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About the Author

Thomas W. Spoehr *is Director of the Center for National Defense, of the Kathryn and Shelby Cullom Davis Institute for National Security and Foreign Policy, at The Heritage Foundation. He is a retired Lieutenant General, who, while in service, served as the Army's most senior officer in the field of countering weapons of mass destruction.*

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The Heritage Foundation
214 Massachusetts Avenue, NE
Washington, DC 20002
(202) 546-4400 | heritage.org

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The lack of commonly defined U.S. denuclearization and verification standards presents a challenge when the United States endeavors to communicate what "final and fully verifiable denuclearization" (FFVD) means. The need for commonly understood U.S. criteria that fulfill the standards of FFVD stems from the fact that in every instance of denuclearization on record, the definition of "final" denuclearization and "fully verifiable" has varied, depending on which nation(s) defined the term. Establishing a standard that defines denuclearization standards also serves to put nations with interests in collaborating with emerging nuclear states on notice regarding U.S. objectives. These guidelines would serve to discourage exceptions, side deals, or other agreements from coming into play during the process or aftermath of denuclearization.

Introduction

The lack of commonly defined U.S. denuclearization and verification standards presents a challenge when the United States endeavors to communicate what "Final and Fully Verifiable Denuclearization" (FFVD) means. Former Secretary of State John Kerry, when speaking about the Iran nuclear negotiations, famously said, "A bad deal is worse than no deal." Unfortunately, what was missing at the time, and remains absent to this day, was a common U.S. understanding of the standards that actually distinguish a "bad deal" from a "good deal."

This confusion ultimately resulted in the Joint Comprehensive Plan of Action (JCPOA) that included the expiration of restrictions and Iran's retention of both fissile material enrichment capabilities and enriched uranium. Iran was required to reduce its uranium stockpile by 98 percent, but was allowed to keep 660 pounds of uranium enriched to 3.67 percent, and was able to retain 5,060 uranium-enriching centrifuges in country. The Obama Administration's accession to these terms in the JCPOA negotiations suggested our government believed at the time that this constituted "adequate" denuclearization.

The need for commonly understood U.S. standards that fulfill the criteria of FFVD stems from the fact that in every instance of denuclearization on record, the definition of "final" denuclearization and "fully" verifiable has varied, depending on which nation(s) defined the term. Because the stakes of denuclearization are always high, nations or organizations with a stake in denuclearization will often give differing answers when asked about their goals for denuclearization and their methods for verifying it. Establishing a standard that defines denuclearization standards also serves to put nations with interests in collaborating with emerging nuclear states on notice regarding U.S. objectives. These guidelines would serve to discourage exceptions, side deals, or other agreements from coming into play during the process or aftermath of denuclearization.

Leading the establishment of denuclearization standards sends a signal to the international community that the U.S. is serious about denuclearization

and is spearheading denuclearization efforts. The concessions of the JCPOA and absence of an internationally accepted standard for denuclearization demonstrate the need for the United States to take the reins on defining and communicating a "final and fully verifiable" standard of denuclearization.

Past Frameworks

While certain internationally recognized documents, such as the Non-Proliferation Treaty (NPT), the International Atomic Energy Association's (IAEA's) Additional Protocol, and various U.N. agreements (including the recent Joint Comprehensive Plan of Action), provide some examples of past frameworks for implementing and verifying denuclearization, none of these documents defines what the United States government considers "final or fully verifiable," thus leaving room for interpretation, risky compromise, and for misconceptions to fester.

Some international arms control treaties, however, are recognized for possessing rigorous verification regimes. The protocols of the Strategic Arms Reduction Treaty (START), Intermediate Range Nuclear Forces, and Conventional Armed Forces in Europe Treaties each included extensive verification requirements, with some including short-challenge inspections of non-declared facilities. While even these protocols leave room for improvement, they provide a strong foundation for principles that the U.S. should advocate during future negotiations.

This paper will proceed by addressing three main elements of FFVD: (1) what circumstances must exist for FFVD to commence; (2) the essential elements of FFVD; and (3) the key elements of a "fully verifiable" regime.

