STATEMENT

A CUT-OFF OF PRODUCTION OF WEAPON-USABLE FISSIONABLE MATERIAL: CONSIDERATIONS, REQUIREMENTS AND IAEA CAPABILITIES

by

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Introduction

The United Nations General Assembly adopted Resolution A/RES/48/75/L on 16 December 1993 which, inter alia, requested the International Atomic Energy Agency (IAEA) to provide assistance, as requested, for examination of verification arrangements for a non-discriminatory, multilateral and internationally and effectively verifiable treaty banning the production of fissile material for nuclear weapons or other nuclear explosive devices (referred to heretofore as an FMCT).

The IAEA conveyed its readiness to provide assistance, as required, and its Secretariat carried out internal studies to analyze the potential verification requirements of a fissile material production cut-off and prepared preliminary estimates of the resources needed for their implementation. These findings were duly conveyed at various FMCT workshops in 1995.

An FMCT foreseen by General Assembly resolutions, the Shannon mandate and the NPT States Parties would include an undertaking not to produce any fissile material for use in nuclear weapons or other nuclear explosives nor to assist other States in pursuing such activities. In so far as the production of such material for other legitimate purposes is concerned, it would follow that verification arrangements would need to be such as to meet all the requirements of the undertaking of an FMCT.

In the IAEA Secretariat's view, the technical objective of verifying compliance with an FMCT would be to provide assurance against any new production of weapon-usable fissile material and the diversion of fissile material from the civilian nuclear fuel cycle to nuclear weapon purposes. Thus there would be the need to ensure that stocks of plutonium and highly enriched uranium to be used for nuclear weapon purposes, where they exist at the date of entry into force of an FMCT, are not increased thereafter. A related issue would be how to deal with existing stocks of weapon-usable material.

A number of issues will have to be addressed by the States in order to clarify the basic undertaking of the States Parties and the scope of an FMCT verification regime. These issues, as far as verification is concerned, can be reduced to two basic questions:

- How is the undertaking not to produce fissile material for weapon purposes to be verified? Could the undertaking, as agreed, be verified with a high degree of assurance by simply focusing on verification activities at a core of facilities, or should the verification activities be comprehensive?
- How, and to what extent, should verification ensure that stockpiles for nuclear weapon purposes, where they exist, are not increased, and where they do not exist, are not created thereafter?

The way in which States will address these issues would determine:

- the verification architecture and the scope of activities under the verification system (i.e., application of verification measures to the entire nuclear fuel cycle or parts of it only),
- the ability of the verification organization to provide a high degree of assurance that no activity proscribed by the treaty is being conducted in or by a particular State, particularly through provisions to enable the verification body to detect possible undeclared nuclear facilities and activities, including fissile material production, and
- the overall costs of the verification system for the States party to an FMCT

The IAEA is well aware of the differing views of States inter alia on the scope and verification of an FMCT and does not wish to pre-judge the discussion of such issues in the Conference on Disarmament. This paper presents an overview of the Agency's safeguards and verification activities for the information of States taking part in the work of the Conference on Disarmament and identifies activities that could be of relevance to a discussion on verification of a future FMCT.

Definitions: Fissile Material vs. Nuclear Material

UN General Assembly resolutions and the Shannon mandate refer to "fissile material" – in this regard, it would be useful to provide a precise definition of fissile material. For example, fissile material might be defined as nuclear material from which nuclear weapons or other nuclear explosive devices could be manufactured directly, without the need for further enrichment or transmutation. This would correspond to the term "direct-use nuclear material" used in IAEA safeguards.

The term "fissile material" is not used in implementing IAEA safeguards agreements. Rather, IAEA safeguards are applied to "nuclear material"[1] — any source or special fissionable material[2] as defined in Article XX of the IAEA Statute. Special fissionable material is defined in the IAEA Statute as: "plutonium-239; uranium-233; uranium enriched in the isotopes 235 or 233; any material containing any of the foregoing; and such other fissionable material as the Board of Governors shall from time to time determine." The term source material is defined in the IAEA Statute as "uranium containing the mixture of isotopes occurring in nature; uranium depleted in the isotope 235; thorium; any of the foregoing in the form of metal, alloy, chemical compound, or concentrate; any other material containing one or more of the foregoing in such concentration as the Board of Governors shall from time to time determine; and such other material as the Board of Governors shall from time to time determine."[3]

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[1] INFCIRC/153/(Corrected), paragraph 112 (http://www.iaea.org/Publications/Documents/Infcircs/Others/inf153.shtml).

[2] "Fissionable" nuclei will fission when struck by fast neutrons having appreciable kinetic energy, while "fissile" nuclei will fission when struck by fast or slow neutrons with any amount of kinetic energy, including neutrons with essentially no kinetic energy. "Fissile" nuclei are therefore "fissionable", but only some "fissionable" nuclei are "fissile". Uranium-233, uranium-235, plutonium-239 and plutonium-241 are "fissile" nuclei; uranium-238, plutonium-238, 240 and 242, neptunium-237, americium-241 and 242(m) are examples of "fissionable" nuclei that are not "fissile".

[3] IAEA Statute, http://www.iaea.org/About/statute.html.

In the context of IAEA safeguards, "nuclear material" is further categorized into: (1) "direct-use nuclear material"[4] – unirradiated (UDU) and irradiated (IDU) – that could be used in the manufacture of nuclear weapons or other nuclear explosives without transmutation or further enrichment, and (2) "indirect-use nuclear material" that would require irradiation or enrichment to make it suitable for use in nuclear weapons. For the purposes of IAEA safeguards, direct-use nuclear materials are: plutonium except that containing 80% or more of the isotope plutonium-238, uranium containing 20% or more of the isotope uranium-235, and uranium-233. "Separated direct-use nuclear materials" are those direct-use nuclear materials that have been separated from fission products and thus the processing that would be required for their use in nuclear weapons is substantially less and the times required substantially shorter than if mixed with highly radioactive fission products. The definition of fissile material to be included in an FMCT could be close to this definition of separated direct-use nuclear material. Differences in these basic definitions could complicate the obligations as well as actions required of States and the implementation of IAEA safeguards and FMCT verification.

Types of IAEA Safeguards Agreements

IAEA safeguards are applied under different types of agreements and arrangements and the scope, objectives, measures, technology, evaluations and reporting employed may vary.[5]

Following the conclusion of the Treaty on the Non-Proliferation of Nuclear Weapons (NPT) in 1968, the IAEA has become the instrument with which to verify that the "peaceful use" commitments made under the NPT, or similar agreements, are kept through the implementation of safeguards.[6]

At present, 183 non-nuclear-weapon States parties to the NPT have undertaken treaty commitments that include not to manufacture or otherwise acquire nuclear weapons or other nuclear explosive devices.[7] Such States have also undertaken to submit all nuclear material in all nuclear activities to IAEA safeguards, and to conclude a comprehensive safeguards agreement (CSA) with the IAEA to fulfill their obligation under Article III of the NPT.

The five nuclear-weapon States (NWS) parties to the NPT, have in force voluntary offer safeguards agreements with the IAEA, which cover some or all civilian nuclear material and/or facilities from which the IAEA may select material or facilities for the application of safeguards.

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[4] The *IAEA Safeguards Glossary* (2001 edition) defines "direct use material" as nuclear material that can be used for the manufacture of nuclear explosive devices without transmutation or further enrichment – it includes plutonium containing less than 80% Pu-233, high enriched uranium and U-233 (paragraph 4.25) http://www-pub.iaea.org/MTCD/publications/PDF/nvs-3-cd/PDF/NVS3_prn.pdf#search=%22IAEA%20Safeguards%20Glossary%22.

[5] See, *The Safeguards System of the IAEA*, http://www.iaea.org/OurWork/SV/Safeguards/safeg_system.pdf.

