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VERIFICATION LESSONS LEARNT FROM STRATEGIC ARMS REDUCTIONS

by Edward M. Ifft

Introduction

Over the past half-century, the world has gained a great deal of experience with the verification of arms control agreements. With a few notable exceptions, these efforts have been successful.[1] In addition, capabilities to carry out monitoring and verification have improved substantially. Whereas *monitoring* generally refers to the gathering of information relevant to compliance with an agreement, *verification* generally refers to a judgment, made at the political level, regarding compliance. In this paper, the terms are used interchangeably.

Nevertheless, emerging new and more difficult arms control goals, such as further reducing U.S. and Russian strategic and non-strategic nuclear weapons, will require more innovative and intrusive techniques and lessons can be learned from a number of arms control agreements. The aim of this paper is to summarize those lessons learnt and to link them to the goal of deep nuclear reductions. Special emphasis is placed on the New START Treaty between the U.S. and the Russian Federation. The lessons learnt from this experience to date are noted throughout the text, as appropriate.

Defining the Task

To begin with, three fundamental questions can be posed about verification. First, is it possible to detect illegal activity? Second, who decides whether an activity is illegal? And third, if a determination is made that illegal activity has taken place, what should the response to it be? While the first question is rather technical, the other two are largely political. It is obvious that not all violations are of the same nature. Some violations are mostly technical and could involve mistakes in declarations, failure to meet reporting deadlines, incomplete declarations, mistakes made by commanders in the field, who may not be experts on the details of an agreement, etc. Other violations could be more

United Nations Offices in Vienna, host to the International Atomic Energy Agency (IAEA) and the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO). Copyright: Wiktor Wojtas.

serious and might affect the fundamental purpose of the agreement.[2] Such violations are defined by Article 60 of the Vienna Convention on the Law of Treaties as a “material breach” and are said to affect the “object and purpose” of the treaty. The issue of effective responses to violations has proven to be probably the weakest aspect of verification regimes – as the cases of North Korea, Iraq and Iran have shown. A discussion of this is beyond the scope of this paper, but an important lesson is that compliance issues need to be dealt with quickly and effectively.[3]

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Strategic arms control agreements involve the presence or absence of certain well-defined weapon systems, related facilities and activities, and, in some cases, their elimination. It is useful to divide the verification task into stages based upon the life cycle of the weapon systems in question. At the outset, it is important to stress the importance of crafting the agreements themselves extremely carefully. Thus, the fundamental obligations must be clearly spelled out and agreed upon. This is obviously at the heart of what is to be verified. Terms should be clearly defined, especially when they may have a specialized meaning. The START I Treaty had 124 definitions, while New START has 90. If on-site inspections (OSI) are involved, the rights and obligations of both the inspecting and inspected sides must be clear. For example, this would include the size of the inspection teams, areas to be inspected, inspection activities to be carried out and equipment to be used, preparation of reports, transportation and financial arrangements, resolution of disputes, and so on. In many cases, the agreement will be in two or more languages, each of which is equally authentic. This points out the need for world-class interpreters and translators at all stages of the negotiation, agreement drafting and inspection processes.

Proving the Negative

An important question, but one that cannot be answered in the abstract or in advance, is how good is "good enough" for verification? It is reasonable to expect that the answer will become clearer as the world gains experience in moving to very low levels of nuclear weapons. However, it is already clear that verification will never be perfect. Thus, it is not reasonable to expect to be able to certify with complete confidence that no undiscovered illegal nuclear weapons exist anywhere in the world. This problem could become particularly vexing if there were suspicions or vague allegations from anonymous sources. Consider the problems caused by the source "curveball" in Iraq (2003) or how long it took to convince people there were no SCUD missiles there (despite the unlimited access the inspectors had and the fact that a SCUD is hardly a small object). The consequences of undetected levels of cheating and possible responses to it are important, but beyond the scope of this paper. However, the importance of having an implementing organization, whose responsibility it is to deal effectively with compliance issues, is clear.

At least from the U.S. perspective, verification of New START has clearly been "good enough" thus far. The U.S. State Department's Compliance Report for 2013 states that, although implementation-related questions have been raised with the Russian Federation through diplomatic channels and in the treaty's Bilateral Consultative Commission (BCC), "based on the information available as of December, 2012, the United States certifies the Russian Federation to be in compliance with the terms of the New START Treaty."[4]

Verifying Objects or Activities

Probably the most basic and common verification task in the nuclear area is verifying the numbers or quantity of defined objects – for example, missiles, missile launchers, bombers, nuclear warheads, fissile material, etc. Initially, this task will come into play when establishing a *baseline* of accountable items, from which changes can be determined. In the absence of an agreed initial baseline, establishing future quantities of anything during reductions could be very difficult. Generally, declarations on quantities and movements of accountable objects are required in an agreement. New START raises these requirements to new levels and over 3,000 notifications have already been exchanged. A combination of National Technical Means of Verification (NTM) and OSI is very effective at monitoring such declarations and the world has a great deal of experience in this area. In the area of nuclear weapons, the U.S. and Russia have high confidence in counting the numbers of *deployed* strategic missiles, missile launchers, nuclear warheads and heavy bombers. They have also established procedures for verifying the numbers of *non-deployed* missiles, missile launchers and heavy bombers. Under New START, each side is allowed up to ten inspections per year of sites with deployed systems and eight inspections per year of sites with non-deployed systems. Inspection teams are able to begin their work with detailed information, provided by the host, with respect to the numbers of missiles, heavy bombers and warheads at that site. Both sides have been using their maximum quotas.

