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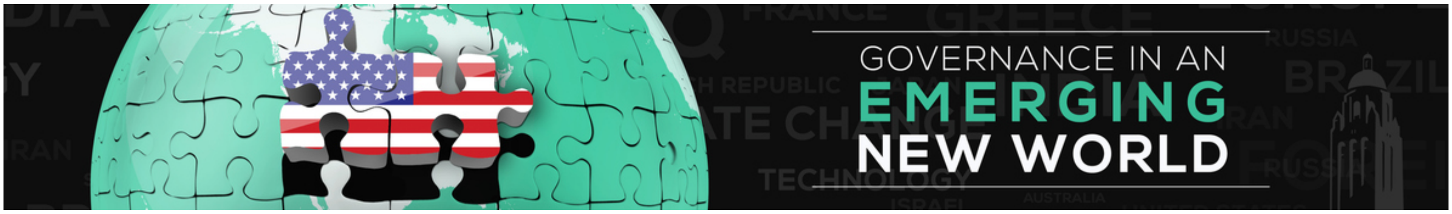

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Nuclear Non-Proliferation: Steps For The 21st Century

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The United States knows that if the fearful trend of atomic military build-up can be reversed, this greatest of destructive forces can be developed into a great boon, for the benefit of all mankind.
– President Dwight D. Eisenhower, "Atoms for Peace," United Nations General Assembly, December 8, 1953

Introduction

The dual nature of nuclear fission—both risk and opportunity—was recognized almost immediately after the seminal physics discoveries of the late 1930s and was articulated as a matter of policy in Eisenhower's consequential Atoms for Peace speech in 1953. The following years and decades saw both the continued build-up of nuclear weapons arsenals, eventually reaching tens of thousands of weapons, and Western assistance to Iran, India, Pakistan, Israel, and others in starting nuclear reactor programs, often with the supply of high-enriched uranium (HEU) for fuel. The irony of having U.S.-supplied weapons-useable material in HEU fuel sitting in Tehran even today is not lost on many participants in the non-proliferation dialogue.

Eventually, the world saw the building of institutional structures to achieve the Atoms for Peace vision: reversal of nuclear stockpile build-up and the provision of nuclear technologies for energy, medical, and industrial uses. The Treaty on the Non-proliferation of Nuclear Weapons (NPT), establishment of the International Atomic Energy Agency (IAEA), creation of an arms-control architecture between the United States and the Soviet Union (later Russia), establishment of the Nuclear Suppliers Group, and negotiation of the Comprehensive Test Ban Treaty (CTBT) are some of the milestone achievements for operationalizing the Atoms for Peace vision. More recently, initiatives such as the IAEA Low Enriched Uranium Bank (with the Nuclear Threat Initiative (NTI) playing a catalytic role both conceptually and financially) and the Treaty on the Prohibition of Nuclear Weapons (which has yet to enter into force and is opposed by the nuclear-weapon states) demonstrate the continuing focus on Eisenhower's vision.

In fact, the non-proliferation architecture has been reasonably successful. Clearly, nuclear weapons have not been confined to the P5 "official" nuclear weapons states: the United States, Russia, the United Kingdom, France, and China. India, Pakistan, and North Korea have demonstrated nuclear weapons capability through testing, and Israel is generally acknowledged to have the capability as well. On the other hand, there have been significant rollbacks, such as the removal of Soviet weapons from Ukraine, Belarus and Kazakhstan, acknowledgement and repudiation of the South African program, elimination of HEU from numerous countries, and more. The projections of decades ago that the number of nuclear weapons states would multiply dramatically have been proved wrong—so far.

In the 21st century, this success is looking less secure for a number of reasons, both geopolitical and technological. The recognized need for transitioning to a low-carbon energy economy is providing impetus for nuclear power expansion, including in regions of proliferation concern. The advance of computational, additive manufacturing, novel materials, and project execution technologies raise the specter of a concomitant spread of capabilities to produce weapons-usable materials—the most difficult part of nuclear weapons program development. Indeed, it is interesting to note that much about the Iranian nuclear weapons program through 2003 has been revealed, with the notable conclusion that they had made considerable progress in all dimensions short of actual production of the weapons-usable fissionable materials, HEU, and plutonium. The Israeli and Iranian nuclear programs, together with the announced nuclear energy ambitions of Saudi Arabia, Egypt, Turkey, and others are one example of heightened regional proliferation concerns.

The connecting tissue for the array of challenges we face in combating proliferation in the 21st century thus centers around nuclear materials, their means of production, their security, and the level of access that state and non-state actors have to them. From the dawn of the nuclear age, the world has been challenged by the inherent dual-use nature of the nuclear fuel cycle. The fact that the same technologies—uranium enrichment, nuclear reactor operations, and reprocessing—can be used both to generate nuclear power and to produce the material needed for a nuclear weapon has confounded policymakers from the very beginning. Early attempts to establish international control over the nuclear fuel cycle, prompted by the Acheson-Lilienthal report and spurred on by the Baruch plan, failed to gain support.

The NPT's authors split the difference—affirming in Article IV that all States Parties had the "inalienable right" to the peaceful uses of nuclear energy even as Article II commits non-possessor states not to acquire, develop, or seek assistance in building nuclear weapons. As noted above, the NPT's relative success to date is simply that—relative to earlier expectations. In order to uphold the NPT, vigilant efforts to prevent further proliferation must continue.

This paper discusses several technical and policy approaches to mitigating proliferation concerns in the years and decades ahead. While this will not be a complete discussion, it should provide a flavor of the challenges and opportunities in four different non-proliferation areas: detection; prevention; rollback; and subnational risks. An important reality is that elimination of nuclear weapons combined with a major fuel cycle expansion globally will present a particularly challenging verification regime, requiring new transparency measures and international inspection prerogatives similar to—or even more stringent than—those incorporated in the Joint Comprehensive Plan of Action (JCPOA) with Iran.

Detect

Detection of proliferant behavior is critical for a successful non-proliferation regime, and the tools need to evolve with technological advances.

Monitoring for Nuclear Weapons Tests

One important example today of employing detection to address proliferation risks is the global network established to verify the Comprehensive Nuclear-Test-Ban Treaty (CTBT) through the implementation of an International Monitoring System (IMS). The CTBT—which has been ratified by 167 countries but will not enter into force until China, North Korea, Egypt, India, Iran, Israel, Pakistan and the United States have ratified—is intended to be a key element of the non-proliferation regime by banning countries from conducting nuclear explosive tests of all kinds. This constrains the development of nuclear weapons; countries with nuclear arsenals will be constrained in improving them. Some nuclear bombs have been deployed without testing, but such weapons would generally be less efficient and require larger amounts of fissile material. Even though the CTBT has not entered into force, the P5—as signatories to the CTBT—are observing a moratorium on testing. Thus, it has clearly had substantial impact on ending testing and establishing a global norm against nuclear weapons tests However, there are significant gaps given that India, Pakistan, and North Korea are not signatories and have openly tested nuclear weapons since the Treaty was negotiated.