[6] See, *IAEA & NPT: The Verification Challenge*, by Jan Lodding & Tariq Rauf, (http://www.iaea.org/Publications/Magazines/Bulletin/Bull462/iaea_npt.pdf).

[7] A listing is available at: http://www.iaea.org/OurWork/SV/Safeguards/sir_table.pdf; as of 24 August 2006, 31 NNWS party to the NPT have yet to bring into force a CSA with the IAEA (of which 10 States have signed CSAs but have not yet brought them into force, CSAs for 2 States have been approved by the IAEA Board of Governors but have not yet been signed, and 19 NNWS have yet to take any action to conclude CSAs pursuant to the NPT).

In the three remaining non-NPT States, India, Israel and Pakistan, IAEA safeguards are applied at specific facilities to the facilities themselves or to nuclear material and other items specified in the relevant safeguards agreement.[8]

Safeguards in CSA States

IAEA safeguards are regarded as a cornerstone of the international nuclear non-proliferation regime, and comprehensive safeguards agreements (CSAs) are the cornerstone of IAEA safeguards.[9] CSAs obligate States to submit all nuclear material to IAEA safeguards and obligate the IAEA to apply safeguards, in accordance with the terms of CSAs, to all nuclear material in all peaceful nuclear activities within the territory of the State, under its jurisdiction or carried out under its control anywhere. The scope of IAEA safeguards in States pledging not to develop or otherwise acquire nuclear weapons includes what is understood to be "fissile material", together with nuclear material other than fissile material. CSA verification activities address possibilities involving both declared nuclear material and undeclared material and activities; they are intended to confirm that all nuclear materials are submitted to safeguards and remain committed to peaceful use.[10]

Two verification objectives guide the implementation of IAEA safeguards under CSAs:

- to detect the diversion of (significant quantities of nuclear material[11]) declared by the State from peaceful use to the manufacture of nuclear weapons or other nuclear explosives; and

- to verify the correctness and completeness of the declarations made by States, including the objective to detect undeclared production or processing of nuclear material at declared facilities.

Over the years, standard criteria have been adopted to guide the implementation of safeguards at declared facilities, affecting the extent and quality of information to be provided by States, design information verification activities, the safeguards approach to be applied at the facility to satisfy safeguards goals, and specific requirements related to inspection frequencies, inspection activities and the outcome of those activities. For plutonium and for uranium-233, an amount of 8kg is considered adequate for a State to produce its first nuclear weapon, taking into account process losses and the need to be conservative in the design, absent the benefit of nuclear tests. For high enriched uranium (HEU), an amount of 25kg of the isotope uranium-235 is similarly considered adequate.

The structure and content of CSAs and the infrastructure for implementing safeguards may affect FMCT verification not only in CSA States, but may also be of interest in other States as

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[8] INFCIRC/66/Rev.2, which requires the application of safeguards to nuclear material, facilities and other items specified in the relevant safeguards agreement.

[9] All CSAs are based on INFCIRC/153 (Corr.), "The Structure and Content of Agreements between the Agency and States in Connection with the Treaty on the Non-Proliferation of Nuclear Weapons." INFCIRC/153 (Corrected) is available at the IAEA website: www.iaea.og

[10] See *Safeguards Statement for 2005, Background to Safeguards Statement and Executive Summary of the Safeguards Implementation Report for 2005,* Sections 1.1.1 & 2. *(http://www.iaea.org/OurWork/SV/Safeguards/es2005.pdf).*

[11] A significant quantity (SQ) is the approximate amount of nuclear material for which the possibility of manufacturing a nuclear explosive device cannot be ruled out. Direct use nuclear material: 8 kg Pu (containing less than 80% Pu-238); 8 kg U-233. *IAEA Safeguards Glossary,* paragraph 3.14. (http://www-pub.iaea.org/MTCD/publications/PDF/nvs-3-cd/Start.pdf#search=%22'Safeguards%20Glossary%22%22.)

well. Below the level of the Agreements, subsidiary arrangements are concluded as part of the legal framework under which the safeguards are implemented. Subsidiary arrangements include a General Part and a Facility Attachment for each facility identified. The General Parts of the Subsidiary Arrangements are standardized to the extent possible, and while the Facility Attachments for different types of facilities begin with "models", substantial adaptations are often required to accommodate the specific characteristics of individual facilities. Facility Attachments relate specific obligations and inspection rights applicable at individual facilities to specific paragraphs in the Safeguards Agreement with a State.

Under CSAs, a "State system of accounting for and control of its nuclear material" (referred to as a SSAC) must be created to be responsible for implementing, *inter alia*, effective accountancy arrangements and to control imports and exports. States must make extensive declarations regarding their nuclear activities at safeguarded facilities and report at specified periods on their nuclear material inventories and flows. When a CSA first enters into force, the initial inventory declaration is verified to assure that it is complete and accurate. Subsequently, in relation to each facility a State declares, the State is required, *inter alia*, to provide design information, carry out material balances annually and to report material unaccounted for on the basis of a measured physical inventory and measured inventory changes. Those State declarations are verified by the IAEA to assure that they are complete and accurate, and that declared nuclear materials are not diverted to the manufacture of nuclear weapons or other nuclear explosive devices.

Safeguards strengthening measures in CSA States

The discovery of an extensive clandestine nuclear weapon programme in Iraq, an NPT non-nuclear-weapon State with a CSA, gave evidence to the fact that a safeguards system that focused on verifying declared activities was inadequate. In strengthening the safeguards system, the IAEA Board of Governors recognized that to address the possibility of clandestine operations, the IAEA had to be equipped with supplementary tools that would address CSAs limitations. The Additional Protocol to CSAs, based on INFCIRC/540 (Corr.), was created to extend the authority of the IAEA to require States to provide the additional information, access to locations and technology that would enable the IAEA's to verify the correctness and completeness of States' declarations under CSAs.

The provisions of Additional Protocols to CSAs allow the IAEA to require information on States' nuclear programmes including research and development, and activities relating to the manufacture or export of specified equipment and non-nuclear material that could be used to produce or purify nuclear materials. It allows for complementary access to assure the absence of undeclared nuclear material and activities or to resolve questions or inconsistencies pertaining to activities or materials, including managed access to locations in order to prevent the dissemination of proliferation sensitive information, to meet safety or physical protection requirements, or to protect proprietary or commercially sensitive information. Integrating the assurances regarding possible clandestine facilities or undeclared activities in declared facilities provided through the Additional Protocol has allowed the IAEA to adapt its verification requirements at declared facilities.

As part of strengthening the safeguards system the IAEA has been applying "integrated safeguards" – which is a more effective approach that combines the verification activities carried out under CSAs with more advanced methods of analysis and the enhanced access under the Additional Protocol. State-level integrated safeguards approaches take State-specific features into account, such as the effectiveness of the SSAC and the features of the State's nuclear fuel cycle. As of 2005, the IAEA has applied integrated safeguards in multiple States, including Japan and Canada, the two largest programmes under safeguards. The goal is to universalize the Additional Protocol, so that its expanded rights of access apply equally in all States with CSAs. At each of the four annual meetings of the IAEA Board of Governors, a number of Additional Protocols are put forward for authorization for signing, and the total number of States is changing nonetheless the progress on the conclusion and entry into force of Additional Protocols has been slow. (To date, APs have been signed by 109 States and are in force in 77 States.]

In September 2005, the IAEA Board of Governors has modified its policy on "small quantities protocols" (SQP),[12] to ensure, inter alia, effective verification rights in all countries with CSAs. In addition, the Board also established a Committee on Safeguards and Verification (Committee 25) to consider ways and means to further strengthen the safeguards system.

