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Shining a Light on Cyber

An Interview with John C. "Chris" Inglis

Former Deputy Director, National Security Agency
Member, Cyberspace Solarium Commission

Conducted 4 July 2020

The Cyberspace Solarium Commission was established through the 2019 National Defense Authorization Act (NDAA) and charged with answering two questions: "What strategic approach will defend the United States against cyberattacks of strategic consequence? And what policies and legislation are required to implement that strategy?" The Commission began in the spring of 2019 and included four legislators; the deputies of the Departments of Defense, Justice, and Homeland Security; the director of national intelligence; and six commissioners appointed from the private sector by the majority and minority leaders of the House and Senate. It conducted over 300 engagements across the private and public sectors, including 30 face-to-face Commission meetings. The Commission report of 11 March 2020 recommended an overall strategy along with 82 proposals centered around six key areas: government organizational reform, international norms, national resilience, reshaping the cyber system, private-sector collaboration, and the military instrument of power. The entire report can be found at https://www.solarium.gov/. This interview with commissioner Chris Inglis is a behind-the-scenes view of cybersecurity and the Commission's work.

***SSQ*: How bad is the threat to our national security, and is the threat worse in one area, such as infrastructure or commerce?**

JCI: The digital era has brought economic growth, technological innovation, and an improved quality of life to nearly every American. It has also created a strategic dilemma. The more digital connections we make and data we exchange, the more opportunities adversaries from criminals to nation-states have to intrude on national defense, disrupt critical functions, and damage our economic and democratic institutions. The Solarium Commission worked over the past year to identify and address several key national security problem areas, including the defense of our critical infrastructure.

First and foremost, our nation lacks an integrated national cyber strategy. There are inconsistencies and gaps across the various departments and agencies, and our nation does not have a cohesive vision for how to work together across the federal enterprise, let alone with the private sector. Second, most of our critical infrastructure is owned and operated by

the private sector and faces increasing attacks by malicious cyber actors on a daily basis, to include adversarial nation-states. And while the skirmish lines of cyberspace are quite literally manned by the private sector, the government can and must do more to support its efforts with a robust, proactive, and collaborative application of the full suite of government-unique authorities and capability. Third, we must get faster and smarter, improving the government's ability to organize concurrent, continuous, and inherently collaborative initiatives to build resilience, respond to cyber threats, and preserve whole-of-government options that signal capability and willingness to impose costs on adversaries.

***SSQ*: The report critiques current US organization and structure for cyber as inadequate and proposes a new national cyber director, but it does not recommend eliminating any of the current competing organizations. Why not?**

JCI: The Commission determined that the fundamental problem across the federal cyber enterprise was a lack of coherence—not duplicative efforts or competition—a problem significantly exacerbated by the lack of a person or organization accountable for anticipating and preparing for coordinated action. Looking at the history and current structure of the executive branch, three clear institutional challenges emerged. First, the federal government lacks consistent, institutionalized leadership in the White House on cyber and cybersecurity. Second, due to the lack of a consistent advocate, cybersecurity is inconsistently prioritized in the context of national security. Third, the United States lacks a coordinated, cohesive, and clear strategic vision for cyber. While a national-level cyber coordination position has existed in various forms within the White House through the years, it has never been Senate confirmed. It also inherently did not have a robust ability to influence the president's budget or to convene decision makers to prepare and recommend a coordinated strategy and lines of effort to the president. In considering how best to implement such a role, we did not find any organization currently assigned to it, leading us to conclude that we needed to create the role rather than eliminate one or more of the stovepipes.

***SSQ*: The tone of the recommendations appears quite aggressive. Is this an accurate description, and was this the intent?**

JCI: The report and its recommendations *are* aggressive, but it is important to note their overwhelming focus on defense and deterrence. It is past time for the US to seize the initiative ceded to adversaries by our collective

failure to increase the cost of their aggression as a deterrent to their further escalation. The central message embedded in the Commission's recommended strategy is that the US intends to undercut the advantage adversaries have enjoyed in being able to selectively target and defeat weak links in our system. Henceforth, an adversary will find the US more resilient, unified, capable, and willing to impose costs for bad behavior. The Commission's recommended strategy is therefore one of "layered cyber deterrence" based on investments in norms, resilience, proactive defense, cost imposition, a more robust public-private partnership, and leverage accruing from international coalitions.

The Commission recognized the strategic merits of the Defense Department's "defend forward" 2018 cyber strategy. At its heart, defend forward is about protecting the things the United States holds dear, like its democratic institutions, economy, and way of life.

The concept of forward defense has long-standing historical roots. American grand strategy during the Cold War was anchored in this concept. Moreover, there are also risks associated with inaction or, worse, tolerating bad behavior. Defend forward will include taking actions at the operational and tactical levels that will change how our adversaries understand our priorities and decision calculus and, in turn, choose to operate in the domain. We also have to be more proactive in communicating the United States' intentions, goals, and means. This is why signaling is so important and why we need a more robust signaling strategy. We can better manage any potential escalation risks that may arise and better communicate with adversaries as well as our allies. In all of this, the Commission deliberately took into account potential escalation risks.

Some reviewers have raised concerns that the Commission's affirmation of the defend forward concept suggests the United States become more offensive in its defense of cyberspace. We wanted to make clear that, in keeping with the defend forward concept as understood by both the Commission and the Department of Defense, it is an inherently defensive strategy that incorporates early warning and early action against material threats to US interests. More importantly, the Commission recommends that the US extend the concept to the use of all instruments of national power, applying legal, diplomatic, and financial tools in a coordinated fashion that adheres to international law and the associated standards of necessity and proportionality.

***SSQ*: Is it probable that democracies may be able to counter what appears to be authoritarian regime advantage in cyberspace?**

JCI: Authoritarian regimes certainly have undeniable advantages in cyberspace. They can subordinate individual citizen interests to those of the state and are better positioned to present a unified front, long term, in various international fora that determine the internet's norms, standards, and protocols. However, the authoritarian approach stifles innovation—which remains the vital engine on which cyberspace continues to be built—and brings with it unacceptable restrictions on human rights along with the imposition of state surveillance and control. The Commission recommends that the United States work with like-minded countries to counter the malicious actions of authoritarian regimes by building on the vitality and innovation delivered by free, open, diverse, and democratic societies while creating coalitions that act in concert to detect, respond to, and punish bad behavior. In the end, we are more likely to be an attractive alternative to nonaligned states by delivering better performance alongside the values America, its partners, and allies hold dear.

***SSQ*: Can cybersecurity norms realistically prevent malicious activities when many offensive cyber operations seem to violate norms?**

JCI: Norms in and of themselves do not prevent malicious activities, but they are the vital foundation on which incentives and consequences affecting human and nation-state behavior must reside. The Commission's proposed deterrence strategy depends on the concurrent and integrated application of three lines of effort: *shaping behavior* by working with the private sector, partners, and allies to define and promote responsible behavior; *denying benefits* to adversaries who would violate accepted rules of behavior; and *imposing costs* on those who do. The ultimate targets of deterrence then are the humans who—singly or collectively—promote, tolerate, or undertake malicious action in cyberspace. They will respond to incentives and consequences if we are clear in articulating them, unified in applying them, and diligent in following through on "promises made" in the form of incentives or cost imposition. Authoritarian regimes, like China and Russia, sometimes have tactical advantage in cyberspace as they violate international norms through operations that disregard agreed rule of law and impinge on human rights. But international norms implemented and reinforced by a coalition of states willing to call out and impose costs for transgressions will affect the decision calculus and ultimately the behavior of rogue actors. This is why the Commission recommends creating and appropriately funding a new Cyberspace Security and Emerging Technologies Bureau led by a new assistant secretary at the Department of State. The assistant secre-

tary will be responsible for coordinating engagements with partners and allies to build and support that coalition.

***SSQ*: Are you concerned about the intersection and comingling of technologies such as cyber, artificial intelligence, quantum computing, and space?**

JCI: The Commission recognizes that emerging technologies such as artificial intelligence and quantum information science pose both opportunities and risks. Several of our recommendations touch on this very issue. More importantly, the Commission recommends that the national cyber director take on the additional responsibility for coordinating federal efforts to anticipate and address emerging technologies. The Commission's report contains specific recommendations that address federal research and development funding levels, quantum computing, related funding support for the National Institute of Standards and Technology (NIST), and support for the President's National Security Telecommunications Advisory Committee (NSTAC) cyber "moonshot" initiative. This initiative recommends a transformative effort to reengineer the underpinnings of cyberspace to yield an inherently more robust, resilient, and defensible domain.

***SSQ*: What's the best way to get the private sector to take cybersecurity seriously?**

JCI: Many in the private sector *do* take cybersecurity seriously and make the types of investments necessary to secure their networks. Clearly some *do not*. The Commission's recommendations offer a mix of incentives, accountability, and consequences to significantly improve the mobilization and commitment of private-sector capabilities needed to create and defend digital infrastructure largely owned and operated by the private sector. While the Commission's recommendations display a preference for the use of market forces and incentives, they also include compulsory action when and where necessary by private- and public-sector entities.

However, mobilizing the stakeholders in cyberspace within their respective silos is at once necessary and insufficient. A private company acting alone will be unable to prevent all breaches and successfully defend against a well-resourced, sophisticated nation-state adversary. The government must also become a valued partner in the defense of cyberspace, employing the full range of its intelligence assets and inherently governmental powers in a mutually beneficial collaboration with the private sector. The US government can thus play a powerful role, supplying companies with threat information that heightens awareness and advances

security without raising private-sector costs and applying the full power of the government to a whole-of-society effort alongside the private sector. To be clear, the government will not patrol and defend private-sector networks, but it can and must stand alongside, and sometimes out in front of, private-sector defenders in a full-throated collaboration

To advance collaboration, the Commission's recommendations focus on expanding and increasing private-sector participation in voluntary threat detection programs, creating a "joint collaborative environment" between the public and private sectors, and working with the federal government to "strengthen and codify processes for identifying broader private-sector cybersecurity intelligence needs and priorities." Where a given sector's criticality and/or risk was deemed to be particularly significant, the Commission provided more specific and tailored recommendations. One example is the US defense industrial base that the Commission recommends should participate in a significantly improved threat intelligence sharing program with the US government and increase threat hunting on its owned networks.

***SSQ*: The Commission proposed that the US observe, pursue, and counter adversaries short of armed conflict. Where is the line? How do we stay below the line, and under what circumstances should the US consider (and signal) our clear intent to cross the line?**

JCI: The specific definition of *what* would constitute the line to be crossed or what would rise to the level of armed conflict remains an inherently political decision. The Commission believes this should continue to be the case in cyberspace as well. The United States can and must clearly signal the kinds of unacceptable activities that would trigger such thresholds, but without constraining the ability of political leaders to maneuver and adapt in the midst of a crisis. To change adversaries' behavior, it isn't sufficient to simply detect and react by only responding to their initiatives, countering their campaigns, and imposing costs. Rather, the United States must signal capability and resolve, as well as communicate the changes it seeks in adversary behavior, to shape the strategic environment. Beyond deterrence, signaling is also essential for escalation management so actions are not unintentionally perceived as escalatory. This is why the Commission recommends a multitiered signaling strategy aimed at altering adversaries' decision calculus and addressing risks of escalation. It is multitiered because it includes signaling mechanisms at the strategic level through traditional channels as well as signaling at the tactical and operational levels through overt and covert means.

***SSQ*: The report states that the public and private sectors should be allowed to defend themselves and strike back. However, it does not address changes to the Computer Fraud and Abuse Act (CFAA). Is this a problem? And what are the implications of hack back?**

JCI: The Commission does not envision or recommend that the private sector engage in "hack-back" activities. We find them to be ineffective and ill advised when applied by organizations lacking the ability to ensure that cyber response actions are coordinated with other government tools (legal, financial, intelligence, and diplomacy key among them) and, as your question notes, the ability to be consistent with US and international law. However, the Commission does recommend the concurrent and coordinated application of all private- and public-sector capabilities and authorities. It moves away from a division of effort between the private and public sectors toward a robust collaboration. It also acknowledges that cyber defense will always have a significant dependency on the underlying efforts of the owners and operators of private networks and infrastructure operating under current authority to prepare and defend their digital infrastructure.

***SSQ*: Can you foresee the prospect of cyber as an existential threat, and if so, how might this occur?**

JCI: Considering the issue of a catastrophic cyberattack, it is important to acknowledge the millions of daily intrusions that disrupt everything from financial transactions to the inner workings of our electoral system. When viewed through that lens, we experience a cyber Pearl Harbor every day. It is just not registered as a shared event in the collective consciousness of the American people. This steady erosion of cyber system integrity married with increasingly bold adversary behavior sets up an increasing possibility of a catastrophic event. As noted throughout the report, critical functions underpinning commerce, travel, health, and safety rely on networks of digital devices. A major cyberattack on our nation's critical infrastructure mounted by a nation-state adversary capable of preparing and sustaining a dedicated campaign would create chaos and lasting damage. The United States can do much to reduce the risk of major attacks through improving deterrence, resilience, and response. The Commission's 82 recommendations offer a strategy and blueprint to mobilize all available resources and authorities to better defend the US in cyberspace and against destructive cyberattacks.

***SSQ*: The report laments that it was not able to solve all the challenges. What were some of those you would have liked to solve? Which solutions required too great a compromise?**

JCI: While we discussed the challenge of aligning various national perspectives on the use of encryption, we did not come to a consensus. While encryption is an essential tool for the protection of the foundations of critical functions in cyberspace, it is also a tool used by some to hide their depredations from legitimate law enforcement. This remains a critical issue on which we wish we could have done more work.

***SSQ*: What do you imagine as the best-case scenario from the Commission's work, and what is the worst-case outcome?**

JCI: The Commission recommended 82 actions with specific outcomes, timelines, and action owners. Of these, 57 require legislative action, and the Commission drafted proposed legislation for consideration by a specific committee of jurisdiction. With that preparatory work in hand, the best case is that the 25 nonlegislative proposals will be broadly adopted by the executive branch and the private sector at whom they are aimed. Additionally, a substantial portion (50 percent or more) of the Commission's legislative proposals would be adopted within the 2021 National Defense Authorization Act or other legislative vehicles over the next six to 18 months. Legislative proposals not adopted in the present Congress have enduring value as "break glass" proposals that remain at the ready for implementation when political will and the conditions of cyberspace align.

The worst case is that the Commission's recommendations join those of other previous commissions already on the shelf, and the nation carries on toward a sure and certain crisis in cyber for which we could have prepared—but failed to do.

***SSQ*: Do you believe this Commission's recommendations will make a difference? If so, how will you know?**

JCI: I do think they will make a difference. Within 90 days following the Commission's report, 11 of our proposals were included in the Senate markup of the NDAA. These will help shore up the military instruments of power—a key pillar in our report. We have hosted or participated in dozens of sessions engaging a diverse array of private-sector, think tank, and government leaders whose efforts will determine the success or failure of the remainder of the Commission's recommended strategy. The reviews and promise of support have been solid at every turn, though the proof will be in the execution. We anticipate that many more of our recommen-

dations will be enacted by Congress or taken up as a shared effort by government and private industry. This will lead to renewed engagement in cybersecurity thinking and planning.

The Senate and the House are currently working to extend the Commission, with a smaller footprint, for another year through the NDAA. We will use that opportunity to continue to facilitate implementation using an assessment tool that will track progress and hone the Commission's body of work through the production of white papers on specific topics of interest. Cyber workforce development is but one example.

SSQ: On behalf of Team *SSQ* and the *SSQ* audience, thank you Mr. Inglis for serving on the Solarium Commission and for sharing your insights on what may well be the most difficult security challenge of the twenty-first century. SSQ

Assessing the Singapore Summit—Two Years Later

On 12 June 2018, President Donald J. Trump and Kim Jong-Un met in Singapore for the first-ever meeting of a sitting US president with the leader of North Korea. The two men, to much fanfare, shook hands in front of a row of six American and six North Korean flags. The now iconic image of the Trump-Kim handshake heralded the possibility of a better future between the two nations. At the conclusion of the summit, Trump and Kim cast aside 70 years of mutual enmity between their two nations, jointly pledging "a new future" of peaceful relations and the "complete denuclearization of the Korean Peninsula."[1] President Trump hailed the summit as a triumph. "Everybody can now feel much safer than the day I took office," he declared on Twitter. "There is no longer a Nuclear Threat from North Korea."[2]

Two years later, that optimism is gone. A second Kim-Trump summit, held in Hanoi, Vietnam, in 2019, ended abruptly without even a handshake, much less an agreement on how to move forward on denuclearization or progress on sanctions relief.[3] A few months later, the two leaders met once more—this time in the heavily fortified demilitarized zone (DMZ) separating the two Koreas—and agreed to restart negotiations.[4] But that meeting has since proved little more than a photo op. Working-level talks between the US and North Korea have stagnated. The last round of talks, held in October 2019 in Stockholm, Sweden, ended after only eight hours of discussion. The two sides were deadlocked over how much the US would lift sanctions in exchange for Kim's dismantling his main nuclear complex.[5] Since then, both countries have stepped back from diplomacy: the US imposed new sanctions while North Korea resumed short-range ballistic missile tests, continued to enrich uranium, and expanded the size of its nuclear arsenal.[6]

The last embers of optimism burned out on the second anniversary of the Singapore Summit. "Even a slim ray of optimism for peace and prosperity on the Korean Peninsula had faded away into a dark nightmare," said North Korea's foreign minister, Ri Son-gwon.[7] Having long threatened to "find a new way" if diplomacy with the US failed, Pyongyang has returned to its old playbook: ramping up tensions, exploiting loopholes in agreements, and buying time to advance its nuclear and missile arsenals in a dangerous game of brinksmanship.[8] For all the rhapsodizing about his re-

lationship with Kim—the praise of "beautiful letters" and the public musings that "we fell in love"—President Trump's efforts failed.[9] He made a series of concessions, including the unilateral cancellation of annual military exercises between the US and South Korea, but got very little in return.[10] Washington finds itself back where it started, but with North Korea now more nuclear capable and less isolated and its leader more self-assured.

The US can still learn a great deal from the events of the past two years. The diplomatic outreach to North Korea has exposed the limitations of personal diplomacy and the urgent need for the US to recalibrate its strategic objectives from denuclearization to limitations on the size and sophistication of the North's nuclear and missile arsenals. A comprehensive freeze is the best outcome at this point, but it will be harder to achieve after the string of failed diplomatic maneuvers. Washington and Pyongyang walked away from those talks convinced that "maximum pressure" works against the other. With the US and North Korea set to play a dangerous game of brinksmanship, the risks of miscalculation, inadvertent escalation, and war are now greater.

President Trump's personal diplomacy with Chairman Kim has done much to discredit the great man (or great woman) theory of history. During the 2016 presidential campaign, he extolled his "deal-making" skills, asking Americans to place their trust solely in him. Claiming that "I alone can fix" the foreign policy problems, he vowed to end the "international humiliation" and restore American prestige abroad.[11] Solving some of the toughest global challenges was simply a matter of striking deals with other world leaders. What mattered were the statesmen, not the structural forces shaping international politics or realpolitik calculations. Touting his experience negotiating business deals, the president claimed to know how to cultivate the kind of personal relationships that would resolve foreign policy disputes on terms more favorable to the US and elevate America's global standing in the process.[12] That personalized approach to diplomacy has been on full display in his dealings with the North Korean leader. Since the start of diplomatic outreach to Pyongyang in 2018, Trump has touted his personal relationship with Kim, stating, "I have a good chemistry with him." The president claimed the relationship was responsible for a reduction in the North Korean threat to the US and its allies. "Look at the horrible threats that were made," Trump argued. "No more threats . . . No missiles."[13] The president also credited his strong personal rapport with Kim for averting a war on the Korean Peninsula. He asserted, "Many good conversations with North Korea—it is going well. . . . If not for me, we would now be at War with North Korea!"[14]

But those claims do not stand up to scrutiny. For one, President Trump seems to forget that he was the one who ramped up tensions with Pyongyang, famously calling Kim "Rocket Man" and threatening to "totally destroy" North Korea in an address to the United Nations General Assembly. What personal diplomacy accomplished was a reprieve from the tit-for-tat insults and mutual threats of preemptive strikes and nuclear war. Beyond that, the "bromance" produced meager results. North Korea returned remains of 55 US service members killed during the war, but 450 sets of remains—many of them later found not to be Americans—have been sent back in previous administrations.[15] Pyongyang reportedly still has the remains of hundreds more US service members in its storage facilities, kept as bargaining chips in future negotiations.[16] The North released three American detainees from its custody, but it has made similar gestures in the past, including 11 Americans freed during the Obama administration.[17]

Nor can the president take credit for Kim's moratorium on long-range missile and nuclear tests. On 21 April 2018, Kim declared that his country would cease intercontinental ballistic missile and nuclear tests in the lead-up to the Singapore Summit. Kim's stated reason was entirely strategic, not personal: the North had "finished its mission." He added, "We no longer need any nuclear test or test launches of intermediate and intercontinental range ballistic missiles."[18] In other words, the North Korean leader was now confident enough in his nuclear and long-range missile arsenals so as to make future testing of limited value. In coercion parlance, it constituted a "cheap signal."[19] Kim has incurred few costs with his self-imposed testing pause, rendering it of little use in assessing whether his commitment to a diplomatic solution was credible or a bluff.

Despite heaping praise on Kim for being a "great leader" and "very smart guy," President Trump was not able to parlay his personal relationship with Kim into a diplomatic breakthrough.[20] On 4 May 2019, two months after the failed Hanoi Summit, North Korea fired a new type of solid-fuel, short-range ballistic missile and tested two separate multiple launch systems. Since then, North Korea has conducted some 20 short-range missile tests.[21] These tests did not break any promises made to the Trump administration since Singapore. However, the real significance lay in what they tell us about the limits of personal diplomacy. North Korea initiated missile tests in direct response to the US and South Korea's start of a combined military exercise, called Dong Maeng—a scaled-back exercise compared to the Foal Eagle and Key Resolve exercises carried out in previous years. Despite the reduced scope of Dong Maeng, North Korea perceived the exercise as threatening and a violation of the joint agree-

ment signed with the US. "They seriously rattled us," Kim admitted, and in his view, the exercise was evidence of Washington's "open hostile policy" toward Pyongyang. North Korea responded to the exercise with "corresponding acts"—missile tests calibrated to match the scope of allied drills.[22] In short, Kim's personal rapport with the president held little sway in North Korea's strategic calculations.

If President Trump thought he could translate his personal relationship with Kim into a comprehensive nuclear deal, he was sorely mistaken. The efforts did not even end low-level provocations, and North Korea stated as much. Foreign Ministry adviser Kim Kye Gwan admitted his country's leader has "good personal feelings about President Trump" but cautioned that "they are, in the true sense of the word, 'personal.'"[23] Warm personal feelings are not enough to resolve the nuclear standoff between the two countries.

Trump is not the first US president to forge close bonds with foreign leaders. President Franklin D. Roosevelt and Prime Minister Winston Churchill attempted to foster a strong personal relationship during the Second World War, meeting in person nine times, sending each other gifts and birthday greetings, and exchanging personal letters.[24] To be sure, the camaraderie between Roosevelt and Churchill helped in maintaining alliance cohesion during the war, but it could not settle their differences. Each pursued his country's definition of its national interests, allies or not.[25] They would have likely identified with the sentiments of President Richard Nixon, who observed, "There is an intangible factor which does not affect the relations between nations. . . . When there is trust between men who are leaders of nations, there is a better chance to settle differences than when there is no trust."[26] Nixon harbored no great illusions about the shortcomings of personal diplomacy. "A smile or a handshake or an exchange of toasts or gifts or visits," he remarked, "will not by themselves have effect where there are great differences."[27]

That is the case with North Korea today. President Trump's trademark personal diplomacy did not fail because he and Kim did not like each other. Rather, Kim operated under the structural constraints and limitations imposed on his country's foreign policy by its place in the international system. In this realpolitik world, he could not do personal favors for the American president when bargaining over his country's nuclear program. Given the enormous strategic consequences, he simply could not accept a deal against his country's national interests, even if he might like the man seated across from him at the negotiating table.

In clarifying each country's notion of its national interests, strategic preferences, and bargaining positions, the diplomatic process has offered a valuable lesson.[28] If Washington learns anything from the past two years, it should be to give up the illusion it could ever provide Pyongyang with sufficient incentives to denuclearize. For the impoverished country, nuclear weapons—and a credible delivery capability—are the best means to ensure survival and deter a US attack. As Vipin Narang argues, North Korea has most likely adopted a nuclear strategy of asymmetric escalation—threatening to use short-range nuclear weapons early in a military conflict against the US to degrade a conventional attack while retaining long-range nuclear missiles to deter nuclear retaliation by Washington. Given its conventional inferiority, Pyongyang would likely use nuclear weapons first to damage US and allied military bases in South Korea, Japan, and Guam for a chance to slow or halt a US attack. [29] Thus, having a credible nuclear weapons capability is inextricably linked to North Korean survival.

Beyond that, nuclear weapons also advance other long-standing North Korean aims, such as weakening US alliances with Japan and South Korea, preserving its strategic independence from China, and acquiring international prestige and recognition.[30] After all, it was Kim's nuclear and missile weapons programs that led to direct negotiations with a sitting American president—a feat neither his father nor grandfather could claim.[31] It is not hard to see why the Kim regime would never surrender its nuclear capabilities. No deal could ever offer the regime sufficient security guarantees or adequate compensation for the loss of its nuclear standing.

In Singapore, Kim and Trump agreed to "work towards complete denuclearization of the Korean Peninsula." However, *denuclearization* is a term of art, subject to each side's interpretation of its precise meaning. For Washington, it meant the North would eventually hand over its nuclear weapons and missile systems and allow international inspectors into the country to monitor compliance. Denuclearization was shorthand for "complete, verifiable, irreversible denuclearization" (CVID). To Pyongyang, it meant something else altogether. North Korea interpreted the phrase to mean the eventual end of the US military alliance with South Korea—including the US provision of a nuclear umbrella—and, more broadly, global nuclear disarmament.[32] The vague wording of the Singapore joint declaration allowed Trump and Kim to paper over those differences, as neither leader committed to taking concrete actions on denuclearization.

It was hardly surprising, then, that Washington and Pyongyang found themselves at odds when they attempted to turn that vague pledge into substantive steps toward denuclearization. North Korea has stuck stub-

bornly to the same negotiating position, which rejects nuclear reversal out of hand. Similarly, the Trump administration has doubled down on the goal of complete denuclearization. Following the collapse of the Hanoi Summit, a senior official in the Trump administration insisted that "nobody in the administration advocates a step-by-step approach." "In all cases," he added, "the expectation is a complete denuclearization of North Korea as a condition for all the other steps."[33] In response, North Korea accused the Trump administration of advancing a "unilateral and gangster-like demand for denuclearization."[34]

On the second anniversary of the Singapore Summit, Pyongyang complained that Washington continues to make "nonsensical remarks that denuclearization of the Korean Peninsula is still a secure goal of the US" and suggested it would expand its nuclear weapons program in response.[35] Put simply, North Korea has repeatedly told the US that it is a nuclear power, and it has no intention of going back. Should Washington nevertheless persist with its ill-conceived pursuit of denuclearization, it will only meet with failure. Whereas the US goal of denuclearization once required discouraging the North Koreans from acquiring nuclear weapons, it now requires persuading them to reverse course and relinquish existing capabilities—a much greater task. What was once a situation of deterrence has turned into one of compellence. The latter is harder because Pyongyang would have to publicly give way to Washington's demands even though it would risk regime survival, loss of face, and damage to its international reputation.[36] The US thus needs to recalibrate its expectations about what it can hope to accomplish with diplomatic negotiations. It may *want* to denuclearize the country, but what does it *need* to live with a nuclear North Korea? It is a question that needs an urgent answer.

Each day that passes without an agreement is one that gives North Korea more time to expand its nuclear programs and evade international sanctions.[37] In the two years since the Singapore Summit, Pyongyang has amassed enough fuel for about 20 additional nuclear weapons.[38] Gen John E. Hyten, vice chairman of the Joint Chiefs of Staff, recently warned, "North Korea has been building new missiles, new capabilities, [and] new weapons as fast as anybody on the planet."[39] At the same time, North Korea has revitalized its relationship with China and Russia, both of which have weakened sanctions and aided Pyongyang's illicit commerce.[40] North Korea's strategic position is better now than it was when Kim and Trump first met in Singapore and continues to improve, thus increasing its leverage in future negotiations. Put simply, time favors North Korea, not the United States.

Accepting these strategic realities, the US urgently needs not only to recalibrate its negotiating position but also to shift its objective—from denuclearization to limiting the size and sophistication of North Korea's nuclear missile arsenals. In pursuing a comprehensive freeze, the US should prioritize no further development, production, or testing of miniaturized thermonuclear weapons, solid-fuel missiles, long-range ballistic missiles, and their launch platforms.[41] In addition, the US should aim to rein in the transfer of sensitive nuclear technology and know-how from North Korea to other countries—a pressing goal given its history of assisting Syria with its chemical weapons program and a suspected nuclear reactor that Israel destroyed in 2006.[42]

Importantly, a comprehensive freeze appears to fall within the realm of possibility. At the start of the year, Kim stated that "the scope and depth of bolstering our deterrent will be properly coordinated depending on the US future attitude" toward his country. This indicates that Kim might be willing to put future development of his nuclear and missile arsenals on the negotiating table, but not existing capabilities. Of course, Pyongyang will want sanctions relief in return. But trading sanctions relief for a comprehensive freeze is the best the US can expect to achieve. The big deal the Trump administration sought is certainly dead, but diplomacy still offers a pathway for constraining, even if not eliminating, the North's nuclear and missile capabilities.

Unfortunately, there is a real danger that such an agreement will not come to pass. Both Washington and Pyongyang seem to have walked away from the summits with the strengthened belief that "maximum pressure" is effective. To many in Washington, the fact that Kim prioritized sanctions relief in his talks with Trump reinforces that the maximum pressure campaign—the escalating series of sanctions and twitter threats—had worked to bring Kim to the negotiating table.[43] A Washington think tank with close ties to the Trump administration has called for a "maximum pressure 2.0" campaign against North Korea.[44] Likewise, the North Koreans seem to have taken away that provocation, demands, and intransigence are enough to soften the US negotiating position. North Korean missile tests serve to remind Washington that Pyongyang can quickly ramp up the pressure if diplomacy fails to deliver some tangible sanctions relief.[45] There is a real danger that both countries will not moderate but double down on their hardline policies, increasing the risk of war. SSQ

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Notes

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FEATURE ARTICLE

Ready, Set, Getting to Go: US Nuclear Test Readiness Posture

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Abstract

In a geopolitical environment dominated by great power competition, the stakes of maintaining a credible nuclear deterrent have returned to the forefront of national security. Yet nearly 30 years have passed since the United States conducted a nuclear test. There remains a legal requirement, with origins in hard-earned Cold War lessons, for the nation to return to underground nuclear testing if called upon to do so. However, the considerable challenges create uncertainty about how quickly the United States could resume nuclear testing if the geopolitical situation warranted it. This article overviews nuclear testing and its legal framework, outlines the challenges the United States would face to resume testing, broadly considers conditions that could prompt testing resumption, and offers recommendations on how to improve its nuclear test readiness posture.

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As the geopolitical environment has returned to one of great power competition and nearly 30 years have passed since the United States conducted a full-scale nuclear test, there is considerable uncertainty about how quickly the US could conduct a nuclear test if deemed necessary. Should a US administration decide to resume nuclear testing, significant challenges exist.[1] These include personnel and infrastructure atrophy, a complicated but necessary regulatory environment, the lack of a viable location to conduct a nuclear test, and some daunting organizational hurdles.

In the absence of underground nuclear testing, the US has developed innovative tools and methods to ensure and improve the safety, security,

This article is dedicated to all the nuclear testing experts that informed my research. While it would be easy to take a path of least resistance in retirement, you inspired me by your continued work, dedication to our nation's national security, and your passion to pass on your hard-won lessons to ensure the next generation is ready to execute nuclear tests if called upon to do so.

and effectiveness of the nation's nuclear weapons stockpile. Today's science-based Stockpile Stewardship Program (SSP) is a comprehensive effort that involves experiments, modeling and simulation; surveillance of the stockpile; and evaluation of the potential impact of any issues through design, engineering, fabrication, and testing.[2] Using state-of-the-art computational tools and engineering test facilities, the SSP has thus far functioned successfully to ensure the reliability of the nation's nuclear weapons for the past 24 years. There remains, however, a legal requirement for the nation to return to underground nuclear testing if needed.[3] This mandate is codified in former president Clinton's Presidential Decision Directive (PDD-15). Signed in November 1993, it requires the nation to be able to return to a testing footing within two to three years.[4]

The context and importance of the geopolitical forces leading to this directive are hard to overstate. The Cold War had just ended. The Berlin Wall had fallen. Both superpowers were six years into a successful arms control regime—the Intermediate-Range Nuclear Forces (INF) Treaty—and the signatories were well on their way to eliminating an entire class of medium range nuclear missiles.[5] President George H. W. Bush had implemented a nuclear testing moratorium in October 1992. Furthermore, in an effort to reassure the Russians that the US would not take advantage of their tenuous strategic situation following the collapse of the USSR, Bush directed several unilateral Presidential Nuclear Initiatives (PNI) to reduce the US nuclear alert posture vis-à-vis the former Soviet Union.[6] Building on the experience and success of the INF, the groundbreaking Strategic Arms Reduction Treaty (START) was also being negotiated to drastically cut the number of longer range nuclear weapons.[7] By the early 1990s, it looked as if history had ended, to paraphrase Francis Fukuyama's famous declaration made to mark the shift in the heretofore bipolar struggle between competing superpowers.

Within this revolutionary historical context and post–Cold War euphoria, President Clinton extended Bush's moratorium and considered pursuing a test ban treaty of limited duration and permitting a low explosive yield.[8] However, less than a year into his first term, he signed PDD-15 following a Chinese nuclear test in October 1993.[9] Two years later, in 1995, Clinton announced his support for a zero-yield comprehensive test ban treaty, conditioning his support on six safeguards.[10] These safeguards, extant since 1963, represented a set of conditions that had been deemed critical to ensuring the readiness of the entire nuclear complex to preclude any strategic or technological surprise.[11]

Weighing the merits of a resumption of nuclear testing is a complicated topic. Decision-makers must consider whether it is strategically prudent, fiscally affordable, or even necessary. Those questions are beyond the scope of this article. Instead, the focus here is on a related and less politically charged subject—whether the United States is actually *prepared*, as currently mandated, to resume nuclear testing. To be clear, nuclear test readiness is not the same as conducting a nuclear test, just as maintaining a credible nuclear deterrent is not the same as exchanging intercontinental ballistic missiles. This article first provides an overview of nuclear testing and then outlines the challenges the United States would face to resume testing. It considers some general conditions that could prompt testing resumption and makes recommendations on how to improve nuclear test readiness.

