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AUTHOR(S): K. K. S. Pillay

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Los Alamos National Laboratory
Los Alamos, New Mexico 87545

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APPLICATION OF SAFEGUARDS TECHNOLOGIES IN SUPPORT OF A BILATERAL TREATY TO REDUCE NUCLEAR WARHEADS*

K. K. S. Pillay
Safeguards Systems Group
Los Alamos National Laboratory

ABSTRACT

The on-going negotiations between the US and the USSR are likely to lead to a reduction in the number of deployable warheads and delivery systems. One way of maintaining stability under this regime could be to control fissile materials within the defense complex of the parties involved and to assure separation of commercial and defense fuel cycles. A verifiable production scheme and a stable fissile material inventory can prevent a "breakout" and its consequences. Some of the well-established principles and practices of nuclear material safeguards can be brought to bear on this problem and help maintain a stable inventory of nuclear materials and indirectly a limit on the number of warheads. For the purpose of discussion, this paper assumes a treaty regime wherein a large number of deployed warheads will be dismantled under supervision and the disposal of recovered nuclear materials will be in a verifiable regime so that they may not reenter the weapons fuel cycle. This paper examines a pragmatic scenario for dismantling warheads so that the declared special nuclear material contents can be verified without compromising design information. Also, we discuss several scenarios for the disposal of nuclear materials recovered so that they can be safeguarded to prevent their reentry into the weapons fuel cycle.

I. INTRODUCTION

During the past four decades, the United States and the Soviet Union have advanced a variety of proposals to limit the nuclear arms race.[1,2] The last decade saw a ground

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swell of political support for the nuclear freeze movement, including the reduction or total prohibition of certain classes of nuclear weapons. This was accompanied by a steady increase in national debate over arms control and a proliferation of scholarly pursuits of the subject.[2,3] Although there has been an abundance of discussions of the socio-political and strategic implications of arms control, there have been few discussions of the verifiability of arms control treaties to maintain the stability of military relationships among nuclear powers. Advocates of nuclear freeze movements and nuclear disarmament often by-pass serious discussions of the verifiability of agreements and assume the existence of nuclear force parity and that national technical means and inspections of the type employed by the International Atomic Energy Agency (IAEA) will detect breakout from agreements. At the same time, opponents of arms control agreements continually point out the limitations of modern technologies and systems to detect breakout from nuclear freeze agreement on a timely basis. Arms control treaties that affect the vital security of nations will not be acceptable unless it is possible to determine with a high degree of confidence that the other side is honoring the agreements. Because systems that monitor compliance can never guarantee absolute verification, the debates over arms control treaties have a tendency to be protracted academic exercises.

The ongoing strategic arms reduction talks (START) between the US and the USSR have the potential for eventually reaching an agreement to reduce the number of deployable warheads and delivery systems. Two of the essential requirements of maintaining stability under such a regime are controlling fissile materials within the defense production complexes of the parties involved and assuring the total separation of commercial and defense fuel cycles. One possible way of maintaining assurance is by applying verifiable safeguards regimes to both commercial and defense fuel cycles within the countries involved. A verifiable production scheme and a stable fissile material inventory can prevent a "breakout" and its consequences. Some of the well established principles and practices of nuclear material safeguards can be brought to bear on this problem and help maintain a stable inventory of nuclear materials and indirectly limit the number of warheads.

For this discussion, this paper assumes a treaty regime between the US and the USSR, wherein a large number of deployed warheads will be dismantled under supervision and special nuclear materials (SNM) will be disposed of in a verifiable regime. Also, we have identified several scenarios for the disposal of nuclear materials recovered from dismantled warheads so that they can be safeguarded from reentering the weapons fuel cycle. All the scenarios discussed here, we think, lend themselves to management under bilateral, multilateral, or international supervision. Verification schemes similar to ones presently used for international safeguards can be adapted to satisfy the parties involved that the SNM from warheads dismantled under the treaty does not reenter the weapons fuel cycle. Also, we have examined one pragmatic scenario in some detail so that the declared SNM contents can be verified without compromising design information.