IAEA Safeguards in Other States With or Planning Nuclear Activities

IAEA safeguards implementation in India, Israel and Pakistan are applied under Safeguards Agreements[13] that were established prior to the NPT to cover research and power reactors, components thereof, nuclear fuel and heavy water. These agreements stipulate that any fissile material created through irradiation in those reactors is also subject to safeguards, and any plant processing or using that nuclear material will be subject to safeguards as long as that safeguarded nuclear material is in the facility. Note that while the safeguards verification requirements at a given type of facility generally follow the requirements established in CSAs, specific differences may arise from the fact that the facility itself or equipment or material may be subject to safeguards, and the safeguards agreement may include provisions that reflect the selective nature of such safeguards agreements — especially provisions for substitution.[14]

Safeguards Implementation in NWS

The five NWS recognized by NPT, France, the People's Republic of China, the Russian Federation, the United Kingdom and the United States of America have entered into voluntary offer safeguards agreements (VOAs) modelled on CSAs. These VOA agreements place no obligation on the State in relation to the nuclear material to be subject to safeguards and they

[12] In order to simplify certain procedures under CSAs for States that have little or no nuclear material, and no nuclear material in a facility, the IAEA began making available in 1971, a "Small Quantities Protocol" (SQP), which held in abeyance the implementation of most of the detailed provisions of CSAs until such time as the quantities of nuclear material in a State exceeded certain limits or the State had nuclear material in a facility. As part of the continuing process of strengthening the effectiveness and improve the efficiency of the IAEA's safeguards system, on 20 September 2005, the Board of Governors took the decision to retain the SQP as part of the IAEA safeguards system, but subject to certain modifications. The revised SQPs standardized text now requires States to submit initial reports on nuclear material, to inform the IAEA once a decision to build a nuclear facility is taken, and to permit inspection activities. The Board also decided that SQPs would not be made available to States with planned or existing nuclear facilities. The Board authorized the Director General to conclude with all States with SQPs exchanges of letters giving effect to the modifications in the standardised text and the change in the SQP eligibility criteria, and called on the States concerned to conclude such exchanges of letters as soon as possible. The Secretariat is currently in the process of concluding exchanges of letters with all States concerned to give effect to these modifications. At the same time, the Board called on the IAEA Secretariat to assist States with SQPs in developing and maintaining their State Systems of Accounting for and Control of Nuclear Material.

[13] INFCIRC/66/Rev.2: The Agency's Safeguards System (1965) as provisionally extended in 1966 and 1968. (http://www.iaea.org/Publications/Documents/Infcircs/Others/inf66r2.shtml)

[14] See *Safeguards Statement for 2005, Background to Safeguards Statement and Executive Summary of the Safeguards Implementation Report for 2005,* Section 1.3. *(http://www.iaea.org/OurWork/SV/Safeguards/es2005.pdf).*

permit the State to withdraw nuclear material and to remove facilities from the list designated by the State which the Agency can select for the purposes of safeguards implementation. Moreover, there is no obligation on the IAEA to carry out safeguards at facilities designated by the State.[15] At present, the most germane application of IAEA safeguards to an FMCT is at enrichment plants in China and the United Kingdom. All nuclear facilities in France and the United Kingdom, except those dedicated to nuclear weapon programmes and naval reactor programmes are subject to EURATOM safeguards under the provisions of the Treaty of Rome. EURATOM is seen as a regional control authority and a partnership arrangement is being implemented where both the IAEA and EURATOM collaborate in the application of safeguards in States of the European Union.

Additional Protocol

The Model Additional Protocol[16] is designed for all States having a safeguards agreement with the Agency, including NWS parties to the NPT and non-NPT States.[17] All five NWS recognized by the NPT have signed Additional Protocols that include certain measures provided for in INFCIRC/540 and three of the NWS have brought them into force For the most part, the Protocols adopted by the NWS are intended to provide the IAEA with additional information to assist the IAEA in safeguarding nuclear activities in NNWS. The Additional Protocols in the NWS and the non-parties to the NPT may affect or be affected by provisions that might be included in an FMCT relating to exports of equipment or materials that could assist other States in efforts to acquire the capability to produce fissile material.

Other relevant IAEA Verification Activities

In addition to the normal range of safeguards implementation, three cases where the IAEA carried out additional verification activities might be relevant to an FMCT:

- The IAEA carried out extended verification measures in Iraq under the provisions of United Nations Security Council resolution 687 and related resolutions,[18] including unrestricted access to locations of interest and wide area environmental monitoring to detect clandestine production of nuclear material. The experience gained in this extreme situation may be of benefit in considering the access provisions to be established under an FMCT — the rights granted and the difficulties encountered;

- The IAEA monitored a freeze on operations at nuclear facilities in the DPRK[19] in relation to an Agreed Framework concluded between the DPRK and the United States, including monitoring a freeze on operations at the reprocessing plant at Nyongbyon, which was maintained at operational stand-by. Again, the experience gained may be of benefit in considering provisions for inspections under an FMCT; and

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[15] *Ibid*. Section 1.4.

[16] See *Non-Proliferation of Nuclear Weapons and Nuclear Security: IAEA Safeguards Agreements and Additional Protocols*, http://www.iaea.org/Publications/Booklets/nuke.pdf.

[17] For the latest status see: http://www.iaea.org/OurWork/SV/Safeguards/sg_protocol.html.

[18] For IAEA reports, see: http://www.iaea.org/NewsCenter/Focus/IaeaIraq/index.shtml.

[19] For IAEA reports, see: http://www.iaea.org/NewsCenter/Focus/IaeaDprk/index.shtml.

- The IAEA participated with the Russian Federation and the United States in a Trilateral Initiative to develop a verification system for excess defence fissile materials in those States, as described below in some detail.

The Trilateral Initiative

The Trilateral Initiative was launched by Russian Minatom Minister Viktor Mikhailov, IAEA Director General Hans Blix, and US Secretary of Energy Hazel O'Leary at their 17 September 1996 meeting. The aim of the initiative was to fulfill the commitments made by Presidents Clinton and Yeltsin concerning IAEA verification of weapon-origin fissile materials and to complement their commitments regarding the transparency and irreversibility of nuclear arms reductions.

The three parties established a Joint Group to consider the various technical, legal, and financial issues associated with IAEA verification of relevant fissile materials. The group sought to define verification measures that could be applied at Russia's Mayak Fissile Material Storage Facility upon its commissioning and at one or more United States facilities where identified weapon-origin fissile material removed from defence programmes would be submitted for verification. The task entrusted to the Trilateral Initiative Working Group was declared concluded on 16 September 2002.[20]

The Trilateral Initiative has addressed the scope and purpose of IAEA verification; the locations, types, and amounts of weapon-origin fissile material potentially subject to IAEA verification; technologies that might be capable of performing verification and monitoring objectives without disclosing sensitive information; and options for funding and providing a legal framework for IAEA verification measures.

Scope and Objectives

The Trilateral Initiative is intended to establish a verification system under which States possessing nuclear weapons might submit excess weapon material. Just what materials are to be declared would be for the States to decide, but the decision to submit the material to IAEA verification, once made, would be irrevocable.

Moreover, in keeping with the need for verification, once the decision is made to submit certain material to IAEA verification, inspections would be obligatory.

Every nuclear weapon uses one or more fission energy elements, and every fission energy element of every nuclear weapon requires certain nuclear material, generally plutonium containing 93% or more of the isotope plutonium-239, or highly enriched uranium (HEU). Controls on the possession, production and use of such materials are the basis for the international non-proliferation regime. Similarly, as the nuclear-weapon States Parties to the NPT move to meet their obligations under Article VI of the Treaty, a treaty banning the production of fissile material for use in nuclear weapons or other nuclear explosive devices, together with a framework with provisions for removing existing materials from nuclear weapons, could become a central part of the arrangements to come.

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[20] IAEA Press Release 2002/13, IAEA Verification of Weapon-Origin Fissile Material in the Russian Federation and the United States, http://www.iaea.org/NewsCenter/PressReleases/2002/prn0213.shtml.

Placing weapon material under international verification can serve different purposes, depending on when it occurs and on the scope of verification.

