Safeguarding This and Verifying That: Fuzzy Concepts, Confusing Terminology, and Their Detrimental Effects on Nuclear Husbandry

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Words and concepts may have remarkable power, especially in international matters where subtleties and ambiguities in meaning can have major implications for treaty interpretation and compliance. In the diplomatic and political sphere, ambiguity has its benefits, such as for attaining consensus or strategic gain. Fuzzy concepts may thus be embraced purposefully by international players to achieve policy goals.[2] While deliberate fuzziness may therefore have a role in the international *political* arena, inadvertent ambiguity should be avoided for *technical* arms control.[3] When it comes to actually planning and implementing practical nuclear arms control efforts, inaccuracy and incorrectness can only confuse and lead to misunderstandings—potentially with detrimental effects on long-term nuclear security. Moreover, as an important input to political arms control discussions, technical inaccuracy may stand at risk of blurring opportunities for sound political action, thereby limiting the fulfillment of the true potential of specific arms control measures.[4]

Fuzzy arms control concepts and misleading terminology can be particularly dangerous in the multipolar post-Cold War world. Today, international nuclear arms control is at crossroads, with both great promise for new agreements, but also great risk that the existing regime may unravel.[5] Whereas the two nuclear superpowers in the past often had their own well-defined attitudes with regard to verification and compliance, today other states are also involved in defining the approach to verification.[6] Moreover, the public is increasingly interested in the planning, discussion, negotiation, and implementation of arms control regimes.[7]

The revolution in information technologies has made it more difficult to keep secrets by removing the veil of secrecy that previously marked much of international politics and, at the same time, shortening the time in which decisions must be made. These trends have tended to redistribute power away from centralized governments and placed more of it in the hands of non-governmental organizations (NGOs), multinational corporations, and international regimes.[8] In short, more players with more information and different agendas are now involved in nuclear arms control. With persistent nuclear security challenges, clarity is essential to identify and optimize practical nuclear security measures.

With this in mind, it is the ambitious goal of this article to take a critical and somewhat provocative look at the existing arms control nomenclature and concepts. In doing so, the authors hope to clarify the inherent features of different arms control measures to ensure their optimal and efficient implementation. While this exercise itself is likely to be controversial, it may help fuel a much needed debate on contemporary nuclear security activities and facilitate the development of systematic and sound practices for practical nuclear arms control.

THE IMPORTANCE OF TERMINOLOGY

If the world is to reduce nuclear arms and bring a halt to nuclear proliferation, effective controls over highly enriched uranium and plutonium—the essential ingredients of nuclear weapons—are fundamental. Today, much of the stability created by the nuclear standoff between the two former superpowers has disappeared, replaced by new nuclear proliferation challenges.[9] Inadequately protected and poorly controlled weapons-usable nuclear material, most notably in the former Soviet Union, could end up in crude nuclear weapons of "states of concern" or even terrorist organizations.[10] Terrorists are beyond deterrence, and especially in light of the September 11, 2001, attacks on the United States, it should be anticipated that some of these groups will eventually attempt to use weapons of mass destruction if allowed the opportunity.[11] Prevention of any of the terrorist cells from obtaining chemical, biological, radiological, or nuclear weapons or materials is, therefore, paramount. However, while the potential proliferation threats and the consequences of such chilling scenarios are fairly easy to understand, the problems of weapons-usable nuclear material management have proven anything but simple to solve.[12]

Moreover, continued international cooperation on arms control, including the control of fissile material and the implementation of pending bilateral and international treaties, is likely to play a significant role in defining the security context and relations between states in the decades to come.[13] However, in some cases one can argue that fuzzy concepts have contributed to errors in planning and implementation of practical arms control measures. The lack of careful thinking may not be as obvious in the literature as in real-world arms control efforts. The authors have observed first-hand numerous examples of confusion about key concepts by arms control researchers, program managers, and security personnel.

Even something as fundamental as the disparate goals of "P," "C," and "A" in nuclear Material Protection, Control, and Accounting (MPC&A)[14] are not always well recognized. For example, U.S. officials maintain that their "physical security system" will *detect* unauthorized movement of strategic material, once installed in Russian facilities.[15] While physical security is typically considered a "P" function, detecting unauthorized movement of material is classified as a "C" or "A" function. There are a number of examples of this kind of fuzzy thinking or terminology among people who should be more rigorous, particularly in the context of discussions about tamper-indicating seals, tags, and intrusion detectors.[16] There is also great confusion about the nature and purpose of vulnerability assessments.[17] The implications of such misunderstandings for nuclear security may be severe.

In our experience, much of the confusion rests within the United States. This confusion may have far-reaching consequences for international arms control, because the United States—a recognized leader in MPC&A technology—engages extensively in nuclear security consulting and technical assistance abroad.[18] Confusion is particularly common over the practical differences between international and domestic "safeguards," even among security experts.[19] For instance, the U.S Nuclear Regulatory Commission (NRC), a domestic agency, claims that it "supports U.S. Government nuclear safeguards and nonproliferation objectives through participation in international activities"[20]—as if international safeguards were just a trivial extension of domestic safeguards.

This misperception extends even to safeguards equipment. There is an unfortunate tendency to believe that U.S. domestic safeguards hardware and methods are automatically appropriate for international applications. A recent example of this involved the T-1 Radio Frequency Seal.[21] This active seal is in use for U.S. domestic nuclear MPC&A, but is also being heavily promoted as a tool for international safeguards, without, at least in our view, a careful and holistic analysis of the system's vulnerabilities in different contexts.[22]

Too often nuclear security equipment is fielded without a serious assessment of its intended purpose, overall context, expected performance, or vulnerabilities.[23] There tends to be a simplistic "one-size-fits-all" attitude about nuclear security. Consequences may include unrealistic expectations for monitoring hardware and security systems, overconfidence in the power of verification, and failure to appreciate critical security vulnerabilities. Many of these problems can be avoided simply with an appreciation of the disparate character and nature of the various arms control functions. The differences should be fairly obvious, yet in practice they often seem to be overlooked—with potentially serious consequences for nuclear security.

Lumping together arms control activities blurs their separate goals, means, methods, adversaries, and limitations. It is therefore our intent to pragmatically examine the existing nuclear arms control concepts and how the relevant terminology affects our understanding of and approaches to the challenges faced in this field. To this end, the authors will submit the widely but often misleadingly used terms "safeguards," "verification," and "transparency" to rather harsh treatment.

As a result of this deconstructing exercise, the authors have identified seven distinct "nuclear husbandry" functions, or key activities for responsible management of nuclear weapons and weapons-useable nuclear material.[24] Because they have less overlap, reduced ambiguity, and no multiple interpretations, the seven nuclear husbandry functions identified here can help clarify issues and avoid both political and technical pitfalls. These seven fundamental functions not only differ in how they operate in a practical sense, but also have very different strategic rationales. Domestic safeguards, for instance, are primarily designed to maintain adequate protection and control of a state's own nuclear material. International safeguards, or any other type of verification activity, are designed to deter violations and to increase confidence in non-diversion or non-violation by treaty signatories. Taken to the extreme, international safeguards do not have to be 100 percent reliable to contribute to the strategic goal of deterring misbehavior. This is in sharp contrast to domestic MPC&A, where an operational failure in the functionality of domestic MPC&A activities (having the prime strategic goal of protecting fissile materials) could be nothing less than disastrous from the point of view of the state.

By referring to simple analogies from everyday life, the authors hope to help elucidate each of these seven fundamental functions and their associated characteristics, providing a framework to characterize each one according to its given attributes.[25] These attributes include the methods (or means) used to implement the function, types of potential adversaries the function is meant to neutralize or must at least confront, and obstacles to implementing the function. Finally, the attributes of each of the seven nuclear husbandry functions are analyzed in a semi-quantitative manner, using correlation analysis. The results of this analysis lead to some important recommendations—and warnings—about present and future nuclear arms control efforts. These include the need for caution in mixing domestic and international arms control approaches, and the dangers of overly simplistic attitudes towards verification and traditional treaty monitoring.

THE PROBLEMATIC NUCLEAR ARMS CONTROL NOMENCLATURE

Perhaps it is unrealistic to expect great clarity or elegance in the nomenclature for a field where "national technical means" indicates satellite spying; "tamper-proof" seals are used for nuclear security and safeguards, even though they are not tamper-proof and are actually intended to detect tampering, not resist it; and "managed access" is an option for nuclear facilities that already have tight access control. There are other nomenclature oddities as well.[26]

As mentioned previously, these oddities may in fact have a touch of necessary diplomatic pragmatism associated with them. For instance, a phrase like "safeguarding the atom" may create both political interest and sympathy for the activities of the International Atomic Energy Agency (IAEA). However, as a tool for describing (and understanding) the activities of the IAEA, it may be misleading. The terms and euphemisms used—some of which verge on being comical—may have created unfortunate inaccuracies with regard to the ways that key concepts of arms control are employed and understood. In this introductory part of the paper, the authors hope to get at the core of the nomenclature problem by examining the (multiple) meanings, implications, and typical misinterpretations associated with use of the arms control terms "safeguards," "verification," and "transparency". Each term will either be discarded in favor of more appropriate terminology, or else the term will be retained, but its meaning and implications will be critically reviewed.

"Safeguards"

In the opening words of a talk given by Theodore B. Taylor in 1967, he stated, "The most important requirement for nuclear safeguards research and development is a clear definition of what nuclear safeguards are meant to do."[27] More than three decades later, a clear, concise, and consistent definition is still missing—with increasing confusion and misuse as a consequence.[28] Today there are at least two distinct and dissimilar uses of the word "safeguards"—domestic (U.S.-type) safeguards and international (IAEA-type) safeguards.[29]

The United States uses the word "safeguards" in a rather imprecise fashion, often in combination with "security," to cover a wide range of domestic nuclear nonproliferation activities, from physical protection and containment to accounting of nuclear material (MPC&A). The IAEA uses the terms in an equally ambiguous and open-ended manner, making it hard to assess safeguards effectiveness.[30] The IAEA sometimes adds the adjective "international" and generally understands "safeguards" as "nuclear material verification activities at nuclear facilities."[31] While domestic "safeguards" are designed primarily to detect theft of material by rogue individuals or small groups working at cross-purposes to the nation that owns the facility, international "safeguards" are designed to detect diversion of material by the state itself from peaceful uses into a military weapons program.

If asked, most arms control theorists, nuclear security experts, safeguards program managers, and national laboratory personnel in the United States will readily agree that domestic "safeguards" are not the same thing as IAEA "safeguards." In our experience, however, many still seem to operate under the implicit assumption that U.S. domestic MPC&A hardware, methods, and personnel are directly applicable to IAEA applications without critical analysis or significant modification. This is a fallacy; the goals, adversaries, personnel, costs, environment, consequences of a failure, and other factors in these two different environments differ enormously. But still, there continues to be an unfortunate tendency to push U.S. domestic MPC&A hardware, approaches, and personnel on the IAEA and other countries for quite dissimilar international purposes.[32]

Domestic "Safeguards"

Domestic safeguards and security programs operate on a national level, with a largely domestic security agenda. U.S. security and safeguards are regarded as an integrated system of physical protection, material control, and material accounting measures designed to prevent, detect, and respond to unauthorized possession, use, or sabotage of nuclear material.[33] The measures are introduced to protect national interests against a range of threats that include: (1) unauthorized access; (2) theft or diversion of nuclear weapons, weapons components, or special nuclear material; (3) sabotage; (4) espionage; (5) loss or theft of classified matter or U.S. Government property; and (6) other hostile acts that could cause unacceptable adverse impacts on national security or on the health and safety of employees, the public, or the environment. All sensitive U.S. facilities and facilities handling nuclear material are subjected to stringent regulations and requirements. Designated official offices, bureaus, and divisions are responsible for the independent evaluation of the effectiveness of safeguards and security policies and programs, including protection of special nuclear material, protection of classified and sensitive information, and foreign visits and assignments.[34]

Over the years, the United States has accumulated significant domestic MPC&A experience and technical expertise. To meet nuclear proliferation challenges, the United States has for the last decade engaged in "cooperative threat reduction" programs with Russia and other Newly Independent States (NIS).[35] A significant part of this cooperation is carried out under the United States/Former Soviet Union Program of Cooperation on Nuclear Material Protection, Control and Accounting, which includes providing technical assistance, consulting, training, and hardware to Russia.[36] It is important to note, however, that the United States does not perform any MPC&A functions for Russia or other NIS. While the United States may act on a consultative basis, Russian MPC&A is a domestic responsibility and a function undertaken by Russia on its own soil, using Russian personnel (and increasingly more equipment bought in Russia). Currently, there is no such thing as "cooperative MPC&A" or "international MPC&A." In other words, there are no nuclear facilities where MPC&A responsibility is shared, or where MPC&A activities are jointly supervised by different states.

Though it does not yet exist, there may well be true cooperative international MPC&A in the future. The concept of a "nuclear island," global repository, or international parks for nuclear power plants or nuclear material could eventually involve cooperative MPC&A.[37] Some third party or international agency such as the IAEA may eventually be given true custodianship of nuclear material or warheads, either by states no longer willing to pay the costs of domestic MPC&A, or as part of some comprehensive arms control or nuclear waste management agreement. Presumably such "cooperative," "international," or "third party" MPC&A would resemble current domestic

MPC&A, except with international players. It would probably have many of the same attributes; and unlike international safeguards, it could be appropriate to use similar domestic hardware and security protocols.