Words Matter

During the 2018 talks between the United States and the Democratic People's Republic of Korea (DPRK, or North Korea), the language employed by the United States concerning denuclearization changed. The long-held language employed by the U.S. and others called for "Complete, Verifiable, and Irreversible Dismantlement" (CVID) of nuclear capabilities. While CVID has been the terminology employed in many U.N. Security Council Resolutions, in 2018 the language the U.S. employed evolved, first to "Permanent, Verifiable, Irreversible Dismantlement" (PVID), before changing to the current term: "Final, Fully Verifiable Denuclearization." For reasons unknown, Secretary of State Michael Pompeo and the Trump Administration apparently favor this term.[1] While some have expressed concern that the changes to this language around denuclearization suggest more lax standards, the Administration has denied this claim.[2]

Throughout this paper, we will use the term FFVD. Even if the terminology were to change again, the proposed standards that follow remain constant: Denuclearization must be *permanent* and must be *verifiable* to the greatest extent possible. It is worth a moment to examine the meaning of these terms.

"Final"

"Final" means "not to be altered or undone." In that context, final denuclearization is forever. The restrictions and requirements do not lessen over time. Nuclear weapon capabilities are permanently eliminated, for example, when all uranium-enrichment and plutonium-refinement equipment present in a nation being denuclearized is either destroyed or removed and action taken to prevent its reconstitution. When describing the word "final," the United States government must emphasize the principles of complete and irreversible denuclearization.

This includes conveying to all parties involved that denuclearization is indeed permanent and that the strict guidelines would not be lifted after a period of time, unlike, for example, the JCPOA agreement, which included provisions to lift the restrictions (such as restrictions on centrifuges) after 10 and 15 years.[3] These permanent restrictions should include restrictions on the nation's capability to enrich or reprocess Uranium 235 or Plutonium 239, respectively. Because the lifting of restrictions can directly reduce the breakout time (the time it takes a nation to build a fully functioning nuclear weapon), any time-based removal of restrictions represents a direct danger to the "final" aspect of FFVD.[4]

"Fully Verifiable"

"Fully verifiable" is more difficult to define than "final." Experts report that even the most comprehensive of verification regimes can never be perfect. As the Congressional Research Service noted, "[T]he verification regime in an arms control treaty cannot remove all doubts about the existence of possible violations."[5] Thus, defining "fully verifiable" takes the form of insisting on the most rigorous and intrusive of overlapping and complementary verification

protocols possible in order to achieve a high (but not perfect) degree of confidence that the state being denuclearized is complying with the denuclearization agreement(s).

Included in defining "fully verifiable" is the description of the constitution and authorities of a trustworthy and empowered verifying organization (VO). Any such organization must have the ability to inspect any nuclear facility—or other site—without interference and to make unfiltered and timely assessments, quickly communicated to the treaty parties.

Critical to any agreement that is "fully verifiable" is the establishment or designation of a single, authoritative VO to conduct the verification regime and monitor the standards of denuclearization. In order to satisfy the United States' high requirements for FFVD, the VO should be a multi-national body, either led or co-led by the United States. (For reasons that will be described later, despite its considerable expertise and experience, the IAEA, by itself, is not able to act or perform in a manner that provides sufficient assurance for the U.S. that a verification regime is "fully verifiable.")

The duly constituted VO, in whatever form it takes, must enjoy the backing of the U.N. and other governing bodies and be able to rely on qualified and vetted experts from organizations such as the IAEA to act as inspectors. The VO must enjoy the unquestioned authority to enter a country, conduct denuclearization monitoring and verification, communicate candidly on the progress made (or lack thereof), and make evaluations of agreement compliance and risk.

Scope

This paper will articulate the standards of denuclearization—not the global conditions in which the process takes place, which is a narrow subset of the issues concerning denuclearization. This paper will neither endeavor to describe the political circumstances nor the actions necessary to compel or persuade a state to denuclearize, nor will it describe the phases or steps of denuclearization in conjunction with sanction relief or other incentives employed to persuade or coerce a state to denuclearize. This paper solely aspires to describe the recommendations for an ideal standard of final and fully verifiable denuclearization but does not imply that the conditions necessary to achieve FFVD standards are completely achievable in every conceivable political, geographical, or international situation.

Nonetheless, this paper *does* assert that a willful departure from these articulated standards carries an increased probability that a country undergoing denuclearization would be more likely to be able to: (1) hide existing nuclear weapons, components, facilities, fissile material, or production equipment; (2) clandestinely maintain or manufacture or proliferate fissile material; or (3) resume the production of fissile material and nuclear weapons more quickly than anticipated.