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Both START I and New START have also shown the value of one-time "exhibitions." These are used to exhibit new systems or to demonstrate modifications to existing systems and may involve greater information or access than would be available in regular inspections. Under New START, the sides have already conducted four exhibitions. The U.S. has exhibited the B-2A and converted B-1B heavy bombers and a ballistic missile submarine converted to carry cruise missiles, while Russia has exhibited its new RS-24 ICBM.

However, there are not, and have never been, constraints on *non-deployed nuclear warheads,* a requirement as reductions proceed further. In addition to the declarations required in New START, deep reductions will almost certainly require new types of declarations on the production, storage and dismantling of nuclear warheads. Corresponding declarations will also be needed for tactical (non-strategic) nuclear systems. The U.S., UK and France have all made declarations on the size of their nuclear stockpiles, though these voluntary declarations have not been subject to verification. Russia, China and other states with nuclear weapons have not made corresponding declarations. It is obvious that, before deep reductions in overall stockpiles in nuclear weapons can begin,

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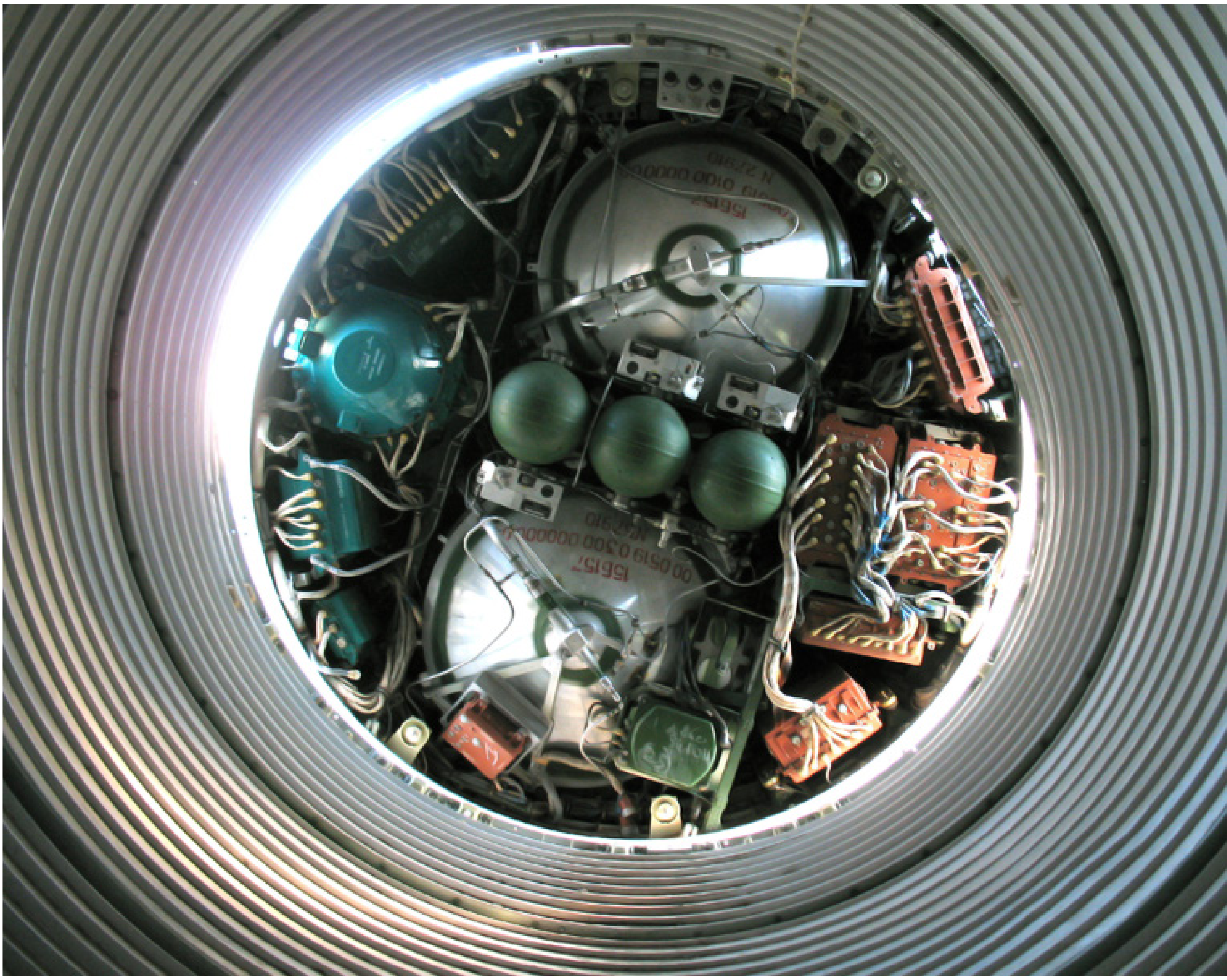

Inside view of ICBM SS-18, Satan. Copyright: Nataliia Pogrebna.

these countries must become more open about their inventories.

