Science & Global Security, 1993, Volume 3, pp.223–236
Photocopying permitted by license only
Reprints available directly from the publisher

Printed in the United States of America

On the Application of IAEA Safeguards to Plutonium and Highly Enriched Uranium from Military Inventories

Thomas E. Shea[a]

INTRODUCTION

Progress toward the reduction of nuclear arsenals may render surplus hundreds of tonnes of plutonium and highly enriched uranium by the end of the century. None of the acknowledged nuclear weapon states (NWS) is under a specific obligation to submit surplus military inventories to international control. However, inviting the International Atomic Energy Agency (IAEA) to apply safeguards to the plutonium and highly enriched uranium (HEU) released from military use could contribute to building confidence as part of the reductions currently envisaged and could encourage further steps within the states currently planning reductions or by other NWS.

If invited, specific arrangements for the application of IAEA safeguards to plutonium and highly enriched uranium from military inventories would be determined by:

- The institutional provisions adopted.
- The specified verification requirements.
- The amounts and forms of plutonium and HEU and the types of facilities to be safeguarded.

a. International Atomic Energy Agency, Wagramerstrasse 5, P.O. Box 100, A-1400 Vienna, Austria. The views expressed are those of the author and do not necessarily represent the views of the IAEA.

- Facility-specific features for the control and accounting of the plutonium and HEU.
- The number of facilities where safeguards will be applied.

These considerations would be used to establish the most appropriate verification arrangements, including the technology to be employed and inspection scheduling arrangements, to provide effective and efficient safeguards.

If an invitation is made, the IAEA Board of Governors must approve of the obligations and commitments of the states involved and of the financial arrangements that will ensure the safeguards can be implemented as agreed.

INSTITUTIONAL ARRANGEMENTS

The IAEA could be invited to apply safeguards to plutonium and/or HEU from military inventories under a variety of arrangements. For the purposes of illustration, three cases are considered here: an expedient case, under an existing framework; an intermediate case, permitting control over future access and use of the transferred materials; and a framework under which the IAEA would have a specific role in the context of steps towards nuclear disarmament.

Under the provisions of Article III.A.5 of the Statute of the International Atomic Energy Agency, the Agency is authorized,

> To establish and administer safeguards designed to ensure that special fissionable and other materials, services, equipment, facilities, and information made available by the Agency or at its request or under its supervision or control are not used in such a way as to further any military purpose; and to apply safeguards, at the request of the parties, to any bilateral or multilateral arrangement, or at the request of a State, to any of that State's activities in the field of atomic energy.

IAEA safeguards are applied in states which are *members* of the IAEA, in accordance with one or more Safeguards Agreements.

Table 1 illustrates relevant provisions of the Voluntary Offer (VO) Safeguards Agreements for Russia and the United States. Similar VO Safeguards Agreements are in force for China, France and the United Kingdom. These Agreements were conceived well before the current political changes occurred. They were intended to enable the Agency to apply safeguards to facilities where inspectors would gain useful experience in applying safeguards in similar facilities in non-nuclear weapon states (NNWS). They also served to pro-

Table 1: Relevant provisions of existing Voluntary Offer Safeguards Agreements for Russia and the United States.

State	Scope	Objective	Withdrawal provision	Comments
Russia	The Preamble to the Agreement specifies that the Soviet Union has expressed its willingness to place under Agency safeguards some of its peaceful nuclear facilities, namely several nuclear power stations and nuclear research reactors. Also, the Soviet Union may add to or remove from the List of facilities from which the Agency may select, as the Soviet Union deems appropriate.	"the timely detection of withdrawal of significant quantities of nuclear material from facilities selected in accordance with Article 2(b) (of the Agreement), other than withdrawal carried out in accordance with the terms of this Agreement." (Article 28)	"the Agency shall be notified in advance, other than in exceptional circumstances," "any facility ... shall be removed from the List ... and the nuclear material contained therein shall cease to be subject to safeguards under this Agreement in accordance with and at the time specified in the notification by the Soviet Union." (Article 34(b))	The conditions of the Agreement could be used to apply safeguards to plutonium or HEU and/or HEU from military inventories. In this regard, it would be useful to incorporate an understanding that the facility(ies) involved could not be withdrawn without advance notification of, for example, six months prior to the withdrawal taking effect, the Board of Governors to be notified of such action.

Table 1: (cont.)

