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POLICY AND TECHNICAL ISSUES FOR INTERNATIONAL SAFEGUARDS IN NUCLEAR WEAPONS STATES

J. T. Markin and W. D. Stanbro

1. INTRODUCTION

Expansion of international safeguards into the military and commercial fuel cycles of the nuclear weapons states (NWS)—the subject of previous proposals in international safeguards discussions and of studies in the safeguards literature—has been given impetus by recent US government initiatives for safeguards on excess weapons materials and a verified fissile materials production cutoff. These proposals, if implemented, would have implications on the safeguards objectives, approaches, and technologies that are traditionally employed in international safeguards. This paper examines the modifications and innovations that might be required to the current international safeguards regime in meeting these proposed new roles. Although the examples given are in the context of the US materials and facilities, many of the conclusions are valid for other NWS.

None of the statements in this paper represent official US position on policy for international safeguards in weapons states. Instead, the purpose is to identify policy and technical issues and to offer, where possible, options for their resolution.
This paper limits consideration to the potential role of the IAEA in verifying these proposed initiatives for declared facilities, recognizing that there may also be a role for bilateral, multilateral, or regional verification regimes. Indeed, in some cases verification of weapons materials may be more appropriate for a bilateral arrangement. Because traditional IAEA safeguards may not be admissible for weapons materials, the concept of "transparency" is suggested as a less intrusive alternative providing some confidence that materials are as declared.

Among the possible objectives of international safeguards in a NWS are 1) safeguards for excess weapons materials, 2) verification of dismantlement of nuclear weapons, 3) verification of shutdown of facilities for producing fissile materials for weapons, 4) verification that reactors for production of tritium are not used for fissile material production, and 5) verification that commercial facilities and their nuclear materials are not used for proscribed purposes.

2. POLICY AND TECHNICAL ISSUES

The application of IAEA safeguards to verifying excess weapons materials or cessation of fissile material production for weapons would create policy and technical issues for both the IAEA and NWS needing resolution before any international safeguards regime could be implemented. These issues are driven by conflicting requirements in two areas: 1) the conflict between the limited resources of the IAEA and the increased resource requirements for safeguarding military and commercial fuel cycles in the weapons states and 2) the conflict between traditional IAEA safeguards practices and the classified nature of some weapons materials and facilities.

Resolution of these issues could be approached through some combination of the following: modifications in the IAEA verification goals and safeguards approaches that would reduce inspection effort, modifications in NWS classification laws to allow measurement of selected attributes of sensitive materials or allowing access to classified data by inspectors from selected NWS, offering weapons materials in an unclassified form to accommodate traditional IAEA safeguards, innovations in technology that would reduce resource intensity of inspections, and innovations in technology that would allow verification of weapons materials and facilities while limiting disclosure of sensitive data.

2.1. Verification Goals

International safeguards verification goals are a quantitative statement of the significant quantities of materials, the probability for detecting their loss, and the timeliness of the detection. Because these criteria derive from the goal of detecting a state's acquisition of materials for a single weapon, they could be modified in the context of a nuclear weapons state to reflect, for example, detection of acquisition of a militarily significant amount of materials.

Relaxing the current verification goals would result in reduced frequency and intensity of applying inspection effort, enabling the IAEA to accept increased verification requirements while limiting the needed resources.

2.2. Safeguards Approaches

International safeguards approaches are detailed descriptions of the inspection activities applied at each type of nuclear facility including the facility reports to be reviewed, the locations for making measurements, the number of items to be randomly selected for verification, and the measurement method. An example of a modified safeguards approach is the departure from the current IAEA practice of inspecting facilities according to an announced schedule to allow inspections at randomly selected times. Indeed randomized inspections have been applied by the IAEA in centrifuge enrichment plants and on a limited basis at a low-enriched uranium fuel fabrication plant in the US. Where randomization is practical, it can reduce the numbers of inspections while still maintaining a deterrent to diversion of materials.

2.3. Modification of Accounting Procedures

A key policy issue is the conflict between full scope IAEA safeguards as implemented in NPT countries and the classification laws of weapons states, which restrict the information that can be disseminated about weapons materials and facilities. Application of traditional IAEA safeguards with its reliance on precise measurement of the attributes of materials accounting including concentration, isotopics, and masses of nuclear materials would require data about weapons materials that is currently classified.

An option for modifying the IAEA regime to accommodate classification of weapons materials attributes such as mass and isotopics is to replace IAEA materials accounting procedures with transparency measures that rely on a combination of item accounting including item counting, verification of serial numbers and application of tamper indicating devices, and qualitative measurement(s) to confirm emissions characteristic of the declared nuclear material while avoiding disclosure of sensitive data.

