CHAPTER 12

NUCLEAR WARHEADS AND WEAPONS-GRADE MATERIALS

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The nuclear weapons limitation and reduction process that Russia and the United States began over 20 years ago after the prolonged and fierce confrontation of the Cold War has by necessity included transparency and verification measures, usually drafted and implemented to provide both sides evidence and confidence that agreed-upon cuts in nuclear weapons within the framework of mutual nuclear deterrence would not upset the strategic balance. At the same time, the application of such measures has gradually worked to build mutual trust in matters of control over nuclear weapons and weapons-grade fissile material. In addition, the use of transparency and control measures during the nuclear arms reduction process has effectively supported and reinforced the nonproliferation regime.

Transparency and verification measures in U.S.-Russian nuclear arms reduction agreements have related primarily to delivery means: intercontinental ballistic missiles, submarine-launched ballistic missiles, and strategic bombers. For such purposes, both national technical means of verification and various inspection regimes have been used. However, these agreements have lacked transparency measures with respect to nuclear munitions, their elimination, or the nuclear materials they contain.

Using national technical means to control nuclear munitions would be impossible because of their rather small size. Such control could only be made to work with an adequate level of confidence through on-site inspections of the production (dismantlement) facilities, storage facilities, and delivery vehicles. However, the fact that the development, production, and maintenance of such weapons are held under the most closely-guarded secrecy precludes the use of the mechanism of inspection. Clearly, foreign inspectors would not be granted access for nuclear munitions verification unless a sufficiently high level of trust has developed between the respective countries.

For deep cuts to be made in U.S. and Russian nuclear weapons and for other nuclear states to be engaged in this process, international stability and security must be preserved. The participants in the process must be confident that none of the sides have hidden or removed from accountability even a small portion of their nuclear munitions or weapons-grade materials. Thus, the issue of transparency for nuclear warheads and nuclear materials has become one of the most pressing problems, requiring a practical solution.

It will take thorough and comprehensive study to apply transparency measures to nuclear munitions arsenals and nuclear materials. Obviously, each side's approach to this issue will depend on the laws and standards that regulate the handling of nuclear munitions and weapons-grade fissile materials. That means that any agreement would need to overcome not only the inadequate degree of trust between the two sides, but also differences in legislation and in definitions of what constitutes sensitive information. In this context, the experience of previous U.S.-Russia agreements controlling nuclear munitions and weapons-grade materials and their technical implementation measures would doubtless be of interest.

Elements of Transparency For Nuclear Munitions in Nuclear Arms Limitation Agreements

The first strategic offensive weapons limitation agreements (the Strategic Arms Limitation Treaty (SALT I) of 1972 and SALT II of 1979) did not broach the issue of nuclear warhead transparency. This was essentially a result of the state of relations between the two countries at the time, characterized by deep suspicion and mistrust, along with numerous political and technical reasons.

The first limited warhead transparency measures were developed and implemented for the Intermediate Range Nuclear Forces Treaty (INF Treaty) of December 1987, under which the United States and the Soviet Union agreed to eliminate all ground-launched missiles having ranges between 500 and 5,500 kilometers. The missile front sections, including the warheads without their nuclear explosive charges, were to be destroyed at designated sites.[1]

However, the only procedures specified for eliminating these warheads were to either crush (flatten) their launch canisters or destroy them with explosives, while the issue of disposing of the warheads' nuclear cores, their nuclear explosive charges (removed from the warheads before the missiles arrived at the elimination site), was not addressed. The launch canisters were to be destroyed under the supervision of inspectors, who would first record the types and numbers of weapons being eliminated before witnessing the elimination process and preparing their inspection reports.

From the very start of the negotiations, the Soviet side had expressed its desire to convert some of the missile bases previously used for the SS-20 missile (which had fallen under the terms of the INF Treaty) into bases for its mobile intercontinental SS-25 missile. For its part, the United States expressed concern that deployment of the SS-25 missile in closed launch containers could allow the Soviet side to avoid destroying some of its SS-20 missiles. Following protracted negotiations, the Soviet side agreed to allow U.S. inspectors to use radiation-monitoring equipment to measure the neutron intensity emitted from the SS-25 launch containers.

The purpose of these controls was to confirm that the SS-25 ICBMs did not have the same front section as the SS-20 missile, since radiation readings for a container holding a missile armed with a single warhead (SS-25) would differ from readings for a container holding a missile armed with three warheads (SS-20). If the measured neutron intensity matched a reference reading, the inspectors would be able to confirm that these containers actually held SS-25 missiles. If there was more than a 50 percent divergence between the measurement results and the reference readings, a procedure was to be followed for opening and visually inspecting the missile transport/launch container to confirm that it was not an SS-20.

