4. Challenges of Verification and Compliance within a State of Universal Latency

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Executive Summary

Achieving the vision of a world free of nuclear weapons will require a monitoring and verification effort more challenging, comprehensive, and systematic than anything attempted in arms control heretofore. Whereas most previous arms control arrangements have been geographically and functionally limited, this effort will have to grow to global scope and involve all aspects of the nuclear fuel cycle and weapons cycle while also encompassing actors ranging from established nuclear states to non-state entities.

There are at least four major areas in which monitoring and verification would play a crucial role on the way to the desired end state.

First, the established *nuclear weapons states* (NWS) must revive momentum toward further deep reductions in nuclear weapons and ensure the renewal of essential monitoring and verification provisions that otherwise will become moot when the START I agreement expires in 2009. They must also enter into negotiations on non-deployed warheads now in storage, about which little has been revealed in previous bargaining.

- For the first of these tasks—continuing reductions of deployed weapons—intelligence agencies have both a template and a body

of precedent and should be well prepared to monitor and to contribute toward verification of compliance.

- Regarding non-deployed weapons, however, intelligence would face a tougher task, for which success would require extensive new data declarations to cue intelligence sources.
- Requirements for technology development to support the monitoring and verification mission would need to be tailored to achieve the balance between transparency (confidence of the verifying party) and legitimate needs to protect nuclear weapon design information, proprietary information related to process design and technology, as well as operations security (opsec) -related logistical information critical for protection of materials and weapons.

Second, diplomacy will have to focus on slowing and ultimately stopping the momentum toward nuclear armament in the *non-nuclear weapons states*—a task that should benefit from any demonstrable progress toward stockpile reductions in the current nuclear weapons states. The Non-Proliferation Treaty will need to be enhanced by augmenting and expanding the Safeguards regime to develop better confidence in the completeness of member states' declarations.

- Monitoring and verification in this arena will be more difficult by an order of magnitude because there is virtually no tradition of arms control, with its associated provisions for declarations and inspections outside of the NPT regime—nor has much systematic thought been given by these countries to deterrence.
- Successful monitoring and verification can occur, but intelligence will have to move in lockstep with diplomacy to embed the arms control practices developed among the NWS in the past.
- Based on prior experience, it is doubtful that monitoring confidence will come quickly, but it can be achieved if, as in the past, we break what will seem to be overwhelmingly difficult problems into individual tasks that are achievable.

Third, to account for and globally secure *nuclear explosive material*, a number of initiatives would have to converge to produce what might be called a global Fissile Material Control Initiative (FMCI). Current programs and initiatives, such as the Fissile Material Cutoff Treaty (FMCT), if successfully negotiated and brought into force, along with natural follow-on programs to the Cooperative Threat Reduction Program and the Materials, Protection, Control, and Accountability Program could form a foundation for a more rigorous system of accounting and security.

- Confident monitoring and verification of this effort would require an unprecedented aggregation of monitoring techniques.
- Thorough and detailed data declarations would be the crucial starting point to enable essential synergy among National Technical Means, human source reporting, on-site inspections, and other techniques.
- Broadly based, "bottom-up" awareness related to integrated security management of nuclear materials would need to follow a path similar to a World Association of Nuclear Operators in the field of nuclear reactor safety.

Fourth, international consensus must be built regarding ways to deter—or in the extreme respond to—secret attempts by countries to "breakout" of any agreements that are achieved. The challenges here are many: developing diagnostic tools to detect and disable any nuclear devices smuggled into the country, building international consensus on the conditions that would justify a "last resort" use of force to deter a potential violator, and initiating cooperative multinational work on a Ballistic Missile Defense capability to counter unexpected threats by treaty violators.

- Intelligence challenges would be substantial but manageable in this environment; by the time the global system had achieved a state of "universal nuclear latency," there would be such an extensive body of data and practice that intelligence would have an excellent basis for detection programs.

- As the National Academy of Sciences noted in its recent study (*Monitoring Nuclear Weapons and Nuclear Explosive Materials: Methods and Capabilities*, 2005), it is very doubtful that a clandestine nuclear weapons program would escape early detection by the intelligence community. The harder questions would center on what to do about it.

Finally it must be noted that efforts to reach a nuclear weapons-free world cannot ignore the growing threat posed by *non-state actors* such as al-Qaeda. Presumably, their access to nuclear material and expertise would diminish as progress is made on all the foregoing objectives. But their clear intent to actually use nuclear capability for attack or blackmail gives them an especially menacing character—made all the more worrisome by uncertainties about how to deter them from such use. Detecting and countering their activities in the future will, as now, require all intelligence capabilities, with HUMINT playing an especially prominent role. Broad information-sharing would enhance the effectiveness of international and domestic law enforcement.

As we progress with force reductions and implementation of the steps toward realizing the vision, as discussed in the *Wall Street Journal* op-ed and in the other papers prepared for this conference, we should expect growing trust between the nations, starting with the U.S. and Russia. This, in turn, can be expected to lead to increasing transparency in all these nuclear matters, thereby improving prospects for being able to monitor compliance and verify that our security interests are not being compromised.

The central argument of this paper is that a coherent and comprehensive technical/policy paradigm should be sought in order to enable attainment of the vision being analyzed at this conference. Such a paradigm would provide the proper vehicle(s) for managing the inevitable security risk, as well as supporting the political confidence and international trust that would be required to reduce nuclear arms to very low levels over time and to provide the pervasive vigilance demanded of a universally latent nuclear world, i.e., a world in which most nuclear weapons have been eliminated but in which many countries would retain the technological know-how and requisite materials to resume nuclear weapons work. Such vigilance would continually address the risk of nuclear material diversion in a world enjoying expansive utilization of nuclear energy, as well as provide early warning of technical activities indicative of weaponization.

Introduction

Much has been written with regard to the relationship between verification and trust between adversaries when addressing arms control negotiations. The issue is central to our discussion at this conference: will going to the Zero Option result in verification requirements that would simply be unsustainable in any practical sense?

In 1961, President Kennedy's Chief Science Advisor, Jerome Wiesner, proposed a notional model for gauging the amount of inspection required to effectively verify the degree of disarmament achieved [1]. A corresponding graphic is reproduced as Figure 1.

- At high levels of armament, and at a particular specified trust level between parties, fairly high uncertainties in the assessed level of arms could be tolerated from a less than perfect verification regime because the consequences of incorrect assessments were dwarfed by the sheer size of the stockpiles.
- However, as disarmament proceeded and the number of arms held by each side tended to much lower numbers (even approaching "zero"), the marginal utility of each extra warhead becomes more significant, driving the required work of inspection to very high order in order to achieve very exacting conditions on uncertainty.

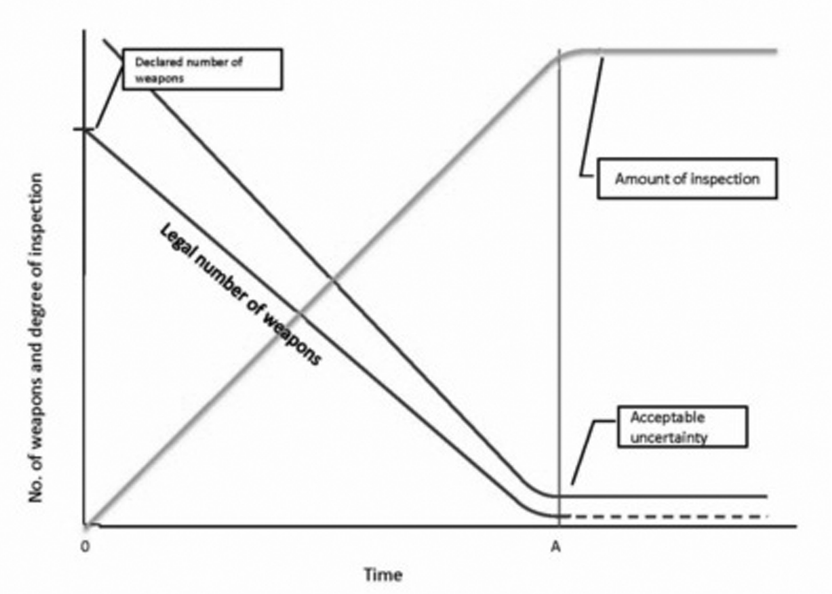

Figure 1. The Wiesner Curve, showing relationship between extent of disarmament and demand for inspection. (Reproduced from Krass, 1985)

- Simply put, if there are few weapons left, your opponent having a few of them hidden means more.