The CTBT Organization has proceeded aggressively to achieve the verification capacity set out in Article IV of the Treaty. The IMS is designed to detect any nuclear explosion conducted on Earth—employing seismic, infrasound, hydroacoustic, and radionuclide measurements in combination for underground, underwater, and atmospheric monitoring. The principal method that would be most difficult to detect is underground testing, so seismic detection is a crucial element of the CTBT verification regime. Today the IMS operates around the globe and around the clock. Once completed, the regime will comprise 337 monitoring facilities supported by a global communications and data-processing infrastructure. Over 90 percent of the monitoring system is already up and running.

As CTBTO Executive Secretary Lassina Zerbo has noted, the IMS has already proven its worth, successfully detecting North Korea's nuclear tests and providing independent confirmation that Pyongyang was proceeding in its campaign to develop nuclear weapons. For instance, in 2013, the IMS detected a North Korean nuclear test and announced evidence of that test, publishing information about the location, magnitude, time, and depth within two hours, even before the DPRK made an official statement.

The global character of the CTBT monitoring system is a critical factor. Indeed, as Zerbo as stated, "This network is truly multilateral and unprecedented in terms of worldwide reach. No one state could build and deploy something like this alone." It is essential that the international community sustain its vigorous support for the CTBTO so that it can continue to refine its measurements and methods and lower the explosive threshold for detection. This will raise the bar for detection of any covert test.

Stockpile Stewardship

Since signing the CTBT and observing the moratorium on nuclear testing, the United States has been able to maintain a safe, secure, and effective nuclear deterrent for several decades without nuclear testing by employing an approach known as "science-based stockpile stewardship." The National Nuclear Security Administration (NNSA)'s Stockpile Stewardship Program uses a science-based assessment to assure the reliability of U.S. nuclear weapons, accurately modeling nuclear weapons performance and physics without nuclear explosive testing. To accomplish this, NNSA scientists conduct new research and combine it with existing data from past nuclear tests, the nation's long history in nuclear science, and computer simulations.

This nuclear weapons research and development supports stockpile stewardship through advanced development of science-based capabilities to assess a broad range of weapons-related concerns. In the words of former NNSA Administrator Gen. Frank Klotz, "It has been said publicly by some laboratory directors that we probably know more about the science and engineering of a nuclear weapon now as a result of 20-plus years of Stockpile Stewardship than we did when we were testing."

The conclusion is that continued support of stockpile stewardship supports non-proliferation objectives by enabling continuation of the U.S. testing moratorium of the last twenty-five years. Together with the effective verification afforded by the CTBT IMS, the technological conditions are ripe to revisit CTBT ratification in the United States.

IAEA Safeguards and Wide Area Environmental Sampling

The International Atomic Energy Agency (IAEA) is the internationally recognized independent authority charged with monitoring and verifying that non-nuclear weapon states are using nuclear technology only for peaceful purposes. This mandate is spelled out in the NPT itself, as well as in the Agency's statute, and the IAEA has established a system of safeguards to carry out this mandate, combining a mix of inspections, visits, open source analysis, and scientific measurements to draw conclusions about a state's nuclear activities. Nearly all IAEA member states have in place a Comprehensive Safeguards Agreement (CSA) to accomplish this task, focused on a state's declared nuclear activities. However, in the aftermath of the Iraq and Libya cases, the IAEA developed a Model Additional Protocol (AP) to complement CSAs; an AP provides additional tools to the IAEA to monitor and verify the absence of *undeclared* nuclear activities in a state. At the time of publication, 134 states, as well as Euratom, had an AP in place, with 14 states having signed an AP but not yet brought it into force. Iran is provisionally applying the AP as part its JCPOA commitments, but its parliament has yet to formally bring its AP into force.[1] The JCPOA is unique in supplementing Iranian adherence to the AP with a finite time window (up to 24 days) for providing IAEA access to a suspect site.

The IAEA has also invested heavily in the science of detection and verification, making great strides in enhancing its tools and technology to identify proliferation-sensitive activities. However, much of that work has been focused in the area of declared nuclear activities, such as by upgrading cameras, developing active electronic seals that can detect tampering, using robotics technology to monitor spent fuel pools, and installing specialized detectors to observe uranium enrichment in Iran (the "Online Enrichment Monitor," or OLEM).

There has been less progress in addressing the challenge of detecting undeclared nuclear activities, particularly those related to the fuel cycle. One approach that holds great promise for detecting covert nuclear material production is the concept of wide-area environmental sampling (WAES), also known as wide-area environmental monitoring. WAES is the use of air, water, soil, and other environmental data, taken over time, to determine the presence or lack thereof of nuclear material or nuclear activity within a large area, such as a province or entire country.[2]

Though the IAEA's Model Additional Protocol includes references to "the collection of environmental samples…for the purpose of assisting the Agency to draw conclusions about the absence of undeclared nuclear material or nuclear activities over a wide area," the use of wide area environmental sampling has not been pursued by the IAEA. A multi-state, two-year-long study in the late 1990s led to a decision that the cost would be prohibitively high. Eleven years after the original study, the IAEA made another decision to not pursue the use of this tool, as the overall price "would need to decrease by a factor of ten" before it could be deployed."[3]

Ten years after the last IAEA decision, the time is right to build a research agenda that can support a multi-disciplinary approach to WAES. Such a research program, ideally international and university-based, would help determine if and when WAES might be credibly deployable, as technology continues to improve. Research that can be easily applied to WAES continues to be performed, even if it is not immediately applied to this problem set. The advancement of new tools (such as drones), the emergence of hyperspectral remote sensing, and the use of satellite imagery to interpret the chemical composition of the earth, may be immediately applicable to WAES.[4] Data processing and computer science have also seen extreme changes that may bring down the overall cost for WAES, in addition to reducing false positives and negatives.

Using Big Data, Social Media, and New Technologies to Enhance Detection

Advances in big data have other significant implications for the nuclear detection mission. In the longer term, the vast quantities of publicly available data might be used to supplement traditional means of verifying international agreements. Traditionally, proliferation detection has been the exclusive task of governments and international organizations like the IAEA and the CTBTO. Monitoring and verification of proliferation and arms control agreements have historically relied on tools such as monitored party declarations, on-site inspections, and national technical means.