- If the fissile material has been processed to the point that it no longer has any properties that could reveal weapon secrets, then bringing that material under inspection with an undertaking that it cannot be re-used for any military purpose serves two purposes: a) capping the capabilities of the State (together with a production ban) and b) providing a means to build confidence and thereby encouraging further arms reductions and increasing the amounts of excess material subject to inspection.

- Including provisions for inspecting fissile materials that still contain weapon secrets could add an additional benefit: namely, allowing the submissions to proceed much faster than otherwise, given the high costs and lengthy periods required for converting weapon materials to unclassified forms. Allowing IAEA verification of weapon materials having classified properties can only be considered if the State is convinced that the verification process will not reveal such properties.

- Including provisions to confirm that the properties of items submitted are characteristic of nuclear weapon components could allow monitoring of the arms reduction process.

- If the measures above are implemented, then in principle, it would be possible to begin verification at the point where warheads are de-mated from their delivery systems, allowing for verification of specific arms reduction measures.

Under the Trilateral Initiative, verification encompasses the first two steps.

The steps necessary to verify classified forms of fissile material introduce new requirements on the verification processes and equipment to be used by the IAEA. However, if a verification scheme could be implemented that States possessing nuclear weapons could accept, then this would open the possibility for moving faster and for moving further towards confirming the steps taken towards disarmament.

Under the Trilateral Initiative, most of the technical work carried out this far has been devoted to developing verification methods that would allow the States to submit fissile material with classified characteristics, including intact components from dismantled nuclear warheads.

Technical Requirements and Methods

Much of the technical work carried out under the Trilateral Initiative over the past years has been devoted to designing a verification technique that could allow nuclear-weapon States to invite IAEA inspectors to make measurements on the components of nuclear weapons without any possibility that the inspectors might gain access to nuclear-weapon design secrets. At the same time, the verification technique must allow the IAEA to gain sufficient assurance that the verification is credible and independent. Every possible measurement method was considered, beginning with those currently used by the IAEA in safeguarding plutonium and HEU in non nuclear-weapon States. The Trilateral Parties concluded that every method identified could reveal weapon secrets if inspectors were allowed access to the raw measurement data. Therefore, direct, quantitative measurements following normal IAEA safeguards practices were ruled out.

It was then agreed that the IAEA verification of weapon-origin fissile material would be based upon measurements that would provide the most robust verification, but the measurement systems would be designed in such a manner that IAEA inspectors would only be presented with “pass/fail” information. As the raw measurement data could reveal classified information, special security provisions would be included in the measurement systems to prevent any storage of classified information, and to disable the systems in the event access to the raw measurement data was attempted. The “pass/fail” determinations would be made by comparing the actual measurement data to unclassified reference “attributes”. The method adopted is referred to as “attribute verification with information barriers”. The following attribute tests for IAEA verification of excess plutonium in a container were agreed upon:

- plutonium presence;
- weapon-grade isotopic composition (i.e., the ratio of 240Pu to 239Pu is less than 0.1); and
- amount of plutonium is greater than a specified threshold mass.

“Information barriers” combine hardware, software and procedural protective systems in a layered structure designed to provide defence-in-depth protection of classified information. Trilateral Initiative experts have examined all known verification technologies to determine whether any method might be applied that would enable the Agency to derive credible and independent conclusions. They developed a General Technical Requirements and Functional Specifications for measurement system. A prototype of the measurement system was developed and demonstrated. It is referred to as an “Attribute Verification System with Information Barrier for Plutonium with Classified Characteristics utilizing Neutron Multiplicity Counting and High-Resolution Gamma-ray Spectrometry” or “AVNG”. A full-scale system is now under construction at the Russian Federal Nuclear Centre/All-Russian Scientific Research Institute of Experimental Physics (RFNC-VNIIEF) at Sarov (formerly known as Arzamas-16) under a contract with Los Alamos National Laboratory. This system will measure storage containers AT-400 holding classified forms of plutonium (a container used for demonstration is kept at the IAEA Trilateral Initiative Office). Experts have made good progress towards the design and development of the inventory monitoring system for Pu storage facility.

The attribute verification technique comprises a neutron multiplicity assay system integrated with a high resolution gamma ray spectrometry system, within a special environment that must prevent classified information from being transmitted or otherwise conveyed beyond its borders, while preventing any external signals from tampering with the operation of the system. A security watchdog system will disable it in the event that any access way is opened, and the computational block and transmission devices to the inspector’s readout provide the agreed outcomes without breaching security restrictions.

All such instruments are manufactured in the country where they are going to be used. The country itself will certify them and its certification will include normal industrial concerns plus certification against espionage in effect to ensure that IAEA inspection does not lead to any release of classified information. Normal IAEA authentication practices cannot be used under these limitations; a new approach is being developed and while some of the elements of this approach are moving towards adoption, authentication remains the most challenging IAEA task.

In addition to the work described on the full attribute verification systems, work also proceeded on inventory monitoring systems for dedicated storage facilities for weapon-origin fissile material, that will track material within the facilities and assure that its identity, integrity and location are verified at all times. These inventory monitoring systems will combine the traditional safeguards containment and surveillance measures. Where applicable, the protection of classified information will be essential, and national certification will be required. Authentication is also a concern. Moreover, inspector activities will be closely regulated.

Consideration has also been given to the steps required for the conversion from classified to unclassified forms of fissile material and to the subsequent disposition activities. In 2000, the Plutonium Management and Disposition Agreement (PMDA)[21] was signed between the Russian Federation and the United States, under which the two countries agreed to the symmetric disposition of 34 tonnes of weapon plutonium on each side. The PMDA called for "early consultations" with the IAEA on a verification role in relation to this plutonium. Most of the plutonium identified in the PMDA is expected to be subject to IAEA verification pursuant to the Trilateral Initiative, so in effect, the arrangements must look to meet the requirements of both activities. The costs for disposition were estimated at about $2 billion in the Russian Federation and $6.6 billion in the United States.

For unclassified forms of fissile material, the verification methods should be similar to those applied under IAEA non-proliferation safeguards in non-nuclear-weapon States. However, even then there will be requirements for departures from IAEA safeguards. Some of the facilities are (or will be) located at sites used for nuclear weapons work, and even for the facilities in which unclassified forms of fissile material are found, site security restrictions could complicate the implementation of normal safeguards practices. There is also the practical matter of the verification effort that should be given to the materials after they have been blended or irradiated, to the point that they would be less well suited for weapon purposes than the comparable materials found in the civil sector.

If classified forms of fissile material are submitted to verification, the State must make declarations. However, neither the Russian Federation nor the United States could declare the properties of classified forms of fissile material without violating Article I of the NPT and their respective national laws.

Under IAEA safeguards, the Agency carries out unrestricted measurements of all nuclear properties and takes representative samples of the nuclear material subject to safeguards in which all properties, including impurities, are measured to the highest standards of precision and accuracy. For classified forms of fissile material, such measurements could clearly not be undertaken.

IAEA comprehensive safeguards agreements are a part of the nuclear non-proliferation system which is intended to prevent non-nuclear-weapon States from acquiring even one nuclear weapon. The two NWS States involved in the Trilateral Initiative, both possess thousands of nuclear weapons and are in the process of reducing those to substantially lower levels, hopefully eventually to zero. The verification requirements applied for nuclear disarmament must eventually converge with the non-proliferation verification requirements, but this will take some period of time.

The Trilateral Initiative has addressed the scope and purpose of IAEA verification; the locations, types, and amounts of weapon-origin fissile material potentially subject to IAEA verification; technologies that might be capable of performing verification and monitoring objectives without

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[21] http://www.nnsa.doe.gov/na20/docs/2000_Agreement.pdf#search=%22%22Plutonium%20Management%20and%20Disposition%20Agreement%22%22

disclosing sensitive information; and options for funding and providing a legal framework for IAEA verification measures.