Under START I, transparency measures applied only to the warheads of strategic delivery systems.

Under this Treaty, the two sides exchanged information on the number of warheads on their deployed ICBMs, SLBMs, and bombers. In accordance with START I, the parties were prohibited from launching or deploying ICBMs with more warheads than assigned to them. Numbers of ballistic missile warheads were to be verified at launch, using national technical verification means to count the number of warhead separation operations during each launch and confirm that they did not exceed the number of warheads assigned to that missile type.

In addition, START I provided for inspections to confirm that the ICBM and SLBM missile front sections did not contain more warheads than the number allocated to them. No more than 10 such inspections could be carried out each year, with each inspection focusing on no more than one missile (ICBM or SLBM). The inspections would consist of visual examination of the missile front section lasting no longer than 15 minutes and carried out from a fixed location designated by the side under inspection to be located no further than five meters away from the missile and having a clear and unobstructed field of view. Prior to the visual inspections, the side under inspection was entitled to cover its warheads and other equipment located on the bus with a flexible cover in such a way as to avoid interfering with the inspection.

The equipment in the front section exclusive of the warhead was to be demonstrated by the side under inspection in such a way as to convince the side conducting the inspection that these items were in fact not warheads. The side conducting the inspection was entitled to use radiation detecting equipment to ensure that the items declared as non-nuclear were in fact non-nuclear.

Both sides repeatedly filed complaints against each other during the process of implementing the START I nuclear warhead control measures, which demonstrated that these measures were far from perfect. It should also be pointed out that the START I Treaty provided no measures for verifying nuclear weapons on strategic bombers and the warheads removed from decommissioned delivery vehicles.

U.S.-Russian Cooperation in the Development of Transparency Measures 1994-1998

During the Presidential Summit of January 1994, the United States and Russia agreed to set up a joint working group to "consider ...steps to ensure the transparency and irreversibility of the process of reduction of nuclear weapons."[2] A Working Group on Nuclear Safeguards, Transparency, and Irreversibility was formed and began work in May 1994, with an agenda that included discussion of such issues as the potential for concluding cooperation agreements, sharing information on nuclear warheads and nuclear materials, holding selective inspections to verify the validity of such information, and for arranging and carrying out joint inspections.

The cooperation agreement was to have provided for an exchange of information between Russia and the United States on nuclear munitions that was secret under the laws of both countries and to guarantee the continued secure handling of this information. This agreement was to have created a new basis to successfully pursue the whole initiative on the transparency and irreversibility of the process of reduction of nuclear weapons. This information sharing on total numbers of nuclear warheads and nuclear materials and the possibility of selective verification of such information had the aim of providing the two sides with a basic foundation for a future transparency regime.

However, before arranging or carrying out joint inspections, U.S. and Russian experts were to cooperate in the development of non-intrusive measures to verify the dismantlement of nuclear munitions. The purpose of such measures was to confirm that the declared containers exiting the nuclear munitions dismantlement facility contained parts made of highly-enriched uranium or weapons-grade plutonium matching the weight and shape of the dismantled warhead components. Working in this area, between 1994 and 1995, U.S. and Russian experts developed and demonstrated a number of promising new methods for exercising control over such dismantlement activities.[3]

However, despite the importance attached to achieving progress in increasing transparency and irreversibility of the nuclear weapons reduction process in subsequent Joint Statements by the presidents of the Russian Federation and the United States of America (September 1995 and May 1995),[4] by the autumn of 1995 discussion of this issue between the two sides had reached a dead end.

According to U.S. experts in the working group, one of the reasons was the lack of interest on the part of the Russian agencies (in particular, the Ministry of Nuclear Energy and the Ministry of Defense) in pursuing negotiations on transparency and irreversibility.[5] The impending Russian presidential elections also played a negative part, since they distracted the administration of President Boris Yeltsin. At the same time, the transparency and irreversibility issues failed to duly capture the attention of senior U.S. administration officials due to the complexity involved.

It must be noted, however, that the subject was never completely dropped, and reappeared in the agreement reached during the Helsinki U.S.-Russia Presidential Summit of March 21, 1997. The two sides agreed that the number of basic elements of a future START III agreement should include “measures relating to the transparency of strategic nuclear warhead inventories and the destruction of strategic nuclear warheads and any other jointly agreed technical and organizational measures to promote the irreversibility of deep reduction. ...The Presidents also agreed that in the context of START III negotiations their experts will explore, as separate issues, possible measures relating to ...tactical nuclear systems, to include confidence-building and transparency measures."[6] The two sides further agreed to study questions related to transparency for nuclear materials.