NTI was an early proponent of the potential for "societal verification," given the expansion and spread of social and other digital media, as part of its *Cultivating Confidence* project. In addition to a wealth of social media content, increased digitization of public records such as import/export data, corporate registries, and transport logs can also provide visibility into potential illicit proliferation networks or other suspicious activity. The many examples of this phenomenon include:

- Shipping companies are digitizing details of the contents of millions of containers. Supply chains are rapidly digitizing.
- On the social media front, 6000 tweets are posted per second, there are 6 billion Google searches per day, and 40 million photos are shared on Instagram daily.
- 200 corporate registries from 120 countries are available commercially.
- Commercial, high resolution images are available for any site on the globe more than once a day.
- Dozens of countries have publicly available land registries.

Taken together, these data have the potential to provide a detailed view of what countries are trading and where the traded goods are going, including clues as to possible illicit behavior. Capitalizing on these data for proliferation detection or monitoring is not simple, however. The data sets are expensive, and extensive reformatting is necessary to conduct analyses. Perhaps not surprisingly, government agencies encounter bureaucratic challenges to comprehensively integrate open source data into intelligence analyses and forecasts.

Last year NTI, in partnership with the Washington-based nonprofit group C4ADS, initiated a project to determine what might be possible in terms of using publicly available data for proliferation detection and monitoring. This project aims to demonstrate how use of publicly available data and network analysis techniques can supplement traditional monitoring and verification of international agreements. To do this, the project takes advantage of the large quantities of data that are generated around the world every day (e.g., financial records, scientific publications, property records and registrations, import/export data, shipping data, etc.) as well as novel, proprietary technology (e.g., Palantir, Windward) that permit network analysis and facilitate investigation of possible illicit activity.

The initial phase of the project is nearly complete, and the early results are promising. The data analysis has allowed the project team to detect trade in dual-use items. It has also been possible to determine whether freight forwarders are used and the location of an entity within a trade network. More broadly, mining these data permits researchers to generate trade profiles for companies, setting comparable baselines to help determine what sorts of trade and activities appear "normal" and which ones indicate illicit or proscribed actions.

The overall goal is to characterize "risky" trading patterns that could then prompt a more detailed analysis. One of the key issues will be needing to do this at scale. In that regard, it will be necessary to take advantage of machine-learning approaches to look for unique signatures of proliferation. If efforts such as these prove successful, in the future there may be a situation in which it becomes nearly impossible to hide illicit nuclear activity of any scale, or at least to raise the detection bar considerably.

Prevent

Prevention of proliferant behavior associated with the nuclear fuel cycle revolves around dual-use technologies that can produce weapons usable materials, that is, uranium enrichment technology for HEU, and spent fuel reprocessing technology for plutonium, often shorthanded as "ENR" for enrichment and reprocessing. The reality that much less enrichment capacity is needed for a nuclear weapon than for a power reactor fuel load is a serious issue for detecting covert enrichment programs. For plutonium, a major concern is that very different isotopic mixtures (corresponding to very different fuel burn-up times in the reactor) are weapons usable.

New Approaches to Addressing Fuel Cycle Proliferation

While the system set up under the NPT has mostly worked, the fact that proliferation has still occurred under this model requires us to assess whether current policies are working and consider new mechanisms that could more effectively manage the tension that arises when states seek to avail themselves of nuclear technology—ostensibly for peaceful purposes, but raising questions about the potential for illicit weapons development. Moreover, the exceptions to the general norm of non-proliferation have been with countries embroiled in regional tensions—namely in Northeast Asia, the Persian Gulf, and South Asia—that threaten to spill over into wider conflict, threatening not only those regions but also global security.

Time to Reconsider the "Gold Standard"

In recent years, the United States has negotiated two unique approaches to achieve some measure of "control" over ENR. The first of these was with the United Arab Emirates (UAE), where it sought to establish a new standard of prevention through its civil nuclear (or so-called "123") agreement. The U.S.-UAE 123 agreement legally bars the Emirates from developing or acquiring enrichment and reprocessing (ENR)—enshrining the UAE's existing policy on ENR—and requires the UAE to accept the IAEA's Additional Protocol. This arrangement, which somewhat accidentally came to be known in Washington as the "Gold Standard" agreement, achieved its narrow goal in the case of the UAE, but the model has yet to be adopted by others in the region, with only Taiwan also agreeing to a legally binding ban on ENR in its updated 123 agreement.

The U.S. tactic of using the "Gold Standard" as a basis for nuclear cooperation agreements has not succeeded in constraining proliferation-sensitive activity and has, in some cases, hindered U.S. goals of both promoting American competitiveness for civil nuclear exports and reducing proliferation risks. Some states have balked at the concept, seeing the gold standard requirement as an infringement on sovereignty and NPT rights. Others have forgone U.S. cooperation to work with other countries (primarily Russia) who do not insist on the same commitments as a precondition of supply. The Obama Administration ultimately took a "principled, tailored approach" in deciding not to require the "Gold Standard" for all 123 agreements it negotiated, completing "non-Gold Standard" deals with Vietnam and South Korea. Still, both the Obama and Trump Administrations have pressed for "Gold Standard" arrangements in the Middle East, and key members of Congress have gone on record in support for upholding the "Gold Standard" in all future Middle East 123 deals.

The "Gold Standard" debate has put the United States into a self-imposed box, removing creativity or flexibility in devising effective strategies for encouraging U.S. civil nuclear cooperation that do not lead to further proliferation. The United States should find a way to extract itself from this box and take a new look at what other methods are available, including enhanced verification techniques and new ways of assuring supplies of nuclear fuel. Even in a region like the Middle East, where the "Gold Standard" has been a *sine qua non* for nearly a decade, recent history demonstrates that there could be other ways.

Enhanced Monitoring and Verification

The Joint Comprehensive Plan of Action (JCPOA) with Iran represented a different approach to preventing further proliferation in that it was negotiated with a country that already possessed enrichment capabilities. Though the Iran nuclear deal was more reactive than preemptive, its goals were similar to those of the "Gold Standard" in seeking to enact controls on ENR and enhance the level of IAEA monitoring and verification to provide assurances of exclusively non-military uses of nuclear technology, whether declared or undeclared. In the case of Iran, the United States had to grapple with a fundamental question regarding enrichment: did the insistence on "zero" enrichment help or hurt overall U.S. and international security objectives? Moreover, if the negotiators had to accept some level of enrichment in Iran as a *fait accompli*, could they define both limits on enrichment and stronger verification that provided an acceptable level of confidence in detecting undeclared nuclear activities or facilities, or the diversion of nuclear material for undeclared military uses, in enough time to allow for a strong international response in the case of "breakout?" The participants in the JCPOA were able to answer this with a strong "yes."