Legal Basis

Traditionally, all states striving to dismantle their nuclear weapons programs begin by taking two steps. First, nations sign the Nuclear Non-Proliferation Treaty and then ratify the Model Protocol Additional to the Agreement Between the States and the IAEA, hereafter referred to as the "Additional Protocol." The NPT establishes the basis of denuclearization by requiring signatories to agree to prevent proliferation of nuclear weapons and materials, to foster the peaceful use of nuclear energy, to further the goal of disarmament, and to establish a safeguard system that the IAEA is responsible for maintaining.[6] The NPT, established in 1968, was meant to stem the spread of nuclear weapons technology.[7] Although it failed at stopping the spread of nuclear programs, the NPT established a basis of international cooperation on nuclear issues. The addition of the Additional Protocol in 1997 greatly expanded the IAEA's ability to oversee nuclear development, particularly in civilian nuclear programs,[8] and strengthened the NPT.

While the NPT establishes the guidelines for the peaceful use of nuclear materials and for the transfer of nuclear weapons technology, it does not provide concrete methods to ensure that these steps are taking place. This is where the Additional Protocol comes into play. The IAEA's Additional Protocol is a supplementary safeguard agreement that lays out guidelines on open access for inspectors, provision of information, guidelines for inspectors, and subsidiary agreements on nuclear issues.[9] Once the Additional Protocol is ratified, it provides tools that can be used to verify denuclearization efforts and increases the ability to verify the peaceful use of nuclear materials in civilian power.[10]

However, even the Additional Protocol by itself does not lay out defined steps that must be taken to ensure nonproliferation or the acceptable peaceable use of nuclear materials. It lacks sufficient

state-specific details, causing it to fall short of completely outlining standards sufficient for full and final denuclearization. This is the basis for the requirement that the NPT and the Additional Protocol must be supplemented with a *state-specific agreement* tailored to the nation whose nuclear weapons capabilities are being eliminated.

Who Is Involved

While the United Nations facilitated the NPT, which seeks to prevent the spread of nuclear weapons and technology, and the IAEA has traditionally led the oversight of the verification process, a host of international actors have also played significant roles in denuclearization. The United Nations and its member states have often played a role in establishing additional multi-lateral treaties on denuclearization, such as the establishment of the Joint Comprehensive Plan of Action, which was led by the five permanent members of the U.N. Security Council—the U.S., the U.K., France, Russia, and China—and Germany, the so-called P5+1 with Iran.

The Six-Party Talks regarding North Korea's nuclear program represent another example of a series of multilateral denuclearization negotiations. These took place starting in 2003 with the United States, Russia, China, Japan, North Korea, and South Korea as participants.

Many other regulatory agencies, such as the World Nuclear Association, the Nuclear Regulatory Commission, and the Organization for World Peace, among others, have often claimed a role in promoting a nuclear-free world. During the process of denuclearization, these organizations may be directly or indirectly associated with the process. This may take the form of the U.N. establishing guidelines for the duration of the process and facilitating cooperation between involved states or of other organizations providing qualified experts to work on negotiations and verification teams.

Conditions Necessary to Commence FFVD

Although the specifics of denuclearization vary based on the circumstances surrounding the nation to undergo the process, there are certain criteria that must be satisfied in order to set the conditions for successful FFVD. Without the accomplishment of these entrance criteria, it is impossible to proceed to the actual, more tangible steps of denuclearization. This is not to say that reaching these criteria is easy; indeed, attempts at denuclearization typically fall short of achieving these steps.

State Cooperation and Transparency. While a rigorous verification regime is vital to ensuring a country's nuclear program is eliminated, state cooperation and transparency are a necessary precursor to the verification process.[11] Unless a country proves itself willing and able to cooperate with international oversight agencies, denuclearization remains extraordinarily difficult—if not impossible—due to state resistance, as exemplified by the case of Iraq, which obstructed IAEA inspections by the removal of materials from inspections sites and denial of access to facilities in 1991 at the time of the First Gulf War.[12] Indeed, as Paula DeSutter, former Assistant Secretary of State for Verification, Compliance, and Implementation, said in 2008, "The single most important basis for an adequate verification capability is a strategic commitment on the part of that country to adhere to its obligations."[13]

Additionally, a state moving toward FFVD must also be transparent. Without full transparency in its dealings with the VO and other governing bodies, the necessary accounting of a country's nuclear materials and facilities cannot be established.[14] Without initial transparency, the VO has no baseline from which it can audit the amounts of nuclear materials within a state—or their disposition.