Approaches to Nuclear Weapon Transparency by the Two Sides

It is important to note that the two sides developed substantially different approaches in the 1990s to discussions of transparency for nuclear warheads and nuclear materials. The United States considered it imperative that as much information as possible be obtained and that comprehensive verification be established for the entire arsenal of nuclear warheads and weapons-grade fissile material, as shown in the draft text of an agreement on data sharing on the two nuclear arsenals that the United States submitted to Russia in the summer of 1995,[7] in which the U.S. side proposed the following:

- exchange of data on the numbers and deployment locations of all nuclear warheads and their fissile components, including quantities, types, and serial numbers of warheads produced and dismantled at each serial facility over the years of its existence;
- exchange of quantitative data on the annual production of fissile materials at each facility, including the degree of enrichment and composition.

In order to confirm the validity of the information submitted, it was proposed that selective inspections be carried out on-site, with a verification mechanism organized for the process of dismantling the nuclear munitions, removing, and subsequently recycling the fissile material.

As follows from the text of the joint statements, Russia supported efforts to develop transparency measures for existing inventories of strategic nuclear munitions, for the process of eliminating the strategic nuclear munitions slated for reduction, and for the weapons-grade materials deemed superfluous to national security needs. However, Russia's interest in nuclear munitions transparency was motivated primarily by its desire to see the verified elimination of the U.S. ability to redeploy warheads ("upload potential") that it was getting under START II. This is why the Russian experts had wanted to establish a transparency regime that included only those strategic nuclear munitions (both deployed and in reserve) that were destined for elimination under the new nuclear weapons reduction agreements once these came into effect.

The Russian experts felt that a transparency regime for strategic offensive weapon warheads and their surplus weapons-grade fissile material should include the following primary components:

- initial declarations by the states party to international agreements detailing the parameters of their nuclear weapons and surplus fissile material subject to the transparency regime;
- periodic updates to the information contained in the initial declarations;
- a system of mutually-agreed measures to include mutual inspections of dismantlement sites for the nuclear munitions under reduction and of storage facilities for the weapons-grade nuclear components extracted from them so as to check the completeness and accuracy of the information contained in the initial declarations and their periodic updates.

The Russian approach was based upon the premise that the only measures needed were those aimed at confirming the actual dismantlement of the decommissioned nuclear weapons and the proper treatment of the surplus fissile material; however, such measures should not relate to any engineering, technological, or other information not directly connected to the process of reducing nuclear munitions. They should also be non-intrusive, i.e., be based only upon open, unclassified information. Finally, it was thought appropriate to start with only a limited system of measures, to be gradually expanded over time as the international climate improved and further trust developed between Russia and the United States.

Thus, although both sides agreed with the transparency regime's objectives and implementation mechanisms, they had differing approaches to defining its scope. For example, the categories and volumes of data that the U.S. side proposed for information exchange went well beyond what the Russian side was willing to agree to.

The Russian approach assumed that the transparency measures would be expanded gradually, while the U.S. approach strove to apply such measures to the entire nuclear weapons complexes of both sides to the maximum possible extent. These divergences in approach, as well as the negative impact on the full spectrum of bilateral relations that had been caused by NATO expansion and the debate in the United States over the merits of keeping the ABM Treaty, prompted the Russian side to leave the talks in 1999.

The Organizational and Technical Aspects of Transparency For Nuclear Munitions Dismantlement in Studies by U.S. and Russian Experts

Obviously, it would not be possible to achieve agreement on a transparency regime for nuclear munitions without first developing potential technical approaches for accomplishing it in practice. In order to establish the scientific and technical basis for making the corresponding political decisions, the U.S. and Russian sides both initiated programs to study the technical aspects of transparent nuclear munitions dismantlement.

The U.S. Department of Energy conducted a special study and produced a report evaluating the ability and preparedness of the nuclear military-industrial complex to implement measures of transparency and control over warhead dismantlement.[8] Among the participants in the study were representatives of national nuclear laboratories and nuclear warhead production facilities.

One of the goals pursued by the researchers was to establish whether an agreement on cooperation (sharing classified information) was actually necessary for the verifiable elimination of warheads. Another goal was to assess the ability to reliably confirm the dismantlement of the various types of warheads, both strategic and tactical. Moreover, the scope of the verification procedures was also examined: would it be sufficient for them to be conducted only at U.S. Department of Energy facilities, or should those delivery vehicles, storage sites, and bases that are under Department of Defense control also be included?

It was assumed that the verification procedures would only apply to warheads that had been declared as superfluous to the interests of defense, and that the activities of the nuclear military-industrial complex in maintaining the existing nuclear arsenal would not be subject to verification.

