Thinking the Other Unthinkable

Disarmament in North Korea and Beyond

BY TOBY DALTON & GEORGE PERKOVICH

Livermore Papers on Global Security No. 8
Lawrence Livermore National Laboratory
Center for Global Security Research
July 2020

Thinking the Other Unthinkable

Disarmament in North Korea and Beyond

BY TOBY DALTON & GEORGE PERKOVICH

Livermore Papers on Global Security No. 8
Lawrence Livermore National Laboratory
Center for Global Security Research
July 2020

Livermore Papers on Global Security

# 1	Lewis Dunn	*Redefining the U.S. Agenda for Nuclear Disarmament* (2016)
# 2	Yukio Satoh	*U.S. Extended Deterrence and Japan's Security* (2017)
# 3	Dave Johnson	*Russia's Conventional Precision Strike Capabilities, Regional Crises, and Nuclear Thresholds* (2018)
# 4	John K. Warden	*Limited Nuclear War: The 21st Century Challenge for the United States* (2018)
# 5	Michael Nacht Sarah Laderman Julie Beeston	*Strategic Competition in China-US Relations* (2018)
# 6	Newell L. Highsmith	*On the Legality of Nuclear Deterrence* (2019)
# 7	Brad Roberts	*On Theories of Victory, Red and Blue* (2020)

Lawrence Livermore National Laboratory is operated by Lawrence Livermore National Security, LLC, for the U.S. Department of Energy, National Nuclear Security Administration under Contract DE-AC52-07NA27344.
ISBN: 978-1-952565-03-8 LLNL-TR-811808 LCCN: 2020911491 TID: 59565

Table of Contents

About the Authors

Toby Dalton is co-director of the Nuclear Policy Program and a senior fellow at the Carnegie Endowment for International Peace. Among his publications, he is author (with George Perkovich) of *Not War, Not Peace? Motivating Pakistan to Prevent Cross-Border Terrorism* (Oxford University Press, 2016), and he has testified on Pakistan's nuclear program before the U.S. Senate Foreign Relations Committee. From 2002 to 2010, Dalton served at the U.S. Department of Energy's National Nuclear Security Administration, including as acting director for the Office of Nuclear Safeguards and Security and senior policy adviser to the Office of Nonproliferation and International Security. He also established and led the department's office at the U.S. Embassy in Pakistan. Dalton previously served as a professional staff member to the Senate Foreign Relations Committee, a Luce Scholar at the Institute for Far Eastern Studies in Seoul, and a research associate at the National Bureau of Asian Research. Dalton received a Ph.D. in public policy from the George Washington University, an M.A. in political science from the University of Washington, and a B.A. in diplomacy and world affairs from Occidental College.

George Perkovich is the Ken Olivier and Angela Nomellini Chair and vice president for studies at the Carnegie Endowment for International Peace, overseeing the Technology and International Affairs Program and Nuclear Policy Program. He is author or co-author of *Toward Accountable Nuclear Arsenals: How Much is Too Much?; Adelphi Paper 396: Abolishing Nuclear Weapons; Universal Compliance: A Strategy for Nuclear Security; Not War, Not Peace?: Motivating Pakistan to Prevent Cross-Border Terrorism*, and *India's Nuclear Bomb*, which won the American Historical Society's Herbert Feis award and the A. K. Coomaraswamy Book Prize from the Association of Asian Studies. He is a member of the Japanese Foreign Ministry's Group of Eminent Persons for Substantive Advancement of Nuclear Disarmament, and an NGO advisor to the inter-governmental dialogue on Creating an Environment for Nuclear Disarmament. He served as a principal advisor to the Inter-

national Commission on Nuclear Non-proliferation and Disarmament, and has been a member of the National Academy of Science's Committee on Arms Control and International Security, and the Council on Foreign Relations Task Force on Nuclear Policy.

Brad Roberts has served as director of the Center for Global Security Research at Lawrence Livermore National Laboratory since 2015. From 2009 to 2013, he was deputy assistant secretary of defense for Nuclear and Missile Defense Policy. Prior to entering government service, Roberts was a research fellow at the Institute for Defense Analyses and the Center for Strategic and International Studies, editor of *The Washington Quarterly*, and an adjunct professor at George Washington University. He has a Ph.D. from Erasmus University, The Netherlands.

Preface

Brad Roberts

The P5 have defined nuclear disarmament as both a process and an end state. Differences of view about the latter are sharp, bitter, and abiding. This has stripped the discussion about the former of much of its potential content and value. Where might we get, practically and conceptually, if we were to set aside for now questions about the ultimate feasibility and desirability of the long-term goal and focus instead on the process? Further, what if we were also to posit that there will be no "fundamental transformation" of the international political system of a kind that would make the nuclear-armed states, and their unarmed neighbors, unconcerned about the effectiveness of mechanisms for peace and security in a disarmed and disarming world? In this context, might it be possible to give states the confidence they would require to take more ambitious incremental steps on the disarmament pathway? How could such steps contribute to the relaxation of international tensions that the NPT itself describes as a critical enabler of disarmament?

These questions motivate this timely and innovative new work by Toby Dalton and George Perkovich of the Carnegie Endowment for International Peace. Their core objective is to "infuse needed realism into disarmament discussions." Using North Korean disarmament as a test case, they explore a series of practical challenges and associated conceptual issues to frame a discussion of the possible disarming nuclear-armed states. They begin by rightly noting that neither the advocates of the Ban treaty nor the advocates of North Korean disarmament have set our practical agendas for achieving their aims. They conclude that without an infusion of realism the "two polarized blocks" will continue to "stonewall and repel each other" and thus that "the risks of global nuclear disorder will grow."

This is the latest in the series of Livermore Papers begun in 2017 to stimulate the development of new strategic thought on emerging nuclear challenges. Conceptually, it is a follow-on to the inaugural Livermore Paper by Lewis Dunn on disarmament pathways. The views expressed in these papers are those of the authors and should not be attributed to Lawrence Livermore National Laboratory or any of its sponsors.

Introduction

In September 2017, the Democratic People's Republic of North Korea (DPRK, or North Korea) conducted its sixth nuclear weapon test—a claimed hydrogen bomb with an explosive yield far larger than its previous tests of smaller, fission devices. United Nations (UN) resolutions condemned North Korea's actions and called on it to "abandon all nuclear weapons and existing nuclear programs in a complete, verifiable and irreversible manner." U.S. officials steadfastly insist that North Korea must agree to "final and fully verifiable denuclearization" if it wants relief from economic sanctions. That same month, the Treaty on the Prohibition of Nuclear Weapons (TPNW) was opened for signature. It calls on states possessing nuclear weapons to agree on "a time-bound plan for the verified and irreversible elimination of that State Party's nuclear-weapon program." One hundred and twenty-two states have signed it as of March 2020.

Remarkably, though, neither the governments attempting to negotiate with North Korea, nor the drafters of the TPNW, define in any detail what verifiable elimination of nuclear weapons and associated infrastructure would entail, whether in one country or in all. The TPNW stipulates that a disarming state eliminate or irreversibly convert "all nuclear weapons-related facilities," without enumerating which facilities those might be. Further, the treaty specifies that a "competent international authority" should verify whether nuclear facilities have been eliminated, after which the state would subject remaining fissile materials and facilities to safeguards by the International Atomic Energy Agency (IAEA). No nuclear-armed state, to our knowledge, has proffered a model for nuclear disarmament that it would demand of its adversaries and accept for itself. The oft-cited precedents of nuclear rollback—Libya, Iraq, and South Africa—offer little useful guidance because the nuclear and related capabilities they possessed were rudimentary compared with those of today's nine nuclear-armed states. Their relatively simpler programs mitigated concerns that they could quickly reconstitute militarily useful nuclear arsenals.

Of course, before any state agreed to and implemented disarmament, decisionmakers would have concluded that they and their societies would be better off dismantling nuclear arsenals than retaining them. Presumably, relations with adversaries would have improved and perceptions of threats that nuclear weapons are meant to deter would have diminished. Similarly, within each disarming state, decisionmakers would have overcome political-economic resistance to this course, at least temporarily. Under such conditions it is possible to imagine states agreeing on requirements of a shared disarmament regime.

However, current arguments for nuclear disarmament, whether of North Korea alone or all nine nuclear-armed states, generally do not stipulate that major changes in the political-security environment must occur first. The U.S. and others do not convey this to North Korea. Likewise, the TPNW and its promoters do not say this to China, France, India, Israel, Pakistan, Russia, the United Kingdom, and the United States. Instead, the message tends to be "disarm now."

Given the debates that are occurring today, it does little practical good to assume that internal and international circumstances will change so positively that states will agree to implement nuclear disarmament with little concern over their counterparts' capacities and intentions to renege on disarmament and nonproliferation commitments. Nor are nuclear-armed states likely to be moved by saying, "Just get on with disarmament and don't obsess over the details." In our view, collective understanding of current international nuclear politics and the realistic challenges of nuclear disarmament would be enhanced by exploring how to give the international community confidence that the risks of arsenal reconstitution would be manageable. If states find it in their interests to commit to dismantle their nuclear arsenals, then what would be the key benchmarks for assessing the progressive implementation of such a commitment?

Designing sustainable, effective nuclear disarmament—of North Korea or any other nuclear-armed state—requires much more than dismantling warheads and controlling fissile material stocks. Disarming states would need to collectively agree what types and numbers of delivery systems (especially missiles) would be permissible and not, as well as how to design a monitoring and compliance regime that would meet their ongoing security interests. Both nuclear-armed and non-nuclear-weapon states would need to determine what peaceful nuclear

and space activities may remain during and after nuclear disarmament, and under what reassurance/monitoring conditions. Quite possibly, at least some states would press for monitored limits on research and development activities vital to building or reconstituting nuclear arsenals. Each disarming state would need to provide confidence that its rollback commitment is durable and that it will not pose new security threats to others. Neighbors and potential rivals would need to reassure disarming states that relinquishing nuclear arms will not invite new threats against them.

It seems strange to explore these challenges today. No state is disarming or on the verge of disarming, even though the five nuclear-weapon states under the Non-Proliferation Treaty have committed repeatedly to do so. Russia and the United States—and to lesser extents China, India, Pakistan, and the DPRK—are adding new delivery and warhead capabilities to their arsenals. The main nuclear antagonists don't even engage in sustained dialogue on how to stabilize their competitions, let alone to eliminate their nuclear arsenals. All this is true. Yet the United States and other governments are unlikely to give up seeking meaningful constraints and rollback of DPRK nuclear capabilities. Similarly, non-nuclear-weapon states and advocates of the Prohibition Treaty are unlikely to stop insisting that nuclear-armed states do more to eliminate their nuclear arsenals.