Finally, cooperation and transparency must be uniformly shared within the government. This is particularly important in countries in which there exist completely different allegiances and power centers, such as in Iran, where the Supreme Leader, Ali Khameni wields extraordinary power (including control of the armed forces) compared to the President, Hassan Rouhani, whose powers are more circumscribed.[15]

State-Specific Agreement. Another requirement for FFVD to proceed is the agreement by all parties to a state-specific agreement that addresses the specific aspects of each individual country's nuclear program. Clearly delineating the required actions by all parties in a comprehensive, well-crafted accord is a basic, but critical, requirement. Precise agreements enact more comprehensive and preventative measures to avert the weaponization and proliferation of nuclear materials. The implementation of state-specific agreements[16] that explicitly address all facets of denuclearization—such as the exact facilities to be dismantled, the precise disposition of fissile material

and weapons components, the implementation of specific verification protocols, and a detailed timeline for denuclearization—provides the necessary additional framework for the state in question to denuclearize. The specificity of such an agreement presents less opportunity for misunderstanding and can specify the incentives or reciprocal agreements from the international community that will be provided once the state has accomplished specific, described steps of denuclearization.[17]

How a vague and ill-defined agreement can undermine subsequent denuclearization efforts is highlighted by the experience surrounding the 1994 Agreed Framework negotiated between the U.S. and North Korea. The document lacked much of the detail necessary for implementation and, as one evaluation assessed, its "specific milestones under the Agreed Framework were repeatedly subject to divergent interpretation by the two sides."[18] Conversely, the 1991 START treaty between the U.S. and the USSR contained an extraordinary amount of detail on the verification regime (including intrusive verification measures), described 12 different types of on-site inspections, as well as the provisions for continuous monitoring, and is widely viewed as representative of a very detailed state-specific agreement.[19] When describing START, the Congressional Research Service, assessed "the level of detail was designed not only to provide comprehensive data, but to minimize ambiguities and uncertainties that might arise during the treaty's implementation."[20]

Similarly crafted specific denuclearization agreements enable the VO to effectively implement the verification regime.[21]

A Detailed Timeline. In conjunction with the establishment of state-specific safeguard agreements, a timeline to complete denuclearization must be established. A timeline prevents the state in question from dragging out negotiations or its denuclearization actions in order to exploit more favorable terms, as well as preventing the state from gaining *de facto* status as a nuclear state, if it has not already done so.[22] The importance of a detailed timeline was vividly demonstrated in the early 1990s, when the Iraqi regime obstructed IAEA inspections despite initially agreeing to their presence, and delayed signing U.N. Resolution 715, which allowed the IAEA and the U.N. Special Commission (UNSCOM) to monitor and verify the Iraqi nuclear, chemical, and biological weapons programs, until November 1993.[23]

Additionally, while a timeline of denuclearization must be established, there should be no timelines in place that allow for a nuclear program to be restarted—and no expiration of restrictions. For example, the JCPOA agreement allowed Iran to increase the amount of uranium the country enriches above 300 kilograms after 15 years and decrease the number of centrifuge restrictions and IAEA inspections after 10 years and 15 years, respectively.[24] The easing of restrictions after this relatively short amount of time would have significantly lowered the "breakout time" necessary for Iran to create a nuclear weapon[25] and given the country a much higher chance of successfully restarting its nuclear program. No matter how difficult it makes the negotiations, a "final" denuclearization agreement does not, *by definition*, include the potential for restrictions to end or ease.

Constitution of a Competent and Empowered Verifying Organization. The key to successfully conducting FFVD is the constitution and maintenance of an empowered, authoritative, and internationally recognized VO. In addition to state compliance, there must be a mechanism in place to verify state transparency, accuracy of declared information, and compliance. The VO therefore plays a key role in order to assure that FFVD occurs successfully.

Since 1957, the IAEA has existed to promote "safe, secure, and peaceful" use of the atom and to ensure that atomic energy was not used "in such a way as to further any military purpose."[26] The IAEA has evolved over the years and has developed elaborate protocols designed to monitor state compliance with the NPT and the Additional Protocol. With 152 member states and an annual budget of $400 million, the IAEA possesses deep experience and expertise in nuclear matters.[27]

While the IAEA is very experienced in monitoring the NPT among the "community of the willing" states, over time it has proven itself neither sufficiently organizationally agile nor empowered to singlehandedly meet the needs necessary to satisfy the U.S. standards for FFVD. Internal IAEA reports reflect that nations are routinely late in submitting required reports and declarations with little consequence.[28] Past cases of IAEA inspectors being blocked from entering nuclear facilities (such as what transpired in Iraq in the 1990s), restrictions imposed on IAEA inspectors' ability to take samples, and its inability to quickly come to judgments on violations, have, over

the years, highlighted the limitations of the IAEA—despite its acknowledged expertise.