According to the study, the key control and verification activities conducted at the Pantex plant were as follows:

- declaration of the schedule for dismantling the munitions and components resulting from their disassembly;
- spot checking of documentation for the munitions, their storage locations, and the storage locations of their components;
- remote monitoring of the munitions, their storage locations, and the storage locations of their components;
- escort of munitions and components from storage to dismantlement site;
- continuous surveillance of the perimeter of the dismantlement facility's secure zone with accountability for every item delivered or removed;
- escort of munitions and components through the dismantlement area;
- pre- and post-dismantlement inspection of the dismantlement rooms;
- remote monitoring or direct observation of the dismantlement process;
- escort of nuclear components extracted during the munitions dismantlement process from the dismantlement area into storage;
- control over the recycling of non-nuclear components of the munitions (explosives, electronics, etc.) after the dismantlement has taken place.

Various options were considered and evaluated for the verification of dismantlement based on different combinations of key operations. Among the criteria for evaluation were the following: the level of certainty that the dismantlement has actually been performed; the potential for inadvertent loss of classified data; the impact upon the regular operation of the facility; the potential that an agreement could be achieved with the Russian side; and the cost of preparing for the inspections and of carrying them out. The results presented in the report indicated that the best option would include control measures over the munitions and/or their components starting at the storage facility and continuing through their escort from storage to the dismantlement area and back again (with additional accompaniment of the munitions and their components through their dismantlement locations).

The participants in the study arrived at a number of interesting conclusions. In their opinion, by combining a certain set of proposed verification measures, a moderate level of confidence could be established in the munitions dismantlement processes without the need to conclude an agreement on classified information disclosure; however, any control measures for nuclear weapons, their dismantlement, and fissile materials would heavily impact operation of the entire nuclear weapons branch of the Department of Energy. The most difficult part of the assignment involved confirming that the object arriving at the dismantlement plant was actually a nuclear weapon. This stimulated the development of escort procedures that began at the Department of Defense facilities and relied upon the use of radiation profiling of the warheads and their components.

The Russian specialists developed the following key stages in the life cycle of nuclear munitions slated for reduction during the process of transparent dismantlement and recycling of extracted nuclear material:

- removal and transfer of a nuclear warhead to the repair and engineering base;
- dismantlement of the warhead and preparation for transport;
- transport of the containers with warheads to the facilities for their dismantlement;
- dismantlement of the nuclear warheads and removal of their components containing weapons-grade nuclear materials; preparation of these components for transport to temporary storage sites;
- transport of the weapons-grade component containers to temporary storage sites;
- storage of the containers with weapons-grade components;
- transport of the containers with weapons-grade components to conversion facilities for processing into unclassified types of nuclear material;
- processing of the weapons-grade nuclear components into unclassified forms and preparation of the processed materials for long-term storage;
- transport of the containers with processed material to their permanent storage locations;

- storage of the containers with processed material;
- transport of the containers with processed material to the recycling sites to be subsequently converted into fuel or other materials unsuitable for use in nuclear weapons.

It was assumed that every step of the nuclear weapons dismantlement process would be tracked by a detailed paper trail, including the documentation for the specific weapon, route chart records, and so on.

This approach was broadly similar to the U.S. study and its conclusions described above. As their U.S. colleagues had concluded before them, the Russian experts also felt that it was essential to establish confidence in the fact that an object removed from a delivery vehicle or from the arsenal that had passed through all of the dismantlement stages was in fact a nuclear device, and that it was the fissile material from this specific device that was being put into storage. This requirement was particularly necessitated by the fact that the arsenals of both Russia and the United States had warheads of various classes, differing construction, and with varying quantities of fissile material.

The first joint discussion of the subject of transparency in dismantling nuclear munitions was held between U.S. and Russian nuclear experts at the end of 1995 in Snezhinsk. These talks resulted in the signing of a joint research contract between the All-Russian Research Institute of Technical Physics and Sandia National Laboratories.[9] Subsequently, once the All-Russian Research Institute of Experimental Physics in Sarov, the Nikolai Dukhov All-Russian Research Institute of Automatics, and the All-Russian Research Institute for Pulse Technology in Moscow had joined the effort, this joint project between U.S. and Russian nuclear centers became known in the United States as the Lab-to-Lab Program.[10]

The primary goal of the project as stated by the U.S. side was to initiate and maintain a technical dialogue with the Russian expert community and through this dialogue to create spearhead groups to advance the efforts toward transparency of Russia's nuclear defense complex.[11] The tasks of the program were as follows:

- define the process of dismantlement of nuclear munitions;
- identify and demonstrate the technical means that could be used to confirm actual dismantlement;
- identify measures to ensure control over the munitions during the entire process from dismantlement to storage of their nuclear materials;

- identify the technical measures required for transparency during the storage of plutonium and highly-enriched uranium.