Instead of insisting on the "Gold Standard," it could be possible to provide a similar level of assurance against proliferation by learning from the JCPOA model. One could imagine a different kind of 123 agreement that requires a much more expansive framework of intrusive monitoring and verification—including not only the Additional Protocol with a fixed time period of IAEA access to suspect sites but also additional measures to guard against undeclared activities, such as monitoring the entire uranium supply chain and confirming the absence of any weaponization activities. Rather than bar it, such an agreement would place strict limits on enrichment, including the level of enrichment and the amount of material a country could keep in its stockpile. Finally, no U.S. 123 agreement would authorize the transfer of ENR technology or equipment, relying instead on the strict controls put in place by the Nuclear Suppliers Group in the past decade that have effectively protected against such transfer.

Adopting this alternative concept could have multiple benefits. It could remove the political downside for states (like Saudi Arabia) to be perceived as renouncing sovereign “rights” to enrichment, whether or not they have a serious plan to pursue it. The NSG’s strict controls on ENR would remain in place, making it unlikely for new states to acquire fuel cycle capabilities, without requiring an explicit “ban.” Furthermore, it could even prove to incentivize the “Gold Standard” for states who want to engage in nuclear trade with the United States if they decide that a no-ENR deal is preferable to accepting more intrusive monitoring and JCPOA-style limits. For Iran (assuming it is in compliance with the JCPOA verification regime), it can have confidence that other regional players are not pursuing a nuclear weapons program.

The Assured Nuclear Fuel Services Initiative

As John Deutch, Dan Poneman, the late Arnold Kanter, and I wrote in a Survival article more than a decade ago, there could be also be a pragmatic approach to preventing proliferation that relies on commercial arrangements in the existing nuclear fuel market, namely between nuclear fuel service suppliers and electrical utilities that own and operate nuclear power plants.[5] Under this “Assured Nuclear Fuel Services Initiative” (ANFSI), states that do not possess ENR facilities would commit to refrain from acquiring those technologies for a set period, such as 15 years. In return, these states would be eligible to receive “cradle-to-grave” fuel services, both the supply of fresh nuclear fuel for power reactors and removal of spent nuclear fuel from the state once it has been irradiated. This “time limited Gold Standard” would be negotiated as a set of commercial contracts between existing market entities, rather than a political or legal agreement that would be much more difficult to achieve. While voluntary in nature, this initiative could be bolstered by international institutional arrangements. At a minimum, all nuclear fuel cycle activities related to this approach should be subject to full scope IAEA safeguards, including the Additional Protocol.

ANFSI offers several strong incentives for states on both sides of the fuel cycle equation. For user states, it would allow for a guaranteed, economic pathway to nuclear fuel that did not involve the environmental, regulatory, technical, and political headaches associated with spent nuclear fuel disposition. Supplier states would benefit not only from the economic proceeds of selling nuclear fuel but also from the assurance that the fissile materials contained in the fuel would not be diverted for non-peaceful purposes. Practical implementation of the ANFSI concept is admittedly a heavy lift, not least of which due to the challenges that supplier states face surrounding spent nuclear fuel disposition, discussed further below. However, this “fuel leasing” idea continues to have merit and deserves consideration as another alternative to the current system.

Front End of the Fuel Cycle

The existing market-based approach for supplying nuclear fuel is working well, with several reliable firms in the United States, Europe, and Russia well situated to continue meeting demands for the foreseeable future. There is no need for a large scale, expanded enrichment capacity globally, due to lower global demand and excess SWU[6] capacity. One concern that deserves greater attention in light of the growing availability of new technology is the potential for non-commercial enrichment technologies to be used by proliferators. As already noted, the enrichment requirements for a small nuclear weapons program are relatively small. Further, cost competitiveness and continuous processing are not necessary for a state intent on developing a weapon capability. As an example, laser enrichment technology is not yet commercially viable, despite decades of development, but could be useable for a small weapons program. Supply chain surveillance for multiple non-commercial enrichment technologies should be significantly upgraded as a priority.

The establishment of the IAEA Low Enriched Uranium (LEU) Bank adds another layer of assurance for states operating nuclear power plants. The internationally funded $150 million bank—which was spurred into creation by the Nuclear Threat Initiative and a $50 million investment by Warren Buffett—serves as a backup source of fuel for IAEA member states in good standing with their non-proliferation obligations but which have experienced an interruption in their acquisition of fuel on the commercial market. This would be part of the fuel assurance system in fuel leasing.

Even as the market is working well, further commercial arrangements could bolster assurances, such as the establishment of multinational facilities for enrichment. The Urenco consortium already represents a form of this concept, as it is jointly owned and operated by Germany, the Netherlands, and the United Kingdom and operates facilities in all three countries, as well as in the United States. New multinational groupings such as in the Middle East or East Asia could organize either to invest in existing facilities or work together on new ones. Multinational facilities would still need to be subject to strict international monitoring and limits on access to sensitive technology, mindful that the AQ Khan network proliferated technology stolen from Urenco.

Back End of the Fuel Cycle

On the back end of the fuel cycle, spent fuel contains plutonium—approximately 1% by weight—that can be separated through reprocessing. Because fissile material production is the biggest hurdle in a nuclear weapons program, the separation and stockpiling of plutonium poses real security and proliferation risks. In addition, the longer spent fuel is stored, the more the shorter-lived “self-protecting” isotopes decay and the less radioactive it becomes, the greater security risk it presents. Considering some terrorists’ demonstrated willingness to disregard their self-preservation in the pursuit of their objectives, the adequacy of the current self-protection standard has been called into question. Dr. John Holdren, President Obama’s Science Advisor, recently observed: “there is a danger that either countries or individuals will in fact get their hands on that plutonium, make nuclear bombs with it and use them maliciously.”[7]

Despite well-developed programs in Finland, Sweden, and France, and encouraging progress in Canada, political and technical difficulties have delayed and, in many cases, prevented the construction and operation of commercial spent fuel repositories. As a result, most waste management organizations continue to struggle to establish sustainable disposal pathways. The problem is particularly acute in South Korea and Taiwan, where spent fuel pools are almost full and dry cask storage is limited or non-existent.

Reprocessing and MOX—False Solutions

The lack of disposal options has led several countries—notably Japan and South Korea—to conclude that reprocessing the plutonium from spent fuel and recycling it for use as mixed oxide (MOX) fuel is an alternative to spent fuel storage, at least in the short-to-medium term, and a waste reduction technique over the long-term. Some have even made the argument that recycling is an alternative to disposal altogether. However, none of this is true. MOX fuel cycles still generate significant waste streams that require storage and permanent disposal. Continuous recycling of spent fuel does make it possible to concentrate the radioactive materials in a much smaller volume of high-level waste (HLW), but most countries today are recycling plutonium only once due to technical challenges. The heat output of spent MOX fuel is dramatically higher than the output of spent LEU fuel, and decay heat is a more significant determinant of repository size than waste volume. Reprocessing also generates significant volumes of intermediate-level waste (ILW) and low-level waste (LLW). The ILW typically contains long-lived actinides (including plutonium) and therefore in most cases will probably have to be ultimately disposed of in deep geologic repositories along with the HLW. And if LLW is also included, the total volume of waste arising from reprocessing is significantly larger than the total volume arising from direct disposal of spent fuel.