Additionally, even if the IAEA were able to detect a clandestine restarting of a nuclear program, it has been assessed as not able to provide adequate warning time to Western powers to stop a weapons "break out" in a country such as Iran.[29] The IAEA has also been deemed "clueless" about nuclear weapons in states that are not party to the NPT (India, Israel, Pakistan, and South Sudan), and concerns over a lack of ability to enforce compliance have been noted.[30] Finally, due to budget constraints, increases in fissile material under IAEA control, and technical limitations, the IAEA has been unable to keep up with its own inspection goals, much less deal with the large burden of a *new* denuclearization agreement.[31]

Moreover, the IAEA and its charter organization, the U.N., do not have an organic intelligence apparatus with the national technical means able to provide additional confidence that denuclearization measures are being implemented completely and without subterfuge. Although the Additional Protocol increased the ability of the IAEA to receive classified information from member states such as the U.S., the process remains cumbersome. Discrepancies between Western intelligence assessments and assessments made by the IAEA have historically differed and hampered past denuclearization efforts. Due to high levels of classification and the covert or clandestine collection of information on foreign nuclear programs, much of the CIA and other intelligence agencies' information cannot be released to IAEA inspection teams and can still be heavily redacted years later.[32]

To ensure that a future denuclearization agreement is indeed "fully verifiable," for the reasons described above, the U.S. should not rely on the IAEA as the sole verifying organization. An ideal verifying organization would thus be formed around a U.S. core and would include trusted parties to the denuclearization agreement, the IAEA, and a group of the parties to the agreement. A brand-new U.S. organization does not need to be formed; it could, for example, be based on the U.S. Department of Defense's Defense Threat Reduction Agency.

For the U.S. to have sufficient confidence in the results, the U.S. should require an American presence on each inspection team. An American presence on these teams could provide additional confidence that the denuclearization standards are not being diluted or modified.

Standards of Denuclearization

Certain actions are widely recognized as being the keys to the elimination of a state's nuclear program. Therefore, states wishing to have their denuclearization process recognized as fulfilling FFVD by the United States must meet the following standards. These standards should be considered non-negotiable, as they are the fundamentals of what constitutes "final and fully verifiable" denuclearization. Refusal or inability to cooperate with these standards demonstrates that the state in question is unwilling or unable to denuclearize in a fashion that is fully verifiable and final.

Declaration of All Materials and Intellectual Assets. A state wishing to denuclearize must declare all its nuclear materials, past production of fissile material, facilities, and intellectual assets at the beginning of the denuclearization process. The greatest marker of this transparency is the full and accurate declaration of all nuclear materials, sites, and projects within a nation. The declaration of types and quantities of nuclear materials is necessary so the VO is aware of what materials are subject to verification protocols. The VO must be able to verify that the declaration of materials is correct, and states that offer this information to the VO voluntarily and accurately demonstrate their commitment to the denuclearization agreement.

This information must include a complete list of production equipment, fissile material, the status of uranium enrichment and plutonium reprocessing, location of all nuclear sites, uranium mines, thorium concentration plants, facility designs, fuel rods of both plutonium and uranium, and the status of any of these materials that are in the process of being exported. Nuclear facilities must also have a site diagram, including a boundary map and locations of all storage areas. It is important the declaration not just include the present inventories, but also an accounting of past nuclear efforts in order to establish an accurate baseline.[33]

The accuracy of the declaration sets the stage for all that follows, good or bad. In 2008, during the Six-Party Talks, a comprehensive declaration from the DPRK included an outline of its nuclear program followed by a declaration of all nuclear activities, which was released to all parties involved in these talks.[34] However, the declaration was later found to be flawed by the complete omission of the DPRK's extensive uranium enrichment program, as well as their

support of a Syrian nuclear program, which served to engender renewed distrust and suspicion within the parties.[35]

Access to information about all nuclear materials, sites, and projects is vital to beginning denuclearization and to ensuring that materials are not proliferated during the process. All such facilities must be subject to baseline inspections after declaration.[36] States must declare the type and exact quantity of nuclear material they have so that it can be subjected to monitoring and so the VO can also take steps to verify that no nuclear material has been diverted to other uses or to non-state groups for weapons-development purposes.[37] The VO must also have access to information on enrichment equipment and the state's progress in enriching uranium or refining plutonium.[38] The state must provide assurance that there are no undeclared nuclear materials in the country, and, if necessary, the interested parties must take steps or use tools defined below to verify that there are no undeclared nuclear materials.[39]

This declaration must also include the nuclear intellectual assets the state has, including technical drawings, photographs, and knowledge possessed by the individual scientists and engineers who have worked on the program so that a program cannot be easily restarted. The destruction of technical documents helps lower the risk of program restart with any such information.