State	Scope	Objective	Withdrawal provision	Comments
US	The Preamble states that "the US will permit the Agency to apply its safeguards to all nuclear activities in the United States, excluding only those with direct national security significance."	"the timely detection of withdrawal, other than in accordance with the terms of this Agreement, of significant quantities of nuclear material from activities in facilities while such material is being safeguarded under this Agreement." (Article 28)	"in exceptional circumstances, the United States may remove facilities without giving advance notification," "any facility ... shall be removed from the List ... and the nuclear material contained therein shall cease to be subject to safeguards under this Agreement in accordance with and at the time specified in the notification by the United States." (Article 34(b))	The conditions of the Agreement could be used to apply safeguards to plutonium or HEU and/or HEU from military inventories. In this regard, it would be useful to incorporate an understanding that the facility(ies) involved could not be withdrawn without advance notification of, for example, six months prior to the withdrawal taking effect, the Board of Governors to be notified of such action.

vide information to NWS on how safeguards are applied in NNWS facilities, and to some extent, to mitigate any financial disadvantage that NNWS facilities subject to safeguards might experience. None of the existing Voluntary Offer Agreements were conceived with an arms control objective in mind.

As shown in table 1, Russia, assuming the rights and obligations of the Union of Soviet Socialists Republics, has in force an IAEA Safeguards Agreement, the preamble of which limits its applicability to *research and power reactors*. In the text of the Agreement, the Agency may select facilities identified on a list to be provided. Presumably, Russia could identify a facility or facilities where plutonium and HEU from military inventories might be made available for IAEA safeguards, thereby providing an expeditious means for applying safeguards to those materials. However, note that the "objective" of safeguards under the Agreement and the conditions for withdrawal of materials or of facilities are not consistent with an arms control purpose. If safeguards were applied under the existing VO Agreements, a new or amended Safeguards Agreement could be prepared absent the pressure that might otherwise exist.

If plutonium and HEU were made available for safeguards under the current VOs, then existing provisions and requirements of the IAEA safeguards system would apply. As discussed in the following section, however, some *modifications would be required.*

Recognizing that the existing VO Agreements were not established with arms reductions in mind, modifications of the existing agreements or new agreements could improve the confidence to be secured through IAEA involvement. Various options could be pursued. For example, an International Plutonium/HEU Store could serve the purposes of restricting the subsequent use of the materials transferred from military inventories without overtly involving the IAEA in arms control related activities. The Agency would be empowered to undertake such arrangements under the provisions of Article IX.A of the Statute:

> Members may make available to the Agency such quantities of special fissionable materials as they deem advisable and on such terms as shall be agreed with the Agency. The materials made available to the Agency may, at the discretion of the member making them available, be stored either by the member concerned or, with the agreement of the Agency, in the Agency's depots.

Under Article IX.H, the provisions are further clarified:

> The Agency shall be responsible for storing and protecting materials in its possession. The Agency shall ensure that these materials shall be safeguarded against (1) hazards of the weather, (2) unauthorized removal or diversion, (3)

> damage or destruction, including sabotage, and (4) forcible seizure. In storing special fissionable materials in its possession, the Agency shall ensure the geographical distribution of these materials in such a way as not to allow concentration of large amounts of such materials in any one country or region of the world.

Parallel arrangements could also apply to NNWS when the inventories of plutonium exceed immediate requirements for reactor fuel manufacturing, for example. The existing agreements could be modified for this purpose in a straightforward manner.

Possibilities for International Plutonium Stores were considered in the mid 1980s and at that time agreement was not achieved, particularly on the questions of geographic distribution for storage and on the provisions for withdrawal. World circumstances have changed in the interim, and a request by a state to establish an International plutonium and/or HEU Store on its territory might now be viewed more favorably.

With the accession of China and France to the Treaty for the Non-Proliferation of Nuclear Weapons (NPT), all of the acknowledged NWS (except at present Kazakhstan) are or will be NPT states. As such, all are (or soon will be) obligated under Article VI of the Treaty,

> To pursue negotiations in good faith on effective measures relating to cessation of the nuclear arms race at an early date and to nuclear disarmament, and on a Treaty on general and complete disarmament under strict and effective international control.

Options beyond the International Plutonium/HEU Store are also possible. In the event that nuclear disarmament is achieved within an NPT NWS, then that state would henceforth be required to submit all its nuclear materials to IAEA safeguards under the provisions of Article III of the NPT. Should the Agency be invited, it could be involved earlier in the process of disarmament. For example, it could supervise a cessation on production of special fissionable materials for military use and apply safeguards to all nuclear materials except for those remaining in military use.

