
# A Fissile Material Cut-off Treaty

## Understanding the Critical Issues

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# FOREWORD

A mandate to negotiate a treaty banning the production of fissile material for nuclear weapons has been under discussion in the Conference of Disarmament (CD) in Geneva since 1994. Agreement on a mandate to negotiate such a treaty—sometimes called a "fissile material cut-off treaty" or FMCT—has proved elusive for a range of political reasons.

On 29 May 2009 the Conference on Disarmament agreed a mandate to begin those negotiations. Shortly afterwards, UNIDIR, with the support of the Government of Switzerland, launched a project with two main objectives. The project sought to remind diplomats of the history of the CD's treatment of the topic of banning the production of fissile material for nuclear weapons. It also aimed to shed light on the critical issues at stake in the negotiation of a fissile material treaty.

This UNIDIR publication is a compilation of various products of the project. It includes a briefing paper on the work of the CD on developing a mandate for the negotiation of a fissile material treaty, a list of relevant CD documents, a bibliography of relevant academic and other materials, and papers presented or drawn upon at three seminars convened by UNIDIR under the project.

Our hope is that this publication and the activities conducted under the project will help illuminate the critical issues that will need to be addressed in the negotiation of a treaty that stands to make a vital contribution to the cause of nuclear disarmament and non-proliferation.

Theresa Hitchens
Director
UNIDIR

Jürg Lauber
Permanent Representative to the CD

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Swiss Confederation

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**Tim Caughley,** up to February 2009, served as the Deputy Secretary-General of the Conference on Disarmament and the Director of the United Nations Office of Disarmament Affairs in Geneva. Prior to this, he was New Zealand's Permanent Representative to the United Nations in Geneva and Ambassador for Disarmament. He also served as President of the Conference on Disarmament in 2005, and chaired the 2005 Nuclear Non-Proliferation Treaty Review Conference's Subsidiary Body on Nuclear Disarmament. During his earlier diplomatic career, he headed New Zealand's post in the Cook Islands and served in Malaysia and the United Kingdom. He holds a law degree from the Victoria University of Wellington. Tim is currently Resident Senior Fellow at the United Nations Institute for Disarmament Research in Geneva.

**Harold Feiveson** is a Senior Research Scientist and Lecturer in Princeton University's Woodrow Wilson School of Public and International Affairs. He has a PhD in public affairs from Princeton University (1972). Feiveson is the editor of the journal *Science & Global Security*. He is a co-founder of the Program on Science and Global Security and was its co-director until July 2006. Feiveson was lead author for chapter 8 of the *Global Fissile Material Report 2009*.

**Annette Schaper** is a Senior Research Associate at the Peace Research Institute Frankfurt. Her PhD (1987) is in experimental physics from Düsseldorf University. She is a co-founder of the Interdisciplinary Research Group in Science, Technology, and Security at the Institute of Nuclear Physics at the Technical University, Darmstadt. She was a part-time member of the German delegation to the negotiations on the Comprehensive Nuclear-Test-Ban Treaty and a member of the German delegation at the 1995 Nuclear Non-Proliferation Treaty Review and Extension Conference. Her research covers nuclear arms control and its technical aspects, including the test ban, a fissile material cut-off, verification of nuclear disarmament, fissile materials disposition, and nonproliferation problems arising from dual-use technology.

**Bruno Pellaud**, a physicist from Switzerland, served from 1993 to 1999 as Deputy Director General of the International Atomic Energy Agency

(IAEA) in Vienna and Head of the Department of Safeguards. He oversaw the strengthening of the safeguards system that led to the adoption of the Additional Protocol in 1997. He dealt extensively with the North Korean and Iranian cases, as well as the cases of South Africa, Argentina and Brazil. Since leaving the IAEA, Pellaud has maintained a keen interest in nuclear energy and non-proliferation. From 2001 to 2009, he was President of the Swiss Nuclear Forum, the main nuclear energy association of the country. In 2004–2005, he chaired the international group of experts brought together by the IAEA Director General to investigate “Multilateral Nuclear Arrangements” for the fuel cycle. He is a frequent lecturer on proliferation issues at the World Nuclear University and in various academic and political circles. He is a Non-Resident Associate of the Liechtenstein Institute on Self-Determination at the Woodrow Wilson School of Public and International Affairs of Princeton University.