If this, indeed, were the case, our vision of a world of zero nuclear weapons would be doomed due to the unacceptably high cost of verification. But technology that can more accurately portray what your counterpart has could reduce distrust. If you have more confidence in the means of detection, it cancels out the worst concerns in Wiesner's model. Therefore, we need an explicit and nationally supported program of technology development to prepare for the eventuality of getting close to zero and therefore needing greater transparency than current techniques are likely to provide.

In a world completely transformed by paradigm-shifting advances in microelectronics and sensors, nanotechnologies, and information technology, it is hard to imagine that the power of technology could not be engaged to sense, communicate, characterize, and identify the observables of illicit activity in a timely enough manner to permit effective policy responses.

- The key challenge would be to create coherent government-sponsored programs that would be effective at motivating the development process toward ambitious technology performance goals.

Some means must also be found to quantify relevant concepts and metrics and provide an objective basis for coherently driving the technology requirements. Periodic assessments that would engage the entire technical and policy community and could be broadly reported would aid in creating such requirements. At the least, such assessments would guarantee long-term vigilance.

In this regard, some methodological and practical means for quantifying and periodically assessing “latency” must be developed. We notionally associate “latency” with time delay needed to attain an imminent nuclear threat: thus, higher latency is “good,” lower latency is “bad.” “Proliferation resistance” is another quality or characteristic that is referenced in multiple forums, but never methodically quantified. It is a quality that is a key component of latency. The challenge remains to quantify these concepts and to transform them to technology requirements.

The Four Interlocking Verification Strategies of a Comprehensive Framework

The new paradigm differs from “traditional” notions of arms control

In constructing a framework and appropriate terms of reference for programs that would implement a path forward for the Zero Option, it is important to reiterate a point made earlier: The confluence of terrorism and proliferation create the basis of a newly emerged threat environment that the United States has not heretofore faced in a coherent manner. Post-9/11 considerations addressing the potential attack on this nation with stolen, smuggled, or improvised nuclear explosives generally characterize such an event as an "asymmetric" attack on the sole remaining superpower. Therefore, more traditional approaches to nuclear disarmament (e.g., those pursued in the SALT and START epochs) must be augmented by more broadly based initiatives that address the ultimate "source" of nuclear threat—the special materials that can be used in relatively small quantities to render a very effective and destructive asymmetric attack.

Such a threat creates renewed urgency to address the Zero Option for this option alone promises to make tractable the challenge of controlling nuclear materials indefinitely on such a global scale. Correspondingly, the focus must shift to the security of, and accountability for, nuclear materials worldwide. The United States government has only partially addressed this concern with the chartering of a Domestic Nuclear Detection Office (DNDO). However, detection by itself is not enough to adequately address the overall risk of the threat, driven as it is by unacceptable consequences. Access to relatively small amounts of the special nuclear materials is all that stands between security and disaster. Such a threat environment does not involve stockpile-size quantities of material, but may indeed be hidden in the uncertainties surrounding such large quantities. Given the huge global landscape on which sources of nuclear material are to be found, ensuring comprehensive security of these materials becomes an imperative. The United States must engage with the other nations of the world to address this problem.

The concept of "virtual stockpiles" has been addressed before. Molander and Wilson [2] identified the "Virtual Abolition of Nuclear Arsenals" as one of several alternative future scenarios ("asymptotes") for post-Cold War (but pre-9/11) deliberations on nuclear strategy. Even then, the unprecedented requirement for the attending intrusive and relentless international inspection regime was well understood. In light of today's threat environment, however, we are compelled to focus on what it would take to reach such as state of "universal latency," and to galvanize our collective resources to go beyond conceptualizing to actually managing our global nuclear security environment to such an end state.

The intelligence community (IC) will play an unarguably pivotal role in this envisioned paradigm. Although we will address several strategies comprising an overarching framework for achieving universal latency, a common denominator across all of them will be successful end-to-end exploitation of information by the IC. The IC has the experience and skills to successfully monitor the various end states we seek in this proposal and to contribute to verification decisions. That said, the intelligence requirements for this will be more challenging and labor intensive than anything else in arms control history and will have to compete with escalating demands for intelligence coverage of complex post-Cold War problems.

- In contrast to earlier arms control intelligence tasks, this one will gradually expand to be global in scope, as compared to the geographically and functionally limited requirements of the Cold War.
- The effort will have to go well beyond the kinds of elements arms control intelligence was previously most comfortable with and skilled in monitoring—silos, deployed nuclear weapons, large conventional formations.
- On the other hand, the goal of a world free of nuclear weapons and with nuclear material effectively secured meshes well with the intelligence community's current highest priority: the potential nexus between terrorism and weapons of mass destruction.

There are basically five tools essential to successful intelligence monitoring:

- *National Technical Means* (*NTM*) is popularly understood to mean collection of information by satellites capable of taking photographs and intercepting communications. Although this is the most common interpretation of the term, precise definitions of NTM were resisted during Cold War negotiations, largely because neither side wanted to bargain directly over the role of human intelligence (HUMINT), fearing that to do so would implicitly authorize the other side to recruit spies as part of the monitoring process. This imprecision allowed the sides to understand that NTM could actually include all of a country's intelligence capabilities.

- That said, *HUMINT* is unquestionably a vital tool that will become more important in any effort that aims to monitor "universal latency." As we note elsewhere, the closer we get to that end state, the more important will be intent and motivation—facets that technical intelligence can seldom discern and that often only HUMINT, i.e., classic espionage, can confidently gauge.
- *On-Site Inspections* (*OSI*)—everything from periodic visits to in-place observation (portal monitoring)—will also be vital at various stages. Experience has shown that this technique is most effective when it is fairly routine as opposed to aggressive or challenging, particularly when one of the goals is building mutual confidence. To be sure, there is a role for aperiodic, unscheduled visits but these are most effective when integrated into a series of predictable and routine visits.
- *Declarations* of existing capability are essential to give intelligence a baseline from which to make judgments. Without such declarations, all sides start with a deficit of confidence, intelligence has to define its own arena of operations, and it is almost impossible to move beyond a cat-and-mouse mentality.
- *Specialized sensors*, with capabilities ranging from detection of radiation to interpretation of hyper-spectral data, also have an important part to play. Many are useful primarily in close-in rather than remote roles. Their design and operating characteristics must reflect the specific nature of the monitoring task and its physical

environment, and new technologies must adapt in a timely way to opportunities that present themselves for exploitation.

None of these techniques is likely to suffice alone for any particular monitoring task. While a critical insight may occasionally come from a single intelligence source, the key to monitoring success is *synergy among all of these methods*. For example, declarations can provide the guide for targeting on-site inspections, while NTM can allow you to watch the "back door" to see if anything is being removed from a site slated for examination. Or when NTM detects an anomaly that cannot be squared with declarations or the results of inspections, a good HUMINT source may be able to "get under the roof" or "behind the doors" that NTM cannot penetrate.

The intelligence community will need to focus on how to maximize this synergy as the effort goes forward. A way must be found to develop an effective and timely manner for linking data collection, information analysis and integrative technical assessment, and development/deployment of new collection technologies, in an "end-to-end" manner that creates an endless stream of actionable information to the policy community. The IC must work closely with policymakers to ensure that diplomats negotiate provisions that take advantage of particular capabilities. For example, this means ensuring that if the community has a portable or covert device capable of detecting radiation, that provision is made to install it along a road likely to be used by cheaters to "clean" a facility. *This kind of synergy will be key to the success of monitoring efforts and will increase in importance as we get closer to "universal latency."*

To get to the desired end state, intelligence will have to monitor activities in diverse arenas, ranging from traditional nuclear weapons states to new nuclear weapons states and non-state actors. The difficulty, prominence, and importance of particular techniques—and the requirement for innovation—will increase as the ladder is climbed to higher and higher states of latency. In fact, latency must be quantified in some manner, regularly assessed, and eventually managed across numerous negotiations over time, and at both ends of the nuclear capability spectrum. The respective roles of different states in this regard must be played simultaneously to realize the hoped-for holistic effect.