2.4 Modification of Classification Laws

Relaxation of NWS classification rules to permit a broader range of materials attributes to be measured could allow international inspections to employ traditional safeguards procedures. However, application of IAEA accounting methods would require disclosure of isotopics and mass, an action which would conflict with NPT prohibitions against sharing weapons design information with non-nuclear weapons states (NNWS). Alternatively the NWS could allow full disclosure of materials attributes provided the inspectors were limited to representatives of selected NWS.

2.5. Weapons Materials

A resolution of the conflict between traditional IAEA procedures and protection of sensitive information is provided if the offered materials are not in the form of weapon components. Processing of weapon components or offering of fissile materials from the weapons program in the form of metal ingots or oxides would remove their association with a particular weapon type and declassify attributes such as isotopics and mass, allowing application of traditional IAEA accounting, provided that the less sensitive quantity, total amount of special nuclear material in a facility, could be declassified.

2.6. Safeguards Technologies

Safeguards technology developments can reduce the inspection resource requirements for implementing international safeguards in weapons states and provide options for mediating the conflict between full scope IAEA safeguards and classification of sensitive information. Examples of reductions in inspection effort are the use of continuous unattended monitoring devices that record optical and radiation histories of facility operations for periodic review by inspectors. and the use of video surveillance combined with fiber optic seals to verify item sealing in the absence of an inspector. In both instances the frequency of inspector visits to a facility is reduced by the technology.

Developments in nondestructive measurement technologies can offer options for gaining confidence in the validity of a states declaration of weapons material while restricting disclosure of sensitive data. For example low resolution gamma detectors limited to counting gamma rays in a selected energy window could confirm the presence of fissile material with some of the appropriate gamma emissions while avoiding disclosure of the materials complete isotopic composition.

3. SAFEGUARDS FOR EXCESS WEAPONS MATERIALS

3.1. Classification Issues

The sensitive nature of the materials and facilities involved in verification of excess weapons materials will constrain the permitted verification activities. Thus, a key issue is the balance between adequate verification by an inspector and adherence to the classification laws of a NWS. The basis for classification in the US is the Atomic Energy Act of 1954 as amended and the Nuclear Nonproliferation Act of 1978, which prohibit the disclosure of weapons design information. In addition, the NWS have agreed under the NPT not to disseminate weapon design information.

Under current US classification guidance the only attributes of a weapons component that could be measured are the total dose rates from neutron and gamma rays combined at a single point and distance, and a single energy neutron or gamma (less than 300 keV) measurement revealing only counting rates. Other parameters such as shape, total mass of nuclear material, and isotopic composition are classified and could not be disclosed without violating classification guidance.

Excess weapons materials that are not in component form, for example, metal ingots or oxides, are not subject to the same classification restrictions as components. Indeed, the masses and isotopic composition of these materials are not classified, although the total amounts within a facility may be. These materials, if offered as excess, would resolve the classification issue and allow traditional IAEA safeguards based on quantitative determination of material amounts.

3.2. Transparency

In this context the notion of "transparency" has been introduced as a means of achieving the balance between an inspector's need to know and nondisclosure of sensitive data. This word implies a nonintrusive observation of the sensitive materials or related activities which gives confidence that the situation is as declared, but stops short of full verification. For IAEA safeguards, transparency may not be an acceptable compromise because traditionally inspection activities are uniformly applied in all countries. Moreover, the US Voluntary Agreement, whereby facilities are offered for safeguards, provides for traditional IAEA safeguards in the selected facilities. Thus, if materials and facilities are subject to international safeguards under the aegis of the voluntary offer, standard IAEA safeguards approaches would be applicable.

Alternatively, transparency could provide the needed bridge between the two extremes of traditional IAEA safeguards and strict adherence to classification laws. Thus, safeguards on classified weapons components could consist of item counting, checking of item serial numbers, verification of seals, and one or more qualitative measurements. The qualitative measurements could consist of some combination of neutron or gamma measurements chosen so that classified data such as mass and isotopics are not disclosed. For example, classification laws could be relaxed to allow gamma measurements in a few energy channels characteristic of the emissions from highly enriched uranium (HEU) and plutonium. This could be allowed without disclosing the complete isotopic composition of the material or the mass.