This paper is motivated by the idea that thinking through and debating *what* would be involved in nuclear disarmament—and how it could be done in ways that would not make major warfare between states more likely—can constructively inform policy decisions that states are making now. More extravagantly, we believe that serious analysis and international discussion of the requirements for verifiably eliminating nuclear arsenals could help depolarize international nuclear politics. Clearly, the issues involved do not have easy or obvious solutions, regardless of whether one is an avid disarmer or deterrer. Yet if officials and analysts with varying preferences on the deterrence-to-disarmament spectrum would address these vexing issues constructively, they might identify steps that states could take to enhance everyone's security by addressing underlying international disputes, engaging in dialogue or negotiations to control the most destabilizing nuclear and non-nuclear weapons now being procured, and affirming the priority of avoiding escalatory warfare.

We acknowledge that some officials and influential commentators in nuclear-armed states believe the contrary: that exploring potential nuclear disarmament regimes in detail will intensify polarization and accomplish no good. This could prove true, but stonewalling such explorations also produces polarization and violates commitments made throughout the Nuclear Proliferation Treaty (NPT) review processes since 1995. The more haughty or obnoxious such stonewalling is, the more validated the advocates of prohibition feel in the righteousness and justness of their position.

We start the discussion by laying out a basic logic that could inform a denuclearization agreement with North Korea. Though most states still treat North Korea as a nonproliferation problem, Pyongyang increasingly uses arms control-oriented language to discuss the circumstances under which it would eschew nuclear weapons. There is utility, then, in thinking about this process in terms of managing North Korea's retention of nuclear weapons-related capabilities for an open-ended period, rather than wishing them away. These capabilities include nuclear energy production, conventionally-armed ballistic missiles, and a space launch program, among others.

Using the North Korea challenge to conceptualize what denuclearization could entail, we then explore comparable political and technical choices that would need to be made in the disarmament of other nuclear-armed states. We highlight six challenges that will shape negotiations on parameters for acceptable dual-use capabilities and activities that would remain during and after disarmament, as well as how they would be monitored. We do not pretend that a particular roadmap could be charted today; rather, we suggest how progress toward disarmament could be defined and assessed in light of challenges that are likely to exist. We then discuss the complexity of verifying disarmament and offer thoughts on reframing compliance requirements in a way that could improve the sustainability and durability of the disarmament process. Finally, we survey the often-avoided challenge of enforcing disarmament agreements. Our aim is not to provide the final word on these issues. No one can predict the political, security, and technical circumstances in which one or more of the nuclear-armed states move toward dismantling their nuclear arsenals. Rather, we offer an agenda to engage governmental and civil society experts in a more rigorous disarmament debate than has occurred in recent decades.

North Korea as a Test Case for Disarmament?

U.S. officials have wrestled with how to reverse North Korea's nuclear weapons ambitions since the George H. W. Bush administration. They have constantly called for North Korea to eliminate its nuclear weapon stockpile and related capabilities. Yet they have not conceptually or practically connected the disarmament of North Korea to the broader question of what a global nuclear disarmament regime might entail. Because North Korea is not a legitimate possessor of nuclear weapons, the United States and other nuclear weapon states (NWS) prefer to see the DPRK as *sui generis*, rather than a precedent for global disarmament.[1]

Nonetheless, a denuclearization agreement with North Korea could serve as a laboratory for thinking about and experimenting with approaches to nuclear disarmament in other states, too. This assumes that the U.S. will not pursue denuclearization of the DPRK by force and subsequent occupation of the country, which we presume would also be the case with disarmament of other nuclear-weapon states. Further, we assume that other states negotiating their own nuclear disarmament would seek security arrangements that are robust enough to give them confidence against cheating, even if they had previously improved relations with their former adversaries.[2]

1 International society certainly views North Korea's weapons as illegitimate, even if international law is not as clear regarding the meaning of North Korea's withdrawal from the NPT. North Korea withdrew from the NPT while it was in violation of its safeguards agreement with the IAEA, and was deemed non-compliant with its NPT obligations. Its continued possession of these weapons also violates UN Security Council resolutions.

2 The TPNW mostly elides these issues. Specifically, it does not address whether and how states would negotiate nuclear disarmament. It makes no reference to underlying security conditions and offers no redress other than to refer disputes to the UN Security Council (where five nuclear-armed states may veto any proposed action). And it prescribes a simple process for states that have decided to disarm to 1) declare this intention, 2) "cooperate" with an international authority to verify the irreversible elimination of the nuclear weapons program, and 3) conclude an IAEA safeguards agreement "sufficient to provide credible assurance of the non-diversion of declared nuclear material from peaceful nuclear activities and of the absence of undeclared nuclear material or activities in that State Party as a whole." *Treaty on the Prohibition of Nuclear Weapons*, Article 4(1), available at https://undocs.org/A/CONF.229/2017/8. Accessed May 27, 2020. As discussed in the verification section below, however, monitoring a disarmament regime will require more than assuring that there are no undeclared activities involving fissile material.

By sketching elements of a disarmament process that we think could minimally satisfy the U.S. and other interested parties, we hope to highlight key questions that any nuclear disarmament regime would confront. We do not venture to say here what incentives the U.S. and others would need to offer in order to reach agreement with North Korea. The point is simply that compromises will be required, as would be the case with the disarmament of the other eight nuclear-armed states. Some compromises will relate to security guarantees and military posture, others to technical capabilities.

Many of the challenges arise from the likelihood that even after disarmament, North Korea and the other nuclear weapon possessors will invariably retain some or even much of the knowledge, materials, and production capacity to reconstitute a nuclear arsenal. This was the case with South Africa, which in 1991 joined the NPT and transitioned from apartheid to democracy. After disarming, it retained over 800 kilograms of highly enriched uranium (HEU) of varying levels of enrichment, the technology for its uranium enrichment process, and presumably some of the enrichment machines and associated process equipment.[3] Disarming states would likely insist on retaining at least some capabilities that could enable them to reconstitute nuclear forces, and this likelihood shapes both the necessity and possible terms of the compromises necessary to achieve nuclear disarmament without war. (Some non-nuclear-weapon states may also insist on retaining nuclear hedging capabilities, which also bears on the types of infrastructure and activity permitted after disarmament.) Managing the potential that states could reconstitute nuclear weapon capabilities also defines key requirements of a disarmament verification regime.

In sum, where and when disarmament is negotiated (rather than unilaterally volunteered), the challenge will be to define acceptable arrangements under which key elements of a state's nuclear-related

3 On South African HEU holdings in 1991, see David Albright, "Highly Enriched Uranium Inventories in South Africa," Institute for Science and International Security (November 16, 2015). Accessed May 27, 2020. https://isis-online.org/uploads/isis-reports/documents/Highly_Enriched_Uranium_Inventories_in_South_Africa_November_2015.pdf. On the disposition of South Africa's enrichment program, see David Cliff, Hassan Elbahtimy, and Andreas Persbo, "Irreversibility in Nuclear Disarmament," VERTIC (September 2011), p83. Accessed May 27, 2020. http://www.vertic.org/media/assets/Publications/Irreversibility_Report_Sept_2011.pdf. The Klydon Corporation (https://www.klydon.co.za/), a spinoff from South Africa's Atomic Energy Corporation, aims to commercialize the aerodynamic separation technology utilized in the original Helikon uranium enrichment machines to separate isotopes for various industries.

scientific, technical, industrial, and military capabilities and activities can be removed, destroyed, curtailed, or monitored under a given disarmament regime. It will also be necessary to elaborate the conditions under which other military and dual-use capabilities and activities will continue.

To repeat our key political assumptions: the U.S. and others will not be able to dictate these terms to North Korea; they will emerge only from complex and multidisciplinary diplomacy. Presumably, others will not be able to dictate such terms in the future to China, France, India, Israel, Pakistan, Russia, the United Kingdom, or the United States. North Korea may pose unique challenges and be subject to greater pressure than the others would be, but the categories of technical issues to be negotiated will be similar, as will the metrics used to assess North Korea's progress toward denuclearization. (We freely admit that these assumptions may not be widely shared. One of our purposes is to encourage constructive debate on these issues.)

A "Firewall" Approach to Nuclear Rollback in North Korea

For nearly a decade, we and colleagues at the Carnegie Endowment have worked with nuclear weapons and missile experts from P5 countries to develop a generic model for distinguishing the technologies, materials, and activities that are most uniquely necessary for building and sustaining nuclear arsenals. The research centered on four technical categories, as well as the connections between them: fissile material production; nuclear weapons research, design, testing, and development; delivery vehicles and systems integration; and the incorporation of nuclear weapons into military operations.

Beyond the general categorization, which is fairly obvious, our project sought to identify specific technologies, materials, and activities—or combinations thereof—that experts believe most distinguish nuclear weapons-oriented enterprises from others. The rationale for this approach was threefold. First, focusing on a broader range of activities and behaviors can help clarify some of the political and technical lacunae in existing nonproliferation regimes which do not explicitly define the activities that comprise a nuclear weapons program. Second, embracing a broader definition of the proliferation/disarmament challenge corrects an overly simple preoccupation with fissile material acquisition. This allows for more nuanced assessment and treatment of states that have existing fuel cycle capability, especially non-nuclear weapon states. And third, strengthening nonproliferation instruments without getting into the highly politicized debates about peaceful nuclear rights enshrined in the NPT requires thinking more broadly about reassurance options beyond the fuel cycle, including in other technical domains pertinent to nuclear weapons development, such as nuclear-capable missiles.

The main analytic focus of our work was assessing and measuring prospective proliferation, not rollback and disarmament. However, the categories of underlying technology are the same. We termed this work a nuclear "firewall" that, like an internet firewall, would identify and aim to block the relatively few activities that have few plausible non-weapons purposes, reassure international society about sensitive

dual-use activities that could relate to weapons, and facilitate legitimate peaceful nuclear and space activity.[4]

A similar "firewall" logic can be applied to the technical elements of nuclear rollback and disarmament. The notion is to design a hypothetical filter through which nuclear weapon possessors must pass in order for other states to agree that a nuclear weapons program no longer exists in that state. That filter would look different for each state depending on, for instance, how it defines its security requirements, the status of its science and technology, its remaining nuclear energy and space industries, whether it has a closed fuel cycle, its stockpile of conventionally-armed ballistic and cruise missiles, and so forth. In other words, the point at which nuclear disarmament can be affirmed—when weapons no longer exist and remnant hedging capabilities are sufficiently monitored—will look different for North Korea than for India or the United Kingdom. Anticipating differences in how states might reach the disarmament filter, in turn, expands the space for compromises that can help sustain progress toward disarmament in each state.