IAEA Safeguards Measures and Technology Related to Reprocessing and Enrichment

As the scope and verification requirements for an FMCT are established, the relevance of IAEA experience and existing requirements in States would enable detailed investigations to proceed for specified types of facilities and for specific facilities as appropriate. Given the negotiating mandate, it would appear that verification of reprocessing and enrichment operations logically would be required, and thus a preliminary review of IAEA experience in applying safeguards at enrichment and reprocessing plants might be useful.

Declared Reprocessing Plants

The plutonium produced in nuclear reactors is separated from the uranium, fission products and other actinides in reprocessing plants. With very few exceptions, all plutonium reprocessing plants employ the same process technology, the Purex process.[22] .Reprocessing plants require processing of intensely radioactive materials and hence require remote processing within very substantial structures to contain the radioactivity. These characteristics, together with difficulties inherent in measuring accurately the amounts of plutonium (or uranium-233) at the starting point of the processing, make the application of safeguards complex and more expensive than any other safeguards application.

Safeguards at reprocessing plants are designed to detect misuse of the facility (undeclared reprocessing) and diversion from declared flows and inventories of plutonium and uranium. Meeting safeguards verification requirements is most difficult in large operating plants, as the IAEA safeguards quantity component of the inspection goal are fixed in terms of amounts necessary for manufacturing one nuclear weapon, and as those amounts become small in relation to the total amounts of nuclear material processed, the safeguards approach must be expanded in scope and made increasingly intrusive in order to provide the required assurances that the plants are not misused and that the nuclear materials are accurately measured, declared and are not diverted. The technical problems are further complicated if the plants operated before safeguards were applied, and if the plant instrumentation is incomplete or unreliable.

The safeguards approach for a reprocessing plant would depend on a range of considerations, chief among which is its operational status – whether it is in operation, stand-by mode, decommissioned or abandoned. The following conditions might apply:

- continued reprocessing operation;
- operation for non-reprocessing purposes (e.g., removal of americium-241 from plutonium, waste fractionation, etc.);
- stand-by (here the verification requirements depend very much on the length of time between a notice of intent to resume operations and the actual resumption);

[22] Uranium-233 is produced in a similar manner by irradiating thorium, and separated through a similar process; however, no uranium-233 reprocessing plants are in operation.

- decommissioning (here the safeguards approach is progressively simplified as the time and effort required to resume operations increases with the destruction, entombment or removal of key components); and

- decommissioned or abandoned. (The frequency with which periodic checks are required depends on whether the buildings remain and, if so, if they remain in use; the methods may entail periodic visits or satellite imagery analysis, depending on cost considerations.)

The cost and effort required can vary from almost no cost for decommissioned or abandoned facilities up to continuous inspection with tens of millions of dollars of verification equipment.

IAEA safeguards at reprocessing plants begin with the examination of information required of the State on relevant aspects of the design and construction of the facility, on its operation and on the nuclear material accountancy system employed. Design information examinations are made early in the consideration of the safeguards approach for a facility to determine whether the information is sufficient and self-consistent. During construction, commissioning and thereafter during normal operations, maintenance and modifications, and into decommissioning, the design information is verified through inspector observation and appropriate measurements and tests to confirm that the design and operation of the facility conforms to the information provided. In addition to these methods, environmental sampling would be applicable depending on the circumstances, as a means to detect reprocessing of plutonium with different characteristics. This safeguards measure provides the basis for determining the other elements of the safeguards approach for a given facility and the basis for applying all other safeguards measures.

For each reprocessing facility, depending on its operational status, whether it is a small, medium or large-scale plant, and facility-specific features, appropriate combinations of the following measures are combined with design information verification activities in the safeguards approach for the facility:

- application of containment and surveillance at key parts of the plant, to maintain continuity of knowledge of verified information and to track operations to determine whether or not observed operations conform to operator declarations;

- application of measurements, including measurements made by the operator for accountancy, criticality safety or process control and measurements made by the IAEA using Agency equipment or, under suitable arrangements, using operator equipment;

- solution measurement and monitoring systems, to track the movement of solutions containing nuclear materials within the process area and to provide authenticated volume measurements of nuclear materials in solutions;

- near real-time accountancy, to detect plutonium losses within the specified monthly timeliness intervals;

- nuclear materials accountancy, involving annual material balances based upon verified physical inventories and physical inventory changes (this includes the analysis of shipper-receiver differences and material unaccounted for over successive material balance periods); and

- cumulative nuclear materials accountancy, involving total and trend analysis over the full period during which IAEA safeguards are applied at the facility.

Safeguards at reprocessing plants include the taking of samples for analysis at the IAEA Safeguards Analytical Laboratory, located in Seibersdorf (Austria), and at 14 other labs located in eight Member States that form the Agency's Network of Analytical Laboratories. Sample preparation at the facilities includes spiking with reference materials and dilution to reduce the radioactivity of the samples to facilitate shipment and handling. Shipping such samples is expensive and requires appropriate radiation protection measures.

The verification equipment used at reprocessing plants includes standard seals and surveillance equipment, plus specialized systems, including:

- pneumatic measurement systems for determining the volume and density of solutions in instrumented vessels;

- secure sample containers to protect samples from tampering;

- densitometry equipment to permit IAEA verification of the concentration of plutonium in solutions before, during and following its separation and purification (K-edge densitometry for purified solutions and hybrid K-edge densitometry for solutions containing fission products and uranium); and

- in large-scale plants, on-site analytical laboratories are necessitated in view of the number of samples required and the timing for analysis.

Clandestine Reprocessing Plants

In a CSA State, any undeclared reprocessing would constitute a clear violation of the provisions of the Agreement and the Additional Protocol. Reprocessing operations normally involve the release of gaseous fission products into the atmosphere and the release of particulates, some of which are deposited at significant distances from the facility. The detection measures for detecting clandestine plants are as follows.

Enhanced Information Analysis: Under the provisions of the Additional Protocols, CSA States are required to be thorough in providing information relating to research and development concerned with reprocessing, manufacturing and, upon request, imports of specialized vessels for reprocessing and the construction, operation and decommissioning of any reprocessing plants, past, present and future. The IAEA analyzes the information provided and compares that information with information obtained from a range of sources, including:

- information obtained through the implementation of safeguards within the States;

- information reported to the IAEA involving transfers of nuclear materials and specified items of equipment;

- information obtained through other IAEA activities, including technical cooperation projects;

- open-source information from scientific journals and the media; and

- other information as States may provide.

Complementary Access: Under the provisions of the Additional Protocol, the IAEA has the right to request access to locations to resolve inconsistencies in information provided. The specific provisions for such access would be required to determine their relationship to FMCT requirements as negotiations proceed.

Environmental Sampling: Environmental samples may be taken under existing provisions of the Additional Protocol at locations where complementary access is carried out. Procedural arrangements for wide-area environmental sampling would require to be approved by the Board of Governors before this feature of the Additional Protocol can be implemented.

Declared Enrichment Plants

IAEA safeguards at a uranium enrichment plant are intended to meet three objectives:

- to detect the undeclared production of HEU, or excess high enrichment production if high enrichment production is declared;
- to detect excess LEU production (that might subsequently be further enriched at a clandestine plant or within a plant under safeguards, with a higher risk of detection);[23] and
- to detect diversion from the declared uranium product, feed or tails streams.

Nuclear material accountancy verification applied to detect diversion from the declared feed, product and tails streams in an enrichment plant provide, in combination with other measures, a means to assure that a plant is not being used to produce undeclared HEU, and in those cases where a low enrichment plant has been used earlier to produce HEU, this method assumes increased importance.