If non-deployed objects or activities that should be declared are not declared, they become illegal and finding them becomes one of the most difficult verification activities. This could require reliable intelligence (NTM or an agreed international information-gathering system) or perhaps human intelligence, including civil society and whistleblowers. Iraq's extensive illegal activities under the NPT were basically only discovered when UNSCOM, UNMOVIC, and IAEA inspectors had access to the diverse facilities as a result of the first Gulf War. Iran's undeclared uranium enrichment activities were revealed to the IAEA by a dissident group. The USSR's illegal production of anthrax was found as a result of a leak leading to deaths in the local population.

It is clear that objects or activities, which are small and easily hidden, will be the hardest to discover. Nuclear warheads are the obvious example. An important facet of this problem is the possible deployment of nuclear warheads on platforms ostensibly dedicated to conventional weapons. A related issue is the possible rapid deployment of nuclear warheads on specific platforms in excess of the numbers permitted ("uploading"). Challenge OSI may be the most effective tool for discovering illegal objects or activities, as well as for deterring them in the first place. Such inspections have rarely been used and are likely to be an essential part of verification of deep reductions in nuclear weapons. The long delay in arranging UN inspections in response to the initial allegations of chemical weapons use in Syria illustrates the problem. Thus more work needs to be done on how to conduct challenge inspections, as well as on educational efforts to gain acceptance of the idea of challenge inspections as an effective method of resolving ambiguities and not necessarily an accusation to be avoided at all costs.

In the case of objects which are relatively small, but very dangerous, "signatures" are

Geiger counter with radioactive materials in the background. Copyright: Dennis Van De Water.

important. For example, nuclear warheads would be expected to have special security arrangements where they are manufactured and stored. Undeclared uranium enrichment facilities using centrifuge cascades might be difficult to detect and enrichment using laser techniques would be even easier to hide.

The problem of illegal activities and objects illustrates the importance of national legislation to support international agreements. If something is illegal under an international agreement, it should also be illegal under the domestic law of each State-Party, which is not always the case. This should include penalties for violations. It is possible, for example, that a scientist or engineer could be engaged in some activity which is illegal under an international arms control treaty, but be unaware that this is illegal because of a lack of well-publicized domestic legislation. Correcting this problem would also increase the possibility that citizens might come forward as whistleblowers. The Helsinki Watch Groups, which publicized violations of the Helsinki Agreement of 1975 in the Soviet Union, are a good example of how this could work.

Challenge on-site inspections have rarely been used and are likely to be an essential part of verification of deep reductions in nuclear weapons.

Verifying the Reduction and Elimination of Objects and Activities

Once agreed baseline levels of permitted objects and activities are established, deep reductions will obviously require their reduction and, possibly, elimination, according to an agreed schedule. This could involve physical destruction or conversion to permitted uses. It is important that the agreed procedures for this process be spelled out in detail. If they are, there is considerable experience with such activities and high-confidence verification can be achieved. Verification could be by NTM (in the case of the blowing up of missile silos or cutting up bombers) or it could require OSI. The INF and START Treaties used OSI extensively to verify reductions. New START retains this option, but the sides have decided, based on the START I experience, that they could reduce the frequency of such inspections. Specifically, the greater trust and transparency which came with the START I experience and the end of the Cold War, along with the fact that many previously inspectable bases had been closed, made this simplification possible. Facilities which have been closed or converted can be characterized as "formerly declared sites" and can be subject to inspections to increase confidence.

The elimination of nuclear weapons systems can be difficult and expensive. INF, START and New START all had detailed protocols specifying the exact details of acceptable elimination methods and how these should be verified. As far as missiles, missile launchers and bombers are concerned, these well-established procedures should be appropriate at any level of reductions. The dismantlement and elimination of *nuclear warheads,* however, presents an entirely new set of issues, with which we have not had to deal in the past.[5]

The first problem will be in defining a nuclear weapon or warhead. A similar problem was encountered in START, when it was necessary to define a *missile* for accountability purposes. This problem, which proved to be more difficult than many would have expected, was solved by separating all missiles into three classes, based upon how they are maintained, stored and transported, with different definitions for each class. Warheads will present greater problems. They are, of course, dangerous because of both the fissile material and the conventional explosives they contain. In addition, if inspectors from non-nuclear weapon states are involved, they must be prevented from obtaining design information, which would violate the NPT. The most obvious approach would be to consider the bare pit to be the accountable item, along with the canned sub-assembly. However, one could ask if it matters whether high explosives are attached. Other components that might need to be controlled would include neutron generators and tritium bottles. Another question would be how one would define a pure, highly enriched, uranium (HEU) (gun) weapon. This might center on the fabrication of HEU into a weapon-related shape.

A further problem will involve whether it would be necessary merely to determine that a nuclear warhead is being stored or eliminated or whether it would also be necessary to determine the *specific type* of warhead being dealt with. The U.S., for example, currently has seven types of nuclear warheads in its stockpile. Furthermore, it may be desirable to determine the specific provenance of the warhead – e.g., is it the same one inspectors saw being removed from deployment or storage at a specific location earlier?
It is obvious that tracking a specific warhead will be more difficult than merely providing assurance that an object *is* a nuclear warhead.

Some verification activities with respect to warheads are already well-established. Under the INF, START I and New START Treaties, inspectors have been allowed to use hand-held neutron detectors to determine the presence or absence of nuclear warheads. In addition, IAEA Safeguards involve nuclear

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measurements, both in the field and at an IAEA laboratory near Vienna.