Ready: The Requirement, Spectrum, and Current Status

Even though the US hasn't conducted a full-scale nuclear test since 1992, it retains a legal requirement to be ready to do so as spelled out in PDD-15. Crafted in the wake of decisions over the course of several US administrations to reduce and eventually stop any kind of nuclear testing, the PDD and associated safeguards frame the conditions under which future US leaders would consider a resumption of testing.[12]

The origins of the current test ban began in 1991 when Soviet leader Mikhail Gorbachev unilaterally declared a moratorium on the USSR's nuclear testing. In 1992, President George H. W. Bush followed suit, declaring a US testing moratorium. This was formalized in 1996 when President Clinton signed the Comprehensive Test Ban Treaty (CTBT). After a lengthy debate in the Senate, it rejected a resolution for ratification, technically leaving the door open for the US to conduct future tests. The US has, however, continued to refrain from testing.

PDD-15 also addresses the safeguards that were codified alongside nuclear treaties in an attempt to avoid strategic and/or technological surprise by an adversary. The genesis for the safeguards was a resumption of testing by the Soviets in 1961 that surprised the US.[13] Following the Soviet test, the Joint Chiefs conditioned their support for future nuclear treaties on an ability to resume testing should geopolitical and/or technological conditions warrant it.[14]

These safeguards have evolved over time, modified as various treaties were negotiated. Generally, they stipulate that the US maintain readiness in the following areas:[15]

- Safeguard A: to conduct underground testing or stockpile stewardship
- Safeguard B: to maintain laboratories and human scientific resources
- Safeguard C: to maintain the capability to resume nuclear tests prohibited by treaties
- Safeguard D: to conduct research and development to improve treaty monitoring
- Safeguard E: to develop intelligence programs to monitor nuclear programs of other nations

While all these safeguards are important elements of nuclear deterrence, Safeguard A relates explicitly to underground testing readiness. Attempts were made in 1997 and 1999 to adjust this safeguard by removing verbiage requiring a return to an "underground nuclear test program" and replacing it with scientific assurances based on the Stockpile Stewardship Program. However, the most recent set of safeguards—which were ratified by the Senate and remain legally binding—were contained in the Threshold Test Ban Treaty (TTBT) and the Peaceful Nuclear Explosions Treaty (PNET), both entering into force on 8 December 1990.[16]

In summary, the PDD and associated safeguards were put in place to ensure that regardless of the direction of the geopolitical winds of the period, the US would remain ready to resume testing. While nuclear testing is complex and nuanced, not all nuclear tests are alike. Rather, there exists a variety of testing options the US has used over time. Each of these options has tradeoffs regarding cost and complexity, as well as their own specific purpose.

A Spectrum of Nuclear Testing

Starting with the Trinity Test on 16 July 1945, the US has conducted a total of 1,054 nuclear tests—more than any other nation.[17] These tests spanned a wide spectrum, varying greatly in scope and purpose (see fig. 1). That said, most tests aimed at advancing the collective understanding of nuclear science and weapons design generally fell into one of two categories—Department of Energy (DOE) scientific tests or Department of Defense military tests. The vast majority of these tests were accomplished under the direction of the DOE or its predecessor, the Atomic Energy Commission. These tests tended to focus on gaining a better understanding of the science behind nuclear weapons. Less frequent, the DOD tests primarily focused on understanding whether stockpile weapons met military requirements for performance and safety.

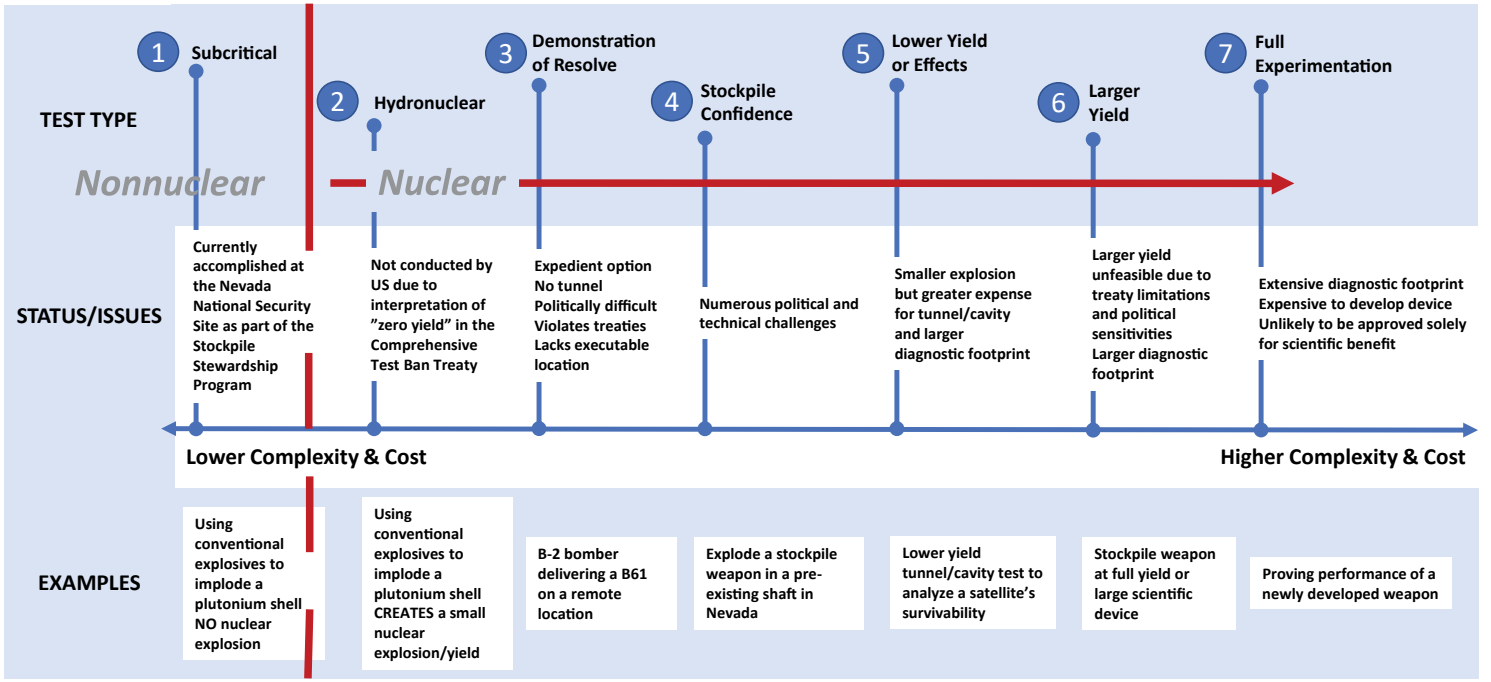

Figure 1. Testing Spectrum

The key takeaway from the testing spectrum depicted in figure 1 is that a resumption of testing involves more than simply "decide to test, conduct the test." Leaders must recognize that varying degrees of testing are available, consider what type of test is appropriate for the situation, and understand that the decision to move from left to right along the spectrum of testing requires a commensurate increase in preparedness, risk, cost, complexity, and national resolve.

Regardless of the sponsoring department or purpose, underground nuclear tests share three requirements: an emplacement site—typically a shaft, tunnel, or cavity to ensure containment of the radioactive products of the detonation, a nuclear explosive device, and a diagnostic suite capable of capturing data.[18] While all tests share these basic attributes, the complexity and cost of a given test varies greatly with the type of emplacement required, device tested, and scientific data captured.

As shown in figure 1, tests on the left end of the spectrum tend to be relatively simple and cheap to execute. Tests on the right—requiring more sophisticated devices, diagnostics, and emplacement—are generally costlier and more complex. When considering the tradeoffs associated with creating an emplacement site, drilling vertical shafts is typically less expensive than digging tunnels or hollowing out cavities in a mountain. Regardless of the type of test, any emplacement site must be designed to effectively contain its nuclear yield. Larger explosions typically require shafts, while tunnels or mined cavities are generally only able to accommodate smaller yields. Regarding the tradeoffs associated with devices, highly optimized and novel devices are more complex and costlier to test than proven designs. Finally, the costs and complexity of developing a proper diagnostic suite can vary greatly. It is difficult to develop equipment that is accurate enough to capture data transmitted over fractions of microseconds yet safe enough to ensure radiation doesn't leak into the atmosphere via the diagnostic tool.[19] A short discussion on each type of test in the testing spectrum follows.

Subcritical tests. These tests (as illustrated on the far left in the low-cost, low-complexity end of fig. 1) are still performed at the Nevada National Security Site (NNSS). Since they don't produce any nuclear yield, they don't violate any nuclear testing treaty and don't require containment.[20] These tests are key contributors to the science-based SSP.[21]

Hydronuclear tests. Increasing in complexity and cost are hydronuclear tests that generate minimal nuclear yields, typically less than the chemical energy released by the explosives used in the test.[22] These are not conducted by the US given how it interprets CTBT Article I language to

preclude *any* nuclear explosion no matter how small—in other words, *zero yield*.[23] However, hydronuclear tests would facilitate an improved understanding of the behavior of plutonium relative to subcritical tests.

Demonstration-of-resolve tests. These show-of-force tests would most likely be used in response to a geopolitical event where speed of response is at a premium to deter an adversary from conducting further nuclear explosives testing, or more provocative measures. For example, a B-2 bomber could deliver a B61 thermonuclear weapon on the open ocean to demonstrate the US deterrent/assurance credibility to allies and adversaries. This kind of test would be relatively simple and comparatively cheap to conduct as it requires no emplacement site/underground footprint and little to no diagnostics, and it would likely use a stockpile weapon. Of course, the political barriers to actually conducting a test like this would be extremely high and may require the abrogation of the Limited Test Ban Treaty (LTBT), which "precludes parties to the treaty from conducting any tests outside their territory that would cause radioactive debris to enter the atmosphere."[24] Additionally, the lack of a suitable location to conduct an above-ground nuclear explosion would be extremely challenging.

Given these likely insurmountable issues, an underground test to demonstrate resolve *promptly* would be more likely. However, challenges to an underground test are hardly trivial. The major issue is location. While the NNSS offers an optimum location in terms of a preexisting holes and geographic suitability, it is no longer the relatively remote location it once was in the 1950s and 1960s. Las Vegas has grown considerably; the risks of testing in proximity to a large urban area and large military installations, such as Nellis and Creech Air Force Bases, would require considerable deliberation. Other potential underground test sites also pose significant challenges, discussed later in this article.

Stockpile confidence tests. These tests, designed to prove the performance of an aging stockpile weapon, would be similar to the underground demonstration-of-resolve test described above. A preexisting hole would be needed as would a stockpile weapon. However, to capture the required performance data (not a necessity when simply demonstrating resolve), a sophisticated diagnostic suite would be essential. These tests would also pose the same locational challenge described in the previous paragraph.[25]

Lower yield or effects tests. These tests would likely be conducted in a preexisting shaft or tunnel at the NNSS and require a larger diagnostic footprint than the stockpile confidence tests. Counterintuitively, lower

yield tests may pose a higher risk of an unplanned release of radioactive gasses and thus a danger to nearby populations as they can be harder to contain than larger yield tests.[26] Effects tests tend to be lower yield and are usually exploded in a cavity or tunnel near an object of interest such as a satellite, aircraft, or another nuclear warhead. The scientific purpose is usually to determine how a nuclear explosion affects an object's (e.g., a satellite, an aircraft, etc.) survivability in a nuclear environment. Effects tests necessitate more sophisticated diagnostics and more expensive tunnels or cavities. Historically, these were usually conducted by the DOD utilizing a DOE supplied device.

Larger yield tests. For numerous reasons, these tests would have significant political constraints. Policy makers must not only consider whether to violate or abrogate treaty obligations to achieve a higher yield but also choose a test site with less risk of creating negative effects (e.g. environmental).

Full experimentation tests. Finally, on the far-right spectrum of testing, full experimentation tests could be the most expensive and complex of all testing options. Used to test a new device, they require a sophisticated diagnostic suite and possibly drilling a specialized hole to accommodate the test.

Leaders may find that given the current challenges within the nuclear enterprise, supporting and conducting any of the more complex, costly tests further to the right of the relatively simpler tests (e.g., the subcritical ones) could prove extremely difficult within the legally defined timelines of two to three years specified in PDD-15. And as with any major program involving significant organizational, technical, and political challenges, the costs are likely to be much higher than initial estimates. Table 1 shows a representative sample of historical tests that highlight some of the issues described in this section.

Table 1. Historical nuclear tests

Testing Spectrum	Test/ Event	Date	Type/ Location	Description
Subcritical	Rebound	2 July 1997	Underground at U1a, NNSS	First subcritical experiment after testing moratorium announced in 1992.[a]
Hydronuclear	Multiple series of tests	12 Jan 1960[b]	Underground at Los Alamos	First of eight tests in a series ending 11 February 1960. Tests were a series of safety experiments that identified then extant one-point safety problems and drove remedial action for the stockpile's safety features.[b]

Table 1 (*continued*)

Testing Spectrum	Test/ Event	Date	Type/ Location	Description
Demonstration of resolve	First operational combat use	6 Aug 1945 9 Aug 1945	Airdrop at Hiroshima, Japan Airdrop at Nagasaki, Japan	While not considered tests, one could argue that the two atomic bombings to end the war with Japan fit the definition. Two nuclear weapons that the US exploded over Japan ending WWII were not "tests" in the sense that they were conducted to prove that the weapon would work as designed (as was the first test near Alamogordo, New Mexico, on 16 July 1945), advance nuclear weapon design, determine weapons effects, or verify weapon safety—as were the more than 1,000 tests since 30 June 1946.[c]
Stockpile confidence	Multiple series of tests	1979–86*	Underground at various locations, NSSS	Seventeen tests (*including four tests from the early '70s, now called Stockpile Confidence Tests) were conducted on each weapon type; there were no catastrophic failures.[d]
Lower yield or effects	Huron King	24 June 1980	Underground at U3ky, NSSS	Tested radiation hardness of the then new DOD Defense Satellite Communications System. It was a combination Los Alamos-DOD test.[e]
Larger yield	Handley	26 Mar 1970	Underground at U20m, NSSS	One of the largest detonations conducted at NSSS. Test was part of 52 tests in Operation Mandrel, 1969–70.[c]
Full experimentation	Grabel	25 May 1953	Airburst at Area 5, NSSS	Test of Mk9 nuclear weapon from a 280 mm cannon.[c]

[a] "Nuclear Weapon Hydronuclear Testing," Global Security, Weapons of Mass Destruction, accessed June 2020, https://www.globalsecurity.org/.
[b] Robert N. Thorn and Donald R. Westervelt, *Hydronuclear Experiments*, Report LA-10902-MS (Los Alamos, NM: Los Alamos National Laboratory, February 1987), https://www.osti.gov/.
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The Current State of Nuclear Test Readiness

Before examining the obstacles associated with being prepared to resume underground nuclear testing, it is important to review the positive attributes of the current testing posture with regard to the safety, security, and effectiveness of the nuclear stockpile. This status is best understood through the lens of the Stockpile Stewardship Program.

The SSP was authorized by Congress in response to the 1992 nuclear testing moratorium "to ensure the preservation of the core intellectual and technical competencies of the US in nuclear weapons."[27] Absent a program of underground testing, the nuclear enterprise had to leverage science in a novel way to gain a deeper understanding of "weapons design, system integration, manufacturing, security, use control, reliability assess-

ment, and [*ultimately*] certification [*of the device*]."[28] Embracing its mandate forcefully, the SSP pioneered numerous scientific inventions and tools, some of which are one of a kind, to ensure the safety, security, effectiveness, and reliability of stockpile via "a combination of weapons surveillance (i.e., disassembly and identification of mechanical problems), nonnuclear tests, and computer modeling."[29]

The surveillance program. A major concern of the SSP is to address the advanced age of stockpile weapons. Given that the current stockpile weapons are considerably older than their initially designed shelf life, a cornerstone of the SSP is the surveillance program that monitors a weapon's health. This program employs some of the world's best scientists to better understand the effects of aging on all components within a weapons system—nuclear and nonnuclear. A main focus of surveillance is to understand how plutonium, one critical fissile material used to drive a nuclear reaction, would age and how this aging could affect a weapon's performance. Periodically, stockpile weapons are returned to the national laboratories to perform "weapons autopsies" to look for aging and other defects.[30]

Nonnuclear testing. Another fundamental component of the SSP is the requirement to conduct nonnuclear testing. These tests are primarily performed at the NNSS and national laboratories within the nuclear enterprise (i.e., the National Nuclear Security Administration) using some of the nation's most unique facilities and novel instruments. Test readiness events are a critical component within the nonnuclear testing arena. Scientists, on a fairly regular basis, engage in these events in Nevada to sharpen their skills.[31] These test readiness events are often guided by retired scientists, many of whom are the last of their discipline with firsthand nuclear testing experience. These events offer younger scientists a unique and fleeting opportunity to learn from true experts.

Recognizing that these experienced scientists will not be around forever, Los Alamos National Laboratory has created the National Security Research Center (NSRC) with the mission to archive, digitize, catalog, and make available 75 years of classified research materials. These include films, drawings, scientists' notes, and other documents to aid future generations' understanding of how to execute a nuclear test as well as a host of other information related to weapons design and so forth.[32]

Subcritical tests. "Subcrits" are another essential feature of the SSP. Conducted at NNSS underground facility U1a, these tests use high explosives to dynamically compress plutonium and model its behavior. To be clear, per executive order and in accordance with congressional direction,

these tests never produce a critical mass.[33] In addition to the improved understanding gleaned from these experiments, these tests, like the nuclear test readiness exercises, serve as "the primary method of training the next generation of diagnosticians while at the same time exercising many of the fielding capabilities that would be used for an underground nuclear test."[34]

Dual-Axis Radiographic Hydrodynamic Test (DARHT). Complementing the subcritical experiments is Los Alamos National Laboratory's DARHT facility. The DARHT is a high-tech invention that provides a "rich suite of diagnostic measurements," allowing scientists to model the microseconds during a "weapon's crucial triggering phase" when the conventional explosives that surround the nuclear fuel are detonated. Aside from being one of the world's most powerful X-ray machines, the advanced data DARHT provides is second only to an actual nuclear test in understanding an implosion's progress.[35]

National Ignition Facility (NIF). Another important contributor to nonnuclear testing is Lawrence Livermore National Laboratory's NIF. The NIF has the distinction of being the world's "largest and most energetic laser facility ever built." Goals of the NIF mission are to pursue fusion ignition, improve scientific understanding across numerous disciplines, and help ensure the reliability of the nation's nuclear stockpile—without testing, which is of course fundamental to the SSP.[36]

Los Alamos Neutron Science Center (LANSCE). The LANSCE facility provides a linear accelerator producing neutron and proton beams and detector arrays for industrial and defense research.[37] A portion of those beams function in a uniquely developed science known as proton radiography (pRad), which "uses protons to take images of many of the materials in the physics package at pertinent times with high contrast. Proton radiography is especially well suited to studies of the movement of waves inside the explosives themselves." Proton radiography offers an enhanced capability (e.g., beyond X-ray radiography) to understand the underlying physics of what drives a nuclear explosion.[38]

Electromagnetic Environments Simulator (EMES) and the Z machine. Sandia National Laboratory is home to two unique machines that are able to test objects in extreme environments. The EMES is used to conduct susceptibility testing by sending electromagnetic waves through objects of interest and, to some degree, explores some of the same vulnerabilities as nuclear effects tests.[39] Likewise, the Z machine "provides the fastest, most accurate, and cheapest method to determine how materials will react under high pressures and temperatures."[40]

Supercomputing. Scientists use data from past nuclear tests, coupled with data supplied by SSP's surveillance and nonnuclear test programs, to simulate and hopefully verify results from extremely sophisticated computer codes used to model the behavior of nuclear weapons. These simulations run on some of the world's largest and fastest computers.[41] Programs such as Los Alamos's Advanced Simulation and Computing (ASC) Program develop simulation capabilities and deploy computing platforms to "analyze and predict the performance, safety, and reliability of nuclear weapons and to certify their functionality in the absence of nuclear testing." The codes developed by the scientists and processed by these computers serve as a key component to certifying effectiveness of the nation's nuclear stockpile.

The facilities, programs, and technology described above represent only a fraction of the numerous scientific tools used throughout the nuclear enterprise to support the SSP. The ability to model the extraordinary complexity of nuclear weapons systems is absolutely essential to the SSP, which is, after all, reliant on science and numerical simulation absent actual nuclear testing.

Interestingly, as explained by senior Los Alamos scientist Joseph Martz, it is somewhat ironic that the inability to test weapons and produce a nuclear yield has, in certain aspects, actually led to a better scientific understanding of how the weapons work. In the past, having a testing capability meant scientists did not need to understand all the details of a nuclear weapon to assess weapon performance. Dr. Martz also noted that while nuclear testing was a "unique and wonderful tool, it was also the world's biggest shortcut. The SSP has forced today's scientists to do their homework and model a device's physics and engineering at a much greater level of detail than in the past."[42] Since 1996, every director of each of the national nuclear security laboratories has signed 24 annual assessment letters to the Secretaries of Energy and Defense and the chair of the Nuclear Weapons Council. Every letter to date has reported that there was no need to conduct nuclear testing to maintain the certification of the warheads/bombs for which each laboratory is responsible.[43]

Set: Challenges to Resuming Testing

Referring to the testing spectrum in figure 1, the challenges generally become more complex for tests farther right on the spectrum. These challenges involve location, personnel, equipment, the regulatory environment, and organizational complexities.

A Suitable Location

This is certainly the most significant challenge in any decision calculus regarding a resumption of underground nuclear testing. On the surface, a return to the NNSS—with its dry soil, porous rock, and deep water table—seems the obvious choice as the deserts of southern Nevada are perhaps the world's best environment for conducting underground nuclear tests.[44] However, Nevada now has considerable disadvantages that didn't exist during the nuclear testing heyday. Specifically, the region's population boom makes the effects of testing potentially much more damaging and potentially hazardous than before. The greater Las Vegas metropolitan area, which had a population of 25,000 in 1951, blossomed to 700,000 inhabitants by 1992 when it hosted its most recent nuclear test. Since then, this growth has intensified as the area has transformed into one of the world's premier tourist destinations with a population of 2.7 million.[45]

In the past, tourists flocked to Las Vegas hotels and casinos to witness and feel atomic explosions. The DOE put seismometers on high-rise buildings, checked building plans, and maintained extensive files on buildings throughout the valley to monitor structural resiliency.[46] However, since the apex of Las Vegas "nuclear tourism" in the 1950s and 1960s, casinos have grown significantly taller, and the distance between the highly populated Las Vegas metropolitan area and the NNSS has shrunk considerably.[47] Given these factors, any further nuclear testing operations in southern Nevada, other than perhaps small (hydronuclear) or no-yield tests that reside on the left side of the spectrum in figure 1, are probably highly unlikely.

For many of the same reasons, other alternative locations would also likely be off limits. Historical test locations such as New Mexico, Alaska, Mississippi, and Colorado pose many of the same challenges to host testing as Nevada. Some experts view Amchitka Island in Alaska's Aleutian Island chain as a possible site given its past testing history and remote location. However, as the decades have passed since the last tests conducted there in the 1960s and 1970s, its infrastructure has decayed. The significant distance from the mainland would likely make test operations expensive, not to mention inconvenient.[48] The political challenges are probably even more formidable than the logistical ones. Amchitka Island is part of the Alaska National Maritime Wildlife Refuge, and the island still bears the scars from its 1971 nuclear test.[49] Given the known difficulties of performing activities like offshore drilling in nationally designated

wildlife refuges, it is highly likely that any suggestion to conduct a nuclear test there would be politically dead on arrival.

Personnel

Given that the last underground nuclear test was performed over 25 years ago, the US lacks personnel—specifically geophysicists, physicists, and engineers with hands-on experience—to perform not only these tests but also some of the essential associated experimentation. At its peak, Los Alamos had approximately 4,000 people contributing to the test program, while the test site in Nevada employed 7,000 individuals.[50] With the reduced scope of nonnuclear tests, the number of people devoted to testing is a fraction of what it once was. According to Wendee Brunish, retired Los Alamos Containment Group leader and current chair of the Containment Evaluation Review, the most crucial loss impacting test preparedness is that "the expertise that allowed us to produce and evaluate containment designs has greatly diminished and will soon be almost non-existent."[51]

Equipment and Infrastructure

While 33 predrilled holes exist that could be used for an immediate test assuming they are still open and stable, the equipment required to safely conduct underground testing has atrophied severely.[52] The ability to emplace a rack or canister has been compromised as the large crane capable of handling this load was salvaged and the wire ropes and pipes required to lower the test device need pull testing to ensure viability.[53] While the remaining unused racks and canisters are helpful for instructional purposes, they may be of limited utility to conduct an immediate test as racks are developed specifically for each test and aren't interchangeable. The specially designed gas-blocked cables that prevent radioactive material from releasing into the atmosphere have been baking in the Nevada desert for almost 30 years, and there is no longer a manufacturer to supply replacements.[54]

Furthermore, the ability to manufacture the specialized expansive grout and epoxies used to form the plugs for the shaft that block rising debris would need to be reconstituted along with some of the diagnostic instruments used for ground motion analysis.[55] A major question would be whether to invest in new technology to aid in testing or whether it is more prudent to reconstitute proven, but antiquated, testing methods. In either case, a two- to three-year timeline to test would be a significant challenge given these issues.

Regulatory Environment

Known in DOE parlance as "authorization basis," the regulations that ensure worker, public, and environmental safety have expanded considerably since the early 1990s when the most recent nuclear test occurred. To resume nuclear testing in a timely fashion, these regulations would need to be thoroughly reviewed to ensure compliance or to determine areas requiring changes. Would the responsible parties be able to navigate this complicated but necessary regulatory environment within the time constraints posed by PDD-15?[56]

Organization

While the issues described so far are challenging in their own right, the organizational problems posed in planning and conducting a nuclear test are equally daunting. In nuclear testing, the sum of the parts required to execute a test is not equal to the whole of actually executing a test. According to the NNSA, functional test readiness is broken into at least 15 specialized areas: containment, security, assembly, storage and transportation, insertion, emplacement and stemming, timing and control, arming and firing, diagnostics, test control center activities, post-shot drilling, nuclear design, weapons engineering, test integration, and nuclear chemistry.[57] All these specialized areas either complement or are in addition to the aforementioned challenges in that they represent a unique level of complexity. In the words of one experienced Los Alamos nuclear tester, "a successful test requires developing the nuclear design, organizing the porta-potties for the test site, and everything in between!"[58]

While each of these entities can and does maintain its own capabilities through a variety of day-to-day work activities, exercises, and such, it's important to appreciate the organizational challenges that must be overcome to integrate these 15 specialties as part of an entire system to conduct an underground nuclear test. As explained by a Sandia National Laboratory scientist:

> By exercising all of the skills and capabilities required to design, test, qualify, and produce complete systems on a regular basis, those skills are ready and available to address higher-priority problems on a moment's notice. The complex must exercise all of the skills required, not just the science, modeling, and simulation skills, to have them available. These skills include but are not limited to a strong scientific foundation, systems analysis, engineering analysis, design definition, systems engineering, component design, test and evaluation, component production, and weapon assembly and disassembly. Like an athlete, you cannot exercise

> 20 percent of the skill base and expect to function at 100 percent on game day. You have to practice all parts of your craft or you will not be able to perform up to expectation when a problem arises unexpectedly.[59]

Questions of whether or not to resume underground nuclear testing are largely political and driven by geostrategic conditions. After almost 30 years since the end of the Cold War, and the consequent hiatus from conducting nuclear tests, the US has become desensitized to any situation that could warrant a return to Cold War–style nuclear competition. Moreover, the global war on terror consumed much of the United States' strategic thinking such that concepts like nuclear deterrence and assurance fell by the wayside for many years. Today it is difficult for America's senior leaders and the general public to imagine an environment where the nation might be compelled to conduct a nuclear test.[60] That said, history and surprise offer two broad areas to consider in thinking about the potential resumption of nuclear tests.

Getting to Go: Recommendations to Improve Test Readiness

Although the geostrategic environment is much different than it was during the Cold War, it provides some examples of periods when the US had to play catch-up in the world of nuclear science to maintain and/or ensure parity and consequent strategic stability with the Soviet Union. The Soviets first discovered that a high-altitude electromagnetic pulse (EMP) could have a catastrophic effect on electronics and were the first to develop special alloys in their weapons to counter those effects.[61] The US, previously unaware, was forced to quickly follow suit. Additionally, Soviet scientists were the first to recognize that the intense X-rays emitted from a nuclear explosion could be used to destroy a warhead's heat shield. Again, the US had to move expeditiously to return to the drawing board to protect its weapons from a phenomenon an adversary had discovered.[62] And perhaps the most compelling example of a historical lesson learned is the Soviets' sudden withdrawal from the testing moratorium in 1961. The Soviets went on to accomplish 57 tests in the remaining three months of the year, to include the history's largest detonation—the 55 megaton Tsar Bomba. The great difficulty the United States faced in the aftermath to generate a timely and equivalent response formed the basis for today's test readiness safeguards.[63]

Surprise comes in many varieties and, as the Cold War examples above illustrate, can catch a nation and its leaders off guard and unprepared. Black swans, grey rhinos, and pink flamingos are terms to characterize what former defense secretary Donald Rumsfeld called unknown unknowns (black

swans), known unknowns (grey rhinos), and known knowns (pink flamingos). Furthermore, the adversary "gets a vote," and according to Nassim Nicholas Taleb who coined the term in his book by the same title, a black swan is perspective dependent. In other words, a black swan event may be "a surprise for a turkey but not a surprise for the butcher"—so the object should be to "avoid being the turkey."[64] The nuclear weapons certification process is highly complex, and although the national laboratories have not encountered a significant issue to call the viability of the stockpile into question, the US is still learning about the science behind plutonium aging and its associated impact on weapons components. In short, when it comes to the safety, security, and effectiveness of the nation's nuclear deterrent, the United States must have a plan to not suffer the same fate as the turkey. The US has several opportunities to improve its nuclear testing posture and at the same time prevent unexpected surprises.

Take Inventory

First, the US needs to assess exactly where it stands with respect to its test readiness posture (i.e., capabilities and deficiencies) and develop a plan for success. As discussed earlier, much of the material infrastructure, human capital, and specific organizational experience needed to resume testing has deteriorated or disappeared. While a lot of the hardware (cables, cranes, diagnostic equipment) no longer exists or needs refurbishment, more troubling is that the limited number of experienced scientists available to help develop, advise, and support the execution of a nuclear tests is diminishing with each passing year. Additionally, reviewing the regulatory environment's must-do's in advance could rapidly improve the timeline to return to testing. Finally, scientists and policy makers must work together to identify the "least bad" of all available testing site locations to avoid paralysis should a test become required. Taking this inventory of extant capabilities sooner rather than later, and developing a plan, will help mitigate the natural degradation of material, people, and experience over time.

Capture Corporate Knowledge

Perhaps the most time-critical aspect of developing an effective test readiness plan is to take measures to ensure that the hard-earned corporate knowledge on how to accomplish testing is effectively captured and cataloged. Some efforts, like the Los Alamos National Security Research Center's endeavor to digitize and catalogue the over 10 million historical

documents in its archive, are a step in the right direction. Efforts like this should be copied and accelerated across the enterprise. Additionally, steps should be taken to interview the last generation of nuclear testing scientists to capture their technical expertise and lessons learned. Fortunately, many of these scientists, like the ones that took the time to inform this paper, are still passionate about their experience and national security. They are eager and honored to pass on lessons learned to the next generations. Adequately capturing today's corporate knowledge is critical—especially leveraging the human knowledge capital of older scientists and engineers with nuclear testing experience.

Leverage the Stockpile Responsiveness Program

As outlined in the 2018 *Nuclear Posture Review*, the Stockpile Responsiveness Program (SRP) is a congressionally mandated program "that explicitly directs that the US ensure the responsiveness and flexibility of our nuclear weapons infrastructure."[65] The SRP's goal is to improve resiliency and responsiveness "via the full life-cycle spectrum of nuclear weapons conceptualization development, design, manufacture, and retirement to face technological surprise and potential geopolitical shifts in the future."[66] One of the main ways the SRP accomplishes these objectives is to expose early-career staff to challenging problems under the guidance of experienced mentors. While the scope of the SRP is vast, if the program is properly funded and includes a sufficient focus on test readiness, the SRP will, according to Michael Bernardin, at that time the Los Alamos associate lab director for weapons physics, "provide the opportunity to grow the needed expertise to mitigate risk to national security."[67]

Rethink and Refresh the Arms Control Environment

Somewhat counterintuitively, a new look at arms control treaties may provide an opportunity to improve test readiness posture, avoid a "testing arms race," and enhance deterrence/assurance confidence. If major powers like Russia and China share similar concerns about weapons reliability, rather than "cheating" on existing treaties, they might find it advantageous to collaborate on an agreed-upon testing protocol.[68] For example, a relook at and fresh interpretation and specification of language in the CTBT could provide the opportunity to engage both Russia and China on arms control around an issue of mutual concern.[69] While unlikely, perhaps the nuclear powers might agree to a construct that would allow for a limited number of tests, under scripted scenarios, during a defined time horizon,

and within a very specific definition of allowable yield (e.g., an extremely small, underground hydronuclear test). Doing so could allow participants a transparent and predictable option to gauge and reassess stockpile confidence and improve safety (nuclear surety). Additionally, this approach could reduce the risk of a "rogue defector" possibly triggering an all-out nuclear testing resumption. Reengaging collaboratively in an arms control environment with the major nuclear powers may further concrete steps to reduce stockpiles while retaining the proven concept of strategic stability as a bedrock to prevent a nuclear exchange of any kind.

Consider Hydronuclear Testing

The capability to conduct an extremely small yield (e.g., < 100 tons) nuclear test—a hydronuclear test—may offer the US advantages in several areas. Perhaps most importantly, it would provide a means to improve the safety, security, and effectiveness of the stockpile. As explained by a retired Los Alamos testing expert, "a little bit more yield can be a lot more useful" and may provide some reassuring insights into weapons performance.[70]

By allowing hydronuclear tests, other nuclear states—namely, Russia and China—might be induced into a new or revised arms control agreement. Advantages accrued to the parties in any potential agreement could relevel the playing field in terms of stockpile confidence and security. Parties would also have a transparent mechanism to avoid the geopolitical downsides of abrogating existing agreements and/or getting caught doing so.[71] This transparency will help to negate any asymmetric advantages that may currently exist (e.g., if, in fact, Russia and China have been cheating on existing treaties or understood nuclear testing norms). Furthermore, undertaking hydronuclear tests could be a key to opening some, but not all, of the "black boxes" that challenge the best science of the SSP. That is, it could eliminate or mitigate the black swans and/or grey rhinos that might otherwise remain unknown until a crisis occurs.

There is some historical precedent regarding the benefits of hydronuclear testing when it comes to safety. In fact, scientists conducted a series of hydronuclear safety tests in the late 1950s to clarify some of the puzzling results regarding one-point safety of certain stockpile weapons already deployed to the field.[72] These tests occurred during a critical time in the Cold War—a test moratorium initiated by the Eisenhower administration in late 1958. Calculations and hydrodynamic experiments were unable to resolve these problems, which turned out to be reflective of a critical safety design flaw for four weapon systems that had become operational in 1958.[73] The military halted production, and weapons handling procedures

were severely constrained.[74] Los Alamos responded quickly with a proposal for a series of extremely small yield tests (i.e., hydronuclear) that could be conducted to help inform a solution to the safety problem. The administration approved; the series was conducted (within the constraints imposed by the testing moratorium); and within four months, the most urgent safety questions had been answered. Without these tests, the likelihood that the nation would field weapons that weren't one-point safe was much higher. In fact, had the nation mistakenly fielded nontested one-point safe weapons on the B-52 that crashed in Palomares, Spain, scientists estimated the chance of an accidental nuclear yield to be 1,000 times greater.[75]

Finally, if the Russians and the Chinese have been conducting their own hydronuclear experiments (that would violate the US understanding of language in the CTBT), a return to some kind of regime within which the US could conduct these tests would go a long way to eliminating any technical advantages (i.e., strategic superiority) our adversaries may have accrued by cheating.

