6. Monitoring Nuclear Warheads

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Summary

The effective verification of deep reductions in, and eventual elimination of, nuclear weapons will be an essential and challenging task, posing verification issues never before encountered in an arms control agreement. The emphasis will be on monitoring warheads, which are considered the most important component of weapons systems. They are also the smallest and contain the most sensitive technology. It is possible to distinguish among four monitoring tasks—deployed warheads, non-deployed warheads, virtual warheads, and disassembled/dismantled warheads.

Fortunately, the successful implementation of the SALT, INF, and START Treaties has provided us with a number of powerful and proven tools. These include National Technical Means, data exchanges, on-site inspection, Perimeter and Portal Continuous Monitoring, nuclear detection devices, and remote monitoring techniques. The experience of UNSCOM and UNMOVIC in Iraq can also be useful.

Counting warheads which are *deployed*, or considered to be deployed, is straightforward and can be carried out with high confidence

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using techniques which have previously been agreed between the U.S. and the Russian Federation. Monitoring the numbers of *non-deployed* warheads has never been attempted in an arms control agreement. Since this was on the agenda of the 1997 Helsinki Framework (START III), some work was done in the U.S. on how one might approach the task. The appropriate level of intrusiveness also became an issue in the Cooperative Threat Reduction Program. Keeping track of warheads removed from deployed status under agreed procedures should be possible, but an agreed baseline should also be established. Depending upon the degree of confidence required, rather intrusive inspections might be necessary.

Keeping track of "*virtual*" warheads would be similar to the problems posed by non-deployed warheads. If virtual is understood to be simply warheads removed from deployed status under agreed procedures, the problem should be manageable. However, there are systems which have never been deployed, but which are "real" and need to be accounted for, especially at very low levels of deployed systems. In addition, a realistic accounting of a virtual force should also consider the capability of missiles and bombers to carry additional warheads. One reason for this is that it will probably be difficult to account for all non-deployed warheads with high confidence. Another is that a portion of reductions will almost certainly result from "downloading" existing systems. Thus, although the focus will properly be on warheads, one cannot ignore the other components—missiles, missile launchers, and bombers, especially as the numbers get very low.

Monitoring the *disassembly/dismantlement* of warheads and accounting for their special nuclear material will be the final task. Some useful work related to this task was done in anticipation of the Helsinki Framework, most specifically the Trilateral Initiative among the U.S., Russia, and the IAEA. This work should be revived.

Existing, proven verification techniques are adequate for levels significantly lower than presently exist. At very low levels, however, new and quite intrusive measures will be needed, along with higher levels of transparency and trust than exist today. As reductions proceed, things may fall into place faster than we can now anticipate. On the other hand, verification and compliance problems may arise that will make further reductions politically difficult. Thus, it might be wise to plan for strategic pauses or plateaus to assess how well we have designed our verification regime and to make adjustments as necessary.

Introduction

Determining numbers of nuclear warheads could well be the most important single task in monitoring a future arms control regime.* Of the three major components of strategic offensive arms—delivery vehicles (missile launchers and heavy bomber airframes), missiles, and warheads—warheads are the most important. They are also by far the smallest and most numerous. They can be moved and stored clandestinely with relative ease, compared to the other components. Thus, a well-designed and rather intrusive verification regime is essential. Even that may not be sufficient to verify effectively certain possible constraints. Fortunately, we do have a number of relevant verification tools that are well-understood and accepted by the U.S. and Russian Federation:

- National Technical Means (NTM)
- Data exchange/Notifications
- On-Site Inspection (OSI), both routine and challenge
- Perimeter and Portal Continuous Monitoring (PPCM)
- Nuclear detection devices, both handheld and fixed
- Remote monitoring techniques developed by UNSCOM and UNMOVIC in Iraq

One could distinguish among four general monitoring tasks. These

*"Warheads" in this paper are understood to mean reentry vehicles for strategic ballistic missiles, as well as bomber armament (ALCMs, SRAMS, gravity bombs).

involve deployed warheads, non-deployed warheads, virtual warheads, and dismantled/disassembled warheads.