While essentially all reprocessing plants use a single process, nine uranium enrichment technologies have been advanced. Some of these technologies are unlikely to be exploited and some would no longer be selected because of very high electrical power requirements. While the safeguards approach for any enrichment plant will include common elements, the differences in the various process characteristics and the plants requires different safeguards methods. While IAEA safeguards have been applied primarily to gaseous centrifuge plants, the IAEA has carried out investigations in relation to aerodynamic nozzle enrichment plants, gaseous diffusion plants, molecular laser enrichment (MLIS) and electromagnetic (calutron) enrichment systems. Limited studies have been carried out to consider safeguards at atomic vapour laser enrichment (AVLIS) plants, but little if any work has proceeded in relation to the remaining technologies that have yet to advance to the point of being incorporated in industrial scale plants: chemical exchange enrichment, ion exchange enrichment and plasma separation enrichment.

As in the case of reprocessing plants, design information examination and design information verification are central to the implementation of IAEA safeguards at enrichment plants. Enrichment technology is considered to be proliferation-sensitive and thus IAEA inspector

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[23] More than 80% of the separative work required to produce uranium containing concentrations of uranium- 235 of 90% or more is spent in raising the enrichment from natural levels (0.71% uranium-235) to approximately 4% enriched. A much smaller top-end facility would be needed to increase the enrichment from 4% to high enrichment levels than if the facility were to start with natural uranium.

access to the areas where enrichment equipment is installed is restricted by the technology holders, and inspector observation of the inside details of enrichment equipment is limited, as is access to critical plant operating parameters. Nonetheless, effective verification arrangements have been established within these restrictions that allow the IAEA to meet the objectives indicated.

Design information examination and verification provides a reference for understanding the normal steps for introducing feed and removing product and tails, and for assuring thereafter that no temporary or permanent modifications are made that would allow the plant — or any part thereof — to be used for the production of undeclared HEU. (During construction, commissioning, during normal operations, maintenance and modifications, and into decommissioning, the design information is verified through inspector observation and appropriate measurements and tests to confirm that the design and operation of the facility conforms to the information provided.)

Environmental sampling has proven to be an extremely potent method for determining whether or not an enrichment plant produces HEU. Clearly, if the plant is producing HEU for a non-proscribed purpose, or if a low enrichment plant was formerly used for HEU production or is near a high enrichment plant, environmental sampling may be less useful. The safeguards approach in such facilities would require greater emphasis on other aspects of the safeguards, but even in such circumstances, cluster analyses of particulates over time may provide a basis for detecting new production, as may differences in minor isotope ratios.

For a given enrichment technology, in a manner similar to that for declared reprocessing plants, the safeguards approach for an enrichment plant will depend to a great extent on the operational status of the facility. In particular, the following conditions are fundamental to establishing effective and efficient safeguards:

- operating enrichment plants:

— producing HEU for non-proscribed purposes (here the verification must assure that only the declared amounts of HEU are produced, and environmental sampling may be of little if any relevance);

— producing LEU in a plant reconfigured from earlier high enrichment production or in a plant nearby another plant used for HEU production (here the verification activities intended to detect undeclared HEU production will be more complicated due to remaining traces of HEU, so, for example, environmental sampling may be of little relevance);

— producing LEU and never having produced HEU;

  - operational standby (again, as for reprocessing plants, the verification requirements will differ depending on the advance notification interval required);

  - decommissioning (the safeguards activities will be progressively simplified and the plant is dismantled; the destruction or disposition of the enrichment equipment removed should be monitored); and

  - decommissioned or abandoned (here again, as for reprocessing plants, the inspection methods and frequency will depend upon the final State of the structures and periodic assurance that steps are not being taken to return a decommissioned or abandoned plant to operation will differ accordingly).

For each enrichment plant, depending on its technology, operational status, capacity and layout, the following measures are incorporated in the safeguards approach:

- measurements of the amounts of uranium and the enrichments of uranium in feed, product and tails cylinders, by means of weighing the cylinders and the use of non-destructive assay systems to measure the uranium enrichment, and sampling for analysis at the IAEA Safeguards Analytical Laboratory;

- applications of containment and surveillance on feed, product and tails cylinders, and at key parts of the plant, in particular at the uranium feed point and the product and tails removal points (integrated sealing-surveillance systems are being used at some plants that allow the facility operator to attach and remove seals as an efficient means to obtain assurance that all cylinders attached or detached from the declared feed and take-off points are verified), and at locations where instruments are installed to maintain continuity of knowledge of verified information and to track operations to determine whether or not observed operations conform to operator declarations;

- collection of environmental samples from material handling areas outside cascade halls to detect indications of undeclared nuclear material or activities;

- determinations that uranium in the process piping contains less than 20% of the isotope uranium-235, through continuous enrichment monitors or specialized measurement systems used in conjunction with limited-frequency unannounced inspections inside the cascade areas of some centrifuge plants;

- in other centrifuge plants, in-line instruments will be introduced for measuring the actual enrichment of the uranium in uranium hexafluoride gas in the feed, product and tails lines, and mass flow meters on the product flow line;

- in most facilities, use of limited frequency unannounced access inspections into the cascade hall to detect plant modifications and to collect environmental samples that might signal high enrichment operations;

- in some facilities, monitoring of the separative work produced between successive inspections and comparison of those amounts with operator declarations and supportive inspection data;

- nuclear materials accountancy, involving annual material balances based upon verified physical inventories and physical inventory changes (this includes the analysis of shipper-receiver differences and material unaccounted for over successive material balance periods); and

- cumulative nuclear materials accountancy, involving total and trend analysis over the full period during which IAEA safeguards are applied at the facility.

Clandestine Enrichment Plants

The methods used to detect undeclared enrichment plants are essentially as for undeclared reprocessing. Enrichment operations normally result in the release of aerosols — especially at locations where connections to the process piping are made, but also through the plant ventilation system. These aerosols may not travel very far, and thus environmental sampling is likely to be effective close by such facilities.

The difficulty in finding emissions from clandestine enrichment plants is further compounded by advances in enrichment technology that greatly reduce the size of plants and reduce the electrical power requirements.

Enhanced Information Analysis: States are required to be thorough in providing information relating to research and development linked to enrichment, manufacturing and importing enrichment equipment and specialized materials (carbon fibre vessels and maraging steel, for example) and the construction, operation and decommissioning of any enrichment plants, past, present and future. As for reprocessing, the IAEA analyzes the information provided and compares that information with information obtained from the sources identified above in relation to reprocessing.

Complementary Access: As above, for reprocessing.

Environmental Sampling: As for reprocessing, environmental samples may be taken under the provisions of the Additional Protocol at locations where complementary access is provided. Procedural arrangements for wide-area environmental sampling would require to be approved by the Board of Governors before this feature of the Additional Protocol can be implemented. but the detection of enrichment at points distant from plants is less likely.

Verification Choices

The IAEA has studied possible verification scenarios, their associated costs and the level of assurances that those alternatives may provide with respect to compliance by States party to an FMCT. A brief description follows.

Verification coverage

From a technical perspective, applying verification arrangements to anything less than a State's entire nuclear fuel cycle could not give the same level of assurance of non-production of nuclear material for nuclear explosive purposes, as is provided by the IAEA in implementing comprehensive safeguards agreements in NNWS. In order to provide States party to an FMCT with a level of assurance analogous to the assurance provided by the IAEA under comprehensive safeguards agreements, the verification system would have to apply to the entire declared fuel cycle in those States and should be geared to the detection of undeclared production facilities and of nuclear material.

Verification measures of an FMCT would benefit by paralleling the existing strengthened IAEA safeguards system. Such measures are designed to take account of current and future technological developments as they may help increase the level of assurance provided by safeguards practices. In addition, they provide increased assurances with respect to the detection of undeclared facilities and fissile material, as mentioned earlier.

Any fissile material produced after the entry into force of an FMCT, either in fissile material production plants or through the operation of civil nuclear facilities would presumably be subject to safeguards during processing, use and in storage.