It is useful to recognize that the problem here is the opposite of the one encountered in START I and New START. In these agreements, inspectors needed to determine that an object declared not to be a nuclear weapon was indeed not – for example, it could be a conventional warhead or not a warhead at all. In accounting for nuclear warheads during reductions and eliminations, however, inspectors will need to determine that an object claimed to be a nuclear warhead is indeed that and not, for example, merely a piece of radioactive material.

The attributes that would be relevant in determining whether an object is actually a nuclear warhead include the existence of plutonium, whether the plutonium is weapons grade and its age. All of these can be measured with high-resolution gamma spectroscopy. Other relevant characteristics could include whether the plutonium has some minimum mass and whether its shape is symmetrical. These can be determined from neutron multiplicity counting, since spontaneous fissions emit time-correlated neutrons. Such measurements would generally need to be made in a special facility, not in the field. Another attribute that could be relevant would be whether the plutonium is in its pure metallic form or is an oxide. This could be determined through the measurement of both neutron and gamma radiation. Other measurements are possible – for example acoustic signatures or heat, but these are not yet well-developed. Important work has been done on these problems. The Trilateral Initiative among the U.S., Russia and the IAEA made some progress before it was discontinued in 2002.[6] This work should be revived. Another promising U.S.-Russia scientific cooperation program in the 1990s that did not survive the Bush administration, was the Warhead Safety and Security Exchange (WSSX).[7] A more recent UK-Norway Project focused on the role that inspectors from both nuclear weapon states and non-nuclear weapon states could play in monitoring the disassembly of a nuclear warhead.[8] The U.S. National Academy of Sciences has also made important contributions to solutions for these problems.[9]

Two basic approaches have emerged from this research. One, the "attributes" approach, would define a set of minimum attributes common to all nuclear weapons (at least those of the state in question) and determine whether the object under examination had these attributes. The other, the "templates" approach, would define a template of specific characteristics of a real nuclear warhead of each type and determine whether the object in question matched this template. An important component of either approach could be an "information barrier," essentially a "black box" which would determine whether the object met the agreed criteria. It would store no information and merely give a yes or no signal in the form of a red or green light. This would protect sensitive design information, which would not be necessary for verification, and the revelation of which would probably be unacceptable to the side whose weapon it was. The attributes and templates approaches have advantages and disadvantages and some combination of the two may be the best solution. The work is promising, but more research is needed.[10]

The ideal next step would be cooperative work by U.S. and Russian laboratories, which would probably eventually require the exchange of sensitive data, as well as further work on assuring the integrity of data. A partial basis for such cooperation could be the 2011 U.S.-Russia 123 Agreement on Nuclear Energy.[11] This agreement, which is based on a mutual commitment to nuclear nonproliferation, provides the basis for joint efforts on innovative nuclear energy technologies, nuclear fuel cycle services, etc. The IAEA could also be involved, along with participation at some point by other states. Further technical details are beyond the scope of this paper. It is likely that an effective verification regime would require some adjustments in the amount of nuclear

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information that could be shared with other countries.

The techniques discussed above are all "passive," in that they simply measure radiation coming from the object under investigation. "Active" interrogation – for example, using neutron beams – is also possible and would provide more information. This could be useful for detecting HEU, which only weakly emits neutrons and gamma rays. However, such techniques would be more intrusive and would require special facilities.

One approach to laying the groundwork for negotiating detailed treaty provisions would be to conduct reciprocal visits to nuclear warhead production, storage and elimination facilities. This would help to build confidence, as well as provide an opportunity to discuss possible verification procedures in realistic settings. Experience in both START and the 1974 Threshold Test Ban Treaty (TTBT) has shown the value of such activities.[12]

Tags and Seals

Tags and seals will certainly play an important role in assuring the integrity of the chain of custody of objects. The IAEA has used tens of thousands of tags and seals in its activities. Tags are used to identify an object, clarify its loss or avoid confusion with another similar object. In START I, unique identifiers in the form of non-repeating alphanumerics, which inspectors could read and record, were used on mobile ICBMs. This was so successful that New START provides for their use on all ICBMs, SLBMs and heavy bombers. This is proving helpful to inspectors in keeping track of these items. One problem with the wider use of unique identifiers is finding a location that is readily accessible to the inspectors – for example, on a missile in an ICBM silo or submarine tube. A more sophisticated form of tag would be a radio-frequency identification device (RFID). These could be passive and be read by an external reader or active (requiring a power source, such as a battery) and able to broadcast information continuously or on demand. RFIDs have even been developed that can survive in the stomachs of ruminants and provide reliable information on its provenance throughout an animal's lifetime.

An obvious application of tags in the present context would be on a container for a nuclear weapon or key components of a nuclear weapon. If the container had been out of the control of inspectors, either in storage or during transport, an effective tag would provide assurance that it was the same container that had been observed earlier.