Monitoring Deployed Nuclear Warheads

Warheads deployed on, or attributed to, missiles and bombers are the most likely subjects of monitoring and the case with which we have the most experience. NTM can provide valuable information regarding warheads obtained in observing flight tests. However, NTM is of little use in determining the actual number deployed. Under the START Treaty, the U.S. and the Russian Federation each may conduct up to 10 RV OSIs per year. In the first 10 years of START, the U.S. conducted 99 such inspections, failing to use its full quota only once. The Russians conducted 87. Inasmuch as the procedures are very well established and accepted by both sides, there would seem to be no obvious reason to change them. The number of inspections allowed, of course, could be altered or could be combined with other types of inspections. Factors such as the rights and privileges of inspectors (largely drawn from the Vienna Convention on Diplomatic Relations), timelines, entry/exit points, escorting procedures, financial factors, etc., are all well understood and could be adapted to a new agreement with little change.

Under START, each type of ballistic missile is attributed with a fixed number of RVs. This greatly simplifies the verification task. A missile can be deployed or flight tested with fewer than this number (or with none at all), but not with more. The inspection team declares a specific ICBM or SLBM for inspection, is quickly taken to the site and keeps the missile front section under constant visual observation until the process is completed. The inspection may be carried out at the launcher or in a separate building. The shroud is removed and a hard or soft cover is placed over the RVs. This process is not carried out within the direct sight of the inspectors, but is done in a way that guarantees that no RVs could have been removed. This cover must be of a size and shape that enables the inspection team to determine that no more than the allowed number of RVs could be present under the cover. All members of the team (ten inspectors) are permitted to observe the cover from all angles at fairly close range, but not to touch or photograph it. Thus the procedures are designed to enable inspectors to determine the maximum number of RVs that could be present on the missile, but not their precise shapes or details of their structures or mountings.

It is clear that the procedure above does not distinguish between nuclear and conventional RVs. This is not important in START because the Treaty counts nuclear and conventional warheads equally. If it is desired to count only *nuclear* RVs in a future agreement, the task is clearly more difficult. However, the START Treaty does provide at least the beginnings of how this could be done. The Joint Compliance and Inspection Commission has developed agreed procedures for determining whether an object on the front end of a missile, which could resemble an RV, is nuclear or not. The object can be removed and scanned with a portable neutron detector (He^3 tube, moderated with polyethylene). The detector is calibrated using an $Americium^{241}$/Lithium neutron source and the background measured. Under the INF Treaty, agreed procedures were also developed for neutron-counting to determine that a missile was a permitted SS-25 with one warhead, and not a prohibited SS-20 with three warheads. This was necessary because the Soviets deployed SS-25 ICBMs at former SS-20 IRBM bases.

Under START, it is also necessary to monitor the numbers of warheads on heavy bombers. Again, a specific number of warheads is attributed to each type of heavy bomber. Under a special "discounting rule," this number may or may not correspond to the number for which a heavy bomber is actually equipped, but there is no ambiguity regarding the maximum allowed for any specific bomber. The inspection team is allowed to inspect the bomb bay and any rotary or fixed ALCM launcher, if present, as well as attachment points on the wings. From the dimensions measured, along with information provided about both bombers and launchers during technical exhibitions, it is possible to determine that the allowed number of warheads has not been exceeded.

There is also a nuclear dimension to the verification of heavy bomber armament. Because nuclear-armed and conventionally-armed heavy bombers are counted differently and geographically separated, no nuclear armaments are permitted at bases for conventional bombers. Therefore, inspectors may take measurements, using the neutron detectors described above, in the weapon storage areas at conventional bomber bases to determine that no nuclear armaments are present. Because weapons such as ALCMs may be in containers in such storage areas, there are procedures for measuring the nuclear-shielding properties of any such containers.

Under the Moscow Treaty (SORT), life is more complicated. Although this Treaty has no verification regime at all (thus far), it is instructive to consider how it might be verified, since some of its features might be present in a future agreement. There are no “type rules” in SORT. Any particular missile or heavy bomber can have any number of warheads at any particular time, so long as the agreed overall aggregate is not exceeded. These numbers could change from day to day, so that it is not easy to say how much confidence would be gained from spot checks of actual numbers. Monitoring of START is greatly facilitated, not only by agreed counting rules, but also by quite extensive data exchanges, which give inspectors a clear expectation of what they should find on any particular missile or bomber. Deviations from the database, due to lags in notifications or other factors, are clarified by the host side in their briefings to inspectors at the start of the inspection.