Accuracy is important to build confidence. Iran's declaration of nuclear assets under the terms of the JCPOA was later found to be false, based on the subsequent discovery by Israeli agents of two large undeclared archives of nuclear plans and documents in downtown Tehran.[40]

While the knowledge that nuclear scientists and engineers have cannot be destroyed, periodic VO access to the scientists involved in the nuclear weapons program is required in order to help lower the risk they will engage in restarting nuclear weapon programs. Monitoring of scientist's activities, as well as private interviews with the scientists, must be employed to help ensure that they are not re-engaged in the creation of nuclear weapons at the behest of the state.[41]

International Control or Monitoring of Materials and Assets. Having a full and accurate accounting of materials and facilities also instills greater confidence that all fissile material has been transferred to a VO for safekeeping, monitoring, testing, removal, or destruction.[42] The VO may take nuclear materials to their approved facilities and clean labs for sampling and disposal.[43] The ability to emplace international monitoring and controls must be allowed in order to limit the likelihood that materials will be diverted for weapons testing or proliferated.

Removal of Fissile Material. Fissile material is defined as nuclear material with a "nuclide capable of undergoing fission after capturing neutrons."[44] There are two materials—uranium-235 and plutonium-239—that are used in the creation of nuclear weapons and are considered fissile material. U.S. policy must require the removal of all fissile material in order for a state to be considered denuclearized. Placing fissile material under monitoring or seal, which the IAEA's Additional Protocol allows, is insufficient because it leaves fissile material under the state's nominal control.

Plutonium-239 is considered to be weapons-grade when it contains 7 percent or less of other plutonium isotopes; generally, plutonium used in civilian nuclear power plants contains 24 percent of other plutonium isotopes, making the difference between fuel and fissile materials notable.[45]

Only highly enriched uranium that has been enriched to 90 percent or greater can be directly used in nuclear weapons; however, any uranium enriched over 20 percent is considered highly enriched.[46] Fuel-grade uranium can be relatively easily enriched, using a centrifuge, to weapons-grade uranium. *Due to material reduction throughout the process, it becomes significantly easier to purify uranium to weapons-grade from fuel-grade than it is to purify uranium to the fuel-grade level of 3 percent to 5 percent from the natural purity of about 0.7 percent.*[47] The ability to more easily enrich uranium greatly decreases the breakout time for making nuclear weapons, bringing the time necessary to enrich uranium to 90 percent to approximately *16 weeks* when working with uranium initially enriched to 3.5 percent—as opposed to approximately 50 weeks when working with naturally occurring uranium.[48] Thus, all enriched uranium and plutonium material must be removed from the country to make it more difficult for these nations to restart their nuclear programs and to increase nuclear weapon breakout time.[49]

Removal of All Nuclear Weapons and Unassembled Components. In addition to the removal of all fissile materials, any assembled nuclear weapons and all components of nuclear weapons that have

yet to be assembled must be removed from the state or destroyed. Removal from the state may constitute placing the weapons under international control outside the state or the supervised destruction of nuclear weapons and related components. Without the removal of all components of nuclear weapons, there is a risk that weapons research and production may be restarted when monitoring stops.

This occurred in December 2002, when IAEA inspectors were asked to leave North Korea, and the DPRK tampered with or removed all monitoring equipment, which allowed the DPRK to quickly regain access to nuclear materials.[50] Had the materials been removed fully, the presence of inspectors or monitoring equipment would not have been necessary, and access to the materials could not have been re-gained by the state. Obviously, removal of actual nuclear weapons and components by a third party represents a large intrusion on a state's sovereignty; the presumption is that extraordinary circumstances brought all nations to this point where certain incursions on sovereignty are acceptable.

Disablement of Facilities That Produce Fissile Material and Weapons Components. Any facilities that produce weapons-grade materials or components, such as trigger materials and enrichment equipment, must be similarly removed, disassembled, or destroyed.[51] The complete and permanent decommissioning of nuclear facilities causes states looking to restart their nuclear program to be forced to rebuild their plants, greatly increasing breakout time. Permanent destruction measures include crushing, demolishing, and rendering completely inoperable. Special measures like filling plumbing or vessels with materials like concrete is appropriate.