**Andreas Persbo** was appointed Executive Director of the Verification Research, Training and Information Centre (VERTIC) in February 2010. He joined VERTIC in 2004. He specializes in nuclear arms control. This includes work on confidence-building measures between states and the verification of nuclear disarmament. Persbo is also responsible for maintaining the organization’s watching brief on issues relating to the 1996 Comprehensive Nuclear-Test-Ban Treaty, the 1968 Nuclear Non-Proliferation Treaty and IAEA safeguards. He also monitors the development of verification mechanisms for the proposed Fissile Material Cut-Off Treaty. In addition, he acts as the chief liaison to the IAEA and the Comprehensive Nuclear-Test-Ban Treaty Organization in respect to national implementation of nuclear arms control agreements. Andreas holds a *juris kandidat* (LLB, LLM) in public international law and European human rights from Stockholm University, Sweden.

# FISSILE MATERIAL NEGOTIATIONS IN THE CONFERENCE ON DISARMAMENT

*Note: see annex A for a list of relevant documents from the Conference on Disarmament, and the bibliography on fissile material negotiations.*

## BACKGROUND

### A MANDATE TO NEGOTIATE IN THE CD A BAN ON THE PRODUCTION OF FISSILE MATERIAL

Fissile materials are those elements that "can sustain an explosive fission chain reaction" and "are essential in all nuclear explosives", the most common being highly enriched uranium (HEU) and plutonium.[1] Since the early days of the Cold War, banning the production of fissile materials for nuclear devices has been a primary goal for advocates of nuclear disarmament. As early as 1953 US President Dwight Eisenhower called for their elimination in his "Atoms for Peace" speech before the United Nations.

The end of the Cold War brought a renewed call for nuclear disarmament and for a ban on the production of fissile materials used in nuclear weapons. In a statement to the United Nations General Assembly in September 1993, US President Bill Clinton addressed the issue. Saying that these materials were "raising the danger of nuclear terrorism in all nations", President Clinton called for the negotiation of an international agreement to halt their production.

In December 1993, shortly after that statement, the General Assembly passed Resolution 48/75L entitled "Prohibition of the Production of Fissile Material for Nuclear Weapons or Other Nuclear Explosive Devices". This resolution recommends an appropriate international body to negotiate a "non-discriminatory multilateral and internationally and effectively verifiable treaty banning the production of fissile material for nuclear weapons or other nuclear explosive devices". In 1994, the Conference on Disarmament (CD) began discussing the basis on which to initiate those negotiations.

## The Shannon Mandate

The CD appointed Ambassador Gerald Shannon of Canada as Special Coordinator to determine the views of CD members on the prospective scope of a treaty banning the production of fissile material for use in nuclear weapons. Such a treaty is sometimes referred to as a Fissile Material Cut-off Treaty (FMCT), Fissile Material Treaty (FMT) and Fissban. It needs to be noted, however, that use of the word "cut-off" (i.e. preventing future production) raises the question as to how or whether the treaty would also cover existing stocks of fissile material). Indeed, the primary debate that surfaced during the Shannon discussions centred on the inclusion of rules that would cover both existing stockpiles and future production of fissile material.

Nuclear-weapon-possessing states were not united in their approaches to a ban on fissile material. The P5 and India took the view that existing stockpiles would fall outside the purview of the ban. By contrast, many delegations felt that an effective treaty had to be broad in scope, verifiably banning future production, while at the same time mandating the declaration of existing stockpiles of fissile materials held by states. These delegations, including Pakistan, asserted that the treaty regime would be a meaningful disarmament measure only if it applied to both current stockpiles and future production. Given Israel's ambiguous nuclear weapon status, Egypt and other Arab states insisted that all stocks of weapon-usable fissile materials would have to be declared and be subject to inspection and inventory under international supervision and control.