Each of these options (and many others that could be identified) carry costs and benefits, and each would affect the timing and intensity of Agency involvement. The ultimate disposition of the plutonium and HEU may help determine which option is the most meaningful and how it might be financed.

Note that in the event that an NNWS might invite the Agency to take such steps, the resulting provisions would be very carefully considered by the state and the IAEA, and would require formal approval of the IAEA Board of Governors.

Table 2: Verification parameters for normal IAEA safeguards implementation.

Material type	Significant quantity	Timeliness goal
Plutonium	8 kg plutonium	Separated: monthly Spent fuel: 3 months
HEU (≥ 20% enriched)	25 kg U-235	Separated: monthly Spent fuel: 3 months
U-233	8 kg U-233	Separated: monthly Spent fuel: 3 months
LEU (< 20% enriched)	75 kg U-235 10 t natural uranium 20 t depleted uranium	1 year
Thorium	20 t thorium	1 year

VERIFICATION REQUIREMENTS

IAEA safeguards in NNWS are based on, or derived from, the objective explicitly stated in Paragraph 28 of INFCIRC/153, the model for Safeguards Agreements based on the NPT:

> The Agreement should provide that the objective of safeguards is the timely detection of diversion of significant quantities of nuclear material from peaceful nuclear activities to the manufacture of nuclear weapons or of other nuclear explosive devices or for purposes unknown, and deterrence of such diversion by the risk of early detection.

For NNWS, the terms embodied in this objective have been defined explicitly to serve as a practical and objective basis for safeguards planning and performance evaluation. The parametric values shown in table 2 were recommended by experts and relate to the potential acquisition of a first nuclear explosive by an NNWS.

These parameters have little relevance in the context of applying IAEA safeguards to plutonium and/or highly enriched uranium transferred from military inventories. What quantities are significant in that context? What timeliness requirements are meaningful?

For a storage facility, the parameters would probably not have an important effect on the safeguards provisions. For example, if the Agency is invited to apply safeguards to a secure store of fixed items containing plutonium and/

or HEU, then safeguards would be arranged to detect the removal of, or tampering with any single item. The costs for such coverage would depend primarily on the number of such facilities; within a storage complex, the costs would remain relatively flat over wide variations in the amounts of material stored. If the Agency is invited to apply safeguards to processing facilities as well as storage facilities, the costs may be appreciably higher for plutonium processing this would certainly be so, but for uranium, if the HEU enrichment is lowered to low enrichment levels, then the costs are not as great as would be the case if HEU fuels were to be used.

For an International plutonium and/or HEU Store, the verification requirements may also differ, for example, depending on geographical arrangements and international participation in the ownership and operation of the Store. Also, if the safeguards are ultimately included within a broader scope agreement with explicit arms control provisions, then the statement of objectives and their parameterization for planning and evaluation may be entirely different

FORMS AND AMOUNTS OF PLUTONIUM AND/OR HEU, AND TYPES OF FACILITIES TO BE SUBJECT TO IAEA SAFEGUARDS

The safeguards arrangements would depend on the plutonium and/or HEU forms presented for IAEA safeguards. The role of the IAEA is specifically restricted to peaceful nuclear activities, and until now, the Agency has not been asked to safeguard metal ingots of fabricated shapes which could be used in the manufacturing of nuclear warheads, let alone pits or secondaries, or completed warheads. Naturally it would not be sensible to involve the IAEA in any verification activity which could disclose sensitive information related to the composition, geometry or manufacturing of nuclear warheads.

From first considerations, then, it would seem simplest to consider IAEA verification after warheads have been dismantled and after the plutonium and/or HEU is conditioned to obscure any such information. However, should earlier involvement be desired, arrangements could be created which would minimize the risk of disclosure of sensitive material. Such arrangements, for example, could emphasize the application of IAEA verification measures to sealed containers holding sensitive materials. In such cases, the verification activities would be restricted to preclude any disclosure of information. Also, the inspectors chosen for this work could be restricted to NWS nationals as a further means to limit a risk of disclosure, following a "technology holder"

practice accepted for safeguarding centrifuge enrichment plants.

If the plutonium and/or HEU is only to be stored, then IAEA safeguards would be easiest to apply on uniform containers designed for a specifically engineered storage facility. The material form should be critically safe and chemically stable, so that access would not be required for safety purposes. The storage systems employed by the Power Reactor and Nuclear Fuel Development Corporation (PNC) and Cogema provide an excellent basis for such safeguards, for example.