The START Treaty is set to expire in December 2009. It could be renewed, but this is not the preferred position of the sides. Negotiations are underway for an agreement to replace START. It is not clear what verification measures will be agreed or what the relationship of a new agreement will be to SORT. In any case, it seems clear that the replacement agreement will have neither the reductions, nor the verification measures contemplated in this study.

Presumably, one would like to have a future agreement that is less complicated than START, but more amenable to verification than SORT. It is not appropriate to go into great detail here, but some guiding principles would be useful. Among these would be that there must be some OSIs, though one would not expect these to be sufficiently numerous as to be statistically significant. There should be a sufficient data exchange that the inspectors have some reasonable expectation of what they will find. It should also be such that the sides can make sense of what they learn from NTM. If only nuclear warheads are to be counted, there should be some geographical separation between nuclear and conventional warheads. For example, ICBMs with nuclear warheads should be based separately from those with conventional warheads. In the case of SSBNs with mixed loads, it should be known which tubes have which type of armament.

It is clear that monitoring a regime that allows no deployed warheads at all is a special case of the above. The concept of eliminating all deployed warheads was put forward in the article in the *Wall Street Journal* by Shultz, Perry, Kissinger, and Nunn on January 4, 2007. This was given a further boost in an important speech by former U.K. Foreign Secretary Margaret Beckett on June 25, 2007, in which she called for a renewed dedication to the goal of complete nuclear disarmament, together with serious new work on how to verify such a regime. The OSI procedures noted above would clearly be applicable to a regime which allowed deployed missiles and bombers, but without nuclear warheads. In principle, determining that there were no warheads would be easier than deducing the maximum number under a cover. Access to the front section of a missile and the bomb bay of a bomber would be sufficient. Of course, this would not guarantee that warheads could not be rapidly installed and, in fact, the sides might insist on such a capability as a hedge. Presumably, there would be some minimum distance between the deployed systems without warheads and the storage sites where the warheads were located. There are similar geographical constraints in START and these can be verified by a combination of NTM and OSI.

Monitoring Non-Deployed Nuclear Warheads

Monitoring *non-deployed* warheads has never been attempted in an arms control agreement. As reductions in deployed systems proceed, the numbers of non-deployed warheads are increasing and dealing with them is becoming more important. The numbers and locations of such warheads are classified, but there are clearly thousands on each side. The U.S. has announced that it will cut its stockpile in half by 2012, but without revealing what the number is now or what it will be when these reductions are completed. As long as deployed systems exist, there will be a need for some non-deployed systems. There should be declarations of the numbers of non-deployed warheads by systems. If the precise number is considered too sensitive, or is changing rapidly, the declarations could specify a range. The locations should also be declared. Counting these objects would be possible in theory, but difficult and intrusive in practice. As a minimum, there should be a right to challenge inspections to assure the sides that there are no illegal undeclared storage sites. Presumably, the evidence that such might be the case would come from NTM.

A *minimal* monitoring system could involve declarations and perhaps a one-time visit to storage facilities to establish a baseline. Much more intrusive arrangements can also be envisioned. It would be possible to establish a PPCM system at what would presumably be a small number of storage sites. The sides have excellent experience with such systems under the INF and START Treaties. Under START, the sides are allowed up to 30 monitors at a PPCM site. They do not enter the site, but have complete access to the perimeter at any time and can examine items leaving the site that have dimensions such that they could be a controlled item. The small size of warheads could make this a burdensome task, but traffic into, or out of, a facility that only stores warheads should be light. The warhead containers could be tagged and/or could contain a unique identifier. Nuclear detectors could be used to verify that the container did contain nuclear material consistent with a warhead. Experience with designing the Russian Mayak facility would be quite helpful. However, the problems with monitoring and access which arose in connection with this project also illustrate that it may not be possible to establish a highly intrusive system.