To what extent States would be permitted to exempt from verification any existing fissile materials in their inventories, at the time of entry into force, would need to be discussed by States. For the purpose of clarity these stocks can be identified as follows:

- military stockpiles for weapon purposes (including nuclear material released from weapon dismantlement);
- military stocks of nuclear material for uses in non-proscribed activities; and
- civil stocks.

If the verification regime were to be strictly limited to the task of verifying the undertaking not to produce fissile material for purposes proscribed by an FMCT, it would not provide the assurance that existing stocks of fissile material to be used for the said purposes are not increased by means other than production (e.g. by declared and/or undeclared (illicit) imports of fissile material for use in nuclear weapons or other explosive devices, or by use of existing civil stocks or military stocks for non-proscribed military purposes) after the entry into force of the treaty.

Notwithstanding the fact that technically a comprehensive system of verification under an FMCT would appear to be the best alternative; States might opt for a less resource intensive alternative, with a trade-off regarding the non-proliferation and disarmament benefits of a comprehensive approach against the reduced costs of more focused (nuclear facility targeted) approaches. States could, for example, constrain the technical objective of verification to the provision of assurance that all production facilities of direct-use material are either shut down or operated subject to verification; and that all stocks of fissile material not specifically excluded from verification once an FMCT enters into force would remain subject to verification.

Thus, some other alternatives with their specific resource requirements have been considered by the Agency. These alternatives are more limited in scope, and therefore less costly, but the level of assurance provided by these less resource intensive alternatives would be significantly lower than the one given by the implementation of safeguards in NNWS pursuant to comprehensive safeguards agreements unless the verification body were given the necessary authority and strong capabilities to look for undeclared activities and material.

One important question is: Will the international verification regime include measures to detect undeclared nuclear facilities and fissile material?

Depending on the answer to this question, the verification system would or would not be able to deter potential violators and provide assurances against undeclared production of fissile material for weapon purposes in civil and/or military production facilities, and against the production of fissile material for weapon purposes in undeclared facilities.

Needless to say, any limitations placed on the verification system with respect to the items subject to verification would seem to reinforce the need for a well defined and efficient mechanism allowing the verification organization to look for potential violations of an FMCT, so that an acceptable or credible assurance can be given to all parties by any limited verification alternative that no violation has been perpetrated by a party.

States would have to decide on a verification mechanism to detect proscribed activities. Two aspects of this issue would need to be addressed:

- what activities related to detecting indications of a possible proscribed activity would be permitted beyond and above the analysis of available information from various sources (for example, installation of a network of air and water monitoring stations to detect particles emitted by operating reprocessing plants or HEU enrichment plants; access to locations anywhere within the State for the purpose of collecting samples, atmospheric monitoring to detect various emissions from production plants and reactors and/or satellite imagery analysis to detect the construction of shielding required for reprocessing plants, satellite analysis of thermal emissions, etc.); and

- what activities could be undertaken to resolve suspicious indications, once detected (special inspections or challenge inspections limited or not by quota-based arrangements for access to most locations within States such as those in the CWC or CFE Treaties, "managed access" arrangements similar to those adopted under the Model Additional Protocol or the CWC for sensitive locations, etc).

The verification requirements for the detection of undeclared production facilities will depend on the provisions incorporated in an FMCT. If a high degree of assurance is required, the provisions of an FMCT would have to allow for such measures as wide area environmental sampling of radionuclides emitted by reprocessing or enrichment operations, including airborne radiation mapping and environmental samples of soil, water, sediment and biota, together with visual inspection of selected sites and discussions with designated government, scientific and industry personnel. Most of these measures are already employed by the IAEA within the framework of strengthened safeguards.

In addition to the issues of coverage and scope, States would have to consider a number of specific issues relevant to the verification of an FMCT. Although IAEA-type safeguards would need to be applied in many of the facilities which could become subject to verification; virtual turn-key application of IAEA safeguards may not always be possible because of the unique characteristics of monitoring former nuclear weapon facilities (specific security and safety issues, operational constraints stemming from decades of nuclear weapon material production, the "unfriendly character" of such facilities with respect to safeguards, and the need to protect sensitive information against the risks of proliferation).

States may decide not to permanently de-activate some production facilities constructed for the sole purpose of supplying plutonium but instead to adapt such facilities to carry out peaceful activities or continue to operate them in support of non-proscribed nuclear military activities, as might be permitted by an FMCT. The verification requirements (and resources) would differ significantly if specific plants are shut down or continue to operate. If the plants used in the past to produce fissile material for actual or potential use in nuclear weapons are shut down, verification could be based primarily on remote sensing and the use of seals and their periodic inspection; which would be a straightforward, inexpensive and non-intrusive method. However, the provisions for assuring that such facilities remain shut down would also depend on their readiness to resume operations. If steps have been taken to decommission the plant or to dismantle key components, monitoring can be carried out infrequently, after initial on-site verification to confirm that the plant is decommissioned or that key components have been dismantled. However, if a State wants these facilities to continue to operate for non proscribed purposes, their safeguarding would be more costly and more elaborate.

In some States, the military and civilian nuclear fuel cycles are not entirely separated therefore verification arrangements will have to be devised in such a manner as to take account of such States' legitimate concerns regarding the protection of classified information without hampering verification requirements. Measures involving various degrees of intrusiveness could be considered:

- remote sensing (i.e. visual and infrared overflight data collected by satellites and/or aircraft) could be effective in verification of shut-down production facilities, with no risk of compromising sensitive information and little or no impact on the facilities;
- environmental sampling at a site or in its vicinity, to detect the nuclear and chemical signatures of reprocessing and enrichment activities, would cause very little interference with normal facility operations; and
- managed access inspections, to balance the needs of inspectors to carry out their duties and the rights of the inspected State to protect sensitive information.

Some States might continue to use HEU for naval propulsion reactors and for fuelling tritium production reactors; verification that no HEU has been diverted to proscribed explosive uses would have to be addressed in such a way as to keep intrusiveness at an acceptable level, while concurrently enabling the verification agency to provide the appropriate level of assurances of compliance with the treaty's provisions.

With respect to HEU for naval propulsion reactors, a possible approach might be to follow a procedure similar to the one provided in paragraph 14 of INFCIRC/153 – the model agreement for comprehensive safeguards. This provides that nuclear material may be released from IAEA safeguards for non-proscribed military activity (i.e. naval propulsion), but the Agency must be kept informed of the total quantity and composition of the material and safeguards must be applied again once the material is discharged from the reactor and returned to the inventory. This safeguards provision has never been invoked to date and thus its effectiveness has never been put to the test.[24]

Tritium production would impact on verification of an FMCT in two respects: first, HEU used as fuel in tritium production reactors could be diverted to weapons; and second, reactors dedicated to tritium production could also be used to produce plutonium for weapons. Thus, verification approaches would have to be devised to ensure that no proscribed activity is being conducted.

Verification: Technical Requirements, Costs and Implementation

Technical requirements

Precise requirements are useful in creating and operating a verification system, as guides for budgeting, negotiation of specific implementation arrangements, staffing, routine inspection

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[24] No State has ever exercised the provision allowed in CSAs to designate nuclear materials for non-proscribed military applications that employ the fission characteristics of nuclear materials – in 1987, Canada contemplated using this exemption for nuclear-powered submarines but eventually cancelled its nuclear submarine acquisition programme. States have exempted safeguards on depleted and natural uranium for use in ceramics, for example, and as a catalyst in petrochemical processes, and on depleted uranium metal for use as ballast material in aircraft and boats.

planning and evaluation, research and development, etc. The capabilities of a verification system can be specified in terms of measurement goals: amounts of fissile material of interest; time parameters during which the verification system should provide conclusions in relation to the amounts of fissile material; and the level of certainty desired about the conclusions.

These goals generally represent a balance between technical effectiveness and cost. As the specified amounts of fissile material to be measured decrease, as the timeliness increases, and as the confidence associated with conclusions increases, the verification costs commensurately go up and the level of assurance provided by the system increases.