Assessing Progress Toward Disarmament

States contemplating or beginning their own nuclear disarmament, as well as non-nuclear-weapon states, will want benchmarks to measure progress toward disarmament. The logic is similar to that which drove the international community to devise proliferation yardsticks for assessing how close a state is to acquiring nuclear weapons. There are different ways to measure this "distance" from acquiring weapons. The IAEA defines it in terms of "timely detection of the diversion of significant quantities of fissile materials."[5] The Joint Comprehensive Plan of Action (JCPOA) with Iran focused on "breakout" time, the time it would take to produce a sufficient quantity of fissile material to make at least one weapon. In both metrics, fissile material production remains the most important category of activity. This is one reason why IAEA safeguards on such materials are the primary tool for ensuring compliance with the nonproliferation requirements enshrined in NPT Article II.

4 Toby Dalton, Wyatt Hoffman, Ariel E. Levite, Li Bin, George Perkovich, and Tong Zhao, "Toward a Nuclear Firewall," Carnegie Endowment for International Peace (March 2017), available at: https://carnegieendowment.org/2017/03/20/toward-nuclear-firewall-bridging-npt-s-three-pillars-pub-68300. Accessed May 27, 2020.

5 International Atomic Energy Agency, "The Evolution of IAEA Safeguards" (1998), p52-3. Accessed May 27, 2020. https://www-pub.iaea.org/MTCD/Publications/PDF/NVS2_web.pdf.

In the case of disarmament, however, the objectives are to reduce and ultimately eliminate an extant nuclear arsenal. This encompasses not just nuclear weapons themselves, but also the infrastructure to produce and maintain the weapons, as well as the capacity to militarily (that is, physically) use the arsenal. The most important categories of interest are the nuclear weapons themselves (warheads and their delivery vehicles), the status of their deployment, and how the state organizes its military and political decision systems to use them. In relative terms, fissile material production and stockpiles should carry less weight in measuring progress toward disarmament, since these would (presumably) eventually be placed under IAEA safeguards. Uranium enrichment and plutonium separation capabilities are extremely important in states that possess zero nuclear weapons, but in states that have already acquired nuclear weapons and are either building up or reducing their arsenals, other capabilities and activities are at least as important, if not more, in assessing their technical and political commitment to disarmament.

Similarly, in proliferation analysis, the antidote for a state that has accumulated many of the necessary weapons technologies and is perceived as a breakout threat is to augment monitoring capabilities (in the case of the IAEA) or negotiate technical constraints on fissile material production and accumulation (in the case of some state-specific agreements). The JCPOA with Iran, for instance, sought to establish a 12-month breakout time through a series of quantitative and qualitative limits on Iran's uranium enrichment program. No analogous prescription exists for disarmament, however. Nuclear disarmament has never been achieved outside the unique case of South Africa, which disarmed itself and later provided unusually broad access to international inspectors to verify its lack of nuclear weapons and a broader weapons program. Given this lack of clear precedent, what steps (or stops) should be prioritized?

Phasing and Challenges in DPRK Denuclearization

Applying the "firewall" logic to a North Korea denuclearization roadmap suggests four phases of activity: a declared freeze, a verified cap, reduction, and then elimination. Given that past freezes on DPRK nuclear programs neither endured nor transitioned into serious dismantlement, the key phase from a negotiating standpoint is the second one, which we define as comprehensive, verifiable capping. This phase would introduce constraints and transparency requirements that are important in and of themselves and create the foundation for reduction and elimination activities to follow. Below, we sketch how the freeze and capping phases might proceed, leaving aside for now the rollback and elimination phases, which could commence once a verifiable cap is in place and political confidence in the durability of the process has been built.

Declared Freeze

The logic of starting with a freeze is simple, as attempting to roll back a nuclear weapon program that is still advancing will not work. A declared freeze should be comprehensive, covering the range of activities relevant to the production and maintenance of nuclear weapons.

Comprehensiveness is a crucial requirement when implementing a freeze, even if it can't be monitored with 100% confidence. This partly reflects the need to capture the breadth of activity in the four technical domains (fissile material, delivery vehicles, weaponization, and militarization) that contribute to both quantitative as well as qualitative improvement of the arsenal. It also reflects the logic that commitments to cease all weapons-related activity are a valuable early indicator of a country's intentions to reach the end state of disarmament. If North Korea rejected the inclusion of long-range missile production under the initial freeze, for instance, that would raise questions about Pyongyang's willingness to reach the harder stages of rolling back the program later. Comprehensiveness also creates a basis to question suspected violations. Intuitively, it makes little sense to permit an activity that violates the spirit of the agreement, but not the letter, simply

because it cannot be monitored with high confidence. In any case, as discussed further in the verification section below, there would also be a deterrence benefit to a comprehensive freeze, because North Korea would not know with certainty the national technical capabilities of monitoring parties—and thus the probability of escaping detection.

A declared freeze should cover, at a minimum, testing and production activity across the four technical domains. A freeze on testing could start with the moratorium unilaterally implemented by Pyongyang beginning in 2018, which covered nuclear explosions and long-range missile flights. To make it comprehensive, the freeze should also include proscriptions on static rocket engine tests and no-yield nuclear explosion experiments. A production freeze would cover nuclear-capable delivery vehicles (including components, fuels, and transport carriers), new warheads, and fissile materials. A fissile material freeze is a hallmark of any plan for the DPRK, but as noted above, our contention is that this matters less now than other elements. This is partially a reflection of the unknowns about the scope, scale, and locations of North Korea's uranium enrichment enterprise, and partially a perceived diminished importance of plutonium given the limited production capacity (as compared to what many analysts assume to be a larger capability to enrich uranium).

Monitoring a declared freeze would rely principally on "national technical means"—i.e., various sources of information and intelligence gathered by parties interested in North Korea's compliance from outside the DPRK's borders. It would not require on-site monitoring and inspection by the IAEA or other parties. Cessation of some activities would be easier to monitor remotely than others. For instance, fuel irradiation and reprocessing of plutonium at Yongbyon can be effectively monitored by outside parties using reconnaissance capabilities and thus can be a useful confidence-building step. However, overall confidence in compliance will be far from absolute. The point in this first phase is to build confidence that North Korea is implementing its initial, declared commitments, rather than rigorously verifying them (which comes in the second phase). Trading some compliance uncertainty for comprehensiveness up front seems worthwhile to build a broad foundation for the second stage of verified capping to follow.

Comprehensive Verifiable Cap

Once North Korea declared that it was implementing a comprehensive freeze, and the various parties to the agreement were satisfied that all commitments were being met (including, presumably, delivery of sanctions relief or other agreed steps), then the second phase could commence to establish a verified cap on the arsenal. The objectives in the capping phase would be to utilize on-site and other monitoring approaches to confirm the freeze, benchmark stockpiles and production capabilities, and verify that relevant facilities are not being used for further augmentation or improvement of existing weapons. Further, a verified cap would be intended to create the political and military stability necessary for future dismantlement of the program, with cessation of military activities involving nuclear-capable missiles. It would also begin to isolate the arsenal from the production infrastructure and reduce the readiness of nuclear forces.

A declaration would be a necessary element of a verified cap. (Other proposals have called for a declaration earlier, at the freeze stage, with some on-site monitoring.) The logic for delaying the declaration to the second phase would be to build initial confidence with North Korea that its decision to proceed to a verified cap of its program would not increase its susceptibility to military intervention. On numerous occasions in 2018–2019, North Korean officials rejected U.S. demands for a comprehensive declaration on the grounds that it would be tantamount to handing over a "target list."[6] That said, a declaration need not be finely detailed at first, even though it should be comprehensive in scope. Specific details—for example, stockpiles of items or materials in certain facilities—could be added in a cumulative manner, material by material, activity by activity, or site by site. Over time, inferential analysis with partial information could help to create a more complete picture. Monitoring measures could be introduced (and declared items or materials verified) sequentially according to the declaration method that was negotiated.

Monitored cessation of nuclear missile activity at military bases specifically would be a key additional element of the capping phase (going beyond monitoring production facilities). Verified restraints on

6 David Sanger and Choe Sang-Hun, "Two Years After Trump-Kim Meeting, Little to Show for Personal Diplomacy," *New York Times* (June 12, 2020).

the arsenal, leading ultimately to accounting and monitoring, would be a prerequisite to reductions in the third phase. Initial monitoring of the arsenal could be accomplished by national satellite reconnaissance of suspected sites to observe absence of movement, transitioning over time to near-site or on-site activities. For instance, North Korea could declare sites that contain nuclear missiles and/or warheads, after which monitoring parties could install perimeter and other observations systems around those sites to increase confidence that elements of the arsenal will not leave the premises.

Another element of the capping phase (that would probably take place nearer the end of the process), would be monitoring to affirm the separation of nuclear pits from warheads, warheads from delivery vehicles, and ultimately fissile material components from the warhead. Subsequently, accounting for these separated components would create a baseline for shifting into a reductions phase, when North Korea would begin to dismantle its arsenal according to agreed benchmarks leading toward zero.

The underlying logic in these initial phases could resemble the broader objectives of past arms control agreements. Starting with the U.S.-Soviet Union Strategic Arms Limitations Talks through to the existing New Strategic Arms Reductions Treaty, arms control agreements have sought to build predictability and stability, mitigate pressures that arise from crises and the arms race, and create security conditions that would permit deep reductions in nuclear arsenals. Notwithstanding the demise of most of these arms control agreements, and the myriad compliance challenges that occurred during their implementation, the agreements helped manage the arms race, facilitate arsenal reductions, and provide stability during the transition after the Cold War. These objectives are also useful in the context of DPRK denuclearization. In this instance, separation and reductions would diminish the readiness of the North Korean arsenal, create a "recessed" posture, and reduce the political and security salience of nuclear weapons. Each and all of these developments could advance progress toward denuclearization. Obviously, much here would depend on sustaining the positive incentives that would be needed to motivate the DPRK to pursue this course in the first place.

Challenges with "Permitted" Dual-Use Activities

It bears repeating: denuclearization involves not just eliminating nuclear weapons. It also requires making changes in the entire infrastructure that cohered to produce them, as well as altering the institutional, legal, and policy structures established to fund, sustain, and utilize them. Changes in most of these elements are feasible, but it is neither plausible nor, perhaps, even desirable to attempt to ban all technical activities outright. Many weapons-related activities could involve legitimate scientific or technical inquiry, not to mention industrial and commercial purposes. (If not, North Korea plausibly could assert this at the very least.) Similarly, the country might argue that some activities are critical to its future economic development or as a means for keeping weapons scientists employed. States preparing to negotiate with North Korea would want to anticipate these arguments in crafting their positions and plans.

