a detailed description of missile-defense countermeasures, including decoys and their effectiveness, see Sankaran and Fetter, "Defending the United States."

117 Sankaran and Fetter, p. 73. For a broader discussion of Russian internal deliberations on hedging and offsetting strategies to overcome US technological advances in weapons systems, see Jaganath Sankaran, "Russia's Anti-satellite Weapons: A Hedging and Offsetting Strategy to Deter Western Aerospace Forces," *Contemporary Security Policy*, Vol. 43, No. 3 (June 2022), pp. 436–63.

glide vehicle, the Poseidon nuclear-powered torpedo, the Kinzhal air-launched hypersonic missile, the Burevestnik nuclear-powered cruise missile, and the Tsirkon hypersonic cruise missile.[118] China, similarly, has undertaken several efforts such as the development of ASAT weapons, hypersonic missiles, and a FOBS in response to US missile defense.[119] The 2022 US Department of Defense report on China's military and security developments notes that China's FOBS is "in part due to long-term concerns about United States missile defense capabilities."[120] The report continues, "PRC leaders are concerned that the United States could achieve rapid advances in missile defense technology. … PRC leaders are concerned that Washington could achieve a breakthrough development in system effectiveness or deployment scale that negates Beijing's ballistic missile arsenal."[121] These Russian and Chinese efforts are leading to demands from some US decision makers for military countermeasures, weakening support for arms control and further catalyzing instability.[122]

A rethinking of the technological scope and purpose of "limited" US missile defense is urgently needed. The 2022 Missile Defense Review declares, "As the scale and complexity of the Democratic People's Republic of Korea (North Korea) missile capabilities increase, the United States will also continue to stay ahead of North Korean missile threats to the homeland through a comprehensive missile defeat approach."[123] But how? Is it possible to stay ahead of a quickly maturing North Korean missile and nuclear arsenal while still not threatening the Russian and Chinese nuclear deterrents? Technological advances and programmatic efforts may have reached the point where the cumulative plans for future US missile-defense architecture cannot be claimed to be limited. A critical discussion of what constitutes limited missile defense and its technological features is urgently needed. The discussion should engage Russian and Chinese counterparts in discussions on the future of arms-control agreements, including extending the 2010 New START past its upcoming expiration on February 4, 2026.

The present geopolitical environment poses challenges to any undertakings that seek to engage with Russia and China on arms control or to conduct multilateral efforts to limit North Korean missile and nuclear capablities. However, limited-scope bilateral diplomatic efforts to constrain North Korean capabilities with a separate political commitment to revisit US missile defense might gain buy-in from Russia and China.

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118 Hruby, *Russia's New Nuclear Weapon Delivery Systems*, pp. 14–35.

119 For an excellent review of several countermeasures undertaken by China and the nature of the debate in Chinese decision-making circles on these decisions, see Tong Zhao, *Narrowing the U.S.–China Gap on Missile Defense: How to Help Forestall a Nuclear Arms Race* (Washington, DC: Carnegie Endowment for International Peace, 2020), pp. 45–50.

120 US Department of Defense, "Military and Security Developments Involving the People's Republic of China 2022: Annual Report to Congress," 2022, <https://www.defense.gov/Spotlights/2022-China-Military-Power-Report/>, p. 98. The report also notes that "PRC leaders are concerned that the United States could achieve rapid advances in missile defense technology, despite the technical limitations and small stockpiles of present U.S. interceptor systems. PRC leaders are concerned that Washington could achieve a breakthrough development in system effectiveness or deployment scale that negates Beijing's ballistic missile arsenal." See US Department of Defense, p. 159.

121 US Department of Defense, "Military and Security Developments," p. 159.

122 Theresa Hitchens, "It's a FOBS, Space Force's Saltzman Confirms amid Chinese Weapons Test Confusion," *Breaking Defense*, November 29, 2021, <https://breakingdefense.com/2021/11/its-a-fobs-space-forces-saltzman-confirms-amid-chinese-weapons-test-confusion/>; Demetri Sevastopulo and Kathrin Hille, "China Tests New Space Capability with Hypersonic Missile," *Financial Times,* October 16, 2021, <https://www.ft.com/content/ba0a3cde-719b-4040-93cb-a486e1f843fb>.

123 US Department of Defense, "2022 Missile Defense Review," p. 1.

Such limited-scope efforts should focus on halting North Korean missile tests and constraining further expansion of the country's ICBM arsenal instead of demanding complete denuclearization. These measures could pay very high dividends and help to keep missile defense limited without diluting its ability to defend the United States.

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No potential conflict of interest was reported by the author.