Due to this topic's extreme sensitivity, laboratory studies focused exclusively on hypothetical dismantlement scenarios, identification of the potential technical means for ensuring transparency, and development of computer models for the munitions dismantlement process. The program consisted of four stages, the last of which assumed that a joint approach could be found to ensure transparency in dismantling nuclear munitions, and that the technical means thus developed could be demonstrated at the Russian nuclear munitions production/dismantlement facilities. Following development and testing, the various technical approaches to implementing the transparency regime could then be recommended to the governments of the two countries and included in future agreements on nuclear arms reduction.

By 1998, research under the next-to-last (third) stage of the program was approaching completion. At joint U.S.-Russian seminars in Snezhinsk and Sarov in April through May 1998, Russian experts demonstrated the methods they had developed for radiation monitoring of the isotope composition and mass of the fissile material and for diagnosis and destruction of the explosives in the munitions, as well as verifiable destruction of warhead casings. The experts had largely worked out a framework for monitoring the process of dismantlement of nuclear munitions and had considered and proposed possible technical and organizational measures to increase confidence in the fact that the dismantled items actually were nuclear munitions. These achievements offered the hope that a system of transparency would be developed and tested in prototype by 1999.

However, the Lab-to-Lab program never made it to its fourth and final stage. According to U.S. participants, this was due to the Helsinki Agreement of 1997, which drew the attention of the Russian Federal Security Service (FSB) to the project. In November 1998, at the insistence of the FSB, work under this program was halted, and its goals and content were submitted for interdepartmental review.[12] After that, it was never resumed.

Potential Measures and Scenarios For the Practical Implementation of Transparency in Nuclear Munitions Dismantlement

As noted above, a critical goal in applying transparency to nuclear munitions is to guarantee the authenticity of the decommissioned nuclear munitions subject to controlled dismantlement. However, this goal could be met by using a number of technical methods for identifying the nuclear munitions. The process of identifying the warheads removed from their delivery vehicles might proceed as follows: in the presence of inspectors, the warheads are placed into special transport containers; these containers are then marked and each fitted with a device for indicating unauthorized access.

Additional guarantees of the authenticity of the nuclear munitions could come from a radiation profiling process to record the passive spectrum of their gamma emissions and neutron flow characteristics. Both U.S. and Russian experts have demonstrated the feasibility of such a method.[13] The measurement results (or radiation logbook) obtained under this method are recorded and stored in some type of archival medium by the monitoring side. During inspection of the munitions as they enter the dismantlement or storage facility, they are subjected to the same types of measurement using the same equipment and under the same conditions as for the original measurement, after which the new results are compared to the earlier ones to ascertain the unit's security and authenticity. The radiation profiling process may be accompanied by information barrier technology to avoid measurement intrusivity.[14]

Confirming the authenticity of warheads would likely be especially important in cases when they have not been removed from their delivery vehicles in the presence of inspectors, but are already located at the storage facility. The monitoring side may suspect that such units are dummy warheads containing a lesser amount of fissile material. This would also be a situation where the radiation profiling method could be used. In order to do so, the inspecting side should be allowed to conduct radiation measurements on a number of randomly-selected weapons of the same type removed from their delivery vehicles and placed into containers. Comparison of the radiation profiles of munitions arriving from storage for dismantlement and weapons removed from their delivery vehicles using the agreed-upon methodology should allow the inspecting side to establish that no deception has taken place.

The use of radiation profiling and unique individual markings on munitions containers would allow the process of transparent dismantlement of nuclear weapons to be structured of the following three stages:

During the first stage, the two sides would declare and monitor their surplus nuclear munitions and locations. Then, in the presence of inspectors, the nuclear munitions designated for controlled dismantlement would be removed from their delivery vehicles or from storage and placed into containers, which then would receive unique individual markings. These containers would be fitted with devices to prevent unauthorized access. If necessary and agreed, the monitoring side would also record the radiation profile. Subsequently, the nuclear munitions would be moved either to a temporary storage facility or the dismantlement facility itself. During temporary storage, the uniquely-sealed containers could be subjected to random checks.

Stage two would begin with the arrival of nuclear munitions at the entrance of the dismantlement facility, where the monitoring side would check the container markings and the access protection device, and would take and compare radiation profile readings for the particular nuclear munitions. Inspection would also be allowed of the rooms at the facility both before and after dismantlement to insure that there are no hidden areas within the confines of the facility. Radiation profile readings and markings could also be used during intermediate shifts of the containers and their fissile material components around the facility.