Fundamental tensions exist here. A simpler arrangement would be ideal—one that did not leave North Korea with the capacity to reconstitute nuclear weapons. Unfortunately, we see no evidence that North Korea is prepared to negotiate and implement such a deal, or that the United States would be prepared to agree to terms that the DPRK might demand if it were interested (in principle) in the deal. Beyond that, the more non-weapons-related nuclear and missile activity that would be "permitted," the greater North Korea's capacity would be to reconstitute a nuclear weapons program in the future. On the other hand, if the DPRK will not relinquish much of its capabilities, establishing and monitoring limits on many of them (as opposed to a few) would deter breakout by broadening the range of activities that would violate an agreement if detected. Such an approach would also create opportunities to engage North Korean scientists and technical staff in benign spinoff enterprises.

As states negotiated through these tensions, a number of challenges would arise pertaining to which ongoing North Korean dual-use activities might be "permitted" in the areas of nuclear research, nuclear power, conventional missiles, and space launches. "Permitting" ongoing nuclear and missile activities like this would be politically very hard to swallow in Washington, Seoul, Tokyo, and probably also in Beijing. Yet there is likely no alternative, other than militarily destroying the relevant capabilities.

North Korea froze its plutonium activities under the 1994 Agreed Framework in return for the promise that an international consortium would supply two nuclear power plants. Pyongyang presumably accepted this arrangement both for the energy supply and to secure a demonstrable long-term commitment by the United States to peaceful relations. Later, after the Agreed Framework fell apart, the DPRK committed in the September 19, 2005 Joint Statement from the Six Party Talks to abandon "all nuclear weapons and existing nuclear programs." In the context of this commitment, Pyongyang stated that it "has the right to peaceful uses of nuclear energy. The other parties expressed their respect and agreed to discuss, at an appropriate time, the subject of the provision of [a] light water reactor to the DPRK." The talks broke down before this subject was discussed, but probably the other parties would have sought to supply fuel for the reactor in lieu of DPRK indigenous enrichment on the assumption that this would satisfy Pyongyang's appetite for a peaceful program. Negotiations with North Korea in 2018–2019 never reached the stage of discussing a peaceful nuclear quid pro quo. However, analysts expect any new agreement with the DPRK to again involve the provision of nuclear energy. The DPRK does not currently possess a nuclear power or fuel-cycle program that utilizes enrichment or reprocessing. This differentiates (for now) its future requirements from several other states with nuclear weapons (U.S., U.K., France, China, Russia, and India, in particular). There are no obvious "credible" needs for North Korea to retain those capabilities. Negotiators with North Korea will no doubt demand that fuel cycle capabilities be dismantled. Yet, it is plausible that North Korea will attempt to retain at least some functions—whether to extract more concessions or for purposes of domestic politics, prestige, and strategic hedging. For example, Pyongyang might argue that it should be permitted to transform its investment in centrifuge enrichment facilities into a capability to sell enriched uranium on the global market. Whether this is a sufficiently credible basis on which to agree to North Korea's retention of its enrichment capability will be a difficult issue for negotiators to grapple with.

North Korea's missile arsenal is sizable and diverse. Decades prior to acquiring nuclear weapons, North Korea already possessed a substantial conventional military capability that could turn Seoul into a "sea of fire," which proved sufficient for effective deterrence (to the extent

it was needed). Over time North Korea's delivery capability grew to include extended-range SCUD and other medium-range ballistic missiles that could be armed with conventional ordnance to target U.S. military bases in the region. These same missiles can also carry nuclear weapons. Assuming denuclearization of North Korea would not be the result of a reunification process, retaining conventional deterrence would be a necessary condition for North Korea to decide to eliminate nuclear weapons. The DPRK also would likely continue producing and perhaps even selling ballistic missiles for conventional military use up to some agreed range and payload limit. We assume it is theoretically possible to come to negotiate parameters of acceptable missile production and sales, but unlikely that North Korea would give them up entirely, at least early in a denuclearization process. Which should it be permitted to keep, and on what basis can they be distinguished from other weapons of mass destruction (WMD)-capable delivery systems?

One idea, suggested by Van Jackson, would combine range category and fuel choice.[7] He posits that North Korea could cease production and dismantle solid-fueled medium-range ballistic missiles (MRBMs), while retaining initially liquid-fueled nuclear-armed intercontinental ballistic missiles (ICBMs) that can reach the United States, and solid-fueled conventionally-armed short-range ballistic missiles (SRBMs) that can target South Korea. SRBMs and ICBMs are necessary for North Korea's conventional and nuclear deterrence, respectively, while MRBMs are less critical. Eventually, North Korea would dismantle the nuclear-armed ICBMs, leaving only conventionally-armed SRBMs, which would ultimately come under some type of numerical limitation and monitoring arrangement.[8]

Related to the missile issue, North Korea's space ambitions go back decades. It first attempted to orbit a satellite in 1998, and succeeded on its fourth attempt in 2012 when it placed an earth observation satellite in polar orbit. It subsequently launched a second satellite in 2016. Both successful launches utilized the *Unha-3*, a three-stage liquid-fueled rocket. Though its space program is rudimentary, North Korea is none-

7 Van Jackson, "Risk Realism: The Arms Control Endgame for North Korea Policy," Center for a New American Security (September 14, 2019). Accessed June 2, 2020. https://www.cnas.org/publications/reports/risk-realism.

8 North Korea currently possesses two short-range anti-ship cruise missiles, neither of which are suitable for carrying nuclear weapons. It could retain these provided it does not convert them for land-attack roles or develop, test, or deploy additional cruise missiles for that purpose.

theless now a spacefaring nation. Negotiations could explore whether North Korea would forego an independent launch capability, perhaps in exchange for access to launch services and payload development assistance. However, perhaps as a matter of national pride, if not also commercial and military necessity, North Korea is likely to sustain its space ambitions during denuclearization. Here, too, negotiators would have to find ways of distinguishing permissible space activities—and developing associated monitoring and reassurance provisions—from those that could have WMD delivery applications.

For all these dual-use activities, monitoring will be exceedingly difficult. Few established contemporary protocols and tools exist. For example, there is no standard approach to monitoring compliance with missile production limitations, let alone tracking existing missiles at military bases to ensure they have not been modified to exceed agreed limits.[9] Supplementary methods to monitor permitted and ongoing nuclear and missile activities would require creativity in design and negotiation. Standard tools—for example, IAEA safeguards and end-use checks on imported dual-use goods—are necessary components, but alone are insufficient to build the layered approach to monitoring that generates confidence in compliance over time. International cooperation with ongoing peaceful programs could provide additional insights into those activities. Another plausible and highly useful tool (that could be used to improve confidence that sanctions relaxation would not be mis-used for covert procurement) would be an import/export trade monitoring regime, which could be implemented at the relatively small number of ports of entry for goods entering and exiting North Korea. Such a regime would necessarily require active and sustained participation by North Korea's neighbors, as well as authorities at other ports frequented by North Korean trading vessels.

9 The U.S.-Soviet Union Intermediate-Range Nuclear Forces Treaty included on-site monitoring at one missile production facility in each country. This was designed and negotiated in the mid-1980s, in the context of reciprocal commitments. Presumably a contemporary approach for North Korea would involve more modern technologies and not be constrained by reciprocal access to U.S. facilities. For some additional ideas on missile monitoring in North Korea, see Joshua H. Pollack, Miles Pomper, Ferenc Dalnoki-Veress, Joy Nasr, and Dave Schmerler, "Options for a Verifiable Freeze on North Korea's Missile Programs," CNS Occasional Paper #46 (April 2019). Accessed June 2, 2002. https://www.nonproliferation.org/wp-content/uploads/2019/04/options_for_a_verifiable_freeze.pdf. During the UNMOVIC operations in Iraq, its inspectorate developed ideas for an improved missile verification regime that could be useful in North Korea. See "Twenty-eighth quarterly report on the activities of the United Nations Monitoring, Verification and Inspection Commission in accordance with paragraph 12 of Security Council resolution 1284 (1999)," United Nations Security Council, S/2007/106 (February 23, 2007), p6-14. Accessed June 2, 2020. https://www.un.org/Depts/unmovic/new/documents/quarterly_reports/s-2007-106.pdf.

Looking Beyond North Korea

The North Korea case highlights a fundamental challenge for disarmament negotiators: to define mutually acceptable and technically viable means for *denuclearizing* military capabilities and *de-weaponizing* nuclear research and energy enterprises. Both parts are necessary; neither alone is sufficient.

Disarmament is a physical and political process that is more likely to reach fruition if it follows a strategic logic. Technical steps should address and inform political requirements and vice versa. Disarmament of all nuclear-armed states likely could be designed according to a logic similar to that discussed above for North Korea: a comprehensive freeze; a verified cap with declarations and monitoring; reductions; and elimination. We explored the first two phases in some detail above. The latter two phases are also crucial, but for the sake of simplicity we skip over them and instead set out a high-level description of a comprehensive phased process.

The first phase could involve a declared, comprehensive freeze: an end to quantitative growth and qualitative improvement (modernization) of existing arsenals in order to demonstrate the intent to carry on with the harder phases to follow. This requires parties at a minimum to define all relevant elements of arsenals, such that future declarations of holdings would use consistent categories and terminology.

Second, states could provide initial declarations and facilitate the international monitoring of frozen activities that would lead to a verified cap. During this phase, parties could also define and negotiate which multiple-use capabilities, activities, and technologies would be permitted in both the capping phase and after disarmament is achieved. This list could include, for example, nuclear fuel-cycle facilities and material production, as well as size and composition of fissile material stocks; conventional missile development, testing, and deployment; space-launch vehicle programs; nuclear scientific research and development; and organizational attributes for such programs to facilitate transparency.

In parallel, parties would probably need to define how to monitor and verify that the states undergoing the disarmament process are implementing the defined cap, that nuclear arsenals are separated, and that prohibited activities are stopped, while permitted activities are within accepted parameters.

Third, once the arsenal has been comprehensively defined, capped, and subjected to monitoring, and the elements that will persist during and after disarmament are agreed upon, the process of dismantling the capabilities that are to be disarmed could begin and proceed on an agreed timeline. (Some activities could begin sooner under appropriate monitoring, such as the disposition of excess fissile materials.)