Coordinate and Collaborate

During the period when the US conducted nuclear tests, the national labs—Los Alamos, Lawrence Livermore, and Sandia—were permitted wide discretion in determining how to perform them. This meant that each lab often took a different approach and adopted different specifications for racks, canisters, test hole dimensions, and other methodological differences. The labs could revive and review recommendations from the now defunct Joint Testing Organization to ensure coordination and collaboration if necessary. This would prevent unnecessary slowdown in the event that PDD-15, with its two- to three-year timeline, is executed. Related to lab-to-lab coordination (that should be easier today due to the establishment of the National Nuclear Security Administration), an assessment of the regulatory environment would help planning and improve timeliness. Given the more stringent and necessary safety and environmental concerns since 1992, a menu of options, key regulatory must-do's, and challenging issues could be identified and resolved ahead of time—avoiding paralysis should an administration order testing resumption.

Conclusion

The United States has continued to abstain from nuclear testing since 1992. Regardless of one's position on the merits or lack thereof when assessing a resumption of nuclear testing, the act of actually performing

nuclear tests should not be confused or conflated with the nation maintaining a capability to do so as stipulated by presidential decision directive.

As nearly three decades have passed since the country's most recent nuclear test, it is easy to forget the origins and context that drove PDD-15 and the safeguards. Both were crafted and agreed upon by the executive and legislative branches of government to ensure that conditions to resume nuclear testing were maintained even under the most favorable of geostrategic conditions. Hard lessons from the Cold War were learned, and the safeguards were modified over time to reflect those lessons. As time has passed, these guideposts have faded from the collective consciousness. Yet these hard-earned lessons of past presidents, statesmen, and military leadership remain important reminders with respect to national security.

So too, in some sense, have the aspirations of global collaboration faded as nation-states return to mimic, in many ways, the great power competition of the late 1800s and post–World War I. A nuclear-armed Russia is challenging the European order, and China is attempting a revision to the rules-based international norms that have existed since the end of World War II. Both of these competitors have modernized their nuclear forces in earnest while the US capability aged and, in some respects, atrophied. Their aggressive modernization programs—conventional, nuclear, and nonconventional—that are underway across multiple domains threaten to upset the strategic stability prevailing since the end of the Cold War. These threats became clearer as events unfolded in Ukraine and the South China Sea, through destabilizing actions regarding US domestic politics, and with the creation of organizations that upset and offset long-standing international norms in the economic and technology sectors—to name just a few examples.

As a result, the US, specifically the DOD and DOE, have engaged in a massive effort to reconstitute the nuclear enterprise. Through the creation of Air Force Global Strike Command, a reinvigoration of the ICBM force, and a national security strategy that gives nuclear forces a seat at or near the head of the table, the nation's nuclear deterrent is on the road to recovery. Funds are being allocated to modernize the three legs of the triad, and a renaissance of strategic deterrence thinking is underway across government institutions, private sector think tanks, and in academia. The partnership between the DOD and DOE that can trace its roots to the Manhattan Project is being revitalized as both organizations collaborate even more deliberately on key nuclear national security programs like the SSP, SRP, Life Expectancy Program, Alts (alterations), gaming, modeling,

and personnel exchanges such as the Air Force Fellows program across the national laboratories.

Many challenges remain as the US works to rebuild and improve the health of its nuclear enterprise and infrastructure. The DOE and DOD will deal with competing priorities as they attempt to modernize all legs of the triad and simultaneously rebuild and improve the material and personnel resources of the critical national laboratories. Test readiness posture may not make the cut in terms of the lengthy list of wicked problems facing the enterprise. However, the longer the nation waits, the more intractable this problem becomes.

The United States is at a crossroads on how to address its nuclear test readiness deficiencies. Perhaps the simplest path to remedy issues regarding test preparedness is to change the law. Replacing, revising, or rescinding the requirement for the US to be ready to resume nuclear testing could obviate the need for the enterprise to be prepared to test in a given time horizon. Taking this path would be akin to the Ford administration removing the costly requirement for the US to be ready to resume atmospheric nuclear testing. However, any decision to change the legal requirements for test preparedness should carefully consider the geopolitical, national security, and fiscal implications.

The alternate path is to resource nuclear test readiness appropriately and adopt the recommendations outlined here. Should the US choose this course, it must address the shortcomings surrounding current nuclear test readiness with a plan to conduct a test if directed. In a world defined by great power competition, the next emergency is likely just around the corner. The effects of black swans, grey rhinos, and pink flamingos become more consequential the less prepared the nation is for a surprise. The longer nuclear testing atrophies, the more the problem will have to be reframed as reinventing testing rather than resuming it. SSQ

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Notes

1. *Nuclear testing* refers to any test that would generate a nuclear yield, however small.

2. Los Alamos National Laboratory, "Nuclear Deterrence and Stockpile Stewardship," 6 April 2018, https://www.lanl.gov/. In 1994, Congress established the science-based Stockpile Stewardship Program, which combines advanced scientific and experimental capabilities with high-performance supercomputing to help scientists and engineers understand and resolve issues in the nation's nuclear deterrent. Los Alamos National Laboratory, "Nuclear Deterrence."

3. The Senate also passed 98-1, S. 1050, the FY2004 National Defense Authorization Bill, sec. 3133, directing the Secretary of Energy to achieve the ability to conduct a nuclear test within 18 months of a decision to test.

4. Randolph D. Moss, "Legal Effectiveness of a Presidential Directive as Compared to an Executive Order," Memorandum Opinion for the Counsel to the President, Office of Legal Counsel, Department of Justice, 29 January 2000, https://www.justice.gov/. Both an executive order and a presidential directive remain effective upon a change in administration unless otherwise specified in the document, and both continue to be effective until subsequent presidential action is taken.

5. The INF Treaty was signed in 1987 and was a landmark arms control agreement eliminating both the Soviet SS-20 and the US Pershing II mobile medium-range ballistic missiles.

6. Susan J. Koch, *The Presidential Nuclear Initiatives of 1991–1992*, Center for the Study of Weapons of Mass Destruction, National Defense University, Case Study Series 5 (Washington, D.C.: National Defense University Press, 2012), https://ndupress.ndu.edu/. The PNIs were declarations made by President Bush in the 1991–92 timeframe. While unilateral in nature, they were intended to seize the initiative in arms control and elicit reciprocity from his Soviet/Russian counterparts.

7. START built upon the INF in the sense that similar reductions of weapons were planned—in this case, ICBMs, SLBMs, and strategic nuclear-capable bombers. Additionally, components like the verification framework and counting rules were refined based on the INF experience.

8. Jonathan Medalia, *Comprehensive Nuclear-Test-Ban Treaty: Issues and Arguments,* CRS Report RL34394 (Washington, D.C.: Congressional Research Service, 2008), https://www.everycrsreport.com/.

9. National Security Council and National Security Council Records Management Office, "PDD-15 – U.S. Policy on Stockpile Stewardship Under an Extended Moratorium and a Comprehensive Test Ban, 11/3/1993," *Clinton Digital Library*, https://clinton.presidentiallibraries.us/. Signed by President Clinton on 3 November 1993, PDD-15 stipulates that the US must maintain a capability to resume testing and "a capability to conduct a nuclear test within 2–3 years . . . will be assumed by the Department of Energy."

10. Medalia, *Issues and Arguments,* CRS-6.

11. Jonathan Medalia, *Comprehensive Nuclear-Test-Ban Treaty: Updated "Safeguards" and Net Assessments*, CRS Report R40612 (Washington, D.C.: Congressional Research Service, 2009), https://www.everycrsreport.com/.

12. It is important to point out that a president can issue a new executive order or presidential decision directive with different stipulations that would supersede PDD-15.

13. Thomas Kunkle, *A Short History of the United States Nuclear Treaty Safeguard Program* (Los Alamos, NM: Los Alamos National Laboratory, 2004).

14. Medalia, *Updated "Safeguards" and Net Assessments*, app. A, 3. According to Medalia, "during the 1963 debate on the ratification of the LTBT [Limited Test Ban Treaty], the Joint Chiefs of Staff expressed concern that the treaty would lead to 'euphoria' and cause the United States to let down its guard against the Soviet Union," Medalia, 3 and app. A.

15. Medalia, app. A, 21.

16. Kunkle, *Nuclear Treaty Safeguard Program, 11*.

17. US Department of Energy, National Nuclear Security Administration Nevada Field Office, *United States Nuclear Tests: July 1945 through September 1992* (Oak Ridge, TN: US Department of Energy, Office of Science and Technical Information, 2015), xiii, https://www.nnss.gov/. This number is 50 percent more than the next closest country, the former Soviet Union with 715 tests. For a quick summary of tests, see Arms Control Association, "The Nuclear Testing Tally," fact sheet, accessed July 2020, https://www.armscontrol.org/.

18. Dr. Michael R. Furlanetto (deputy program director for the Office of Experimental Sciences, Associate Laboratory Directorate for Weapons Physics, Los Alamos National Laboratory, Los Alamos, NM), interview by author, 26 September 2019.

19. Wendee Brunish, *Containment of Underground Nuclear Tests: A Primer* (Los Alamos, NM: Los Alamos National Laboratory, 2014).

20. Test devices don't reach critical mass, which is the minimum amount of nuclear material needed to realize a self-sustaining chain reaction. Thus, while fissions occur because there is a convergent chain, these don't multiply because the system is subcritical and a self-sustaining chain reaction isn't possible. These tests conform with the US interpretation of language in the Comprehensive Test Ban Treaty, discussed later in this article.

21. Joseph Martz, "Detonation from the Bottom Up," *National Security Science Magazine*, July 2014, 3–14, https://www.lanl.gov/.

22. Furlanetto, interview.

23. US Congress, Senate, Committee on Foreign Relations of the United States, *Final Review of the Comprehensive Test Ban Treaty: Hearings before the Senate Foreign Relations Committee*, Statement by Ambassador Stephen J. Ledogar (Ret.), 106th Cong., 1st sess., 7 October 1999, https://www.govinfo.gov/. In testimony, Ambassador Ledogar, the chief US negotiator, stated unequivocally that zero yield meant exactly zero yield and that at the time, the negotiating parties to the treaty, including Russia, understood that language.

24. US Department of State, Treaty Banning Nuclear Weapons Tests in the Atmosphere, in Outer Space, and Underwater, 10 October 1963, https://2009-2017.state.gov/.

25. Kent Johnson et al., *Stockpile Surveillance: Past and Future,* Sandia Report SAND95-2751 (Albuquerque, NM: Sandia National Laboratories, 1996), 4, https://www.osti.gov/. Beginning in 1970, the DOD and DOE agreed to a formal series of underground tests of weapons withdrawn from the stockpile, called stockpile confidence tests. They differed from development nuclear tests in that the weapon was from actual production, had experienced stockpile conditions, and had minimal changes made to either the nuclear or nonnuclear components prior to the tests. Johnson et al., 4.

26. Wendee Brunish (retired Los Alamos Containment Group Leader and current chair of the Containment Evaluation Review, Los Alamos, NM), interview by author, 29 October 2019. The Baneberry test accident was an example of such a containment failure

that occurred in part due to its smaller yield, but also due to the test's proximity to fault lines and other geological features. See US Department of Energy, *United States Nuclear Tests.*

27. US Congress, House, Fiscal Year 1994 Defense Authorization Act, sec. 3138, 103rd Cong., 1st sess., 5 January 1993, https://www.congress.gov/.

28. Medalia, *Updated "Safeguards" and Net Assessments,* 5.

29. Los Alamos J-Division (Weapons Experiments), "Dual Axis Hydrodynamic Radiographic Test (DARHT): Validating Weapons Performance without Nuclear Testing," November 2018, 2.

30. Martz, "Detonation from the Bottom Up," 3–14.

31. Chris Bradley (senior scientist and Los Alamos member of the Containment Evaluation and Review Panel, Los Alamos, NM) and Garrett Euler (Los Alamos containment scientist, Los Alamos, NM), interviews by author, 5 December 2019. Scientists, on a fairly regular basis, engage in testing preparedness events in Nevada such as UNICORN (2005), SPE Phase I in Granite (2011–16), and SPE Phase II in Alluvium (2018–19) to sharpen their skills.

32. With an expert staff of research librarians and archivists, the NSRC houses the largest collection of national security and nuclear weapons documents in America. The center's collections encompass work produced not only at Los Alamos but across the nuclear enterprise in the DOE and DOD. Rizwan Ali (director, Los Alamos National Security Research Center, Los Alamos, NM), interview by author, 6 April 2020.

33. Martz, "Detonation from the Bottom Up," 11.

34. US Department of Energy, National Nuclear Security Administration, Nevada Operations Office, *Enhanced Test Readiness Cost Study*, DOE/NV-828 (Las Vegas, NV: DOE, National Nuclear Security Administration, 1 July 2002), 15.

35. Los Alamos J-Division, "Dual Axis Hydrodynamic Radiographic Test."

36. "What Is NIF?," Lawrence Livermore National Laboratory, accessed 22 January 2020, https://lasers.llnl.gov/.

37. "Los Alamos Neutron Science Center [LANSCE], Weapons Neutron Research Facility," Los Alamos National Laboratory, accessed 21 April 2020, https://lansce.lanl.gov/.

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39. "Electromagnetic Environments Simulator (EMES)," Sandia National Laboratories, accessed 8 April 2020, https://www.sandia.gov/.

40. "Z Pulsed Power Facility," Sandia National Laboratories, accessed 8 April 2020, https://www.sandia.gov/.

41. Fred Mortensen (Los Alamos Fellow and Design Leader, Los Alamos, NM), interview by author, 25 April 2020.

42. Joseph Martz (senior staff scientist, Los Alamos National Laboratory, Los Alamos, NM), interview by author, 15 October 2019.

43. Sieg Shalles (director, Office of Stockpile Assessment, Los Alamos, NM), interview by author, 26 February 2020.

44. Bradley, interview.

45. John C. Hopkins, "Nuclear Test Readiness: What Is Needed? Why?," *National Security Science Magazine,* December 2016, 10, https://www.lanl.gov/; and "Las Vegas, United States Population, Population Stat, accessed 6 July 2020, https://populationstat.com/.

46. John C. Hopkins (former Los Alamos Laboratory associate director, responsible for Nuclear Weapons Program, Los Alamos, NM), interview by author, 8 October 2019.

47. Glen McDuff (Los Alamos research scientist, retired, Los Alamos, NM) and Keith Thomas (Los Alamos research scientist, Los Alamos, NM), interviews by author, 1 October 2019; and Glenn McDuff, *Underground Nuclear Testing: A Primer*, LA-UR-18-24015 (Los Alamos, NM: Los Alamos National Laboratory, 2019), https://permalink.lanl.gov/.

48. Hopkins, interview.

49. The 1971 Cannikin Test was one of the largest underground nuclear tests and, according to Greenpeace's website, was the impetus for its formation. Kieran Mulvaney, "A Brief History of Amchitka and the Bomb," Greenpeace, 25 August 2007, https://www.greenpeace.org/.

50. Hopkins, interview.

51. Brunish, *Containment of Underground Nuclear Tests*.

52. DOE, *Enhanced Test Readiness Cost Study*, 7, 16.

53. Hopkins, "Nuclear Test Readiness," 9.

54. All retired testing experts interviewed for this research highlighted the importance of gas-blocked cables and expressed concerns about the viability of the aged inventory and the ability of the nation to remanufacture replacements.

55. DOE, *Enhanced Test Readiness Cost Study*, 9.

56. DOE, app. E, 37.

57. DOE, app. F.

58. McDuff, interview.

59. Joseph Medalia, *Nuclear Warheads: The Reliable Replacement Warhead Program and the Life Extension Program* (Washington, D.C.: Congressional Research Service, 2007), CRS-31, https://fas.org/.

60. Nina Tannenwald, "How Strong Is the Nuclear Taboo Today?," *Washington Quarterly* 41, no. 3 (2019): 89–109, https://doi.org/10.1080/0163660X.2018.1520553. Tannenwald's idea of the "nuclear taboo" is related.

61. Houston T. Hawkins, "Rethinking the Unthinkable," *National Security Science Magazine*, December 2014, 14, https://www.lanl.gov/.

62. Hawkins, 14; and Office of the Under Secretary of Defense, *The Nuclear Weapons Effects National Enterprise: Report of the Joint Defense Science Board/Threat Reduction Advisory Committee Task Force* (Washington, D.C.: Defense Science Board, 2010), https://www.airforcemag.com/. In this 2010 study, the authors point out the need for renewed attention to nuclear weapons effects (e.g., EMP) vis-à-vis our nuclear enterprise. As pointed out in this report, weapons effects testing was a major portion of our underground nuclear testing program. The task force report suggests nuclear survivability (e.g., defensive measures to ensure continued operations in radiation environments) has declined.

63. Notable Los Alamos engineer and scientist Robert Osborne stated that "within 6 months of the moratorium the staff had dispersed to such a point that we had *completely* lost our ability to perform a comprehensive test (emphasis added)." McDuff, *Underground Nuclear Testing*, slide 66.

64. Nassim Nicholas Taleb, *The Black Swan: The Impact of the Highly Probable* (New York: Random House, 2007), 93–94.

65. Office of the Secretary of Defense, *Nuclear Posture Review, 2018* (Washington, D.C.: Department of Defense, 2018), 63, https://media.defense.gov/.

66. National Nuclear Security Administration, *Fiscal Year 2020 Stockpile Stewardship and Management Plan: Report to Congress* (Washington, D.C.: Department of Energy, 2019), 4-4, https://www.energy.gov/.

67. Michael Bernardin, Los Alamos associate lab director for weapons physics, *Review of the Hopkins-Sharp Paper on Stockpile Stewardship without Nuclear Testing*, Report LA-UR-18-29194 (Los Alamos, NM: Los Alamos National Laboratory, September 2018), 7.

68. The Defense Intelligence Agency (DIA) reported that there were concerns that Russia was cheating with regards to the CTBT by conducting hydronuclear tests. See "DIA Statement on Lt. Gen. Ashley's Remarks at Hudson Institute," Defense Intelligence Agency, 13 June 2019, https://www.dia.mil/.

69. Note the US (and others') CTBT status and "interpretation" of nuclear explosion in Art. 1 of the treaty.

70. Brunish, interview.

71. A State Department report asserts Russia has conducted nuclear tests and has concerns about China adhering to a "zero yield" standard. Department of State, *Executive Summary of Findings on Adherence to and Compliance with Arms Control, Nonproliferation, and Disarmament Agreements and Commitments* (Washington, DC: Department of State, April 2020), 7–8, https://www.state.gov/.

72. Robert N. Thorn and Donald R. Westervelt, *Hydronuclear Experiments,* Report LA-10902-MS (Los Alamos, NM: Los Alamos National Laboratory, February 1987), https://www.osti.gov/. "One-point" safety implies a nuclear detonation may not start "at any single point on or in the explosive components." In other words, if a bullet hits the weapon, it should not explode. Thorn and Westervelt, 3.

73. Thorn and Westervelt, 2.

74. Thorn and Westervelt, 4.

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A National Strategy for Synthetic Biology

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Abstract

We are experiencing a technical revolution in biotechnology that will change the way we live as much as any technological advance in human history.[1] Advances in gene sequencing, gene editing, and gene synthesis have shifted our relationship with the building blocks of life. This new science, synthetic biology, is in its early stages but has already created distinct threats and opportunities in US national security. It promises advances in materials science, manufacturing, logistics, sensor technology, medicine, health care, and human augmentation while simultaneously increasing the possibility and severity of man-made pandemics through unintended consequences in genetic experiments or improved bioweapons. This article proposes a National Strategy for Synthetic Biology (NSSB) to defend the homeland and promote American strength by building security into synthetic biology and by making synthetic biology an investment priority. The United States can achieve greater security by regulating and controlling synthetic biology to prevent unintended consequences while investing in people and industries to maintain a security advantage in the field.

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Futurist Klaus Schwab predicts in his book *The Fourth Industrial Revolution* "a technological revolution that will fundamentally alter the way we live, work, and relate to one another. In its scale, scope, and complexity, the transformation will be unlike anything humankind has experienced." This revolution builds on the Third Revolution based on electronics and information technology to blur "the lines between the physical, digital, and biological spheres."[2] Scientists have begun to use the term "synthetic biology" to describe the blurring of those lines by the convergence of genetic technologies powered by digital tools and engineering principles to create new physical substances and chemicals. Synthetic biology, advancing at rates exceeding Moore's Law, makes it possible to

develop unique solutions to some of the world's most difficult problems and improve the quality of life for billions of people.

The technological revolution brewing around synthetic biology creates two separate but related national security problems. First, synthetic biology enables people to develop—either deliberately or accidentally—pathogens with enhanced transmissibility or lethality, including entirely new kinds of biological agents and toxins.[3] This technology is becoming easier to access and to use. The second problem is that the United States finds itself in an era of global competition among great powers. China, in particular, is exploiting vulnerabilities in American academic and business institutions to erode US military and economic advantages. This creates the very real possibility that China will become the world leader in synthetic biology, with all the military, agricultural, medical, and industrial advantages that are conferred.

The question becomes how to address these problems. Existing strategies for defeating bioweapons and pandemics focus on deterrence and biologic incident response—two inherently public sector actions. The 2018 National Defense Strategy and the Department of State's Joint Strategic Plan focus almost exclusively on biodefense through traditional deterrence against states like North Korea.[4] Documents directly concerned with biodefense—defined as preparing for and responding to bioweapons and pandemics—such as the *National Biodefense Strategy* and the *National Health Security Strategy*, are too narrow because they do not address the public/private industrial and economic issues that would be required for a coherent technology strategy.[5] This matters because many of the steps needed to increase security in synthetic biology involve private industry and academia rather than governmental initiatives. Additionally, focusing on specific threats, whether those are states or viruses, creates the possibility that new actors or viruses will show up like black swans.

The United States should develop a separate, comprehensive, whole-of-government national strategy to address synthetic biology that supports efforts to provide general security and reduce the overall threat and risks. Our article explores this topic by providing background information on the technological innovations advancing synthetic biology, examining how these advances create the above-mentioned threats to national security, and discussing the declining American advantage in these technologies. It then presents the outline of a new National Strategy for Synthetic Biology (NSSB) to defend the homeland and promote American strength.

Technological Innovations Advancing Synthetic Biology

The ability to read DNA has grown exponentially since the first complete sequencing of the human genome and the discovery of a new class of gene-editing tools revolutionized the ability to manipulate DNA. Now, gene synthesis allows scientists to print DNA or biological material from a basic genetic sequence without modifying existing organisms or DNA. The umbrella term "synthetic biology" describes simultaneous advances in three separate genetic technologies: gene sequencing, gene editing, and gene synthesis. Individually, each area is a potential national security disruptor: gene sequencing creates the potential for very accurate individual identification and medical therapies, gene editing creates the potential to augment human performance, and gene synthesis creates the potential for designer pathogens. Understanding these disruptions requires some understanding of the underlying technological changes.

Gene Sequencing

The most successful genetic technology so far has been gene sequencing. It is a process that reads the nucleotides in an individual strand of DNA. Techniques for decoding DNA have existed since the 1970s and vary widely in terms of expense and accuracy. As each person's DNA is unique, gene sequencing is a means of individual identification and may, if DNA databases are available, identify one's parents and children. There are currently no significant restraints on commercial genetic testing, and many public and private organizations have begun to compile massive databases of genetic information. The cost of genetic sequencing has decreased by six orders of magnitude in the past 18 years, creating massive public interest in genetics.[6] In 2015 alone, the cost of sequencing an entire human genome dropped from $4,000 to $1,500. Commercial services such as 23andMe and Ancestry.com offer tests in the range of $69 to $199 to provide consumers information on their genetic heritage. The market for direct-to-consumer genetic tests boomed in 2017–18, when bundled genealogy and health testing kits were an Amazon "Top 5" Black Friday bestseller.[7] An estimated 30 million Americans have now used a home test kit, and the current market is over $747 million.[8] People have put these data to some surprising uses, such as catching dog poop scofflaws and cold case murderers, and there is a potentially massive market for individually tailored medicines.[9] Sequencing, however, is most significant because it enables gene editing and synthesis at the level of the individual base pair.

Gene Editing

Most popularly known as genetic engineering, gene editing describes any process where scientists directly alter the information encoded in a strand of DNA. Gene editing was pioneered in the 1970s when scientists used viruses to insert, remove, or replace specific genes in various organisms, which are then known as genetically modified organisms (GMO). Applications range from scientific research to agriculture. The CRISPR (clustered, regularly interspaced short palindromic repeats) editing tool has been a watershed in allowing scientists to edit genes with ease and precision.[10] CRISPR describes a general class of gene editing tools based on a specific gene sequence within the immune system of bacteria, the most commonly used variant of which is CRISPR/Cas 9, where Cas 9 is the protein that does the actual editing.[11] These tools are most powerful when used on single-celled organisms or in sex cells because the changes are heritable, known as "germ line" edits. These germ line edits can also change genes in living multicelled organisms. CRISPR is revolutionary because it is precise, easy to use, and nonproprietary—its inventors decided to make it widely available as an academic product rather than a proprietary corporate process, as is the case with most GMOs.[12] In fact, it is so easy to use that companies are selling take-home gene editing kits. Those factors have inspired a boom in genetic engineering, with the number of CRISPR-related academic articles jumping from 100 in 2011 to 14,000 in 2015.[13]

While CRISPR is the most important innovation contributing to the speed of change, other advances continue to emerge. New editing techniques are being developed to overcome some of CRISPR's limitations, such as being too large to fit inside certain viruses and occasionally copying bacterial sequences into other DNA.[14] Beyond the actual editing tools, innovative approaches show great promise in defeating the traditional pitfalls caused by genetic complexity and expression. The 2018 Nobel Prize in Chemistry was awarded to scientists who pioneered "directed evolution" by randomly generating mutations in bacteria and then selecting only those mutations that produced useful or interesting effects—using evolution to replace iterative engineering—to "create antibodies, biofuels, drugs, and other important biological molecules."[15]

Gene Synthesis

Whereas CRISPR and other editing technologies modify existing DNA, it is also possible to manufacture complete strands of DNA from

sequences stored on computers. Gene synthesis refers to the process of creating DNA from scratch using chemical precursors. This "printed" DNA must be inserted into some form of host cell to come alive. Scientists conduct synthesis by dividing a DNA sequence into small chunks, "printing" them using strings of raw nucleotides, and then stitching the pieces together.[16] They sequence these, verify their accuracy, and then insert them into blank cells to check their function. Cells created this way can then reproduce normally. While progress has been slower, gene synthesis inspires the term "synthetic biology," which incorporates the idea of applying classic design-build-test-learn engineering principles to genetic manipulation. Synthetic biology has attracted significant interest and investment—the market for synthesis precursors grew from $5.5B in 2015 to an estimated $40B in 2020. Biologically derived chemical production made up only 2 percent of the $1.2T global chemical market in 2008, but that is estimated to rise to an estimated 22 percent in 2025, making the impact of synthetic biology to the chemical industry in the hundreds of billions of dollars.[17]

Threats to National Security

Technology now exists that allows malicious actors to enhance existing pathogens into more effective weapons and to create pathogens for which there is no natural defense. In May 2018, Johns Hopkins University conducted a tabletop pandemic exercise called "Clade X" to evaluate national and international responses to a bioengineered virus released by an Aum Shinrikyo–like cult whose goal was to save the world by eliminating humans.[18] At the conclusion of the exercise, after approximately 20 game months, nearly 150 million people were dead worldwide including 20 million in the United States. Without a vaccine, the game model predicted 900 million deaths worldwide—accompanied by civil disorder, governmental breakdown, riots, and additional deaths from starvation, lack of sanitation, and violence.[19] The military and government have long been aware of how badly pandemics can damage national structures and economies. The Covid-19 pandemic has vividly enacted these once esoteric tabletop scenarios for the whole world; engineered pathogens would cause significantly more harm.[20]

A keystone technology in the future of biomanufacturing is gene synthesis, creating organisms capable of producing advanced materials at scale. However, it also makes possible novel organisms, similar to viruses, engineered specifically to challenge the human immune system. Synthesis has advanced more slowly than sequencing and editing because the cost of

nucleotide precursors and reagents has stayed essentially the same over the past decade.[21] Still, this cost is relatively low. One can recreate smallpox in a private lab today for around $3 million; a similar effort in 2025 may cost as little as $100,000.[22]

Gene Drives and Unrestricted Warfare

Scientists have used CRISPR to develop gene drives. These are tools to "drive" a genetic modification through an entire population. By editing a small version of CRISPR into the gene itself, gene drives avoid the normal Mendelian inheritance process to guarantee a desired trait gets passed along.[23] This new trait is permanently dominant and is transmitted in each subsequent generation. In this way, scientists can genetically engineer whole species, though the process takes generations to achieve. Various nations and nongovernmental organizations are pursuing the use of gene drives to do things like eliminating the species of mosquitos that causes malaria and eradicating rats from the Galapagos by forcing rats to only produce males.[24] Gene drives spread generationally, meaning they are not suitable as direct weapons against human beings. However, when used in species that reproduce rapidly like bacteria and insects, they can eliminate entire species and collapse ecosystems. Because the delivery system of a gene drive can be as simple as a single introduced organism, gene drive effects are limited to a single trait, and the slow speed of propagation could provide anonymity, gene drives could become highly effective weapons in economic warfare. [25]

Dual-Use Technology

Synthetic biology is inherently dual use. From pharmaceutical companies to biohackers, the primary motivation of most is the desire to improve the human condition. Because these tools are "decidedly low-tech, inexpensive, and widely available," however, "life sciences research is now nearly borderless and is a global collaborative activity" that could just as easily cause harm.[26] In 2018, scientists at the University of Alberta used gene synthesis—"mail-order DNA"—to fabricate a sample of "living" horsepox, a relative of smallpox, without having any physical access to the virus.[27] They did this to make a case for reform. Others have conducted similar experiments to do pure viral research, like the team that synthesized the 1918 Spanish flu from frozen lung samples.[28] These efforts demonstrate both how well-meaning efforts can produce highly

dangerous outcomes and how few obstacles exist to the application of synthetic biology and gene synthesis.

Proliferation and Unintended Consequences

With few regulatory hurdles, synthetic biology is proliferating wildly, including to high schools and amateur do-it-yourselfers. In 2018, biohacking became a major trend on the Gartner Hype Cycle as an emerging transformative technology, and it has since gone mainstream.[29] For $169, one can order a "DIY Bacterial Gene Engineering CRISPR Kit."[30] While many biohacking efforts can seem gimmicky, like glow-in-the-dark beer, much of this amateur work is serious. The International Genetically Engineered Machine (iGEM) competition is an annual MIT-sponsored event featuring 6,000 competitors from high school, college, and private industry seeking to produce the best synthetic biology designs. In 2018, the undergraduate grand prize went to Printeria, "a fully-equipped bioengineering device able to automate the process of printing genetic circuits in bacteria but made as simple and easy to operate as a domestic desktop printer."[31] These collaborative projects make synthetic biology easier and more accessible. While innovation drives economic expansion, each unregulated technical improvement decreases the expertise required for malicious actors to produce bioweapons and increases the likelihood of unintended consequences.

Unintended consequences have long been a part of the life sciences because biological systems are quintessentially complex. Genes are notoriously difficult to manipulate, often with negative or perverse outcomes. Gene therapy had its "defining moment" with the accidental death of one of its first subjects, 18-year-old Jesse Gelsinger, who had a bad reaction to a viral delivery agent designed to correct his genetic blood disorder.[32] The classic cautionary tale for genetic engineering is the Australian mousepox experiment in which scientists hoping to control an exploding mouse population introduced an infertility gene using the mousepox virus as a delivery vehicle.[33] Instead, they created a virus that was 100 percent lethal to mice within nine days of infection, even in mice bred to be resistant and in those immunized.[34] The episode was so frightening in its implications that an American effort to create countermeasures was widely condemned.[35] The obvious concern is an accidental release of a deadly pathogen resulting from some innocuous line of research—mousepox for humans.

Weak Regulation

Despite consequences on par with nuclear incidents, biotechnology is not controlled or regulated with nearly the same rigor as the nuclear industry. As a matter of international law, the Biological and Toxin Weapons Convention prohibits the development or production of agents or products that have no peaceful use. The United States applied that standard to develop the Dual Use Research of Concern policy, updated in 2014.[36] However, this policy is limited to "15 agents and toxins and 7 categories of experiments" that are under federal review and oversight. Having a highly selective list of prohibited materials might have made sense at one time, but it cannot keep up with the pace of innovation. Scientists can conduct limitless mutations on existing viruses with the specific intent to better understand or fight them and end up with a constant stream of novel pathogens.[37] So long as research is conducted with a legitimately peaceful research objective, it is permissible.

In the absence of strong regulation, the life sciences rely heavily on professional standards and norms to prevent bad behavior. The 2004 Fink Report outlined a moral duty of scientists to avoid experiments that could advance bioweapon technology, such as "rendering a vaccine ineffective or conferring resistance to available therapeutics, evading detection or diagnosis methods, enhancing or creating virulence, increasing a pathogen's transmissibility or altering its host range."[38] These concerns apply to both existing viruses tweaked to be deadlier or new classes of pathogens (engineered, for example, to evade the human immune system).[39] Under the current regulatory regime, the scientists who synthesized synthetic horsepox or the Spanish flu are doing nothing illegal.