International "Safeguards"

In contrast to U.S. uses of the term, IAEA "safeguards" entail traditional international treaty monitoring. The IAEA safeguards are in place to monitor and ensure that states are honoring their commitments in accordance with the Treaty on the Non-Proliferation of Nuclear Weapons (NPT).[38] The IAEA has neither the legal authority nor the means to physically prevent the diversion of fissile material. Moreover, it is not the custodian of any significant quantities of nuclear material.[39] Instead, the responsibility of the IAEA is to look for evidence of cheating or breakout. The main adversary being monitored by the IAEA is the state that signed the treaty—and, in a practical sense, the owner and operator of the nuclear facility being inspected. This is a very different kind of adversary from that addressed by domestic safeguards. The resources available to states seeking to defeat international nuclear safeguards clearly exceed those of individuals or small groups by many orders of magnitude.[40]

Traditional IAEA safeguards involve a set of techniques and technologies depending less on sophisticated hardware than on an elaborate set of record-keeping and administrative techniques.[41] International safeguards are thus highly dependent on the State System of Accounting and Control set up by the monitored state. Unlike domestic safeguards, this information must be treated as potentially suspect and subject to verification.[42] Moreover, the effectiveness of international safeguards is limited by the fact that acceptance is voluntary, and that there are limitations inherent to traditional safeguards agreements (Comprehensive Safeguards, (INFCIRC 153 (Corrected)). The new Additional Model Protocol (INFCIRC/540 (Corrected)), however, represents an attempt to broaden the scope of safeguards with much more comprehensive declarations.[43] This protocol will also permit a far wider range of information and means for assessing the completeness and accuracy of the expanded declarations. But as of November 2001, 50 states have yet to fulfill their NPT obligation to conclude even the basic comprehensive safeguards agreements with the IAEA, and only 22 states have implemented the Additional Protocol allowing for a much wider range of monitoring activities.[44]

To deter cheating or breakout, international safeguards must be effective enough—and be perceived as effective enough—to detect within a reasonable time the diversion or clandestine production of nuclear material.[45] It might be very difficult for IAEA safeguards to produce proof of the physical diversion of nuclear material, much less the manufacture of a nuclear weapon or explosive device.[46] To establish that there has been a violation of an international safeguards agreement, the IAEA must simply conclude that it is "not able to verify that there has been no diversion of nuclear material required to be safeguarded." "Safeguards" is therefore in many ways a misleading term; sounding an alarm when potential problems are suspected or detected is a more apt notion of the function of the IAEA.[47] Some individuals, however, have questioned the ability and will of the IAEA to sound an alarm when needed.[48]

It is thus incorrect to think currently of the IAEA as an "auditing" agency, as has been suggested, for example, by the U.S. National Academy of Science.[49] An audit would ordinarily involve an aggressive team of investigators, inspectors, and experts with broad, authoritarian, and superior privileges, powers, and duties. While the role of the IAEA is defined through its statutes and specified through safeguards agreements with the inspected member state, IAEA jurisdictional rights are highly limited. *A priori*, formalized sanctions have yet to be invoked for treaty non-compliance. The IAEA, however, is moving in the direction of international "nuclear audits" with the above-mentioned Model Protocol. This would involve more aggressive, holistic, and comprehensive inspections more akin to nuclear auditing than traditional treaty monitoring. It would, moreover, involve a new analytical approach to reveal treaty non-compliance, and hopefully novel monitoring approaches and techniques. Generally, nuclear auditing would also differ from the traditional treaty monitoring ("classical safeguards") currently carried out by the IAEA in being less dependent upon purely quantitative data. The new, more qualitative safeguards would also be set up to better decipher the intentions of the inspected state.[50]

To summarize, the extensive and somewhat mindless use of the term "safeguards" stands at risk of concealing the true limitations of current activities and underestimating ever-increasing (technical) nuclear security challenges. In the international arena, the IAEA should spell out exactly what it is doing, which is monitoring the obligations of the non-nuclear weapon states (NNWS) that have signed the NPT.[51] The term "NPT-monitoring" could be considered an alternative for "international safeguards." For the strengthened safeguards system based on the Additional Protocol, "international nuclear audits" may be an appropriate future term. In the case of domestic safeguards, it is important to be specific and useful to subdivide the tasks into its three separate functions: domestic "physical protection," "control/containment," and "accounting". As further discussed below, all three domestic and the two international functions have highly varying attributes, despite their mutual kinship.[52]

"Verification"

There are endless discussions within the arms control community about how much verification is enough. Adjectives are placed in front of the word "verification" and discussed *ad nauseam*. These include adjectives such as "effective," "reliable," "adequate," "rigorous," "substantive," "legalistic," "intensive," "extensive," "military significant," "reasonable sufficiency," "higher-confidence," and even "metaphysical."[53] All this wrestling with adjectives suggests the term "verification" is problematic and precarious. An additional problem with the term "verification" is that it is often regarded as both a process and, at the same time, an end point. For example, the U.S. Department of Energy (DOE) considers verification to be "*measures* that *confirm* a declared activity is actually taking place."[54]

As with the term "safeguards," "verification" may tend to give an almost absolute sense of security and control. The term "verification" literally means to ascertain the truth or correctness of a statement, fact, figure, or quotation by a process of examination.[55] Another definition is "to prove the truth of by presenting evidence or testimony."[56] Practically, it may be taken to mean the fulfillment and confirmation of an anticipated result. Further evidence of the absolute nature of the term comes from from its Latin origin in the words *versus*, meaning "true," and *facere*, meaning "to make" or "put together;" literally to "make true." This absolutist connotation poses a potential problem.

The very nature of arms control makes absolute verification a difficult, if not impossible, goal to achieve. It will be in the interest of a sovereign state to limit any kind of intrusive revelations about its defensive or offensive national capabilities. Moreover, if sanctions are likely to be used as a tool to punish violaters, those states engaging in undesirable behavior will have few incentives to supply accurate information themselves.[57] States desire the level of intrusiveness to be kept as low as possible, conflicting with the initial verification goals and expectations. While new monitoring technologies tend to be more intrusive and technically capable, they may actually work *against* finding acceptable verification solutions, as they have the potential to reveal considerable details about nuclear weapon designs and other secrets.[58] Further complicating the issue, the "verification" process itself involves a series of steps, each one with costs and vulnerabilities as well as the potential for failure and cheating.[59]

Still, verification has been called "*the* critical element of arms control" by the U.S. government—not *a* critical element, but *the* critical element.[60] The mantra "trust but verify" rules. Thus, no arms control agreements are likely to be accepted by the United States unless they are substantially "verifiable."[61] Verification can thus become a serious bone of contention. Strict verification requirements may be sought politically by groups opposing an arms control regime, believing the other signatories to the treaty will exploit any slight advantage or discrepancy—politically, militarily, or both.[62] Opponents can insist on a high, unrealistic level of absolute verifiability—in effect, killing the regime. Indeed, the uncertainty of the verifiability of clandestine nuclear weapon testing became the final stumbling block for the Comprehensive Test Ban Treaty (CTBT) in the U.S. Senate in October 1999.[63]

While the process of verification may raise confidence that a promise is being violated or kept, it cannot provide 100 percent assurance of either non-compliance or compliance. In international negotiations, therefore, the fundamental question remains whether verification regimes must control capabilities by making noncompliance impossible, or whether they should have the realistic (but more intangible) objective of making defection less attractive than cooperation.[64] Ideally, verification should not be considered (consciously or unconsciously) a tool to provide either absolute proof of compliance or absolute proof of cheating. Instead, verification should be viewed as a probabilistic, "interpretive activity" that involves both evaluating the evidence and attempting to understand its meaning.[65] Again, this underlines the importance of having unambiguous terms and concepts for practical arms control.

"Transparency"

A universal understanding of the meaning of transparency does not exist within the arms control and nonproliferation communities.[66] Unfortunately, the term "transparency" has come to represent a grab bag encompassing all kinds of unrelated nuclear monitoring and disarmament activities. Nevertheless, the term does have merit—as long as its meaning and implications are clear and unambiguous.

One definition of transparency is a "cooperative process that is based on thorough risk-benefit assessments and that (1) increases openness and builds confidence, (2) promotes mutual trust and working relationships among countries, national and international agencies, and the public, and (3) facilitates verification and monitoring measures by information exchanges."[67] While this definition certainly may be useful for understanding some of the mechanisms of transparency, the scope of this definition needs re-examination. Transparency is fundamentally a *unilateral* act. While the transparency process can involve elements of cooperation, mutual negotiability, and interstate interactions, acts of transparency are decided and performed by a sovereign state in its own territory. A nation does not need the assistance, cooperation, or permission of another state to engage in transparency, nor to decide the timing or degree of openness that will be allowed.

The general aims of transparency in the nuclear arms control arena are to contribute to confidence- and security-building, and to foster public and political support by explaining the rationale of a specific nuclear policy and posture.[68] Transparency is, as defined here, a process in which information about governmental actions, preferences, intentions, and capabilities is made available—or more properly, allowed to flow—to citizens and the international community.[69]

The process of transparency is fundamentally non-verifiable—the information is either flowing or it is not. Thus, there are inherent problems with the commonly discussed idea of using hardware and inspectors to "verify" a "transparency regime."[70] Deliberately releasing false information or faking data is not "transparency," it is simply disinformation. Transparency, on the other hand, is truth-telling *per se*. Now, it may be desirable to validate the data that is released in a "transparent" environment, especially in its early stages. This corroboration can be accomplished with a set of broadly applied, (external) means, rather than by on-site inspectors or conventional inspection technologies and techniques. The more established transparency becomes, the more it is self-corroborating, because there are an increasing number of parallel channels of information that intrinsically cross-check each other.[71] Fully established transparency, of course, is an ideal and may never be achieved in any society, let alone internationally. Each state, after all, has secrets that should legitimately not be released to the world. One positive factor, however, is that transparency—once well established—is quite difficult to reverse, short of a severe security scare or substantial societal changes such as war, major terrorist attacks, or the overthrow of a government.

Note that despite being unilateral in nature, transparency can still be negotiable. States or the international community can request or demand more openness in return for other considerations. They can encourage, cajole, threaten, or even horse-trade for increased transparency from the other side, but transparency still remains the decision of a single state. There are typically no specific formal agreements concerning unilateral acts of transparency, hence cheating or breaking-out is not generally relevant. Even if transparency is formalized in a treaty, "verification" should not be expected as part of the deal. For example, consider the declarations on the Management of Plutonium.[72] These guidelines—agreed to by the five NPT nuclear weapon states (NWS) plus Belgium, Germany, Japan, and Switzerland—help increase transparency regarding the management and holdings of civil plutonium, yet no "verification" is involved.

Ideally, transparency surpasses required activities, such as reporting obligations mandated by treaty. In fact, voluntary release is the true meaning of transparency: taking extra steps of openness beyond expectations or promises is the true test.[73] The extra steps are likely to promote higher levels of trust. Transparency should be viewed as "permitted knowledge,"[74] the opposite of secrecy. Whereas secrecy indicates deliberately hiding intents, capabilities, and actions, transparency means deliberately revealing them.[75] Transparency and secrecy are not either/or conditions. As ideals, they represent two ends of a continuum. Based on voluntary measures, transparency permits outsiders to accumulate data flowing from a wide range of sources, over an extensive period of time to build confidence that behavior of a country or a collection of countries is consistent with agreements and norms.[76]

Several scholars claim that a normative shift began to occur in the latter part of the 1990s, triggering an evolving interest in transparency.[77] To the extent this shift has taken place, it has increased the number of states for which increasing transparency is of national interest and raised the likelihood that other states will see secretive behavior as more costly than beneficial.[78] Generally, transparency exposes states' weaknesses as well as their strengths, making them more vulnerable to external pressure.[79] While transparency can increase outside interaction in a positive manner, it might also bring disadvantages. In a crisis, for example, transparency might carry with it a potential for conflict escalation due to miscalculation. Indeed, the quantity of information is typically less important than its correct interpretation. Transparency might also shorten the time span available for critical decisionmaking, as broader audiences could become agitated in a crisis situation. It could potentially fuel conflicts over power, and increase political instability.[80]

However, in the absence of an intense conflict or crisis (or a desire to create one), it is unlikely that transparency would play a role in revealing malicious intentions, particularly in a nuclear setting, due to the inherent vulnerability of all states to a nuclear attack despite asymmetries in striking capabilities. Such is the logic of nuclear deterrence. To the extent that nuclear transparency does occur, it is more likely to take place in an un-offensive (preventive) context. Nuclear transparency, in particular, can be a very powerful tool for arms control and confidence-building. Ideally, it can help adversaries understand each other's nuclear intentions through knowledge of the size of the other's stockpiles of fissile material and nuclear weapons, as well as the rate of reduction of these stockpiles. For example, while relations between the United States and Russia are far from perfect, Russia surely has a much more reliable understanding of U.S. nuclear intentions and activities than would be the case if the United States were a more closed society.

Consequently, transparency may more properly be viewed as a supportive activity for existing and future treaties and/or emerging arms control norms, rather than a regime to be formalized with a treaty, inspectors, monitoring hardware, and "verification."[81]

THE NUCLEAR HUSBANDRY FUNCTIONS

It is common to consider "safeguards," "verification," and "transparency" as comprising the spectrum of nuclear security and arms control measures. These concepts, however, are vague, too general, misleading, and encompass a variety of unrelated activities. Clarification of the concepts and specification of the tools applied is, therefore, both desirable and necessary to be able to meet contemporary nuclear security challenges in a proper way.

In our view, the seven basic functions that constitute the spectrum of nuclear husbandry activities are:

- domestic nuclear physical protection;
- domestic control/containment;
- domestic accounting of nuclear material;
- domestic nuclear auditing;
- international nuclear auditing;
- traditional monitoring of international treaties and agreements; and
- nuclear transparency.

These seven functions fit within two broader categories of domestic and international husbandry respectively, as shown in Table 1.

The seven nuclear husbandry functions do not explicitly include safety, stockpile stewardship, or environmental monitoring issues, since the focus here is nuclear security. International or cooperative MPC&A is also not included because, as discussed above, neither currently exists.[82] Note that "domestic auditing" is meant to monitor the adherence to domestic laws and regulations, not international treaties. "International auditing," in contrast, involves examining adherence to treaties.

Table 1: Seven Basic Nuclear Husbandry Functions

Domestic Nuclear Husbandry				International Nuclear Husbandry		
Physical Protection	**Containment & Control**	**Accounting**	**Domestic Auditing**	**International Auditing**	**Traditional Treaty Monitoring**	**Transparency**

As nuclear transparency is normally aimed at an external (international) audience, it is characterized as an international function, despite the fact that it is largely a domestic activity.[83] Moreover, this article will only address nuclear transparency activities as seen from a state perspective. Information released from dissidents or other external sources will not be considered as part of any interstate transparency.

Simple Everyday Analogies for Nuclear Husbandry

In order to better understand the disparate nature and attributes of the seven nuclear husbandry functions, it is worthwhile to examine some simple analogies based on everyday (household) life.[84] These models should not be taken overly seriously, but may be useful for clarifying issues. This is especially the case for the transparency analogy. Although simplified, these models can provide a basis for understanding the semi-quantitative analyses of the nuclear husbandry functions that follow them.

Domestic Physical—The "P" in Domestic "MPC&A"

Imagine as a homeowner that you have a number of consumer electronics such as televisions, computers, stereos, miniature CD players, radios, microwave ovens, etc. inside your house. Because of their value, these are prime candidates for theft or vandalism should someone break into your home from the outside. To prevent theft, you might consider obtaining a gun, guard dog, or burglar alarm. You might improve/replace the locks on your doors and windows, or even sign up for a private security guard service or advice from security consultants. To protect against tampering or vandalism by an intruder, authorized visitor, or even your own children, you might consider placing the items inside hardened steel cases, or locking them up when not in use.