On 24 March 1995, Shannon produced CD Document 1299 (CD/1299), commonly known as the Shannon Mandate. It called for the establishment of an ad hoc committee[2] within the CD to negotiate a fissile material treaty. The mandate set two primary objectives:

- the establishment of an Ad Hoc Committee on a "ban on the production of fissile material for nuclear weapons or other nuclear explosive devices"; and
- the negotiation of a treaty that in the words of resolution 48/75L would be "non-discriminatory, multilateral and internationally and effectively verifiable".[3]

The latter goal was intended to ensure that the outcome was one that applied the same rules to all states, both nuclear-weapon states and non-nuclear-weapon states (in contrast, for example, to the Treaty on the Non-Proliferation of Nuclear Weapons (NPT)).

The Mandate did not explicitly describe the scope of the negotiations in relation to stocks of fissile materials (i.e. whether an agreement would apply only to future production or would include past production as well). Shannon noted that in the course of his consultations, "many delegations expressed concerns about a variety of issues relating to fissile material, including the appropriate scope of the [eventual fissile material treaty]". The mandate left the issue of scope to be discussed, stating: "It has been agreed by delegations that the mandate for the establishment of the Ad Hoc Committee does not preclude any delegation from raising for consideration in the Ad Hoc Committee any of the [these] issues".[4]

After the Shannon Mandate was issued in 1995, discussions on forming the Ad Hoc Committee stalled. States of the Non-Aligned Group, composed primarily of non-nuclear-weapons states, insisted that progress toward the negotiation of a treaty be linked to real progress toward the elimination of nuclear weapons. Dissatisfied with the pace of nuclear disarmament under the NPT, these states called for a specific timetable for nuclear disarmament. However, the five NPT-recognized nuclear-weapon states refused to agree to this linkage.[5]

In 1998, after India's and Pakistan's nuclear tests, a breakthrough was achieved. On 11 August 1998, toward the end of its session for that year, the CD formally established in CD/1547 an Ad Hoc Committee to negotiate a treaty in accordance with the Shannon Mandate. The Committee met in negotiations for the three remaining weeks of the session, under the chairmanship of Canadian Ambassador Mark Moher. (It should be noted, given the linkages that were subsequently made in the development of the CD's annual work programme, that one other Ad Hoc Committee was established in 1998, with the mandate to negotiate "effective international arrangements to assure non-nuclear-weapon states against the use or threat of use of nuclear weapons", known also as negative security assurances. That committee began work on 19 May, holding nine meetings in all.)

## Disagreement over the CD's annual programme of work

The breakthrough was short-lived. The Ad Hoc Committee did not reconvene during the 1999 session because consensus could not be reached on the CD's annual programme of work, a formality required by the Rules of Procedure.[6] Moreover, the CD would not reach consensus on any programme of work for the next 10 years, stalling negotiations on a fissile material treaty and other substantive matters on the CD's agenda for that entire period. As well as the general issue of nuclear disarmament, the other main issues on the agenda included the prevention of an arms race in outer space (PAROS) and negative security assurances (NSAs). This quartet is sometimes referred to in the CD as the "core issues".

Several factors led to this inability to reach consensus. Differences over whether a fissile material treaty should cover existing stockpiles, and the linking of the successful conclusion of a treaty to a time-bound schedule for nuclear disarmament, complicated the task of establishing the CD's annual work programme. Over time, additional linkages arose. US policy in favour of a national missile defence programme served to increase the urgency felt among some members of the CD for pursuing negotiations on the issue of PAROS.[7] China, the primary advocate of making progress on fissile materials contingent on progress on PAROS, soon gained the backing of Russia, but the United States resolutely opposed the need to negotiate a treaty on PAROS. With these divergences over various linkages among the issues to be covered by a programme of work, negotiations on a fissile material treaty remained stalled.[8]

## Dealing with linkages among items on the programme of work

In 2000, CD President Ambassador Celso Amorim of Brazil impressed on the Conference the need to establish a programme of work that "organized differences" in a manner that did not impede progress on other important goals. Amorim proposed a programme of work in CD/1624 that called for the establishment of four separate Ad Hoc Committees within the CD, each with a separate mandate to take up the "important goals of disarmament".