The Declining American Advantage

Strategic competitors like China are working tirelessly to erode America's asymmetric technological advantage. In synthetic biology, this competition is fierce and stretches across economics, cyber, biosecurity, education, foreign investment, and control of genetic information. The context is one of a declining US advantage. Biotechnology is increasingly important in Chinese military doctrine, with the People's Liberation Army (PLA) designating biology as a separate war-fighting domain. Some of its most influential thinkers have described potential offsets including biomaterials, human enhancement, and "offensive capabilities" that may include ethnically targeted bioweapons.[40] Yet, as transformative as biotechnology will be in the future, American experts do not generally think of it as a transformative

military technology in the same class as "artificial intelligence, autonomous systems, ubiquitous sensors, advanced manufacturing, and quantum science."[41] This oversight creates an opportunity for China, with its closely linked security and economic structures. Seemingly trivial innovations, such as engineered hypermuscular "super dogs," will always have a military or security application.[42]

Economic Competition

Synthetic biology has become a major area of Sino-US economic competition as well. The United States is struggling to respond to what the White House Office of Trade and Manufacturing Policy describes as "economic aggression." The White House estimates China's human infiltration and cyber espionage efforts cost the United States economy between $180 and $540 billion per year as China seeks to "capture the emerging high-technology industries that will drive future economic growth."[43] Biotechnology is a favorite target for Chinese exploitation as one of the top 10 focus areas of the "Made in China 2025" plan, with a target to reach four percent of the country's GDP by 2020.[44] Further, China wants to ensure that it not only catches up to the United States technologically but surpasses and dominates it. Biotechnology was prominent in the Chinese Communist Party's recently launched initiative to become the world leader in relevant military technologies, with $20.9 billion in direct investment in 2019.[45] China's tightly intertwined civilian and military institutions blur any distinction between private and public sectors, guaranteeing the inevitable transfer of superficially nondefense investments to the military-security apparatus.[46]

China's espionage and investment activities reflect the vulnerability of the American synthetic biology industry. Weiqiang Zhang, a former lead scientist at Ventria Bioscience, was recently convicted of trying to steal a technique that uses rice to produce customized proteins for medical research and therapies (with potential revenues of $1 billion per year).[47] Others have been caught smuggling genetically modified corn and cancer cells for genetic research from the United States to China.[48] When not stealing intellectual property, the Chinese are buying it outright. The Beijing Genomics Institute (BGI) recently purchased California-based Complete Genomics and used that acquisition to help build a new generation of genomic sequencing machines capable of cutting 40 percent off the market price.[49]

Cyberbiosecurity

China's renowned hacking abilities present a unique threat to synthetic biology, which relies heavily on information technology. Cyberbiosecurity, which fuses ideas from cybersecurity and biosecurity into a multidisciplinary approach to mitigating those vulnerabilities, has emerged to grapple with the vulnerability of biotechnology-related information systems and laboratory equipment.[50] The digital infrastructure that supports synthetic biology includes data (base pairs or bits), data storage (DNA or silicon), laboratory equipment, communication networks, and supply chains. Most cyberbiosecurity efforts are mundane, such as encrypting medical records and genetic profiles. However, one unique concern is the interface between digital and genetic data. In 2017, researchers at the University of Washington were able to encode malicious "software" into a string of DNA that, when sequenced, allowed them to take control of the underlying computer system.[51] This vulnerability provides a sophisticated attack vector into academic and commercial operating systems, enabling traditional cyber threats such as data exfiltration or industrial sabotage. Facilities and equipment for genetic sequencing and gene synthesis are often colocated, and genetic malware potentially allows bad actors a covert and nonattributional way to synthesize artificial pathogens by hijacking automated laboratory equipment. DNA-based malware then can spread computer viruses that create real viruses.

Education

For decades, the United States' university system brought the world's best and brightest to study, and many of them stayed to work in its technical industries. China, through recruitment initiatives like its "Thousand Talents" program, is trying to take advantage of the US research system based on trust, good faith collaboration, and the free exchange of ideas to build a rival higher education system.[52] When these scholars come to China to build research centers, they often bring cutting-edge or proprietary knowledge with them. Simultaneously, American universities have built their business plans on having a continuous stream of foreign students as full-tuition-paying graduate students who contribute billions of dollars to universities through tuition and on-campus spending. Now, a sharp decline in Chinese students poses a potentially "existential" threat to many science, technology, engineering, and mathematics (STEM) graduate programs that fuel the American innovation base.[53] Although staying in the United States was never part of the "deal" for foreign students, the

current administration's policies increasingly discourage immigration. The State Department has imposed visa limitations for Chinese scholars as "non-traditional information collectors," especially in fields with national security implications.[54] These restrictions simultaneously fail to discourage actual spies, who can jump the bureaucratic hurdles necessary to stay in the United States and damage the institutions they are designed to protect. International student enrollment has flattened over the past two years, with the US economy losing an estimated $5.5 billion. American universities started taking out insurance policies, while international student enrollment has increased as much as 20 percent in countries like Australia and Canada.[55]

Foreign Investment

China has leveraged its newfound economic might to take advantage of the United States' open markets to obtain technology through foreign direct investment. By supporting or buying struggling companies or through venture capital, Chinese investment firms gain legitimate access to business and technical information. In 2018, Congress passed the Foreign Investment Risk Review Modernization Act (FIRRMA) to strengthen the Committee on Foreign Investment in the United States (CFIUS). Originally created to prevent foreign investors from acquiring national security–sensitive companies, both the Obama and Trump administrations used the power of the FIRRMA much more frequently than in the past.[56] The most important update to the CFIUS is that it can now review noncontrolling investments, giving investors certain rights including accessing nonpublic proprietary information, observing the board of directors, or having nonvoting decision-making input.[57] Although biotechnology was a broadly covered industry under FIRRMA's pilot program, critical technologies are included in one of five existing control categories, such as arms control treaties and nuclear dual-use restrictions that do not generally apply to synthetic biology.[58] During the public comment period for regulation under the Export Control Act of 2018, the industry lobbied hard and succeeded in preventing any biotechnologies from making the revised Commerce Control List.[59] Biotech firms also led the way in lobbying to narrow the definition of "sensitive personal information" to protect companies that collect genetic information.[60]

Genetic Information

The foreign sale of genetic data may provide other nations with an information advantage. China has amassed the world's largest genetic database

and prohibited its export to preserve its intrinsic economic and security value. The proliferation of genetic information creates some concerns for privacy and anonymity. In America, enough people have publicly shared their genetic information that 90 percent of European-Americans will be genealogically identifiable within three years. Foreign agencies can obtain DNA from a variety of sources and use profiles either available freely online or obtained through espionage to identify spies, soldiers, and their families—who then become vulnerable to threats, attacks, or exploitation.[61] The DOD is aware of this vulnerability and in 2019 circulated a memo discouraging members from purchasing or using at-home genetic tests.[62] Additionally, genetic information could indirectly provide intelligence agencies with potentially powerful information about individuals' genetic predispositions that could be used to compromise officials or operatives.

A National Strategy for Synthetic Biology

America's bioeconomy relies on openness, transparency, globalized supply chains, and a worldwide customer base to foster innovation and economic growth. This creates inherent vulnerabilities within the biotechnology industry that often go unaddressed.[63] Synthetic biology has too few touch points within the national security structure to rely on existing strategies to address its vulnerabilities and opportunities. It is similar to computer technology in that the private sector's production and consumption far exceeds the public sector's, making the technology difficult to secure by focusing on public initiatives.

There have been several attempts to create national-level frameworks to address the public/private divide in synthetic biology, including the 2018 *Biodefense in the Age of Synthetic Biology* and the 2020 *Safeguarding the Bioeconomy* reports from the National Academies.[64] However, these academic reports fail to provide a strategy to drive priorities and spending. This simultaneously allows them to be quite expansive in terms of describing problems and risks while avoiding concrete solutions. These documents repeatedly point out that any successful strategy will require a broad-based and interdepartmental approach with many public and private stakeholders, which makes their findings incompatible with existing strategy documents.

Defending the Homeland

A national strategy for synthetic biology can defend the homeland by regulating synthetic biology activities. Five key lines of effort include im-

plementing a framework to prioritize threats, regulating synthetic biology processes to guard against accidents and nefarious acts, controlling our technology exports to guard against leaks that threaten our security, building international cooperation to restrain unauthorized synthetic biology activities, and conducting horizon scanning to maintain awareness of and prepare for future threats. Each of these will require an interdepartmental regulatory effort, public-private partnership, or both.

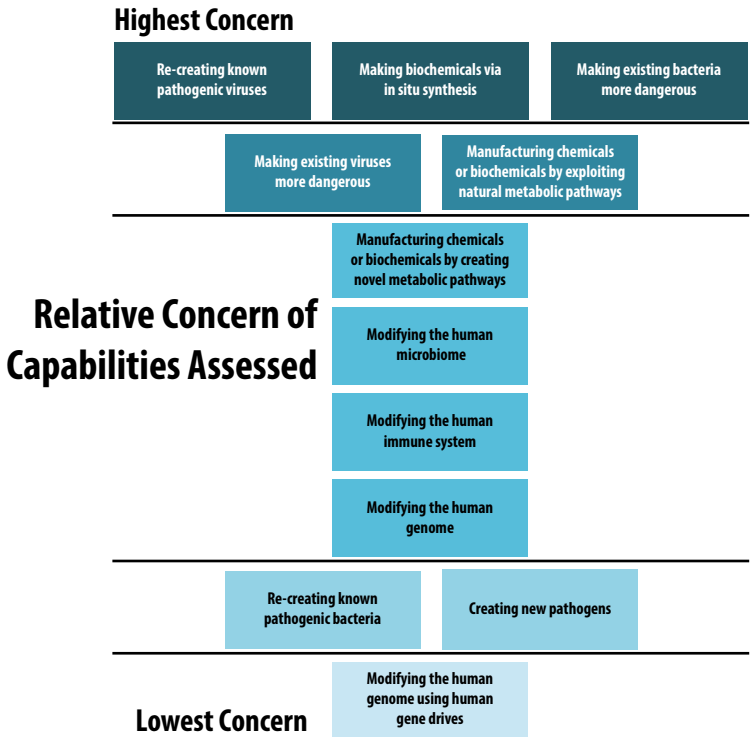

Figure 1. Threat hierarchy. This prioritization of threats was achieved by using the Imperiale Framework. (Reproduced from National Academies of Sciences, Engineering, and Medicine, *Biodefense in the Age of Synthetic Biology* [Washington, DC: National Academies Press, 2018], 5, http://nap.edu/24890.)

Adopt a framework to prioritize actions. The Imperiale Framework introduced by the National Academies in 2018 provides a context for prioritizing actions to mitigate hazards created by synthetic biology. This framework uses the following criteria to establish a hierarchy of concern for potential misuse of synthetic biology: usability of the technology, usability as a weapon, requirements of actors, and potential for mitigation.[65] The resulting threat hierarchy (fig.1, above) shows that the most pressing security concerns include the re-creation of known viruses and toxins and the modification of existing viruses and bacteria. This suggests that actions

should focus on preventing the use of synthesis to manufacture viruses and monitoring and restricting research that could modify existing viruses and bacteria in dangerous ways. The current regulatory structure makes these steps all but impossible without drastically rethinking America's approach to regulating biotechnology, which focuses on products and not process.

Regulate process, not product. Regulation in synthetic biology focuses almost exclusively on consumer safety instead of biosecurity. The nation's regulatory baseline, called the Coordinated Framework for the Regulation of Biotechnology, establishes regulatory agencies responsible for different product groupings but explicitly avoids interfering with production processes.[66] President Trump reinforced that focus with an Executive Order on Modernizing the Regulatory Framework for Agricultural Biotechnology Products in 2019, which further eased regulations.[67] For example, the FDA regulates genetically modified animals but only when a developer decides to sell an innovation.[68] It allows noncommercial experiments to continue without supervision.[69]

To effectively regulate synthetic biology, the government must take an approach to synthetic biology that reduces the possibility of dual use, similar to the way it regulates supply chains in the nuclear industry. Done properly, an agency such as the National Institutes of Health (NIH) would monitor research and development in real time to update the Dual Use Research of Concern policy at the pace of technology, regardless of whether synthetic biology is used by university researchers, corporate developers, or amateur hobbyists. Under this policy, the monitoring agency creates a secured synthetic DNA registry to collect metadata regarding genes, regulators, vectors, hosts, and target species. In accordance with the Imperiale Framework, its immediate emphasis would be to verify that existing pathogens are not being synthesized or modified improperly. Entities involved in sequencing or synthesizing genes for third parties would compare customer requests against that registry to screen for known malicious or suspicious sequences (at an offsite location to protect proprietary sequences), as well as to verify provenance and provide attribution during a bio-incident. Any company, university, or individual conducting independent genetic work would make declarations and submit sequence information. Sensitive equipment, such as DNA synthesizers, would be stored in secured access rooms.[70]

This kind of formal oversight would be a drastic departure from the current system, and it creates an immediate conflict with the DIY/biohacking movement. Scientific self-regulation has done an admirable job of reining in the worst abuses of biotechnology. Yet self-regulation is by

definition unenforceable, and the rapid democratization of biological tools has eroded the social power of professional ethics and norms.[71] The Centers for Disease Control and Prevention (CDC) and the NIH should examine genetic editing technology and propose a set of technical guidelines to restrict gene editing to certified laboratories. Such rules could take the form of the current regime in Germany, where the law prevents unsanctioned work on genes through fines upward of €50,000 and jail terms up to three years. Alternatively, treating key genetic editing materials such as the Cas 9 plasmid as controlled materials may be sufficient. The experts at the CDC and NIH should evaluate the likely effectiveness of such regimes and propose legislation. The moral and legal issues associated with gene editing and gene splicing of mammals and humans should also be evaluated and legislation proposed.

Control exports and investment. Increased regulation will change the business models for many globalized synthetic biology companies, with the risk that they move overseas. While the United States must remain open for biotechnology-related research, we cannot allow this technology to simply move offshore. The CFIUS must, therefore, develop the export control restrictions for synthetic biology technology related to national security that were envisioned by FIRMMA. These export control restrictions would be based on the national roadmap and defense industrial base issues surrounding synthetic biology.

Beyond the requirements of FIRMMA, the United States must examine existing business relationships to ensure they do not result in the loss of important intellectual property. In addition to reviewing new deals, the CFIUS should examine previous and existing deals by foreign companies, especially those like the BGI that have already acquired key American firms or Chinese investment firms like Ever Alpha.[72] It owns a 14.9 percent stake in Twist Bioscience, which is the Defense Advanced Research Project Agency's (DARPA) Living Foundries initiative's leading DNA synthesizer.[73] Finally, the CFIUS should include a wider range of synthetic biology experts. This will improve the committee's effectiveness in policing foreign investment while guarding against overrepresentation in the agricultural and medical sectors.

International cooperation. The United States should work to establish and standardize international rules and norms for synthetic biology research and production. The current international regulatory structure for biotechnology consists of scientific self-regulation based on professional ethics, national-level policies, various arms control treaties, and

some UN-level health initiatives.[74] There are simply too many cracks and gaps in this system.

The absence of an international control regime presents unique national security challenges because of "ethical asymmetry" in places like China, where a loose regulatory regime and strong government-led incentives to spur innovation created a climate where seemingly anything goes.[75] While it is illegal in the United States to create genetically modified babies, and has been since 2015, genetically altered children are living in China.[76] Similarly, Ukraine produced babies using mitochondrial DNA from three biological parents in an effort to avoid inherited genetic diseases for patients from Sweden, Britain, Brazil, and Israel.[77]

Once the United States has developed a sound approach to domestic regulation, the United States should propose to the World Health Organization and signatory states of the UN a set of rules and norms for international adoption. Among these rules, ensuring nation-states retain control over genetic experiments within their borders will reduce the likelihood of errant science experiments being introduced into the environment.

Horizon scanning. Horizons scanning is a frequent recommendation of studies on securing the bio-economy, and the sheer amount of data collected in a centralized gene registry will necessitate a horizon scanning capability based on machine learning.[78] Led by the CDC, this horizon scanning capability should incorporate artificial intelligence to cross-reference foreign investment and business activity derived from CFIUS filings, as well as monitoring ongoing academic research through grant proposals and research papers. Initially, this horizon scanning capability will focus on detecting potentially dangerous or malicious work on existing pathogens and organisms that could create biological toxins per the Imperiale Framework.

Machine learning shows huge potential to improve our ability to detect dangerous or malicious work in synthetic biology. However, some trends will only make sense when placed in the context of things such as unusual military activity or a simultaneous attack on the "health intelligence network" of disease surveillance and electronic medical records associated with a bizarre disease progression.[79] In the longer run, therefore, the United States should expand the Public Health Emergency Medical Countermeasures Enterprise, chaired by the Department of Health and Human Services, into an even broader interagency fusion center to combine domestic genetic horizon scanning with all other available sources.[80] Ultimately, an effective horizon scanning effort might necessitate international cooperation, such as the recent discovery by a CDC team of sev-

eral genetically distinct strains of the hemorrhagic-fever-inducing Marburg virus in Sierra Leone before any humans became sick as part of the PREDICT international partnership system.[81]

Promoting American Strength

Synthetic biology presents an opportunity for scientific and economic gains that can enhance American strength in the international arena. While the United States and China are starting at near parity in this new technological field, China continues to target the American biotechnology industry to make strides toward achieving its ambition to be the world leader in the life sciences. The NSSB will promote American strength by investing in the future. Five key lines of effort include creating a roadmap for defense-applicable synthetic biology investments, establishing an industrial base for defense-related synthetic biology based on that roadmap, investing accordingly in key technologies, creating policy for legally and ethically challenging policy areas, and winning the war for talent.

Create a defense roadmap for synthetic biology. With competing military and economic priorities, the United States needs a synthetic biology roadmap to prioritize technology investments. To develop this roadmap, the Department of Defense must integrate synthetic biology into its strategic, operational, and tactical planning processes to determine how best to apply these technologies in future wars. The roadmap will streamline the research and development processes across the federal government and act as a focusing function for technologies with operational impact (e.g., synthetic biology manufacturing processes that can create structures and runways). Finally, with a vision for future investment, the DOD can develop an industrial base that ensures the security of suppliers and supply chains alike.

Establish a defense industrial base for synthetic biology. There is no defense industrial base for synthetic biology. As synthetic biology has little overlap with traditional major weapon systems, the DOD and its interagency partners largely ignore it as a critical emerging defense technology.[82] This, in turn, leads to a lack of economic clout with synthetic biology manufacturers.

As the Government Accountability Office points out, an improperly secured industrial base could cause supply disruptions from things like interrupted supply chains or failed suppliers, or even contaminated or compromised products.[83] Such consequences could adversely affect military operations as well as domestic synthetic biology research, development, and manufacturing. Therefore, the DOD should acknowledge synthetic

biology as an important defense-related industry, further integrate biotech considerations into its larger strategic and acquisition efforts, and expand on recent progress made by the assistant director for biotechnology under the recently reorganized Office of the Under Secretary of Defense for Research and Engineering.[84]

The federal government should immediately lay the groundwork for a system of "trusted foundries" for both synthetic biology equipment and chemicals, using as its model the existing Defense Department Trusted Foundry program for microelectronics. These trusted foundries will vet people working in the industry, thus ensuring their ability to conduct classified work when appropriate and thereby guaranteeing uninterrupted supply chains, preventing tampering during production, and protecting products from exploitation.[85] Businesses seeking certification as trusted foundries will need to meet certain cyberbiosecurity standards, and these standards will apply to all biotech contracts—including biomanufacturing techniques, genetic sequences for defense-related products, and genetic data storage. Each federal agency that uses the trusted foundry system will need to ensure these trusted foundries remain in business through guaranteed contracts or preferential acquisition plans.

Invest in key technologies. Several key technologies within synthetic biology will enhance economic growth as well as military might. Proper investment in advanced materials, logistics, adaptive materials, living sensors, biochips, and anti-pathogens will create new industries while making our military forces more agile. Investment here collectively will promote American strength.

Advanced Materials. By using gene editing and gene synthesis to create organisms that produce rare substances—especially at the micro and nano levels—synthetic biology provides an avenue to create advanced material on demand and at scale. One of DARPA's signature programs in its $296 million Biological Technologies Office is its long-running Living Foundries initiative to manufacture "critical, high-value molecules that are often prohibitively expensive, unable to be domestically sourced, and/or impossible to manufacture using traditional synthetic approaches."[86] Initiated in 2015, the "1000 Molecules" iteration of this program created its 1,000th biologically produced molecule in 2019.[87] These exquisite materials may fill specific military niches, like radar-absorbing paint for stealth or endothermic fuel for hypersonic weapons. This could be especially game changing with nanomaterials because bacteria already operate at the micro scale and are easy to reproduce naturally. From a health perspective, biological pathways could be similarly repurposed to create "pharmacies on demand";

giving field hospitals the ability to produce medicine as needed would reduce medical logistics.[88]

Logistics. The advantages of biomanufacturing go beyond creating valuable substances: biomanufacturing has the potential to make forces leaner and more lethal. One company, bioMASON, currently sells bacteriologically produced bricks—eliminating the need to transport specialty clay and drastically shortening the normal two- to five-day kiln firing process. This process uses local materials, drastically saving on transportation costs while simultaneously saving fuel and carbon emissions.[89] In 2019, Blue Horizons' Project Medusa used bioMASON materials to create austere runways to show how biomanufacturing could provide a truly innovative approach to the strategic problem of adaptive basing in a contested environment.[90] In fact, biomanufacturing potentially magnifies the tactical and logistical value of additive manufacturing by using local biomass to manufacture the additive polymers on site, rather than relying on transportation systems.[91] Another completely different technology has already been commercialized by companies such as Ecovative, whose prototype bio-buildings are constructed from cardboard origami forms infused with a mushroom-based substance. When sprayed with water, the forms grow into buildings within a few days.[92]

Adaptive Materials. More than decreasing manufacturing and transportation costs, biomanufacturing promises to create materials capable of doing things that inert products cannot. Biologically based self-healing concrete already exists, which works when pellets containing dormant bacteria and calcium-based "fuel" are exposed to water. When cracks allow moisture into the concrete, the bacteria come to life and use the calcium to produce limestone that automatically seals the crack.[93] While this approach has limitations, DARPA has funded several additional efforts, such as the Engineering Living Materials program, that seek to create bioproducts that are not only self-healing but also can grow themselves in place or adapt to their environment. Examples of useful adaptations include adaptive camouflage or pathogenic resistance. One outgrowth of that effort is the successful development by the University of Colorado of using cyanobacteria to create green concrete, both in color and in its ability to trap carbon through photosynthesis.[94] Investment in adaptive materials will improve military adaptive basing and likely produce dividends for the construction and transportation industries.

Living Sensors. Synthetic biology takes advantage of the myriad ways that evolution has equipped organisms to monitor their environment, even beyond the electromagnetic spectrum. Additional investment may

produce bacteria able to act as a trip wire detector for submarines.[95] In one ongoing $45M tri-service program, scientists are engineering bacteria to exhibit photoluminescence in the presence of signature molecules such as lubricants, diesel fuel, or metals.[96] Similar programs are trying to engineer everyday plants to detect explosives or nuclear, chemical, and biological materials in humanitarian relief operations.[97]

Biochips. While living organisms can act as sensors, building actual sensors with synthetic biology involves biochips. A class of medical devices, biochips were initially developed by the Human Genome Project as a search function for DNA sequences, proteins, chemicals, and toxins. Biochips are especially useful for detecting novel or engineered pathogens with previously unknown DNA sequences; they can combine a search for commonly occurring viral DNA sequences with broadly focused protein searches to recognize altered viruses.

One application of biochips is micro-organs—miniaturized models of organs such as hearts, lungs, pancreases, and tumors that work like the real thing.[98] Also known as bio-microarray devices, micro-organs look like large-circuit microchips but are built out of living cells performing biological functions. Like microchips that perform millions of computations per second, these bio-microarray devices perform thousands of biological tests simultaneously as each array is a miniature test site. When integrated in a single device (known as a lab-on-a-chip), they can perform low-cost, high-speed, and high-throughput analysis despite being small.[99] Importantly, by grouping lots of miniature assays together, a lab-on-a-chip can both search for multiple things and run redundant tests to eliminate false results. The ultimate goal would be universal detectors that can sense almost anything, from germs to bombs. Due to their promise as sensors, DARPA and the National Institutes of Health have invested $100M in this technology over the past five years.

Anti-pathogens. Because pathogens can evolve or be engineered to resist vaccines, multiple stakeholders—including the DOD, CDC, and NIH—should explore methods using genetic technology to fight pathogens. Scientists still do not completely understand viral phenomena—a team of virologists in Brazil recently discovered an amoebic virus with no known genetic sequences.[100] Funding cuts to the CDC and Public Health Service have done significant damage to the nation's ability to defend itself, especially in light of a drumbeat of zoonotic outbreaks (SARS, Ebola, and Covid-19).[101] Funding preventative steps makes eminent sense when the cost of responding to an outbreak such as Covid-19 is in the trillions of dollars.[102]

Recent outbreaks have shown that vaccine development is slow, expensive, and limited to the target virus. The global response to Covid-19 further demonstrates how disruptive a potential pandemic can be to an interconnected world. The response also shows the benefit of using cutting-edge tools like biochips and machine learning to speed up the genetic profiling of antibodies to mass-produce antibody serums to provide non-vaccine treatment options.[103] Research on innovative approaches, such as enlisting predatory bacteria to fight other bacterial infections, should continue.[104]

Establish policies for genetic information and human augmentation. The most controversial areas of synthetic biology are those that deal with humans: genetic information and human performance augmentation. Both genetic screening and human augmentation raise a host of ethical and legal concerns, such as whether modified humans are weapons under the Geneva Convention.[105]

Genetic information. The United States should follow the lead of China and Russia to prohibit the export or sale of citizens' genetic information to foreign entities with additional steps taken to ensure the privacy of those who serve in security-related positions. The DOD and CIA should, for instance, prohibit members from taking commercially available genetic tests while increasing the availability of prescribed medical genetic testing. Similarly, local and state governments should be precluded from storing DNA profiles of those employed in national security positions in local (sometimes called "shadow") databases. Most importantly, the DOD should clarify its policies to further restrict access to security for the 50 million DNA samples it has as part of its DOD Serum Repository.

It must also establish policies that will enable it to use genetic information to improve military performance and decrease military and veterans' health care costs. While genetic discrimination has been illegal in the United States since the 2008 Genetic Information Nondiscrimination Act (GINA) for things like issuing health insurance, the act does not apply to military recruitment.[106] Improved genetic testing provides an opportunity to test for certain genetic diseases or proclivities, and it is becoming feasible to test for positive adaptations to high-altitude/low-oxygen conditions, extremely hot/cold environments, or sleep deprivation.[107]

Human augmentation. With gene editing already in use to cure diseases, the United States must have a mechanism to determine how it will approach human augmentation, particularly in defense. In the short term, the DOD should convene a working group that includes private and public sector representatives to recommend to the president and Congress how the military should incorporate human augmentation into operations.

The time available to parse this issue is diminishing due to the pace of innovation in what Army Futures Command dubs the "Era of Accelerated Human Progress."[108] Scientists are already conducting experiments using CRISPR to tweak the immune system of people with genetic disorders such as cancer.[109] US scientists began clinical trials in 2019 to use CRISPR to treat sickle cell disease by editing a woman's blood marrow to produce fetal hemoglobin protein to compensate for the protein that creates sickle cells.[110] Early results suggest the treatment is working, providing hope to millions of people with that condition.[111] This makes possible a treatment that could just as easily give someone with normal hemoglobin the ability to process oxygen like a world-class marathon runner, which has obvious implications for military performance.

Military necessity is creating increasing pressure to pursue "bio-convergence" in military operations.[112] If the United States does not take the lead on ethically using biotechnology in both of these areas, it seems inevitable that some other country will. China has expressed interest in using synthetic biology to improve its soldiers' performance. By moving early to codify how it intends to balance military advantage with ethical restraint, the United States will be able to influence worldwide norms and expectations for what is and is not acceptable.

If using biotechnology is deemed acceptable, research could make humans less prone to disease. Defense researchers are already working on projects to modify the bacteria that make up the human microbiome that will result in increased caloric uptake and less fatigue. A similar approach may change skin bacteria to repel mosquitos that carry malaria or dengue fever or change the microbiome into a secondary immune system capable of reacting to pathogens or environmental contaminants.[113] Other efforts seek to make human beings hardier by identifying and triggering genes present in all people in a manner to give some people enhanced disease resistance when activated. Potential benefits go beyond disease protection to intrinsic resistance to infections, drug overdoses, radiation, and toxins.[114]

Win the war for talent. The United States must take seriously the "competition" part of great power competition and try to beat China in the emerging war for talent.[115] China targets academia and corporations for information largely by funding research. In many cases, including the recent arrest of Harvard's preeminent professor of chemistry, people caught transferring technology to China did so to be better researchers or entrepreneurs, not spies.[116] To compete with China's "Thousand Talents" program, the United States needs to subsidize research fellowships through the CDC, NIH, DARPA, and/or the National Laboratories, where top

researchers can get research grants, access to laboratories, and permissions to commercialize major research findings.[117] Current efforts to tighten vetting of foreign students and strengthen laws requiring the disclosure of foreign investment in American universities or research should be augmented by programs to increase American participation in graduate STEM programs, such as scholarships, internships, and targeted hiring practices. The loss of revenues for American STEM programs due to visa restrictions needs to be counterbalanced with investment lest those programs fail and disappear. Cuts to the budgets for the CDC and NIH only exacerbate this problem and should be reversed.[118]

Conclusion

Synthetic biology is going to remake the world. The tools available to scientists today create the vast potential to do great good or great harm. As innovation in biotechnology accelerates, the United States must take immediate steps to safeguard against catastrophe and capitalize on those innovations. Reducing the threat of engineered pathogens and preventing the loss of intellectual property to our strategic competitors requires a strategic approach that heavily involves regulating academia and industry. It must look beyond traditional defense and national security stakeholders to address systematic weakness and deep root causes. Policy makers will need to think differently about what national security means if they want to solve problems like an educational system that produces too few American students in STEM programs but relies on foreign students to keep those programs solvent, or a highly permissive and globalized business environment that prioritizes profits over security. Consequently, successfully implementing this strategy will require the creation of a broad-based steering committee that includes public and private stakeholders. It will also require carefully balancing security with freedom. Every regulation, restriction, or limitation incurs a cost to innovation and expansion. Many of those costs are offset by investments, research, and the creation of guaranteed supply chains and contracts, but each compromise must be carefully considered. Finally, the American approach must be exportable to the world at large. This strategy cannot be successful if America imposes unilateral restrictions on its own activities that the rest of the world ignores or exploits. As America is faced with increasing global competition and domestic partisanship, the collaborative approach demanded by this moment may seem unrealistic. The alternatives, however, demand that we try. SSQ

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The Future of the Transatlantic Alliance: Not Without the European Union

Sven Biscop

Abstract

The debate about the division of labor between the European Union (EU) and NATO has been ongoing ever since the former was created in 1993. Much more sensitive than the details of EU-NATO relations is the question of whether the EU, as a supranational, state-like organization, is actually seeking more autonomy—not from the alliance but from the United States. The EU has become indispensable to the security of the European continent because its member states largely set overall strategy on foreign policy through the EU and because only EU membership can guarantee their political and economic power base. EU member states are now also endeavoring to generate more military capabilities through the EU. A viable transatlantic alliance, therefore, requires the US to interact more directly with the EU, in addition to its engagement through NATO.

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The transatlantic security architecture does not resemble a Le Corbusier or Oscar Niemeyer design. It is not a neatly planned whole in which every component elegantly and effectively fulfils a specific function. It rather resembles a sprawling palace complex; every successive occupant has added, restyled, or abandoned another wing. It functions, but one would never build it this way if one were to start from scratch.

Unearthing the foundations of this complex architecture takes us back to the years immediately following the end of the Second World War. Initially, the US strongly supported European defense cooperation because it was wary of a permanent military commitment on the European continent. Washington pushed hard for the European Defence Community, which would have merged the armed forces of France, West Germany, Italy, and the three Benelux countries into a single European army—thus rearming Germany without recreating the German armed forces. When in 1954 that project failed, however, the emphasis shifted to

NATO. The US therefore ended up taking the lead in the security and defense sphere anyway, through NATO, while European integration assumed a mostly economic focus through the European Economic Community (EEC), created in 1957.

When the Cold War ended, this neat division of labor became more complex. In 1993 the European Union (EU) succeeded the EEC and gradually developed its own strategy, foreign policy, and defense policy for the post–Cold War world. Ever since, there has been debate between the EU and NATO about who does what. Officially, both organizations talk only about complementarity; they adopted joint declarations in 2016 and 2018 and are working on 74 areas of cooperation.[1] In reality, many decision-makers on both sides of the Atlantic see this as a zero-sum game: what strengthens the EU must of necessity weaken NATO and vice versa. An unhelpful beauty contest has developed between the two organizations. Even in the fight against the coronavirus, for example, both NATO and the EU were at pains to prove that they were coordinating the support that Europe's armed forces were providing to the security and health services.

Nevertheless, if it were merely a matter of redefining the division of labor between the EU and NATO, this debate might have already been settled. Offering a view from Europe, the underlying and much more politically sensitive question concerns the autonomy of the EU, as a state-like organization, not from NATO but from the US. The EU has already become indispensable to the security of the European continent because EU member states largely set overall strategy on foreign policy through the EU and because only EU membership can guarantee their political and economic power base. If EU member states are successful in their endeavor to generate military power through the EU, it would require a reconfiguration of the transatlantic architecture.

The Nature of the EU-NATO Relationship

Formally at least, the EU in its 2016 Global Strategy set itself the objective of achieving "strategic autonomy" in security and defense.[2] The strategic community in the US nearly universally condemns this EU ambition as undermining NATO. On 1 May 2019, the under secretary of defense for acquisition and sustainment and the under secretary of state for arms control and international security even sent a joint letter to the EU in which they described some of the subsequent EU defense initiatives as "poison pills" for the transatlantic relationship.[3]

At the same time, the US keeps pressing its European allies to spend more on defense. The pledge they made at NATO's Wales Summit in

2014, to "aim to move towards the 2% guideline" by 2024, has been reinterpreted in Washington as an obligation to spend 2 percent of the GDP. At the July 2018 Brussels Summit, US president Donald Trump even spoke of a 4 percent spending target, though that was quietly ignored by everybody else.[4] In March 2019, however, he impetuously returned to the charge with the idea that allies hosting American troops should pay the US the full cost of that deployment plus 50 percent. In June 2020 he announced a reduction of American troops in Germany—apparently in retaliation for Germany's alleged underspending.[5] The US cannot have it both ways: it cannot realistically expect the Europeans to pay more without having more of a say.

The stated goals of the Global Strategy notwithstanding, the Europeans remain very divided about strategic autonomy themselves. Some, such as French president Emmanuel Macron, but also German chancellor Angela Merkel, have grandly stated that the EU should take its destiny into its own hands.[6] Others, especially in eastern Europe, are wary of upsetting the US without a firm alternative in place. In the EU institutions, the debate about the meaning of strategic autonomy has created much debate since 2016, but it has remained inconclusive. In 2020, the terms of the debate shifted; increasingly, EU member states and institutions now speak of "sovereignty" or "freedom of action." The focus has now moved to the German initiative to draft a "strategic compass" to provide more political guidance for the EU's defense policy, starting with an updated threat assessment during the German presidency of the EU in the second half of 2020. The Europeans have yet to decide, therefore, how autonomous they really want—and dare—to be in security and defense. The fact is that in many areas of international relations, the EU has already become an autonomous actor because of its very nature.

The EU is a supranational union in which member states have pooled sovereignty. Joining the EU is like moving into an apartment building. Inside your own apartment, you can do as you please within certain rules and as long as you don't overly disturb the neighbors. About the building as a whole, however, you still decide, but only as part of a collective decision by all the owners; you cannot decide to replace the elevator by yourself. And you better participate in the meetings, tedious though they may be, for decisions are taken by majority and are binding even if you don't attend. The EU is not a state, but it is not just an organization of states either; it is something in between, a state-like organization. That is why the EU has become an autonomous actor in its own right, in addition to

the individual actions of its member states, including in areas of international relations (most notably trade).

Foreign policy and defense constitute an exception: in these areas the EU as such is not an actor but still operates on an intergovernmental basis; member states take all decisions by unanimity. These member states are, of course, sovereign countries in that they make their own decisions. However, their national strategic autonomy—that is, their capacity to act on those decisions and to safeguard their interests by themselves—is nonexistent for most and severely constrained for the others. The individual European states mostly have but negative sovereignty: they can in all freedom decide not to do something, but each on its own cannot undertake significant actions. France, for example, can deploy a brigade—but not much more—to Mali and, even then, only with the support of other Europeans and the US in terms of intelligence, transport, and so forth. The current European debate is about the extent to which EU member states should further pool their sovereignty, notably in defense, and thus become an autonomous actor in this area as well.