In this model and in the next two, the valuable electronics obviously play the role of nuclear material and warheads. The adversaries are mostly outsiders (burglars), though there must also be protection from rogue insiders (in this case, the children). As will be seen, all the P, C, and A functions undertaken by the homeowner are ordinarily domestic functions, not external or cooperative ones.[85]

Domestic Control/Containment—The "C" in Domestic "MPC&A"

In your home, there might be a risk of theft by burglars, visitors to your home, or even your own children. To prevent, or react to, these items disappearing from your house, you might chain them down, lock (or seal) the rooms in which they are stored, attach motion sensors equipped with audible alarms or passive transponder tags that are detected when objects pass through the front door, or use video surveillance to record who stole them. You might also have your social security number or phone number etched onto each item; should the electronic units be stolen, these numbers (tags) might be of assistance in retrieving them.

Domestic Accounting—The "A" in Domestic "MPC&A"

It might be necessary to keep careful track of the electronic items in your home to detect theft or vandalism for insurance purposes, and to monitor the status of these items should repairs or replacements be needed. One might periodically count these items to ensure that none are missing. This function would act as a check on your P and C functions and would be helpful in alerting you if and when to call the police. A periodic inventory of your possessions is thus useful, but if you have a lot of them, this can be very time-consuming. As an alternative, you might decide to seal (or lock) a number of these items inside a room or storage container. As long as the seal remained unopened, you would have some confidence that it is not necessary to perform another inventory.

Domestic Auditing

Imagine that your spouse is going on a business trip. As usual, you are put in charge of the household and the kids. When your spouse returns, there may be a broad audit of the housekeeping and supervision of the children that took place in her or his absence. A wide range of issues and decisions regarding the operation of the "plant" are open for critique. Measures to rectify serious deficiencies in the household may be ordered. Your powers (and the wisdom) of contesting the findings and decrees produced by the audit, however, are extremely limited. On the other hand, your motives and fundamental loyalty to the enterprise are not ordinarily going to be questioned, unless there is evidence of extreme pathologies.

The spouse, in this case, is analogous to the domestic nuclear auditor. Like most domestic government auditors, the spouse has at least some ownership of the facility (i.e., the household). Also, he or she has a certain kinship to and authority over the personnel being audited (the family). One weakness of this model, however, is that the spouse typically resides inside the house. While there are domestic auditors that are stationed permanently inside nuclear facilities, most auditors or national inspectors show up on a regular or *ad hoc* basis, but are stationed elsewhere. Consider, for example, a DOE nuclear facility. This facility can be inspected by the DOE internal auditing office, the Defense Nuclear Facilities Safety Board, state or federal Environmental Protection Agencies, or other government agencies. All have the authority to order a wide variety of draconian changes if they detect problems.

Traditional Treaty Monitoring

Now, imagine that you are asked by the neighborhood association to pledge to improve the quality of life in the neighborhood by signing an agreement. You feel obliged—and it may be in your best interest—to participate in this agreement for several reasons, including: (1) pride and peer pressure; (2) to demonstrate that you are a good citizen; and (3) to ensure that your neighbors behave in a similar fashion in the interests of peace and stability in the neighborhood. A committee from the neighborhood association may periodically visit you to check on how well you are honoring the agreement. They can point out to you areas of departure from your promises. If they decide you are not significantly honoring your pledge, they might report your non-compliance back to the neighborhood association and to your neighbors—something you would normally like to avoid. The neighborhood association has no real authority to force or order changes in your home or behavior, and somewhat limited power to penalize you. They can, however, organize sanctions that would make your life more complicated and unpleasant.

Note that the neighborhood association's representatives are tightly constrained in what they can review or critique; they must focus only on issues covered in your signed agreement. They thus play the role of inspectors in a traditional treaty monitoring regime, in that they have a limited and formal checklist of facts to review, rather than being "auditors" who can critique a wide variety of broader issues.

The neighborhood association, a coalition of neighbors, plays the role of the IAEA, an association of governments. In this model, the inspectors are limited in what they can inspect or criticize and especially with regard to what remedial actions they can demand. Issues that may be important for nuclear security, but are not specifically covered in the treaty, are off-limits. Typical examples (for a nuclear facility) include personnel practices and policies, and details of day-to-day operations.

International Auditing

Consider that as a member of the community, you are obligated to abide by certain standards and regulations regarding electrical and plumbing codes, fire regulations, taxes, environmental laws, zoning restrictions, noise ordinances, refuse disposal, health standards, upkeep of property, use of utilities, and social welfare standards pertaining to, for example, the upbringing of your children. Although you are the owner of your house, you are nevertheless subject to audits and reviews by meter readers, Internal Revenue Service auditors, social welfare workers, and municipal and law enforcement officials. While they do not have unlimited power, these auditors have considerable latitude in the types of issues and problems that fall within their particular mandates. They can consider information from a variety of sources, including reports from neighbors and legal or financial documents, in making their judgments as to your compliance with your responsibilities. They are not limited to on-site inspection.

The auditors have considerably more authority to insist on corrective action than was the case for the neighborhood association considered in the traditional treaty monitoring analogy. The main difference lies in the breadth, depth, authority, power, and aggressiveness of the audits and the auditors. One of the weaknesses of this analogy is, of course, that the homeowner does not (unlike signatories to international agreements) sign any agreement, though there are implied agreements as well as specific laws involved in the purchase of the house.

Transparency

For your own benefit, you would like your neighbors to know about some of the activities that take place inside your home. You would like to reassure them that these activities are wholesome, legal, ethical, responsible, safe, and the type of activities that belong in their neighborhood. You can do this by installing a window so that neighbors can look in. Apart from providing obvious benefits to you (sunlight, views, fresh air, etc.), this form of openness allows others to look inside to get an idea of any ongoing activities as well as your possible intentions. Another benefit to you of such openness is that neighbors might, for example, see you fall inside your home and be able to summon help. Installing the window may also make your neighbors less suspicious and hostile, and if you put in a window perhaps they will too—allowing you to better understand their activities.

Note that it is your house, and only you have the right to install the window. The neighbors can cajole, bribe, or threaten you into installing the window. They can reciprocate unilaterally or negotiate mutual window installations. They can help pay for your window, or even come over to help you install the window. In the end, however, installing the window on your private property is ultimately your decision and, fundamentally, a unilateral action.

You may be willing to put up with a certain loss of privacy in installing the window, but there are limits to how much transparency you will permit. Not every room or all activities inside the house are appropriate for public viewing. Intelligence gathering activities by the neighbors, such as installing a covert listening device inside your house or external video surveillance on your property, are not acceptable, nor part of your transparency measures. That is why, for example, "national technical means" should not be regarded as transparency.

You might choose to install your own video cameras (or cameras you control and can turn on or off at will) inside your house to transmit images unedited and freely (e.g., over the Internet) in order to increase the neighborhood's confidence that no improper activities are taking place inside the house. This would certainly constitute an act of transparency. If, however, outsiders own and control the cameras, the video imaging would be considered monitoring rather than transparency. The video equipment in this case, and the people who own, control and install it, would be outsiders/intruders and not a natural part of your home and the activities that take place therein.

Note that your transparency does not need to be "verified." The window (and/or video cameras) is either in place or it is not. Your neighbors may nevertheless be concerned (especially early on) that some of your activities seen through the window or camera are staged for purposes of misleading them. They may believe that the data gathered from observing requires double-checking. If so, they can combine information from a wide range of different sources to gain the desired level of confidence. All available data will then be used collectively to arrive at a general determination about your past activities and future directions.

The Disparate Nature and Unique Characteristics of the Nuclear Husbandry Functions

The overall objective of this analysis is to clarify and identify the uniqueness of different nuclear husbandry activities and to characterize each of the seven functions in ways that allow for their correct and optimized practical implementation. One obvious way to identify the similarities and the differences between the functions is to compare some of their associated attributes.

While the basic objectives of the nuclear husbandry functions may be fairly obvious (e.g., to hinder diversion of weapons-usable material, monitor treaty compliance, etc.), there are varied possible methods (means) for implementing the functions. There will also be many different kinds of potential adversaries and obstacles that can be encountered for any given function. The means, adversaries, and obstacles are likely to differ, depending on the function's objectives and goals, its intrusiveness, the level of change required, and possible divergence from existing mindsets, habits, and traditions.

The following section examines the key attributes of the "means," "adversaries," and "obstacles" associated with the nuclear husbandry functions. Each attribute is evaluated in accordance with its importance for the nuclear function of interest. Fairly self-explanatory measures are employed: highly relevant (++), partly relevant (+), neutral (0), irrelevant (-), and highly irrelevant (--). While a highly relevant categorization signifies that the attribute plays a major role in the husbandry function, partly relevant indicates that the measure or consideration is only partly relevant to the activity in question and not critical for its functionality. A neutral input signifies that neither harm, nor good is accomplished by considering or involving the given attribute. An irrelevant score, in contrast, indicates that the attribute is not particularly germane to the function in question. Finally, highly irrelevant denotes that the attribute in question is an inappropriate choice that could actually be harmful to the nuclear husbandry function of interest, because resources might be wasted, a false sense of security created, or distraction generated. The use or consideration of that attribute may well reflect a profound misunderstanding of the nuclear husbandry function in question.

The results are shown for "means" in Table 2, for "adversaries" in Table 3, and for "obstacles" in Table 4. They are all based on the authors' interpretations of current approaches to nuclear husbandry, their own first-hand

Table 2: Means for Nuclear Husbandry

Means	**Nuclear Husbandry Functions**						
	Domestic Physical Protection	**Domestic Containment & Control**	**Domestic Accounting**	**Domestic Auditing**	**International Auditing**	**Treaty Monitoring**	**Transparency**
Locks and barriers	++	++	+	+	+	+[87]	- -
Radiation monitors: Portable	0[88]	++	++	++	++	++	- -
Radiation monitors: Fixed (portal or volumetric)	0	++	++	+	++	0[89]	- -
Portal detectors: Access control	++	++	+	0	0	0	- -
Portal detectors: Prohibited items	++	++[90]	0	+	+	0	- -
Portal detectors: Video surveillance	++	++	+	+	++[91]	++	- -
Seals	- -	++	++	0	++	++	- -
Tags	- -	+	++	0	++	++	- -
Nuclear archaeology	0	+	+	+	++	++	- -
Satellite surveillance	0	0	0	0	++	++	- -[92]
Environmental sampling	0	+	+	++	++	++	- -
Citizen-watch, whistle-blowing, NGOs, free press	0	0	0	+	++	++[93]	+[94]
Open source information	0	0	0	+	++[95]	+	++
Intelligence (covert sources)	0	0	0	+	++	0	- -

Video monitoring (volumetric or perimeter)	+	++	+[96]	+[97]	++	++	+[98]
Personnel background screening	++	++	+	++	++	++[99]	- -
Personnel assurance programs[100]	++	++	+	++	++	++[101]	- -
Sensors: Non-radiological, non-video	++	++	+	+	++	+	- -
On-site Inspections	0	0	0	++	++	++	- -[102]
On-site Visits	0	0	0	++[103]	0	0	++[104]
Vulnerability assessments	++	++	++	++	++	++	- -
Guard force	++	++	+	0	-[105]	-	- -
Seismometer	0	0	0	0	++[106]	++	- -
Information protection[107]	++	++	+	+	+	0[108]	- -

Legend:
For each of the means listed in non-prioritized order in column 1, the nature of its contribution to the nuclear husbandry functions is characterized as listed in the remaining columns. The possible values for the contribution score are:
Relevant (++): Use or consideration of this means is highly relevant to the function in question.
Partly relevant (+): Use or consideration of this means is less critical, but still retains value.
Neutral (0): This means is not applicable. It is beyond the technical limitations or jurisdiction of the function, but its use is not inherently harmful, nor beneficial.
Irrelevant (-): Use or consideration of this means reflects a faulty understanding of the function in question.
Highly irrelevant (--): Use or consideration of this means reflects a profound misunderstanding of the function in question and may be detrimental.

experiences, and supporting literature. Some of the contribution scores are justified or given further elaboration in the text and endnotes. Clearly, the scores in Tables 2 to 4 are subjective and open to further discussion and debate. These evaluations should be considered a first approach in analyzing trends in nuclear husbandry. The authors invite all readers to perform their own personal assessments, and alternatively, to further explore and develop the model themselves.

MEANS FOR NUCLEAR HUSBANDRY

The term "means" for nuclear husbandry has a broad definition in this study, including technology for detection and measurements, physical barriers, security measures, and procedural rules.

Domestic MPC&A consists of three distinct and rather intuitive functions of protection, control, and accounting. The three functions may, as seen in Table 2, overlap. For example, portal detectors using video surveillance have value for both detecting intruders (as part of the physical protection), for observation of personnel and containers leaving the plant (containment), and, in some instances, for counting of containers (accounting).

Tags and seals are clearly very important for nuclear accounting. Thus, this function is valued at "++" in Table 2 in the domestic accounting column. Such means are not, however, of any significance for physical protection, thus a rating of "--" in this square of the matrix.[86] Note that all but four of the means in Table 2 have been assigned a contribution score of "--" for transparency. This is consistent with our view that transparency—the free flow of information—is most properly considered a compliance support activity requiring neither verification nor the traditional tools of nuclear security and safeguards. For example, locks and barriers do not have a role to play in implementing transparency. Considering them for use in transparency indicates a faulty understanding of what transparency is, and pursuing the use of such technological tools may actually limit the true potential of transparency in improving nuclear security. Thus, both transparency columns in these cases reflect a "--" rating.

While MPC&A is a purely domestic function (at least to date), compliance corroboration is currently undertaken both domestically and internationally. Domestic compliance corroboration typically includes audits in conjunction with laws, regulations, government licensing activities, or cross-agency or internal auditing. These activities are unilateral and need not involve other governments or international bodies, nor do they typically require international agreements. International auditing is, as discussed above, a natural growth area for the IAEA with its Additional Model Protocol. It is worth noting that international and domestic compliance corroboration differ in terms of possible sanctions to be evoked, the intrusiveness of inspections (or audits), the level of suspicion on the part of the inspectors or auditors, and the technical means to be applied. While a domestic facility may be shut down or put on "stand down" by domestic auditors, or its employees even fired, fined, or arrested if deemed necessary, international inspectors can only sound alarms in cases of non-compliance. In contrast to on-site inspections, however, open source information is of high importance for transparency, and is thus given a high contribution score.

ADVERSARIES OF NUCLEAR HUSBANDRY

There are a number of different potential adversaries that any one of the seven nuclear functions must counter. Adversaries are specified in Table 3, columns 1 and 2, by both their identity and their intentions.[109] In Table 3, a contribution score has been assigned to the different types of adversaries and their intentions, based on their relevance to the nuclear husbandry function of interest.