Key elements of maintaining the stability of and confidence in a treaty regime preserving reduced numbers of warheads include verifying the

(1) dismantling of warheads,

(2) disposal of the fissile materials, and

(3) production of fissile materials in all fuel cycles.

Because the maintenance of safeguards for nuclear material production in fuel cycles is identical to the application of international safeguards to nuclear facilities in non-nuclear weapons states by the IAEA, item (3) above will not be discussed separately in this paper.

II. A DISMANTLING SCENARIO WITH SAFEGUARDS

The following narrative is an approach to dismantling warheads to protect weapons design information while monitoring the disposal of SNM recovered from the warheads. Assuming that the warheads will probably be disassembled where the other side will not be able to infer the design features of warheads, we propose a simple scenario for verifiable SNM recovery. We also assume that warheads removed under supervision have a declared SNM content and can be moved to a disassembly location as a sealed item bearing tamper-resistant seals.

The disassembly location within each State can be a controlled access facility with all design features declared and verified, including the SNM inventory before a planned disassembly campaign. Only representatives of the weapons State participate in the dismantling. All access to the facilities is monitored by the verification team to ensure that no undeclared SNM movement takes place during the campaign.

The disassembled SNM can be transformed into other geometries, or physical or chemical forms within this facility before the recovered SNM is verified. The SNM can be melted and recast, crushed, chipped, etc., within a short time to protect physical design features. It is also possible to carry out more extensive chemical processing to protect compositional-material design information. The recovered SNM can be placed in containers to which tamper-resistant seals can be applied after the SNM content is established. It is possible to design an acceptable verification scheme to account for all the SNM from the dismantled warheads. Non-nuclear components of the warheads may be removed after a predetermined verification scheme has assured the disassembly of all declared warheads and accounted for the SNM.

III. SAFEGUARDABLE DISPOSAL SCENARIOS

Disposal of the SNM recovered from dismantled warheads offers several options, and the final choices may be up to the State having the title to the SNM. Just as the alternative strategies for disposal are numerous, so are the safeguards requirements for each of those strategies. Detailed safeguards system studies of strategies considered for dismantling and disposal are necessary to develop strategy-specific safeguards schemes and verification requirements. The following paragraphs mention a few realistic scenarios for the disposal of SNM. Storage of warheads removed from stockpiles as warheads may cause more concerns about a potential breakout. We have deliberately avoided the discussion of disposal scenarios involving deliberate destruction of SNM, for example, through detonations.

A. Permanent Disposal under Supervision

Disposal of plutonium in outer space or on other planets is a theoretical possibility. However, this is a highly unlikely scenario because of the enormous costs, unnecessary risks, potentials for serious environmental damage, and possible accidents during propulsion into space. Extensive studies done during the early 1970s indicated that the cost of disposing of nuclear wastes in outer space is about 200 times the cost of geologic disposal. With the present heightened concern for the environment throughout the world, this proposition may be least acceptable. Furthermore, discarding such valuable energy resources may not be considered as a very sane idea by rational observers of the nuclear technologies. However, if this option is chosen by the parties involved, presently used safeguards technologies can be used to quantify the SNM, to store it in sealed containers, and to maintain continuity of knowledge about the sealed containers until they are permanently disposed of under supervision.

B. Extended (or Permanent) Storage/Disposal of Material [Plutonium and Highly Enriched Uranium (HEU)]

SNM from disassembled warheads may be stored in critically safe configurations in sealed containers after independent verification of declared quantities. For indefinite long-term storage, it may be preferable to use engineered geologic repositories, rather than surface facilities. Measured containers of SNM may be placed in such a repository and all access to the repository can be sealed under supervision. During the construction and operation of the geologic repository, unannounced design verification of the repository and engineered facilities could provide additional deterrence to facility alterations or design changes. Because periodic verification is not viable after closure of the repository, systems can be designed to provide adequate assurance through containment and surveillance alone. To prevent access to the SNM containers in the repository through minimally intrusive methods, such as borehole drilling, it is possible to design and build features into the containers and placement boreholes.