NATO, to continue the architectural analogy, is the neighborhood watch. Some of the owners in the EU building have joined it while others have not. It also has members from other buildings, including the huge mansion across the street—the US. The neighborhood watch is important, especially when security problems arise, but it does not shape your daily life; the EU building and your relations with the other owners in it does. NATO is fully intergovernmental; it is an organization of states. It can never be an actor in its own right, therefore, nor can it acquire autonomy; it always was and will be an instrument of its member states.

Whether increased EU autonomy in defense undermines NATO is, therefore, a meaningless question. One might as well ask whether US autonomy undermines NATO. If the European members (and partners) of NATO that compose the EU were to decide to pool their defense efforts that would not in any way detract from the strength of the alliance—just like bilateral or trilateral cooperation between allies (Belgian-Dutch naval cooperation, for example, or the Dutch-German army corps) does not. Of course, if the EU member states were increasingly to act as a bloc within NATO, it would be more difficult for the US to maintain its predominant position in alliance decision-making. That is why the EU ambition of strategic autonomy is such a sensitive political issue.

The US has been facing this dilemma since the end of the Cold War. Should it continue to prioritize working with individual European allies through NATO? That would make it easier to maintain American leader-

ship—but of less capable allies. Or should it support defense integration through the EU in the hope that this would render the Europeans militarily stronger and more capable of relieving the burden of the US, even if that would mean accepting a greater EU role in decision-making? Arguably, whichever option the US chooses, it will have to accord a greater role to the EU. Today, although foreign policy remains an intergovernmental area, the EU plays an indispensable role in strategy making.

A Strategy for Foreign Policy

NATO was, of course, created long before the EU. As a consequence, many still perceive a hierarchy in which NATO comes first and the EU second, as if the EU can make decisions only within a prior strategic framework set by NATO. In reality, things work the other way around: NATO provides a military instrument that is put to use within the framework of a foreign policy strategy defined elsewhere. As far as the US is concerned, it is in Washington; for EU member states, it is in Brussels—that is, if the EU works as it should. In practice, EU member states indeed do not arrive at a common EU strategy on each and every specific issue. The fact is that, in general, on issues of strategic importance, the Europeans cannot have much impact unless they adopt a collective EU approach. What could even the largest European states do alone about the war in Ukraine, the war in Syria, or the rise of China? If the EU does adopt a strategy and it coincides with US strategy, Europeans and Americans can then opt to have recourse to NATO if implementation requires military action.

The measures taken since the Russian invasion of Ukraine in 2014 clearly illustrate the actual strategic "line of command." The European reaction to the invasion depended on the relationship Europe wanted to offer Ukraine, the price Europe was willing to pay for it, and how Europe saw the long-term future of its relations with Russia itself. Certainly, the Europeans took into account Washington's position. Nevertheless, these political and economic decisions could only be taken collectively, through the EU. Within this broadly defined EU understanding, the Europeans contribute military forces to Enhanced Forward Presence in the Baltics and Poland, under the NATO flag, while applying sanctions against Russia through the EU. Diplomatic initiatives at the highest level to end the conflict have mostly been undertaken by Germany and France. But their leverage also derives to a large extent from their membership in the EU: only the EU can apply or end economic and diplomatic sanctions. No individual European state will adopt sanctions unilaterally and risk the ire of Russia on its own.

In those instances when the EU does not set strategy, NATO cannot fill the void. NATO obviously has neither the competence nor the authority to step in and decide on issues of foreign policy, trade and investment, or energy; but even in defense, NATO will find it difficult to act if the EU is divided.

Absent an EU strategy, the majority of EU member states will have at most a token policy on big questions of foreign policy and security for lack of leverage, or they may simply follow US policy. Even larger member states, though perhaps more vocal, will find it difficult to act by themselves. If the lack of EU strategy is mostly the result of inertia, the US may still be capable of convincing many or most Europeans to follow its lead and to act jointly, either through NATO or through a broad coalition of the willing. Sometimes, even when there is a common EU position, an ad hoc coalition rather than NATO is the preferred option. This was the case of the US-led coalition against ISIS, created at NATO's Wales Summit in 2014 but not run as a NATO operation.

If, however, EU member states are actively divided on an issue, the US will find that it will then also be very difficult to mobilize NATO or to have more than a handful of European states sign up for an ad hoc coalition. If the Europeans are divided when they meet in the EU, logically they will be no less divided when they meet in NATO or with the US. The example that best illustrates this scenario is the US-led invasion of Iraq in 2003. As the EU was split right down the middle over the invasion, the US had to forgo the active support of all but a few European allies. The 2011 air campaign in Libya is another example: formally presented as a NATO operation, it was in fact a British-French-US led coalition that made use of the NATO command structure. Very few European allies participated, and the EU initially abstained in the face of German disagreement with the intervention. In such cases, the EU's political and economic instruments and resources, many of which are controlled by the supranational European Commission, cannot be made available or at least not from the start. The implementation of a comprehensive approach will then be very difficult.

On issues of foreign policy, therefore, the US would be well advised to consult with the Europeans directly through the EU on a permanent basis. The EU is the only forum where the European allies can adopt and implement strategies on the major foreign policy issues of the day—strategies that will shape the framework within which transatlantic cooperation can take place. Deepening US-EU interaction on strategy is all the more necessary because the trend is for American and European poli-

cies to diverge. The differences are obvious in the Middle East and the Gulf: the US has withdrawn from the Iran nuclear deal, while the EU continues to support it, and declines to choose sides in the regional competition between Iran and Saudi Arabia. In Brussels, undermining the nuclear deal is widely seen as detrimental to Europe's security interests. On multilateralism as well, divergences are growing. Washington and Brussels often identify the same problems with entities such as the World Trade and World Health Organizations. Whereas the EU answer is to engage and seek reform, the US has opted to withdraw and pull funding.

Future US administrations may perhaps shift gears again on these issues, but on China there is a strong bipartisan consensus that the US is engaged in a long-term strategic rivalry. This is the most important divergence, therefore, because it concerns the world order as a whole and China's place in it and because it is unlikely to diminish. The Europeans are increasingly aware of the need to safeguard their sovereignty in the face of China's growing influence but do not perceive China as a strategic threat in the same way as the US.[7] The EU's High Representative, Josep Borrell, has made it clear that Europeans cannot accept the idea that the world should organize itself around a new bipolarity between the US and China.[8] Europeans, in other words, are not keen to pick sides in Sino-American rivalry. This is a key reason why there is a desire in Europe to increase the strategic autonomy of the EU rather than stepping up defense efforts through NATO. At its December 2019 London meeting, NATO put China on its agenda—but that will not be sufficient. For the European allies, deterring Russia remains NATO's raison d'être, and they do not see the alliance as the forum to make strategy on China. Any US administration will have to directly engage the EU on China because on many of the political and economic issues at stake, the EU rather than the individual member states has decision-making power.

Integrated Political and Economic Power

Supranational European integration is the foundation of the political and economic power of the EU member states. Although inequalities remain in their societies, the single market has allowed the Europeans to achieve unprecedented levels of prosperity. For most member states, quitting the single market would amount to economic suicide. Thanks to EU measures, member states recovered from the 2008 financial crisis; the crisis, in fact, led to further economic and financial integration. Likewise, recovery after the crisis caused by COVID-19 will be thanks to an EU support package. Member states do not always show solidarity from the

start, and the EU often arrives at decisions only after lengthy and painful negotiations. The point is that member states have pooled their sovereignty to create the single market with (for most members) a single currency; hence, only the EU can now make the required decisions in an economic or financial crisis. Thanks to European integration, the Europeans have also achieved the scale to hold their own against the continent-sized great powers of the US, China, and Russia in economic and, to a lesser extent, political terms. The EU could certainly improve its geo-economic performance—as in putting its economic clout to use to pursue its strategic objectives—but if it holds any sway in world politics, it is because of European unity. The same goes increasingly for innovation and technology: here too scale has become ever more important. In the areas in which Europe has fallen behind, such as artificial intelligence, only a concerted EU effort could redraw the balance.

Post–World War Two, the US strongly encouraged European integration. The success of the EEC was intertwined with the success of NATO, cementing the American security guarantee to Europe. This has now come to work both ways, however. Before, the EEC and then the EU could not do without NATO. Now, because the EU has become indispensable to the political and economic stability of Europe, NATO can no longer do without the EU either. Without the EU, there would be political instability and economic crisis, which could only result in rivalry between European states with limited power but a lot of mutual suspicion. And if the states of Europe once again became rivals, Europe would no longer be a source of allies for the US but of risks. In sum, if the EU were to flounder that would be the end of NATO as well. In such a scenario, the US might seek to replace a defunct NATO with a set of bilateral alliances—but not necessarily with all current allies. Europeans would do well to understand that if another power would seek to exploit the floundering of the EU and NATO to gain control of significant parts of the European continent, the US might intervene but not necessarily in defense of all European states. Where the US would draw the line would depend on which parts of Europe it would judge to be essential to the American interest and on how many resources it would be willing to spend on Europe in the context of its strategic competition with China.

There are important tensions within the EU already today as some member states, such as Hungary, appear to be returning to more authoritarian forms of government. Such governments feel that they can safely violate fundamental EU values like the rule of law and human rights and antagonize their fellow EU member states because, in terms of defense,

the US will always have their back. The Trump administration has even openly sided with the Polish and Hungarian governments in their disputes with EU institutions. Yet undermining the EU might precisely provoke other powers to leverage that to their advantage while, as stated above, one cannot be sure of future US strategy. The current Polish government may feel that inviting the US to build a "Fort Trump" on its territory is a sufficient guarantee against any eventuality. During conflict, though, the cavalry manning the fort may decide that those living around it are expendable. This is why the populist European political parties and governments actively undermining the cohesion of the EU are playing with fire—as are those Americans who support them. Hungarian prime minister Viktor Orbán may espouse the fiction of "illiberal democracy," but he forgets that today the purpose of NATO is to defend not just the territory of its members but also the democratic model that they have created in their countries. That was not the case when NATO was founded, when for strategic reasons more than one dictatorship was invited to join. Today, any democratic government in a NATO ally would be hard-pressed to convince its public to put its armed forces in harm's way to defend a dictatorship in another NATO country. It is first and foremost the EU's responsibility to uphold democracy for all its members, yet it is surprising, and worrying, how little NATO, and the US, have to say about the democratic backsliding of several allies.

The worst-case scenario of disintegration of the EU will not come to pass. As the drawn-out Brexit process shows, leaving is easier said than done. The current lack of unity within the EU also weakens NATO. Unfortunately, the Hungarian government and others willingly allow themselves to be instrumentalized by other powers and, at their behest, tone down or block EU decision-making altogether. Since nearly all decisions on foreign and defense policy require unanimity, it is sufficient for another power to convince one or two capitals to betray the EU. So far this stipulation has not appreciably affected the EU stance on Russia and Ukraine despite continued Russian attempts to divide the union. Nevertheless, China has often been very successful in recruiting member states as its agents and weakening or avoiding EU policies that it considers detrimental to its interests. Once again, since there is little scope for concerted transatlantic action in the absence of a broader EU strategic consensus, this weakens NATO and transatlantic cooperation as well.

Given that the European states gain leverage on the international scene through the EU, leaving the union is equal to giving up that leverage and becoming vulnerable to outside pressure from other powers. Brexit did not

even have to become a reality for the UK to already experience this. When in September 2018 a Royal Navy ship sailed through what China considers its waters in the South China Sea, Beijing explicitly warned London that such actions might jeopardize the future bilateral economic relationship post-Brexit.[9] China could never blackmail Britain to such an extent if it stayed in the EU, for it cannot afford to put economic relations with all of the union at risk. This means that, contrary to Britain's assertions, Brexit does weaken NATO. London may decide not to give in to other powers, but it does provide China in particular with more leverage to influence British decision-making through nonmilitary means.

Generating Military Power

In the field of defense, European integration has finally become indispensable as well, but defense is far less advanced than other areas. During the Cold War, when the European states maintained large conscript forces, each had the scale to create a full-spectrum force or at least a very broad range of capabilities; integrating defense efforts was not necessary. Today, however, smaller-scale forces, smaller defense budgets, and inordinately more expensive arms and equipment mean that not a single European state can maintain a full-spectrum force of any significant size. Fragmentation and protectionism have resulted in a patchwork of national forces of mostly low readiness. Taken together, these national forces do not constitute a comprehensive full-spectrum force package. There are critical shortfalls in terms of strategic enablers, reserve forces, and stocks of munitions and equipment. Consequently, Europe depends on the US for any major deployment. The European allies have agreed, in the framework of NATO, to spend more on defense. But if each state continues to do so separately, the status of Europe's armed forces and their dependence on the US will basically remain unaltered, even if they all spend 2 percent of their GDP. Only by pooling their defense efforts could a group of European states field a comprehensive full-spectrum force package, including the strategic enablers that allow capabilities to be projected at the borders of Europe and beyond.

The EU is not the only framework in which the required pooling of efforts could be organized, but it definitely is the most promising one. Twenty-five EU member states have joined Permanent Structured Cooperation (PESCO) institutionalizing defense collaboration in the union, while the commission has set up the European Defence Fund (EDF) that, for the first time ever, will provide defense funds in the EU budget. If it is put to maximum use, PESCO can become the single platform where Eu-

ropeans organize themselves to collectively develop all the capabilities that they require to meet their EU as well as NATO targets. Rather than undermining NATO, PESCO could help NATO ensure that the additional means that the European allies are making available are put to the best possible use.[10] Many Americans and Europeans are understandably skeptical of PESCO since, in the past, so many EU (and NATO) attempts to promote defense cooperation failed to produce meaningful results. PESCO is different in that unlike all previous informal initiatives (such as "pooling and sharing" in the EU and "smart defense" in NATO), it is now part of the institutional setup of the EU. In other words, it will not go away. Just like under the NATO Defence Planning Process (NDPP), member states will be systemically held accountable. That does not guarantee that PESCO will work (just like few allies meet all of their NDPP targets)—but that is all the more reason why NATO and the US should encourage rather than question it.

Naturally, if and when the Europeans spend more, they will purchase European arms and equipment. For NATO, that is not an issue, but it has become one for the Trump administration. It was always unrealistic of Washington, however, to expect that all additional means would be used to place orders in the US. One of the reasons why the "poison pill" letter mentioned above caused such a stir in Brussels is that Europeans read it as being motivated by narrow US defense industrial concerns rather than by strategic interests. For the Europeans, defense industrial autonomy is but a logical exponent of the overall economic and technological autonomy that the EU, just like all other powers, aspires to. So if PESCO works, Europe will buy more—but not only—European products. If PESCO and the EDF are successful, the EU could become indispensable in military capability development.

The EU aims also to put those capabilities to use and to conduct certain expeditionary operations autonomously in the broad neighborhood of Europe. Doing so is in line with the long-standing but still unachieved EU objective of being able to deploy and sustain up to an army corps and equivalent naval and air forces (the so-called Helsinki Headline Goal from 1999). Autonomous operations do not necessarily mean EU operations, though. In practice—yet not always apparent from EU rhetoric—these can be operations under any flag (EU, NATO, UN, national, ad hoc coalition) but under the political control and strategic direction of European governments, with a European general or admiral in command, and relying only on European forces and assets.

Seen from NATO, the bone of contention is the command and control (C2) of such operations: Is the EU seeking to create a standing operational headquarters alongside the NATO C2 structure? NATO and the EU do have an arrangement, the Berlin Plus agreement, to allow the EU access to NATO C2. Many in Europe see this as unsatisfactory, however, because it requires the EU to pass through the North Atlantic Council and then SHAPE rather than directly interacting with a specific NATO headquarters. Such a circuitous delegation amounts to an abdication of control. If a standing EU headquarters is undesirable, the only other alternative would be to give the EU or an ad hoc coalition of European states direct access to the NATO headquarters, which would conduct an individual operation (such as Naples that commanded the Libya air campaign). Arguably, the US should welcome autonomous European operations. If the Europeans were capable of singly handling any contingency in their neighborhood falling below the threshold of Article 5 (NATO's collective defense guarantee) that would allow Washington to focus its attention on Asia.

Precisely because Asia and, more specifically, China, is now the focus of American strategic attention, the Europeans might also have to consider whether even in the area of collective territorial defense they should not aspire to more autonomy. The US has adopted a one-war standard for its defense effort geared to defeating a great power.[11] The question for the Europeans is what would happen if the US were absorbed in an escalating crisis in Asia: Should they be able to deter and, if necessary, defend themselves against any military threat? Would American reinforcements arrive as soon and in such numbers as expected? The idea of more European autonomy in territorial defense (whether imagined as a European pillar within NATO or through the EU) is anathema to the US and to most European governments. It is the US pivot to Asia that has invited such thinking, however. Washington could indeed also wish to see more European independence in defense as enabling its pivot. The fact is, given the resources and the willpower required, European autonomy in territorial defense could only become reality in the long term.[12]

Conclusion

The most strategic decision that the European states have taken since the end of the Second World War was to launch European integration. This could not have taken off without NATO: it prospered thanks to the stability that the American security guarantee, embodied in the alliance, provided. Today, the EU itself has become indispensable to the stability of Europe, and now NATO can no longer do without the EU either. There is

no going back to pre-EU days, at least not as a matter of choice. For the first time in history, Europe has united voluntarily rather than through force of arms (as Charles V, Louis XIV, Napoleon, Wilhelm II, and Hitler all attempted—and failed). Therefore, the unravelling of the EU could only be the result of a catastrophic crisis; it would signal the return of intra-European rivalry and possibly even war. In a world that has seen a return to great power rivalry, in political, economic, and military terms the Europeans should strengthen their unity and deepen EU integration to maintain their chosen way of life. The US ought to encourage them in that effort and work more directly with the EU, in addition to NATO, if it wants the Europeans to support its strategy.

It is always likely, of course, that Europeans and Americans will just muddle through without any fundamental change in the way that EU-NATO and EU-US relations operate. The current situation may, at times, suit the US. An EU that can muster but a weak strategic consensus and does not adopt strong courses of action may be easier to mobilize for US-led initiatives—and will at least not cause interference with American policies. Herein lies the eternal dilemma for the US: relatively weaker European allies may be easier to recruit for American designs, but will they be able to contribute much to their implementation? If allies are too weak, they might actually hinder implementation and handicap the alliance. They may even become a source of security problems.

The other option therefore is to deepen EU integration and reconfigure the alliance with the US accordingly. The obvious steps to take would be to introduce decision-making by majority in EU strategy and foreign policy and to use PESCO and the EDF to maximally streamline the European defense effort. The aim would be to shift the center of gravity from the national capitals to Brussels in both diplomacy and defense. If the EU were to manage this—but it is a very tall order—then over time it would make sense to begin to think of NATO as a bilateral alliance between the US and the EU as such rather than between the US and a host of individual European states. This is what some American authors are proposing as the only way of actually forcing the Europeans to shape an adequate defense.[13] For the US, the dilemma remains: What is worse—European strategic autonomy or the absence of it? For the EU itself, muddling through remains the most likely scenario. Taking this route is highly unlikely to be sufficient to safeguard the European interest in the face of external powers actively trying to divide and subvert EU member states. For the great powers, Europe is but one of the theaters where their rivalry is playing out. Basically, Europe's choice is this: to be an actor or to be a theater prop. SSQ

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Challenges to the Nuclear Non-Proliferation Treaty

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Abstract

The effectiveness of a given treaty hinges on states acknowledging the necessity of membership in that treaty, its functioning as intended, and its members preferring the treaty's continued existence. A number of challenges threaten the effectiveness of the Nuclear Non-Proliferation Treaty (NPT). These include continuing proliferation efforts, nationalism, great power competition, the spread of nuclear technology, the increasing burden on the International Atomic Energy Agency (IAEA), and polarization among NPT member states. This article models the mechanism that underpins the NPT and then assesses the effects of the identified challenges. When the various challenges work together within the NPT mechanism, effectiveness is likely to decrease in the foreseeable future unless the international community adopts specific measures. We conclude by offering policy recommendations intended to strengthen the NPT.

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The Treaty on the Non-Proliferation of Nuclear Weapons (NPT) is an international framework designed to uphold the nuclear nonproliferation regime. It opened for signatures in 1968 and entered into force in 1970. As a result of the obligations enshrined within the NPT, the nuclear weapons states (NWS) agree not to assist the nonnuclear weapons states (NNWS) to either develop or acquire nuclear weapons, while the NNWSs are required to refrain from developing and/or acquiring nuclear weapons (Articles I and II).[1] To verify the NNWSs' compliance with the principles of the NPT, they accept the imposition of safeguarding measures, including inspections and monitoring by the International Atomic Energy Agency (IAEA), in relation to all the nuclear materials held within their territories (Article III). In exchange, all the signatories to the NPT pledge to facilitate the peaceful use of nuclear energy through the exchange of nuclear materials, equipment, and technology (Article IV). Finally, the NWSs are required to engage in negotiations

concerning the cessation of the nuclear arms race and the pursuance of nuclear disarmament (Article VI).[2]

Critics of the NPT have alleged it has exhibited only a relatively limited correlation with nuclear nonproliferation to date.[3] However, we consider the treaty largely effective because states acknowledge the necessity of NPT membership, the treaty's framework is functioning as intended, and its members prefer its continued existence. While the number of signatories to the NPT has grown since 1968, only five states are now nonsignatories, including one case of withdrawal from the treaty.[4] The NPT has prevented the majority of signatories from shirking their nonproliferation obligations by offering combinations of positive and negative incentives, applying stringent safeguards, and enhancing the international consensus and norms against the acquisition of nuclear weapons.[5] Member states agreed to indefinitely extend the treaty in 1995, and more than 130 member states have now ratified the additional protocol to the NPT. This protocol strengthened safeguards that allow IAEA inspectors to access all parts of a state's nuclear fuel cycle, all buildings on an inspection site on short notice, all manufacturing and import locations in the state, and all environmental samples beyond declared locations.[6]

The prior success of the NPT and the apparent firmness of member states' agreement as to its importance, however, are not sufficient to guarantee its effectiveness in the future. In fact, history tells us that an international treaty can lose its effectiveness and eventually even collapse. International law scholars consider two pathways to be of particular relevance to the threshold at which an international treaty is deemed to be ineffective and defunct.[7] First, if some or all of the signatories to a given treaty officially end their membership without supplanting any rules, then that treaty would be rendered severely weakened or even defunct (e.g., the 1987 Intermediate-Range Nuclear Forces [INF] Treaty). Second, even if the signatories do not officially withdraw from a given treaty, some states might cease to comply with that treaty if they consider its framework to not be working (e.g., the 1994 Budapest Memorandum). These two cases emphasize the key role played by state behavior in relation to the rise and fall of international treaties. Thus, a sound understanding of why states choose to adopt a nonproliferation policy and then continue to comply with the principles of the NPT is important when investigating whether or not the NPT will continue to be effective in the future.

Among the various challenges associated with contemporary international security, five are particularly relevant to the effectiveness of the NPT. These five challenges are continuing proliferation efforts of states

such as North Korea and Iran, global resurgence of nationalism, intensified competition among the great nuclear powers, increasing burdens faced by the IAEA, and growing polarization among NPT member states. While denuclearization of North Korea and Iran remains undecided, the novel coronavirus (COVID-19) pandemic will likely accelerate the resurgence of nationalism, the competition among the great powers, and the burdens on the IAEA.[8]

Without an adequate model of the mechanism that underpins states' choices with regard to the NPT, we are limited when it comes to assessing the potential impact of the challenges currently facing the treaty. In general, a *mechanism* can be defined as a set of statements that provides a plausible account of how certain variables are linked to one another.[9] The mechanism underpinning states' choices with regard to the NPT represents a set of statements that provides a plausible account of why a state chooses to sign the NPT and then to continue complying with the treaty. Here, we explore the mechanism behind the NPT using a rational choice approach with a focus on the interactions that occur among the various international and domestic actors involved. These international and domestic actors include a state's government, which decides whether or not to comply with the requirements of the NPT; domestic groups, which either support or oppose the state's adoption of, and compliance with, a nonproliferation policy; rival states, which might pose security threats; and the international community, which comprises states and international institutions that support the existing nuclear control order and which provides incentives, generates norms, and monitors noncompliant behavior.[10]

The article begins by explaining the actors within the mechanism that underpin the NPT. Each actor alone is inadequate when it comes to predicting the potential impact of the five identified security challenges, as each is based on a particular perspective. Next, we present our model of the strategic choices available, which is intended to supplement the work of prior studies as well as to help overcome their limitations. Building on the presented mechanism, the article then assesses the potential impact of the challenges on the effectiveness of the NPT. The results show that an increasing number of NNWSs may deviate from the requirements of the NPT by ignoring the relevant principles or by withdrawing from the treaty. If this occurs, the effectiveness of the nonproliferation regime will decrease. We conclude by offering policy recommendations intended to strengthen the NPT and achieve a more robust nonproliferation regime.

Understanding the Mechanism behind the NPT

How exactly does the NPT work, and what explanations of the treaty have been, or could be, offered by the major theoretical approaches in the field of international relations? The neoliberal institutional theory considers the NPT to resolve two collective action problems because, as an institutional framework, it can "provide information, reduce transaction costs, make commitments more credible, establish focal points for coordination, and in general facilitate the operation of reciprocity."[11] In particular, the principles enshrined within the NPT involve a commitment on the part of the NWS to the nontransfer of nuclear weapons technology to the NNWS. Thus, the nuclear powers consider the treaty to be useful for preventing rival nuclear powers from providing nuclear weapons technology to their allies. For the NNWS, the NPT framework is also a useful tool for monitoring potential proliferation behavior, forcing NNWS rivals to remain nonnuclear and thereby mitigating a security dilemma.[12]

A more strategic perspective regarding the NPT framework interprets it as a grand bargain struck between the nuclear haves and the have-nots, with the aim of ensuring the nonproliferation of nuclear weapons and moving toward complete nuclear disarmament.[13] That is, the NWS provides the NNWS with both security and economic benefits, while in return, the NNWS complies with the principles of the NPT and accepts international safeguards. Key to the whole agreement are the nuclear powers' commitment to the obligations contained within the NPT and the institutions' capacity for screening and constraining noncompliant behavior.[14] Within the broader nuclear nonproliferation regime, the NPT facilitates states' commitments to, and coordination with, other institutional bodies—including the IAEA, the Comprehensive Test Ban Treaty (CTBT), supplier mechanisms that control the export of materials and equipment that could potentially be diverted for nuclear weapons development (i.e., the Nuclear Suppliers Group), and other United Nations resolutions (i.e., UN Security Council Resolution 1540 and 1673) and disarmament treaties.

A realist view, also known as the "cartel" theory of the NPT, sees the treaty as a way for the five NWSs to maintain their nuclear oligopoly and preeminence.[15] Initially, the nuclear powers considered their allies' nuclear weapons proliferation to be a means of strengthening their side's influence against the opposing side. Later, however, the nuclear powers realized that the spread of nuclear weapons would actually reduce their influence over their allies, as those allies could substitute the availability of nuclear weapons for the nuclear powers' security assurance and subsequently gain au-

tonomy.[16] Therefore, the NWSs collectively bribed and coerced the NNWSs to comply with the principles of nonproliferation through a combination of multilateral and bilateral agreements.[17] According to this theory, the NPT resulted from the NWSs' joint action to stop nuclear proliferation, and it now serves as a framework for coordinating the NNWSs' expectations concerning the benefits of compliance and bolstering the monitoring of noncompliant behavior.

The fourth relevant strand of theory is a normative explanation. Constructivists define a *norm* as "a standard of appropriate behavior for actors with a given identity."[18] Such scholars argue that states shift from following "a logic of consequences" to following "a logic of appropriateness" as norms diffuse among them and alter their belief systems.[19] In the field of nuclear politics, the prominent norm is nuclear nonproliferation, conveying a very clear meaning: "nuclear weapons are not acceptable weapons of war, . . . no new states should be allowed to obtain them, and . . . states with nuclear weapons should work to reduce and eventually eliminate them."[20] The nuclear nonproliferation norm is the core idea embodied within the NPT.[21] Thus, when a state signs the NPT, its membership does not solely involve material terms but also means that it must abide by the associated ideas and rules in exchange for enjoying the rewards offered through the treaty framework.[22]

As Maria Rost Rublee and Avner Cohen note, "Norms as an analytical framework provide great insight to understand the current roiling in nuclear politics."[23] In particular, this normative approach sheds light on the behavior of states that cannot be explained by material factors alone. First, the normative approach explains why the number of NPT member states has gradually increased over the years as well as why many states willingly abide by the nonproliferation principles enshrined within the treaty. Since the introduction of the NPT, leading states have sought to promote the nonproliferation norm. In fact, during the early 1990s, a norm cascade occurred that resulted in almost all states worldwide adopting the nonproliferation norm.[24] Through the process of international socialization, the majority of states gradually recognized the importance of becoming responsible and respected members of the international community, and it was their desire for membership that motivated them to willingly comply with the nonproliferation principles.[25] Second, the concept of norm contestation (i.e., the conflict between old and new norms) serves to explain why states' behavior can result in different outcomes under similar material situations.[26] The nonproliferation norm is an idea and a standard imposed by international actors, and it arguably conflicts with the NNWS's

sovereign right to develop nuclear weapons. Therefore, when there is a growing sense of nationalism within a given state, the conflict between new and old norms will be more intense. In particular, nationalistic coalitions "thrive on popular resentment over adjustment policies they regard as externally imposed, reliance on foreign investment, and the 'Western' principles and norms embodied in most international regimes."[27] When facing real or perceived national security threats, these nationalistic coalitions, which oppose compliance with the nonproliferation norm, could choose the nuclear weapons option as a means of achieving greater self-reliance.

Although the above-mentioned theoretical approaches offer valuable insights with regard to exploring the mechanism behind the NPT, no single theory is sufficient to explain the net effects of such challenges when they work together through one mechanism. For instance, the bargaining theory would be useful in terms of explaining the impact of the IAEA's capacity for monitoring noncompliant behavior on the effectiveness of the NPT. However, the effect of the growing competition among the great nuclear powers is not clearly explained by this theory. Rather, we could better understand the potential outcomes of the competition among the great powers using the cartel theory because it focuses on the coalition formed by the NWSs. Meanwhile, the normative theory would prove valuable in relation to assessing the likely impact of the rise of nationalism and the decline of globalization, although such an approach might be less effective in explaining the impact of the other highlighted challenges. To extend this line of research, our model of the mechanism underpinning the NPT is intended to supplement the work of prior studies and to help address our research question.

A New Model of the Mechanism behind the NPT

We model the mechanism behind the NPT using a rational choice approach and focusing on the interactions that occur among the associated international and domestic actors rather than on the actions of any one of them (table 1). There are four actors involved in our model. First, a state government decides whether or not to comply with the requirements of the NPT. Second, the *international community* (IC) is defined as a network of governments that prefers the current nuclear control order and nonproliferation regime, which are capable of providing incentives, generating norms, and monitoring noncompliant behavior. Third, if they exist, rival states pose security threats to the state government. Finally, the state government's decision in this regard is also influenced by certain domestic groups that either support or oppose the adoption of, and compliance with, a policy of nonpro-

liferation. A state's behavior in relation to the NPT is shaped by the process of strategic interactions that occur among these actors.

		NPT membership	
		Yes	*No*
Nonproliferation	*Yes*	Full compliance	Nonmembership / Nonproliferation
	No	Cheating	Nonmembership / Proliferation

Table 1. A state government's possible choices with regard to the NPT

The interactions begin with the IC offering the benefits of NPT membership, contriving disadvantages for non-NPT member states, and possibly imposing sanctions on cheating states. We assume that all the states are originally nonmembers of the NPT. When interacting with the associated actors, a state government chooses one of the following three policy options. First is *full compliance* (upper left, table 1), which implies that a state signs the NPT and then genuinely upholds the rules and principles enshrined within it. Second is *nonmembership/proliferation* (bottom right, table 1), which implies that a state either fails to sign or withdraws from the NPT and develops or acquires nuclear weapons. The second policy option is relevant to both those states that have never signed the NPT (e.g., Israel, India, and Pakistan) and states that initially signed but later withdrew from the NPT (e.g., North Korea). Third is *cheating* (bottom left, table 1), which implies that a state clandestinely develops nuclear weapons despite remaining a signatory to the NPT, as seen in the cases of Iran (prior to the Joint Comprehensive Plan of Action [JCPOA]) and North Korea (prior to its withdrawal from the NPT). Thus, a cheating state is able to enjoy the benefits of NPT membership awarded by the IC while continuing to pursue the development of nuclear weapons, unless (or until) its clandestine activities are uncovered. We focus on these three policy options and do not consider the final option, namely *nonmembership/nonproliferation* (upper right, table 1), for two key reasons. First, logically, if a state does not have any intention of developing and/or acquiring nuclear weapons, it is better off choosing *full compliance*, as doing so results in positive and non-zero benefits.[28] Second, historically, all states except for South Sudan—only founded in 2011—have chosen one of the three policy options. No state has remained a nonmember/nonproliferator.

If a state government decides to choose *full compliance*, then the game ends with compliance equilibrium (see fig. 1). The IC does not change its strategy profile (i.e., the provision of rewards and disadvantages) during the subsequent period.[29] If a state government decides to choose *nonmembership*,

disadvantages will be imposed on it. The IC will change its strategy profile during the subsequent period based on updated beliefs and understandings regarding the situation. If a state government decides to choose *cheating*, there exists a certain probability (i.e., p) that its cheating will not be detected and that the IC will not change its strategy profile during the following period. Yet there also exists a probability (i.e., $1 - p$) that the cheating will be revealed and that sanctions will be imposed on the state government. During the next round, the IC will change its strategy profile based on its updated beliefs and understandings. In the remainder of this section, we will examine the costs and benefits associated with each strategic choice during one period of the game.

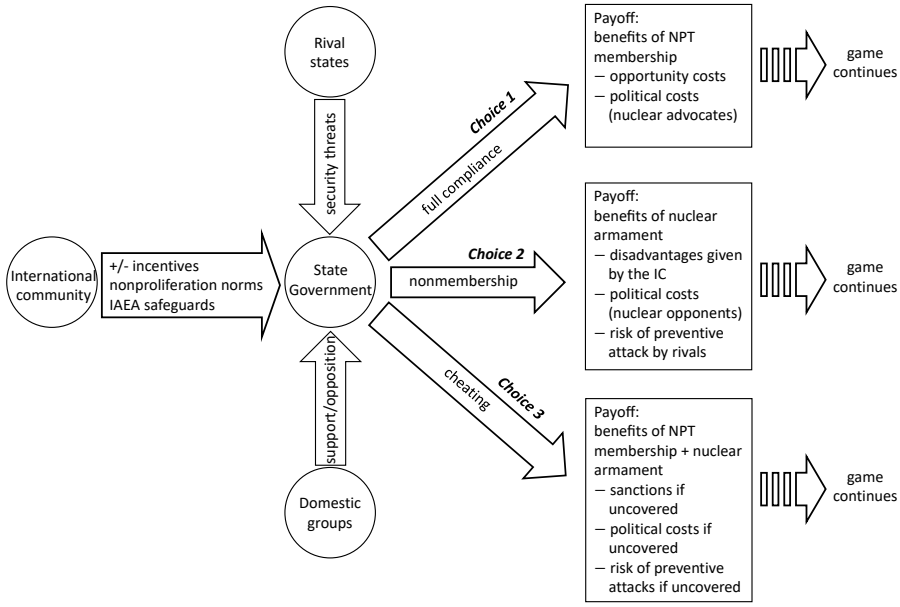

Figure 1. Strategic interactions in a state government's choice of a policy with regard to the NPT. The outcome of a state government's policy choice returns back to the beginning and affects subsequent behavior of the IC, rivals, and domestic groups in the next period.