Japan's effort to close the fuel cycle is a cautionary tale: the MOX program has been plagued by technical problems and challenges in developing IAEA safeguards for the country's reprocessing plant at Rokkasho.[8] The country has now accumulated 47 tons of separated plutonium (10.5 tons in country and 36.7 tons stored in France and the UK)—enough plutonium to make thousands of nuclear weapons—with no pathway to draw down the inventory in any meaningful sense. It is vital to identify spent fuel solutions that do not result in the further build-up of plutonium inventories. However, only four of the nine reactors restarted after the Fukushima accident can use MOX fuel and the government's repository program is highly unpopular with the Japanese public.

Fuel Leasing and Disposition Pathways

As noted above, rather than invest in reprocessing, with its proliferation risks, enormous costs, and complicated monitoring requirements, a better approach would be to explore the concept of "fuel leasing," in which a state could buy fuel services from an existing technology holder, receive fabricated fuel and irradiate it in a reactor, with the spent fuel then returned to the originating states once it has been discharged and cooled. Russia already operates much in this manner, offering a fuel takeback for Rosatom's customers that purchase reactors and fuel from it. Indeed, this takeback approach is one of the reasons that the international community exempted Iran's Bushehr reactor from sanctions, knowing that the nuclear fuel there was not at risk of reprocessing since it would be returned eventually to Russian soil.

For the fuel leasing concept to work on a more global scale, though, one must grapple with the daunting task of spent fuel management and disposition. Other than Russia and France, states generally do not accept the transfer of another state's spent fuel to its territory. Even if they did, it would require a disposition pathway for the fuel, which remains a challenge for states with large amounts of installed nuclear power, including the United States.

Globally, commercial nuclear reactors generate roughly 10,000 metric tons of spent nuclear fuel each year; more than 250,000 tons of spent fuel is currently held in storage worldwide. According to the World Nuclear Association, "Total world generation of reactor-grade plutonium in spent fuel is some 70 tons per year. About 1300 tons have been produced so far, and most of this remains in the used fuel, with some 400 tons [of plutonium] extracted."[9] Using the IAEA significant quantity of 8 kg of plutonium to manufacture a nuclear weapon, the global stockpile of plutonium could create approximately 162,500 warheads, with an additional 8,750 warheads-worth of plutonium produced each year. While this plutonium cannot be used for a nuclear weapon without being separated out from the spent fuel, it is imperative that a solution is found for dealing with this waste that does not contribute to the proliferation of special nuclear material. In addition, there is more than 350,000 cubic meters of high-level waste from defense programs in storage worldwide.

After removal from a reactor, spent fuel must be cooled in pools for extended periods of time before it can be moved to storage and disposal. However, in most countries it will be decades before repositories are available to accept waste in sufficient quantities to begin to significantly reduce the inventory.

In the short term, a well-managed national program of interim spent fuel storage using above-ground dry casks is a reasonable and responsible way to maintain spent fuel stocks, but ultimately a long-term depository is necessary. Even for dry cask storage, local community acceptance, financing, and regulatory issues all have hampered moves toward more consolidated facilities, and most waste is currently stored at reactor sites scattered across the United States. The lack of functional disposal pathways strains the credibility of the nuclear community and undercuts public and political acceptance for all nuclear activities. Similarly, except for the Waste Isolation Pilot Plant in New Mexico, which receives transuranic waste from U.S. Department of Energy sites, defense waste also lacks a disposal pathway.

Waste management organizations in many countries suffer from a lack of public trust. Regional cooperation integrating engineering, hard science, and social science research to address challenges that are common to all spent nuclear fuel generators, is one possible path forward. Spent fuel and high level waste disposal research and development is expensive, complex, and time-consuming; a multinational cooperative approach would enable the efficient sharing of costs, resources, knowledge, and experience, and will generate the credibility that is gained from collaborative work among the leading experts in the field. This type of cooperation would also enhance transparency and confidence, thus increasing regional security.[10]

Deep Boreholes

Disposing of waste in deep boreholes has long been considered an elegant solution for relatively small volume, high activity defense sources—such as the cesium and strontium capsules stored at DOE's Hanford Site—as well as separated plutonium from commercial reactor operations and plutonium designated as no longer required for defense purposes by the United States and Russia. In a 1994 report, the National Academy of Sciences identified two promising plutonium disposition alternatives: fabrication and use as MOX fuel, and vitrification in combination with high-level radioactive waste. The report acknowledged that while less thoroughly studied than the other options, deep borehole disposal "could turn out to be comparably attractive."[11]

The Academies' assumptions about the cost and timeliness of the MOX and disposal alternatives have proven extremely optimistic, however. Indeed, Dr. Holdren, who co-authored the Academies' study, recently said that "today, if most of us were asked to write that book again, we might well argue that the best solution is...deep boreholes."[12]

Wider diameter boreholes could also complement national spent fuel disposal programs. Boreholes offer a number of advantages over geological repositories, including: the drilling technology is already being used by the oil and gas industry, at least at smaller diameters; waste can be disposed of more quickly, at much lower cost and at a larger number and variety of possible host sites, making it particularly attractive for countries with small waste volumes, limited financial resources and/or poor natural geology; disposal capacity could be expanded relatively quickly; and the holes leave a small environmental footprint. Challenges include the fact that borehole disposal includes drilling through crystalline rock rather than the sedimentary rock characteristic of oil and gas deposits.

The bottom line is that failure to resolve disposition of spent fuel is a non-proliferation concern both by leading to some plutonium separation (even if misguided) and by blocking any chance for fuel leasing.

Rollback

Despite our best efforts to detect and prevent nuclear proliferation, there have been cases where the international community has been unsuccessful in stopping new actors from acquiring nuclear weapons. In those cases, international security and the health of the nuclear non-proliferation regime require that the international community seek to rollback illicit nuclear weapons programs where they exist and to bring states back into compliance with the NPT.

Exhibit A is North Korea, which withdrew from the NPT in 1994 and continues to expand its growing arsenal of nuclear weapons and delivery vehicles. Diplomacy and pressure on North Korea over the past 25 years has had successes and failures, but the bottom line is the international community has not yet succeeded in persuading North Korea that its interests lie in giving up nuclear weapons and committing to a peaceful, non-nuclear Korean Peninsula.

President Trump's unorthodox approach of creating a top down opening to Chairman Kim Jong Un had the potential to inject new energy and direction into the negotiations, but the reality is that if there was opportunity, it has not yet been capitalized on. Even after the recent renewal of U.S.-DPRK working-level diplomacy in Stockholm in early October 2019, there has been no concrete progress in implementing the broad political goals laid out in the June 2018 Singapore summit joint statement.