An early priority in the dismantlement phase would be to disconnect (separate) the most dangerous elements of each arsenal from the other capabilities that enable their use, namely missiles from transport vehicles, warheads from delivery vehicles, fissile material cores from warheads, and so on. This process would be inherently more credible—to both disarming states eyeing their adversaries and to the international community—if the primary focus of capping activities is nuclear weapons themselves and not merely their production infrastructure.

Finally, parties would need to agree on procedures and technologies for verifying the dismantlement and disposition of all these elements, and for sufficient monitoring of each state to maintain confidence that permitted sensitive activities in the nuclear and space domains would serve purely conventional military or civilian purposes.

Enforcement provisions will also be an important subject of negotiation among nuclear-armed states, and perhaps others, at some point, as we will discuss near the end of this paper.

As the North Korean case study amply attests, these phases bring with them a set of hard practical questions. Especially in the later phases, these questions require disarming states as well as monitoring parties to come to grips with significant new conceptual challenges. The following analysis highlights and explores six of these challenges, all of which relate to some aspect of the basic problem: by design and out of perceived necessity, disarming states would retain during and after disarmament significant military, nuclear, scientific, and industrial capabilities that could enable them to reconstitute nuclear weapons as a hedge against a breakdown in the disarmament process.

How to measure disaggregation of an existing arsenal?

One useful metric for progress toward nuclear disarmament would be the separation of the most dangerous elements of arsenals from their enabling capabilities. Such separation can occur physically and/or institutionally, by transferring custody of warheads or fissile materials to other governmental bodies, for instance. Such transfers could provide one way to measure progress toward disarmament before the verified physical dismantlement or destruction of warheads and delivery vehicles would begin.

Separation would involve declarations and the accounting of warheads and their relevant components, especially fissile material pits, as well as a system for monitoring them, even as the state continued to possess them. It could also entail steps to diminish the perceived coercive utility of nuclear weapons, such as confining them to specific bases and, over time, reducing the number of sites at which they are stored. Such steps are a central feature of the capping concept for North Korea.

Negotiated transparency would be required for separation to have both technical and political meaning. Transparency is often boiled down to declarations and on-site inspections. These tools are highly useful and indeed necessary. But they also provoke considerable sensitivity on the part of the inspected state given how intrusive such measures can be and the types of information potentially revealed to adversaries. Relatedly, the competent authority designated to monitor and verify separation would need to address potential proliferation concerns that could arise given the information gleaned from the disarming state.

How to separate the arsenal from its production/maintenance infrastructure?

A broader, longer-term objective for separation would be to identify and then sever links between the arsenal and the capabilities necessary to maintain and deploy (or reconstitute) it. Such surveying—literally, identifying the institutional, bureaucratic, technological, material, and personnel relationships between different elements of the weapons program—would permit the monitoring of links between some dual-use activities, such as the manufacturing of rocket fuel, and the arsenal during the period in which the disarming state retained weapons. Surveying the military complexes would also build the foundation for

subsequent actions to verify the disposition of nuclear weapons and associated delivery systems and fissile materials. Finally, surveying could be useful in benchmarking parameters of permitted activities in each of the technical domains.

As the extant arsenal is isolated and monitored, production of new capabilities would be capped. This would begin to degrade the arsenal's readiness, as well as the disarming states' confidence in the reliability of the remaining arsenal. Modernization or qualitative improvements would become harder and costlier to undertake, while reconstitution timelines would lengthen if the disarming states opted to pause or abandon the disarmament process.

However, degradation of arsenal readiness also raises an interesting question about safety and security, at least for weapons that have not yet been separated into fissile and non-fissile components. On the one hand, degraded readiness would be desirable, such that weapons eventually must be taken out of service if components or materials need to be replaced. On the other hand, there could be risks (including accidental detonation) if weapons were not actively maintained. (This may be less the case for the decades-old arsenals of other nuclear-armed states than for North Korea.) How to define permissible maintenance for safety versus non-permissible maintenance for readiness could be a significant technical and monitoring challenge. States would need to decide on acceptable and credible arrangements for monitoring the status of a capped nuclear arsenal, including remote vs. on-site procedures, with all the complexity of introducing additional people and equipment around nuclear weapons.

How to deal with dual-use weapons research and development activity?

Researchers in states without nuclear weapons are not barred (according to current international interpretations of NPT's Article II) from undertaking a broad range of scientific inquiry into many of the technologies and principles that are necessary to produce nuclear weapons, even if these inquiries raise suspicions. Such research might involve, for instance, calculating equations of state for transuranic elements, modeling implosive systems, testing shaped charges, or developing high precision detonation systems. These activities all have other scientific or conventional military purposes. However, once a state has

produced a nuclear weapon, these kinds of activities must necessarily be considered no longer legitimately dual-use. The applicability of these activities to weapons use would be of paramount concern, even if they also have non-weapons applications. This rubicon cannot be uncrossed. A disarmament process theoretically could stipulate that nuclear-armed states destroy their nuclear weapons design and related information. What that would mean in practice, especially for verification, is an especially difficult problem.

Even if dual-use activities clearly contributed to a nuclear weapons program, states would likely not forego all such scientific or technical R&D activities. Rather, they would insist on being able to conduct those that are necessary for non-nuclear weapons purposes. National nuclear laboratories, for example, perform basic and applied research on nuclear weapons science. Many of these labs also work on non-weapons-related activities, often in partnership with universities. States could choose to shut down these labs, though that may be politically difficult.

Elucidating principles for distinguishing between permissible activities during and/or after disarmament, and those that should be proscribed, would be politically and technically complex. Principles would need to be sufficiently flexible to allow for variation among states based on industrial, military, or other scientific capacities, and perhaps institutional or bureaucratic factors. Principles could be formulated with the understanding that monitoring all activities occurring in research labs for proscribed work is neither possible nor probably desirable, simply because the ratio of costs to marginal reassurance value is very likely poor. A likely impediment is the desire by states to continue "defensive" nuclear research.[10]

Monitoring dual-use R&D activities that satisfy agreed upon principles would be a clear challenge. The TPNW envisions IAEA safeguards as one part of this answer, but there are limitations at least with the current standards of IAEA safeguards and their focus on assessing the completeness and correctness of a state's nuclear declarations. In practice, additional modes of assessment for the broad range of dual-use activities involved in nuclear weapons programs would be required. For instance, monitoring parties might also assess the compatibility of indi-

10 This was the case with past cases involving the rollback of nascent nuclear weapons efforts, as well as the dismantlement of established chemical and biological weapons programs.

vidual activities with their stated permitted purpose, the consistency of a program with agreed attributes of credible non-weapons applications, and whether there is a cohesion of disparate activities that are needed to reconstitute nuclear weapons.[11]

An additional approach would be to assess the compatibility and consistency of a state's activities with the benchmarks and best practices established by industries that utilize dual-use activities or materials. Does the stated non-weapons use of these activities or materials conform with patterns normally seen in applications with no plausible connections to nuclear weapons? For instance, a disarming state that wishes to retain work on neutron generators for industrial purposes could be expected to exercise both domestic and international transparency and comply with regulations related to those industries.

A third analytic approach could involve the use of a broader array of contextual indicators to help assess compliance with agreed delineations of permitted activities. For instance, involvement of military institutions in nuclear research and/or fuel cycle activity could raise flags. Conversely, implementation of international safety, security, and liability standards and practices, such as peer review, could underscore the legitimacy of permitted programs. Over time, these and other analytic approaches could help guide the separation of weapons from non-weapons activities, as well as improve confidence that ongoing activity does not serve covert programs.

How to manage ongoing peaceful or non-weapons nuclear activities?

If peaceful nuclear activity during and after disarmament is necessary for North Korea—for reasons of energy security, prestige, domestic political buy-in, and so forth—it could be even more so in the case of the other states with nuclear weapons, all of which have large (and in several cases growing) nuclear industries that span electricity generation to isotope production. Some nuclear-armed states maintain a clear separation between civil nuclear industries (whether private or state-owned) and nuclear weapons programs. In many instances, civilian nuclear power reactors and associated facilities are made available

11 The Carnegie Firewall report described how this analysis could be used in diagnosing prospective proliferation. Dalton et al., "Toward a Nuclear Firewall," p8.

for IAEA safeguards, even if the IAEA does not apply safeguards to these facilities. There are gray areas, however, and clearer principles to guide a clean separation during and after future disarmament would be useful.

Some of the gray areas were illuminated during the negotiations between the U.S. and India to define how India would separate its peaceful, civilian nuclear program from its military program under the 2005 bilateral nuclear cooperation initiative. Initially, U.S. negotiators argued that as a matter of principle India ought to declare 1) any nuclear reactor producing electricity and connected to the electrical grid (and place the facility under safeguards), and 2) any upstream (uranium fuel manufacturing) and downstream (spent fuel handling) facilities.[12] India rejected this position and instead advanced a piecemeal approach that was ultimately accepted by the United States. Several unsafeguarded reactors deemed not civilian by India remained connected to the grid (which, at least in theory, could then simultaneously produce plutonium for nuclear weapons). India will decide whether future reactors that may be grid-connected should be deemed civilian and placed under safeguards on a case-by-case basis.

The U.S.-India deal revealed the political difficulty of establishing clear principles for defining civilian facilities. One lesson from this experience is that disarming states would not agree to more restrictions on their fissile material activity than is demanded from states that never sought nuclear weapons. Indeed, it seems likely that disarming states would try to retain as much technology and capability as possible, probably more than they would accept in non-nuclear-weapon states. The South Africa precedent here is notable in that it retained both HEU stocks and enrichment technology, despite having no developed civilian purpose for either.

In theory, it is possible to identify ways to clarify that new civilian facilities are exclusively peaceful. Mostly these relate to reactor operations and fuel cycle capabilities. Other peaceful nuclear applications (for example, isotope production for medical or industrial purposes) could be addressed in ways that raise fewer breakout concerns. Some plausible initial principles might include the following:

12 Dinshaw Mistry, *The US-India Nuclear Agreement* (Cambridge: Cambridge University Press, 2014), p67.

- Current civilian facilities should remain civilian.
- No new non-peaceful facilities should be constructed.
- No material should be removed from the civilian ledger once it is declared and under safeguards.

Applying these principles to legacy facilities and activities would be more difficult but should be feasible over time. Some capabilities could be required during disarmament—for example, the downblending of fissile material in a criticality-safe environment, if dilute-and-dispose options are not readily available. However, materials and activities that have few credible purposes in that state other than for nuclear weapons should be subjected to special monitoring and phased out early. For instance, nuclear-weapon-possessing states should cease work with metallic fissile materials, except for use in established peaceful reactor programs that require metallic fuel. Disarming states should also phase out the use of HEU and plutonium for any purpose. These materials should be separated and placed under safeguards as soon as practicable, given the importance they could serve for a decision to reconstitute nuclear weapons.