During stage three, the non-nuclear components extracted from the nuclear munitions (explosives, electronics, etc.) and warhead casings would be disposed of and submitted to the monitoring side in such a way as to maintain the secrecy of sensitive information. The containers and their fissile material components would pass through a verification check as they exited the facility and would be marked by the receiving and monitoring parties. Among the parameters that could be checked might be non-intrusive confirmation that the materials within the container are of weapons-grade quality. Subsequently, the containers could be sent to storage or (if their final disposition has been decided) to a conversion facility, where they would be subject to entry controls.

Verification of Fissile Materials Declared Superfluous to Defense Needs

For irreversibility to be achieved in the nuclear weapon reduction process, the two sides, in addition to their political obligations, would also have to institute bilateral measures of transparency for the surplus fissile material extracted during the nuclear munitions reduction process and dismantlement. The amount of this material extracted under the START I cuts was quite significant. Russia, for example, quoted a figure of 500 tons for its surplus highly-enriched uranium (HEU);[15] the United States declared 178 tons of surplus HEU.[16] With respect to plutonium, Russia and the United States reached an agreement in September 2000, under which each side committed to irreversibly utilize 34 tons of surplus weapons-grade plutonium. Both sides have by now gained considerable experience with transparency in the recycling of surplus fissile material, which may be of use in verifying the irreversibility of deep nuclear weapons reductions.

In February 1993, Russia and the United States concluded an Intergovernmental HEU Agreement (the HEU-LEU Agreement) for recycling the HEU extracted from decommissioned Russian nuclear munitions. Under this 20-year Agreement, 500 tons of Russian HEU was to be diluted to a level of four or five percent of the U-235 isotope and then shipped to the United States to be converted into commercial nuclear reactor fuel. The two sides also signed a Memorandum concerning the implementation of transparency measures to ensure the following:

- the HEU subject to the Agreement actually had been extracted from the nuclear weapon, and it was specifically this HEU that was being sent to the oxidation installation;
- the stated quantity of HEU actually had been reduced to LEU levels;
- the HEU delivered to the United States actually had been used to manufacture commercial nuclear reactor fuel.

Under this Memorandum, each side was entitled to send its observers to the facilities in the other country to observe the process of uranium sampling for technical analysis and the placement of seals on the containers. U.S. inspectors received the right to observe the manner in which the extracted HEU was being sent to the oxidation or fluoridation facility, as well as the way HEU was poured from testing vessels into transport containers; they also had the right to observe the loading and unloading of the uranium during down-blend, including the way the Russian operators measured the mass, chemical makeup, and isotopic and natural compositions of the HEU. Russian inspectors were to have the right to observe the way the Russian HEU was being introduced and removed during its conversion into fuel at the U.S. production facilities.

In March 1994, Secretary Hazel O'Leary and Minister Victor Mikhailov signed a protocol on HEU-LEU Agreement transparency measures for the purpose of implementing the Memorandum's provisions.[17] The protocol listed the following facilities as being subject to monitoring:

- the Urals Electrochemical Integrated Plant (UEKhK) and the Siberian Group of Chemical Enterprises (SKhK), where metal HEU extracted from the nuclear munitions was oxidized;
- the Zelenogorsk Electrochemical Plan (ZKhK), UEKhK, and SKhK, where the HEU oxides are fluoridated into uranium hexafluoride and subsequently diluted;
- the Portsmouth Gaseous Diffusion Plant, as well as plants in the states of North and South Carolina, Virginia, Missouri, and Washington, belonging to Westinghouse, General Electric, Babcock & Wilcox, Siemens, and Combustion Engineering.

Between 1994 and 1996, Russian and U.S. experts developed a number of appendixes to the protocol regulating the monitoring procedures at these facilities.[18] In the framework of the implemented transparency measures, U.S. inspectors use portable equipment to carry out non-destructive verification of HEU enrichment levels at every stage of the LEU conversion process: upon arrival of the weapons-grade components at the SKhK plant, after rendering of these components into metal shavings, and during the process of fluoridating the shavings and converting them into uranium oxide.[19] Under this method of control, the material remains inside sealed containers throughout the process. At the UEKhK, SKhK, and ZKhK enrichment plants, U.S. inspectors observe the process of collecting samples from the blend-down pipes (weekly) and their laboratory analysis at the plant.

The experience accumulated in implementing transparency measures within the framework of the HEU-LEU Agreement indicates that they present no problems for relations between the two sides, which testifies to their reliability and credibility.