During the sealing of such repositories, remote monitoring systems similar to those presently used to detect seismic activities may be installed to detect intrusions (large earth movements, mining operations, etc.) into the repository. It is possible to design special devices to continuously monitor for possible intrusions into these storage facilities and to instantaneously alert interested parties anywhere in the world using a satellite-based communication system. This scenario also assumes that large-scale mining operations for mineral extraction or geologic exploration will not take place in the vicinity of these repositories. There is an ongoing discussion among the international safeguards community to develop systems and technologies to maintain safeguards for geologic repositories of spent fuels. Each of these repositories would contain several hundred tons of fuel and other strategically important materials. Some features of the integrated safeguards systems being considered for such repositories would be valuable for safeguarding the proposed repository for SNM removed from nuclear warheads.

C. Civilian Use of Plutonium within the State

SNM contained in warheads is an excellent energy source and can be used for large-scale power generation. Although there are restrictions on plutonium use in the civilian sector in the US, this situation may change. Therefore, it is prudent to consider alternative strategies for disposing of plutonium that will lend themselves to future verifiable uses of plutonium for power generation within the US. World-wide, technologies for using plutonium in light water reactors (LWRs) and fast breeder reactors (FBRs) in the civilian sector are highly developed. There are four such liquid metal fast breeder reactors (LMFBRs) now in full-scale operation in the USSR with several being planned. In addition, the USSR has a program for recycling plutonium in LWRs. Therefore, it is possible that the USSR may choose to use plutonium removed from the weapons fuel cycle in the FBR or LWR fuel cycles. The diversion of weapon's-grade plutonium from declared civilian use may be made more difficult by mixing the weapons-grade plutonium with plutonium from spent reactor fuels. Because we understand both civilian and defense nuclear fuel cycles rather well, it is possible to design systems to minimize diversion of nuclear materials from peaceful applications.[4] The flow of plutonium in the civilian fuel cycle can be safeguarded by modifying technologies and regimes presently used by the IAEA.

D. Alternative Use of Plutonium for Power Generation

The above mentioned scenario of using plutonium in the civilian sector for power generation is not a viable option now in the US because of existing restrictions on the recycling of plutonium in thermal reactors and on commercializing fast reactor technologies within the US. However, the US is an active participant in international programs using plutonium recycling and FBR technologies. United States allies, such as Japan, France, and Germany are among the countries that use US-originated uranium and plutonium in the civilian sector for power generation in LWRs and FBRs. Presently, the reprocessing capacity world-wide is extremely limited to meet the needs of recycling plutonium for power generation. So far less than 40% of spent fuel released from water-cooled reactors has been reprocessed, and this ratio is likely to remain below 40% for a long time. The US could, under negotiated terms and appropriate supervision, transfer (lend, lease, or sell) the available plutonium to friendly countries that can use plutonium in the civilian sector under full international safeguards.

The transfer of weapons-grade plutonium to friendly nations can be controlled by combining this plutonium with commercial-grade plutonium and fabricating it into mixed oxide fuel assemblies in the US. Again, using the currently available, well developed safeguards technologies, the movement of the plutonium contained in fuel assemblies can be monitored and verified.

E. Disposal of HEU

The most logical use of enriched uranium recovered from warheads may be in naval propulsion reactors. Both the US and the USSR have large numbers of reactors using HEU for naval propulsion. Monitoring and verifying this HEU during shipboard use may be difficult because naval propulsion systems are excluded from the safeguards regime. However, it is technically possible to incorporate trace-element tags during fuel fabrication and verify them through their unique radiation signatures when they return as spent fuels from naval vessels.

Alternatively, HEU may be recycled in the civilian fuel cycle as LEU after diluting it with natural or depleted uranium. The processes involved in diluting the HEU and converting it to LEU fuel lend themselves to monitoring and verification under presently acceptable safeguards regimes. The safeguards for LEU in the civilian fuel cycle are well established.