First, the nuclear weapons states (NWS) must proceed to *increase* the "latency" of their deployed weapon stockpiles, by pursuing measures that would give increased warning time and would systemically shift emphasis onto conventional responses to undergird their strategic posture. In effect, reduction of the nuclear stockpiles would proceed along with steady progress in de-legitimizing the use of nuclear weapons in matters of national defense.

In parallel, the Non-Nuclear Weapon States (NNWS) would be challenged to *maintain* their nuclear capability latency at very high levels, i.e., long time delays before launch, restricting nuclear technology to civilian applications, most notably in meeting the energy needs of developing and developed nations and supporting sustainable development in the global community. The promise of "Atoms for Peace" would be revisited, but this time in a much more controlled manner that pays more than lip service to the imperatives of proliferation resistance.

Assessing and verifying the actual capability latency of nations that participate in fuel cycle activities will require the transparency achievable with an independent, internationally managed inspectorate supported by modern technology. This would allow timely and precise assessments with regard to declared activities and material stocks, but with an intrusiveness level restrained to some degree, reflecting the trust placed in the inspectorate by the inspected nation. Therefore, as noted above, the NTM of member states will still play a very major role in a comprehensive program. The proper "firewalls" will need to be maintained between these two sets of capabilities to ensure the continued effectiveness of each.

The greatest perceived danger to a proposed paradigm of universal latency would be the possibility of breakout. For this reason, a deterrence posture must be redesigned away from historical practice driven by threats and counterthreats of arsenal exchange. Deterrence might now be achieved through implementation of tailored, but credible and timely non-nuclear response capabilities to preclude success of any imminent nuclear threat. Another mechanism might involve institutionalizing some reconstitution capability under appropriate mechanisms of legitimized authority.

It is impossible to imagine how anything like the foregoing proposal for managing nuclear latency could have any chance for success without a return to bilateral and multilateral negotiations. Only such processes can bring forth the attendant verification protocols designed to engage transformational technology, as well as broadly based confidence-building measures, in providing the salutary feedback effects in the reduction process. The latter would build trust and hopefully preclude the types of unbearable cost burdens associated traditionally with effectively verifying very small stockpiles (Wiesner "prediction").

Strategy 1. Verifying phased stockpile reductions

The role played by the NWS in a comprehensive global latency management framework involves a demonstrable, effective effort at negotiating a phased reduction in the levels of stockpiled nuclear weapons, consistent with global and national security requirements of the P5, as well as with obligations embodied in Article VI of the Non-Proliferation Treaty. These latter obligations were renewed in 1995 as part of the agreement reached at the 25th Anniversary Review Conference of the NPT, which extended the treaty indefinitely. Pursuing a notional road map consistent with these obligations begins by first identifying the verification challenges along the path of stockpile reductions.

The arguments for and against specific stockpile reduction mileposts are beyond the scope of this paper. Nevertheless, any potential set of these will step through a natural progression of stages that will require special consideration in blending verification technology with trust-enabled procedures to attain the desired transparency objectives. The three general stages will include (a) return to negotiated verification protocols; (b) monitoring of nuclear warhead inventories at various stages or "states" of latency, throughout a prolonged period of stockpile reductions; (c) monitoring nuclear materials and "virtual stockpiles" at the end-state of the Zero Option. We will consider these in greater detail.

Return to verification protocols

The first step in following a long path to the Zero Option will obviously begin with a return to the negotiation of verification protocols, presumably to accompany the already agreed-upon strategic arsenal levels of the Moscow Treaty of 2002 (SORT). The clock is running out on the START I accords, which are scheduled to expire in 2009. This treaty imposed reductions in deployed strategic arsenals to the level of 1600 delivery vehicles with an attending number of 6000 warheads. Special counting rules had been agreed upon for imputing numbers of warheads to the verified number of strategic delivery vehicles, which were the actual "countable" entities referenced in the accompanying verification measures.

Meanwhile, the Moscow Treaty was signed between Presidents Bush and Putin in 2002, merely documenting the unilateral declarations by the U.S. and Russian Federation to reduce strategic deployed warheads to 1700–2200 on each side. In the declared interest of ensuring maximum "flexibility," no further accompanying disaggregation of the total numbers was identified and no verification protocols were negotiated. The numerical limits were to take effect (and then immediately expire) on December 31, 2012. Presumably, both sides have been reducing their numbers since 2003.

Given the verification provisions associated with START I are still in effect until 2009, it would seem a most logically straightforward step to immediately begin the required planning to apply the means of verification established under the START process to the numerical limits set by SORT, and extending them to enable adequate verification of further reductions for both deployed and responsive forces.

The technology development challenges for this first step would be, in fact, only incremental. Means and protocols for verification had been worked out in START I and START II with a focus on counting delivery vehicles (missiles and launchers). The arms control experience of the Cold War gives us a proven template for monitoring deployed nuclear weapons in established nuclear weapons states. The traditional combination of declarations, OSI, and NTM provides a solid basis for progress among states such as the U.S., the Russian Federation, the U.K., and France.

Eventually the challenge will shift to bringing other established nuclear weapons states, principally China and Israel, into some kind of negotiation/monitoring regime. This will also be required for newly minted de facto NWS such as India and Pakistan. Most of the "heavy lifting" for this will be in the diplomatic realm. Intelligence has a proven track record and ample precedent to work with.

However, the challenges for intelligence and technology development will increase in moving to the next level; i.e., that associated with providing the necessary transparency and monitoring capability that would be required for building confidence in the process of controlling actual numbers of warheads, both those in responsive as well as deployed status.

Verification of Warhead Inventories

As we proceed to the next phase of stockpile reductions, a key principle of latency management would make it imperative to include provisions for ensuring the irreversibility of deeper stockpile reductions. This would involve appropriate monitoring capabilities to enable transparency and resulting confidence in the negotiated joint elimination of nuclear warheads. However, the case of verifying numbers of deployed (and for that matter: stored, disassembled, and destroyed) warheads is much more formidable than counting numbers of the more easily observable missiles and strategic bombers. The former are smaller, more numerous, and can be more easily moved and stored clandestinely than the larger delivery vehicles.

Dealing with non-deployed nuclear warheads will be a tougher challenge for intelligence, with no proven template and very few precedents. Absolutely key to success here will be declarations, followed by on-site inspections. *The importance of HUMINT will begin to increase*, because we will be entering a realm where intent is untested, practice is scant, and suspicions will be more prominent. So will the importance of increasing trust between nations as the goals for reductions to lower force levels proceed.

Thinking about all of these challenges, it is important to recall one of the major lessons of the past: *The key to successful monitoring of arms control and nonproliferation agreements is to break overwhelmingly hard problems into individual tasks that are achievable.* This has historically and successfully been done by implementing a series of unilateral intelligence and multilateral negotiated measures that work synergistically together.

- Negotiated information exchanges provide a framework for understanding normalcy.
- The exchanges declare where material of relevance to an agreement is normally based, outline the ranges of usual behavior in storing and moving such material, and provide checkable facts for on-site inspections, technical verification measures, and intelligence targeting.

In some respects, data declarations are like income tax returns. They provide a basis for a monitoring organization to sample behavior to see if there are discrepancies that require further review. For international agreements, the sampling is done through some combination of negotiated inspection measures, overt technical monitoring, and covert intelligence-collection methods.