Quantity goals

The minimum amounts of fissile material to be verified under an FMCT could be based on different rationales, for example:

- a fixed percentage of the amounts of fissile material submitted for verification under an FMCT; this rationale would establish the most direct link between the undertaking of the treaty and the amounts of fissile material needed by each State to obtain a significant increase in its existing fissile material inventory. However, this rationale would create a situation where verification activities are less intensive in States with large fissile material inventories than in States with small inventories; and
- an amount considered necessary for the production of one nuclear weapon; this is the basis for IAEA safeguards, and adopting the same goal would have the benefit of establishing a verification system which does not create any discrimination.[25]

Timeliness requirements

The timeliness requirements could be chosen in relation to the time needed by a State to convert fissile materials into nuclear weapons.

First, how fast could a State act if it had made all preliminary arrangements and decided to acquire nuclear weapons in the shortest time possible before its activities were detected. In the IAEA safeguards system, the physical form of the nuclear material will determine the time required for fabrication into nuclear weapons. For pure forms of separated nuclear materials, the timeliness goal for successive conclusions is one month; for irradiated nuclear material, three months; goals are also defined for other nuclear materials.[26]

The second timeliness consideration is a function of the minimum rate of diversion that a State could plan for. A large diversion occurring in a short period of time is more likely to be detected than a trickle diversion prolonged over an extended period. IAEA safeguards are designed to detect diversion of nuclear material to nuclear weapons or other nuclear explosive devices (for timeliness purposes this is operationalized through a detection time corresponding estimated conversion time of one month for one significant quantity (SQ) of plutonium (8 kg) or HEU (25 kg of U-235 or 8 kg of U-233),[27] and the timeliness detection goal is used for establishing the

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[25] See *IAEA Safeguards Glossary*, op. cit., paragraphs 3.13-3.14 (pp.22-23).

[26] See *Ibid.*, paragraph 3.20 (pp.24-25).

[27] *Ibid.*, paragraph 3.13 - 3.15 (pp. 22-24).

frequency of inspections and safeguards activities at a facility (or a location outside a facility) during a calendar year, in order to verify that no abrupt diversion has occurred).

Detection probability

The third parameter characterizing the technical effectiveness of a verification system is the degree of certainty desired in relation to the findings of the verification system, i.e. the probability that the system will detect a possible diversion. For separated plutonium and HEU, IAEA safeguards are implemented so as to obtain credible assurances that a diversion of one significant quantity would be detected.[28]

From a technical point of view, it would be preferable to adopt the same criteria under an FMCT, as for current IAEA safeguards. Aside from avoiding a disparity between two verification regimes, the adoption of identical sets of requirements would be substantially easier to administer and to implement than criteria with different requirements.

Estimates of resources

The Agency has extensive data on verification costs for facilities currently subject to safeguards. However, in relation to an FMCT, estimates would be needed for facilities which are not currently subject to IAEA safeguards, those which have been or currently are part of national defence programmes in the NWS and in non-NPT States. It should be noted that the Secretariat does not currently possess all the required information regarding such facilities, and this information would have to be provided by States once the treaty is concluded.

The Secretariat's initial estimates are therefore based on information drawn largely from open literature and on the Agency's experience in carrying out safeguards implementation. Algorithms can be developed to compute the safeguards effort likely to be required based on relevant facility parameters (e.g. facility type, status, type and amount of nuclear material, location etc.).

It is clear that verification of an FMCT would require substantial financial resources. Should States consider the IAEA as the most appropriate organization to be entrusted with verification of compliance with an FMCT, they would need to agree on the modalities of the verification costs.

The Agency could propose an FMCT verification system based upon existing safeguards, but sustained funding would be required for additional staff and supporting activities. Additional technical staff that would be needed would include inspectors and their immediate support staff, system analysts, computer programmers and data clerks, chemical analysts, statisticians, safeguards analysts, equipment development specialists, equipment management specialists and technicians. A limited increase in non-technical staff would also have to be considered. The equipment requirements for the verification of an FMCT would be substantial, especially during the initial phase of implementation of the treaty.

Cost estimates prepared by the Secretariat in 1995 relied on a data base of 995 nuclear facilities (including decommissioned and shut-down facilities and facilities under construction) in eight States (China, France, India, Israel, Pakistan, Russia, the United Kingdom, and the United States

[28] See *IAEA Safeguards Glossary*, op. cit., paragraph 3.15 – 3.16 (pp.23-24).

of America). Depending on the parameters, the costs of verifying an FMCT could vary between 50 to 150 million euros.

Implementation in Stages

Even if an FMCT verification system was not comprehensive, a substantial period of time still would be required to fully implement the verification provisions since between 200 and 1000 nuclear facilities (depending on the scope of the treaty) could become subject to verification. In some States, nuclear material control and accounting systems would have to be brought to internationally accepted standards, and some facilities are not designed to facilitate verification activities.

In addition, it remains unclear whether or not the conclusion of a verification agreement between a verification agency and each State Party would be an additional requirement for the implementation of the verification provisions of such a treaty.

The Agency has already successfully dealt with the issue of verifying the correctness and completeness of the declarations made by some States which have developed large safeguarded nuclear programmes. The Agency has, inter alia, examined historical accounting and operating records of both operating and shut-down facilities. This task has been challenging and the key to the Agency's ability to fulfil its mandate remains getting the full cooperation of the State in giving the Agency open access to all relevant information and sites.

Following an order of priority based on principles which have guided the Agency's implementation of comprehensive safeguards agreements (i.e. concentrated verification of the stages of the nuclear fuel cycle involving the production, processing, use or storage of nuclear material from which nuclear weapons or other nuclear explosive devices could readily be made), it could be possible to implement verification activities in stages.

Conclusion

IAEA safeguards began in the 1960s and have continued to evolve, without pause, as new verification responsibilities were assigned, as peaceful nuclear operations increased in size and complexity and as international relations posed new challenges. At present, with a safeguards regular budget of $130 million supplemented by $16.1 million in extrabudgetary contributions, more than 250 IAEA inspectors carry out over 2,100 inspections representing more than 9,000 person-days of inspection[29] work each year, using more than 100 different verification systems. As of 31 December 2005, Agency safeguards were applied to 930 facilities (including inter alia 240 power reactor units, 158 research reactors and critical assemblies, 13 enrichment plants, seven reprocessing plants, 89.9 tons of unirradiated plutonium outside reactor cores and 845 tons of plutonium contained in irradiated fuel, and 29.5 tons of high enriched uranium). The legal, technical and administrative arrangements adopted in different States and in different facilities respond to obligations mandated through Safeguards Agreements. In a wide range of areas, consideration of the existing safeguards arrangements will ensure that an FMCT

[29] A '"person-day of inspection" (PDI is defined as a day during which a single inspector has access to a facility at any time for a total of not more than eight hours. The *IAEA Annual Report for 2005* is posted at: http://www.iaea.org/Publications/Reports/Anrep2005/index.html; and the *Safeguards Statement for 2005, Background to Safeguards Statement and Executive Summary of the Safeguards Implementation Report for 2005* is available at: http://www.iaea.org/OurWork/SV/Safeguards/es2005.html.

verification and IAEA safeguards are implemented in ways that provide the maximum value at the minimum cost.

It is the IAEA Secretariat's assessment that verification of a treaty banning the production of fissile materials would be possible through a verification system quite similar to the one applied for the current IAEA safeguards system. The choice of a system to be developed to verify compliance with a fissile material production cut-off treaty is a matter for States to resolve. In this regard, States will have to address questions related to the different levels of assurance as well as the costs involved. As noted earlier in this paper, the IAEA is well aware of the differing views of States, inter alia, on the scope and verification of an FMCT and does not wish to pre-judge the outcome of the discussion of such issues in the Conference on Disarmament. The Agency, if requested, stands ready to assist in the process of further discussions and negotiations in whatever way is considered appropriate by States.

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