IV. SAFEGUARDS TECHNOLOGIES

Over the past two decades a variety of systems and technologies have been developed for both domestic and international safeguards. Nuclear material safeguards regimes embody both assurance and deterrence. Almost 95% of all nuclear materials in peaceful applications in the non-nuclear weapons states are subject to international safeguards, and there have been no reported diversions of any nuclear material under international safeguards.[5] Because of the commitment of a large majority of the world community (140 nations as of September 1990) to nuclear nonproliferation, safeguards systems and technologies are becoming more and more acceptable. One of the primary measures of international safeguards is materials accountancy. There are well established procedures for reliably estimating quantities of nuclear materials through both destructive and non-destructive assay (NDA) techniques.[6] Some of these methods can be minimally intrusive and acceptable to parties engaged in controlling nuclear materials.

The amounts of nuclear materials recovered from warheads can be quantitatively estimated through simple, highly reliable, non-intrusive NDA techniques because of the materials' unique radiation signatures. A variety of well-developed attributes and variables measurements can be judiciously combined to conclusively identify and quantify fissile materials in a variety of matrices and bulk geometries. Simple attributes measurements, such as weight, heat generation, characteristic radiation emission, etc., are ideal for qualitative identification of the contents of containers of fissile materials. More sophisticated passive and active gamma-ray and/or neutron measurements are accepted as reliable methods to quantify SNM in known matrices.[7] NDA techniques fall into two major categories, passive and active. Passive assay techniques use naturally emitted nuclear radiations (primarily gamma-rays and/or neutrons) to uniquely identify fissile materials. Active assay techniques consist of irradiating materials with neutrons or photons to induce fissions. The resulting nuclear emissions (neutrons and/or gamma rays) are analyzed to quantitatively estimate the amount of fissile material present in the sample. Another form of active assay is through atomic excitation followed by characteristic X-ray emission. Here low-energy photons and electrons are often used as sources of excitation. To excite fluorescence, the primary radiation must obviously have a wavelength shorter than the absorption edge of the spectral lines desired.

Destructive chemical analysis of small quantities of SNM can conclusively identify and quantify SNM irrespective of its initial chemical or physical characteristics. A variety of volumetric, gravimetric, potentiometric, and coulometric methods are routinely used for assay of fissile and fertile materials.[8]

Another complementary measure used in international safeguards is the application of containment and surveillance. Here again, developments over the past two decades have provided a variety of systems and technologies to meet both short-term and long-term requirements of safeguarding nuclear materials recovered from warheads. Containment and surveillance measures in international safeguards regimes for nuclear materials can be readily adapted to meet the requirements of maintaining the identity and integrity of SNM containers and enclosures required to prevent the fissile materials removed from dismantled warheads from reentering the weapons fuel cycle. Containment and surveillance equipment, which is used in the international safeguards regime, is designed to operate unattended within a host country facility for extended periods. Optical surveillance systems, tamper-safing devices such as ultrasonic seals, and the authentication of monitoring and data acquisition systems used in Non-proliferation Treaty verification have potential application in other treaty regimes involving nuclear materials.[9] Because there is a vast literature[10,11] on both nuclear material assay techniques and containment/surveillance measures, additional details of the safeguards approaches based on materials measurements, containment, and surveillance are not considered here.

V. SUMMARY AND CONCLUSIONS

Nuclear materials recovered under a bilateral agreement to reduce the number of deployable warheads can be safeguarded to prevent their reentry into the weapons fuel cycle. Known safeguards technologies can be directly used to safeguard nuclear materials entering the nuclear power generation fuel cycle. Alternative scenarios for managing nuclear materials can also use existing safeguards technologies or their modifications to assure parties concerned that the nuclear materials removed from the weapons fuel cycle under bilateral agreement remain outside the weapons fuel cycle. The precise character of verification agreements will reflect the concerns of parties involved and must include redundant measures to minimize perceived concerns. To stabilize the number of nuclear warheads and delivery systems and to prevent the reintroduction of fissile materials removed from the weapons fuel cycle, it may be necessary to have inspections of most of the fuel cycles. Safeguards technologies can make a positive contribution toward establishing and maintaining such stability in nuclear arms control. Innovations in integrated safeguards and verification systems and technologies employing judicious combinations of NDA techniques and containment/surveillance methods can be valuable assets to the proposed nuclear warhead dismantling and SNM disposal scenarios discussed in this paper.

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