Seals are devices that indicate whether tampering has occurred. A padlock is a common form of seal. More sophisticated seals could be in the form of fiber-optic cables. These can be formed into a loop or other configuration and the ends placed into a special connector with the ends crushed. This forms a unique pattern which can be read by a special camera. These have been used in the START Treaties. An effective tag and seal combination, preferably with cryptographic protection, could provide confidence that a specific container is as advertised and that it has not been opened.[13]

Continuous Monitoring

Continuous monitoring of a facility may be needed to ensure that prohibited or accountable items are not going into or out of it undetected. This would be highly relevant for monitoring the production, storage and elimination of nuclear warheads and their accountable major components (as noted above, warhead *deployments* would be monitored primarily through OSI). There is a significant amount of successful experience with continuous monitoring, which should be drawn upon in setting up an effective verification regime for deep reductions. Perimeter and Portal Continuous Monitoring (PPCM) was an important component of the verification system in both INF and

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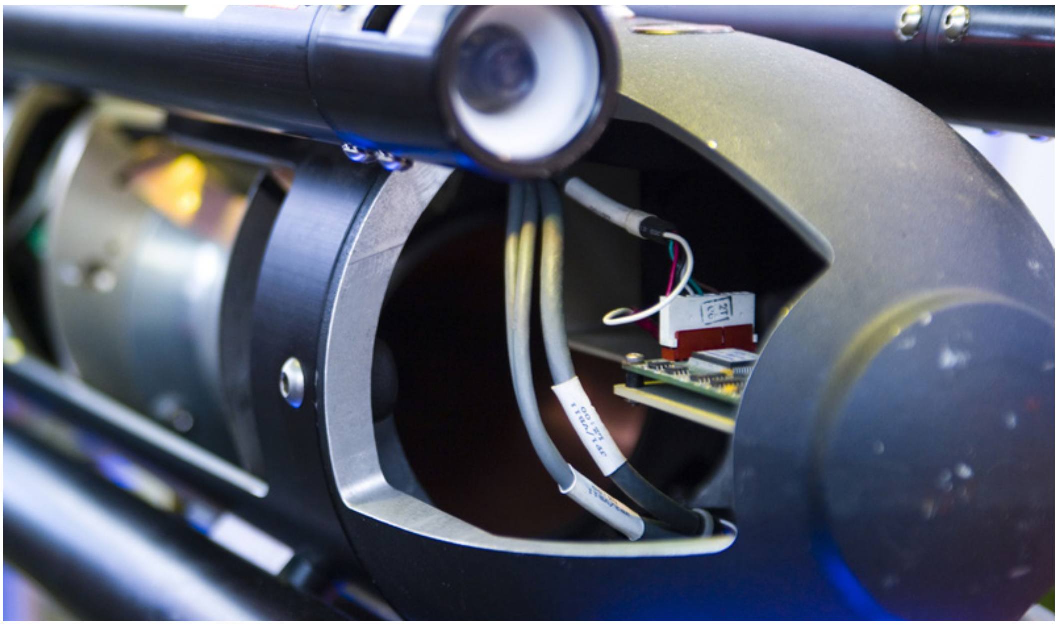

Missile warhead mechanism in cutout on display. Copyright: Constantin Opris.

START I. The depth of experience gained with PPCM is indicated by the fact that, during the 21 years of its existence, over 100,000 road vehicle inspections and over 11,000 railcar inspections were carried out under INF and START I at Votkinsk (Russia). Under the Chemical Weapons Convention (CWC), inspectors from the OPCW monitor activities on-site 24/7 at all destruction facilities. A less intrusive form of continuous monitoring could be by Closed Circuit Television (CCTV) which was used during UN monitoring operations in Iraq.[14] If accountable nuclear warheads or fissile material from them is stored under international control, some form of continuous monitoring would likely be required. Periodic checks of randomly selected containers would strengthen confidence. Such checks could read the tags and seals as well as a radiation signature. This could be both intrusive and expensive, especially if it required the continuous presence of personnel on-site. The U.S. and Russia missed a golden opportunity to develop relevant capabilities when they were unable to agree on transparency arrangements at the Russians' Mayak nuclear storage facility in the Urals.[15] If a Fissile Materials Cut-off Treaty (FMCT) were negotiated, its verification regime would likely be relevant to disarmament verification. However, given the unpromising current prospects for FMCT, it is probably necessary to proceed independently of it.[16]

Challenge Inspections

Although considerable work has been done on how challenge inspections should be conducted, including both tabletop exercises and realistic mock inspections in the field, there is relatively little actual experience to draw upon. The CWC provides for such inspections, but no State-Party has ever called for one. START I also provided for such inspections, but they were not needed and have been omitted in New START. Under the Comprehensive Nuclear-Test-Ban Treaty (CTBT), all inspections would essentially be of the challenge variant. Realistic field exercises are part of the preparations should the CTBT enter into force. A major such exercise was held in Kazakhstan in 2008 and another is planned for Jordan in 2014.[17] This experience, especially the logistics which might be required, is valuable. Provisions to conduct challenge inspections would almost certainly be required to effectively monitor deep reductions. It is assumed that challenge inspections would also be an important part of any WMD-free Zone in the Middle East, but this work is still in its early stages, with actual negotiations for such a zone not yet underway. The successful establishment of such a zone, which could gain momentum if the situation with chemical weapons in Syria were resolved, could provide a major boost to efforts to rid the world of nuclear weapons, since it would require progress on many of the issues discussed in this paper.

The Additional Protocol under IAEA Safeguards provides for activities similar to challenge inspections, but, again, these have not been extensively utilized. Clearly, more experience with challenge inspections is needed and the work being done by the OPCW in Syria should provide valuable lessons for the future.