One possibility that would avoid extreme intrusiveness would be to establish radiation portal monitors at the entry/exit points of the storage facility. These could resemble the portals now being used at U.S. border crossing points. Because these could be relatively large, they could be more sophisticated than handheld devices. They could be designed to detect both neutrons and gamma-rays. The detectors themselves could be NaI, activated with 1% thallium, and He^3 gas tubes. These would not require cooling. The high false alarm rates experienced by similar devices at U.S. border crossings, due to agricultural products, ceramics, people with radioactive isotopes in their bodies following medical procedures, etc., should not be a major concern at a warhead storage facility. Each type of warhead could be measured to establish a baseline radiation signature or template. The host side should declare each incoming or outgoing warhead and the portal monitor should be able to confirm this declaration. Accurate logs of all movements of warheads into and out of the facility would be essential. In general, however, while Pu should generally be detectable, HEU may not be, due to its much lower activity.

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

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

It is clear that monitoring non-deployed *tactical* nuclear warheads would be quite similar. However, this task would be complicated by the smaller size and portability of such warheads, as well as the fact that we would be starting with a less reliable intelligence baseline. In any case, the prospects for a negotiation on tactical nuclear weapons in the near future do not appear bright.

Monitoring Virtual Nuclear Warheads

Monitoring "virtual" or "latent" nuclear warheads will become increasingly important as countries gradually shift away from operational, deployed forces. Such forces would be similar, but not identical to, those considered "non-deployed" as discussed above. In START, there are systems which have legitimate purposes which are separate from the operational deployed forces, but which have the potential to circumvent the central limits on these deployed forces. Examples are systems used for spares, testing, training, space launch, static displays, etc. These are not counted in the central limits, but are subject to a variety of specific numerical and geographical constraints to limit the possibility that they could be used for hostile purposes. Some of these systems—for example, those used for space launch at designated space launch facilities—should not carry warheads at all. Others—for example, missiles used for testing at designated test ranges—must be allowed to carry dummy warheads.

In order for the concept of virtual forces to be effective, serious consideration must be given to how to define such forces and to verify, at least to some degree, the numbers, locations, and status of these forces. One could then focus on the actual number of warheads in existence, along with the credible capability of the *deployed* delivery force to deliver them. As noted above, while it seems necessary to require declarations of at least the approximate numbers of virtual nuclear *warheads*, verifying these numbers would be very challenging. It might not even be desirable to try (beyond the use of NTM), since any use of OSI would require revealing the locations of these warheads, which in turn would compromise their survivability. Thus, it becomes important to control the *delivery vehicles* on which these warheads could be deployed. These would be fixed and mobile ICBM launchers, SLBM launchers, and bombers. The missiles themselves should also be included. Under the START Treaty, we have extensive successful experience in monitoring non-deployed missile launchers, missiles, and bombers.

Assuming that the primary virtual limit is on *warheads*, there might be no limits *per se* on missiles, launchers, and bombers, but the numbers of such systems must be consistent with the limit on virtual warheads. As an example, if a side declared that it had 1000 virtual ICBM warheads, the capacity of its ICBMs and ICBM launchers should not be wildly in excess of what would be required to deliver these 1,000 warheads, since the 1,000 warhead number itself will probably not be effectively verifiable. A further complication is that one must take into account more than just missiles, launchers, and bombers in storage, mothballed, or otherwise non-deployed. If, as seems highly likely, some portion of the reductions is achieved through "downloading," the capacity of the still-deployed forces should also be taken into account. Thus, if a type of missile which previously was tested and deployed with 10 warheads has been downloaded to, say, 5 warheads, it would be logical to require that the additional 5 warheads that could be reinstalled on it should be counted in the virtual force. One might decide to count in this way even if the 5 downloaded warheads had been dismantled, since the capability would remain and it could not be ruled out that 5 additional warheads were available or could be readily produced.

Another way of posing the issue is to ask whether virtual warheads are simply all existing warheads which are not deployed, or, alternatively, virtual warheads represent the capability of the existing launchers, missiles, and bombers to deliver warheads beyond those warheads actually deployed. The former would be easy to define, but hard to verify. The latter might be difficult to agree upon, but relatively straightforward to verify once the counting rules were established.