In Table 3, the "insiders" are perpetrators who have legitimate direct or indirect access to the targeted facility or material. "Outsiders" are perpetrators without such privileges. Both types of adversaries may try to steal nuclear material or weapons, or perform sabotage, depending on their motives. The purpose or goal of physical protection is primarily to protect fissile material or nuclear weapons from unauthorized handling or damage by either insiders or outsiders. Thus, while physical protection can play a role in preventing theft, it is more critical for preventing acts of sabotage. The contribution scores in Table 3 for P are thus stronger when sabotage is the issue than when theft is of concern. Containment/control and accounting tend to be more important for averting theft than for preventing sabotage, so they have stronger scores for diversion.

Neither terrorists nor saboteurs should be considered adversaries to treaty monitoring or transparency measures. Their activities are outside the scope of (at least current) treaties or transparency efforts. Thus there are neutral (0) or non-relevant (-) scores in Table 3 for these adversaries. While transparency may increase the risk of diversion or sabotage by making more information available to possible intruders, saboteurs and terrorists are not direct adversaries to transparency *per se*. Nevertheless, widespread knowledge about the location of fissile material and nuclear weapons, as well as the systems of physical protection and containment used, may facilitate acts of sabotage and unlawful diversion.

A signatory to a treaty is not an adversary to domestic MPC&A or domestic auditing, because such activities are generally carried out by the signatory and are in that state's best interests. Thus, non-relevant inputs are placed in the lower left-hand corner of Table 3.

OBSTACLES TO NUCLEAR HUSBANDRY

Nuclear husbandry functions can encounter resistance, especially when they are initially implemented or when they are expanded. The extent of the political, military,

Table 3: Adversaries of Nuclear Husbandry

Adversary		Nuclear Husbandry Functions						
Intention	**Identity**	**P**	**C**	**A**	**Domestic Auditing**	**International Auditing**	**Traditional Treaty Monitoring**	**Transparency**
Diversion	Outsiders	+	++	++	+	+	-	- -
	Insiders	+	++	++	++	+	-	- -
	Insider cooperation with outsiders	+	++	++	++	+	-	- -
	Facility managers working at cross purposes	0	+	++	++	+	0	- -
Sabotage	Outsiders	++	+	0	+	0	- -	- -
	Insiders	++	+	0	++	+	- -	- -
	Insider cooperation with outsiders	++	+	0	++	+	- -	- -
	Facility managers working at cross purposes	+	0	0	+	+	-	- -
Cheating	Signatory to inter-national treaty or agreement	- -	- -	- -	- -	++	++	-
Breakout	Signatory to inter-national treaty or agreement	- -	- -	- -	- -	++	++	-

Legend: For each of the adversaries (identity + intentions) listed in non-prioritized order in column 1, their relevance to the nuclear husbandry functions has been characterized and listed in the remaining columns. The values are as follows:
Relevant (++): Planning for this adversary is highly relevant for the function in question.
Partly relevant (+): Planning for this adversary is less critical, but still important.
Neutral (0): This adversary is not particularly relevant for the function in question.
Irrelevant (-): Planning for this adversary reflects a faulty understanding of the function in question.
Highly irrelevant (- -): Planning for this adversary reflects a profound misunderstanding of the function in question, and may be detrimental.

technical, diplomatic, or bureaucratic opposition typically depends on the amount of change, resources, and inherent risks involved. The resistance might be strategic in nature, where the changes are opposed due to security concerns. Or it might stem from more subtle organizational (structural), political, cultural, psychological, or personal motivations.

In the following table, various obstacles to the implementation of the seven nuclear husbandry functions are listed, along with their estimated ratings. These inputs indicate the relative degree of relevance or importance for each obstacle.

Every country has both a right and an obligation to protect classified and sensitive information. Releasing such information would be unlawful and could potentially harm national and even international security.[121] To members of the defense community in particular, increased openness might be viewed as a threat to maintaining military effectiveness and strength, owing to the general need to maintain ambiguity concerning actual capabilities and military strategies. Revealing military weaknesses could be detrimental to a state's national security. In the case of nuclear deterrence, for example, it depends critically upon the ambiguity of retaliatory attacks.

While domestic nuclear husbandry functions are relatively unlikely to be affected by these desires for ambiguity, international functions are not. Compared to the domestic setting, the obligations to protect classified information (first row, Table 4) become more relevant in the international sphere. Obligations to protect classified information will rarely interfere with a country's efforts to implement or improve domestic physical protection and containment/control. On the contrary, systems of physical protection and containment work best with some level of secrecy. Secrecy, however, does not impede effective domestic auditing or accounting, nor is it particularly helpful. Hence, neutral values for domestic accounting and auditing appear in row 1. In the international arena, concerns about the loss of classified and sensitive information are likely to hamper the implementation of any international corroboration. Thus, there are positive relevance scores in the last three columns of row 1. Transparency will likely fall victim to these concerns, as it is fundamentally inconsistent with secrecy.

In addition, nuclear husbandry can be severely hampered by cultures and traditions of secrecy, extreme militarism, xenophobia, and/or a lack of progressive thinking. Transparency, in particular, is likely to be affected by cultural beliefs and attitudes towards openness.[122] Bureaucratic inertia can also be a serious obstacle. An example is the typical insistence on over-classifying documents, data, and "secrets."[123] Moreover, in situations where the nature and advantages of compliance corroboration and support are not properly understood, the anticipated benefits might be underestimated. This is likely to result in less interest, and possibly less emphasis on implementing or expanding certain nuclear husbandry functions.

Note that the costs (in terms of resources) required for transparency are fundamentally lower than for the other nuclear husbandry functions, because (1) no complex or expensive technical tools are required; (2) no lengthy negotiations are needed; and (3) the information may be distributed through open and existing media channels. In Table 4, costs are accordingly characterized as "not relevant" for transparency. However, the need to protect proprietary information could, to some degree, hamper the implementation of almost all nuclear husbandry functions, including unilateral, non-verifiable acts of transparency.

IMPLICATIONS FOR NUCLEAR HUSBANDRY

By comparing Tables 2, 3 and 4, it becomes apparent that the seven nuclear husbandry functions differ significantly with regard to the means to be applied, the possible obstacles to overcome, and the potential adversaries to neutralize. However, as suggested above, there are also related features amongst the functions. Domestic physical protection appears, for instance, to be somewhat related to domestic containment and control; and containment/control seems to be related to accounting. In the international arena, there are some links between international nuclear audits and traditional treaty monitoring. However, a rough comparison of domestic and international nuclear auditing reveals more dissimilarities than similarities.

To further investigate these differences, it is helpful to carry out a semi-quantitative analysis, where each entry in Tables 2, 3, and 4, is assigned a relative numerical value. For this study, the following values have been assigned:

Relevant (++) = 2;
Partly Relevant (+) = 1;
Neutral (0) = 0;
Irrelevant (-) = -1;
Highly Irrelevant (- -) = -2.

Table 4: Obstacles to Nuclear Husbandry

Obstacles	Nuclear Husbandry Functions						
	Domestic Physical Protection	**Domestic Contain-ment & Control**	**Domestic Accounting**	**Domestic Auditing**	**International Auditing**	**Traditional Treaty Monitoring**	**Transparency**
Protection of national security	- -[110]	-	0	0[111]	+	+[112]	++
Deterrence requirements	0	0	0	0	+[113]	+[113]	+[113]
Protection of proprietary information[114]	+	+	+	0	+	+	+
Culture of secrecy; militarism; xenophobia	+[115]	++[115]	++[115]	0	++	++	++
Job security for nuclear complex workers	0	0	0	+ +[116]	+	0	0
Bureaucratic inertia	0	+[117]	+[117]	++	+[118]	+	++
Safety and environmental rules[119]	+	+[120]	+[120]	++	+	0	-
Negative perceptions to change	-	0	0	0	+	+	++
Costs	++	++	++	++	++	++	-
Technical limitations	+	++[117]	++[117]	+	++	++	- -

Legend: For each of the obstacles listed in non-prioritized order in column 1, they are characterized with regard to their relevance to the nuclear husbandry functions listed in the remaining columns. The allowed values are:
Relevant (++): Overcoming this obstacle is highly relevant to the function in question.
Partly Relevant (+): Overcoming this obstacle is less critical, but still important.
Neutral (0): Overcoming this obstacle is not particularly relevant, nor useful for the function in question.
Irrelevant (-): Devoting effort to overcoming this obstacle reflects a faulty understanding of the function in question.
Highly Irrelevant (- -): Devoting effort to overcoming this obstacle reflects a profound misunderstanding of the function in question, and may be detrimental.

Using these numerical values allow us to compute the Pearson linear correlation coefficient (r) between every pair of nuclear husbandry functions (i.e., between each pair of columns). There are a total of 44 different relative contribution scores for each of the seven nuclear husbandry functions (combining Tables 2-4). All 44 contribution scores are weighted equally, regardless of whether they fall within the "means," "adversaries," or "obstacles" categories.

The correlation coefficient provides a measure of how interconnected one husbandry function is to another.[124] The correlation coefficient (r) assumes a value from –1 to +1. A value of r = +1, for example, signifies perfect correlation (i.e., the two nuclear husbandry functions compared are identical). A value of r = 0 indicates that the two functions are completely uncorrelated and completely dissimilar. A value of r = -1 shows that the functions are perfectly anti-correlated.[125] The square of the correlation coefficient, also known as the coefficient of determination, has an additional interesting interpretation. Let r be the correlation coefficient for function A versus function B. In this case, r^2 provides the fraction of the sample variation observed in A that can be explained by the existing variation in B.[126] Traditionally, r^2 is reported as a percentage.

The correlation coefficients appear below for each pair of nuclear husbandry functions. While there are 49 unique pairs of husbandry functions, only 21 boast non-trivial values of r.[127] The non-trivial correlation coefficients are provided in Table 5, and an interpretation of these values is given in the following sections, after a brief discussion of the strength and validity of the model applied.

The Strength and Validity of the Model Applied

The strength of any model is determined by its ability to produce meaningful predictions. This model produces several. However, to avoid misunderstandings, some of the potential problems of the model are discussed briefly below.

Table 5: Linear correlation coefficients (r) comparing the seven nuclear husbandry functions

(based on the values assigned to the relative contribution scores provided in Tables 2-4)

	Domestic physical protection	**Domestic containment and control**	**Domestic accounting**	**Domestic auditing**	**International auditing**	**Traditional Treaty monitoring**	**Transparency**
Domestic physical protection	1	0.66	0.30	0.51	-0.29	-0.37	-0.33
Domestic containment and control		1	0.84	0.50	-0.06	-0.11	-0.36
Domestic accounting			1	0.47	0.07	0.04	-0.23
Domestic auditing				1	-0.05	-0.27	-0.17
International auditing					1	0.73	-0.09
Traditional treaty monitoring						1	0.17
Transparency							1

First, there are an unequal number of attributes in the three categories of means, adversaries, and obstacles. This is not a problem, though, as the authors have combined all 44 attributes together for the overall correlation analysis. On a more profound level, one might wonder about the appropriateness of assigning equal weights (importance) to all 44 attribute contribution scores for each nuclear husbandry function. It can be effectively argued, however, that the attributes chosen are all approximately equal in importance and roughly orthogonal, or non-redundant. Regardless, it is important to bear in mind that the primary goal in this correlation exercise is to show that the seven nuclear husbandry functions are quite distinct. It is not the goal of this study to prove that the chosen attributes and their contribution scores completely *define* the seven husbandry functions (though it is hoped that they at least come close).[128] Indeed, it is probably not possible to determine the appropriate weights for the attributes in general (or even identify all relevant attributes), since they depend critically on details of the specific nuclear facility and application of interest.

Second, the correlation coefficients in Table 5 obviously depend upon the contribution scores (-2, -1, 0, +1, +2) chosen for each attribute. As mentioned previously, the contribution scores in Tables 2 to 4 are the authors' best subjective estimations and, as such, certainly open for debate. If readers are not happy with the choices for the contribution scores, they are free to choose different values and recalculate the correlation coefficients. Still, the authors believe that, assuming the contribution scores are chosen with some degree of common sense and insight, the correlation coefficients—and the resulting conclusions—will be more or less qualitatively unchanged. Indeed, multiplying all of the contribution scores for a given function by a constant has no effect. Similarly, using weights of, for example, -1, -0.5, 0, 0.5, and 1 does not affect the r-values at all, because the correlation coefficient is invariant to offsets and scaling of one of the variables.

For a more specific example of the relative insensitivity of our results to the exact choices for the contribution scores, consider what occurs when one of the 44 contribution scores is changed by +2 or –2 (a major rescoring) for one of the seven nuclear husbandry functions (that is, changing one value in one column of Table 2, 3, or 4 by ±2). With this change, only 6 of the 21 non-trivial correlation coefficients in Table 5 are affected at all. These six values of r change by an absolute average of only 0.04 (up or down) ± 0.02, with the largest possible change in r being ±0.17.

Similarly, changing any three of the 44 contribution scores for one husbandry function by ±1 (including all three by +1 or all three by -1) again results in changes in only 6 of the 21 correlation coefficients. These six r-values change by an absolute average of only 0.03 ± 0.02, with the worst-case change in r being ±0.20. So even with some alterations in the contribution scores, the overall effect on the correlation coefficients, and how they are interpreted here, is largely unaffected.

Finally, the strength of the model can be investigated by focusing on variations resulting largely from the two extreme values, "highly relevant" and "highly irrelevant"—the values of highest concern for practical nuclear arms control measures. To test this, the authors expanded the "neutral" category to include the contribution scores of "partly relevant" and "irrelevant" (all are given the score 0). In addition, the correlation coefficients are recalculated (now with only -2, 0,and 2 as possible inputs). The resulting correlation coefficients are quite close to the original results, as seen in Table 6.

The resulting correlation coefficients now change by an absolute average of only 0.09, the most radical change in r being ±0.29. Correlations that were strongly positive remained so more or less; correlations that were near zero stayed near zero; and correlations that were significantly negative persisted. This indicates a certain level of model robustness.

IMPLICATIONS FOR DOMESTIC MPC&A

Examining now the results for r as represented in Table 5, one sees that, as expected, there is a fairly strong correlation (r = 0.66) between domestic physical protection and containment/control, and an even stronger correlation between containment/control and accounting (r = 0.84). Intuitively, however, physical protection has relatively little to do with accounting, and there is indeed a moderately weak correlation (r = 0.30). P is thus "connected" to A by a coefficient of determination of only r^2 = 9%. Clearly, the functions must be considered distinct.