Probably the most difficult issue in managing ongoing civilian nuclear activity during disarmament is how to handle the full fuel cycle. (This problem is well known in cases of prospective proliferation.) It would be implausible to immediately ban fuel cycle activity in disarming states, just as it is for non-nuclear-weapon states. A progressive ban over a decades-long timeline seems more feasible. All nuclear weapon possessing states have some fuel-cycle capability, and there are multiple reasons that they might want to retain it in the near term that have nothing to do with nuclear weapons hedging. Indeed, entrenched political and technical constituencies in those states—just as in many non-nuclear-weapon states today—are likely to advance a variety of arguments for retaining these capabilities. For instance, in states with large nuclear power sectors, the capability to enrich uranium is often argued to be economical and provide some sense of energy security. Other states might pursue spent fuel reprocessing as a technical solution to the political challenges associated with spent nuclear fuel, such as siting a repository.

Whether these rationales have technical merit or not is beside the point, since it seems likely that many non-nuclear-weapon states would similarly reject further constraints on their ability to pursue fuel cycle capabilities. Some states could opt to retire outdated fuel-cycle facilities during disarmament, while others could wish to expand them. Currently, some states continue reprocessing spent fuel, while others stopped the practice and are unlikely to restart. Several nuclear weapon possessors operate enrichment facilities that supply the global market. Without major growth in demand for enrichment services, the commercial viability of new or converted national enrichment facilities brought to the international market would be questionable, at least without sizable and enduring governmental subsidies. But history in several countries indicates that economics do not determine fuel-cycle policies.[13]

Although fuel-cycle decisions seem likely to be made on a case-by-case basis among disarming states, ideally it would be possible to agree on a principle that requires fuel-cycle capability to be scaled to credible peaceful applications.[14] This type of commensurability principle was included in the 2013 Joint Plan of Action with Iran, under which it agreed that its enrichment program would be defined by "mutually agreed parameters consistent with practical needs." Such a principle would limit the scale of fuel-cycle capabilities while also endowing those capabilities with additional legitimacy.[15] Enhanced monitoring of fuel cycle facilities would still be required, of course.

How to distinguish conventional military from nuclear weapons delivery vehicles?

Just as North Korea may insist on retaining missiles up to certain range and payload capabilities for "conventional military purposes," so too might other nuclear-armed states. The alternative—banning all mis-

13 Japan's commitment to reprocessing spent nuclear fuel is a case in point. See James M. Acton, "Wagging the Plutonium Dog: Japanese Domestic Politics and Its International Security Implications," Carnegie Endowment for International Peace (September 29, 2015). Accessed June 2, 2020. https://carnegieendowment.org/2015/09/29/wagging-plutonium-dog-japanese-domestic-politics-and-its-international-security-implications-pub-61425.

14 Ariel E. Levite and Toby Dalton, "Leveling Up the Nuclear Trade Playing Field," Carnegie Endowment for International Peace (September 7, 2017). Accessed June 2, 2020. https://carnegieendowment.org/2017/09/07/leveling-up-nuclear-trade-playing-field-pub-73038.

15 One interesting issue relates to whether states could agree to the reprocessing of spent fuel (using a specific technology that does not result in a plutonium stream or with prescribed throughput) on a "commensurate" basis. This may be more politically feasible than seeking an outright ban on reprocessing.

siles—would have to apply to all states, not only those that have or had nuclear weapons. Distinguishing between nuclear and missiles for delivering conventional weapons solely on technical grounds seems quite difficult. The most widely accepted distinction is the Missile Technology Control Regime (MTCR) category 1 limit of 300 kilometers (km) of range and 500 kilograms (kg) of payload. However, North Korea might plausibly argue that it needs missiles that range beyond 300 km to target, for instance, U.S. forces in Guam located over 3,000 km away. All other states that possess nuclear weapons also have missiles with ranges in excess of 300 km and can articulate similar conventional munition targets for them. The MTCR may remain a useful instrument for slowing the spread of missile technologies, but focusing solely on range and payload limitation seems to be less useful in guiding a disarmament process.

Fuel choice is another possible basis for distinguishing permissible from impermissible ballistic missiles. States with nuclear weapons tended to first develop liquid-fueled missiles, followed later by solid-fueled missiles. The latter are better suited for nuclear postures that require greater mobility and readiness, since they can be stored for longer periods with low maintenance and readied for launch faster than liquid-fueled rockets. North Korea is transitioning its medium-range missile arsenal from liquid to solid fuel. On its current development trajectory, Pyongyang will eventually achieve a solid-fueled ICBM. Yet, the characteristics that make solid-fuel missiles well suited to nuclear delivery are also useful for conventional military operations. This is evident in ongoing deployments: the Russian Iskander and the North Korean KN-23, for example. China utilizes at least one of its solid-fueled missiles, the DF-26, in both nuclear and conventional military missions. These examples indicate that a distinction on the basis of fuel can run into practical challenges.

One path through this thicket might entail something akin to a global Intermediate-Range Nuclear Forces (INF) treaty. Under a disarmament regime, nuclear-armed states might similarly pursue a progressive ban on certain range classes of missiles (ballistic, cruise, or boost-glide), combined with numerical limits on those that remain. This would permit flexibility for disarming states—at least for a defined period—to determine an appropriate mix of offensive and defensive missiles within these limits that are suited for its unique deterrence requirements.

How to manage peaceful civilian space activities?

Nearly all states that possess nuclear weapons are active in space. As with North Korea, how could such ambitions be managed in the context of global disarmament, given that the technology base for space launch programs is effectively the same as that required for launching nuclear-armed ballistic missiles?

Obviously, dual-use space activities can serve as a cover for ballistic missile development.[16] Just as the NPT permits peaceful nuclear activity that could easily yield fissile material for nuclear weapons, the MTCR attempts to both restrict missile proliferation and facilitate legitimate space activity. The MTCR Guidelines reflect this dilemma, stipulating that the regime is "not designed to impede national space programs or international cooperation in such programs as long as such programs could not contribute to delivery systems for weapons of mass destruction."

However, once a country has already developed long-range missiles, the proliferation concern about that state changes. Presumably there is little more it would learn from ongoing space activity that would improve existing ballistic missile programs. After disarmament, it could be plausible to transform a Satellite Launch Vehicle (SLV) into an ICBM, though not without some technical risk and questions about whether this could be done reliably without detection.[17] A more pressing concern, at least in the North Korean case, is proliferation of space and missile technologies *from* that state if it is not adhering to MTCR technology transfer guidelines.

Thus, the question really boils down to whether the given space program would be credible as such, and whether space launch vehicles stockpiled as a hedging capability could be easily converted to nuclear weapon delivery systems.

Some common hallmarks of peaceful space programs could help distinguish them from ballistic missile programs. These indicators are more contextual (how the program is set up and operated) than technological. Contextual indicators include: a separate, civilian-run space

16 Some contemporary space launch programs utilize liquid cryogenic engines, which are less suitable for nuclear delivery purposes, but others use solid fuel engines that could also power ICBMs.

17 Michael Elleman, "Why Iran's satellite launch does not amount to an ICBM test," International Institute for Strategic Studies (January 17, 2019). Accessed June 2, 2020. https://www.iiss.org/blogs/analysis/2019/01/iran-satellite-launch.

agency and domestic regulatory framework; participation in international space fora; satellite payload development programs; and an array of ground receiving stations. Space programs without these attributes should raise credibility questions.

There are a few contextual and technical differences between ballistic missiles designed to deliver nuclear weapons and rockets designed to launch satellites that could be exploited to help address this issue. However, most of these differences are likely to be difficult to detect or measure remotely. During disarmament, international best practices for space launch could be sharpened in order to accentuate technical and contextual differences, making ballistic missile enterprises potentially easier to distinguish. For example, states could agree not to produce engines that exceed a gravitational force equivalent of 5, which are generally harmful to the sensitive instrumentation in satellite payloads as compared to more rugged nuclear re-entry vehicles that can withstand higher gravitational forces and heat. Similarly, space launches could be required to maintain unencrypted telemetry to permit monitoring, while re-entry tests could be banned. Further, a space launch transparency or reassurance regime could utilize these and additional distinctions as a means of more clearly differentiating between purposes.

Verification and Enforcement

Beyond the conceptual challenges described above, two additional disarmament problems merit deeper consideration: verification and enforcement.

Reconceptualizing Verification

Verifying compliance with a disarmament agreement could well be the most vexing issue for negotiators, assuming that the states involved had not previously achieved friendly political-security relations analogous, say, to the European Union. It is difficult to build mutual confidence that adversaries (even former adversaries) are implementing restraints without having these adversaries divulge potentially sensitive information. The complexity of this challenge can be found in the voluminous technical annexes that accompany U.S.-Russia arms control treaties, and the record of contentious negotiations over the reach of the IAEA Additional Protocol for safeguards, among other agreements. The record of compliance disputes with North Korea underscores the danger that acrimony over verification provisions can quickly stop progress and even lead to the downfall of agreements.

In June 2018, on the eve of the U.S.-DPRK Singapore Summit, seven U.S. senators, all Democrats, sent a letter to President Trump enumerating standards by which they would evaluate any agreement to emerge from the meetings.[18] These included:

- no "sanctions relief for anything other than the verifiable performance of its obligations to dismantle its nuclear and missile arsenal";
- "a full, complete and verifiable declaration of all its nuclear activities";
- "robust compliance inspections including a verification regime for its nuclear and ballistic missile programs"; and

18 Letter to President Trump by Senate Democrats (June 4, 2018). Accessed June 2, 2020. https://www.foreign.senate.gov/imo/media/doc/06-04-18%20Menendez%20joint%20letter%20to%20Trump%20on%20NK%20Summit.pdf.

- "'anytime, anywhere' inspections, including of all non-declared suspicious sites."

Regrettably, U.S.-DPRK discussions never progressed to the point where these (infeasible) objectives could be negotiated. According to reported comments, DPRK officials rejected most of them. If North Korea would not accept these provisions in a denuclearization context, it seems reasonable to expect that other states with nuclear weapons might also object to them in future disarmament negotiations. It is hard to imagine that any sitting U.S. senator or Russian Duma member would vote for a treaty, for instance, that offered potential adversaries "anytime, anywhere" inspections at any "non-declared suspicious sites" in their countries. Therefore, in disarmament negotiations politicians and policymakers will struggle to balance the intensity of surveillance and inspections they want of others and requirements which they would be willing to accept in their own lands.