Managed Access

An important lesson from world experience with OSI has been the development of managed access. This became necessary when it was realized that, in most cases, "anywhere, anytime" inspections are not feasible. In Iraq, the UNSCOM, UNMOVIC and IAEA Action Team inspectors had virtually unlimited access and power. However, this was a special case with Iraq under duress from the UN Security Council and is not likely to be repeated, especially in a negotiated agreement. The agreements we are considering here would need to spell out in some detail the rights and responsibilities of both the inspecting and inspected parties. In general, these would ensure the *inspecting* side sufficient access to gather the information necessary to make an informed judgment about the matter at hand. At the same time, it would protect the *inspected* side from unwarranted intelligence gathering or unreasonable interference with its normal activities. In addition to these procedures, which would be agreed upon in advance, situations would almost certainly develop in the field, which would require the teams to work out the details of their activities on the spot to correspond to specific circumstances. This would include questions, such as the degree of access to specific areas or buildings, how to deal with local conditions related to safety or weather, and so on. The principle of random selective access has been useful in this respect. Under this principle, inspectors may be asked to select a percentage or number of buildings they wish to inspect in a large complex.

They may also be asked to select which rooms to inspect in a large building. Although such procedures do have the potential to create controversy, in practice, they have proven surprisingly effective and will need to be incorporated into future verification regimes. New START is the latest embodiment of these principles.

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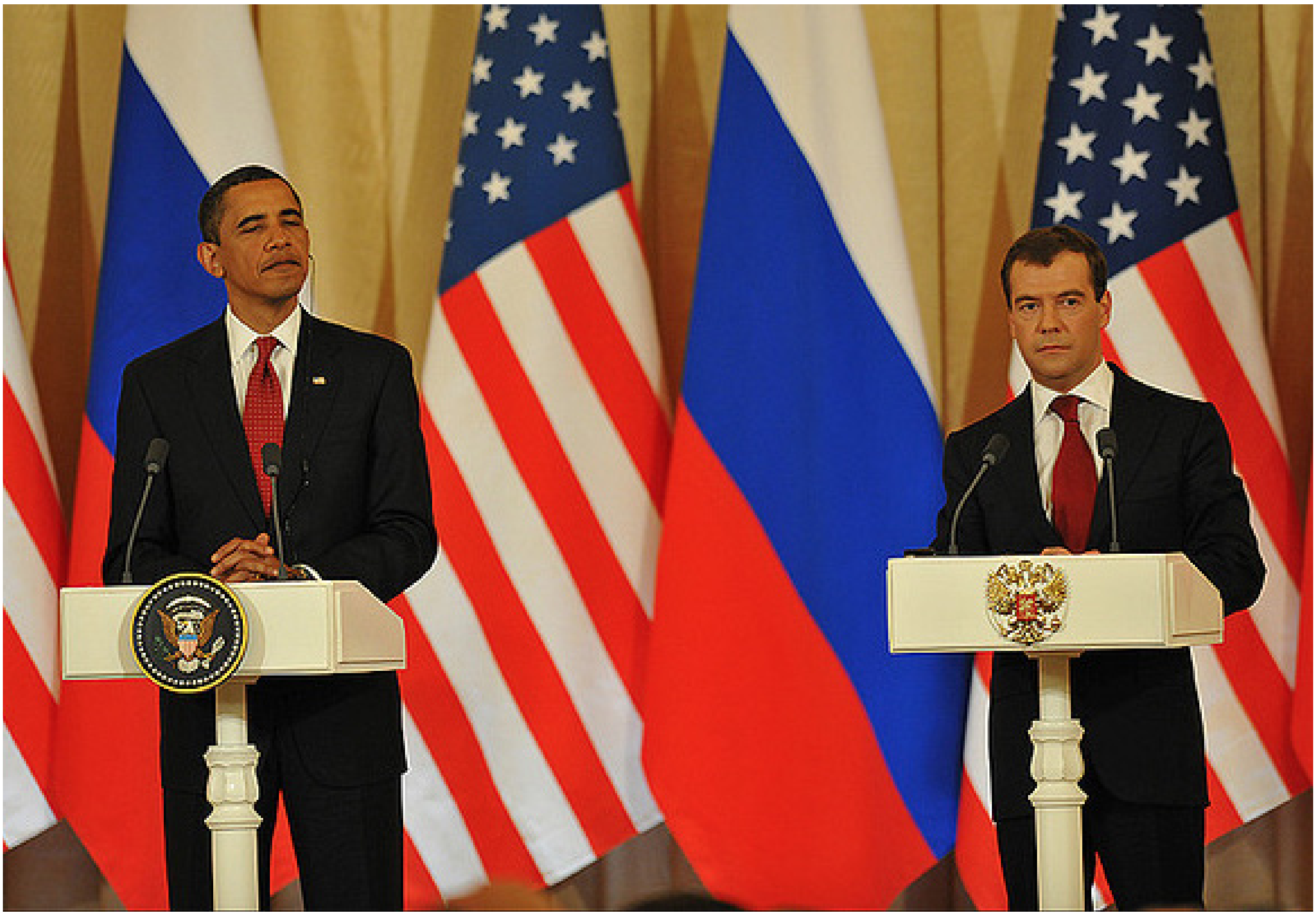
Virtual Deterrence