A more promising approach is a step-by-step process with sanctions relief and assistance metered according to denuclearization step. This too has risks but is the only approach that appears feasible. As further detailed below, a sequence, in very broad strokes, could proceed from cessation of nuclear tests and elimination of test infrastructure, to cessation of weapons material production and elimination of that infrastructure, and finally dismantling of nuclear weapons. All of this would need extraordinary verification measures, exceeding those in the JCPOA because of the reality that North Korea already has nuclear weapons. A step-by-step approach will need a variety of incentives for North Korean nuclear weapons program personnel. A "Nunn-Lugar" type Cooperative Threat Reduction program should be one of those incentives.

A Pragmatic and Phased Approach to North Korean Denuclearization

Achieving security and stability and reducing catastrophic risks on the Korean Peninsula will require intensive, expert level negotiations and comprehensive step-by-step implementation over many months and years. An effective and politically sustainable denuclearization effort must be supported by strong and intrusive verification, on par with the extraordinary measures achieved in negotiating the JCPOA with Iran.

Denuclearization should result in the elimination of North Korea's nuclear weapons and the direct means for producing them. This will be a long process—perhaps decades. Pyongyang will expect "corresponding measures," and they should be provided but must be balanced to match the significance and verifiability of denuclearization and WMD threat reduction steps. This balance can be achieved with North Korea taking defined denuclearization or dismantlement steps as the United States and other partners take targeted reciprocal diplomatic, economic, and other measures leading to U.S.-DPRK diplomatic normalization, a new Korean Peninsula peace regime, and the removal of economic sanctions. The next logical step in denuclearization, in addition to formalizing North Korea's voluntary freeze on nuclear and long-range ballistic missile tests, would be a verifiable freeze on fissile material production, both at plutonium production and uranium enrichment sites, coupled with some set of corresponding measures by the United States, such as limited and reversible sanctions relief.

Preparing for Success—A Cooperative Threat Reduction Approach for North Korea

Economic, military, and diplomatic pressure helped bring North Korea to the negotiating table in 2018 but reaching a successful agreement will require carrots as well as sticks. In addition to the traditional set of inducements that have been raised in previous talks—such as sanctions lifting, an "end of war" declaration, or opening liaison offices in Washington and Pyongyang—negotiators should incorporate a new idea that could provide an incentive to North Korea that also would facilitate denuclearization.

As former senators Sam Nunn and the late Richard Lugar wrote in an April 2018 Washington Post op-ed, to enhance the prospects for the comprehensive, verifiable, and enduring denuclearization of North Korea, the United States should incorporate into the negotiations an offer to Pyongyang of a Cooperative Threat Reduction (CTR) program. Such a program would facilitate the dismantlement of the DPRK's nuclear and other WMD programs and incentivize North Korea to take those dismantlement steps in return for technical and economic assistance on denuclearization and WMD threat reduction and to help redirect human and technical resources to civilian economic development.

NTI released a study earlier this year—*Building Security Through Cooperation*—exploring how the CTR model championed by Nunn and Lugar and implemented in the former Soviet Union in the early 1990s could be adapted to the needs and realities of the North Korea situation, which of course is very different. A CTR program would help achieve dismantlement of the DPRK's nuclear and possibly other WMD programs, with Pyongyang taking the lead to implement concrete steps in a cooperative effort backed by support and assistance from the United States and others.

The NTI report offers a menu of examples of how CTR could be offered to help North Korea carry out specific denuclearization obligations and facilitate converting elements of its militarized economy, facilities, and personnel to contribute to its civilian economic goals. This is an important balance, since it will be difficult if not impossible for Kim Jong Un to eventually give up all his nuclear weapons if he cannot foresee an economically prosperous North Korea continuing under the current political system.

While the report does not presume whether the DPRK would be permitted to retain a civilian nuclear capacity under a new deal, the likelihood of long-term, sustainable cooperation would be greater under an agreement that allowed the DPRK to retain a civilian nuclear program under strict verification. Rather than simply require the North Koreans to dismantle the Yongbyon nuclear facility, for example, the United States and other international partners could work with the DPRK to convert that site to a research park for exclusively peaceful nuclear research. There could also be projects to downblend nuclear materials from weapons stocks for use in civilian reactors outside North Korea (analogous to the U.S.-Russia Megatons to Megawatts Program), as well as joint work to address environmental remediation and waste issues from decades of nuclear operations. For each of these projects, the United States or partner countries could provide funding, training, equipment, or other resources to facilitate dismantlement of proliferation-sensitive facilities and help with conversion to peaceful uses.

CTR cooperation could also assist in dismantling elements of the DPRK's missile inventory and production facilities, including demating warheads and securely transporting them to storage and elimination facilities; removal, transport, and neutralization of missiles and fuels; and elimination of missiles and launchers, production facilities, test sites, and other infrastructure. If an agreement permitted North Korea to engage in civilian space activities, North Korea's missile workforce could be redirected to elements of a space program, perhaps focused on satellite design and construction, with other states providing launch services.

Finally, without prejudice to the sequencing of when such matters might be addressed in negotiations, the report also addresses how an offer of CTR assistance could play a role in reducing risks from other North Korean weapons of mass destruction by assisting with elimination of chemical weapons and encouraging steps toward full compliance with the Biological Weapons Convention. In the context of eliminating chemical and biological weapons capabilities, the United States and other members of the international community could assist North Korea in building capacity for peaceful basic and applied research and development, as well as potentially on biosafety, biosecurity, and overall health security.

Moving Beyond the Bilateral Track to Get Regional Buy-in for Denuclearization

While recent talks have been focused on bilateral exchanges, a long-term solution for the Korean Peninsula will need to be multilateral in nature—including China, South Korea, Japan, and Russia—and address the security, economic, and political concerns of all the parties. It is hard to see how North Korea would actually eliminate its nuclear weapons stockpile without such a comprehensive approach. The Iran negotiations showed the importance of having the multilateral partners speak to Iran with one voice, and the negotiations were structured consistent with this requirement.

The involvement of multiple countries in a CTR effort would contribute to a successful denuclearization effort. It would provide reassurance to the DPRK of the sustainability of implementing CTR projects over the longer term and would benefit the United States by sharing the economic and implementation burden among the most interested and capable partners. The role of regional states is vital because of their relationships with the DPRK and the expertise they can offer, but other states outside the region along with international organizations also could play a constructive role. There are multiple states that have experience in the nuclear, missile, mining, industrial, and energy areas directly applicable to a CTR effort aimed at ending military programs and redirecting facilities and personnel to civilian activities.