Elements of The Necessary Verification Regime

Verification involves collecting and analyzing data through inspections, technical means, and intelligence gathering to determine whether parties to an agreement are complying with its terms. Verification aims are threefold: deterring cheating, detecting violations, and providing confidence that all parties are adhering to their commitments.[52]

There is no such thing as perfect verification, as there can never be complete certainty that every violation will be detected. "Fully verifiable" indicates that the inspection regime will include every possible effort to achieve high confidence to assess compliance,[53] and a rigorous verification regime includes an expansive protocol and sufficient inspection provisions that significantly reduce the potential for a nation to cheat in any significant manner. However, it is widely agreed that "verifying arms control agreements is one of the global community's greatest security challenges" due to the difficulties associated with verification and the manpower that strict verification requires.[54] Using all means possible includes support by the United States intelligence community of the VO.

When defining FFVD, there must be *explicit* reference to the actions the verifying organization can take and to the tools that can be used to verify that a denuclearization program has been followed. There have been numerous examples when vagueness in a verification regime has led to later problems, such as in 2008 when the DPKR denied that it had agreed to sampling as part of a verification regime.[55] Thus, it is necessary to include within the negotiated state-specific agreement the types, frequency, and number of allowed inspections, the composition of inspection teams, the types of equipment allowed, entrance notification and access requirements, and the manner in which inspections are carried out. Without reference to such elements, the state in question can delay and dispute the terms of the agreement while simultaneously covertly re-starting their nuclear program.

Complete Access to Materials, Facilities, and Information

In the inspection of a state's nuclear programs, an empowered VO must have access without delay to all materials, facilities, and information regarding nuclear programs. *This includes both declared and non-declared sites.* The VO must have cooperative access to information on facilities, materials, and equipment in order to keep track of nuclear sites and materials.

Audits. The VO cannot rely on state transparency and honesty to provide full and accurate information. For this reason, it is necessary for the VO to conduct its own information analysis through audits. Conducting audits allows the VO to verify the veracity of information provided by the state. Therefore, the VO needs to be able to perform audits of accounting and operational records as well as conducting materials inventories when the organization so chooses.[56] In recent years, audits have been performed in Argentina and Brazil as a verification measure to ensure that reported data matched the actual amount of nuclear

material within these countries.[57] Unlike inspections, audits are simply a review of available information that has already been disclosed; in contrast, inspections can search for violations of the agreements and search for new data or information.

Inspections. The primary tool of the VO in confirming denuclearization is inspections. Inspections by an international team of VO inspectors take place at declared nuclear facilities and sites and suspected undeclared sites to determine if they are being used for nuclear weaponization, fissile material production, weapons component manufacture, or testing.

The START I treaty provides a usable outline for inspection types, including when requests for inspection should be submitted.[58] In that construct, there are primarily five types of inspections, including:

1. Ad hoc. Ad hoc inspections are used to verify reported nuclear materials.

2. Routine. Routine inspections take place at nuclear facilities and other locations where nuclear materials are used or stored.

3. Special. Special inspections are used when information coming from the state is inadequate or suspect.

4. Safeguard. Safeguard inspections are used to verify that safeguards are in place in relevant design information, facility construction, facility operation, facility decommissioning, and equipment destruction.[59]

5. Short notice/no notice.[60] Short-notice and no-notice inspections are used to challenge the state when it is suspected that they have violated safeguard and denuclearization agreements. In line with Article IX of the Chemical Weapons Convention, inspections should have 48-hour notice for short notice inspections, 24 hours for no-notice inspections, and the state would be considered non-compliant if it has not allowed for an inspection after these time periods.[61]

Open Access for Inspectors. To facilitate the aforementioned inspections, a state must provide the VO with access *without delay* and aid for inspections through allowing inspection teams into the country, granting extended visas, and opening all sites to inspection teams. This includes special accommodations for inspectors, such as a streamlined visa process for entry into the country and granting inspectors visas that last multiple years.[62]

Specifications of Verification Equipment. In addition to allowing inspectors open access, experts must be permitted to bring, use, and remove their own equipment when inspecting nuclear sites. This includes measurement devices, radiation-detection equipment, sampling materials and equipment, and GPS receivers, as well as any other measurement devices needed to take forensic measurements of nuclear materials and equipment.[63] The types of equipment used should be determined at the discretion of the inspectors, and there should be no restrictions on the type of equipment employed by inspectors.