Table 5 demonstrates that domestic P, C, and A activities are somewhat related to domestic nuclear auditing. The r-values are all near 0.5. This is to be expected, as the context is analogous, and many of the same means and adversaries are involved. Thus, expertise developed

Table 6: Extreme linear correlation coefficients (r) comparing the seven nuclear husbandry functions, with only three main categories of contribution scores *(original correlation coefficients in parentheses for comparisons)*

	Domestic physical protection	Domestic containment and control	Domestic accounting	Domestic auditing	International auditing	Traditional Treaty monitoring	Transparency
Domestic physical protection	1	0.48 (0.66)	0.00 (0.30)	0.34 (0.51)	-0.20 (-0.29)	-0.32 (-0.37)	-0.37 (-0.33)
Domestic containment and control		1	0.63 (0.84)	0.26 (0.50)	0.09 (-0.06)	0.12 (-0.11)	-0.34 (-0.36)
Domestic accounting			1	0.38 (0.47)	0.07 (0.07)	0.10 (0.04)	-0.23 (-0.23)
Domestic auditing				1	-0.19 (-0.05)	-0.14 (-0.27)	-0.10 (-0.17)
International auditing					1	0.80 (0.73)	-0.13 (-0.09)
Traditional treaty monitoring						1	-0.03 (0.17)
Transparency							1

for domestic MPC&A will have some, though not total, applicability to domestic nuclear auditing, and vice versa.

Note however that even when the differences between domestic P, C, and A are fully appreciated, there might be substantial problems in transferring MPC&A hardware, methods, and personnel from country to country, due to the new context in which to operate.[129] Despite their expertise, for instance, U.S. technical MPC&A consultants face profound challenges when assisting the upgrade of Russian domestic MPC&A systems.[130] Internal U.S. reviews indicate that, at approximately one-fourth of the sites involved, the security systems already installed in Russia do not reduce the risk of theft of nuclear material.[131]

IMPLICATIONS FOR INTERNATIONAL HUSBANDRY

Figure 1, generated from Table 5, points out that traditional international treaty monitoring is not very similar to any of the domestic functions (P, C, A, or domestic auditing). Hence, one should not assume that U.S. domestic MPC&A hardware, procedures, or personnel are automatically suitable for IAEA-like inspections. Yet this is exactly what is often assumed.[132] These results should warn us against the "knee-jerk" tendency to insist that (unmodified) seals, radiation monitors, intrusion detectors, portal monitors, personnel, and security procedures used by the United States for its own domestic nuclear MPC&A purposes make the most sense for IAEA safeguards and other traditional treaty monitoring.

The IAEA is in the business of international compliance corroboration, not MPC&A or U.S.-type domestic nuclear auditing. Given the significant differences, one should be suspicious of the idea that domestic auditors (such as the NRC) or domestic MPC&A experts are automatically the most appropriate personnel to assist with international compliance monitoring.

In contrast to the above discussion, Table 5 does tell us that international auditing *is* strongly correlated to traditional treaty monitoring (r = 0.73), another international husbandry function. This correlation makes sense, because the former can be viewed as basically a more comprehensive and aggressive form of the latter. Furthermore, the potential adversary is the same (the inspected state). Note, however, that international nuclear auditing is not simply a trivial extension of traditional treaty monitoring. They are connected by an r^2 value of only 53%.

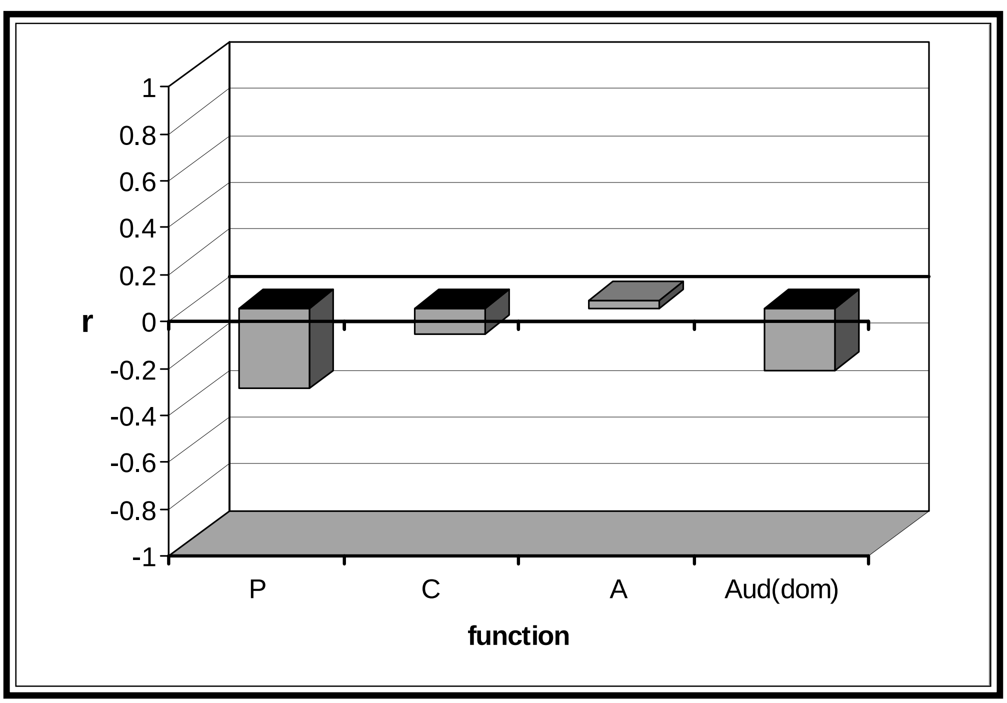
While international nuclear audits are only in their infancy, the model presented herein predicts several key features. Note, for instance, that international auditing is strongly unrelated to its domestic counterpart (r = -0.05, r^2 = 0.2%) and quite unrelated to any of the domestic MPC&A functions ($r^2 < 9\%$). Obviously, the strengthened safeguards system (future nuclear audits) should therefore be based more on the traditional safeguards system (i.e., traditional treaty monitoring), than on domestic auditing or domestic MPC&A. The shared attributes of traditional treaty monitoring and (future) international nuclear auditing should be examined in detail, so that the international community can utilize what is already known about traditional treaty monitoring for developing effective nuclear auditing. Environmental sampling techniques used for the CTBT and non-intrusive monitoring for weapons-usable material in the "Trilateral initiative," for example, may be applicable to future international nuclear auditing.

WARNINGS ABOUT MIXING DOMESTIC AND INTERNATIONAL HUSBANDRY

It is important not to confuse domestic and international husbandry functions because, as seen above, they are very different. It is worth considering areas of potential confusion in distinguishing between the domestic and international nuclear husbandry functions. It has been argued, for example, that existing security fences at Russian nuclear facilities can be leveraged to assist with traditional international treaty monitoring[133]—even though the owners of that fence (the Russians) are the ones being monitored! Such errors in thinking occur more often than is widely appreciated.

For instance, the United States and Russia have both declared sizable stockpiles of weapons-usable nuclear material in excess of defense needs. An agreement signed in June 2000 on the management and disposition of 34 metric tons of excess plutonium provides for "International Atomic Energy verification once appropriate agreements with the IAEA are concluded."[134] The United States has

Figure 1: Weak Correlation Coefficients between Traditional International Treaty Monitoring and Domestic Nuclear Husbandry Functions *(from Table 5)*



proposed using advanced U.S. detection systems that will verify, without revealing classified information, that the plutonium arriving at the Mayak Fissile Material Storage Facility in Chelyabinsk Oblast, Russia, actually came from dismantled nuclear weapons. Experts from U.S. national laboratories are helping to establish the U.S.-Russian-IAEA monitoring system for the plutonium, which is scheduled to be stored at the facility. Despite the formalized call for IAEA corroboration, however, it is not clear whether this activity is to be regarded as traditional treaty monitoring, or simply assistance with domestic (Russian) accounting, international nuclear auditing, or some unfortunate/confusing combination of activities.

It seems that much of the same type of confusion has taken place under the U.S. Russian highly-enriched uranium (HEU) deal.[135] Here, a comprehensive set of MPC&A measures is in place, but its objectives remain unclear. The United States is trying to “verify” with radiological measurements that the HEU to be down-blended to low-enriched uranium (LEU) for commercial reactors truly originates from Russian warheads.[136] The question is: is this domestic MPC&A to assist Russia, traditional treaty monitoring, treaty auditing, dismantlement confirmation, quality control, or simply *caveat emptor* for the United States? Again, the means to be applied, the adversaries to neutralize, and the obstacles to overcome are likely to differ significantly depending on the ultimate goals and the strategic rationales.

Finally, if a fissile material cut-off treaty (FMCT) is ever implemented, the IAEA will probably play a significant role in compliance corroboration. The NNWS are already effectively adhering to a cut-off, through their traditional safeguards agreements. At a minimum, a FMCT will require effective control of future production of fissile material in a wide range of facilities in the NWS[137]—a challenging task to implement after years of nuclear autonomy in those countries. It will no doubt be tempting to use familiar domestic husbandry technologies and approaches for ensuring FMCT compliance corroboration, even though the attributes are extremely different. There is a long history of shortsightedly applying domestic MPC&A approaches to international applications without any careful analysis. Moreover, there are strong advocates at DOE and the U.S. national laboratories for automatically fielding existing security technologies in other countries, and there will be economic constraints that make existing methods look superficially attractive. Such temptations must be avoided for a future FMCT.

IMPLICATIONS FOR TRANSPARENCY

Table 5 highlights the fact that transparency is a very unique entity. There is a lack of correlation between transparency and any of the other six nuclear husbandry functions. This lack of correlation is consistent with the view of transparency as a unilateral, qualitative, non-verifiable, domestic activity. Its features (in terms of what, when, and where to reveal) will be up to the state itself, depending on the intentions behind the act of transparency. For example, the motives behind the historical U.S. report on the plutonium production, acquisition, and utilization were to assist discussions of plutonium storage, safety, and security with stakeholders, as well as to encourage other states to declassify and release similar data.[138] The DOE willingness to reveal this data, as well as information about its past nuclear tests, encouraged similar openness by Russia and other states.[139] Such transparency helped create greater confidence in the arms control process, without introducing technical means or “verification” protocols or procedures.

Transparency is likely to be fairly easily implemented, once the political decision has been made to proceed. It requires minimal cost and technology (as compared to formalized traditional treaty monitoring). The potential positive trade-offs are, among other factors, international recognition, an informed citizenry and neighbors, and potentially a more stable nuclear international security environment, because the nuclear intentions of a state (which would hopefully be benign) would be clarified. In this sense, transparency may be particularly powerful and important in the context of unilateral and non-verified arms reductions.

The outcome of the 2000 NPT Review Conference may be indicative of a trend towards increased transparency. For the first time, the final document from a review conference called upon the NWS to “increase the transparency with regards to their nuclear weapons capabilities.”[140] Notably, the document fails to specify what form this transparency should take, and it did not generate an immediate flurry of new transparency activities. Still, it is probably a sign of things to come, and all efforts should be taken to fulfill the true potential of this novel and auxiliary form of international nuclear arms control through active state participation.

CONCLUSION

Increased global nuclear security will require arms control regimes that move beyond treaties that deal merely with delivery-vehicles, as well as steps towards strengthened physical protection for nuclear material, a fissile material cut-off, and accelerated disposal of excess fissile material. These measures, in turn, will demand more effective domestic MPC&A, improved traditional treaty monitoring and nuclear auditing, and increased nuclear transparency. The success of future arms control will therefore depend on having a rigorous, clear-headed understanding of the specific strategic goals, character, and differing challenges associated with each different type of nuclear security activity.

This article has raised concerns that the existing arms control concepts are fuzzy, that the terminology is confusing, and that different nuclear functions are often mixed up. Such confusion may negatively impact how policymakers think about and try to solve different practical nuclear security problems. Particularly worrisome are the typical confusion caused by the multiple meanings and excessive broadness of the term "safeguards," the absolutism often associated with the concept of "verification," and fallacious ideas about transparency.

This article has identified seven fundamental nuclear husbandry functions for the responsible management of nuclear material and nuclear weapons. These are domestic physical protection, domestic containment/control, domestic accounting, domestic auditing, international auditing, traditional treaty monitoring, and transparency. By recognizing key attributes associated with each function, and assigning a relative—admittedly subjective—contribution (or relevance) score to each, the authors have attempted to demonstrate that the seven nuclear husbandry activities are indeed quite different.

In particular, this analysis should leave no doubt that domestic and international nuclear husbandry functions are distinctly dissimilar. The means to be applied, the adversaries to be met, and the obstacles to be overcome differ dramatically, because the contexts are so different. The current tendency towards a "one-size-fits-all" philosophy of nuclear security is likely to be detrimental and not conducive to successfully addressing persistent nuclear security and arms control challenges. Indeed, instead of saving money, we stand at risk of wasting limited arms control resources.

This analysis leads to three specific conclusions about how to best promote a healthy and effective system of nuclear husbandry:

- First, domestic MPC&A personnel and hardware are not automatically appropriate for traditional international treaty monitoring or for international auditing. International inspectors, such as those employed by the IAEA, need tools and training specific for their traditional treaty monitoring mission, not just duplicated from (U.S.) domestic MPC&A approaches.
- Second, domestic auditing experts are not automatically suitable for traditional international treaty monitoring or auditing. In developing a strengthened safeguards system (i.e., future international nuclear auditing), we can learn the most by analyzing existing nuclear treaty monitoring efforts. This conclusion may be somewhat counterintuitive, because one might have expected that hard-nosed domestic nuclear auditing personnel and approaches would be the most relevant for aggressive international nuclear auditing.
- Third, transparency is a unique entity that does not behave in ways similar to other nuclear husbandry functions. It must be better understood if its full potential for assisting nuclear security is to be realized.

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[2] Some analysts view strategic myths as false or fuzzy concepts, embraced to achieve other policy goals. See Jack Snyder, *Myths of Empire* (Ithaca: Cornell University Press, 1991), quoted in Nancy W. Gallagher, *The Politics of Verification* (Baltimore: John Hopkins University Press, 1999), p. 39.

[3] Throughout the paper, the term "arms control" is used in a broad sense, covering all aspects of nuclear disarmament and nonproliferation efforts, including the management of fissile material and proliferation-sensitive information.

[4] One example of reciprocal interdependence is clearly seen in conjunction with a future FMCT. Politically sensitive questions of providing assurances at the cost of intrusiveness have created and will create lengthy discussions that are *inter alia* governed by technical opportunities and limitations.