Strategic Choice 1: Full Compliance

For the NPT compliers, the IC provides a set of rewards involving both security and economic benefits. First, although the text of the NPT does not specify any explicit security guarantees for the NPT states, NPT membership provides certain security benefits to signatories.[30] Some NWSs have provided assurances that they will never use nuclear weapons against signatories to the NPT.[31] For instance, the 2018 US *Nuclear Posture Review* states that the United States will not use nuclear weapons against nonnu-

clear states in full compliance with the NPT.[32] In addition, some NWSs also promised to assist its NNWS allies if they were threatened with nuclear attack.[33] Second, on the economic front, the NPT provides explicit economic benefits in terms of nuclear technology transfers and assistance with nuclear energy programs. Furthermore, being a member of the NPT and becoming part of the global community may catalyze foreign investment and better integration into the international economy.[34] However, such economic and security benefits may incentivize states differently depending on the situations in which those states live. That is, for states rich in energy sources, the promise of assistance with nuclear energy programs is likely to have only little attraction, while states with scarce resources may be more incentivized by the offer of nuclear energy assistance.

On the cost side, a state government choosing to comply with the treaty pays certain opportunity costs.[35] The costs are twofold since security and economic aspects are involved. In the case of the NPT, the most significant cost is security, which arises due to the loss of strategic freedom in the long term. Nuclear weapons are often seen as an effective means by which weaker states can strike a balance with powerful rivals at a relatively low cost. States with developed industrial and scientific infrastructure may regard nuclear armament as a more attractive policy option. Therefore, giving up the nuclear weapons option would limit a state's strategic flexibility and thereby require it to pay a higher price when signing the NPT.[36] This also implies that compliance with the NPT would incur economic costs, which would be required to build and operate larger conventional forces. However, such opportunity costs would differ according to the state's material situation. A state would face higher opportunity costs if it had stronger military rivals. A state facing powerful military rivals requires more investment in conventional forces for effective deterrence.[37]

When a state government decides to join the NPT, the nonproliferation norm embedded within the treaty is also introduced into the state, possibly prompting a clash between the proponents and opponents of those new norms while generating the political costs. That is, if the state government accepts the rewards offered by the IC for engaging in norm-conforming behavior, some groups would lose the benefit they derived from existing norms. For instance, if Pyongyang complied with the nonproliferation norm, it would gain the rewards associated with the receipt of economic support from the IC. At the same time, however, it would no longer benefit from the self-help security effects associated with the possession of nuclear weapons. Thus, a group of people who believe Juche, a

self-reliance ideology, to be the foremost theory of survival would lose their normative foundation in domestic politics.[38] State leaders may well be concerned about such clashes since opposition to new norms on the part of the public or elite could lead to domestic turmoil or even a coup against the ruling elite.

Strategic Choice 2: Nonmembership

The greatest benefit associated with this policy option is that a state's national security could be significantly enhanced by nuclear armament. Indeed, the state could compensate for military weakness relative to its rivals through the development and acquisition of nuclear weapons. Further, the acquisition of nuclear weapons allows the proliferator to rely less on its allies. Thus, the state may improve its ability to make autonomous decisions.[39]

The flip side of choosing such a policy is that both the state's rivals and the IC would launch countermeasures intended to thwart the state's nuclearization, as the proliferator's nuclear possession could alter the current balance of power. First, the IC could bring about punishment for the proliferator.[40] The text of the NPT does not specify the penalties that can be applied to nonmembers. However, it should be expected that economic punishments, both bilateral and multilateral, would be used as a tool to induce states to join and comply with the requirements of the NPT.[41] Furthermore, the state's rivals may seek to prevent its nuclear development by launching different countermeasures, such as a preventive war (i.e., Israel's attack on the Osirak reactor in Iraq in 1981 and the al-Kibar reactor in Syria in 2007). Thus, the state government needs to consider both the disadvantages and risks from the IC and rivals.

Additionally, noncompliance with the nonproliferation norm can result in political costs for a state government. In particular, compliance with the nonproliferation norm may signal that the signatory state intends to adhere to international standards and to promote international peace.[42] Further, signing the NPT can also be a costly signal that the state is taking action to become a legitimate member of the IC. Such action implies that domestic coalitions may recognize the importance of becoming a signatory to the NPT, not only for the associated economic benefits but also for status and normative reasons. Therefore, if the state government decides not to sign the NPT and instead pursues nuclearization, the government may expect both marginalization on the part of the IC and political costs from domestic groups supporting the nonproliferation norm and international peace.

Strategic Choice 3: Cheating

Not all state governments genuinely comply with the requirements of the NPT. Why do such state governments seek to deceive the IC and to covertly develop nuclear weapons, while at the same time claiming that they desire a security guarantee from the IC? One reason is related to security benefits, as such states may want to buy the time necessary to clandestinely build nuclear weapons while still seeking to alleviate tensions with their stronger rivals. The NPT can serve as a tool for signaling peaceful intentions. By pretending to eschew the nuclear option, a state government can seemingly demonstrate its commitment to de-escalating tensions and avoiding a costly arms race with its rivals. In response to the cheater's signal, rivals of that state may slow down their military buildup. If the cheating state government continues to develop nuclear weapons in covert ways, it could narrow the military power gap relative to its enduring rivals, or even possibly outpace its rivals by possessing nuclear forces. Such an approach could prove effective for a state that requires both time and resources to develop nuclear weapons so that it can stand on an equal footing to militarily and economically stronger rivals.

The other type of perceived benefit concerns the economic gains associated with compliance that a cheater can access in terms of nuclear assistance and foreign investment. In a self-help and anarchic international order, reaping the incentives for compliance with the NPT and then going back on one's pledge could represent a promising strategy. Although most states that have signed the NPT have not behaved in such a way, some states have appeared to do so. For example, in 1984, the Soviet Union reportedly agreed to provide four light-water reactors (LWR) to North Korea contingent upon Pyongyang's compliance with the obligations set out within the NPT.[43] Furthermore, in 1994, the United States and an international consortium agreed to provide political and economic assistance to North Korea in exchange for the freezing of its nuclear weapons program.[44] Yet Pyongyang declared its withdrawal from the NPT in 2003 in the face of receiving the benefits offered by the Soviet Union and the United States.

In terms of implications, however, if the clandestine activities are uncovered, the cheater must expect heavy costs due to strong economic and military sanctions imposed by the IC. Economic sanctions, such as the freezing of funds and trade embargos, have often been imposed on cheaters. One case of economic sanctions was the international restrictions on Iranian financial assets and economic resources in response to Tehran's refusal to halt its uranium enrichment program.[45] In some cases, military

measures have been used to punish cheating. Baghdad's alleged development of nuclear weapons, for example, was met with the invasion of Iraq by the United States and its allies in 2003.[46] Sanctions for cheating behavior tend to be stronger than the disadvantages imposed for nonmembership because cheating may signal to other states that they could deceive the IC as well.[47] A state government therefore decides to cheat the IC only if it expects the probability of detection to be sufficiently low and the potential sanctions to be weak, and the benefits of cheating substantially greater than for noncheating.

The Strategic Choice of Noncompliance

We have defined the costs and benefits that a state government considers when it chooses one of the three strategic choices. However, the payoff associated with each outcome does not tell us which strategic choice is preferred over the others. This means that we must compare the utility of each choice and then determine which choice offers greater utility than the others as well as under what conditions. In particular, the economic rationality assumption upon which this study is founded implies that a state government will choose a specific strategic choice if the utility of that choice is greater than the utilities of the other options.[48] Given the three choices, under what conditions will a state prefer a policy of noncompliance (either nonmembership or cheating) over one of compliance?

First, when choosing between full compliance and nonmembership policy, a state government will choose the nonmembership policy if its utility is greater than that of compliance. When compared, the likelihood of a state government's choice of nonmembership decreases when nonnuclear states are more sensitive to the benefits of compliance, when domestic coalitions' support of nonproliferation policy is strong, and when the disadvantages to nonmember states are great. For instance, if a state has an open economy and limited energy resources, its government and domestic groups may be concerned with economic assistance from the NPT framework and with meeting international standards and will therefore be more sensitive to the benefits of NPT membership.[49] In such a case, the state government is less likely to choose the nonmembership policy. A relevant example of this case can be seen in the South African government's decision to dismantle its nuclear arsenal. Along with the improvement in South Africa's security environment seen during the late 1980s, its rollback was driven by Pretoria's growing sensitivity to the benefits of NPT membership and by domestic coalitions' desire to escape

isolation from the international community through the dismantling of its nuclear arsenal.[50]

The likelihood of choosing nonmembership, on the other hand, would increase when domestic opposition to compliance with NPT requirements and the opportunity costs of giving up a nuclear option increase. Then the IC must be able to provide sufficient incentives through the NPT framework to incentivize the state to remain a member and abide by the nonproliferation policy. For instance, when Japan ratified the NPT membership in 1976, it had already developed industrial and technological infrastructure and faced nuclear-armed China. A group of politicians had also openly discussed Japan's desire to develop nuclear weapons.[51] The greater opportunity costs and domestic opposition that Tokyo faced led the IC to provide greater incentives, such as US extended nuclear deterrence and latent nuclear capability, so as to induce Japan to comply with the NPT.[52]

Second, when choosing between full compliance and cheating policy, a state government will also choose the cheating policy if its utility is greater than that of compliance. When compared, the likelihood of choosing the cheating policy increases when the IC cannot impose effective sanctions on cheating states, when the probability of discovery of cheating actions is sufficiently low, and when a state government needs nuclear weapons due to security threats but also needs the benefits of NPT membership. Of particular importance is the IAEA's ability to inspect and monitor nuclear sites belonging to NNWSs.[53] If the IAEA's monitoring capacity is low, more states are likely to pursue clandestine nuclear development.[54] Iraq's and North Korea's covert nuclear programs suggest a correlation between monitoring inefficiency and cheating, as those states relied on their knowledge of the IAEA's limited inspection measures to hide nuclear materials and facilities.[55] The IC's lack of success in imposing sanctions on nuclear proliferators may also lead state governments to consider cheating a viable option. For instance, the UN sanctions against North Korea were weakened by surrounding states' worries about the regime's possible collapse. Pyongyang's belief that the IC cannot levy heavy sanctions against it might have prompted it to continue violating the principles of nonproliferation.[56]

Nonmembership and cheating represent the main pathways that could negatively impact the effectiveness of the NPT. When aggregated, as more states choose either cheating or nonmembership, the likelihood that the NPT will become ineffective increases. Next we examine how the identified challenges are linked to these two potentially harmful pathways.

Assessing Potential Challenges to NPT Effectiveness

Five distinct trends could challenge the future effectiveness of the NPT. These are states' proliferation efforts, the global resurgence of nationalism, the increasing competition between the great nuclear powers, the spread of nuclear technology and the increasing burden on the IAEA, and the growing polarization among NPT member states. Assessing the potential impact of each challenge based on the mechanism defined above is instructive.

Challenge 1: States' Continuing Proliferation Efforts

Although the international community has tried to reduce the potential dangers associated with the spread of nuclear weapons, some states increased rather than decreased their efforts with regard to nuclear proliferation. First, while North Korea has not tested nuclear warheads since the failed negotiations with the United States at Hanoi and Stockholm in 2019, Pyongyang has continued its development of delivery vehicles, such as submarine-launched ballistic missiles and short-range missiles.[57] Second, since the United States withdrew from the JCPOA in May 2018 and later imposed new unilateral sanctions against Iran, Tehran has resumed its uranium enrichment program, restarted research and development on advanced centrifuges, and expanded its stockpile of nuclear fuel—thereby halving the time it would need to produce enough weapons-grade fuel to build a nuclear weapon.[58] As Richard Nephew, a US negotiator on the JCPOA, states, "Iran is manifestly closer to being able to produce a nuclear weapon than they were two years ago."[59] Lastly, in South Asia, both Pakistan and India are continuing to produce nuclear weapons–related materials, develop delivery systems such as sea-based missiles (India) and short-range ballistic missiles (Pakistan), and deploy nuclear weapons in the midst of their nuclear competition.[60]

The continuing proliferation efforts of these states and possible acquisition of nuclear weapons would increase the security and economic opportunity costs of regional rivals in the mechanism. For instance, in East Asia, a nuclear-armed North Korea would pose a threat to South Korea and Japan. These states count on the United States' extended deterrence to tackle the nuclear threat posed by North Korea. Yet, although the credibility of the United States' commitment to its allies' security is believed to be high, it is impossible to be certain that the United States will always be willing to sacrifice its people and territory for its allies. This uncertainty is a risk the protected states endure. In economic terms, the nuclear threat

posed by North Korea forces its regional rivals to commit more resources to the buildup of conventional forces. South Korea, for example, plans to spend 58.8 billion dollars from 2019 to 2023 to build a counter-nuclear system comprising radars, stealth fighter aircraft, and air-defense and ground-to-ground missiles.[61] Similarly, Iran's latent nuclear capability is likely to prompt its rivals in the Middle East to consider deploying similar systems. Such security and economic costs could exceed the cost of nuclear weapons development, while also placing additional pressure on rival states' leaders to consider nuclear-armed options.

Challenge 2: Global Resurgence of Nationalism

Nationalism is defined as an ideology and a movement with the aim of gaining and maintaining a state's sovereignty, implying the belief that each state should be free from outside interference.[62] Today, nationalism is seemingly on the increase in every continent.[63] In the United States, President Trump has called for a wall to be constructed along the border with Mexico as well as for a ban on Muslim immigrants. In Europe, the United Kingdom ended its membership of the European Union. In Asia, China is still pushing hard with regard to the South China Sea, and as political scientist Minxin Pei stated, Beijing would likely "beat the drums of Chinese nationalism to counter the United States."[64] Recently, South Korean courts ruled that citizens can sue Japanese civilian firms for reparations stemming from the use of forced labor during the Second World War. In retaliation, the Japanese government imposed export controls on materials of significant importance to the South Korean economy, including materials that are critical to the production of semiconductors.[65] Elsewhere, nationalist leaders have been elected or reelected on a mandate of seeking independence from foreign influence.

The global resurgence of nationalism would increase the political costs in two possible scenarios. First, opposition to nonproliferation obligations would increase when a rival state has nuclear weapons. Adherence to the nonproliferation regime means that a state needs to rely on extended deterrence from a security patron, even when facing a nuclear threat. Such a condition might not be acceptable to nationalistic leaders, meaning that they might decide to pursue nuclear weapons development.[66] Second, even in the absence of nuclear-armed rivals, nationalists may consider the NPT framework to be unfair and hence seek the renegotiation of its NPT benefits. Such resistance might stem not only from the perceived unfairness between NWSs and NNWSs but also from the unbalanced conditions among NNWSs.

Challenge 3: Competition among the Great Powers

One key trend in international politics is the return of competition among the great nuclear powers: the United States, Russia, and China. In Asia, the United States has been engaged in a "trade war" against China since early in the Trump presidency. Disputes over the South China Sea continue. In Europe, the US government issued a new national defense strategy in 2018 that cited Russia (as well as China) as the main threats to the United States. Soon afterward, the United States declared its withdrawal from the Intermediate-Range Nuclear Forces (INF) Treaty after accusing Russia of violating the treaty, which required the United States and Russia to forswear ground-launched ballistic and cruise missiles with ranges between 500 and 5,500 kilometers. In addition, the 2018 NPR indicated that the United States will acquire new nonstrategic nuclear weapons to address perceived threats from Russia and China. Furthermore, experts predict the US-China competition will be intense after the COVID-19 crisis in the areas of the military, the economy, technology, information, and the future order.[67]

The increased competition between the great nuclear powers allows for incongruence to develop in the international cooperation against nuclear proliferation efforts, thereby weakening the effectiveness of sanctions. While the major nuclear powers remain likely to cooperate on nonproliferation issues, possible mismatches between their intentions and their efforts would render the sanctions approach less effective. In practice, such a scenario is not just likely but has in fact already occurred. For example, in the nuclear agreement with Iran, the United States pressured other states to leave the Iranian market and to not import Iranian oil. However, many Chinese and Russian firms remain active in the Iranian market while also taking over business sectors once dominated by European companies. Iran is relying on these states to remain afloat in the face of US-led sanctions. Consequently, the willingness on the part of both China and Russia to continue to engage with Iran will render the sanctions less effective.[68] Similarly, in terms of North Korea's denuclearization project, China is weakening the efficiency of international sanctions. Although China participates in the international sanction regime against North Korea's nuclear proliferation, a UN report revealed that there have been at least 148 incidents of North Korea smuggling illicit oil between January and August 2018, which mostly occurred in the Chinese-administered Yellow Sea and South China Sea. Some experts argue that these actions indicate that China has adopted a "posture of tacit consent" to the lifting of sanctions.[69]

Challenge 4: The Spread of Nuclear Technology and Burdens on the IAEA Safeguards

Another key challenge to the effectiveness of the NPT is the spread of nuclear technology worldwide and thereby the increasing burden on the IAEA safeguard. According to IAEA statistics, the number of nuclear facilities subject to IAEA safeguards has increased by 12 percent to over 1,300 since 2010. During the same period, the number of significant quantities of nuclear material held under IAEA safeguards rose by 24 percent to over 200,000 significant quantities.[70] Further, the number of nuclear material accounting reports submitted by member states has increased by more than 30 percent. In addition, as more nuclear facilities are decommissioned, the demand for safeguards is also increasing, alongside additional requirements to verify the packaging, movement, and disposition of nuclear materials.[71] All these growing burdens with regard to the IAEA safeguards on nuclear facilities and materials could reduce the effectiveness of its monitoring of cheating activities unless the IAEA is able to expand its capabilities.

Despite the growing need for safeguards, member states' support for the IAEA has not increased to a comparable level. The IAEA's safeguard budget has risen by around six percent since 2010. This means that IAEA inspectors and analysts need to bear increasing burdens and take on increasing workloads, consequently reducing the effectiveness of their monitoring activates. Although the IAEA is seeking more cost-effective means of safeguarding, such as remote monitoring through surveillance cameras, the burden will not decrease anytime soon as the number of nuclear facilities and decommission cases continues to increase.

Challenge 5: Growing Polarization among NPT Member States

As pointed out by Lewis Dunn, a former assistant director of the US Arms Control and Disarmament Agency and NPT review conference ambassador, "the polarization among NPT parties is greater today than it ever has been."[72] First, this polarization is partly the result of many NNWSs' frustration with the lack of progress toward nuclear disarmament as set out in Article VI of the NPT. This frustration is reinforced by some NWSs modernizing their nuclear arsenals with low-yield warheads and high-precision, hyperspeed delivery vehicles. Second, the polarization among NPT member states, in part, reflects the NNWSs' growing concern about the risk of nuclear weapons use. While the salience of nuclear weapons is growing in the security policies of both the United States and

Russia, other states are expressing their concerns regarding the possible humanitarian disaster that would be caused by the use of nuclear weapons in the so-called Humanitarian Pledge and in the Treaty on the Prohibition of Nuclear Weapons (TPNW).[73] Lastly, the polarization is also partly based on the increasing demand for fairness within the existing nuclear order by the middle-ground states (e.g., Argentina, Brazil, and South Korea), which maintain advanced nuclear technology and actively participate in the governance of the nonproliferation regime. These middle-ground states require assess to nuclear technology for peaceful purposes as well as the freedom to share such technology with other states, as guaranteed by the NPT, because exercising this right is seen as critical to their economic growth and their status within the nuclear order.[74]

Among the five challenges highlighted, this polarization problem could pose a structural threat to the NPT, as it fundamentally counters both the existing nuclear order and the NPT's incentive system.[75] For the most part, the NPT framework has remained stable because the NNWSs have preferred the current system over the potential insecurity they would face if they violated the nonproliferation rules and principles. At the same time, the strong nonproliferation norm and the incentive system have induced the NNWSs to tolerate the inequalities inherent within the NPT framework. However, if the sense of injustice and unfairness is growing among certain NPT member states, then the dissatisfied parties might not agree with the treaty framework. Consequently, the international community's capability to offer collective incentives to other NNWSs could be hindered. This is not merely a hypothetical postulation. Indeed, the 2015 NPT Review Conference showed symptoms of this tension, as the conference failed to reach a consensus and was considered an "accurate reflection of the profound inadequacies and disagreement permeating the global nuclear disarmament regime."[76]

Conclusion and Recommendations

Although each individual challenge might not appreciably influence the effectiveness of the NPT framework, working together their net effects should not be underestimated. Domestically, rival states' nuclear proliferation and the rise of nationalism could give state governments reasons to consider nuclear weapons as a means to achieve security goals. Internationally, while the growing competition between great nuclear powers and the polarization among NPT member states would weaken the work of the NPT's incentive system, increasing burdens on the IAEA safeguards might lead states to miscalculate that their clandestine activities could be intact. If

this situation were to occur, NPT effectiveness would certainly decrease, and the treaty would possibly become defunct. This potential development has a number of implications for both policy and research.

First, we suggest that the international community—including NWSs, NNWSs, and international institutions—implement measures to promote cooperation among the NPT member states. The United States and the other NWSs should demonstrate a genuine commitment to nuclear disarmament. While the INF Treaty collapsed in 2019, a particular concern in this regard is the potential expiration of New START in 2021. The end of the INF Treaty has already raised concerns among the NNWSs about the risk of the use of nuclear weapons, and there is no doubt that the failure to renew or extend New START would heighten the divisions within the NPT member states, erode the legitimacy and credibility of the NPT framework, and weaken the collaboration among member states. Additionally, NWSs and NNWSs should renegotiate and redefine the goal of disarmament as set out in Article VI of the NPT. As long as the United States, Russia, and China are all increasing the salience of nuclear forces in their national security policies, the pursuit of the complete elimination of nuclear weapons is neither practical nor realistic. Rather, it serves as a potential flash point between NWSs and NNWSs. Also, the NPT member states should conclude the TPNW and then work toward rebuilding cooperation. While critics of the TPNW have framed it as a radical and destabilizing move that undermines the existing order, it is important to acknowledge that some states consider it to be a potential alternative to the NPT. This debate is related to both economic growth and national prestige. If the member states do not overcome these issues, the NPT's incentive system would be rendered less effective because it works through close cooperation among the states.

Second, the international community should strengthen the nuclear nonproliferation norm. As we have demonstrated, one major reason why the NPT framework has proved effective thus far is the spread of the nonproliferation norm. The norm plays a role as a restraint on domestic support in favor of nuclear armament. In particular, the nonproliferation norm could represent a means of salvaging the NPT framework from the resurgence of nationalism. One way of strengthening the nonproliferation norm is to increase the role of a network of professionals with recognized expertise that can help decision-makers define problems and identify and evaluate various policy options.[77] Although their role might be soft, or relegated to track-two diplomatic status, the members of this community could help to more persistently and deeply advance the norm.

Third, the international community should collaborate to expand the IAEA's safeguards capacity. As our model indicates, the efficacy of the inspection and monitoring of nuclear-related activities on the part of member states is vital to maintaining the effectiveness of the NPT regime. In particular, such a capability is critical to preventing states from deviating from the principles of the NPT through cheating. Unfortunately, the IAEA's budget has risen by only 6.3 percent since 2010. As the secretary general of the IAEA points out, insufficient funding will result in a reduction in the number of inspectors and, consequently, a decrease in monitoring efficiency.[78] In addition, around 60 states have not yet ratified the additional protocol. International support is required both politically and financially to have more states comply with the additional protocol and to maintain the efficacy of the IAEA's safeguarding measures.

Lastly, the international community should be prepared for the potential impact of the COVID-19 pandemic. On the one hand, the enormous damage done to the global economy could significantly reduce budgetary resources devoted to the development and deployment of nuclear weapons. On the other hand, however, the spread of the virus could result in the limitation or suspension of IAEA inspections of various nuclear facilities, including Iran's enrichment and centrifuge development sites.[79] Moreover, states are raising questions about the credibility and the ability of international organizations in dealing with global issues appropriately and fairly. Indeed, states with a damaged economy due to the coronavirus crisis might reduce their financial support to the IAEA. Lastly, as Philippe Legrain notes in *Foreign Policy*, the coronavirus crisis highlighted the downside of globalization while legitimatizing nationalism.[80] Such a trend is not expected to directly affect international cooperation on nuclear nonproliferation, but it may restrict the flow of people and information and reduce the effectiveness of cooperation.

Given the discussed challenges as well as the varied perspectives among the NPT member states that are so evident today, maintaining the effectiveness of the NPT will be difficult. At the heart of such efforts should be a credible vision of the future in terms of a desirable nuclear order. Thus, all member states and other associated actors need to genuinely support the NPT even if not fully comfortable with the overall impact of the treaty. SSQ

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Notes

1. Only the five permanent members of the United Nations Security Council (the United States, Russia, the United Kingdom, France, and China, as listed according to the order of their nuclear test dates) are permitted to possess nuclear weapons.

2. Daryl Kimball, "The Nuclear Nonproliferation Treaty (NPT) at a Glance," fact sheet, Arms Control Association, accessed 23 June 2020, https://www.armscontrol.org/.

3. A common argument in this regard draws on the notion that only those states with little or no intention of pursuing the development of nuclear weapons signed the treaty. Refer to John J. Mearsheimer, "The Case for a Ukrainian Nuclear Deterrent," *Foreign Affairs* 72, no. 3 (Summer 1993), https://www.foreignaffairs.com/; Richard K. Betts, "Universal Deterrence or Conceptual Collapse? Liberal Pessimism and Utopian Realism," in *The Coming Crisis: Nuclear Proliferation, US Interests, and World Order*, ed. Victor A. Utgoff (Cambridge, MA: MIT Press, 2000); Jacques E. C. Hymans, *The Psychology of Nuclear Proliferation: Identity, Emotions and Foreign Policy* (Cambridge: Cambridge University Press, 2006), chap. 1; Matthew Fuhrmann, "Spreading Temptation: Proliferation and Peaceful Nuclear Cooperation Agreements," *International Security* 34, no. 1 (Summer 2009); 7–41, https://www.belfercenter.org/; and Matthew Kroenig, *Exporting the Bomb: Technology Transfer and the Spread of Nuclear Weapons* (Ithaca, NY: Cornell University Press, 2010).

4. These five non-NPT states are Israel, India, Pakistan, South Sudan, and North Korea. North Korea was a member of the NPT and withdrew from the treaty in 2003.

5. See Trevor McMorris Tate, "Regime-Building in the Non-Proliferation System," *Journal of Peace Research* 27, no. 4 (1990): 399–414, https://doi.org/10.1177/0022343390027004005; Scott D. Sagan, "Why Do States Build Nuclear Weapons? Three Models in Search of a Bomb," *International Security* 21, no. 3 (Winter 1996/1997): 54–86, doi:10.2307/2539273; Maria Rost Rublee, *Nonproliferation Norms: Why States Choose Nuclear Restraint* (Athens, GA: University of Georgia Press, 2009); and Matthew Fuhrmann and Yonatan Lupu, "Do Arms Control Treaties Work? Assessing the Effectiveness of the Nuclear Nonproliferation Treaty," *International Studies Quarterly* 60, no. 3 (September 2016): 530–39, https://doi.org/10.1093/isq/sqw013.

6. See Model Protocol Additional to the Agreement(s) between State(s) and the International Atomic Energy Agency for the Application of Safeguards, IAEA INFCIRC/540, September 1997, https://www.iaea.org/; and IAEA, "Status of the Additional Protocol," March 2019, https://www.iaea.org/.

7. Michael J. Glennon, "How International Rules Die," *Georgetown Law Journal* 93, no. 3 (2005): 939–91, https://papers.ssrn.com/; and Laurence R. Helfer, "Exiting Treaties," *Virginia Law Review* 91, no. 7 (2005): 1579–1648, https://www.virginialawreview.org/.

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20. Rublee, *Nonproliferation Norms*, 39.

21. The two components of the nuclear nonproliferation norm are nuclear disarmament and nonproliferation. These components are reflected in the three pillars of the NPT (nonproliferation, peaceful use of nuclear energy, and nuclear disarmament). See Mario Carranza, "The Stability of the Nuclear Nonproliferation Norm: A Critique of Norm-Contestation Theory," *Nonproliferation Review* 26, no. 1-2 (2019): 10, https://doi.org/10.1080/10736700.2019.1587844.

22. Etel Solingen, "The Political Economy of Nuclear Restraint," *International Security* 19, no. 2 (Fall 1994): 140, https://www.jstor.org/stable/2539198.

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24. Carranza, "Stability of the Nuclear Nonproliferation Norm," 9.

25. Rublee, *Nonproliferation Norms*, 47–49.

26. Finnemore and Sikkink, "International Norm Dynamics," 897, 915. For further discussions on norm contestation, refer to Antje Wiener, *A Theory of Contestation* (Heidelberg: Springer, 2014); and for a critique of norm contestation, see Carranza, "Stability of the Nuclear Nonproliferation Norm."

27. Solingen, "Political Economy of Nuclear Restraint," 140.

28. One exceptional case could involve some states choosing the nonmembership/nonproliferation option because they believe that the current NPT system is unfair. Such a situation is possible, as many NNWSs have expressed their concerns regarding the unfairness and unevenness in terms of benefits and status structured in the NPT. Yet we opt to deal with this exceptional case in a separate paper, as the assessment of the potential impact of the growing sense of unfairness appears to require an in-depth investigation.

29. Our model is based on two core assumptions. First, we assume that all actors are rational and capable of conducting a cost-benefit analysis, and our model predicts that they will choose the policy option that is most likely to maximize their payoffs. Second, the IC has a significant interest in maintaining the current nonproliferation regime and preventing states from engaging in nuclear development. That is, the IC strictly prefers the full compliance outcome to the other outcomes. Between nonmembership and cheating, the IC weakly prefers nonmembership. In relation to a nonmember state, the IC could harness the coercive power of an international coalition so as to pressure the state government to abort its nuclear weapons program (i.e., South Africa). However, the IC could not take any action against a cheating state unless its clandestine actions were revealed.

30. For example, the positive security guarantees the United States has given to its NATO allies, Japan, and South Korea do not derive from the treaty. The same holds true for the security support extended to Israel and certain Arab states. Negative security guarantees also do not derive from the treaty directly but are an artifact of the NPT review process. The real security benefits that derive directly from the NPT are that member states can have confidence that their neighbors are not developing nuclear weapons.

31. Daryl Kimball, "U.S. Negative Security Assurances at a Glance," Arms Control Association, fact sheet, accessed 22 June 2020, https://www.armscontrol.org/.

32. Office of the Secretary of Defense, *Nuclear Posture Review* (Washington, DC: Department of Defense, February 2018), 21, https://media.defense.gov/.

33. George Bunn and Roland M. Timerbaev, "Security Assurances to Non-Nuclear-Weapon States," *Nonproliferation Review* 1, no. 1 (1993): 11–20, https://www.nonproliferation.org/; and Matthew Fuhrmann and Todd S. Sechser, "Nuclear Strategy, Nonproliferation, and the Causes of Foreign Nuclear Deployments," *Journal of Conflict Resolution* 58, no. 3 (2013): 455–80, https://faculty.virginia.edu/.

34. Anne-Marie Slaughter, *A New World Order* (Princeton, NJ: Princeton University Press, 2004), 200–203.

35. The *opportunity cost* is defined as "the loss of potential gain from other alternatives when one alternative is chosen." See Angus Stevenson and Christine A. Lindberg, eds., *New Oxford American Dictionary* (Oxford, UK: Oxford University Press, 2010). In simple terms, the opportunity cost here is the security and economic benefit not received as a result of not selecting the nuclear armament option.

36. Christopher Way and Karthika Sasikumar, "Leaders and Laggards: When and Why Do Countries Sign the NPT?" Research Group in International Security Working Paper (REGIS) Working Paper No. 16 (Montreal: University of Montreal/McGill University, November 2004), 7–8, https://www.academia.edu/.

37. Robert Powell, "Guns, Butter, and Anarchy," *American Political Science Review* 87, no. 1 (1993): 115, https://www.jstor.org/stable/2938960.

38. Kyung-Ae Park, "North Korea's Defensive Power and U.S.-North Korea Relations," *Pacific Affairs* 73, no. 4 (2000): 544–46, doi:10.2307/2672443.

39. Nuno P. Monteiro and Alexandre Debs, "The Strategic Logic of Nuclear Proliferation," *International Security* 39, no. 2 (2014): 12, https://www.mitpressjournals.org/.

40. Coe and Vaynman, "Collusion and the Nuclear Nonproliferation Regime"; and Verdier, "Multilateralism, Bilateralism, and Exclusion."

41. For instance, during the mid-1990s, the United States halted economic assistance to Pakistan to compel the country to adhere to the nonproliferation regime. See Samina Ahmed, "Pakistan's Nuclear Weapons Program: Turning Points and Nuclear Choices," *International Security* 23, no. 4 (Spring 1999): 190, https://www.jstor.org/.

42. Solingen, "Political Economy of Nuclear Restraint," 140.

43. Alexander Zhebin, "A Political History of Soviet-North Korean Nuclear Cooperation," in Alexandre Y. Mansourov and James C. Moltz, eds., *The North Korean Nuclear Program: Security, Strategy, and New Perspectives from Russia* (New York: Routledge, 2000), 32–33.

44. Joel Wit, "The Korean Peninsula Energy Development Organization: Achievements and Challenges," *Nonproliferation Review* 6, no. 2 (Winter 1999): 59–69, https://www.nonproliferation.org/.

45. Paul Kerr, "UN Security Council Resolution 1737 on Iran," Arms Control Association, accessed 22 June 2020, https://www.armscontrol.org/.

46. Joint Resolution to Authorize the Use of United States Armed Forces against Iraq, Public Law 107–243, 107th Cong., 1st sess., 16 October 2002, https://www.govinfo.gov/.

47. Bradley A. Thayer, "The Causes of Nuclear Proliferation and the Utility of the Nuclear Non-Proliferation Regime," *Security Studies* 4, no. 3 (1995): 510–13, https://doi.org/10.1080/09636419509347592.

48. According to the definition suggested by DiRita, the *economic rationality principle* is "based on the postulate that people behave in rational ways and consider options and decisions within logical structures of thought, as opposed to involving emotional, moral, or psychological elements." See Peter DiRita, "Economic Rationality Assumption," in *Encyclopedia of Quality of Life and Well-Being Research*, ed. Alex C. Michalos (Dordrecht: Springer, 2014), DOI: https://doi.org/10.1007/978-94-007-0753-5_822

49. Solingen, "Political Economy of Nuclear Restraint."

50. Peter Liberman, "The Rise and Fall of the South African Bomb," *International Security* 26, no. 2 (Fall 2001): 71–82, https://www.jstor.org/stable/3092122.