3.3. Entry into Safeguards

Entry of excess weapons materials into international safeguards could logically occur at three points: 1) at the location of the weapon in the field, 2) at entry into the dismantlement facility, and 3) at entry into long-term storage. The choice of location for acceptance of the excess material into safeguards will depend on whether the purpose is to confirm that the material is from a weapon that is being retired (i.e., an arms control purpose) or to confirm the deposit of fissile materials in the amount declared by the state. For arms control purposes, entry into safeguards prior to dismantlement with subsequent continuity of knowledge until the component is stored would be desirable. This approach would be resource intensive, intrusive, and potentially expose sensitive data. In addition, this may be an inappropriate role for the IAEA because it is outside the scope of NPT safeguards. Alternatively, if the purpose is to verify the receipt of fissile materials in the declared amount, entry into safeguards could occur subsequent to dismantlement, the inspection regime can be less intrusive and, provided the materials are not in component form, traditional IAEA accounting procedures may be applied.

The first option requires observation of the weapon being loaded into a shipping container and subsequent monitoring of its integrity until it arrives at the dismantlement facility. Because of classification issues, the confirmation of initial inventory would not include a quantitative determination of the fissile materials but instead would likely depend on a transparency approach employing visual observations, tags, seals, and limited qualitative measurement of item attributes.

The second option, entry of the weapon component into safeguards at the dismantlement facility, would limit the inspection activities because just the presence of international inspectors within the facility could comprise sensitive information through visual observation of classified shapes. Instead the inspector could rely on transparency measures applied at the boundary of the facility to gain confidence that activities are as declared. These measures could consist of any one or combination of the following: 1) declarations by the state of the types and numbers of weapons being dismantled which could be checked for consistency with unclassified facility or public information; 2) observations by the inspectorate of vehicles and shipping containers crossing the facility boundary; and 3) application of instrumentation such as portal monitors or other devices for measuring radiation at the facility boundary.

These methods would not allow continuous knowledge of the dismantlement history of individual items but could provide assurance that the approximate numbers of weapons declared were in fact being dismantled. Continuity of knowledge of individual items could be resumed upon exit from the facility by applying seals, noting serial numbers, and making a qualitative confirmatory measurement.

The loss of continuity of knowledge of the item at the dismantlement facility would be an impediment to verifying that weapon components from retired weapons were actually being placed into storage, diminishing the value of entering the materials into safeguards prior to weapon dismantlement.

The third option, entry into safeguards at the storage facility, could rely to a large extent on traditional IAEA procedures and technologies including item counting, checking serial numbers, verifying item seals, checking seals on vault doors, use of surveillance devices and qualitative measurements on items. Other innovations in surveillance technologies could be considered such as devices that continuously monitor an item attribute or an area neutron monitor. The latter technology could provide additional assurance that material amounts consistent with those declared are being stored.

In addition to items in the form of weapon components, other fissile materials from the weapons production process such as metal ingots or oxides, not in the form of weapon components, could also be declared excess and accepted into safeguards at a storage facility, provided they were in a stable form for long-term storage. In this form the material attributes such as isotopics and mass would not be classified, and traditional IAEA safeguards based on quantitative determination of material amounts. could be applied, provided the currently classified quantity, total amount of SNM in a facility, could be declassified

Other unclassified weapons materials in various locations within the weapons complex could require further processing to assure their safety for long-term storage. A reasonable approach would be to defer placing these materials under international safeguards until they were processed to a stable form, thereby avoiding the resource intensive application of international safeguards to bulk processing facilities.

3.4. Withdrawal from Storage

Because fissile materials stored in containers can undergo chemical and physical changes that create a safety hazard, any safeguards approach for stored materials must accommodate the need for periodic removal of selected items from storage. For example, plutonium metal may oxidize from exposure to air or moisture, resulting in a large volume expansion that could breach the container, and plutonium oxide readily adsorbs other material on its surface, and radiolytic decomposition of these materials generates gases such as oxygen and hydrogen whose increased pressure could rupture the container.

Safety considerations such as these could require removal of items from a storage facility to an area where the materials are repackaged. In that instance safeguards could be extended to include the items, whereas in the repackaging facility, the item could be removed temporarily from safeguards or an equivalent amount of material could be introduced into safeguards as the defective item is removed.

3.5. Measurement Issues

The principal technical challenge for safeguarding of sensitive excess weapons materials is to develop a confirmatory measurement method giving confidence that fissile materials consistent with a states declaration are present without disclosing sensitive information. Although the technologies for measuring attributes of fissile materials are well developed including those for measuring heat output(calorimetry), total neutrons and gamma rays, gamma energy spectrum, and coincident and multiplicity neutrons, their unconstrained application could reveal item attributes such as fissile mass and isotopics that are currently classified for nuclear components.