It is likely that at least some of the major nuclear weapon states will insist on some sort of residual nuclear capability as a form of "virtual deterrence", as a condition for going to extremely low levels or zero. This would be a hedge against cheating, but, even if cheating were not a concern, against some development in world conditions that led to a breakout from the treaty. This would be similar to the "safeguards" that have accompanied constraints on nuclear testing. It is reasonable to expect that these residual capabilities would themselves be a subject of negotiation and, logically, subject to verification. In addition to delivery systems, elements of such virtual deterrence that would be relevant and could be subject to control could include nuclear weapons laboratories, major components of nuclear weapons and fissile material, including perhaps tritium. Such a task does not seem insurmountable, though the problem of dual-use materials and dual-use activities could prove troublesome.[18] A related issue would be an agreed understanding of the "capability" to produce nuclear weapons. The complications this involves are illustrated by the current controversies surrounding Iran's nuclear



At the U.S.-Russian Moscow Summit in 2009 Presidents Obama and Medvedev agreed on a New START Treaty framework. Copyright: Mika Stetsovski.

activities. More research is clearly needed on the subject of virtual deterrence, which might become a difficult point of contention between the nuclear weapons states and non-nuclear weapons states.

Conclusion

World experience with monitoring complicated arms control agreements is extensive and has generally been successful. However, this experience tends to be concentrated in only a few advanced countries. Experience with the START Treaties – in particular, New START – is highly relevant and will be very valuable going forward. For example, the use of declarations and unique identifiers and procedures for on-site inspections will need to be carried forward into future, more ambitious, agreements. Going to lower numbers of nuclear weapons or eliminating them entirely will introduce new and difficult problems. Chief among these will be accounting for and eliminating the nuclear warheads themselves. Experience to date has dealt almost exclusively with delivery systems, which tend to be larger and less sensitive. More intrusive on-site inspections will play a key role and, fortunately, some research has been carried out with respect to conducting such activities. However, important technical work remains to be done. More timely and effective methods for dealing with ambiguities will also be needed. Educational efforts are also needed to prepare governments and populations for these tasks. Adjustments will need to be made in how much nuclear information can be shared with other countries. Technical solutions to all these problems appear to be within our grasp. However, actually negotiating these solutions among all the countries that will need to be involved may prove to be the more difficult task.

TABLE 1: Major OSI Regimes[19]

Treaty/ Agreement	Number of Inspections	Verification Organization	Verifying Declared Objects/ Activities	Searching for Undeclared Objects/Activities	Verifying Elimination/ Conversion
Antarctic Treaty	About 50		X	X	
NPT/ IAEA	thousands	X	X	X	X
Euratom	thousands	X	X		X
ABACC	1,000+	X	X		X
CWC	5,000+	X	X	X	X
CTBT	challenge	X	X	X	
INF	850+	X	X	X	X
START I	1,100+	X	X	X	X
New START	18/year	X	X	X	X
CFE	5,000+	X	X	X	X
Open Skies	1,000+	X		X	
Ottawa Treaty	challenge	Meeting of States-Parties	X		
Iraq	hundreds	X	X	X	X

Note: Inspections are completed for INF, START I and the special Iraq regime. The CTBT has not yet entered into force. Although the Treaty on Open Skies does not strictly involve on-site activities and is not intended to monitor any specific agreement, it is useful to include it or a similar agreement as a potentially important verification tool.

TABLE 2: The Tools of Verification

➔ **Declarations and Notifications:** *This refers to agreed information one party gives to other parties on its assets and activities.*
➔ **National Technical Means of Verification (NTM):** *This term refers to technical means under national control and includes satellite imagery, electronic surveillance, communications intercepts, etc. Such means are explicitly recognized in the SALT and START Treaties. Cooperative measures to facilitate NTM could include non-interference with NTM, prohibiting certain types of concealment measures, requirements to display objects in the open upon request and a prohibition on encrypting telemetry during missile flight tests.*
➔ **International Technical Means of Verification:** *This refers to monitoring systems agreed upon and utilized by the parties to an agreement. Examples include the International Monitoring System of the CTBT, sensors used on Open Skies missions, etc.*
➔ **On-Site Inspection (OSI):** *This refers to agreed activities carried out by the parties on the territories of the parties. The world has a great deal of experience with OSI (see Table 1).*
➔ **Open Source Verification:** *This refers to information found in the media or other generally available sources that could be relevant to compliance with an agreement*
➔ **Civil Society Verification:** *This refers to efforts by members of the public to monitor the compliance of their own country with an agreement. This could refer to, for example, whistleblowers and could include both classified and unclassified information. This method is used extensively in monitoring the Landmine Convention.*

The views expressed are those of the author and do not necessarily reflect the policies of the U.S. State Department or Georgetown University.

1 Exceptions would include the failure to detect Iraq's WMD programs and the inability to put into place a verification regime for the Biological Weapons Convention. The UN Security Council has also been unable to devise effective responses to violations in certain cases, such as North Korea's violation of the NPT.

2 The U.S. State Department prepares an annual report on *Adherence to and Compliance with Arms Control, Nonproliferation and Disarmament Agreements and Commitments*. The 2013 and earlier reports are available at www.state.gov

3 Several articles relevant to these topics can be found in *Cultivating Confidence: Verification, Monitoring and Enforcement for a World Free of Nuclear Weapons,* edited by Corey Hinderstein, Nuclear Threat Initiative, 2010. See also Edward Ifft, "Witness for the Prosecution: International Organizations and Arms Control Verification," *Arms Control Today,* November, 2005.