Transparency in Handling Weapons-Grade Plutonium Superfluous For Nuclear Weapons

In September 1993, the Russian Ministry of Nuclear Energy and the U.S. Department of Defense reached agreement on U.S. assistance to Russia in the construction of a facility for the storage of fissile material extracted due to nuclear arms reductions. However, a key condition was that the Russian side agree to implement transparency measures at this storage facility in order to confirm the following:

- the fissile materials in storage were recovered from dismantled nuclear munitions;
- the material was being safely and securely stored;
- no material removed from storage was reused for nuclear weapons.[20]

In March 1994, Secretary Hazel O'Leary and Minister Viktor Mikhailov issued a Joint Statement calling for the creation of a working group to develop a list of control procedures and future bilateral inspections of plutonium and surplus HEU extracted from dismantled nuclear munitions under current and future nuclear weapons reduction agreements. The political objective of these inspections (which were to be carried out at each country's weapons-grade fissile material storage facilities) was to guarantee that these components would never be used for the production of new nuclear munitions. From a technical point of view, the goal of such inspections was to give each side the ability to confirm that the sealed containers presented for inspection actually contained components of weapons-grade fissile material.

The primary goal of the working group was to coordinate a list of nuclear component inspection criteria and to determine the technical methods required for such inspections. At the same time, the procedures were to satisfy two mutually contradictory requirements: on the one hand, they were meant to provide the inspecting side with a high degree of confidence in the results; on the other, however, they were also meant to prevent leaks of information about the weapons-grade nuclear components.

Following consultations, the experts of the two countries concluded that sufficient confidence in the inspections could be provided if their methodology and equipment included the option of determining the Pu-240/Pu-239 isotope ratio and the shape and mass of the plutonium components.[21] Prototypes were also proposed and tested of the apparatuses for making such measurement while using information barriers to prevent the leakage of secret information.

Construction of the Mayak Fissile Material Storage Facility was completed in December 2003; its loading began in July 2006.[22] However, to the present day, the two sides have been unable to agree on a final list of verification procedures for the plutonium stored at the site. The U.S. side insists on being able to confirm that the stored plutonium is weapons-origin. The Russian side opposes this, since it would mean extending these controls beyond the bounds of the facility.

A more successful example of transparency measures being applied to weapons-grade plutonium comes from the Intergovernmental Agreement that Russia and the United States signed in 1997 concerning reactors that produce plutonium. This Agreement stipulates the closure of three Russian industrial reactors, two in Seversk and one in Zheleznogorsk. Although these plants had been generating only thermal power and electricity since 1993, they were also producing plutonium (without a corresponding defense contract). The United States promised financial aid to fund the construction of replacement capacities for these plants, while Russia promised not to use the plutonium from these reactors in its nuclear weapons. The two reactors near Tomsk were shut down in the summer of 2009; the reactor near Krasnoyarsk was closed in April 2010.

The Agreement contains a number of appendixes covering control measures, including control over newly-produced plutonium after January 1, 1997. The plutonium (as PuO_2) was placed in containers and sent to storage.

The Russian side gave permission for observers to enter the storage facilities in order to give the U.S. side confidence in the following:

- the amounts of plutonium in the containers matched the amounts declared;
- the plutonium was newly-produced;
- the containers with plutonium had not been removed from the storage facilities.

A joint implementation and compliance commission established formal verification procedures for the Agreement. The two sides relied on the Pu-240/Pu-239 ratio to confirm that the plutonium was obtained from low burnup fuel, i.e., as a product of processed industrial reactor fuel. Under the Agreement, this ratio may not exceed the threshold value of 10 percent. This verification procedure is based upon high-resolution gamma-ray spectroscopy and specialized software that uses information barriers. The results of these tests are displayed by a "yes/no" indicator.[23] The information provided by the Russian side on the age of the produced plutonium based upon the month and year of extraction is verified from the Am-241/Pu-241 ratio. This parameter was also measured using the high-resolution gamma-ray spectroscopy method that includes information barriers. The mass of plutonium in the sealed containers is verified using a combination of two measuring procedures: integral neutron detectors, used to measure the intensity of neutron emissions (which is proportional to the Pu-240 content), and gamma spectroscopy, used to determine the effective isotopic concentration of Pu-240 from the measured Pu-240/Pu-239 ratio. This methodology has proven its effectiveness in confirming that the amount of plutonium in the containers corresponds to the declared value.

Transparency and the Progress Toward a Nuclear-Free World

The idea of a world without nuclear weapons, which gained renewed popularity with the arrival of the Obama administration in the United States, boosted discussions on specific measures and approaches to achieve this. The U.S. and Russian commitment to this idea was noted in a Joint Statement that the presidents of the two nations released on February 1, 2009.[24] In a statement issued following the conclusion of the July 2009 G8 Summit in L'Aquila, Italy, the leaders of Britain, France, Russia, and the United States declared their willingness to work to "create the conditions for a world without nuclear weapons." The UN Security Council Resolution of September 24, 2009, calling for an end to nuclear weapons in the world, was also supported by China.