Awareness of these political tensions animates contemporary work such as that undertaken by the International Partnership for Nuclear Disarmament Verification (IPNDV). That group focuses specifically on the steps involved in the physical dismantlement of warheads, as well as plausible concepts and technologies that could be utilized for monitoring and verification during the elimination phase of disarmament.[19] This work builds valuable knowledge and creates space for constructive discussions between states with and without nuclear weapons. Yet disarmament verification will have to go beyond warhead dismantlement. And when it does, people will be compelled to realize that achieving 100 percent confidence is impossible.

The standard approach to verifying nuclear agreements involves monitoring a few key activities with technologies that deliver a very high—say, greater than 95 percent—probability of detecting non-compliant behavior. The objective is to achieve a high probability that the monitoring system would detect cheating in every monitored activity. For instance, the IAEA utilizes a suite of containment and surveillance tools for safeguards implementation at declared nuclear facilities that give it a high probability of detecting diversion of nuclear material in

19 More information about IPNDV is available at: https://www.ipndv.org/about/project-phases/. Accessed June 2, 2020.

such a facility. Similarly, the United States and Soviet Union utilized perimeter portal monitoring and on-site inspections to gain mutual confidence that neither was producing banned missiles at one declared facility in each country under the 1987 Intermediate-Range Nuclear Forces Treaty. In both cases, however, these monitoring approaches yield little confidence in detecting non-compliant activity at *undeclared* facilities.

Verifying disarmament cannot be boiled down to just a few, high-confidence activities taking place at a small number of declared facilities.[20] States would require confidence that adversaries were reducing and eliminating nuclear weapons at declared facilities (not hiding weapons, equipment, or materials at undeclared facilities), and stopping other research, development, and production activities that support nuclear weapons at declared facilities and *any place else*. If a disarmament agreement proscribed or at least regulated activity in all of the disciplines involved in nuclear weapons, shouldn't the associated verification system monitor all of these relevant activities?[21]

The South Africa case illuminates the magnitude of the disarmament-confidence problem.[22] South Africa produced close to 1,000 kg of HEU at the Valindaba Y-Plant, from which it made six and a half nuclear bombs. In 1990, the South African government decided to dismantle its nuclear weapons program and, a year later, join the NPT. It aggregated its HEU from dismantled weapons, decontaminated weaponization facilities, dismantled productions facilities, and collected and destroyed most of the program documentation, save for some of the production plant's operating records. In 1993, it declared its prior nuclear weapons and gave complete access to IAEA inspectors to verify the absence of a weapons program.

Despite the highly cooperative South African approach, the IAEA could not produce a fully reconciled material balance. Inconsistent operations at the Y-plant and excessive process losses resulted in large HEU-bearing process waste stockpiles. South Africa also was unwilling

20 The IAEA Additional Protocol was developed for a similar reason, to permit monitoring of a much broader range of activities and information.

21 For a "systems approach" to this broad question, see Irmgard Niemeyer, Mona Dreicer, and Gotthard Stein, *Nuclear Non-proliferation and Arms Control Verification: Innovative Systems Concepts* (New York: Springer, 2020).

22 Nathan Busch and Joseph Pilat, "South African Rollback: Revisiting Monitoring and Verification Lessons after 20 Years," *Comparative Strategy* 33 (2014), p236–261.

to discuss its fissile material imports. The initial IAEA efforts to produce a material balance showed a discrepancy of 120 kg HEU, using its standard measurement approaches.[23] An ad hoc estimate of material production narrowed the discrepancy to about 6 kg. But it would take 17 years of additional measurement before the IAEA was finally able to conclude in 2010 that there is "no indication of the diversion of declared nuclear material from peaceful nuclear activities and no indication of undeclared nuclear material or activities."[24] The disarmament verification challenge in South Africa pales in comparison to producing a material balance for a state with a nuclear weapons program that lasted many decades and involved a far more expansive nuclear weapons enterprise. Such enterprises involve tons of HEU and plutonium, multiple facilities, huge material unaccounted for in process losses and other operating inefficiencies, secrecy provisions that restrict access to facilities, millions of documents, and tens of thousands of people. Gaining confidence that fissile materials are fully accounted for may simply not be possible, and not solely or even mainly for nefarious reasons.

Simply put, the traditional, legalistic approach to verifying nuclear agreements does not match the technically complex and politically fraught process of disarmament. Instead, a probabilistic approach might strike a more realistic balance between confidence and intrusiveness concerns, while still meeting other requirements such as deterrence of cheating, timely and reliable detection of cheating, and reassurance about intentions. Each of these functions imposes different operational requirements and opens other opportunities.

In contrast to the legalistic arms control approach, a probabilistic verification regime would monitor a broader range of activities across all the relevant nuclear weapons technical domains, rather than just a couple.[25] The probability of detecting noncompliance would be high regarding some provisions and low regarding others, with many in between. The aggregation of detection probabilities across all monitored

23 David Albright and Andrea Stricker, *Revisiting South Africa's Nuclear Weapons Program*, (Washington DC: Institute for Science and International Security, 2016), p230.

24 International Atomic Energy Agency, "Safeguards Statement for 2010" (2010). Accessed June 2, 2020. https://www.iaea.org/sites/default/files/es2010.pdf.

25 Mareena Robinson Snowden, "Probabilistic Verification: A New Concept for Verifying the Denuclearization of North Korea," *Arms Control Today* (September 2019). Accessed June 2, 2020. https://www.armscontrol.org/act/2019-09/features/probabilistic-verification-new-concept-verifying-denuclearization-north-korea.

activities would result in high confidence that if a state were seeking to break out of its disarmament commitments, *at least one* illicit activity would be detected. Monitoring a broader range of activities would also enhance deterrence, since the monitored state could not know the probability that it could get away with cheating, whether in declared or undeclared facilities. Given the number of activities required to resurrect a nuclear weapons program during or after disarmament, relevant agreements could stipulate that detecting noncompliance in at least one of them would be a sufficient basis for remedial action.

A probabilistic approach to verification could help policymakers resolve the dilemma between intrusiveness and compliance confidence. Yet a probabilistic approach would still suffer from several challenges that bedevil more legalistic approaches, such as false positives, poorly defined gray areas, or "violations" alleged by intelligence services with evidence they will not share. Any of these could spur a compliance crisis that, if not bounded, could result in re-armament or even preemptive conflict. Negotiators therefore would need to agree on robust compliance dispute resolution mechanisms.

Ultimately, confidence that states are reducing and then eliminating nuclear arsenals in good faith can be drawn only in part from the verification system agreed by negotiators, imperfect as it would be. Other indicators would be important complements, such as efforts to reassure about the peaceful objectives of dual-use activities and enhanced trade monitoring arrangements. Probably the most important element in building compliance confidence, whether in DPRK or other states with nuclear weapons, would be time: the longer parties are assessed to be in compliance with disarmament commitments, the lower the perceived uncertainty in their intentions and actions will become.

Enforcement

The challenge of enforcing multiple states' nuclear disarmament has never been rigorously addressed or resolved. The NPT does not contain provisions for enforcing either nonproliferation or disarmament. The Treaty on the Prohibition of Nuclear Weapons does not say anything about how states reneging on disarmament would be treated or how security would be maintained in a nuclear-weapon-free world.[26] The

26 Harald Muller and Carmen Wunderlich, "Nuclear Disarmament without the Nuclear-Weapon

few eminent officials and scholars who attempt to address it reveal the manifest hurdles in the way of enforcement, but offer no clear path over them. The 1995 Canberra Commission on the Elimination of Nuclear Weapons, for instance, merely called upon the UN Security Council to consider "how it might address…violations of nuclear disarmament obligations."[27] The 2008 Adelphi Paper "Abolishing Nuclear Weapons" by George Perkovich and James Acton explored enforcement challenges and possibilities in some depth, but did not find a clear solution. Several commentators on that monograph, from a range of countries, highlighted the importance of the issue, but offered no practical solutions to the identified enforcement challenges.[28]

Enforcement is immensely important because governments (and many populations) will be unwilling to give up their last nuclear weapons if they are not confident that "the risk of even a 'small' break-out was lower than the risk of keeping a small number of nuclear weapons and suffering a failure of nuclear deterrence."[29] Enforcement is immensely difficult because any disarmament agreement will have many ambiguous terms and conditions, plausible verification approaches have known weaknesses, and evidence of alleged non-compliance will be uneven and debatable. Any government contemplating negotiating away its nuclear weapons will want to know who is going to be judging compliance, on what basis, and with what power to bring cheaters back into compliance.

To be effective, any enforcement mechanism must convey to potential violators of a disarmament agreement that they would probably suffer (if not certainly) severe punishment for violations. This is necessary to deter potential violators and to reassure the rest that the disarmament regime is stable. The second—and related—requirement is that enforcement decisions be made by people and institutions that enjoy international legitimacy and demonstrate the capacity

States: The Nuclear Ban Treaty," *Daedalus* 149, no. 2 (Spring 2020), p178.

27 *Report of the Canberra Commission on the Elimination of Nuclear Weapons* (Canberra: Commonwealth of Australia, 1996), p63.

28 See in particular comments by Achilles Zaluar, Patricia Lewis, V.R. Raghavan, Ernesto Zedillo, and Zia Mian in Perkovich and Acton, eds., *Abolishing Nuclear Weapons: A Debate* (Carnegie Endowment for International Peace, 2009), p198, 239, 266, 290, 302.

29 Perkovich and Acton, "Abolishing Nuclear Weapons," in Perkovich and Acton, eds., *Abolishing Nuclear Weapons: A Debate* (Carnegie Endowment for International Peace, 2009), p103. Accessed June 2, 2020. https://carnegieendowment.org/files/abolishing_nuclear_weapons_debate.pdf.

to act quickly and robustly.

Recent experiences with Iran, the DPRK, and Russia (regarding the INF Treaty) show that actors may disagree whether a detected activity occurred and was indeed a violation. They will debate whether an alleged violation or even a proved one represents "break out" or a relatively innocent "misinterpretation" of the rules, and whether it is sufficiently threatening to warrant punishment. Parties (and the rest of the world) may disagree vigorously whether the consequences of trying to punish a given actor could be more destabilizing than not. Moreover, if a disarmament agreement had a withdrawal clause (which is very likely when imagined from today's perspective), a state suspected of a relatively ambiguous violation could threaten to withdraw if enforcers press their case too hard. In all of the scenarios sketched above, the international community's perspectives and interests regarding the case will depend at least somewhat on which state is making a withdrawal threat, which states are most alarmed about it, and what would be the expected costs of sanctioning and fighting that state.