A major benefit of such a program for North Korea could be increased scientific and technical engagement in non-sensitive areas with U.S. and other international scientists and experts—engagement that could help build trust and buy-in over the long run. Scientific engagement offers a way to bolster a broader normalization process through greater exposure to the outside world, introducing North Korean scientists and engineers to international counterparts and promoting an exchange of information and personnel.

It is important to incorporate the potential offer of CTR assistance early into the negotiations to provide concrete incentives to North Korea. It is also important to begin planning now for how to implement a final denuclearization deal. The United States should start identifying the resources it can provide to a CTR effort, as well as adjustments that will be necessary in legal and legislative authorities, crafting exemptions to international sanctions to allow for scientific engagement, and building support for this concept in Congress and with other nations.

In short, a successful denuclearization effort will be one that is done with, not to, North Korea.

Subnational Proliferation Risks

Since 9/11, there has been heightened concern about subnational groups, terrorists, or organized crime gaining possession of nuclear weapons or weapons-usable material. This clearly reinforces the urgent need to continue securing and removing such materials around the world. Removal has often entailed taking material back to the United States and Russia, although China is also beginning to address materials that it provided to other countries in years past.

The potential for a subnational nuclear threat is best managed by securing and eliminating nuclear material that can be used in a nuclear weapon: HEU and plutonium. Currently, only states have the financial and technical wherewithal to create these materials, although advances in miniaturization and advanced manufacturing may put enrichment or reprocessing within reach of non-state actors in the future.

Major Progress in Securing Nuclear Materials Has Been Achieved…

Of the roughly 1,400 metric tons of HEU and 500 metric tons of plutonium in the world today, the vast majority resides in the United States and Russia, most of which is contained in nuclear weapons or within the weapons complexes of both nations. Russia as well as France, Japan, and the United Kingdom also have tens of tons of separated plutonium from spent fuel from nuclear power plants, also usable for nuclear weapons. China, India, and Pakistan are manufacturing additional HEU and plutonium for their growing weapons programs, and Russia has restarted HEU production for commercial sale. Another 14 countries have smaller quantities of HEU or plutonium associated with non-weapons research facilities or legacy programs. If non-state actors seek a nuclear weapons capability, these are the only sources of material.

Concern about the security of nuclear materials began during the 1970s as terrorists hijacked planes, and the first international discussions began on the security of nuclear materials in international transit. This concern ramped up in the early 1990s as the Soviet Union collapsed and instances of nuclear materials smuggling briefly spiked—bilateral efforts such as the Nunn-Lugar CTR program and related efforts focused on eliminating, consolidating, and securing nuclear materials in Russia and other former republics with elements of the Soviet nuclear archipelago. Then, in 2001, the Al Qaeda attacks marked a drastic shift in our understanding of both the capabilities and the intent of terrorists. Not only did the 9/11 attacks show a new and concerning level of sophistication, discipline, and resources, Al Qaeda's apocalyptic ideology and demonstrated interest in nuclear weapons revealed a theory of nuclear use that previous terrorist groups lacked.

The last two decades, therefore, have seen a heightened interest in materials elimination and security. A range of bilateral and multilateral efforts have sought to work with those states who hold these materials to reduce the number of locations and quantity of nuclear materials. One key indicator of success is the elimination all HEU and plutonium from over 30 countries; also, the United States and Russia have together eliminated over 700 metric tons of HEU. The tools of those achievements are still available and applicable to the nuclear materials holdings of the remaining 22 countries: HEU blend-down to LEU, substitution of HEU fuels by LEU fuels, non-HEU production of medical isotopes, or through dilution and underground disposal.

But Hard Work Remains to Address Enduring and Emerging Challenges

The "easy" steps have been taken—what remains will require a mix of additional resources, new technology, and political will. Some HEU-fueled research reactors are still awaiting licensing of LEU fuel designs. Reduction of HEU stocks in the United States will depend on an unlikely and costly shift to LEU for naval propulsion. Some exotic HEU fuel types have no disposition path, stranding them in countries who no longer want or need them. Elimination of the 100+ metric tons of separated plutonium in the UK will cost billions, and shrinking plutonium stocks in France, Japan, and Russia would require the abandonment of those countries' commitment to the closed fuel cycle. Some countries are clinging to legacy holdings of HEU for political reasons.

The number of states with weapons-usable nuclear materials is therefore not likely to decline soon. There are only a few remaining countries for which complete and permanent removal is a realistic prospect. In the meantime, nuclear materials will continue to be transported, handled, processed, and stored for weapons and peaceful purposes for the foreseeable future.

With several important exceptions, the days of U.S. government-funded, industrial-scale destruction of extant weapons, materials, and facilities under CTR and related programs are over and are not likely to return. Future nuclear concerns will likely come from two sources:

- Enduring challenges associated with large and growing stockpiles of fissile materials and nuclear warheads that will likely persist for the foreseeable future, as well as the reality that nuclear knowledge can never be eliminated; and
- Emerging issues that contain within themselves the potential for both benefit and harm, such as advanced nuclear energy, cyber, artificial intelligence and machine learning, autonomous systems, advanced manufacturing and miniaturization, remote operations, and other technological advancements and disruptions.

These enduring and emerging challenges will not be *solved*—they can only be *managed* in ways that limit their inherent risks without overly limiting the inherent benefits of technology. This is the basic philosophy underpinning the expansion of CTR to "Cooperative Risk Management" (CRM).

The central goal of CRM for nuclear security is to improve national and operational capacities for, commitment to, and implementation of long-term stewardship of nuclear materials wherever they exist. This will mean a focus on strengthening regulations and regulators; improving nuclear security culture and practice; integrating security-by-design in construction of new facilities; holding operators accountable for their nuclear security responsibilities; identifying internal nuclear security champions at the operator and state levels; and developing international institutions, treaties, and norms that will support and sustain nuclear security excellence, based on the principle of continuous improvement.

CRM retains the word *cooperative* from CTR—but if CTR was characterized largely by donor-recipient relationships, CRM is characterized by peer-to-peer relationships. Under the CRM model, the United States and other partner countries assume the role of nuclear security cheerleaders and coaches, rather than donors and managers.

CRM replaces the word *threat* with *risk* because potential partners may be unwilling to engage when they suspect that they are seen as a threat. Moreover, the sources of concern going forward will likely contain potential benefits alongside potential for harm—and these positive gains will need to be captured and shared.

Lastly, CRM replaces the word *reduction* with *management* because reduction suggests a permanence or irreversibility that is unlikely, and perhaps not even desirable. By and large, the central challenge for governments and operators is to effectively manage the risks associated with long-term stewardship of nuclear materials.

CRM has many promising features. Such an approach should facilitate incorporation of risk management as an inherent element of dealing with nuclear materials, rather than an external, burdensome add-on. Because CRM does not assume a transfer of resources between states, the legal and bureaucratic burdens of government-to-government agreements, contracts, and so on may be less, leading to more flexible forms of cooperation and a greater diversity of partners.