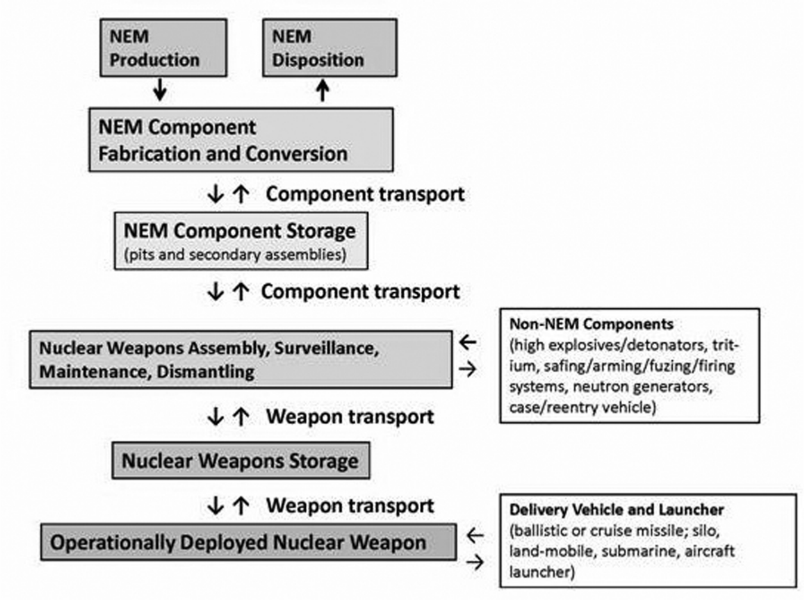

Figure 2. Life-cycle stages of nuclear warhead showing "latency" gradation. (Reproduced from *Monitoring Nuclear Weapons and Nuclear Explosive Materials: Methods and Capabilities*, Committee on International Security and Arms Control [National Research Council], National Academies Press, 2005)

Actual implementation of such general approaches begs the identification of an appropriate model that would serve as a vehicle for framing discussions that center on the life cycle of nuclear weapons. A model would also provide a framework for guiding the deployment of technologies that would be implemented in somewhat more intrusive verification measures. Such a model is presented in the National Academies report, "Monitoring Nuclear Weapons and Nuclear-Explosive Materials: An Assessment of Methods and Capabilities" [3]. An illustrative schematic is reproduced as Figure 2. ("NEM" refers to "Nuclear Explosive Materials.")

As illustrated by this schema, one could "reverse-track" the stockpile gestation of a nuclear weapon from bulk nuclear material, through component fabrication and storage, weapon assembly, weapon storage, and ultimately operational deployment in the stockpile. By drawing an analogy to NPT Safeguards, a material/unit balance can be identified in such a representation, and provisions implemented for monitoring the in-flows, out-flows, and inferring the accumulated (or depleted) stocks within each material balance unit.

The approach would be straightforward in principle, but would demand special attention to ensure chain of custody could be established while observing materials moving “in” and “out” of “black boxes” that figuratively represent processes that, for security purposes, would be obscured from direct inspection and observation. This would include any activities that could reveal the details of point designs of nuclear weapons, or reveal information that could render them vulnerable.

The overall verification “tasks” could thus be identified in the following graded scheme:

- Number of aggregate deployed and non-deployed missiles and launchers;
- Number of deployed warheads at some alert level;
- Number of non-deployed warheads;
- Number of non-deployed warheads removed/de-mated from carrier systems;
- Locations of facilities at which non-deployed warheads are stored;
- Number of warheads dismantled into components: pits, secondary assemblies, and non-nuclear supporting sub-systems;
- Locations of facilities at which nuclear weapon components are stored;
- Mass of bulk nuclear material declared “in excess” of stockpile requirements;
- Location of facilities at which military stocks of nuclear material are stored.

The overall approach for each step in this graded scheme would proceed along the following general pattern:

- Nation formally *declares* numbers or masses of weapons/components/materials within a general category;
- Verifying nation, through on-site inspections, deploys observers and equipment to *monitor* the transport of declared items into and out of the material balance envelope, as well as sample some number of items of the inventory within the envelope to ensure against clandestine diversion;
- Radiation-detection equipment, often supplemented by deployable simulation capability, is employed to establish the *validity* of the observed items and to infer the status of the declared material balance.

Data Exchange and Encryption

Clearly, baseline information for declared quantities, along with associated uncertainties of this information, would be key to subsequently tracking with confidence any further negotiated reductions in numbers. Declarations may be exchanged at agreed-upon intervals following establishment of the baselines, with frequencies most likely in inverse proportion to numbers being counted. Ultimately, one could envision continuous monitoring with real-time reporting of the relevant quantities. This would obviously presume a significantly high trust level between adversaries, but one that could conceivably be attained through successful implementation and experience in verification activities associated with earlier agreements.

The cost/benefit of such a process is driven by the presumed "value" of confidence one party places in the numbers declared by its adversary and confirmed through verification. The countervailing "costs" include the resources required to implement the verification procedures, and more importantly the enhanced vulnerability associated with the monitored party's nuclear assets or national security posture given the detail of declarations made and confirmed.

- The latter factor takes on much more significance in light of the proliferation and operational security risk that is entailed when technical details related to "point designs" and capabilities, as well as locations of weapons and materials in facilities, are made public.

In this regard, technologies that can protect the identity of the source or encrypt the associated declaration information would be absolutely critical for enabling implementation of verification measures. Technologies like this have already been developed in the commercial sector and would need to be adapted to verification needs. Some of these are described in *Monitoring Nuclear Weapons and Nuclear Explosive Materials* (National Research Council, 2005) [3].

Information to be declared can be broken down into data records. The plain text information in these records will contain certain descriptive details about agreed-upon controlled items and materials, as well as their location. The objective is to allow intelligible access to these details ONLY to the verifying party, and to hide it from everyone else.

- One would ideally like to put each record of data into an opaque envelope and give it to the intended receiver, who would be the only one who can open the envelope to access the data.
- This can be done electronically in a process called "encryption." (Similar techniques are now being broadly applied to protect personal identity information on modern laptop computers in light of highly publicized losses of huge quantities of such data when the computers have been lost or stolen.)
- Data records involved in declarations could be carefully encrypted by the declaring party prior to transmittal. Thereafter, the verifying party would sample the records and would request specific encryption "keys" (algorithms used to descramble the cipher lines).
- These then would be applied and the plain-text descriptions would be reassembled. The verifying party would randomly sample from

among the huge number of encrypted records (sampling rate based on the degree of confidence desired) and would use the information to confirm the declarations with actual inspections.

On-Site Inspection

At the core of any verification protocol, the declarations made by a particular state must be *confirmed* to some determined level of confidence by the inspecting party. The declarations discussed in the previous paragraph can be confirmed by several means, but the most straightforward involve some type of on-site inspection (OSI), either routinely scheduled at predetermined intervals, or arising out of specific challenges. Agreed-upon detection technologies and monitoring instruments are used by inspectors to confirm the identity, numbers, and location of declared warheads, all of which give off radiation signatures that are like “nuclear fingerprints.” The use of such inspections has been successfully demonstrated in verifying the numbers of missiles and launchers that were the subject of START I and INF (Intermediate Nuclear Force Reductions) treaties.

Monitoring of declared items would be greatly facilitated by extensive data exchanges, which would give inspectors a clear expectation of what they should find on any particular missile or bomber, or at various storage facilities. Deviations from the database, due to lags in notifications or other factors, could be clarified by the host side in their briefings to inspectors at the start of the inspection. Interestingly, whereas NTM can provide valuable information regarding warheads from telemetry data obtained in observing flight tests, usefulness in determining the actual number deployed is significantly less. On the other hand, NTM can be extremely helpful in periodic or persistent surveillance of activities surrounding declared sites and facilities.

In principle, presumed nuclear warheads could be removed and scanned with a portable neutron detector. They may be presented to the inspector, however, inside a simple-shaped container to prevent visual observation of the details of the weapon design. Neutron-detection technology is employed to identify the presence of actual nuclear material. However, the detection equipment must be designed to be “spoof-proof” in order to ascertain that shielding materials have not been inserted to reduce the intrinsic radiation emitted by the warhead, thus forcing the inspector to infer smaller quantities of material.

There are ways to actually detect such spoofing shields. In conjunction with the neutron-measurement procedure, a low-intensity gamma or neutron source may be placed opposite the appropriate detector and an independent measurement taken of the resulting radiation field to characterize multiplication and shielding properties of the canister assembly. Some computational model of what the “correct” device would look like would be used to enable the proper inferences. Under the INF Treaty, agreed procedures had been developed for neutron-counting to determine that a missile was a permitted SS-25 with one warhead, and not a prohibited SS-20 with three warheads. This was necessary because the Soviets deployed SS-25 ICBMs at former SS-20 IRBM bases.