[5] Increasing and forceful U.S. interest in unilateral arms control measures have boosted international concerns about the future of institutionalized arms control. On the future of international arms control, see for example, Ian Anthony and Adam Daniel Rotfeld, eds., *A Future Arms Control Agenda* (New York: Oxford University Press and Stockholm International Peace Research Institute, 2001); Harold Feiveson, ed., *The Nuclear Turning Point: A Blueprint for Deep Cuts and De-alerting of Nuclear Weapons* (Washington DC: The Brookings Institution Press, 1990); and Ambassador Thomas Graham Jr., "U.S. National Security Policies: the Road Ahead," remarks given at the Center for International Security and Cooperation, Stanford University, Palo Alto, CA, February 7, 2001.

[6] Patricia Lewis, "The New Verification Game and Technologies at our Disposal," in Dietrich Schroeder and Alessandro Pascolini, eds., *The Weapons*

Legacy of the Cold War (Aldershot, U.K.: Ashgate, 1997), p. 147.

[7] Nonproliferation and disarmament discussions are no longer limited to political and military leaders, lawyers, scholars, and scientists. Regulatory agencies, government auditors, security managers, journalists, bureaucrats, interest groups, and other non-governmental organizations (NGOs), as well as individual private citizens, now play an active role. For a useful discussion on the impact of, among other factors, non-governmental actors in international politics, see James N. Rosenau, "Diplomacy, Proof and the Authority in the Information Age," in Bernard I. Finel and Kristin M. Lord, eds., *Power and Conflict in the Age of Transparency* (New York: Palgrave, 2000), pp. 319-320; and Todd E. Perry, "From Triage to Long-Term Care: A U.S. NGO View on the Future of the MPC&A Program," Proceedings of the 40th Annual Meeting of the Institute of Nuclear Materials Management, Phoenix, AZ, July 26-29, 1999, pp. 4-6.

[8] Bernard I. Finel and Kristin M. Lord, "Transparency and World Politics," in Finel and Lord, *Power and Conflict in the Age of Transparency*, p. 2.

[9] Numerous scholars and scientific panels have been studying the post-Cold War nuclear proliferation threat, and voluminous amounts of publications have resulted. For some of the more important ones, see National Academy of Sciences, *Management and Disposition of Excess Weapons Plutonium* (Washington, DC: National Academy Press, 1994); Lisbeth Gronlund and David Wright, *Beyond Safeguards: A Program for More Comprehensive Control of Weapon-Usable Material*, report by the Union of Concerned Scientists (1994); Graham T. Allison et al., *Avoiding Nuclear Anarchy - Containing the Threat of Loose Russian Nuclear Weapons and Fissile Materials,* CSIA Studies in International Security (Cambridge, Massachusetts: MIT Press, 1996); Frank von Hippel, "Fissile Material Security in the Post-Cold War World," *Physics Today* (June 1995), pp. 26-31; William Potter, "Before the deluge? Assessing the Threat of Nuclear Leakage from the Post-Soviet States," *Frontline* (1995), <http://www.pbs.org/wgbh/pages/frontline/shows/nukes/readings/potterarticle.html>; Oleg Bukharin and William Potter, "Potatoes Were Guarded Better," *Bulletin of the Atomic Scientists* 51 (May/June 1995); John M. Shields and William C. Potter, eds., *Dismantling the Cold War: U.S. and NIS Perspectives on the Nunn-Lugar Cooperative Threat Reduction Program*, CSIA Studies in International Security 12 (Cambridge, Massachusetts: MIT Press, 1997); Matthew Bunn and John P. Holdren, "Managing Military Uranium and Plutonium in the United States and the Former Soviet Union," *Annual Review of Energy and the Environment* 22 (1997); David Albright and Kevin O'Neill, eds., *The Challenges of Fissile Material Control*, Institute for Science and International Security, ISIS Report, 1999; National Research Council, *Protecting Nuclear Weapons Materials in Russia* (Washington, DC: National Academy Press, 1999); Center for Strategic and International Studies, *Managing the Global Nuclear Materials Threat: Policy Recommendations*, 2000; Matthew Bunn, *The Next Wave: Urgently Needed Steps to Control Warheads and Fissile Materials,* Carnegie Endowment for International Peace, 2000; Emily E. Daughertry and Fred Wehling, "Cooperative Efforts to Secure Fissile Materials in the NIS: Shortcomings, Successes, and Recommendations," *Nonproliferation Review* 7 (Spring 2000), pp.97-112; Oleg Bukharin, Matthew Bunn, and Kenneth N. Luongo, *Renewing the Partnership: Recommendations for Accelerated Action to Secure Nuclear Material in the Former Soviet Union*, Russian American Nuclear Security Advisory Council, August 2000; Howard Baker and Lloyd Cutler, *Report Card on the Department of Energy's Nonproliferation Programs with Russia*, Secretary of Energy Advisory Board, U.S. Department of Energy (DOE), January 10, 2001.

[10] The nuclear ambitions of states like North Korea and Iraq are widely known. Overall, less attention has been given to the nuclear weapon program of the Japanese cult Aum Shinrikyo and—even given the current military campaign against al-Qa'ida—Usama bin Laden's possible attempts to penetrate a black market for fissile material. For more on this, see, for example, Morten Bremer Maerli, "Relearning the ABCs: Terrorists and Weapons of Mass Destruction," *Nonproliferation Review* 7 (Summer 2000), pp. 108-120; and Gavin Cameron, "Multi-track Micro-proliferation: Lessons from Aum Shinrikyo & Al Qaida," *Studies in Conflict and Terrorism* 22 (1999).

[11] Dick Lugar, "Eye on a Worldwide Weapons Cache," *Washington Post*, December 6, 2001.

[12] Daughtry and Wehling, "Cooperative Efforts to Secure Fissile Material," p. 97.

[13] When a state has signed a treaty, it is, according to Article 18 of the Vienna Convention on the Law of Treaties, obliged to refrain from acts that would defeat the object and purpose of the treaty prior to its entry into force. Examples of pending bi- and multilateral treaties are the Comprehensive Test Ban Treaty and the continuation of the Strategic Arms Reduction Talk (START) process. The FMCT is an example of a case in which no formal treaty negotiations have yet taken place.

[14] Broadly speaking, domestic MPC&A systems are intended to protect material against theft, espionage, sabotage, or diversion, and to detect such events if they occur. See National Research Council, *Protecting Nuclear Weapons Materials in Russia*, p. 12: "Physical protection systems should allow for the detection of any unauthorized penetration of barriers and portals, thereby triggering an immediate response. The system should delay intruders long enough to allow for an effective response. Material control and containment systems should prevent unauthorized movement of materials and allow for the prompt detection of the theft and diversion of material. Material accounting systems should ensure all material is accounted for, enable the measurement of losses, and provide information for follow-up investigations for irregularities."

[15] DOE, "Portal Monitors Provide Rapid Security Upgrades," in the brochure *Special Nuclear Material Detectors & Portal Monitor Technology Upgrades in Russia, the NIS, and the Baltics*, Office of Arms Control and Nonproliferation (undated), < http://www.nn.doe.gov/mpca/pubs/frametn1.htm>. Typically in the United States, "safeguards" is considered to be the "C" and "A" parts of MPC&A, and "security" is the "P."

[16] Roger Johnston, "Tamper Detection for Safeguards and Treaty Monitoring: Fantasies, Realities, and Potentials," *Nonproliferation Review* 8 (Spring 2001); Roger G. Johnston, "The Real Deal on Seals," *Security Management* 41 (September 1997), pp. 93-100, <http://lib-www.lanl.gov/la-pubs/00418795.pdf>; Roger G. Johnston, "Tamper-Indicating Seals for Nuclear Disarmament and Hazardous Waste Management," *Science & Global Security* (forthcoming).

[17] Roger G. Johnston, "The Real Deal on Seals," pp. 93-100 and Roger G. Johnston, "Effective Vulnerability Assessment of Tamper-Indicating Seals," *Journal of Testing and Evaluation* 25 (July 1997), pp 451-454; and Johnston, "Tamper Detection for Safeguards and Treaty Monitoring." Apparent confusion about vulnerability assessments versus other types of testing can be found in, for instance, Lawrence Desonier "SNL Material Monitoring System, The T-1 RF Seal, and the Kams," paper presented at the Symposium on International Safeguards, Verification, and Nuclear Material Security, Vienna, Austria, October 29-November 2, 2001.

[18] See DOE, "Portal Monitors Provide Rapid Security Upgrades."

[19] See Erwin Hackel and Gotthard Stein, "Nuclear Non-Proliferation and Safeguards: From INFCIRC/153 to INFCIRC/540 and Beyond," *Tightening the Reins* (New York: Springer, 2000), p. 19. Wolfgang Fischer presents a country's *domestic* use of "modern tamper-proof monitoring equipment" as an indication of its willingness to allow *international* safeguards. Other apparent examples of confusing or mixing domestic and international safeguards can be found in Don Glidewell, "Leveraging Physical Protection Technology for International Safeguards Applications;" S.P. Chater et al., "The Commercial Application of Near Real Time Materials Accountancy;" and M. Davainis, "The Lithuanian State System of Accounting for and Control of Nuclear Materials," papers presented at the Symposium on International Safeguards, October 29-November 2, 2001..

[20] Nuclear Regulatory Commission (NRC), *Summary of International Safeguards Activities Performed by the Office of Nuclear Material Safety and Safeguards*, Report SECY-00-0163, July 28, 2000, <http://www.nrc.gov/NRC/COMMISSION/SECYS/2000-0163scy.html#_1_6>. The report (pp. 1-2) summarizes the U.S. Nuclear Regulatory Commission's (NRC) "international safeguards activities" to support "the safe and secure use of nuclear materials and…nuclear nonproliferation," in order "to meet NRC's obligations under *U.S. statutes*, treaties, and international agreements" (italics added). The report claims that these "international safeguards activities also support enhancement of protection, control, and accounting of nuclear materials through voluntary information exchange and technical assistance to help safeguard nuclear material." Furthermore, "these activities strengthen the nonproliferation regime, by enhancing its capability to *deter* actions by a country that might seek to violate its Nuclear Nonproliferation Treaty and Safeguards Agreement commitments (note the use of "deter"—italics added—rather than "de-

tect"). Then again on p. 4: "Theft and diversion of nuclear material are of particular concern because of the possibility that terrorist groups or rogue nations could use the material to construct a nuclear explosive device."

[21] See Lawrence Desonier "SNL Material Monitoring System," and John Matter et al., "The T-1 Two-Way Radio-Frequency Seal (TRFS) and Acceptance Testing for IAEA Routine Use," papers presented at the Symposium on International Safeguards, October 29-November 2, 2001.

[22] See Johnston, "Tamper Detection for Safeguards and Treaty Monitoring," endnote 75.

[23] One of the authors (Johnston) is aware of over a dozen critical security devices or systems currently in use for domestic safeguards in the United States for which no comprehensive, holistic analysis or vulnerability assessments have been performed.

[24] We think of "nuclear husbandry" as encompassing a number of functions in the areas of nuclear security, safeguards, nonproliferation, disarmament, and arms control. *Webster's II New College Dictionary* defines "husbandry" as the "careful management of resources." It also has an agricultural connotation that is not far off the mark in this context: "the cultivation of crops and the breeding and raising of livestock; [involving] the application of scientific principles." The *Merriam Webster Collegiate Dictionary* defines "husbandry" as "the control or judicious use of resources." A "husband" is defined as a manager or steward, especially one that is prudent and thrifty.

[25] While some readers might find these analogies over-simplified, others might find them useful (as we do) for reminders of the nature and inherent dissimilarities of the different functions.

[26] Other arms control terms are equally confusing, misleading, or oxymoronic. For example, "protocol" can mean a document, negotiated agreement, technical procedure, formalized rules, or even diplomatic etiquette; the "challenge" in "challenge inspections" is an adjective, not a verb; "nuclear diversion" is theft of nuclear materials, not what bored security guards and underemployed weapons designers do to pass the time; "nuclear materials assurance" is basically guaranteeing security at U.S. nuclear weapons laboratories, not self-confidence amongst the employees; "calculated ambiguity" is a military strategy, not what policy makers think nuclear game theory is; "hold-up" is not the art of robbing nuclear materials, but rather the amount of material stuck in pipes; the International Atomic Energy Agency (IAEA) claims to be "safeguarding the atom," leaving it unclear which one, or why atoms should need guarding.

[27] Talk presented at the Symposium on Safeguards Research and Development, Argonne National Laboratory, June 26, 1967, <www.tbtaylor.com/6706m.html>.

[28] Erwin Hackel, "Implementing Safeguards in Weak and Failed States," in Hackel and Stein, *Tightening the Reins* (New York: Springer, 2000), p. 142

[29] Other types of safeguards exist as well. In the 1960s, the term "international safeguards" was often used as a complement to IAEA safeguards (i.e., "IAEA and other international safeguards," generally meaning Euratom Safeguards). The focus of this text will, however, be on IAEA safeguards. The constitutional objectives of the safeguards systems of the IAEA (INFCIRC/153) and those of Euratom are different. IAEA safeguards fulfill the implementation of the Treaty on the Non-Proliferation of Nuclear Weapons (NPT), while Euratom safeguards address the implementation of the Euratom Treaty. The difference is that the IAEA attempts to discover any diversion of nuclear material from peaceful purposes, while Euratom safeguards exist to ensure that material is not diverted from its intended use as declared by the users, a concept that does not exclude weapon use. This was a requirement by France at the time of negotiating the Euratom Treaty. However, a Euratom member state, also a party to the NPT, is explicitly prohibited from making nuclear weapons. If a cut-off treaty is agreed to in the future, and the member states of the European Union do adhere to such a treaty, then supplies sent for weapons production of individual member states party to such a treaty will become illegal according to the Euratom treaty (Article 52:2 (b)). In this case and depending on the exact provisions of such a treaty, all interstate transfers within the European Union would be reserved for peaceful purposes only.

[30] "…[A]ssessing [IAEA] safeguards effectiveness is not easy. One reason is that the purpose of the system has been stated only very generally." This statement was made by David Anderson, "Nuclear Safeguards," Foreign Affairs, Defense and Trade Group, Australia, Parliamentary Research Service, 1997, <http://www.aph.gov.au/senate/committee/uranium_ctte/report97/ch12_0.htm>.

[31] Pierre Goldschmidt, "IAEA Safeguards: Evolution or Revolution?" Opening Plenary Address at the 41st Annual Meeting of the Institute of Nuclear Materials Management, New Orleans, LA, July 16-20, 2000, *Journal of Nuclear Materials Management* 29 (Fall 2000), pp.10-16.

[32] Johnston, "Tamper Detection for Safeguards and Treaty Monitoring."

[33] DOE, DOE Order 5630.11B, Washington, DC, February 8, 1994.