4 *Adherence to and Compliance with Arms Control, Nonproliferation and Disarmament Agreements and Commitments,* U.S. Department of State, July, 2013.

5 Several articles which shed light on these issues can be found in *Reykjavik Revisited: Steps Toward a World Free of Nuclear Weapons,* edited by George P. Shultz, Steven P. Andreasen, Sidney D. Drell and James E. Goodby, Nuclear Threat Initiative and Hoover Institution Press, 2008.

6 See Thomas E. Shea, "The Trilateral Initiative: A Model for the Future?" *Arms Control Today,* May, 2008.

7 The WSSX program was a cooperative effort among U.S. and Russian nuclear weapons laboratories in the 1990s to assist the Russian Federation with nuclear weapons' safety and security issues following the breakup of the Soviet Union.

8 David Cliff, Hassan Elbahtimy and Andreas Persbo, "Verifying Warhead Dismantlement: Past, Present and Future," VERTIC Research Report No.9, September, 2010, available at http://www.vertic.org

9 U.S. National Academy of Sciences, *Monitoring Nuclear Weapons and Nuclear-Explosive Materials,* The National Academies Press, 2005.

10 Ibid.

11 On the issue of U.S.-Russian civil nuclear cooperation see Mary Beth Nikitin, „U.S.-Russian Civilian Nuclear Cooperation Agreement: Issues for Congress", CRS Report for Congress, CRS: Washington, D.C., January 2011. Available at: http://www.fas.org/sgp/crs/nuke/RL34655.pdf

12 For further development of these ideas, see James E. Doyle, "Preparing for the Next Round of U.S.-Russia Nuclear Arms Reductions," Los Alamos National Laboratory Report LA-UR 11-01657, March, 2011.

13 Further discussion can be found in James Fuller, "Verification on the Road to Zero: Issues for Nuclear Warhead Disarmament," *Arms Control Today,* December, 2010.

14 For further discussion of the UN's monitoring activities in Iraq, see Hans Blix, Disarming Iraq, Pantheon Books, 2004.

15 The Mayak Fissile Material Storage Facility in the southern Urals was built with the assistance of the U.S. Cooperative Threat Reduction (Nunn-Lugar) Program and is accepting weapons-grade materials. It was expected that there would be transparency and some form of monitoring at this facility, which might have established a very useful model for other such facilities in the future. However, the sides were not able to agree on a regime for transparency and access.

16 Disposition and monitoring of fissile material from nuclear warheads is a major challenge, which is beyond the scope of this paper. The IAEA already monitors such material for non-nuclear weapons states. A recent discussion of the plutonium problem can be found in Tom Clements, Edwin Lyman and Frank von Hippel, "The Future of Plutonium Disposition," *Arms Control Today,* July/August, 2013. Much useful work on controlling fissile materials has been done by the International Panel on Fissile Materials, see http://www.fissilematerials.org

17 For further information see http://www.ctbto.org

18 For further discussion of virtual deterrence, see Deterrence: Its Past and Future, edited by George P. Shultz, Sidney D. Drell and James E. Goodby, Hoover Institution Press, 2011.

19 Adapted from Edward Ifft et al., *On-Site Inspections: Assessment of a Major Tool in Arms Control Verification,* Geneva Centre for Security Policy (Geneva) and Centre d'Etudes de Sécurité Internationale et de Maîtrise des Armements (CESIM), 2012, available at http://www.gcsp.ch/Leadership-in-Conflict-Management/Events/International-Research-Seminar-On-site-Inspection-Assessment-of-a-Major-Tool-in-Arms-Control-Verification

Front page: Topol-M (SS-27 Sickle) mobile ICBM launcher during parade in Moscow. Copyright: Meoita.

About the Author

Dr. Ifft, a retired member of the Senior Executive Service, is a Foreign Affairs Officer at the State Department. He has served on U.S. delegations to the SALT, TTBT, START and CTBT negotiations, was the Senior State Representative to both the START and CTBT negotiations, and served as Deputy U.S. Negotiator to START. Dr. Ifft has served as Deputy Director of the On-Site Inspection Agency and Senior Advisor to the Defense Threat Reduction Agency. He served for three years as Executive Secretary of the U.S.-USSR Space Cooperation Agreement. He was Acting U.S. Commissioner for the ABM Treaty for two years. He is currently an Adjunct Professor at the Center for Security Studies, Georgetown University.

Contact: emi3@georgetown.edu

About Deep Cuts

The Deep Cuts project is a research and consultancy project, jointly conducted by the Institute for Peace Research and Security Policy at the University of Hamburg, the Arms Control Association, and the Institute of World Economy and International Relations of the Russian Academy of Sciences. The Deep Cuts Commission is seeking to devise concepts on how to overcome current challenges to deep nuclear reductions. Through means of realistic analyses and specific recommendations, the Commission strives to translate the already existing political commitments to further nuclear reductions into concrete and feasible action. Deep Cuts Working Papers do not necessarily reflect the opinion of individual Commissioners or Deep Cuts project partners.

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Impress:
Institut für Friedensforschung und Sicherheitspolitik
an der Universität Hamburg (IFSH)
Beim Schlump 83
20144 Hamburg, Germany

Phone: +49 (0)40-86 60 77-42
Fax: +49 (0)40-866 36 15

Project Management
Ulrich Kühn
Götz Neuneck
Email: kuehn@ifsh.de