Depending on the sophistication of detection technology agreed upon in negotiations, it is generally desirable to field detection systems that can identify specific radioactive isotopes, and especially can identify the presence of fissile materials. Such technology, previously only available for laboratory settings, has now been developed for portable applications. For example, a “Fission Meter” has recently been commercialized by ORTEC (developed originally by Lawrence Livermore National Laboratory) that can identify uranium and plutonium by specifically counting neutrons that are emitted simultaneously from a nucleus by the process of spontaneous fission. Such correlated neutrons help in distinguishing source material from cosmic ray background, as well as indicating neutron multiplication by fissioning nuclei. The 57-pound package contains the He-3 neutron detectors as well as the HV supplies and discriminator circuits used to identify the “simultaneous" events. Such technology was previously unavailable to support the earlier verification mission.

Chain of Custody

However, the requirement for ensuring "chain of custody" from deployment to storage through destruction implies that some process will be required to authenticate the object (observable through detection equipment) inside a black box. Ultimately, how can one be assured that the fissile material presented as "excess" actually came from a nuclear weapon that was dismantled? The importance of establishing "chain of custody" for designated devices and materials would need to be balanced with due regard for protecting secret nuclear weapon design information. The initial authentication process would then be followed by a rigorous accounting process based on tracking tags and seals. This is where technology could play a major role.

The use of "templates," "attributes," and "information barriers" become key enablers in this regard ([3], pp. 97–108). A nuclear weapon, or one of its key special nuclear material-bearing components, has specific physical observables and signatures that may be measured or observed in the process of identification. These are labeled "attributes."

For example, a prototype attribute system was demonstrated to Russian scientists at Los Alamos National Laboratory as part of the Fissile Material Transparency Technology Demonstration in 2000. It had been developed to confirm the authenticity of plutonium pits to be stored in the Russian Mayak facility. Attributes included the presence of plutonium; isotopic composition of plutonium; plutonium age; plutonium mass; symmetry of the plutonium mass distribution; and absence of plutonium oxide. Specific identification of emitted gamma-ray spectra and signals from neutron multiplicity counters were employed to identify "true" pits by inferring the attributes from these measurements.

A "template"-based system would also key on attributes such as emitted gamma-ray spectra from a particular weapon configuration, but could conceivably include other physical observables such as mechanical, thermal, or acoustical properties. The specific signature, effectively a “fingerprint” of the device, would be compared to an established reference object that was known to be an authentic weapon of a particular type, thus establishing the validity of the “test” object. Template approaches bear the security cost of having to store sensitive data associated with the reference device or component.

Clearly, in many cases such measurements could directly reveal secret design features of nuclear weapon assemblies. The protection of this information in the application of template and attribute identification systems is the principle behind “information barriers.” Such systems are generally designed to automate the data acquisition and analysis process, with a resulting unclassified “summary” display (such as “green” or “red” light) as the only observable available to an inspector. The information barrier system would be designed in a way that prevents access to any compromising intermediate data or analysis product, with strict system design requirements to prevent unwarranted transmission of signals across the “barrier.”

Once a weapon or component is authenticated via procedures described previously, it could be placed inside a specially designed and constructed container, then tagged with a unique identifier (e.g., serial number, barcode, or other intrinsic characteristic that is difficult to alter) and enclosed with a tamper-resistant or tamper-revealing seal. Tags and seals would then be used together, tracked and monitored in the “chain” of events that accompany the life history of the enclosed device. Any observed tampering would provide the unambiguous evidence that a violation has occurred along the chain of custody.

Perimeter-Portal Continuous Monitoring

The conceptual model of device/material balance within a physical or imagined “boundary” around declared facilities becomes the basis for the design and implementation of monitoring systems to confirm declarations made by the inspected party, and to track changes from the baseline over time. A minimal monitoring system could involve declarations and perhaps a one-time visit to storage facilities to establish a baseline. Much more intrusive arrangements can also be envisioned.

It would be possible to establish a Perimeter-Portal Continuous Monitoring system (PPCM) at what would presumably be a small number of declared storage sites. The two sides have extensive experience with such systems under the INF and START treaties. Under START, the sides were allowed up to 30 monitors at a PPCM site. They do not enter the site, but have complete access to the perimeter at any time and can examine items leaving the site that have dimensions such that they could be a controlled item. The small size of warheads could make this a burdensome task, but traffic into, or out of, a facility that only stores warheads should be light. The warhead containers could be tagged and/or could contain a unique identifier. Nuclear detectors could be used to verify that the container did contain nuclear material consistent with a warhead.

One possibility that would avoid extreme intrusiveness would be to establish radiation portal monitors at the entry/exit points of the storage facility. These could resemble the portals now being deployed extensively at foreign and U.S. border crossing points, as provided for by the DOE/NNSA Second Line of Defense and DHS/DNDO port inspection programs. Because these could be relatively large, they could be more sophisticated than handheld devices. They could be designed to detect both neutrons and gamma-rays.

Technology development objectives for radiation detection in DOE, DHS, and DoD programs are currently emphasizing the simultaneous portability and resolution capabilities needed to identify isotopes (including uranium enrichments). Precise spectroscopic measurements of gamma-ray emissions have traditionally involved high-purity germanium-based sensors that required bulky support equipment to provide cooling to cryogenic conditions, greatly complicating the logistics associated with verification activities. Recent developments have included battery-operated, ultra-reliable mechanical cryocoolers (e.g., Stirling cycle) or room-temperature semiconductor materials (e.g., cadmium-zinc-telluride or CZT) to allow for handheld spectroscopic identification capability.

The verification technology program for the Zero Option could very easily leverage the investments now being made in Nonproliferation, Homeland Security, and DoD Force Protection programs. Moreover, the high false alarm rates experienced by similar devices at U.S. border crossings, due to agricultural products, ceramics, people with radioactive isotopes in their bodies following medical procedures, etc., should not be a major concern at a warhead storage facility. Each type of warhead could be measured to establish a baseline radiation signature or template. The host side should declare each incoming or outgoing warhead and the portal monitor should be able to confirm this declaration. Accurate logs of all movements of warheads into and out of the facility would be essential. In general, however, while Pu should generally be detectable, HEU may not be, due to its much lower intrinsic radioactivity. Neutron-based “active” detection systems are being developed to induce fissions in uranium and then measure the emitted gamma spectra.

Given the precautions noted above, non-deployed warheads could be tracked into and out of declared storage facilities through designated portals in the engineered facility perimeter, or even between cells or blocks of assembly/disassembly facilities. It would clearly be desirable to have inspection personnel manning the monitors around the clock. If this is considered too intrusive or expensive, it might be possible to establish automated systems, which would transmit data back to an operations center. Such a scheme could draw heavily upon the remote monitoring systems used successfully in Iraq by UNSCOM and UNMOVIC. A system of cameras would be highly desirable to assure that warheads were not entering or leaving the complex at locations other than the designated entry/exit points. A still less intrusive system could dispense with real-time remote monitoring, relying more upon periodic visits to check logs and unmanned monitors. This could resemble the system used by the IAEA to monitor Safeguards Agreements.

Under either the manned or unmanned scenario, periodic inspections could be conducted to provide confidence in the data being accumulated. Attempting to look at all warheads would not be realistic, nor should it be necessary. However, the inspection team could ask to see a number of specific warheads, identified by the unique identifiers on their containers. If this were done successfully at regular intervals, it would provide some confidence that the system was working as intended, without revealing sensitive design information.

Proceeding to virtual stockpiles

The overarching objective in designing such a comprehensive framework for verifying stockpile reduction in the NWS would be to "raise" the level of latency in each NW state by managing the number of weapons/mass of special materials along a gradient of increasing "latency" over a period of time.

So how does one quantify the level of latency? In fact, for the NWS with established stockpiles, "latency" most generally reflects the time interval measured between the moment a decision is made to launch a nuclear attack against an adversary, to the time the weapon's explosive yield is released at the intended target site.

- On this time line, weapon materials, components, or weapon systems could conceptually be assigned a "latency factor" that reflects the time interval between its current state and yield released on target.
- A "latency state" would correspond to the different groupings of weapons, components, or material along the life cycle time line (boxes in Figure 2).
- The overall "stockpile latency" would be some appropriate number-weighted or mass-weighted average of latency factors, inte-

grated across the "latency states" along the life-cycle, and normalized to the sum total of weapons/components of nuclear explosive devices or mass of material attributed to the nation.

- Verification protocols would be designed to deduce the number of weapons (or mass of material) in each latency state to an acceptable level of confidence.