[34] Examples in the United States include the Defense Nuclear Facilities Safety Board and the Office of Independent Oversight and Performance Assurance (OA), formerly called the Office of Safeguards and Security Evaluations.

[35] For a brief description of the Department of Defense (DOD) Extended Cooperative Threat Reduction (CTR) program, see <http://usa.grmbl.com/s19990624e.html>; the DOD CTR website, <http://www.defenselink.mil/pubs/ctr/ >; or Shields and Potter, *Dismantling the Cold War*.

[36] See U.S. Department of Energy, Office of Arms Control and Negotiation, "Partnership for Nuclear Security" (Washington DC: US Government Printing Office, January 1997); or Jack Caravelli, "Upgrading Nuclear Material Protection Control and Accounting in Russia," paper presented at the Symposium on International Safeguards, October 29-November 2, 2001.

[37] Robert Rinne presents the idea of international monitored storage facilities for civil nuclear fuel in his report, *An Alternative Framework for the Control of Nuclear Materials*, Center for International Security and Cooperation, Stanford University, May 1999. International depositories are suggested, due to the huge uncertainties in the quantities of material and the problems of providing adequate control. This idea is related to international nuclear energy parks, where all sensitive nuclear facilities are clustered in centralized, heavily guarded locations under international control. The electricity would then be distributed to users around the world, or alternatively, be used to produce hydrogen that could be exported. Such international centers, with a specific focus on international enrichment, reprocessing, and spent fuel facilities, have been discussed in DOE, *Nuclear Proliferation and Civilian Nuclear Power*, Report of the Nonproliferation Alternative Systems Assessment Program, June 1980, Volume III; quoted by Hal Feiveson, "Diversion-Resistance Criteria for Future Nuclear Power," remarks given at Stanford University, June 23, 2000.

[38] IAEA safeguards are intended to provide assurance that non-nuclear weapons states (NNWS) are complying with their stated commitments not to acquire NW or other nuclear devices. According to article III of the NPT, each non-nuclear weapon member state undertakes "to accept Safeguards, as set forth in an agreement to be negotiated and concluded with the International Atomic Energy Agency in […] accordance with the Agency's 'safeguards system'". This is outlined in *The Structure and Content of Agreements Between the Agency and States Required in Connection with the Treaty on the Non-Proliferation of Nuclear Weapons*, IAEA INFCIRC/153, June 1972, <http://www.iaea.org/worldatom/Documents/Infcircs/Others/inf153.shtml>.

[39] "It should be noted that the IAEA has no responsibility either for the provision of a State's physical protection system or for the supervision, control or implementation of such a system," in, *The Physical Protection of Nuclear Material and Nuclear Facilities*, IAEA INFCIRC/255/Rev.4 (Corrected), Section 3.2.b, 1998, <http://www.iaea.org/worldatom/program/protection/inf225rev4/rev4_content.html>.

[40] A state has millions of people versus the one or relatively few rogue individuals who are the primary targets of domestic MPC&A. See Johnston, "Tamper Detection for Safeguards and Treaty Monitoring."

[41] Allan S. Krass, *Verification: How Much is Enough?* Stockholm International Peace Research Institute (Massachusetts/Toronto: Lexington Books, 1985), p. 89.

[42] See, for example, National Academy of Sciences, *Management and Disposition of Excess Weapons Plutonium*, p. 55; Eric Gerdes, Roger Johnston, and James Doyle, "A Proposed Approach for Monitoring Nuclear Warhead Dismantlement," *Science and Global Security* (forthcoming); Johnston, "Tamper Detection for Safeguards and Treaty Monitoring."

[43] *Model Protocol Additional to the Agreement(s) between State(s) and the International Atomic Energy Agency for the Application of Safeguards*, IAEA INFCIRC/54 (Corrected), September 1997, <http://www.iaea.org/worldatom/Documents/Infcircs/1998/infcirc540corrected.pdf >.

[44] See *IAEA Strengthened Safeguards System: Status of Additional Protocols*, <http://www.iaea.org/worldatom/Programmes/Safeguards/sg_protocol.shtml>.
[45] *Evolution of IAEA Safeguards*, International Nuclear Verification Series, No. 2, IAEA, Vienna, Austria, 1998, p. 32.
[46] *Evolution of IAEA Safeguards*, p. 33.
[47] David Anderson, "Nuclear Safeguards."
[48] National Academy of Sciences, *Nuclear Arms Control: Background and Issues* (Washington, DC: National Academy Press, 1985), p. 265; Chrzanowski, *Preparation for the Nuclear Non-Proliferation Treaty Extension Conference in 1995*, Lawrence Livermore National Laboratory Report UCRL-JC-113936, pp. 9-10; David Kay, "The IAEA: How Can it be Strengthened?" in Mitchell Reiss and Robert S. Litwak, eds., *Nuclear Proliferation after the Cold War* (Washington DC: Woodrow Wilson Press, 1994), pp. 319-332; Paul Leventhal, "Safeguards Shortcomings—A Critique," <http://www.nci.org/plsgrds.htm>; David Anderson, "Nuclear Safeguards;" Gerald M. Steinberg, "U.S. Non-Proliferation Policy: Global Regimes and Regional Realities," *Contemporary Security Policy* 15 (December 1994), pp. 132-135.
[49] National Academy of Sciences, *Management and Disposition of Excess Weapons Plutonium*.
[50] David Anderson, "Nuclear Safeguards."
[51] Public misconceptions are a serious matter. As some analysts have pointed out, misinterpretation of the word "safeguards" can lead to exaggerated expectations about the ability of the current IAEA safeguards system to prevent, rather than merely detect, clandestine nuclear programs. Such misunderstandings could undermine public support for international arms control activities.
[52] For example, the portal monitoring activities performed as part of the containment function can also be part of a facility's physical protection system. The record-keeping function (accountability) will, moreover, serve as a regular check on the integrity and effectiveness of the other functions and components of the system.
[53] Glenn C. Buchan, "The Verification Spectrum," *Bulletin of the Atomic Scientists* 39 (1983), pp. 16-19; William F. Rowell, *Arms Control Verification: A Guide to Policy Issues for the 1980s* (Cambridge, MA: Ballinger, 1986), p. 79; Jozef Goldblat, *Arms Control: A Guide to Negotiations and Agreements*, Peace Research Institute of Oslo (London: Sage Publications, 1994), p.209; Paul Taylor, "Science Panel Says Test Ban is Verifiable," Reuters, October 30, 2000; Patricia Bliss McFate and Sidney N. Graybeal, "The Revolution in Verification," in Eric H. Arnett, ed., *New Technologies for Security and Arms Control: Threats and Promise* (Washington, DC: American Association for the Advancement of Science, 1989), pp. 140-142; Patricia Lewis, "Verification of Nuclear Weapons," in Regina Cowen Karp, ed., *Security without Nuclear Weapons?: Different Perspectives on Non-Nuclear Security* (New York: Oxford University Press, 1992), p. 128; W.R. Kane, J.R. Lemley, P. E. Vanier, P.B. Zuhoski, and L. Forman, "On Attributes and Templates for Identification of Nuclear Weapons in Arms Control," paper presented at the 41st Annual Meeting of the Institute of Nuclear Materials Management, New Orleans, Louisiana, July 16, 2000.
[54] DOE, *Transparency and Verification Options: An Initial Analysis of Approaches for Monitoring Warhead Dismantlement,* Office of Arms Control and Nonproliferation, 1997. See also James F. Morgan, "Transparency and Verification Options: An Initial Analysis of Approaches for Monitoring Warhead Dismantlement," in Proceedings of the 38th Annual Meeting of the Institute of Nuclear Materials Management, Phoenix, Arizona, July 20-24, 1997, p. 2.
[55] Opening paragraph in Mark F. Imber, "Arms Control Verification: The Special Case of IAEA-NPT Special Inspections," in Iam Bellany and Coit D. Blacker, eds., *The Verification of Arms Control Agreements* (London: Frank Cass, 1983), pp 57-75.
[56] *Webster's II New College Dictionary* provides an example: "Two business associates verified my story."
[57] Ronald B. Mitchell, "Sources of Transparency: Information Systems in International Regimes," in Finel and Lord, *Power and Conflict in the Age of Transparency*, p. 189.
[58] See, for example, Rob Rinne, "Technological Maturity and the Control of the Dangers Associated with Nuclear Materials," Proceedings of the International Conference on Future Nuclear Systems - Global'99, American Nuclear Society, Wyoming, 1999.
[59] Verification is a complex process. It begins with monitoring, or the gathering of information, either by measurement equipment or the use of open and classified written sources. The monitoring step is accompanied or followed by an information processing step, in which monitoring data is assembled in an appropriate form. Once the data are processed, they must be analyzed and the results interpreted. Following analysis, one is presented with the problem of interpretation: does an observed event or collection of results signify a violation or not, and with what probability? See Krass, *Verification: How Much is Enough?* pp.7-8.
[60] U.S. Arms Control and Disarmament Agency, *Verification: the Critical Element of Arms Control*, Publication no. 85 (March 1976), quoted in Gallagher, *The Politics of Verification*, p. 1. For an extensive discussion on this subject, see also Krass, *Verification: How Much is Enough?*
[61] While there seems to be an increasing U.S. interest in uncodified, unilateral arms control measures, the Russian government is still looking for reliable and verifiable agreements. During the November 2001 Crawford Summit between the two presidents, Russian President Putin maintained that he wanted more than just a handshake deal with U.S. President Bush on future nuclear strategic reductions. See "First Move, Bush to Cut U.S. Nuclear Stockpile," ABC News, November 13, 2001, < http://abcnews.go.com/sections/politics/DailyNews/whitehouse.html>.
[62] Gallagher, *The Politics of Verification*, p. 44.
[63] See, e.g., U.S. Senator Richard Lugar's statement announcing his opposition to the CTBT, United States Information Service, October 12, 1999, <http://www.acronym.org.uk/ctbreact.htm>. Specifically, controversy over the CTBT concerned two types of possible errors: (1) failing to detect a test that was actually carried out; and (2) erroneously detecting a test, when in fact none occurred.
[64] Discussions in conjunction with the nuclear test ban focused *inter alia* on making the risk of detection of non-compliance so high that states might choose to formally withdraw from treaties, rather than violate them. This would allow the international community to react and perhaps avoid far-reaching political embarrassment.
[65] As suggested by Seong W. Cheon and Niall M. Fraser, "Arms Control Verification: an Introduction and Literature Survey," *Arms Control* 9 (1998), pp. 38-58; Gordon Thompson, "Verifying a Halt to the Nuclear Arms Race," in Frank Barnaby, ed., *Handbook of Verification Procedures* (London: Macmillan, 1990), pp. 264-309; and Valerie Thomas, "Verification of Limits on Long-Range Nuclear SLCMs," *Science & Global Security* 1 (1989), pp. 27-57.
[66] Center for Strategic and International Studies, *Managing the Global Nuclear Materials Threat: Policy Recommendations*, p. 53.
[67] Ibid, p. 53.
[68] See, for instance, NATO, Press Release M-NAC- 2(2000)121; and *Report on Options for Confidence and Security Building Measures (CSBMs), Verification, Non-Proliferation, Arms Control and Disarmament*, (Brussels, Belgium: NATO, December 2000.
[69] Based on Finel and Lord, "Transparency and World Politics," p. 3.
[70] There are numerous examples. The issue of transparency regimes with verification is the general theme of the book edited by Finel and Lord, *Power and Conflict in the Age of Transparency*. Andrew Bieniawski and Yurin. Busurin even refer to inspectors as "transparency monitors." Andrew Bieniawski and Yurin Busurin, "Transparency Measures Associated with the U.S./Russian Intergovernmental HEU-to-LEU Agreement," Proceedings of the 40th Annual Meeting of the Institute of Nuclear Materials Management, Phoenix, AZ, July 26-29, p. 3. See also Edward F. Mastal, Janie B. Benton, and Joseph W. Glaser, "Implementation of U.S. Transparency Monitoring Under the U.S./Russian HEU Purchase Agreement," Proceedings of the 40th Annual Meeting of the Institute of Nuclear Materials Management, Phoenix, AZ, July 26-29, pp. 1-3, 6, 10; Janie Benton, Joseph Glaser, David Thomas, Alexander Bystrov, Guennadi Skorynine, Valery Yemelyanov, and Vladimir Sinaevsky, "U.S. Transparency Monitoring Under the U.S./Russian Intergovernmental HEU-LEU Agreement," Proceedings of the 40th Annual Meeting of the Institute of Nuclear Materials Management, Phoenix, AZ, July 26-29, pp. 1-5; Steve Fetter, "A Comprehensive Transparency Regime for Warheads and Fissile Materials," *Arms Control Today* (Jan/Feb 1999). One of the authors of this paper sheepishly admits to

suggesting measures to "verify" transparency declarations. See Morten Bremer Maerli, "Deep Seas and Deep-Seated Secrets: Naval Nuclear Fuel Stockpiles and the Need for Transparency," *Disarmament Diplomacy* 49, 2000, <http://www.acronym.org.uk/49fuel.htm>.

[71] Descriptively, such activities have been denoted "information triangulation" by Mitchell, "Sources of Transparency," p.189.

[72] In 1998, the IAEA published Guidelines for the Management of Plutonium (INFCIRC/549). These guidelines increase the transparency of the management of civil plutonium by publishing annual statements of each country's holdings of civil plutonium. Although the annual publication of civil holdings has been successful overall in creating more transparency, the declarations by several countries are incomplete. In addition, more countries possessing civil plutonium must be involved, with the goal to create universal membership and adherence. See David Albright and Lauren Barbour, *Status Report: Civil Plutonium Transparency and the Plutonium Management Guidelines*, Institute for Science and International Security, January 2000, <http://www.isis-online.org/publications/puwatch/infcirc54901.html >.

[73] Masao Senazaki, Robin Keeney, Makiko Tazaki, Charles Nakhleh, John Puckett, and William Stanbro, "Joint DOE-PNC Research on the Use of Transparency in Support of Nuclear Nonproliferation," Proceedings of the 38th Annual Meeting of the Institute of Nuclear Materials Management, pp. 2-3.

[74] The Center for Strategic and International Studies, *Managing the Global Nuclear Materials Threat: Policy Recommendations*, p. 54.

[75] Ann Florini, "The End of Secrecy," in Finel and Lord, *Power and Conflict in the Age of Transparency*, p. 13

[76] Masao Senazaki, et al., "Joint DOE-PNC Research on the Use of Transparency in Support of Nuclear Nonproliferation," pp. 2-3. Thus, transparency is more than a mere description or detailed specification of a nuclear program, specific site, or ongoing activity. In addition, transparency does more than merely provide data mandated by treaty or law.