A so-called "fingerprint" or confirmatory measurement giving confidence that an item contained the declared type of material without disclosing sensitive data could be based on some combination of the following measurement technologies.

Current US classification guidance allows a measurement of the total radiation at a fixed distance from the weapon component container. Ionization chambers or other health physics instruments could be used for this purpose. This measurement would indicate the presence of radioactive material but would not provide information about plutonium or HEU.

Low resolution gamma spectroscopy using, for example, NaI detectors can be applied to confirm the presence of a characteristic gamma emission from the material. The detector could be applied either as a gross gamma-ray counter such that every gamma-ray incident on the detector is counted or as a gamma-ray counter within an energy window or windows. The first mode would confirm the presence of radioactive material and the second mode could confirm gamma ray emissions appropriate to plutonium or HEU.

The simplest category of neutron counters is a passive neutron detector that counts the total number of neutrons emitted spontaneously in a given time interval without external excitation. This instrument gives very little knowledge of the contents of the item except that it is a neutron emitter. Although this method could confirm the presence of radioactive materials, total neutron emissions are currently classified.

Neutron multiplicity counters can give information about the form and mass of spontaneously fissioning isotopes. However, because these neutron measurement results would be related to component mass, they could be regarded as sensitive, and when combined with material isotopics, they would disclose the total mass of fissionable material. The neutron multiplicity measurements would be applicable to plutonium but could only confirm the presence of radioactive material.

Other technical approaches that are less well developed for these applications such as acoustic resonance spectroscopy (ARS), which provides a spectrum of an item's response to an acoustic pulse or infra-red (IR) measurements of temperature contours, could give a unique fingerprint of an item without disclosing classified data. ARS would only assure the continued integrity of the materials, giving no information about its radioactivity, and IR would be applicable only to plutonium, giving confirmation of a heat generating source. However, these methods are not yet proven for this application.

4. VERIFICATION OF SHUTDOWN OF FISSILE MATERIAL PRODUCTION

Application of international safeguards to verify cessation of production of fissile materials for weapons purposes would present new objectives, facilities, and materials for incorporation into the international safeguards regime. The objectives could include verification of shutdown of facilities for producing fissile materials for weapons; verification that reactors for production of tritium are not used for fissile material production; and verification that commercial facilities and their nuclear materials are not used for proscribed purposes.

Verified shutdown of fissile material production for weapons could encompass safeguarding of several facility types including production reactors, facilities for fabricating reactor assemblies, and facilities for reprocessing spent fuel assemblies. Verifying the shutdown of a facility could rely on safeguards applied at the boundary of the facility using traditional IAEA technologies such as seals, video surveillance, or radiation detectors. This equipment could be complemented by technologies developed for domestic physical protection including motion sensors and seismic detectors, and by related technologies applied in verifying compliance with the INF treaty, which required verifying that missile production facilities were shutdown. Effluent monitoring, although not in routine use by the IAEA, is under development and could be applicable to shutdown verification provided it can distinguish between old versus recent production activities.

Verifying that allowed production activities for military purposes are not used for proscribed actions would involve the IAEA in inspections of facilities such as tritium production reactors or gaseous diffusion enrichment plants for HEU production. However, because the Agency has no experience in safeguarding these types of facilities (although there may be future experience with an Argentine diffusion plant), new safeguards approaches and perhaps new technologies would be required. Further because of the classified aspects of these facilities, traditional IAEA inspection practices would probably not be possible, perhaps forcing reliance on transparency measures applied at the facility boundary.

Extension of the verified production cutoff into the commercial fuel cycles of all NWS to include power reactors, spent fuel stores, reprocessing plants, enrichment plants, mixed oxide (MOX) fuel fabrication, etc. would present a daunting challenge to international safeguards resources. Although IAEA safeguards approaches and technologies would be directly applicable to safeguarding these fuel cycles, the implied resources for application of traditional IAEA safeguards would exceed current or anticipated inspection budgets. Clearly, this expansion of the existing safeguards regime could only be accommodated through modifications of the current inspection approaches to include less resource intensive activities (with an accompanying reduction in safeguards assurance) or through increased use of technologies to replace traditional inspector activities.

5. ENHANCED SAFEGUARDS PROCEDURES AND TECHNOLOGIES

Extension of IAEA safeguards into the military and commercial fuel cycles of the declared NWS would significantly increase the inspection resources required to inspect these additional facilities and materials. Because these resource requirements would exceed what could reasonably be expected of a traditionally limited safeguards operating budget, either the NWS must provide the shortfall in resources, or the inspectorate must look to innovations in procedures and technologies to meet these increased demands.