Using the methods, procedures, and models identified in the previous sections as "building blocks," or implementation elements, a general roadmap composed of critical stockpile reduction mileposts may be postulated. It is clear that progress along the overarching process we envision will rely most critically on the state of trust existing between nuclear adversaries, or even more generally among all the nuclear weapon states, in order to ensure methodical progress toward the global condition of effectively *virtual stockpiles*.

Progress will be dominated by policy considerations and collective visions of nuclear and global security; however, the disciplined inclusion of negotiated verification protocols will provide joint experience, relationship-building, periodic reaffirmation of global end-state vision, and ultimately the necessary feedback mechanism to enhance trust while continuing down the disarmament path. Verification experience, including joint resolution of conflicts and implementation issues, is needed to build up sufficient trust to eventually "beat the Wiesner curve."

Stocks of nuclear explosive material accumulating in the category designated "in excess of military requirements" will carry the highest latency factor of all materiel within the legitimate authority of a nation's nuclear weapons complex. Managing the overall transition of material in this framework, beginning with deployed weapons on alert, then "up" the latency gradient toward materials declared as "excess" (and thus scheduled for downblending, final disposition in actinide-burning reactors or in immobilized form for geological disposal), constitutes the engine for achieving the Reykjavik II vision.

A successful regime would provide for declarations of the numbers of warheads in each of the "states" or categories illustrated graphically in Figure 2 and discussed previously. Notionally, as negotiations proceed along the lines of this overarching strategy, it should be possible to deduce a quantitative indication of overall stockpile latency represented by the residual nuclear weapons stockpile with supporting storage and processing infrastructure (weapons complex).

- In the end, as it was in the beginning, we are back to the ultimate issue of controlling global stocks of nuclear explosive material.
- It is here that the *de jure* nuclear weapon states "meet" the de facto nuclear weapon states, and together join with today's truly non-nuclear weapon states, all facing the common legacy problem of accounting for and securing special nuclear material on a global scale.

Besides the challenge of returning to verification regimes involving the P-5 states, meeting the end-state objectives of the "Zero Option" will include the challenge of extending the umbrella to include emerging nuclear weapon states. The intelligence challenge likely to be faced in monitoring the situation in the new nuclear weapons states, principally India and Pakistan, and aspiring or near-nuclear weapons states, such as North Korea and Iran, will rely even more on HUMINT. Here, there is virtually no tradition of arms control and its associated provisions for declarations and inspections. Nor is there a well-developed concept of deterrence. The *full suite of intelligence capabilities* would have to move in harmony with diplomacy to help introduce these concepts and to transfer the experience of successful arms control as practiced in the past among established nuclear states.

Strategy 2. Non-Nuclear Weapon States maintain high latency by eschewing weapons capability

The non-nuclear weapon states (NNWS) similarly play an important role in a global framework of latency management by continuing to resist any temptation to develop nuclear weapons capability. Presumably, with the NWS on the path to stockpile reductions, the political motivations for the NNWS to develop such capability could arguably be reduced, supported also by positive perceptions of their own regional security. The NNWS challenge under NPT will be to remain responsible stewards of civilian nuclear technology. This would be reflected by a collective commitment to strengthen the NPT regime, eventually building and pursuing a more comprehensive global strategy for controlling nuclear explosive materials in partnership with the "former" NWS. As the NWS pursuit of the Zero Option is founded on a regime built on existing treaties and agreements (START, INF, TTBT, CTBT), the NNWS fidelity to maintaining latency also rests fundamentally on the NPT regime administered by the International Atomic Energy Agency (IAEA) since 1970.

However, the contemporary reality is that the NPT regime is at a major crossroads, some would even say at a "tipping point." Without the benefit of a stabilizing world order, some nations (e.g., Iran, North Korea) are strongly tempted to continue to nurture their nuclear weapons ambitions. In the aftermath of the first Gulf War, the limitations of the NPT regime in identifying clandestine nuclear weapons development in Iraq were made quite apparent. Likewise, the example of South Africa (although ending in a much more favorable outcome) indicated how far a determined nation could go in developing nuclear weapons capability in the background of normal military and commercial activities. In general, latency has both a political, as well as the more familiar capability dimension. Political latency would measure a nation state's willingness to live comfortably within the norms of the international power structure; alternatively, a state of "low latency" would indicate intent to challenge or undermine the power structure (e.g., a willingness to develop an asymmetric WMD capability to challenge superpower conventional dominance). The need for early warning to unmask the weaponization intent of a proliferating regime makes it imperative to address both dimensions of the latency problem.

The world faces expansive growth in energy demand over the next 50 years to support the development goals of huge, growing population centers. Nuclear power provides a very credible means for supplying safe, baseloaded, carbon-free energy that does not bring with it the risk of climate change. In the face of such expansion of nuclear energy, the NPT regime must not just be strengthened, it must be transformed to meet the great challenges before it. The three prevailing strategies for doing this include:

- Seeking greater efficiencies and effectiveness in the traditional mission of verifying member states' negotiated comprehensive safeguards declarations in the face of severe resource constraints (INFCIRC/153);
- Seeking transformational capability to also assess the *completeness* of the state's declarations by assuring the international community that no materials or activities required to be declared under safeguards are, in fact, *undeclared*. This involves an aggressive and effective implementation of the Additional Protocol in all of the States that have concluded comprehensive safeguards agreements with the IAEA (Information Circular (INFCIRC)/540);
- Enhancing the scope of nuclear security vigilance to put more attention on rogue, clandestine proliferation networks (à la A. Q. Khan) that procure enabling nuclear materials production technologies hidden in the "background" of globalized trade related to expansive growth in nuclear power or other relevant industries.

In the face of the expected growth in nuclear energy, the $100 million IAEA Safeguards budget, even as augmented by the contributions of Member State Support Programs (e.g., supplying R&D), seems inadequate for executing the traditional nuclear material accountancy mission. Technology development and enhanced inspection training programs are essential to transforming this activity. In the

United States, National Nuclear Security Agency (NNSA) has proposed a visionary technical program to address “Next Generation Safeguards” needs. However, the allocated resources are disturbingly low given the importance of the mission. In the face of a stagnating safeguards technology base, key thrusts have been proposed in the following areas (among others):

- Measurement technologies to improve the “reach” and precision of nuclear measurements, to include non-destructive assay techniques for spent fuel and measurement of plutonium concentrations and isotopics in non-traditional material forms characteristic of new nuclear processes;
- Unattended systems for process monitoring in real time with high reliability;
- Portable inspection equipment allowing high-resolution isotopics identification, e.g., for monitoring enrichment levels of uranium streams.

The most transformational effect could come from investment in advanced information processing and analysis capability. With the strategic and extensive deployment of sensor systems throughout a safeguarded facility to monitor processes in a manner that maximizes the probability of detecting material diversion, real-time integration of the data to facilitate timely analysis becomes a major technology challenge. The application of modern information analysis techniques could address the truly grand challenge problem: create an “activity monitoring engine” that ingests huge amounts of multiple forms of data in real time (text streams, surveillance imagery streams, in-situ sensor streams) and applies automated adaptive learning algorithms to facilitate detection of very small changes on a very “noisy” background of normal plant activity. Knowledge discovery tools could also be adapted to integrate information from state declarations, environmental sample results, commercial imagery, and various open source publications in order to guide and inform the inspection process, as well as facilitate the preparation of accurate, credible State Evaluation Reports.

Such technology could revolutionize the power of an inspectorate that is chronically resource-challenged. The national laboratories are pursuing major research programs in the integration of distributed sensor networks and advanced knowledge discovery and Bayesian inference algorithms, including implementation of computing hardware architectures originally developed for the gaming industry to process huge volumes of information in real time, to create such transformational capability. The Predictive Knowledge Systems initiative at Lawrence Livermore, as well as the Integrated Knowledge Engine being developed at Los Alamos will benefit both the international safeguards regime, as well as the intelligence community.

The Additional Protocol (AP) provides the IAEA with a very powerful means for enhancing the safeguards regime. Under this protocol, a state is required to provide the IAEA with broader information covering all aspects of its nuclear fuel cycle-related activities, including related R&D. In addition to providing inspectors with challenge access to all buildings on a nuclear site, "complementary access" allows access to a much wider range of locations to help verify the absence of undeclared nuclear material and related activities. This includes the collection of environmental samples beyond declared locations. In fact, if enabled by the appropriate technologies, including state-of-the art information analysis/technology as described above, the AP provisions could allow inspectors to detect "telltale" signs of weaponization activities based on multiple signatures that accompany the chain of activities starting with a political decision to manufacture a weapon, through material acquisition and processing, component fabrication, and testing/evaluation. The properly time-correlated indications from multiple data sources and a variety of locations could provide incontrovertible evidence of the "intent" to weaponize.