51. Before signing the NPT, domestic response to the nuclear issue was mixed in Japan. Japan had adopted the "three nos": no possession of nuclear weapons, no manufacturing of nuclear weapons, and no introduction of nuclear weapons on its territory. These were adopted in the late 1960s, before the NPT entered into force. In the meantime, a group of people supported Japan's possession of nuclear force. For example, Prime Minister Eisaku Sato said, "If Chicoms [Chinese Communists] had nuclear weapons, the Japanese also should have them." See Kurt M. Campbell and Tsuyoshi Sunohara, "Japan: Thinking the Unthinkable," in Kurt M. Campbell, Robert J. Einhorn, and Mitchell B. Reiss, eds., *The Nuclear Tipping Point: Why States Reconsider Their Nuclear Choices* (Washington, D.C.: Brookings Institution Press, 2004), 222.

52. Fintan Hoey, "Japan and Extended Nuclear Deterrence: Security and Nonproliferation," *Journal of Strategic Studies* 39, no. 4 (2016): 44–501, https://doi.org/10.1080/01402390.2016.1168010.

53. Laura Rockwood, "The Legal Framework for IAEA Safeguards," *IAEA Brief for Policymakers*, February 2018, https://www.iaea.org/.

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60. Dunn, "Strategic Elimination of Nuclear Weapons," 407.

61. Dagyum Ji, "ROK to Spend over $84 Billion on New Military Capabilities over Five Years: MND," *NK News*, 11 January 2019, https://www.nknews.org/.

62. Anthony D. Smith, *Nationalism: Theory, Ideology, History* (Cambridge, MA: Polity, 2010), 9, 25–30.

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67. Edel and Rapp-Hooper, "5 Ways U.S.-China Competition Is Hardening."

68. Dina Esfandiary and Ariane M. Tabatabai, "Will China Undermine Trump's Iran Strategy? Tehran Is Hedging against International Isolation," *Foreign Affairs*, 20 July 2018, https://www.foreignaffairs.com/.

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75. Ritchie, "Hegemonic Nuclear Order," 425–26.

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PERSPECTIVE

Twenty-First-Century US Nuclear Power: A National Security Imperative

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Abstract

America's twentieth-century policy on the peaceful uses of nuclear power was original US strategic thinking. It was a policy founded on a rules-based liberal international order shaped by personal experiences and aligned with comprehensive, long-term national security objectives. However, in the twenty-first century, the US is embroiled in a national discussion as to whether it should advance its civilian nuclear power enterprise or abandon it altogether. This disposition conflicts with America's original nuclear power policy and does not align with twenty-first-century realities. Nuclear power generation is not merely a domestic energy issue subject to popular opinion or the volatility of energy markets. Competing powers are leveraging civilian nuclear collaborations to meet strategic geopolitical objectives. If America retreats from the civilian nuclear field, revisionist powers will become the global leaders in nuclear science, nuclear engineering, and nuclear technology in the twenty-first-century with adverse implications for US national security. Thus, the civilian nuclear power enterprise should be included as a strategic sector within the US national security industrial base and deliberated as a foreign policy issue within a global alliance.

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In a globalized, interdependent world, energy is among a country's most important natural resources. Abundant supplies of marketable energy such as coal, oil, and natural gas afford resource-rich countries with geopolitical opportunities and advantages that resource-poor countries lack. The historical trend in energy has been toward resources of greater energy density coupled with the development of technologies to harness and channel energy into the human endeavor. Energy animates a country's economy and underpins the technological capacity to protect itself and defend its interests. It has a value proposition beyond that of a

market commodity as it defines and shapes geopolitical relationships and international stature.

Nuclear energy is arguably the most complex energy resource because of its dual utility for civilian power and military weaponry, both of which have distinct strategic roles. Because of this dual utility, it should not be reduced to a mere domestic energy policy issue. Nuclear power is of such strategic importance that it must be viewed as an instrument of US national security and foreign policy. This article first reviews the original principles of US nuclear power policy and evaluates the disposition of twenty-first-century US nuclear power policy. Next, it identifies domestic and international issues that are challenging the US nuclear enterprise. Finally, the article recommends two core actions for aligning twenty-first-century US nuclear power policy with national security and foreign policy.

The twentieth century and the bipolar Cold War that threatened it have given way to a globalized, multipolar twenty-first century with nations turning to nuclear power to meet economic development needs.[1] At the same time, the twenty-first century faces the specter of climate change—a global issue that is complicating US energy discussions. When international control of nuclear energy, competition for global nuclear technology leadership, and climate change are combined, these challenges of twenty-first-century US nuclear power policy appear more complex than those of the twentieth century.[2] It might, then, be considered hubris for the US to conclude it can sustain its global leadership role in nuclear science and technology, uphold its commitment to international control of nuclear energy, maintain a reliable electric grid, and meet the additional challenge of climate change while unilaterally disengaging from civilian nuclear power. In all, America is facing a perfect storm of twenty-first-century domestic and international challenges to its nuclear power enterprise. We contend that the legacy principles of US nuclear power policy established in the twentieth century remain sound and valid and that actions are required to operationalize those principles to meet this century's national security challenges.

US Nuclear Power Policy: First Principles

With the discovery of the neutron in 1932 and fission in 1938, enough was understood about the energy available in the nucleus of a uranium atom that scientists and engineers were understandably concerned that this energy could be channeled into the construction of an explosive. In 1944, and with the atomic bomb close to reality, some scientists and engineers working on the Manhattan Project, along with key officials from the

State and War Departments, were already thinking of postwar US nuclear policy and the impact atomic energy would have on a yet-to-be-constructed world order.[3] Knowing that scientific discovery could not be monopolized long term and that technological advantages are similarly temporary, the US convened numerous proceedings from 1945 to 1953 focused on America's nuclear power policy. Among these was the Acheson-Lilienthal Committee and its board of consultants, which concluded, among other key points, that the US was "not dealing simply with a military or scientific problem but with a problem in statecraft and the ways of the human spirit."[4] The committee realized that America's nuclear power policy and its engagement in a global effort to control atomic energy would require a brand of statecraft aligned with twentieth-century international arrangements that were unfolding and unpredictable. What became evident was that nuclear power had become a political issue "in the context of the great contest between Western freedom and Soviet totalitarianism" and would require candor, trust, and confidence with the American public and with US allies in an emerging world order.[5]

Subsequently, in December of 1953, President Eisenhower delivered his "Atoms for Peace" speech to the United Nations. He proposed that atomic energy "be allocated to serve the peaceful pursuits of mankind"—particularly to "provide abundant electrical energy in the power-starved areas of the world"—thus dedicating strength to "serve the needs rather than the fears of mankind." President Eisenhower essentially framed the first US nuclear power policy.[6] Consequently, the Atomic Energy Act of 1954 liberalized the US nuclear enterprise by allowing private companies to develop and construct nuclear reactors domestically under the regulatory authority of the federal government and to engage internationally in the sharing of nuclear science and technology for peaceful civilian uses. Pursuant to President Eisenhower's policy declaration, in 1955 the National Security Council (NSC) produced a Statement of Policy on Peaceful Uses of Atomic Energy. It specified that in the interests of national security, US programs for development of the peaceful uses of atomic energy should be directed toward the following:

- "Maintaining U.S. leadership in the field, particularly in the development and application of atomic power.
- Using such U.S. leadership to promote cohesion within the free world and to forestall successful Soviet exploitation of the peaceful uses of atomic energy to attract the allegiance of the uncommitted peoples of the world.

- Increasing progress in developing and applying the peaceful uses of atomic energy in free nations abroad.
- Assuring continued U.S. access to foreign uranium and thorium supplies.
- Preventing the diversion to non-peaceful uses of any fissionable materials provided to other countries."[7]

The foundational NSC discussions of America's nuclear power policy were carried out at the dawn of a new liberal international order but in the shadow of a rising Communist power. Communist intentions, which were at that time unknown, had to be anticipated and incorporated into America's foreign policy calculus to ensure US national security and global stability in Europe and Asia. The life experiences of the individuals involved were as central to their deliberations of the postwar world as was the science behind nuclear fission. It was the undercurrent of these experiences that motivated the NSC to establish an international system to safeguard the US and the world from future great power conflicts by controlling atomic energy in all its various pathways that could offer peaceful applications and prevent military extensions.

The potential implications of atomic energy came into focus as the key discussants realized they were not dealing with just another domestic energy issue or simply a science and technology issue. Rather, they were ushering in a new era of energy statecraft that would require a level of technological capacity within the US industrial complex and the US diplomatic corps fundamentally different from that associated with traditional energy commodities such as oil and natural gas. They recognized the importance of US technological primacy in the nuclear space, underpinned by a vigorous nuclear research and development enterprise. Primacy would sustain America's early technological lead and its credibility as a nation of experts capable of engaging authoritatively, competently, and competitively in a global network of ever-evolving developments in the nuclear field.[8] Moreover, they perceived the strategic imperative of crafting US nuclear power policy as an extension of US foreign and security policy.[9]

From these proceedings emerged the most robust civilian nuclear power program in the world today—one that includes 95 US reactors and 25 Section 123 agreements with other nations.[10] The US monopoly on nuclear science and engineering was short-lived as Russia, the UK, France, and China developed nuclear weapons by 1964. They were followed by India, Pakistan, and North Korea with declared nuclear weapons and Israel with undeclared nuclear capabilities.[11] As for civilian applications,

since 1954, 38 countries have engaged in the construction and operation of nuclear reactors, much of which has been through international partnerships to ensure international control, safety, and security within the global nuclear materials cycle.[12] However, while in the twentieth century the US was the global leader and international authority for the development and deployment of civilian nuclear science, engineering, and technology, the twenty-first century is unfolding differently—domestically and internationally—and with many challenges.

Twenty-First-Century Nuclear Power Challenges and Implications

According to Ambassador Thomas Graham Jr., a former senior US diplomat, and Adm Richard W. Mies, retired, "The recent struggles of the U.S. nuclear energy industry may appear to be no more than the usual economic disruption caused by competition among technologies. But from our experience in diplomacy and the armed forces, we understand that a declining domestic civil nuclear industry has other ramifications. Critical U.S. national security interests are at risk."[13]

The first principles of US nuclear power policy clearly convey the national security imperatives of nuclear energy and technology. However, most of the original principles are not being fulfilled. Policy makers today must understand the challenges confronting America's civilian nuclear power sector and the national security implications of a declining US nuclear enterprise—both domestic and international in nature. Despite the ever-expanding field of international players, the national security implications of US nuclear power policy are rarely included in America's domestic energy debate.

Domestic Challenges and Implications

The domestic debate on US nuclear power policy is fragmented into several issues that precipitate the decline of the US civilian nuclear enterprise, three of which are briefly discussed here.[14] First, atomic energy has long been controversial within the public domain due in part to concerns about reactor safety and the security of nuclear materials and technologies that could be misused for nuclear weaponry.[15] To this end, it is not uncommon for the civilian use of nuclear power to be conflated with military applications.[16] The Acheson-Lilienthal Committee noted that "one of the most serious dangers to the promotion of effective international action is . . . that our natural preoccupation with the destructive aspects of atomic

energy may blind us to its useful aspects."[17] Today, that conflation continues with calls for the US to opt out of the nuclear industry altogether based in part on waste and proliferation concerns.[18]

Second, within America's overall energy policy debate there is a call to move the US away from all traditional fuels—meaning fossil fuels and nuclear resources—and transition the country to 100 percent renewable energy, in part to address the impacts of global climate change.[19] This is an ongoing issue with considerable political overtones, not only in the US but globally as well.[20] The underlying theory is that the US and the world can meet all energy needs with renewable energy alone, with no need for fossil fuels or nuclear power.[21] The rationale is that renewable energy will improve energy security by displacing imported energy with a domestic resource that poses near-zero risk, whereas fossil fuels and nuclear energy have import/export dependencies, emissions issues, waste, and proliferation risks. The push for 100 percent renewable energy in the US is likely to remain part of the national energy policy debate well into the future as global climate change concerns are elevated in the national energy conversation and renewable energy is promoted as the lowest-risk pathway to address those climate concerns.[22] It is important to note that global climate change has been identified as a national security issue by the US Department of Defense and the US Office of the Director of National Intelligence. Since US climate policy influences US energy policy, US climate policy will influence the trajectory of US energy technology—including nuclear power. Consequently, US energy and climate policy are entangled with US nuclear power policy and national security.[23]

Third, the free market historically has been a dominant driver of the US energy portfolio, and some contend that market forces alone should determine the fate of America's nuclear industry.[24] Currently, those market forces are moving the US electric power sector toward natural gas because it is abundant and inexpensive and because large nuclear construction projects, by comparison, are more capital intensive and require a long-term investment perspective. Consequently, about 20 percent of US civilian nuclear power reactors are under threat of premature closure.[25] Moreover, domestic nuclear construction waned toward the end of the twentieth century. New construction has been largely dormant in the twenty-first century with only two reactors under construction at Plant Vogtle in Georgia—the first new US nuclear construction project in over 30 years.[26]

Further complicating America's nuclear power policy debate is that, in spite of the twenty-first-century emergence of China and Russia and bipartisan agreement in Washington of this emergence, recent polling indi-

cates that great power competition is not a top priority with the American public.[27] By extension, the national security implications of US civilian nuclear power policy within the context of the strategic geopolitical objectives of these two revisionist powers are even less likely to be a priority. The US debate over the fate of its nuclear enterprise has been generally reduced to that of a domestic energy policy issue within the overall debate of global climate change—a debate that includes considering whether the US should retain its nuclear enterprise or abandon it altogether. This disconnect between nuclear power as a national security issue, as understood by policy makers post–World War II, and nuclear power as only a commodity in the energy market may reflect what Hal Brands and Charles Edel characterize as contemporary amnesia with the United States "losing the tragic sensibility that impelled it to do great things."[28]

The debates over waste and proliferation concerns, renewable energy, and the role of markets are creating strong domestic headwinds for the future of US nuclear power and have the potential to bring the civilian US nuclear industry to a close. Moreover, the domestic challenges to America's nuclear enterprise raise an even more pointed question: Does the US see any value in retaining its twentieth-century nuclear leadership into the twenty-first century? At the same time, international forces are presenting additional challenges to America's nuclear enterprise and global leadership in nuclear power—challenges that are more strategic and have broader implications for US national security.

International Challenges and Implications

The greatest national security challenge to the original principles seems to emanate from international actors, particularly through geopolitical exploitation. The decline in US domestic nuclear construction over the past 30-plus years—relative to the growth of nuclear power development in other regions of the world—has created opportunities for revisionist powers China and Russia to aggressively engage in expanding nuclear power collaborations. Since 2000, 96 nuclear reactors have been connected to the grid in 13 countries. Of these, 45 were constructed in China and 12 in Russia. An additional four Chinese-designed reactors and seven Russian-designed reactors were deployed in five other countries, meaning 71 percent of reactor deployment is associated with China or Russia either by domestic location or by reactor design. Currently, 54 reactors are under construction in 20 countries. Of these, 13 are Chinese designed (11 in China, 2 outside of China), and 16 are Russian designed (4 in Russia, 12

outside of Russia). Thus, 54 percent of reactors under construction are associated with China or Russia.

In all, since 2000, 150 nuclear reactors have been connected to the grid or are under construction in 22 countries. Of these, 97 are associated with China or Russia in 11 of those countries. Thus, for the past 20 years, China and Russia are associated with 65 percent of reactor construction in half of the countries where nuclear power has been or is being deployed.[29] Much of the new reactor construction can be attributed to the practical need for electricity in developing economies in Eurasia and the Asia-Pacific region.

China and Russia are deftly leveraging their nuclear expertise for strategic geopolitical gain and are on track to displace America as the reliable global partner in nuclear technology and international nuclear collaborations.[30] From planning to construction, operation, and decommissioning, nuclear collaborations span decades, affording China and Russia the ability to project their respective geopolitical influence in countries that will be dependent on them for nuclear technology and services. Both nations are positioned to assume global leadership in civilian nuclear technology and services and are outcompeting other states on the global stage to the extent that "the nuclear industry in a few decades is likely to be decidedly non-Western."[31] China is a particularly adept competitor as it is taking an "integrated approach to innovation" as well as a "whole-of-nation implementation of military-civil fusion" to "leverage synergies between defense and commercial developments" including global nuclear commerce, which is embedded within its Belt and Road Initiative.[32] This status isn't a reflection of superiority in nuclear expertise or capabilities so much as how each country views nuclear power—as an energy technology subject to popular opinion and political leanings or as a geopolitical tool subject to the will of the state. It also indicates that China and Russia are exploiting nuclear energy to attract allegiance.

China has developed a three-phase strategy to transition from its current light-water-reactor technology to nuclear fusion.[33] It has also structured a deal to establish a nuclear industry university for advanced study.[34] Lin Boqiang, director of the China Center for Energy Economics Research at Xiamen University, emphasizes that "China is the fastest-expanding nuclear power generator in the world . . . at a time when traditional giants like the US are retreating." He characterizes China's state-owned nuclear sector as an "incomparable advantage" of the Chinese system as it offers "long-term stability and rich financing sources to support research and development."[35] This advantage is unique compared with the US capitalist-based nuclear sector. China is leveraging that ad-

vantage, having identified advanced nuclear technologies in its Thirteenth Five-Year Plan as a strategic industry for development.[36] With its state-owned nuclear enterprise, Russia has its own strategic build-own-operate plan for international nuclear agreements, has deployed its BN-800 fast breeder reactor, and is working on closing its fuel cycle.[37]

The nuclear power enterprises of China and Russia are state-owned enterprises (SOE) and are being leveraged as extensions of the state to meet strategic foreign policy and geopolitical objectives. This structure stands in contrast to the privatized US civilian nuclear power industry that, while regulated by a centralized federal authority, is driven by competition and is not supported by national financing to achieve foreign policy or geopolitical objectives. This is not a military competition—rather it is a strategic competition wherein China and Russia are deploying civilian nuclear technologies and services with high geopolitical stakes.

While unilateral efforts by China and Russia are concerning enough, those concerns are heightened given that "the two countries have significantly expanded their cooperation, especially in the energy, military, and technology spheres, since 2014 . . . as the overall US lead in science and technology shrinks."[38] The geopolitical synergism of Chinese and Russian nuclear enterprises raises questions as to whether the US is positioned to maintain its nuclear leadership role and warrants attention to issues contributing to the US decline relative to the rest of the world.[39]

Aligning US Nuclear Power with National Security Objectives

Henry DeWolf Smyth, a US physicist who played a key role in the early development of atomic energy and US nuclear policy, posed a question in 1956 that still reverberates today: "Are the aims of our foreign policy consistent with the aims of our domestic policy as far as nuclear power is concerned?"[40] Global leadership in the twenty-first-century landscape of civilian nuclear power will belong to the country that not only sustains its existing nuclear plants, an issue the US is dealing with currently, but also has a long-term vision for growth and expansion of its nuclear enterprise. Further, it must have a strategy to operationalize that vision—a vision and strategy the US currently is not projecting. Such a strategy will require research and development programs for advanced reactors, advanced and alternative nuclear fuels, spent fuel management, and technologies for closing the nuclear fuel cycle.[41] The strategy must also show evidence of a long-term commitment to nuclear power technologies and peripheral services that attract developing economies looking to establish long-term

cooperative nuclear power relationships—as was the custom in the early years of nuclear power programs.

Currently, the US is facing two national-level issues affecting the fate of the US civilian nuclear power enterprise. Those two issues are global climate change and the reemergence of long-term, strategic competition by revisionist powers.[42] It is imperative to ensure that any policies engendered by these issues align US nuclear power policy with the objectives of US foreign policy and national security. To that end, we propose two core actions—one domestic and one international. First, expand the scope of nuclear science, engineering, and technology within the national security industrial base to include US civilian nuclear power as a strategic sector, and conduct a whole-of-government industrial base review of the US civilian nuclear enterprise. Second, marshal US allies having core nuclear expertise and capabilities into a twenty-first-century coalition capable of doing collectively what each nation is not doing individually—outcompete illiberal, authoritarian powers in global nuclear partnerships.[43]

Civilian Nuclear Power as Part of the National Security Industrial Base

US and allied nations generally approach nuclear power from an economic feasibility basis, be that in domestic projects or bilateral cooperation. China and Russia, on the other hand, approach it with a strong emphasis on geopolitical gains and not economic feasibility alone. As long as it does not include the national security value of nuclear power, economic feasibility of itself will not compete with the geopolitics of a state. Given that the twentieth-century liberal international order was constructed with America's nuclear power policy aligned with national security objectives, this potential shift in civilian nuclear primacy from democratic to authoritarian nations raises a broader question as to the geopolitical arrangements of the twenty-first century. Specifically, can the US, without world-class civilian nuclear power expertise in its industrial base, sustain in a more geopolitically complex twenty-first century what it established in the twentieth century with the world's premier civilian nuclear power expertise? This question demands a response as a decline in the US civilian nuclear industry translates to a decline in US nuclear expertise, which is acutely problematic if that decline is countered by an increase in nuclear expertise in competing great powers.

While the overarching role of nuclear capabilities in US foreign policy unquestionably will be to maintain America's military superiority, the full scope of twenty-first-century great power competition will not be re-

stricted to military means. Twenty-first-century great power competition is a strategic competition where "technological advances and an economic rebalancing" are leveraged as "low-cost and relatively low-risk opportunities to weaken the United States and the Western alliance."[44] Given that authoritarian powers are leveraging civilian nuclear technology as extensions of the state in this contest for technological superiority, concerns regarding America's national security industrial base should extend to the US civilian nuclear power industry.

We propose expanding the scope of nuclear science, engineering, and technology within the US national security industrial base to include US civilian nuclear power as a strategic sector. This will shift US civilian nuclear power from an issue debated predominantly as a domestic energy and climate policy issue to a core foreign policy issue deliberated within the national security space. Doing so will serve to ameliorate much of the political volatility associated with populist energy policies as well as some of the inherent fluctuations in domestic energy markets. It will also provide grounds for conducting a whole-of-government nuclear industrial base review—led by the Department of Defense and the intelligence community—to evaluate risks, identify impacts, and make recommendations for strengthening, reorganizing, and reconstituting the US nuclear sector's domestic and global manufacturing and supply chain. The US nuclear sector is currently working from a twentieth-century model wherein the US had substantial momentum from its post–World War II monopoly and its great power competition in the nuclear space was military competition with the USSR. The twenty-first century is far different, and the US must evaluate how its nuclear enterprise should be structured and organized to efficiently and effectively compete on a global scale with Chinese and Russian SOEs and how to out-innovate state-backed R&D programs in advanced nuclear technologies.

The domestic challenges previously noted are fundamentally misaligned with the foundational principles of US nuclear power policy that considered nuclear power strategy to be first and foremost a foreign policy and national security issue—not merely a domestic energy policy issue. Moreover, relegating the future of US nuclear power to markets alone, particularly a global market without fair market signals, is a gamble that will not pay dividends on the national security value of nuclear power. Smyth emphasized that "decisions about the peacetime development of nuclear energy have not, cannot and probably should not be made on the basis of strict economic realism."[45] Smyth's opinion was echoed by Thomas E. Murray, Jr., businessman and commissioner of the Atomic Energy Commission,

who considered attaining economical nuclear power to be as vital to national security as US preeminence in nuclear weapons.[46] Affordability matters, of course, and the competition inherent in free market capitalism is critical to innovation in next-generation nuclear reactors. However, national security is not an emergent property of capitalism and free markets because the national security benefits of nuclear power are non-monetized benefits. As the US has witnessed, if left to markets alone, America's nuclear power policy and its nuclear legacy would be overly influenced by near-term profits and marginal costs of energy. Therefore, the free market's invisible hand should be allowed limited pull on the levers of foreign policy and national security or on any market approach that marginalizes or precludes nuclear science, engineering, and technology from the US industrial base.

The robustness of the US industrial base and supply chain in a highly interdependent globalized economy recently triggered concerns pertaining to America's industrial capacity to respond to contemporary threats. This was evidenced by President Trump's issuance of Executive Order 13806 directing "the Secretary of Defense to conduct a whole-of-government effort to assess risk, identify impacts and propose recommendations in support of a healthy manufacturing and defense industrial base—a critical aspect of economic and national security."[47] This order can serve as the model for a similar industrial base review of America's civilian nuclear enterprise to evaluate how the US should "transform, organize, sustain, and leverage [its] national security technology and innovation community to prevail in a long-term competition against an authoritarian regime that has centralized, long-range national plans to dominate the critical dual-use technologies central to future economic and military competitiveness."[48] This inherently will include an evaluation of the various sectors of the US nuclear enterprise, including plant operation, fuel services, safety, security, and project management, to name a few, as well as a reevaluation of the US public-private nuclear partnership that prevailed throughout the twentieth century. Moreover, since this evaluation is oriented toward restructuring the US nuclear sector for twenty-first-century international arrangements, consideration should be given to engaging allied nations in a broader contingent, which prompts the second proposed core action.

A US-Led Global Alliance

While the US deliberates the fate of its nuclear industry, Japan, South Korea, France, and the UK—all US allies—are having domestic issues over the future of their respective nuclear power enterprises. Following the

Fukushima incident and the shutting down of its nuclear reactors, Japan has announced plans to construct 22 new coal-fired power plants.[49] South Korea has proposed a nuclear phase-out policy that is creating domestic concerns of an exodus of nuclear expertise from the ROK and a collapse within its nuclear supply chain.[50] France will soon face the uncertainty of whether nuclear power is considered clean enough to meet the green energy objectives of a post-Brexit European Union and has embarked on a path of reducing its dependency on nuclear power.[51] Meanwhile, the UK has faced numerous challenges in the construction of new nuclear capacity at Hinkley Point C. Exacerbating these challenges is UK collaboration with China as an investment partner in the project, triggering security concerns among UK policy makers questioning the decision to engage China in its civilian nuclear industry.[52]

International control of atomic energy in the twentieth century was accomplished by a US-led coalition of nations to prevent proliferation of nuclear weapons, which will remain the paramount objective for all activities related to nuclear power. However, additional proliferation concerns have emerged in the twenty-first century—the propagation of ideologies from authoritarian powers leveraging technologies such as nuclear power to project soft power and advance their respective geopolitical interests. Since bilateral nuclear cooperation translates to decades-long relationships, a US response must be geopolitically strategic with long-term objectives, not merely transactional as if nuclear power is only an energy commodity. We propose that it is incumbent upon the US as chief signatory of the twentieth-century liberal international order to reassert its leadership and unite its allies into a twenty-first-century coalition of civilian nuclear power partners. This coalition must be capable of competing with China and Russia in the deployment of nuclear technology, fuel, and services in emerging economies where energy demand is increasing rapidly and countries are seeking partnerships.

The National Technology and Industrial Base (NTIB) focuses on defense applications. Its creation stems from the priority of "retaining access to global technology and industrial capabilities" and the need for industrial cooperation between the US and other nations—particularly Canada, the UK, and Australia.[53] The NTIB could be paralleled with a Civilian Nuclear Technology and Industrial Base (CNTIB) to facilitate US nuclear power cooperation with Canada, the UK, Australia, France, South Korea, and Japan—each having nuclear expertise or resources critical to the global nuclear ecosystem (fig. 1). The CNTIB would be fundamentally informed by the afore-proposed nuclear industrial base review and then used as the

framework for organizing a US-led coalition of allied nuclear collaborators (fig. 2). Each country could contribute unique, specialized services in a best-of-practice arrangement capable of doing collectively what isn't being done individually—respond strategically to China's and Russia's efforts to be the trusted, reliable partner in nuclear power.

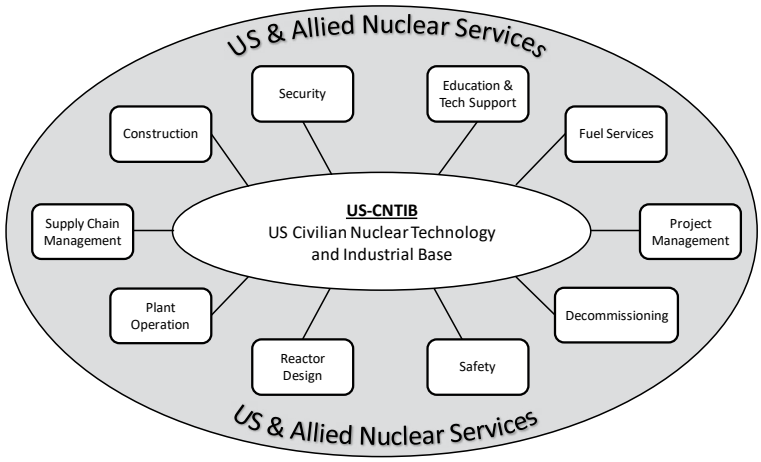

Figure 1. A proposed US Civilian Nuclear Technology and Industrial Base that leverages allied nuclear expertise within a global network of services and technologies

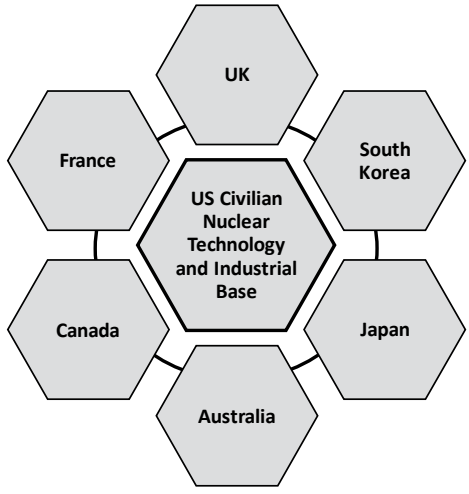

Figure 2. US-led allied coalition of nuclear collaborators capable of competing with China and Russia

As nuclear construction is capital intensive and presents financial and investment challenges on the domestic front, this allied arrangement provides a shared risk environment for new nuclear projects as well as for research and development into advanced nuclear science, engineering, and

technology. As such, it will position the US and allied partners with the organizational capacity to compete with Chinese and Russian SOEs to be the preferred nuclear power partner for meeting global energy demands under low-carbon constraints of global climate change. It also will shift the purview of nuclear power from one that is predominantly focused on nuclear energy as a transactional commodity issue at the domestic level to one of a strategic geopolitical issue at the international level. This transactional to geostrategic shift, in keeping with the shift proposed in the first core action, will project an allied show of force that democratic nations are willing and capable of responding to the challenge of twenty-first-century great power competition for superiority and dominance in nuclear technology and services.

A US-led international arrangement will facilitate a transition of the US civilian nuclear enterprise from a model aligned with twentieth-century foreign policy and national security challenges to one that aligns with foreign policy and national security objectives of the twenty-first century. It will refurbish America's nuclear brand while adhering to the original principles of US nuclear power policy. Such a move will foster "maintaining U.S. leadership . . . [,] using such U.S. leadership to promote cohesion within the free world . . . [,] increasing progress in developing and applying peaceful uses of atomic energy . . . [,] assuring continued U.S. access to foreign . . . supplies[, and] preventing the diversion to non-peaceful uses."[54]

Conclusion

America's twentieth-century nuclear legacy was established through strategic public-private research and development collaborations. This basis gave the privatized US nuclear industry the momentum to engage the world in civilian nuclear power partnerships as the US nuclear brand was accepted as the technology, safety, and security standard to which other nations ascribed—a nuclear brand that can be characterized as mutualistic and nonpredatory. America's initial advantage of having a monopoly on nuclear science, engineering, and technology was not exploited to subject defeated nations to US rule. Instead, the US leveraged its initial advantage in a strategic global effort to establish nonproliferation-focused international control over atomic energy, to share the science and technology for peaceful purposes, and to project security guarantees for allies against the inevitable development of atomic weaponry by illiberal, authoritarian nations. In essence, the US established international protocol to safeguard the world from the very science it had discovered and the technology it had developed. To that end, America's nuclear policy has

been mutualistic, not predatory, providing benefits to both the US and Section 123 partners. However, abandoning or severely reducing peaceful applications of nuclear energy will tarnish this brand and shift the culture of US nuclear applications to predominantly military. Such a reframing does not reflect the first principles of nuclear power policy articulated in the National Security Council's 1955 Statement of Policy on Peaceful Uses of Atomic Energy and the dual-use applications of atomic energy.[55]

The twentieth-century liberal international order was arranged under US leadership, with US nuclear power policy aligned with US foreign policy and national security objectives to sustain and extend the benefits of that liberal order throughout the world. This framework was accomplished during a time when great power competition was largely a bipolar struggle for military superiority, when global climate change had not been elevated as a national and international security concern, and when the US was the dominant, most reliable partner for global civilian nuclear technology and services. The twentieth century gave way to a much different, more complex, and more globally interconnected twenty-first century with great powers seeking to, at a minimum, erode US influence globally and regionally and using technology as one of the eroding forces. This includes civilian nuclear technology. However, as the US is engaged in a national debate over the fate of its nuclear power enterprise, authoritarian powers China and Russia are having no such debate. Rather, they are embedding nuclear power partnerships into their respective geopolitical strategies—including designs for dominating the global market in civilian nuclear technology and services—thereby occupying in the twenty-first century the nuclear technology space occupied by America in the twentieth century.

Given America's legacy of commitment to global leadership in nuclear science, the conversation is not aligned with twenty-first-century challenges—thus the need for sober discussion within America's security and foreign policy community. America's nuclear power enterprise is at a strategic crossroads for decision-making that original policy makers likely would have never imagined—one that could set the US on a trajectory toward unilateral disengagement from civilian nuclear power. If the US disengages from civilian nuclear power, whether by the hidden hand of economics, fear of waste, proliferation, misplaced confidence in the potential of renewable energy, or a lack of political resolve, it will signal America's abandonment of its foundational principles of nuclear power. SSQ

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Notes

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8. It was broadly agreed upon that the US nuclear enterprise must appeal to the scientific imagination to attract the ablest and best minds. Robert Oppenheimer was adamant that "only a unit that was organic and alive could keep abreast of the changing technology

and attract an able, imaginative staff." Richard G. Hewlett and Oscar E. Anderson Jr., *The New World*, vol. 1, *History of the United States Atomic Energy Commission*, *1939–1946* (University Park, PA: Pennsylvania State University Press, 1962), 536, https://www.energy.gov/. The Acheson-Lilienthal Report specifically pointed out the following:

> One cannot look intelligently for a factor of whose principle of design and operation one has never heard. It therefore becomes absolutely essential that any international agency seeking to safeguard the security of the world against warlike uses of atomic energy should be in the very forefront of technical competence in this field. If the international agency is simply a police activity for only negative and repressive functions, inevitably and within a very short period of time the enforcement agency will not know enough to be able to recognize new elements of danger, new possibilities of evasion or the beginnings of a course of development having dangerous and warlike ends in view.

Department of State, *International Control of Atomic Energy*, 13, 27.

9. Henry DeWolf Smyth, physicist, author of a landmark report on the wartime atomic energy program and an early member of the Atomic Energy Commission, contended that America's "knowledge of atomic energy should be used as a major instrument to promote our foreign policy of universal peace and freedom" and that the US had "a great obligation to maintain leadership in the development of this new technology of nuclear power" with "a specific obligation to back up our foreign policy gestures in this field with growing technological strength" and "a vigorous program of reactor development." Henry DeWolf Smyth, "Nuclear Power and Foreign Policy," *Foreign Affairs* 35, no. 1 (October 1956): 1–16.