Material forms arising from other than warhead components may also be submitted for safeguards, including powders or even scrap materials. In all cases, Agency safeguards will be simplest to apply when these materials are contained in canisters similar to those used by PNC or Cogema.

The arrangements agreed for the ultimate disposition of plutonium and/or HEU from military inventories may involve the use of the materials as fuels for existing or future reactors. In such cases, consideration may be given to applying safeguards through the processing and fabrication steps leading to the production of finished fuel assemblies, storage, transportation and irradiation. Whether further steps would be subject to Agency safeguards would depend on broader agreements being put into effect, for example, a production cutoff coupled with verification of all civil nuclear activities within a state. The costs for IAEA safeguards under such an arrangement may be comparable to the existing safeguards budget.

Compared with storage-only options, the requirements for effective safeguards for processing activities would demand more intensive safeguards and greater expenditures. If a conversion/fuel fabrication facility is to be included, particularly of the mixed oxide variety, the safeguards equipment and operating costs will be higher by several multiples, depending on plant construction and operational features.

The measurement technology used for HEU differs from that used for plutonium. Different chemical analysis procedures are applied, and while passive non-destructive neutron and gamma ray spectral assay procedures are sufficient for plutonium, a combination of active neutron interrogation methods and passive gamma ray spectral analysis is used for HEU. Combinations of all methods are used when plutonium is combined with HEU.

Establishing a disposition plan for long-term storage or use in current or new reactors will—in any event—require storage for extended periods. Given the amounts of material mentioned, in some cases a period of 25 years or more may be required to construct the facilities required. Under such an arrangement, the disposition plan may comprise several phases, calling for different safeguards arrangements. For example, first, the storage of feed materials

under restricted verification provisions would be required; second, safeguards arrangements would be needed during processing and fuel assembly manufacturing; third, safeguards would be applied to the storage of fuel assemblies and during transportation to the reactors; and fourth, safeguards may be applied at the reactors until the fuels are sufficiently irradiated as to require reprocessing to recover the remaining plutonium and/or HEU.

FACILITY SPECIFIC FEATURES FOR THE CONTROL AND ACCOUNTING OF THE PLUTONIUM AND HEU

The verification arrangements to be employed at a given facility depend on the factors identified above, together with the specific features of each facility. In applying safeguards to a new type of facility, the IAEA carries out studies sometimes for a period of years, to understand the nature of the facility and the proposed operations and to establish complementary verification arrangements. In these investigations, the Agency will examine design information to understand the operations to be carried out, how nuclear materials will be controlled within the facility (both physically and procedurally), how construction features will enhance this control (and how they might be used for safeguards containment and surveillance purposes), how amounts of nuclear materials will be measured for total mass, elemental concentration and isotopic composition, and how reports will be created to account for the nuclear materials subject to safeguards. Through consultations, features to facilitate the application of IAEA safeguards are normally incorporated into the design of new facilities.

In designing its safeguards approach for a given facility, the Agency established a system of containment and surveillance in combination with nuclear material accountancy verification measures to verify state declarations regarding the amounts and locations of nuclear materials subject to safeguards. For facilities storing, processing or using plutonium or HEU, the safeguards approach is layered to provide "defense-in-depth." While the elements vary depending on the items identified above and facility-specific features, the overall system will incorporate the following:

- *Design Information Approval*, including requirements for the provision of specified design information by the state from the conception of a facility through commissioning and for changes, systematic examination of the design information, physical verification of selected construction features, plant equipment and plant performance as established during commis-

sioning tests, provisions to maintain continuity of knowledge of verified design information to ensure its continued validity, evaluation of the design information and its verification for completeness, accuracy and adequacy for safeguards purposes, and reporting.

- *Design and Implementation of the Safeguards Approach*, including the selection of material balance areas, key measurement points for the verification of inventories and inventory changes, strategic points for the application of containment and surveillance and other strategic points for verification timeliness purposes; the selection or specification of equipment and associated data acquisition, collection, analysis and archiving; the specification of accounting and operating records to be used by Agency information as the basis for day-to-day verification activities; equipment installation arrangements including cost provisions, acceptable tests and calibration arrangement; the specification of safeguards tests to be employed to establish normal vs. anomalous conditions and follow-up actions in the event anomalies are detected.

- *The Facility Attachment*, setting forth the specific agreements between the state and the Agency for carrying out safeguards at the facility.

- *Inspector Deployment Arrangements*, including requirements for numbers and skills, for designations and travel arrangements, training and scheduling.