Obviously, the process of shifting to a world without nuclear weapons cannot be completed overnight. It will require considerable effort and time to reduce nuclear weapons, which in turn will only be possible in an environment of global security and stability, with a reduced role for nuclear weapons in maintaining national security. It can be said with some certainly that elevating the fears that a country might violate its international obligations and conceal a portion of its nuclear arsenal to keep it from being completely destroyed will be of particular significance for this process. Such fears can be minimized only by implementing effective and transparent verification mechanisms for reductions in nuclear weapons and weapons-grade fissile materials. In this context, the experience that Russia and the United States have accumulated in controlled reductions in nuclear weapons will be of particular relevance.

U.S. experts believe that the next stage in bilateral reductions of nuclear weapons following the recently concluded New START Treaty should include non-strategic nuclear weapons. The verified reduction of non-strategic nuclear weapons will require that controls be implemented over the actual nuclear weapons directly rather than their delivery vehicles, as, for example, is the case with strategic nuclear weapons.

As the overview presented above shows, the problem of achieving the verifiable destruction of nuclear weapons has proven extremely difficult (even for Russia and the United States, which have considerable nuclear arsenals). Even greater difficulties may be expected in the future once these countries begin to pursue deeper cuts (to the levels of 1000 and then 500 warheads) and to bring other nuclear nations into the process. This is primarily due to the need to protect design information, the requirement that the governments disclose the numbers of their nuclear weapons and amounts of weapons-grade fissile materials, and the obligation to have them inspected. Such declarations can be valuable as sources of some amount of basic information, but during deep reductions in weapons they would obviously still need to be verified.

In preparation for making such declarations, each nuclear-weapon state will need to conduct a comprehensive check of the data for its entire nuclear arsenal. To avoid deception, the declarations must contain as much information as possible. Ideally, they should contain the chronology of nuclear material production and recycling, their quantities, enrichment levels, and storage locations, as well as the total number of nuclear munitions and nuclear components available (broken down by type and including the fissile materials and amounts used for their production) and the exact locations of the munitions. However, some of this information (particularly the locations of storage facilities for the weapons) would be extremely sensitive. It could therefore hardly be expected that the nuclear states would agree to implement a transparency regime for their entire nuclear arsenal all at once.

As noted above, the elimination of nuclear weapons will need to be accomplished in stages. With this in mind, the optimal approach would appear to involve initial declarations of the total amounts of weapons-grade nuclear material that each nation has available, with the transparency regime applying only to the nuclear munitions that fall under agreements on the staged reduction of nuclear weapons (including nuclear munitions that have not yet been deployed or are slated for dismantlement), as well as weapons-grade fissile material that the governments have declared to be superfluous to their defense needs. Such an approach would enable the nuclear-weapon states to gradually gain experience in transparency during dismantlement of nuclear weapons, thus improving their efforts and minimizing the risk that one country or the other might conceal a portion of its nuclear arsenal. The IAEA's involvement in the process of developing a verifiable process of eliminating nuclear munitions and control over the fissile materials extracted from them could prove decisive. One point worth remembering is that U.S. and Russian experts have already worked with IAEA experts in the period between 1996 and 2002 to study potential methods for properly controlling weapons-grade components produced from fissile materials.[25]

Among the most crucial elements of the transparency regime are inspections, including inspections on short notice, which enhance confidence that both sides will meet their obligations in implementing the agreements. The goals of such inspections could include the selective verification of declarations to confirm that a particular location does contain the amount of materials and munitions declared. The experience that Russia and the United States (as well as the IAEA) have acquired from conducting inspections in South Africa and Iraq could prove useful in organizing such inspection activity in the future.

In conclusion, it must be noted that reliable verification of nuclear weapons reductions (up to the full elimination of such weapons) is an essential condition for the success of the nuclear arms control process. Verification becomes particularly important in the case of deep reductions, when even a small number of weapons escaping control measures would be capable of undermining the stability of the entire process. Resolution of this problem would require the development of organizational procedures and technical methods capable of ensuring verifiable nuclear weapons cuts.

It should further be noted that the current inadequate level of trust between the parties concerned makes them unwilling to provide general information on their arsenals or more detailed information about nuclear weapons or their components. Only by overcoming the mistrust toward other nations and applying the transparency regime to their own nuclear arsenals will they be able to establish one of the conditions under which irreversible nuclear weapons reductions could succeed. To create such a regime of trust will not be simple; however, as the history of U.S.-Russian cooperation has shown, when the issue has been the reduction of nuclear weapons (in which both sides have a vested interest and the political will), they have been able to find a way organizationally and technically to implement measures of transparency.

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