Any imagined institution or procedure for enforcing nuclear disarmament must either utilize the UN Security Council or devise a plausible path around it. Given that the five veto-wielding members of the Council are also nuclear-weapon states, it is difficult to envisage a path around the Council. Why would the P5 agree to relinquish their nuclear weapons and delegate enforcement of the arrangement to an entity wherein they did not have veto power?

Yet, as Harald Muller and Carmen Wunderlich have noted, retaining the veto here would enable one or more of the five to violate its disarmament obligations and then veto enforcement against itself. This would be a recipe for instability and conflict. Further, India would be unlikely to join any disarmament agreement whose enforcement was assigned to a Security Council in which it did not have equal status with China and the rest of the P5. Nor would Pakistan agree to any arrangement in which India would enjoy greater power or status than it. So, the Security Council does not appear to be a viable enforcer even if its permanent members do seem able and willing to prevent the emergence of an alternative arrangement.

These considerations lead us to think that at least some of the current nine nuclear-armed states will retain a number of nuclear weapons until relations with their military adversaries and political competitors

become cooperative enough to demonstrate to each other that war is a lesser risk than the risks stemming from retaining nuclear weapons. When cooperative relations among today's nuclear-armed states can be achieved, this cooperation could extend to enforcing common commitments to uphold nuclear disarmament. A concert of powers or a coalition of the willing would, in Harald Müller's words, "maintain political unity in effectively confronting the rule-breaker and take determined steps to prevent [disarmament] from becoming derailed."[30] Today it is difficult to see an alternative to a coalition-of-the-willing approach. Still, the test for such a coalition would be to imagine whether and how participating states would mobilize to counter an alleged violation of a disarmament agreement by one of the world's largest, most powerful countries, namely the U.S., China, or Russia.

All of this is another way of highlighting that durably implementing nuclear disarmament would depend on profound changes in political relations among the states involved, even if one could imagine negotiating how disarmament could be designed before such cooperative relations exist. This need not preclude much more ambitious reductions of nuclear forces and other measures to reduce threats of nuclear use in the meantime, especially by the United States and Russia. With much smaller nuclear arsenals these two states and others would still retain deterrents that could provide them confidence in being able to deter or contest new threats of major aggression. Reduction to minimal arsenals would have intrinsic value in diminishing the potential for humanitarian catastrophe, until such time as relations had improved enough to give weapon possessors confidence that final steps to eliminate the last remaining nuclear weapons could be taken with confidence that no one would be able to get away with cheating.

30 Harald Müller, "The Importance of Framework Conditions," in Perkovich and Acton, eds., *Abolishing Nuclear Weapons: A Debate*, p172.

Conclusion

Whether in North Korea or among all nuclear-armed states, the inherent challenges with nuclear disarmament do not make the entire topic unassailable. The absence of conceivable approaches to some of the hardest problems should not distract from the search for solutions to more readily solvable challenges. In the spirit of finding such solutions, we hope the ideas presented here not only stimulate further analysis and international discussion and debate, but also more practical cooperation among states.

The U.S. and others have long demanded North Korea's denuclearization, and the Nuclear Non-Proliferation Treaty for five decades has obligated states to (at least) pursue negotiations in good faith on nuclear disarmament. Yet, in neither context have states or other actors rigorously defined and debated, let alone negotiated, what actually must be done to achieve non-violent nuclear disarmament in one or more countries. While the first step with North Korea and/or with the eight other nuclear-armed states would be to produce clear intentions to disarm, determining and negotiating what to disarm—and how to verify along the way—will be at least as difficult. Indeed, in our view, fuller understanding of what would be involved could help clarify the conditions under which states would conclude whether they are willing and able to do it. The biggest doubts to overcome would be within and between nuclear-armed states. But non-nuclear weapon states may also learn that moving from a world where no state has more than a few hundred nuclear weapons to one with zero weapons would require more burdensome transparency and controls on potentially dual nuclear/conventional-use capabilities than, at the very least, some non-nuclear-weapon states would ultimately support.

We do not know why no nuclear-armed state has offered a detailed description of how it would define nuclear disarmament and the steps that it envisions would be required to implement and verify it. One reason could be that the leaders and beneficiaries of the institutions—governmental and industrial—who design, produce, and deploy nuclear arsenals do not want to give them up, and therefore resist what they

fear could be a slippery slope to that outcome. Only the United States and Russia have negotiated reduction agreements, and these did not involve anything close to the challenges that eliminating their nuclear arsenals would entail. (France and the United Kingdom unilaterally reduced their forces.)

Decades of debate over nuclear policies have ignored the issues we have sketched here. This paper, then, invites officials, experts, and other concerned actors to flesh out and debate models for approaching nuclear disarmament in theory, while recognizing that no state today is prepared to pursue them in practice.

The primary onus must be on the nine states that possess nuclear weapons, and allies that may depend on the nuclear deterrence extended to them. They are largely the ones who cause or fail to resolve the disputes that, in their views, necessitate retention of nuclear weapons. These states often eschew serious, open discussion with non-nuclear-weapon states of issues that challenge (explicitly or implicitly) the long-term necessity and value of nuclear deterrence.

For example, nuclear-armed states largely avoided the three conferences on the Humanitarian Impact of Nuclear Weapons (in 2013 and 2014) which led to the negotiation of the TPNW. These conferences would have demanded nuclear-armed states to explain to the rest of the world why the probabilities of catastrophic nuclear war—in humanitarian and environmental terms—are low enough that the global risk/benefit calculus of nuclear deterrence is better than that of nuclear disarmament. The United States and Russia would have been pressed to explain why their massively disproportionate arsenals (in terms of numbers and explosive yields) are necessary and could plausibly be used without violating the Law of Armed Conflict. At the same time, nuclear-armed states could have raised hard questions of their own about how to implement nuclear disarmament in verifiable ways that would leave the world more secure not only from escalatory nuclear war, but also from other forms of massively destructive conflict. Non-nuclear-weapon states tend to elide such questions, as well as issues relating to their own roles in a disarmament process.

The proposition here is that nuclear-armed states would help the world and themselves by developing models for nuclear disarmament and inviting officials and experts from non-nuclear-weapon states to join in debating and refining them. The Treaty on the Prohibition of

Nuclear Weapons avoided defining nuclear disarmament and how to verify and enforce it. But non-nuclear-weapon states and societies as well as those that possess nuclear weapons will need to confront the enormous technical challenges, security dilemmas, political-ethical dilemmas, and costs that would be involved if nuclear disarmament is going to be achieved anywhere, let alone everywhere.

To cite a few obvious examples from the foregoing pages, it will be necessary to decide whether states would be allowed to retain nuclear-capable ballistic and cruise missiles, and aircraft designed to carry nuclear weapons. If not, how politically feasible would nuclear disarmament actually be, and over what period of time? Nuclear-armed states as well as non-nuclear-weapon states must find common ground on such issues, especially if the latter also possess relevant delivery systems. Both groups of states (and civil society organizations) will have to address whether and how nuclear energy production would be permitted and managed under a nuclear disarmament regime (with implications for climate change). Other political-ethical dilemmas will include whether and how to limit academic research and intrusively monitor people and facilities that could be diverted to produce nuclear weapons. Even if direct costs of dismantling arsenals might fall to the states with nuclear weapons, who would pay for the enormous expense of verifying the disposition of their component materials, equipment, and facilities, as well as indirect expenses that extend beyond the disarming states? The burdens of increasing confidence in disarmament, not just in disarming states but among all states, could require a re-imagined international monitoring system that would, for example, track academic research in nuclear-weapons-related disciplines, watch trade in dual-use goods, and scrutinize space and ballistic missile programs more intensively than heretofore.

Skeptics of nuclear disarmament—not merely today, but in any circumstance in which powerful states have not resolved their most pressing disputes—will contest the value of exploring nuclear disarmament more seriously. They will note the turmoil this could cause within nuclear-armed states, as well as between them. They will argue that such discord could make the world more volatile and is not worth the risk because non-nuclear-weapon states and civil society groups will give them no credit for undertaking such explorations. They will caution that the concerns of nuclear-armed states will be dismissed

and turned against them in even more rancorous international debates than occur today. In addition, they will point to unrealistic demands that they should simply rely on the UN Security Council to redress threats to international peace and security (as if that notion does not raise more intractable issues than it resolves). No doubt readers associated with existing nuclear weapons establishments can add to this list of arguments against the sort of analysis and international dialogue urged here.

Yet, nuclear disarmament is not a morality play in which one set of actors represent evil and another virtue, and in which the choices to be made are relatively simple. If nuclear disarmament is to be enacted, all states will have to share in the trade-offs and costs involved. The sooner governmental officials and civil society experts engage in open and detailed analysis and discussion of these challenges, the more likely a common agenda to resume progress on (now-stalled) nuclear disarmament could be developed. This would not mean that nuclear-armed states would radically reduce their arsenals tomorrow or that supporters of the TPNW would stop demanding prohibition, but it could infuse needed realism into disarmament discussions—whether negotiations with North Korea or NPT Review Conference deliberations. A continuation of the status quo in which two polarized blocks stonewall and repel each other is more likely. Yet, if nothing better is tried, the risks of global nuclear disorder will grow.

"It is impossible to envision a pathway to 'sustainable, effective nuclear disarmament' without a clear idea of how to design concrete steps and measures while also ensuring security. In this important new study, George Perkovich and Toby Dalton have stepped up to this challenge. Drawing on practical experience with North Korea, they offer a concrete, detailed vision of how to begin to design a disarmament process that is feasible from a technical and political perspective and that is effective in providing security, including for the disarming state. This work should stimulate a significant new debate about the future of nuclear risk reduction—one that can break new ground by engaging both deterrers and disarmers."

Nobumasa Akiyama
Professor, Hitotsubashi University, Tokyo

"Dalton and Perkovich, two of the world's leading disarmament and nonproliferation thinkers, provide a sober, serious, and thorough investigation of some of the knottiest problems confronting nuclear disarmament that supporters must grapple with and skeptics cannot ignore."

Elbridge Colby
Former Deputy Assistant Secretary of Defense for Strategy

"Dalton and Perkovich like a challenge. Their thoughtful approach certainly lays down a few gauntlets—particularly to the nuclear weapons states. Taking North Korea as the hard case, they outline the challenges that, if serious about their commitments, all nuclear weapons possessors would have to face. So, they ask, why are they not engaging with each other and solving these issues now? It is a good question and one that needs to be answered, soon."

Patricia Lewis
Research Director, International Security,
Royal Institute of International Affairs, London

Lawrence Livermore National Laboratory

ISBN: 978-1-952565-03-8