However, in order to leverage the opportunities accorded the inspectorate by the AP, appropriate technology transfer from the member states must be forthcoming to empower the international regime. Technologies such as airborne air sampling, hyperspectral imaging, commercial satellite imagery, nano-scale secondary-ion mass spectrometry (NanoSIMS), as well as access to export/import data and automated intelligent searches of the International Nuclear Information System, could form the backbone of a very powerful "Information-Driven Safeguards" program.

- For example, processing of materials in a nuclear program will inevitably involve effluent emissions from chemical processing.
- Mobile, precisely tuneable lasers can be used near suspected nuclear locations to stimulate specific airborne molecules that are released from nuclear materials processing.
- Co-located light-sensitive telescopes can scan the atmosphere to detect the presence of signature molecules. This is the general principle behind LIDAR (Light Detection and Ranging) systems.

With another technique, particles as small as 500 atoms in size can be probed by an ion beam to identify the elemental and isotopic composition of the particles that might indicate the chemical and physical processes that produced them. The impact of the beam on the particle sputters the matter, and the liberated atomic clusters are ionized and collected by a mass spectrometer for registration. Forensic analysis enabled by NanoSIMS technology could provide "nuclear CSI" capability to the IAEA ("CSI" refers to the popularized "Crime Scene Investigation").

- A complete suite of instruments like this could allow inspectors to literally build a credible model of a nuclear weapon development program from the indicators and signatures associated with the nuclear fuel cycle.

Strategy 3. Beyond Safeguards: a comprehensive global Fissile Material Control Initiative (FMCI)

Despite the significant challenges facing the international community in supporting the enhanced Safeguards program of the IAEA, the ultimate enabling capability for a truly Zero Option end state must go to the very heart of universal latency: complete global accountability for all nuclear explosive material. If the NWS are truly successful in driving stockpiles to zero (therefore disposing of huge quantities of excess nuclear material), and IAEA effectively monitors the world's nuclear power programs and supporting infrastructures for diversion of nuclear materials, there is still a nagging problem posed by uncertainties in the quantities of nuclear material accumulated as the end state is approached. Thus, a veritable safety net is required to continuously reduce, secure, and monitor all nuclear explosive materials on the planet.

This state of affairs becomes the necessary complement to the Zero Option; in fact, it becomes the veritable insurance policy for the Zero Option. Halting the production of fissile material for weapons globally becomes the first order of business along the nuclear materials path to the Zero Option. Phasing out the use of highly enriched uranium in civil commerce and removing weapons-useable uranium from research facilities around the world becomes another milestone. Somewhat more difficult, but strongly highlighted by the recent Global Nuclear Energy Partnership (GNEP), is the goal of removing separated plutonium from civil commerce and materials processing infrastructures. This latter mission imperative will remain as long as there is an active nuclear power program throughout the world (whether or not the GNEP survives in its current programmatic manifestation).

Just like the two previously identified strategy elements of our program (phased negotiated stockpile reductions and transformed Safeguards), this one is founded on current programs and initiatives. Most notably, multilateral discussions addressing a *Fissile Material*

Cutoff Treaty have been going on for decades. Until recently, and going back to the 1946 Baruch Plan, control over the production of weapons materials had been a consistent U.S. policy objective. Successful negotiation and entry into force of this treaty, along with a negotiated verification protocol, would arguably be the single most straightforward action in support of this strategy. In 1993, the UN General Assembly adopted a consensus resolution that recommended "the negotiation in the most appropriate international forum of a non-discriminatory multilateral and internationally and effectively verifiable treaty banning the production of fissile material for nuclear weapons or other nuclear explosive devices." The U.S. strongly supported the Treaty during the discussions that took place surrounding the indefinite extension of the NPT in 1995. The reader is referred to Chapter 8 by Robert Einhorn for a more complete exposition.

Technology development can also enable verification of a worldwide ban on plutonium production. A recent R&D accomplishment, borrowing science from modern astrophysics and cosmology research, provides a very useful example in this regard. Lawrence Livermore, in partnership with Sandia National Laboratory, has developed and fielded an anti-neutrino detector to provide continuous, nonintrusive, and unattended monitoring of fissile material inventory in an operating nuclear reactor. The cubic-meter-sized (liquid scintillator) detector was located 24 meters from the reactor core in an area of the plant rarely accessed by plant personnel. The anti-neutrino detection rate is sensitive to plutonium inventory in the reactor core (2 percent decrease in count rate correlates to 60 kg increase in Pu). A prototype of the detector was demonstrated over a period of 1.5 years at the San Onofre Nuclear Generating Station in California. With such an instrument, the declared power history and Pu inventory of a reactor can be verified, and the frequency of inspections can be reduced significantly.

Beyond the FMCT, other initiatives address the more distributed nature of nuclear materials outside of material production. Cooperative

Threat Reduction (CTR) complemented by the DOE's successful programs of *Materials Protection, Control, and Accountability (MPC&A)* and the *Global Threat Reduction Initiative*, have addressed the legacy issues associated with nuclear weapons and materials "orphaned" at the end of the Cold War. Some of these programs are actually coming to programmatic conclusion, as targeted by the Bush administration's Global Initiative to Combat Nuclear Terrorism. Admittedly, these are laudable accomplishments. However, there is currently no vision in the U.S. government to comprehensively move this to the next level. In the previous discussion of phased reductions to NWS stockpiles, the verification of weapon dismantlement and destruction inevitably leads to related consideration of a verification regime to assure transparency, monitoring, and destruction of fissile material very similar to that for nuclear weapons.

Just like the methodical consideration given to stockpile reductions, a material control regime would involve historical accounting in each nation of fissile material production (accompanied by requisite "declarations"), exchanges of data regarding existing stocks of materials, and verification of existing fissile material stockpiles. This would cover all processes through storage or other disposition. Conversion of nuclear material for civilian purposes would accordingly be monitored as well.

Ultimately, consideration must be given to the level of security accorded all stocks of nuclear material throughout the world. Although a long-term professional objective of the Institute for Nuclear Materials Management (INMM), physical security of nuclear materials has become an imperative in the post-9/11 terror threat environment. The International Convention on Physical Protection of Nuclear Materials has adopted an amendment that extends protection of nuclear materials from an initial historical focus on international transport, now to all activities within the boundaries of member states. Principles have been established for safeguarding the materials, and the IAEA's Office of Nuclear Security has oversight responsibilities related to compliance with these principles. A four-year Nuclear Security Plan (NSP) has been developed and is owned by the IAEA Department of Safeguards, in support of the strategic goal to establish a "comprehensive and effective international framework for promoting nuclear safety and security."

However, more detailed physical protection standards are needed. To meet this need, the Nuclear Threat Initiative (NTI), partnering with the INMM, has proposed a World Institute of Nuclear Security (WINS), patterned after the nuclear safety-focused World Association of Nuclear Operators (WANO). Its charter presumably would include a professionally managed forum for exchange of information between operators, industry, governments, and government entities; promulgation of "best practices" in physical protection and nuclear material control and accounting; support of IAEA peer review objectives; and assistance with self-assessments related to physical security and material control/accounting. This initiative is another element that integrates into a comprehensive approach for attaining a truly global *Fissile Material Control Initiative*. [See the discussion by Robert Einhorn in Chapter 8.]

Monitoring the state and security of nuclear explosive material would further increase the intelligence challenge. *Declarations* will be critical to establish a baseline. *NTM* will be helpful but not definitive. *On-site inspections* will play a more critical role. *HUMINT* will have to focus on issues such as "insider theft." And it will be particularly important to have a coalition of states equipped with *technical equipment to monitor borders* across which such material might be smuggled.