5.1. Continuous Unattended Monitoring

Use of equipment to replace inspector presence at inspected facilities has been demonstrated to reduce inspection resource requirements and promises further economies as these technologies are developed for new applications. The basis of this approach is a sensor such as a video camera or a radiation detector that continuously monitors and records the environment in an inspected facility; a method for communicating and storing the acquired data for review by an inspector; and a method for authenticating the validity of the data. These data can periodically be reviewed on-site to detect anomalies in facility operations that are of safeguards interest.

Examples of the application of these technologies include a continuous unattended monitoring system consisting of nondestructive assay and surveillance sensors at an automated MOX fuel fabrication facility; radiation sensors monitoring movements of spent fuel assemblies in an on-line reactor; and a system of radiation detectors and video cameras that monitors movements of spent fuel from the receiving area to the storage area of a reprocessing facility.

Where there is technology for transmitting the recorded information from the facility to the IAEA, further savings are achieved because the inspector need not visit the facility to retrieve and examine the recorded data. Technical feasibility of such a system has been demonstrated using surveillance data from the spent fuel pond of a reactor, which was transmitted directly to IAEA headquarters.

The technology developments that are needed to facilitate unattended monitoring of nuclear facilities are optical, chemical, and radiation sensors that can be tamper protected and operate in an unattended mode for extended periods, methods and technology for compressing and storing large amounts of data, methods and technologies for encrypting and transmitting the data, and algorithms and software for automating the review of large databases.

These technologies could reduce inspection resource requirements in NWS and other states by, for example, eliminating the need for interim inspections at reactors through remote transmission of surveillance data; providing remote assurance that shutdown facilities are not operating; and eliminating the need for inspector presence at measurement of material flows through unattended monitoring.

5.2. New Safeguards Approaches

The application of international safeguards to excess weapons materials and materials in the commercial fuel cycle of nuclear weapons states will require development of procedures and technologies for materials and facilities not previously safeguarded by the IAEA. Excess weapons materials may be in forms for which no measurement methods presently exist, and facilities in the military fuel cycle such as production reactors or diffusion enrichment plants that are of a type not previously under international safeguards will require new safeguards approaches and instrumentation.

In the commercial fuel cycle new safeguards approaches are needed to conserve inspection resources. Examples include the zone approach in which a sector of a fuel cycle containing similar materials is treated as a single materials balance area, thereby eliminating the need to confirm transfers between facilities, and randomization of inspections, which relies on unpredictability of inspections to reduce inspection resources while maintaining a deterrent to diversion. Both of these approaches have been tested by the IAEA in the field and could be applied in NWS.

6. SUMMARY

In applying international safeguards within the NWS, an important policy issue is whether the implementation of safeguards will be the same as in non-nuclear weapons states. Resolution of this policy issue must consider that classification of some weapons materials precludes traditional IAEA safeguards and that traditional safeguards approaches, especially applied to the commercial fuel cycles, would exceed any anticipated Agency resources.

A fundamental policy issue for application of international safeguards to excess weapons materials is whether the purpose is an arms control function of verifying the retirement, dismantlement, and storage of declared weapons components or the acceptance into safeguards of declared amounts of fissile materials. Indeed application of traditional IAEA safeguards to material in intact weapons would be resource intensive, intrusive, and could result in disclosure of sensitive information. The arms control objective is more compatible with a bilateral inspection regime.

If the objective is to confirm declared amounts of excess weapons materials, traditional IAEA materials accounting procedures could be applied provided materials are in unclassified form. Safeguards for classified weapons components could be based on transparency measures that depart from traditional Agency practice by employing only qualitative measurements.

Safeguarding of classified weapon components by the IAEA, if deemed appropriate, would be facilitated by development of procedures and technologies for application of nondestructive measurement methods in modes that would not disclose classified data but would give confidence that materials are as declared.

Because the presence of inspectors in dismantlement facilities could compromise weapons design information through visual observation of classified shapes, entry of declared amounts of excess weapons materials into safeguards should occur subsequent to dismantlement. However, some assurance that dismantlement activities are as declared could be provided by transparency activities applied at the facility boundary.

Application of IAEA safeguards to the commercial fuel cycles of NWS would be facilitated by innovations in safeguards approaches and technologies that reduce inspection effort. If departures from traditional safeguards were acceptable, approaches such as random uncertainty in inspection times could conserve inspection resources. Technologies for continuous unattended monitoring and remote transmission of surveillance data also offer resource savings.

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