[77] See Florini, "The End of Secrecy," p. 13; David Albright, Frans Berkhout, and William Walker, *Plutonium and Highly Enriched Uranium 1996: World Inventories, Capabilities, and Policies* (Oxford: Oxford University Press, 1997), p. 6; and David Albright, "Secrets that Matter," *Bulletin of the Atomic Scientists* (November/December 2000).

[78] Gallagher, *The Politics of Verification*, p. 39.

[79] Finel and Lord, "Transparency and World Politics," p. 6.

[80] Bernard I. Finel and Kristin M. Lord, "The Surprising Logic of Transparency," in Finel and Lord, *Power and Conflict in the Age of Transparency*, pp. 168 and 359.

[81] As George Lindsey puts it, "Transparency is important. Confidence building is important. Each reinforces the other. And, when there is complete compliance, each helps verification and is helped by verification." George Lindsey, "Symposium Summary: The Verification Response," in J. Marshall Beier and Steven Mataija, eds., *Proliferation in All Its Aspects Post 1995: The Verification Challenge and Response* (Toronto: Centre for International and Strategic Studies, 1995), p. 138.

[82] As discussed in the text, while it is theoretically possible, international cooperative MPC&A, such as "nuclear islands," is not currently happening. The so-called "cooperative" threat reduction programs the United States undertakes with Russia mostly involve the United States helping Russia improve Russian domestic MPC&A. This has benefits for the United States, but the two states are not really sharing nuclear custodianship.

[83] Transparency may be one of many confidence-building and support measures. Others include: enlisting the aid of public opinion or respected celebrities in order to promote arms control; emphasizing/advertising the advantages of treaty compliance; offering international recognition and awards for dismantlement; performing unilateral disarmament in hopes of encouraging reciprocating actions from other nations; encouraging other countries with financial or technical incentives; and threatening boycotts or political, legal, civil, or military action if compliance does not take place. However, in the context of this paper, only state nuclear transparency activities are considered.

[84] The homeowner in these analogies is admittedly somewhat paranoid. Nonetheless, this level of security obsessiveness is not out of the realm of possibility.

[85] The homeowner can employ a security consultant or an actual guard force, but the overall supervision, responsibility, and decisions are still that of the homeowner.

[86] The (all too common) idea that tags and seals have a role to play in physical protection (as opposed to control & accounting) is indicative of a faulty understanding of the purposes of tags and seals and of confusion about what physical protection is meant to accomplish. See Johnston, "Tamper Detection for Safeguards and Treaty Monitoring."

[87] Lockboxes may be applied to protect seals, monitoring equipment, readers, credentials, and identification cards.

[88] Radiation monitors do not ordinarily protect nuclear weapons or materials, though they play a very important role for C and A.

[89] There is considerable discussion about using portal radiation monitors for treaty monitoring under the Trilateral Initiative, but this does not yet appear to be substantially implemented.

[90] Prohibited tools can be used in the process of diverting nuclear material.

[91] Video surveillance is likely to become increasingly important, with the introduction of so-called "e-safeguards," or remote, online monitoring. The term "e-safeguards" fits the critique raised against "safeguards" in general and will not be given further considerations in this paper.

[92] Under our terminology and concept of transparency, satellite surveillance is basically "spying," not transparency. Refer to the window in the house analogy.

[93] See, for example, any number of essays in Finel and Lord, *Power and Conflict in the Age of Transparency*; and Perry, "From Triage to Long-Term Care," pp. 4-6.

[94] NGOs, including the press, can be tolerated, or even invited into nuclear facilities by the state that owns them, as one way of increasing information flow. As discussed in the house analogy section, however, the (perhaps occasional) presence of outsiders often assumes more of an aura of "monitoring" than true transparency. It could involve, for example, an artificial, tightly constrained information flow, rather than information flow taking place via a natural, intrinsic process operating freely.

[95] IAEA INFCIRC/540 (Corrected) calls for a wide range of intelligence gathering activities.

[96] Video systems can watch and count containers.

[97] Live video can be monitored remotely, or auditors can study recorded video.

[98] Ideally, live video may be fed freely to the world community to increase transparency and confidence in peaceful activities of a state. Traditionally, however, video monitoring is a formalized and negotiated verification activity.

[99] Background screening of inspectors is essential for reliable corroboration. The IAEA, however, currently does little or no background screening of personnel.

[100] Personal assurance programs include checks on current employee status, such as testing for illegal drug use or psychological problems.

[101] U.S. international inspectors and security consultants are often included in a personnel assurance program. The IAEA, however, has essentially no such program.

[102] On-site inspection is not appropriate for transparency. It is normally specifically formalized via an international or bilateral agreement or treaty.

[103] One example includes pre-audits.

[104] On-site visits, where international observers are invited to specific nuclear sites, encompass a potentially strong form of transparency. Although as with video or press coverage, there can be a fine line between monitoring and transparency.

[105] While the presence of a guard force may be beneficial from the point of view of general security, trusting the guard force of an opponent to, for example, protect and store monitoring equipment during international nuclear audits or traditional treaty monitoring runs counter to the very purpose of the auditing or monitoring. Such a situation would be analogous to leaving the fox in charge of the hen house.

[106] An example is the CTBT.

[107] This involves protecting classified and proprietary information, as well as details about the function that an adversary could exploit.

[108] The IAEA has little information security and virtually no counter-intelligence capabilities. See, for example, David Kay, "The IAEA: How Can it be Strengthened?" p. 324-326; and David Anderson, "Nuclear Safeguards."

[109] See, for example, David D. Wilkey, Steven T. Croney, Pamela G. Dawson,

and Don L. Jewell, "An Interpretation of Insider Protection Policy," Proceedings of the 40th Annual Meeting of the Institute of Nuclear Materials Management, pp. 1-4; Robert Venot, "Nuclear Materials Control and Accountancy Systems Vulnerability Assessment," Proceedings of the 40th Annual Meeting of the Institute of Nuclear Materials Management, pp. 1-6; and Roger. G. Johnston and A.R.E. Garcia, "An Annotated Taxonomy of Tag and Seal Vulnerabilities," *Journal of Nuclear Materials Management* 28 (Spring 2000), pp. 23-30. Adversarial intentions will affect the means to be applied. Physical protection, for example, plays a role in non-diversion, but it is even more critical for preventing acts of sabotage. On the other hand, containment/control and accounting tend to be more relevant for avoiding diversion than for prevention of sabotage.

[110] Maintaining secrecy, and protecting information and national security, is usually quite helpful for physical protection and thus not an obstacle.

[111] Protecting classified information should not interfere with domestic auditing, because the auditors are domestically authorized.

[112] Information provided under treaty monitoring is not usually highly classified, nor is it ordinarily the inspectors' responsibility to protect classified information. Nevertheless, the need of the inspected party to protect information can interfere with this function.

[113] This contribution score could be highly relevant ("++") for non-declared weapons states like Israel and for "weak" nuclear weapon states (NWS), such as China.

[114] Companies may have invested vast resources in the development of equipment and systems optimizing nuclear functions.

[115] Consider Russia, for example, which has a strong tradition of concerns about outside attacks on nuclear facilities, but lesser concern about insiders.

[116] For instance, this may be true due to employee fears of losing their jobs.

[117] Domestic physical protecting is often well established and understood. New procedures and high-tech hardware are more typically introduced for the C & A functions.

[118] The consequences of an international audit are likely to be less severe in terms of changes initiated after its completion.

[119] Safety and environmental rules and considerations, while essential, can conflict with other types of nuclear husbandry. Guns, for example, may be essential for nuclear MPC&A, but their presence may represent a safety hazard.

[120] Containment and accounting may be redefined, based on new and shifting environmental and health standards.

[121] For example, the exchange of location data needed to monitor limits on mobile missiles makes these systems more vulnerable to preemptive attacks. Moreover, according to article I of the NPT, NWS under the treaty are obliged not "in any way to assist, encourage, or induce any non-nuclear weapon state to manufacture or otherwise acquire nuclear weapons or other nuclear explosive devices." The release of information may conflict with these pledges.

[122] Keith R. Krause, ed., *Culture and Security: Multilateralism Arms Control and Security Building* (London: Frank Cass, 1999).

[123] Albright, "Secrets that matter," p. 59.

[124] Technically, the Pearson linear correlation coefficient, r, measures the strength of the linear relationship between two variables. The model assumptions that go into computing and interpreting r are discussed in a straightforward manner in William Mendenhall and Terry Sincich, *A Second Course in Statistics: Regression Analysis* (NJ: Prentice-Hall, Upper Saddle River, 1996), pp. 115-116.

[125] For example, the two series of numbers –2,-1, 0, 1, 2 and 2, 1, 0,-1,-2 are fully anti-correlated (i.e., the correlation coefficient is r = 1). One series has a large value, when the other series has a small value. The two series are thus not fully independent, but they are not identical, either. If one were to encounter two strongly anti-correlated nuclear husbandry functions in this work, they would likely be different manifestations of some more general function.

[126] More rigorously, about 100 x r^2 percent of the sample variation in A, measured by the total sum of squares of deviations of the sample A values about the mean of A, can be attributed to using B to predict A via a linear model. See Mendenhall and Sincich, *A Second Course in Statistics*, pp. 133-136.

[127] The reason is that the correlation coefficient between function A and function B is the same as between B and A, because the correlation coefficient of any function with itself is trivially r = 1.

[128] An analogy may be helpful. Imagine that instead of trying to determine if two nuclear husbandry functions are related, one wants to determine if two people, Alice and Bob, are (1) the same person; (2) distinct but alike; or (3) highly dissimilar. One might consider a number of attributes to cross-compare: height, weight, age, gender, vocation, hobbies, favorite color, favorite food, and ability to memorize numbers. Now, one might argue that physical features are over-emphasized. Height, weight, age, and gender, after all, tend to be correlated. The other attributes appear to be roughly "orthogonal," that is, unrelated. The apparent overemphasis on physical attributes, however, is not really a problem if the goal is simply to determine (in a semi-quantitative manner) the degree of dissimilarity between Alice and Bob, rather than to fully describe the two. After all, if Alice and Bob are exactly the same person, they will match up identically on all the attributes chosen. If they are extremely different, the odds are very good that those attributes will not match. The relative importance and orthogonality of the attributes employed are not highly critical for this exercise, as long as they are chosen with some degree of common sense.

[129] One of the authors (Bremer Maerli) of this paper experienced first hand the problems of fully implementing security upgrades at the Ignalina Nuclear Power Plant in Lithuania 1997 and, in 1996, the problems of correctly operating the security systems installed in Building 116 at the Kurchatov Institute in Moscow. The Ignalina plant had experienced several thefts of material as well as bomb threats. Upgrading of the perimeter fence surrounding the plant was, therefore, considered urgent. After installing only one new gate for vehicles, however, the U.S. team left the scene due to lack of funding. Nearby holes in the fence as well as deficient surveillance and alarm systems were left in place, resulting in continuing poor security. In the case of the Kurchatov Institute—which was intended to be a high profile demonstration project involving the MPC&A for highly-enriched uranium (HEU)—the installed security booth was found jammed in an open position during a visit.

[130] Assisting the Russians in strengthening their MPC&A cannot be effective or sufficiently sustainable without substantial understanding of the problem. New settings often present unexpected technical problems, work force conflicts, novel kinds of adversaries, unique licensing, environmental, export control, tariff, and liability issues, and other obstacles to the implementation of MPC&A systems. See, for example, William Potter and Fred L. Wehling, "Sustainability: A Vital Component of Nuclear Material Security in Russia," *Nonproliferation Review* 7 (Spring 2000), pp. 108-188; Oleg Bukharin, *Achieving Safeguards Sustainability in Russia*, PU/CEES Report no. 305, Center for Energy and Environmental Studies, Princeton University, 1998; Baker and Cutler, *A Report Card on the Department of Energy's Nonproliferation Programs with Russia*, p.25; Matthew Bunn, *The Next Wave*, pp. 81-82. Cultural differences in attitudes about security and funding limitations can also create serious impediments. See, for example, Krause, *Culture and Security*; George Bunn, "Raising International Standards for Protecting Nuclear Materials from Theft and Sabotage," p. 150.

[131] According to United States General Accounting Office, *Security of Russia's Nuclear Material Improving; Further Enhancements Needed*, GAO-01-312, February, 2001, p. 8. Of 30 sites reviewed, the Technical Survey Team found that the security systems installed or being installed for 22 sites are reducing the risk of theft.

[132] Johnston, "Tamper Detection for Safeguards and Treaty Monitoring;" Johnston, "The Real Deal on Seals," pp. 93-100; and Johnston, "Tamper-Indicating Seals for Nuclear Disarmament and Hazardous Waste Management."

[133] As suggested by Ivan C. Oelrich, "Production Monitoring for Arms Control," in Michael Krepon and Mary Umberger, eds., *Verification and Compliance: a Problem-Solving Approach* (Cambridge, MA: Ballinger, 1988), p. 116.

[134] See *Joint U.S.-Russian Statement Concerning Management and Disposition of Weapons-Grade Plutonium Designated as No Longer Required for Defense Purposes and Related Cooperation*, June 4, 2000, <http://www.ceip.org/files/projects/npp/resources/Summit8.htm>.

[135] The *Intergovernmental HEU-LEU Agreement*, signed in 1993, mandates the disposal of 500 tons of HEU from dismantled Russian NW. As of February 2002, some 141.4 tons of Russian HEU—the equivalent of nearly 5,000 nuclear warheads—was converted to low-enriched uranium (LEU) to be used in U.S. nuclear power plants. See Valeria Korchagina, *Moscow Times*, February 27, 2002, p. 5.

[136] While the United States verifies that the LEU originates from HEU, it is not clear whether one can really prove that the material comes from dismantled nuclear warheads.
[137] Morten Bremer Maerli, "A Pragmatic Approach for Negotiating a Fissile Material Cut-Off Treaty," *International Negotiation* 6 (July 2001), <http://interneg.org/in/volumes/6/1/abstracts.html>.
[138] DOE, *Plutonium: The First 50 Years: United States Plutonium Production, Acquisition, and Utilization from 1944 to 1994*, DOE/DP-0137 (1996), p. 5. Two years after this report was issued, the British government reconsidered the levels of confidentiality needed concerning stocks of fissile material for national security reasons, and the United Kingdom declared its total stockpiles of plutonium and uranium held outside international safeguards.
[139] Albright, "Secrets that matter," p. 61.
[140] IAEA, *Final Document 2000 Review Conference of the Parties to the Treaty on the Non-Proliferation of Nuclear Weapons*, NPT/CONF.2000/28 (Vol. I, Part I and II), Article VI and preambular paragraphs 8 to 12.