There will clearly be definitional issues to be solved. For example, should missiles and launchers at test ranges and space launch facilities be considered part of the virtual force? What about systems scheduled for dismantlement? Following the example of START, one would probably decide that such systems with legitimate roles would not be considered part of the virtual force. However, this judgment could change as reductions drive the numbers of deployed forces to very low levels. Dealing with bombers could be particularly complicated because of their inherent dual capability. In START, "discounting" rules count the warheads attributed to certain bombers far below their actual capacity. Heavy bombers equipped for non-nuclear arms, training heavy bombers, and former heavy bombers are not counted in the central limits at all, but are subject to an aggregate limit of 75 units. In SORT, the U.S. has taken the position that any heavy bombers it unilaterally declares to be conventionally armed will not count, which will exclude about 100 B-1 and B-2 heavy bombers. In a world with limits on virtual warheads, it seems unlikely that this would be accepted at face value by other countries, without some convincing proof that these bombers could not carry nuclear weapons. Another consideration is that, as levels come down, the fact that bombers of lesser ranges can also deliver nuclear weapons will likely come into play.

In all of these cases, the amount of time and modification required to return virtual forces to operational status will be relevant in deciding what should be included in the virtual force. None of these issues should be insuperable, but it is clear that serious thought, negotiation, and compromise will be required.

Monitoring the Disassembly/Dismantlement of Nuclear Warheads

This is clearly the most intrusive and most difficult task related to warheads. Some work was done in connection with the 1997 Helsinki Framework, which did envision such monitoring. A prime consideration is the legal barriers which exist on both sides, some of which also apply to the previous section. For the U.S., the 1954 Atomic Energy Act, as amended, requires a special agreement for sharing stockpile information with other nations in support of a program for the control and accounting of nuclear weapons and fissile material, as well as other weapons material. In addition, certain guarantees would be required regarding the protection of such information. There appear to be similar legal requirements on the Russian side.

A successful regime should provide for declarations of the numbers of warheads in retired status and those designated for retirement, along with their locations. A dismantlement schedule should be created, along with notification of warheads actually dismantled, by number and type. For completeness, one would presumably also need information on weapons-grade fissile material not in nuclear weapons—for example, in naval reactors, research reactors, and space systems. It is clear that there is some overlap with a Fissile Material Cutoff Treaty, which has its own set of problems.

A further difficult problem concerns how one can be assured that the fissile material presented actually came from a nuclear weapon. In theory, a system of seals, tags, and intrusive OSI could verify the origin and chain-of-custody of the material. Whether this is achievable in practice, and whether it is really necessary, are open to question. On the technical side, the Trilateral Initiative among the U.S., Russia, and the IAEA led to the concept of an "information barrier." The objective would be to determine that objects in containers have certain attributes of nuclear weapon pits. The device would use gamma spectrometry to detect the presence of Pu, high-resolution gamma spectrometry to determine that the object contains at least a threshold ratio of Pu^{239} to total Pu and neutron multiplicity counting to determine the presence of at least a threshold mass of Pu. The answer would be indicated by a red or green light, showing whether or not the object met the criteria, but without revealing sensitive design information, such as shape or specific isotopic composition. Although all three parties seemed pleased with the technical progress made, the Trilateral Initiative has stalled. The reasons for this are not entirely clear, though the legal issues noted above may be part of the problem. In any case, the effort should be revived, since success seems crucial to any attempt to monitor and control the dismantlement of nuclear warheads.

Efforts should also be resumed to consider how inspectors could be granted access to sensitive disassembly/dismantlement facilities—e.g., Pantex on the U.S. side. Monitoring the final disposition of fissile material, whether as reactor fuel, vitrification or by some other method is beyond the scope of this paper.

As reductions proceed, things may fall into place faster than we can now anticipate. On the other hand, verification and compliance problems may arise that will make further reductions politically difficult. Thus, it might be wise to plan for strategic pauses or plateaus to assess how well we have designed the verification regime and to make adjustments as necessary.