Sampling. Additionally, states must accede to environmental and forensic sampling to validate nuclear declarations, statements, and records. This can either be done on-site or off-site by samples inspection teams secure and take out of the country.[64]

Sampling of nuclear materials falls in the field of nuclear forensics, a discipline developed in the 1990s with the rise of trafficking of nuclear materials. Nuclear forensics applies an array of analytic techniques—such as radiometric and mass spectrometric techniques—to determine if radioactive particles are present and if they are from weapons-grade fissile materials. Case studies of nuclear forensics demonstrate the reliability of sampling in determining the grade of nuclear materials and environmental samples, as well as establishing an investigation routine that involves experts from national laboratories and report protocols.[65] Sampling proved its worth when inspectors examined North Korean plutonium waste samples in 1993 and found extensive discrepancies.[66]

In summary, within the agreements, the VO must have the unquestioned authority to take nuclear materials to their approved facilities and labs for sampling.[67]

Containment and Surveillance. The VO must have the authority to emplace containment and surveillance tools, such as tamper-proof seals, and to install remote surveillance equipment, including cameras, at nuclear facilities.[68] Remote surveillance allows inspectors to monitor facilities without having personnel on the ground or to monitor facilities to ensure materials and equipment are not removed while inspectors are en route.

Import/Export Controls. In cases in which civilian nuclear programs are present in the country and they cannot be abolished, strict import and export controls on fissile material or fuel material that could be weaponized will be established and overseen by the VO.[69] An import/export control regime makes undetected acquisitions of nuclear and nuclear-related materials much more difficult and aids in ensuring that the NPT-type nonproliferation standards are being met. Export controls can include permits, participation in the Nuclear Suppliers Group, and collaboration between governments on nuclear and dual-use materials such as trigger materials.[70]

Destruction Protocol. A protocol must be in place to facilitate the destruction of nuclear materials including but not limited to: nuclear materials, nuclear facilities, designs, and technical drawings.[71] Without complete oversight of the destruction process, the VO may have difficulty verifying that all nuclear materials have been destroyed. While preemptive destruction of related materials may seem like an indicator of a state's willingness to denuclearize, it can hinder the verification process, as it did in South Africa[72] when the destruction of technical drawings and documents were not overseen. Thus, a comprehensive destruction protocol that includes international oversight must be included in the verification regime.

Non-Compliance Penalties. In cases of suspected or confirmed non-compliance, the state should be subject to non-compliance penalties, including economic sanctions, diplomatic measures, and referral to the U.N. Security Council.[73] Over the years, non-compliance has occurred in several countries, including Iran, North Korea, Israel, and Pakistan, and these have typically been addressed through diplomacy, sanctions, isolation, and increased nuclear inspections.[74] However, the willingness and ability to enforce non-compliance penalties is vital to incentivizing and ensuring that denuclearization begins and continues uninterrupted.

Conclusion and Recommendations

While the language used around denuclearization has changed from CVID to FFVD, the importance of verifying denuclearization has not. Thus far, the standards which constitute "final" and "fully verifiable" in the eyes of the United States have not been well defined. The lack of coherence surrounding what this term means for the United States allows for ambiguity to creep into agreements and verification regimes. This can be corrected through defining strict standards of denuclearization and laying out necessary steps that denuclearizing states and verifying organizations must take to comply with FFVD.

With the United States looking to encourage final and fully verifiable denuclearization in both Iran and North Korea, there is an opportunity to establish an international standard about what composes a strong verification regime. The U.S. should embrace this opportunity.

In summary, we recommend the following as the U.S. standards constituting FFVD:

- **Development of a precise state-specific agreement.** In addition to signing the NPT and Additional Protocol, states must sign a state-specific agreement. This agreement must use detailed and precise language describing the verification regime, the conditions constituting denuclearization, and the dispute-resolution mechanism.

- **Constitution of a strong, multi-national verifying organization.** There is a need for a strong, empowered, authoritative verifying organization that capitalizes on the strong expertise of the IAEA, U.S., other international experts, and the U.S. intelligence community in order to ensure that the verification process remains effective and rigorous.

- **Ability to inspect without delay both declared and undeclared sites.** Inspections must be authorized without delay or impediment for both declared and undeclared sites on a similar basis.

- **No expiration or easing of restrictions.** While some previous denuclearization and nuclear arms control agreements have included expiration dates or sunset agreements, a final and fully verifiable denuclearization does not allow for these agreements to expire or for nuclear materials to be re-allowed into the country after a certain period of time. Additionally, the number of inspections should not decline over time.

- **No remaining fissile material or enrichment capability.** All fissile material and enrichment equipment must be removed from the state in order to ensure that denuclearization is final and

that nuclear weapons programs cannot be restarted at a future date once inspectors have left or covertly while the state is under the provisions of the protocols.

Final, fully verified denuclearization is an appropriate U.S. policy goal to increase global security worldwide and to protect vital U.S. interests across the globe. In the face of emerging threats and the development of nuclear capabilities by potentially hostile states, the United States must seize the opportunity to define what final and fully verifiable denuclearization means.

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