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37. Fast nuclear reactors can potentially extract 60 times more energy from uranium than standard light-water reactors and have the capability of significantly reducing the levels of radioactive waste, including plutonium, by consuming the waste for fuel, thus closing the nuclear fuel cycle. Russia deployed its fast breeder reactor, the BN-800, in 2016. The US had made substantial progress in the development of its Integral Fast Reactor (IFR), but the IFR program—characterized by President Clinton as "no longer needed"—was eliminated in 1993. Combined with Russia's aggressive efforts to provide nuclear services to other countries, the deployment of fast reactor technology projects Russia advancing its nuclear enterprise. See President Bill Clinton (address, Joint Session of Congress, 17 February 1993), Miller Center, https://millercenter.org/; James L. Tyson, "Clinton Gives Breeder Reactor Ax, Many Scientists Lined Up Against It," *Christian Science Monitor*, 16 February 1994, https://www.csmonitor.com/; Sonal Patel, "Rapid Advancement for Fast Nuclear Reactors," *Power Magazine*, 28 February 2019, https://www.powermag.com/; and Nick Gallucci and Michael Shellenberger, "Will the West Let Russia Dominate the Nuclear Market?," *Foreign Affairs*, 3 August 2017, https://www.foreignaffairs.com/.

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40. Smyth, "Nuclear Power," 1–16.

41. The nuclear fuel cycle is the industrial process that supports the production of electricity from uranium in nuclear power reactors. The process is characterized as having a "front end" and a "back end." The front end includes uranium mining, enrichment, fuel fabrication, and the service period of the reactor. The back end refers to the safe management of spent fuel from the reactor. In the US, fissile uranium-235 (U-235) is the fuel for light-water reactors (LWR)—the US industry standard. The enrichment process increases the concentration of U-235 from naturally occurring levels of 0.7 percent to reactor-grade levels of 3–5 percent for nuclear fuel rods. Throughout the service period, fission products and transuranic elements, including fissile plutonium-239 (Pu-239), accumulate in the fuel rods, along with residual U-235. This results in spent fuel that must be either permanently stored for safety and security reasons or reprocessed for reuse in a reactor. While Yucca Mountain has been set aside as a long-term geological repository for spent fuel in the US, it is in a political stalemate. Consequently, spent fuel is being stored on-site at nuclear power plants. Closing the nuclear fuel cycle means reprocessing and reusing spent fuel in reactors designed to accommodate reprocessed fuels. Since weapons-grade levels for uranium and plutonium are at least 90 percent, enrichment and reprocessing technologies represent security issues. Advanced reactors are a broad class of reactor designs, some of which can consume not only U-235 and Pu-239 but also transuranics (elements

having a higher atomic number than uranium). Thus, these reactors can serve to reduce or eliminate fissile materials such as U-235 and Pu-239 from spent fuel. Other advanced reactor designs use molten salts rather than solid fuel assemblies, providing enhanced safety features compared with LWRs, while other designs use thorium as the nuclear fuel source rather than uranium. In general, advanced nuclear reactors focus on improving safety and security within the nuclear fuel cycle through proliferation-resistant technologies to recover more energy and reduce waste. Currently, the US has no comprehensive strategy for its nuclear fuel cycle. For further reference, see Mark Holt, *Advanced Nuclear Power and Fuel Cycle Technologies: Outlook and Policy Options*, CRS Report RL34579 (Washington, DC: Congressional Research Service, 2008), https://fas.org/; The World Nuclear Association, "The Nuclear Fuel Cycle," accessed July 2020, https://www.world-nuclear.org/; United States Nuclear Regulatory Commission, "Backgrounder on Licensing Yucca Mountain," fact sheet, accessed July 2020, https://www.nrc.gov/; United States Nuclear Regulatory Commission, "Stages of the Nuclear Fuel Cycle," accessed July 2020, https://www.nrc.gov/; and World Nuclear Association, "Advanced Nuclear Power Reactors," accessed February 2020, https://www.world-nuclear.org/.

42. James Mattis, *Summary of the 2018 National Defense Strategy of the United States of America* (Washington, DC: Department of Defense, January 2018), 2. See also Office of the Under Secretary of Defense for Acquisition and Sustainment, *Report on Effects of a Changing Climate to the Department of Defense* (Washington, DC: Department of Defense, January 2019), 2, https://media.defense.gov/.

43. In the twentieth century, the phrase "arsenal of democracy" signified more than mere World War II propaganda. America's industrial base—and the science, technology, engineering, and education capabilities that undergirded it—became the distinguishing source of its superpower status as well as its economic vitality. Today, the industrial base as a whole is experiencing changes perhaps as never before. While individual firms and programs continue to rise and fall, the overall US national security marketplace (now extending beyond traditional defense issues) is wrestling with revolutions in technology, new modes of warfare, and uncertainty in everything from its labor pool to trade policy to budgetary resources. Many believe that the industry is at a strategic inflection point where its future can sharply change for better or for worse. Yet despite this combination of importance and uncertainty, the topic is too frequently approached in a short-term manner, too frequently defined by consideration of a single program authorization decision rather than broad trends, and too frequently discussed in mere bumper sticker terms." Brookings, Center for 21st Century Security and Intelligence, "About the National Security Industrial Base," accessed July 2020, https://www.brookings.edu/.

44. John Allen, "Disrupting the International Order," in *Shaping a Multiconceptual World 2020* (Cologny-Geneva, Switzerland: World Economic Forum, 2020), 14, http://www3.weforum.org/.

45. Smyth, "Nuclear Power," 1–16.

46. Richard G. Hewlett and Jack M. Holl, *Atoms for Peace and War, 1953–1961: Eisenhower and the Atomic Energy Commission*, vol. 3, *A History of the United States Atomic Commission* (Berkeley: University of California Press, 1989), 194.

47. Department of Defense, *Assessing and Strengthening the Manufacturing and Defense Industrial Base and Supply Chain Resiliency of the United States: Report to President Donald J. Trump by the Interagency Task Force in Fulfillment of Executive Order 13806* (Washington, DC: Department of Defense, September 2018), 1, https://media.defense

.gov/. See also Executive Order 13806, Assessing and Strengthening the Manufacturing and Defense Industrial Base and Supply Chain Resiliency of the United States, 21 July 2017, https://www.whitehouse.gov/.

48. *The Contest for Innovation: Strengthening America's National Security Innovation Base in an Era of Strategic Competition*, Report of the Task Force on 21st-Century National Security Technology and Workforce (Washington, DC: Ronald Reagan Institute, December, 2019), 8, https://www.reaganfoundation.org/.

49. Hiroko Tabuchi, "Japan Races to Build New Coal-Burning Power Plants, Despite Climate Risks," *New York Times*, 5 February 2020, https://www.nytimes.com/.

50. Nguyen V. Phuong, "An Analysis of Moon Jae-in's Nuclear Phase-out Policy: The Past, Present, and Future of Nuclear Energy in South Korea," *Georgetown Journal of Asian Affairs* 4, no. 2 (Winter 2019): 66–72. See also Editorial Notes, "Seoul's Nuclear Phase-Out Is a Self-Injurious Policy: Korea Herald," *The Straits Times*, 25 December 2019, https://www.straitstimes.com/; Jung Min-hee, "S. Korea's Ecosystem of Nuclear Power Plant Industry Collapsing," *Business Korea*, 23 January 2020, http://www.businesskorea.co.kr/; and Jung Min-hee, "Nuclear Power to Be Replaced with LNG, Renewable Energy Powers," *Business Korea*, 11 May 2020, http://www.businesskorea.co.kr/.

51. Charles Digges, "France Begins Winding Down Its Reliance on Nuclear Power," Bellona, 4 March 2020, https://bellona.org/; and J. P. Casey and Umar Ali, "Debate: Is Nuclear Clean Enough for the EU's Green Funding?," *Power Technology*, 16 January 2020, https://www.power-technology.com/.

52. Jonathan Ford, "UK's Reliance on China's Nuclear Tech Poses Test for Policymakers," *Financial Times*, 13 February 2019, https://www.ft.com/.

53. The term "national technology and industrial base" refers to "the persons and organizations that are engaged in research, development, production, integration, services, or information technology activities conducted within the United States, the United Kingdom of Great Britain and Northern Ireland, Australia and Canada," 10 USC § 2500: Definitions, https://uscode.house.gov/; and Rhys McCormick et al., *National Technology and Industrial Base Integration: How to Overcome Barriers and Capitalize on Cooperation*, Report for the Center for Strategic and International Studies (Washington, DC: CSIS, March 2018), https://www.csis.org/analysis/.

54. *FRUS, 1955–1957*, vol. XX, doc. 14, encl.

55. *FRUS, 1955–1957*, vol. XX, doc. 14, encl.

EDITOR'S EPILOGUE

Over the past 11 years, it has been my pleasure to serve as editor of *Strategic Studies Quarterly* (*SSQ*). Being the editor of a journal is never supposed to be a sentence, so I have elected to pardon myself and make way for a successor. The Fall 2020 issue is my final effort.

Since becoming editor, two key standards motivated my decisions: Quality publishing, On time! My vision and goals for the journal focused on several mission objectives. The foundation of our mission is to inform, educate, and influence national security by generating actionable ideas. Our intent was to highlight civilian, DOD, and Air Force author-scholars who could offer profound ideas for the nation. *SSQ* also sought to support the DOD and the Air University in several ways. The journal published useful, relevant content for direct support to all levels of professional military education. It showcased Air University within the DOD and academia while promoting Air University faculty talent through scholarly publishing and multimedia venues. All these efforts generated sustained intellectual development and interest within academia and added value to the larger defense community. The best expressions of our value added are in the foreword and preface of the *SSQ* 10th anniversary issue (https://www.airuniversity.af.edu/).

Any journal is only as good as the profound ideas within it, and *SSQ* has offered many such ideas. In several areas the journal led the way highlighting issues of profound importance such as cyber, nuclear, space, and the Indo-Pacific. It dedicated special editions to these topics and others, including austere defense, emerging technology, civil-military relations, conventional deterrence, and great power conflict. Our content is now hosted by six data aggregators and is being downloaded and used by many of the most respected universities in the world. *SSQ* articles have also been the source of several edited volumes. Additionally, every level of professional military education in the US Department of Defense and several allied countries use *SSQ* articles as coursework.

Much has changed for *SSQ* during the past 11 years; it is safe to say that I did not make changes on purpose but with purpose. Those who read *SSQ* will likely consider the changes significant, especially given the many challenges the journal has faced over the years. Some of the obstacles included tightened budgets, personnel changes, cancelled events, technological roadblocks, and even a pandemic. But through them all, I took great strength and comfort from a superb cadre of authors, many solicited from the International Studies Association, who freely offered their scholarly ideas and suffered our peer review. In the process, they were always too kind in their comments and responses to our finished product. A

critical part of my Air University team is the contributing editors whose expertise and scholarly opinions help maintain our quality and relevance. They endured the monthly burden of evaluations, and I am convinced my twice yearly hosted lunch was little payment for the value of their contributions. Of course no editor is an island, so the majority of the credit for our success rests with Team *SSQ* members—including copy editors, typesetters, graphics designers, managing editors, budgeteers, and our wonderful printer. Their dedication and mission focus was essential to consistent, on-time publishing. Team *SSQ* tolerated me even when I did not deserve to be tolerated—the mark of true professionalism. Together, our authors, contributing editors, and production team created a journal we can be proud of—one that seems to deliver a much larger return on ideas than the difficulty in producing them.

There will always be a need for strategists, statesmen, and diplomats who take an interest in national security for the good of our nation, for the good of other nations, and for the good of humanity. If *SSQ* has helped educate, inform, and influence any of these, then our efforts over the past 11 years will have been worth it. Now, as my tenure ends, please allow me to offer one final thought to my successor and Team *SSQ*: never underestimate the value of what *Strategic Studies Quarterly* represents or the effects of the ideas you produce. Long live the journal, the profound ideas that grace its pages over the coming decades, and its contribution to national security. SSQ

W. Michael Guillot, Editor

For Want of a Nail by Amy Franceschini and Michael Swaine. No place press, 2019, 141 pp.

Typically, books reviewed in military scholarly journals tend to be academic in nature with dense writing backed by copious amounts of cited material. Reviewers can offer their own creative spins on these scholarly works, but they usually fall within an accepted, perceived category. However, there will be times when a book for review does not fit that mode. Such is the case with *For Want of a Nail*, a compilation work from the two main artists associated with Futurefarmers, a San Francisco–based group of design artists.

To say that *For Want of a Nail* is not the usual academic treatise is an understatement. The reader must literally cut open the pages of the book to read it. This is by design as the authors hope to spur reflection in your reading of their work. Once a reader cuts open the pages and reviews the book (in this case, a combination of fingers and index cards to slice open attached pages), the theme of the book is revealed. This is Futurefarmers' take on the creation and testing of the first atomic weapons at Los Alamos, New Mexico. From there, the reader is met with a conglomeration of various essays, plays/scripts, poems, and visual plates that all tie back to the history and evolution of nuclear weapon development and testing.

The genesis of the title *For Want of a Nail* comes from a letter that the authors/artists uncovered from J. Robert Oppenheimer, the lead civilian scientist for the Manhattan Project at Los Alamos. In the letter, dated October 1943, he asks his administrative assistant to call someone to hammer in a nail so he could have a place to hang his hat when in the office. From there, the artists made their first three creations: three nails. One was made from the remnants of a meteor that struck the earth at the Barringer Crater 50,000 years ago. Another was made from melted pennies from 1943 (the year of the request). A third nail was made from Trinitite, the rock found near the site of the first atomic bomb test, composed of melted sand and other components fused together in the aftermath of the detonation. The theme of the nails and what those nails represent permeate the work.

When most people think of an art book, they are apt to consider a coffee table book filled with lithographs and plates of famous works of visual art. Yet art can come in many forms, and *For Want of a Nail* is a unique form. Artists throughout the years have used the written word to convey their artistic visions, looking to impart direct and indirect meaning for their work. This work is no different. Futurefarmers looks to create physical art and design as an expression of an event and its implications. For this work, looking back at the detonation on 16 July 1945, the artists endeavored to describe not only the history of that day but the subsequent consequences of that test. As with a lot of art, the creators have their own meanings, but they also leave much to the reader/viewer to decide—for instance, reflecting on the purpose of a nail made from Trinitite or reading a faux letter from Oppenheimer discussing with a Hollywood figure who should be considered to play him in a movie about his life.

The picture of this work is through the eyes of the beholder. For this reviewer, this work does not take an especially positive view of the atomic bomb test and its effects. In using the opening line from the famous proverb "for want a nail" the authors/artists express their sentiments, for that famous proverb ends with the line "the kingdom was lost." The efforts of Oppenheimer and the Manhattan Project are seen as the "want of a nail" but with nuclear weapons seen as a possible key to "the kingdom was lost." It is remarkable that the artists were able to get near the test site, collecting the Trinitite and managing to create their work of a forged nail. Yet much of the writing focuses on some of the absurdities and contradictions of nuclear weapons. In one faux interview, a physicist notes that after Hiroshima, when others celebrated, he felt sick. Even Oppenheimer, the physicist Futurefarmers lambast for his seeming inability to take a mere hammer and strike a nail into a wall for his hat, eventually soured on the idea of nuclear weapons.

Oppenheimer became a significant critic of the more advanced weapons tests of the 1950s, which would have ultimately fit into the tenor of this work.

Overall, this work is one a military professional might read just for something completely different. There are some interesting facts to be gleaned from this work, but learned facts and details are not a central theme. It is the idea of memory and emotions that this art book desires, and agree or disagree, it does have the potential to make one think. In addition, professional reading can take on many forms. In recent years, professional reading lists look to incorporate not only books that you might expect to find on a chief of staff reading list but also blogs, movies, recordings, and painting. While this reviewer does not advocate placing this particular work on a reading list, the idea of artistic books should not be dismissed out of hand. A reader does not always need many words to get a lot out of a book.

Lt Col Scott C. Martin, USAF

Double Jeopardy: Combating Nuclear Terror and Climate Change by Daniel B. Poneman. The MIT Press, 2019, 258 pp.

Between irreversible climate change and nuclear disaster, one might assume Daniel Poneman's latest work would be a dismal report on these two seemingly insurmountable challenges. In *Double Jeopardy: Combating Nuclear Terror and Climate Change*, however, Poneman draws on his vast experience in the Department of Energy and National Security Council to propose an innovative energy policy that could improve the prognosis on both counts. Poneman acknowledges that climate change and nuclear security have become divisive issues in the current partisan political landscape but suggests that combining them could yield a wider zone of possible agreement. Development of a modern nuclear power infrastructure in the US and reassertion of our dominance in the international nuclear energy market could be attractive policies to both climate activists *and* those more concerned with national security and the strength of the economy. Given this premise, Poneman presents 13 recommendations ranging from "promote market mechanisms that reward efficiency" to "eliminate the North Korean nuclear threat."

Such a broad treatise requires a résumé to match. Poneman's includes decades of public service in both Republican and Democratic administrations, leadership positions in private sector enterprises, and posts at prestigious academic institutions. From 1993 to 1996, he served on the National Security Council as a special assistant to the president and as the senior director for nonproliferation and export controls. In this post, Poneman had a central role in negotiations with North Korea. During the Obama administration, Poneman served as deputy secretary of the Department of Energy and acting secretary of energy. Poneman is now the president and CEO of Centrus Energy Corp. and a senior fellow at the Harvard Kennedy School.

Given his experience with international relations, Poneman's recommendations on US nuclear foreign policy stand out as particularly innovative. *Double Jeopardy* reviews nuclear foreign policy going back to the dawn of the nuclear age and US successes and failures in controlling nuclear proliferation. Poneman notes that the recent decline in US nuclear leadership has created a void quickly being filled by other powerful actors including Russia, China, India, and France. Poneman makes a compelling argument that the world would be safer if the US recommitted to leadership in nuclear power plant construction and invested heavily in the development of next-generation reactors. He also advocates for the launch of an Assured Nuclear Fuel Services Initiative (ANFSI) whereby the US and other established nuclear countries would promote the development of clean nuclear power plants through a reliable supply of nuclear fuel while eliminating the need for additional countries to develop their own enrichment and reprocessing facilities. En-

richment facilities can have, as in the case of Iran, ambiguous purposes. Poneman observes that the US has bungled recent attempts to implement its own gold standard of safety internationally and argues that only active investment in international nuclear enterprises will allow for the adoption of these high safety standards.

While also well developed, Poneman's domestic recommendations may receive more scrutiny. His initial suggestions include levying a carbon tax, rewarding innovation to improve efficiency, and extending incentives provided for renewable energy to all carbon-neutral energy sources, including nuclear. Indeed, nuclear energy already provides the lion's share of carbon-neutral energy and is more reliable than wind or solar energy. Poneman's recommendation, however, that communities in the US opt into selection for nuclear waste storage facilities is unlikely to convince those already skeptical that nuclear waste can safely be stored. More emphasis could be placed on the scale of the nuclear waste problem—something widely misunderstood and exaggerated. Poneman later examines technological developments that could reprocess waste into usable fuel, and even how such innovations might facilitate a program like ANFSI. Although this technology could bring nuclear energy a step closer to being both clean and renewable, it receives no mention in Poneman's main analysis of handling nuclear waste. Poneman also advocates a shift from large reactors to more manageable small modular reactors (SMR). While SMRs could be more affordable, standardized, and easily protected, many will be concerned that escalating numbers of domestic reactors can only mean more opportunity for nuclear disaster.

This journal's readers will be particularly interested in Poneman's advice to the DOD. Every Air Force pilot knows the importance of energy management on a tactical level, but our leaders must also consider the strategic implications of a rapidly changing energy supply chain. California has some of the most ambitious climate goals, and in partnership with the Navy, it built the largest photovoltaic plant on DOD land in 2016. Energy from this plant will power multiple Navy bases, and surplus will be sold back to the state. Poneman suggests this power purchase model could be extended to nuclear power plants. Such a venture, while certainly a logistical challenge, could reinvigorate the nuclear mission of the Air Force. Additionally, the Air Force and Navy have entered into multiple large energy-savings performance contracts to begin improving the efficiency of their buildings. Some may argue that these kinds of projects fall beyond the purview of the Air Force or distract from its primary mission. DOD leadership, however, must consider such innovations before falling behind the power curve.

One does not have to agree with all of Poneman's recommendations to benefit from reading *Double Jeopardy*. Air Force personnel will gain context for their work from his concise review of the history of international nuclear negotiations and a current outlook on nuclear security topics of interest. While adopting all of Poneman's suggestions to increase nuclear power production may not be practical for the Air Force, *Double Jeopardy* will, most importantly, spark conversations about taking decisive action to mitigate the effects of climate change and the dangers of nuclear proliferation.

Lt Frederick Metzger, USAF

Assured Destruction: Building the Ballistic Missile Culture of the Air Force by David W. Bath. Naval Institute Press, 2020, 238 pp.

This history of the Air Force's ballistic missiles and their operators spans from the creation of the first nuclear weapons to the period after the Cuban missile crisis. Author David W. Bath has a PhD from Texas A&M University and currently teaches at Rogers State University. In addition to his academic credentials, he also has experience himself as an Air Force missileer, previously editing *Air Force Missileers and the Cuban Missile Crisis* for the Association of Air Force Missileers.

The book can be divided into two sections. The first half provides extensive background on the development of nuclear weapons before transitioning into ICBMs, perhaps too much so. The second half—providing the most important historiographical contribution—elucidates organizational and operational aspects of the ICBM community, particularly before and after the Cuban missile crisis. Bath argues that most works have focused on making the missiles rather than what happened to them or their operators after their making, especially between 1957 and 1967 (p. 8). It is unfortunate that this intriguing aspect of the work does not receive even fuller treatment, although primary sources admittedly remain a problem in some regards, such as classification issues.

Bath shows how the Air Force initially envisioned missileers being particularly distinguished, seeking those akin to "geniuses" with engineering degrees and combat experience (p. 1). Many early missileers, then, were bomber pilots who had trouble adjusting to a "monotonous environment" (p. 82) and never really felt themselves to be missileers (p. 83). Furthermore, the Air Force sometimes placed pilots with no missileer experience in command, which aggrieved missileers who had not come from the pilot community (p. 134). One could argue that this trend continues in today's Air Force regarding fighter pilots being placed in command of nonrated communities.

The role of missileers in the Air Force changed dramatically after the Cuban missile crisis forced President John F. Kennedy and his advisors to wrestle with whether they really would ever employ nuclear weapons (pp. 117–22). Deciding they wanted to stress the development of nonnuclear options, the Air Force seized the opportunity to begin neglecting the ICBM community. Indeed, the ICBM had never really been accepted or welcomed by Air Force leadership. According to Bath, the Air Force fought for the weapon system to keep the other services from obtaining it while far preferring the manned bomber platform. This portion of the book's themes should not be terribly foreign to anyone familiar with the ICBM community. As a former missileer, Bath unsurprisingly has great sympathy for the community's long-standing grievances. A less sympathetic author might have accentuated the challenges any institution faces in balancing roles and missions while meeting operational responsibilities.

Most interesting about the book is the section on the lesser-known ramifications of rushing this new technology into production and seeking to operationalize it. While it is the need to maintain exacting standards that is probably the best-known aspect of the ICBM community, it is ironic how wide-ranging and haphazard these standards were in the period Bath highlights. Thus, for example, Warren Air Force Base had two completely dissimilar squadrons initially operating, built to entirely different standards and even containing different numbers of missiles (p. 91).

Likewise, during the Cuban missile crisis, the new Minuteman missiles had not been fully operationalized. Thus, missileers rushed to create "workarounds" to get nuclear weapons ready for combat (p. 111). They even desperately tried to obtain enough liquid oxygen to launch missiles if called upon (p. 112). This fascinating section highlights the challenges of incorporating new technology into an institution. But Bath shows his allegiance to the missileer community by accepting at face value the command historians' evaluation of its response as "eminently successful" (p. 113), before venting that the "event that was arguably the crowning success for the missileers caused them to become political pariahs and began their descent into perceived insignificance within the Air Force" (p. 113).

The final body chapter of the book, fittingly entitled "Freefall," then shows the gutting of the ICBM community, particularly in regard to quality of personnel as the Air Force worried about pilot retention and the need to fill billets in Vietnam (p. 127). Simultaneously, what little room ICBMs left for imagination decreased because the Minutemen had received additional automation (p. 128). Missileers had believed in the early 1960s that their community was the "future of the Air Force" (p. 132), but they increasingly

realized that they were not. One missileer, for example, recalls how he could not enter an officers' club in his missile uniform although pilots could wear their flight suits (p. 136).

Bath concludes with the claim that the Air Force's experience with ICBMs taught it to "first gain control of any politically supported mission that threatened the dominance of manned flight and then to devalue it once political attention was directed elsewhere," a point he applies to a discussion of the remotely piloted aircraft community (pp. 145–47). The claim makes an interesting point of discussion, albeit a difficult one to substantiate.

Finally, a work whose title claims to highlight "ballistic missile *culture*" does not go far enough in terms of engaging in actual cultural history, although perhaps this was a regrettable decision made by the publisher. For example, the missileers themselves appear to have no agency, tending to be passive in the face of Air Force neglect. There is still work to be done by a historian who creatively brings new methodologies and insight to this story. Ultimately, though, this work provides a solid introduction to ICBMs and differentiates itself from similar works by focusing on the fascinating challenges of operationalizing a new technology both in peacetime and in a time of crisis while highlighting the Air Force's changing relationship to the community's personnel.

Dr. Heather Venable
Associate Professor, Air Command and Staff College

Burn-In: A Novel of the Real Robotic Revolution by P. W. Singer and August Cole. Houghton Mifflin Harcourt, 2020, 432 pp.

The topic of artificial intelligence (AI)—once confined to limited circles—is now firmly mainstream. To be sure, *conventionality* could be a word used to describe the growing movement to write on the subject; yet *unconventional* approaches exist to help both the professional and nonprofessional appreciate AI and its potential. Enter P. W. Singer and August Cole, writers demonstrably capable of blending theory and practice and making the impossible seem plausible. These features were on full display in *Ghost Fleet,* a seminal work of nonfiction that elevated the authors as leaders in the field of science fiction. *Ghost Fleet* trenchantly drew our collective attention to a world yet to come, establishing a high bar for novelists to follow. With the recently released *Burn-In*, Singer and Cole have exceeded their own standards in connecting the reader to the future and, in doing so, prove that when it comes to AI authorship style is just as important as substance.

With their latest work, the authors energetically carry on the tradition of this genre's giants including Isaac Asimov (*I, Robot*) and Robert Heinlein (*Starship Troopers*), to name a few. In this stirring encore to *Fleet*, however, they break new ground in describing the nexus between human and robot. Singer and Cole clearly use their own proximity to recent innovations in big tech to tell the story—and succeed in telling it. *Burn-In* puts the promise and peril of AI firmly in our grasp such that readers will undoubtedly ask their own questions about the future long after putting the book down.

Through a colorful human and robotic protagonist, the writers hew to novelistic form as the plot unfolds. This attention-grabbing style keeps the reader engaged throughout, while simultaneously providing a nuanced perspective of AI vis-à-vis its intersection with humankind. In this way, Singer and Cole deftly preserve credulity with each passing chapter. Aside from passages replete with action, the thrust of this story resolutely centers on AI's societal impact rather than a robot apocalypse. Herein lies the true value of *Burn-In,* as its artful portrayal of society's reliance on technology pulls readers into a world they may not recognize. Indeed, the authors vividly describe the methodical lurch toward a world where we grow comfortable outsourcing everyday life to AI—starting with the innocuous but eventually graduating to a level of dependence that portends danger. This

slippery slope is an obvious cause for concern, but we are tacitly assured that human action today can preserve AI's immense potential for tomorrow. At the same time, by uncovering the societal vicissitudes that could occur once the full force of AI is upon us, *Burn-In* effectively balances one's sense of optimism with a measure of apprehension. Those who see a future marked by human helplessness in the face of technological inertia would do well to read this book. For even in the future, human values can provide order to what could otherwise be an orderless world.

Through an evocative style, the reader faces an important question as the story develops: *Is the human who fears the machine or the machine that operates with uncontrollable levels of efficiency the larger threat? Burn-In* provides a range of perspectives to help answer this question—from the atavistic collection of human communities longing for the past to those who believe that a robot's probity far exceeds that of a human's. With respect to AI's potential, the writers describe machine-learning algorithms remarkably well. Moore's Law, stating that computer processing power doubles every two years, takes new meaning in these pages. The speed by which robots learn, process, and evaluate data is impressively depicted—so well, in fact, that the reader is left to question the human race's ability to handle AI efficiencies in a world where data is unavoidably ubiquitous. Equally impressive is *Burn-In's* compelling description of a future where humanity's propensity to engage in internecine warfare is the natural byproduct of a robotic rise. To be sure, the sweep of the story brilliantly examines what should drive both current and future debates over AI.

This novel is mostly confined to the physical world, a particular weakness in an otherwise highly readable book. After all, as trends suggest an inevitable merging of physical and cloud-based realities, one could consider a process of eversion whereby we live our lives primarily in the ether. On this score, *Burn-In* falls short of meeting expectations. The application of AI by our competitor states is a topic also left uncovered. Given that America's lead in the AI race is precarious today, Singer and Cole would do a service to policy makers by envisaging a world where a near-peer opponent merges its technological edge with authoritarian ends. In light of their literary record, one cannot doubt that the authors will explore this space in their next novel.

Importantly, the reader who benefits from this work will view current events headlines in a different light. Modern-day efforts like the Defense Innovation Board's recent release of the "Recommendations on the Ethical Use of Artificial Intelligence" report, as well as the Vatican's recently announced "Rome Call for AI Ethics," may otherwise go unnoticed; yet the benefactors of *Burn-In* will find these headlines hard to ignore. Indeed, one quickly realizes that these modern-day initiatives buttress the authors' implicit suggestion that commitment today will help us chart a path tomorrow. Turning today's initiatives into tomorrow's verities will be a monumental task, however—a notion also underscored in this well-timed book.

Anyone who endeavors to write about AI's potential impact runs the risk of being pilloried over speculation. However, a speculative style of writing is most certainly required to broach this pivotal topic, and it is the quality that makes today's science fiction genre resonate. Indeed, how can today's infantryman, pilot, submariner, lawyer, first responder, or teacher imagine a world run by robots without creative prose to keep us engaged? On this score, Singer and Cole clearly understand how to make the unintelligible understandable, and in *Burn-In* they deliver the best of contemporary science

fiction. Defense professionals, policy makers, and American citizens alike would do well to pick up a copy.

LTC Kirby "Bo" Dennis, USA

War in 140 Characters: How Social Media Is Reshaping Conflict in the Twenty-First Century by David Patrikarakos. Basic Books, 2017, 301 pp.

David Patrikarakos, an experienced journalist who has written about foreign affairs for many major publications, decided to write this book while reporting on the conflict in eastern Ukraine (p. 5). Patrikarakos argues that social media—comprising internet applications that allow users to create their own content—has greatly enhanced the power of individuals and networks of individuals at the expense of institutions such as legacy media and the nation-state (p. 9). The new species of technologically empowered human, which Patrikarakos dubs "Homo Digitalis," has harnessed social media during conflict and "irretrievably changed the way that wars are fought, reported on, and consumed" (p. 9).

Patrikarakos makes a persuasive case for his thesis by exploring how individuals, both outside of and within governments, used social media to influence three recent conflicts: the 2014 conflict between Israel and Hamas, the war between Ukraine and Russian-aided separatists, and the conflict between the Islamic State and the United States. Among the powerful aspects of Patrikarakos's approach is his profiling of how individuals on *both sides* of these conflicts employed social media. The reader learns how a Palestinian teenager used Twitter to draw global attention to the impacts on Gaza and its population during the 2014 conflict. Subsequently, Patrikarakos notes how the Israel Defense Forces (IDF) used social media to explain its targeting of Hamas's rockets and tunnel infrastructure as well as to show Hamas's placing of military targets close to civilian areas. For the conflict in eastern Ukraine, Patrikarakos profiles how a Ukrainian civilian innovatively used Facebook to crowdsource supplies and raise funds for the country's army, thereby becoming part of a "virtual state" (p. 129). Examining the other side, Patrikarakos provides a detailed account of a Russian internet troll factory, an outfit that was a "merry-go-round of lies" whose purpose was to bolster support in Russia and eastern Ukraine for the Kremlin's policies and to sow confusion globally about what was really happening (p. 142). Patrikarakos also profiles a third party to that conflict, offering a fascinating account of how Eliot Higgins, founder of the Bellingcat website, and a team of fellow sleuths used data obtained from social media to illuminate the events leading up to the shoot-down of Malaysia Airlines Flight 17 (MH17). Finally, Patrikarakos examines the Islamic State's social media operations as well as the United States' attempts to counter the group's efforts in cyberspace.

All of Patrikarakos's profiles are detailed, riveting, and enlightening. Collectively, they show how social media has altered warfare in major ways, notably including how it has become a means for battling to control the narrative surrounding conflict, equipping armed forces, analyzing what is happening on the ground, and recruiting fighters and supporters.

Patrikarakos's argument falls short only on those occasions when he seems to suggest that social media has superseded the physical battlefield as a domain of warfare. For example, Patrikarakos observed during his time in Ukraine that "it mattered more who won the war of words and narratives than who had the most potent weaponry" (p. 4). He suggests that "the narrative dimensions of war are arguably becoming more important than its physical dimensions" (p. 5). Patrikarakos also argues that "in war as traditionally understood, information operations support military action on the battlefield, but today, military operations are increasingly understood to support information operations" (pp. 259–60). Many readers are unlikely to conclude that the virtual battlespace has

surpassed the physical one in importance. After all, in all of the conflicts the book examines, physical battles remained critical. During the 2014 Israel-Hamas conflict, although the social media realm became a key arena in which Israel had to defend the proportionality of its actions, tweets and social media posts had minimal impact on Israel's goals; pressure from social media did not halt Israel's military campaign (pp. 35, 89–90). Even after reading Patrikarakos's illuminating account of a Russian internet troll factory, including the details that a former employee shared with Patrikarakos, many readers will likely judge that Russia's involvement on the physical battlefield was as important as its social media efforts to destabilizing Ukraine. Finally, in the case of the Islamic State, its propaganda benefitted considerably because the group "gained global infamy on the back of a series of startling military successes on the ground" (p. 244).

Nevertheless, the vast majority of readers will be persuaded by the more precise statement of the book's core thesis: social media has changed conflict in significant ways. For that reason, this book should be read by policy practitioners and scholars interested in understanding the nature of modern warfare. Professionals who have responsibility for national security should read it and use it to ask hard questions about whether they and their organizations are doing enough to harness social media to achieve their mission. Additionally, they should ponder whether they are doing everything they can to blunt the advantages that potential adversaries might accrue from the adept use of social media.

One question that David Patrikarakos does not explore is how social media might affect the course of any future interstate war. That is hardly surprising because the era of social media has been an age largely devoid of such conflicts. Nevertheless, that obviously does not guarantee that state-on-state conflict has ended for all time. How might states use social media during any such conflicts in the future, and how might social media affect outcomes? It would be fascinating to hear David Patrikarakos's answers to those questions because, with this book, he shows himself to be an insightful thinker and expert on how social media has altered warfare.

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