CRM does not seek to eclipse or replace "CTR classic.» Indeed, in some cases, such as the aforementioned North Korea situation and remaining opportunities for weapons/material elimination and consolidation, the United States and other governments need to maintain elements of the traditional CTR toolkit. Nevertheless, an expanded model for engagement is needed, one that is optimally suited to meet today's and tomorrow's nuclear security challenges. This model will likely require new tools, new institutions, new relationships, and new approaches.

In many ways, the U.S. government is already implementing aspects of the CRM model without explicitly calling it such. This shift reflects a natural evolution of CTR-linked institutions and the approaches they use for risk management and mitigation. Nevertheless, providing an overarching framework for nuclear security engagement that is an intentional and considered transformation from the CTR framework may have important benefits that allow the U.S. and other governments to have a more strategic and efficient approach to managing today's nuclear risks.

Building a Global Nuclear Security Architecture

Efforts are still needed to build an effective global nuclear security architecture. Among the ongoing challenges is the lack of a common set of international standards and best practices, the absence of a mechanism for holding states accountable for appropriate and effective security measures, and an incomplete legal foundation for securing materials that is neither universal nor fully implemented.

NTI has been leading work on strengthening the global nuclear security architecture through its Global Dialogue on Nuclear Security, a Track 1.5 dialogue with government officials, representatives from international organizations, nuclear industry, and non-government experts designed to provide a forum for an integrated and creative dialogue. First convened in 2012, the Global Dialogue meetings were held in support of the Nuclear Security Summit process and played a role in shaping Summit outcomes. After the final Summit in 2016, governments encouraged NTI to continue hosting the Global Dialogue to provide a forum to sustain dialogue on nuclear security, including in support of the Nuclear Security Contact Group (NSCG), a group of Summit countries that have continued to meet regularly to track implementation of Summit commitments. NTI continues to play a role in shaping analytic thinking and driving ambition in a post-Summit world.

NTI has also been measuring progress on global nuclear security through its biennial publication of a Nuclear Security Index (NTI Index), a unique assessment, based on publicly available information, of nuclear security conditions around the world published biennially since 2012 and developed with the Economist Intelligence Unit. The NTI Index assesses the security around the HEU and plutonium that can be used to build nuclear weapons, as well as the security of nuclear facilities, which, if sabotaged, could lead to dangerous releases of radiation. The NTI Index tracks country-level progress on nuclear security and encourages governments to take actions to protect and build confidence in the security of their materials and facilities.

Many nuclear security measures are aimed at decisions made by nations or international institutions, but some of the most important impacts are found in the mindsets and behaviors of the practitioners of nuclear security in industrial facilities, research labs, hospitals, and transportation companies. This diverse community was the target of NTI's establishment of the World Institute of Nuclear Security (WINS) in 2008. Since then WINS has attracted almost 6,000 individual members in over 140 countries, published dozens of best practice guides, hosted hundreds of training activities, and certified over 350 nuclear security professionals.

These and related activities are designed to move toward a global nuclear security architecture that is comprehensive in scope, based on best practices, builds confidence in each nation's nuclear security behavior, and reduces overall quantities of weapons-usable materials.

Reassessing Forward Deployment of U.S. Nuclear Weapons

The subnational risk has more far reaching policy implications as well. For example, the forward deployment of U.S. nuclear weapons in NATO states should be reevaluated, in no small part because of elevated risk in unstable situations, such as the coup and recent tensions with Turkey, where the ISIS threat is just over its border in Syria. The President recently acknowledged the stationing of nuclear weapons in Turkey, and it is generally understood that other NATO countries also host U.S. nuclear weapons.

U.S. forward-deployed nuclear weapons are an attractive target for terrorists, as they are more vulnerable if located in areas where there is a heightened risk of terrorism or political instability. In the case of Turkey, the warning bells have been ringing for over three years. We are in the midst of a long stretch of political uncertainty in Turkey, exacerbated by growing anti-Americanism. Any U.S. nuclear weapons stored there are more likely to complicate than to improve the domestic political currents in play, let alone the growing disconnects between Turkey and its NATO allies.

Some may argue that the United States should not remove nuclear weapons from Turkey so as not to signal lack of confidence in Turkey's stability; or that the United States needs tactical weapons throughout Europe to bolster NATO members worried about Russia. But these arguments must be weighed against the fact that storing tactical nuclear weapons in Turkey and potentially in other NATO nations comes with the increasing risk of vulnerability to an evolving and more deadly terrorist threat, or to domestic unrest. In the wake of an incident at a nuclear storage site, it would be difficult to explain that vulnerable targets were left in place due to a perceived need to provide symbolic reassurance to our allies, particularly in the one case where the risks and threats to the safety and security of these weapons are real and growing.

It is important to underscore that the principle of collective defense enshrined in Article 5 of the Washington Treaty is essential, and any changes to NATO's defense policy and posture must be seen through that lens; however, the current security environment should not preclude Washington and NATO from reviewing NATO's nuclear posture. In fact, NATO's security requires a hard look at and new approaches to NATO deterrence and defense through the prism of reducing the risk of nuclear use. Forward-deployed U.S. nuclear weapons in Europe—and Russian nuclear weapons deployed near its Western border—increase the risk of accidents, blunders, or catastrophic terrorism and invite pre-emption. Given these added risks and the absence of any clear military need, it is past time to revisit whether U.S. forward-based weapons are essential for political reassurance.

NTI has been examining these threats for almost a decade. In 2018 at the Munich Security Conference, NTI released a report *Building a Safe, Secure, and Credible NATO Nuclear Posture,* urging U.S. and NATO leaders to re-evaluate forward-deployed nuclear weapons in Europe. Most recently, Sam Nunn and I wrote in the fall issue of *Foreign Affairs* that the United States, NATO, and Russia should consider that U.S. and Russian nuclear weapons in and near Europe may be more of a security risk than an asset. Finally, with the demise of the INF Treaty, Washington and Moscow must find a way to prevent the deployment of U.S. or Russian intermediate-range missile systems in the Euro-Atlantic region. If they do not, leaders throughout Europe will be faced with increased fears of a short-warning nuclear attack that could decapitate a nation's leadership, which would greatly increase the risk of false warnings.

Conclusion

The fundamental test of the nuclear era—balancing non-proliferation with peaceful uses of nuclear energy—has persisted into the 21^{st} century and grown more complex, with the rise of new technologies, increased political instability, and a renewed interest in nuclear energy to combat climate change. The good news is that there are new tools and approaches to help us manage these risks, including many outlined above. What is most urgently needed today is for the United States to reassert its global leadership and start exerting its political will to bring these new tools to bear before the next proliferation crisis. We do not have time to spare—the risks are great, but opportunities are also there to be had if we choose to act now.

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