The challenge is multiplied when plans and capabilities of non-state actors, such as al-Qaeda, are brought into consideration. In most of the foregoing cases examined by this paper, detecting capabilities will be easier than discerning intent. With non-state actors, the challenge is reversed: *intent* is fairly clear—they seem prepared to use nuclear weapons for attack or blackmail—but *capabilities* are hard to define with confidence. Deterrence may be possible, but any calculus would at minimum be more complex than with state-based nuclear weapons. All intelligence capabilities would be in play, but *HUMINT would have an especially prominent role.* Information sharing will be important in order to operationalize any actionable information by empowering international and domestic law enforcement elements.

Strategy 4. Credible Response Capabilities Ensure Desired System Dynamics

The foregoing sections of this paper have introduced three major elements of a global framework for enabling and monitoring a global state of universal latency: (1) a negotiated and verified reduction of State-controlled nuclear weapon stockpiles to the Zero Option (presumably an end state of essentially virtual stockpiles); (2) a revitalized Safeguards program monitored by international authority that has kept NNWS from subverting nuclear power/fuel cycle programs to develop nuclear weapons capability; and (3) the institution of a global Fissile Material Control Initiative to provide a safety net to protect against the smuggling of even small numbers or amounts of nuclear weapons/materials for malicious purposes.

In earlier parts of this paper we identified means by which NWS and NNWS might be driven to higher degrees of latency, but strong emphasis was placed on carefully designed procedures and technology-enabled monitoring to detect violations of declarations in a timely manner and with high levels of certainty. Such credible information would then trigger predetermined sanctions ("restoring forces" in the overall system dynamics). It is the role of detection and information technology to ensure that evidence collected in this process is *compelling* enough to trigger the response.

In light of political circumstances or perceived threat to security, states may from time to time attempt to deviate from their expected degree of latency in this scheme. For the system to reach its designed end state, restoring forces must act promptly, presumably through a set of graded sanctions, to induce the state to return to an “acceptable” condition. (Although this type of behavior works pretty reliably in a home thermostat, there is no illusion about the level of difficulty this may pose in the international arena among sovereign states with complex security requirements. A case in point is the drama being played out now in North Korea and Iran.) This action-and-response principle must play out long enough in time for the entire global system to move to the ultimate goal.

Nevertheless, even having attained this state of universal latency, there is an existential need to protect the system from the insult of “breakout,” for which it must be eternally vigilant. Credible response capabilities, then, must be built into the final solution. These would not be so much for sanctioning moderate transgressions, but rather for creating an ultimate deterrent effect in this new paradigm. We propose three major response modes: tailored emergency disablement; counterproliferation; and ballistic missile defense.

If an improvised nuclear explosive were to be smuggled into the country and detected, there must exist a technologically superior emergency response capability that would not just be capable of detecting the nuclear material in time, but could infer the nature of the design itself via appropriate diagnostics, and then stabilize or effectively disable the device to prevent it from reaching its design objective. This requires a sophisticated nuclear weapon design and diagnostic capability that would rival the capabilities now engaged in Stockpile Stewardship of the enduring stockpile.

Ideally, the collective capabilities of multiple nations could work more collaboratively against the common threat of a rogue adversary armed with a non-state-designed weapon. (The nuclear weapon laboratories do have such capabilities today, but arguably they are not nurtured and developed in a manner robust enough to address the very palpable nature of the contemporary nuclear threat.) Given interdiction of the threat, nuclear forensic capabilities (such as those identified earlier for the detailed characterization of material processing signatures) could be applied to infer the ultimate source and production history of the material in the unexploded device. This would enable a judgment of attribution to be made, establishing ultimate responsibility for the foiled attack (specifically related to the source of the material).

It is quite possible that a nuclear weapons capability breakout could occur somewhere in the world, even from conditions that would accompany the Zero Option end state. This would constitute a very quick transition from latency to imminent threat. Depending on the certainty of the corroborating evidence, as well as the nature of the offense, a politically "transformed" international community that had built high levels of trust might develop agreed procedures for a preemptive attack on the emerging threat by an internationally authorized military force. In short, conventional counterproliferation capability would be a constant companion on the path to universal latency. But in keeping with traditional Just War doctrine, such a capability would be exercised only as a last resort and with careful consideration of collateral effect.

In a similar vein, the issue of Ballistic Missile Defense must also be raised. The subject of the proliferation of missile technology has not been discussed in this paper, nor has there been any presumption made with regard to the future of the Missile Technology Control Regime (MTCR). One could imagine a world of universal nuclear latency, but one that still retained significant numbers of conventionally armed ballistic missiles. The possibility of a clandestine attempt to deliver an improvised nuclear explosive payload cannot be discounted, any more than one can discount smuggling of a nuclear device across the borders of a country. However, the time frame within which to react to the former threat could be orders of magnitude shorter. In this case, Ballistic Missile Defense capability could be regarded as a justified defensive measure in light of an imminent, unexpected threat. Under these conditions, President Bush's characterization would be quite accurate: "America's development of a missile defense (would be truly) a search for security, not a search for advantage."

The problem here is that, although it is fairly easy to justify the implementation of BMD in a presumably de-nuclearized world as an insurance measure against an unexpected WMD attack, it is much more difficult to imagine where on the path to de-nuclearization its introduction would be the most prudent and the least provocative. This topic will not be considered in this paper. It is only interesting to observe that we have come fully back around to Reykjavik in 1986, when the vision of a nuclear weapon-free world and the promise of anti-ballistic missile technology were presented as part of a comprehensive vision. Due to the realities of the time, that particular discussion was not long-lived. It took the end of the Cold War and the advent of global terrorism to lead us to a point where such a relationship could again be revisited.

Space and ASAT

It is clear that in a world of universal latency, NTM capabilities will be so important that special precautions will be required to protect such assets from attack. There are many reasons to maintain space as a benign environment for satellites circling the globe in orbits above the atmosphere, at lower altitudes above 150 kilometers every 90 minutes, and up to geosynchronous orbits at 36,000 kilometers. They are vital components of the global communications and navigation network, of the global economy, and of the scientific exploration of our universe to the outer extremes of space. Central to our present discussion, they also play a major role in our military capabilities and national security (Graham and Hansen, 2005) [4].

Reconnaissance satellites in space have exploited a broad range of the electromagnetic spectrum for half a century, monitoring the development, testing, and deployment of nuclear weapons. This has enabled nations to enter into verifiable arms control treaties that have been, and remain, of great value to many nations, and particularly to the United States as a leader in space technology. It is anticipated that the importance of unhindered operations of NTM will increase, rather than diminish, as we negotiate deeper reductions in nuclear weapons and negotiate protocols to further restrict nuclear activities en route to a nuclear-free world.

The Chinese ASAT test of January 11, 2007 was a direct ascent interceptor that impacted and destroyed one of their dormant weather satellites at an altitude of 850 kilometers, creating more than 900 pieces of debris large enough to be tracked from Earth. Most are circulating in long-lasting orbits, remaining potentially dangerous to many orbiting satellites at a densely populated altitude. That incident reminds us that destructive collisions of our satellites with such space debris, which in turn would further increase the total debris, are potential threats to the benign space environment. It won't take many such debris-creating intercepts to deny the use of space by satellites whose eyes and ears are now serving important missions for communications, navigation, science, and reconnaissance.

The spread of ballistic missile technology is making it possible for increasing numbers of nations to attack and destroy orbiting satellites. This makes it imperative to address the problem of maintaining space as a benign environment, sooner rather than later.

What we can or should do to meet this challenge is not so simple to decide because satellites have more valuable missions than the ones indicated above for peacetime. They also provide instantaneous command control links for directing military battlefield operations. An approach to the problem of limiting the development of potentially threatening ASAT capabilities has been recently described by Geoffrey Forden [5], who proposes two steps for starters that are practical. The first is to make clear that nations will share basic information available from their civilian satellites with any other nation that has lost a satellite due to hostile action, and that is cooperating in a protocol that forbids such actions. The second is to negotiate an agreement that defines a keep-out region around national space assets. The keep-out range might take the form, as suggested by Forden, of forbidding the testing of an interceptor that approaches within 100 kilometers of another country's satellites with a closing speed greater than 100 meters per second. (Orbital speeds are typically several kilometers per second.)

These are two plausible initiatives to begin to regulate activities in space and develop a confidence among nations that space will not become another dimension in which weapons are deployed in a potentially hostile competition as we seek to reduce nuclear weapons and move toward a world free of them.

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