The effort, time and money required to establish effective safeguards will vary by orders of magnitude from very small and simple facilities to large industrial establishments processing great amounts of plutonium or HEU.

VERIFICATION ARRANGEMENTS FOR A PLUTONIUM STORE

For a storage facility for plutonium in a single type of storage container, assuming that construction features afford significant containment, the safeguards provisions may be based upon verification of the amounts declared for each container and subsequent application of containment and surveillance to confirm the continued presence of the materials in the Store. Remeasurement and periodic re-examination of the facility structures and equipment would be carried out. The following systems would be applied:

- Application of optical surveillance in the transfer areas and storage halls, incorporating pattern recognition, radiation and electromechanical sen-

sors to trigger intelligent recording and to facilitate systematic review, and incorporating redundant systems and/or components to enhance reliability.

- Neutron gate monitors at all entry and exit points to detect the presence of any plutonium passing the monitors and the direction of passage.

- Storage Container Assay Systems, based on high-level neutron coincidence assay methods, installed in the transfer routes and operated so as to measure the plutonium content of all containers transferred into the Store or transferred out, and to periodically remeasure the contents of selected containers to ensure that the verification systems had not be deceived or circumvented. If the storage facility is to be automated, the Storage Container Assay system will operate continuously in an unattended mode following the arrangements used in some plutonium fabrication facilities. Note without isotopic verification, such measurements could provide assurance that after initial measurement there is no tampering with the contents.

- High resolution gamma ray spectroscopic analysis equipment, to confirm declared plutonium isotopics and americium content. (Note: the provisions for isotopic verification may be changed to reflect the sensitivity of the materials if a determination were made that such measurements might disclose weapon data.)

- Bulk determination by weighing and sample taking for laboratory analysis of elemental and isotopic composition is normally required. However, the circumstances of storage and the sensitivity of the materials may affect whether such provisions would be applied for the storage of plutonium and/or HEU transferred from military inventories.

- A potential additional containment/surveillance system may be applied in the storage area, given the value of the materials in question. Such a system might be seals on individual containers (although the effort required to apply and service the seals is substantial), or area monitors which might be based on neutron field mapping or infrared mapping, for example.

THE NUMBER OF FACILITIES TO BE SAFEGUARDED

The resources required to apply IAEA safeguards would depend on the number of facilities where safeguards will be applied and their locations. The lowest cost option will be for a single storage facility. The costs for equipment and inspection coverage will increase from that point. If a number of facilities are located at a single site, the resources required will be lower than if those facilities are sited at distant locations At one extreme, a concentration of facilities may make it cost effective to create integrated verification arrangements with an inspection center as the focal point, on-site analytical capabilities and resident inspector deployment. At the other extreme, teams of inspectors with portable equipment would travel from site to site, carrying out their verification activities on an intermittent basis.

CONCLUSIONS

The business of the IAEA is clearly defined as an element of the international nonproliferation regime In conjunction with the five-year reviews of the Treaty for the Non-Proliferation of Nuclear Weapons, the Agency has been encouraged to expand its verification activities in nuclear weapons states, and the IAEA is eager to contribute to the verification of the elimination of nuclear arsenals. The Agency has offered its services to the nuclear weapon states in this regard, but thus far, there has been no invitation to discuss a specific role.

A decision to invite the IAEA to safeguard the storage (and perhaps subsequent processing) of plutonium and highly enriched uranium transferred from military inventories will require a determination that such a step is consistent with international interests and that such activities would not be detrimental to preserving the nonproliferation regime and the role of the IAEA in that effort. Should such a decision be made, the financial arrangements to ensure that the Agency is able to perform such a mission must also be assured.

In this paper, some thoughts are presented to illustrate the range of issues and potential steps to be taken. These issues begin with institutional arrangements and encompass the specification of technical verification requirements, technical implementation arrangements and inspection planning. The actual provisions required would depend on the scope of involvement, the forms and amounts of materials to be safeguarded, facility-specific features and the number of facilities and their siting. An "optimal" verification arrangement will reflect all of these considerations.

Should the Agency be invited to safeguard the storage of plutonium and/or

highly enriched uranium transferred from military inventories, various issues would need to be resolved. If the invitation is more extensive, for example, covering process activities to condition the materials for long-term storage or for use, then the issues and requirements will be more complex and the costs of verification will be correspondingly greater.

The verification requirements are not substantively different from those for safeguarding current facilities or for facilities in planning and construction.