One such committee would be established to negotiate a fissile material treaty. This group would be mandated to negotiate, on the basis of the Shannon Mandate, an agreement to ban the production of fissile materials for nuclear weapons or other nuclear explosive devices.[9] Another committee would be established to "exchange information and views" to move toward the goal of nuclear disarmament, another to "examine and identify specific topics or proposals" pertaining to PAROS, and another to "negotiate with a view to reaching agreement" on NSAs.[10] In an accompanying "Presidential Declaration", Amorim would make it clear upon adoption of the work programme that no matter how each mandate was actually worded (i.e., as a negotiation, an exchange of views, or an examination) the CD was in reality a *negotiating* body. This explanation was designed to accommodate Members for whom anything less concrete than a negotiation, resulting in a binding outcome, was unacceptable.

The Amorim proposal's establishment of four Ad Hoc Committees and the accompanying Presidential Declaration was to become a kind of prototype for future programme of work proposals. Such an approach sought to provide assurances to Members that the CD would actively deal with all four core issues, thus enabling the CD to move forward with negotiations on a fissile material treaty within the framework of the Shannon Mandate by mitigating concerns that the other core issues might become ignored over time. But the differences among the four mandates proved to be an obstacle, in that these differences raised the question of whether or not the mandate for a particular core issue would culminate in a legally binding outcome (i.e. a treaty).

## Negotiation versus discussion

In 2003 a programme of work proposal was tabled, CD/1693 (later CD/1693 Rev. 1), accompanied by a "Presidential Declaration". This effort was dubbed the "A5" proposal (for "five Ambassadors", the former CD presidents, of cross-regional origin, responsible for the proposal[11]). CD/1693 Rev.1 addressed the four core issues through the establishment of Ad Hoc Committees, one with the mandate to negotiate a fissile material treaty on the basis of the Shannon Mandate; one with the mandate to negotiate with a view to reaching agreement on NSAs; one with the mandate to exchange information and views on practical steps for progressive and systematic efforts toward nuclear disarmament; and one with the mandate to identify and examine, without limitation, any specific topics or proposals on PAROS.

The A5 proposal was similar, but not identical, to Amorim's, but there was a subtle difference in the accompanying Presidential Declaration. In terms of divergent views on whether the treatment of a particular issue should—through "negotiations"—result in a treaty, the Declaration stated that the products of the Ad Hoc Committees could lead "in time, to international instruments acceptable to all".

Nonetheless, the CD remained unable to reach consensus. While China was willing to accept the terms of the proposal regarding PAROS, the US administration under President George W. Bush began in 2002 a two-year review of its policy regarding the fissile material treaty, preventing the CD from reaching consensus on a programme of work. In July 2004, following this review, the United States announced that it could support the negotiation of a legally binding ban on the production of fissile material for explosive purposes. Two years later, however, it concluded that it could not support a treaty under the parameters of the Shannon Mandate, claiming that such a treaty could not be effectively verified. In May 2006 the United States tabled a treaty proposal together with a draft mandate (CD/1776 and CD/1777) that did not include verification, a significant departure from the Shannon Mandate. The US position effectively prevented further progress in the CD under the Shannon Mandate during the following years.

## Coordinators instead of Working Groups

In March 2007 the six presidents of the Conference, continuing a practice begun the previous year of working together to provide cohesion and continuity, tabled CD/2007/L.1. This document proposed the appointment of coordinators—rather than subsidiary bodies (such as Working Groups or Ad Hoc Committees)—to chair informal sessions of the CD on each of the core issues, and called for continuing work on the three remaining substantive items on the CD's agenda, items 5, 6 and 7.[12] The approach of appointing coordinators instead of establishing subsidiary bodies was an attempt to overcome sensitivities among those few Members who were reluctant for mandates to be carried out through Working Groups or Ad Hoc Committees.

The coordinator for fissile materials would be given the following mandate by CD/2007/L.1: "to preside over negotiations, without any preconditions, on a non-discriminatory and multilateral treaty banning the production of fissile material for nuclear weapons or other explosive devices". The coordinators for the other core issues were mandated to preside over "substantive discussions" rather than "negotiations".[13]

## Outcomes: treaties or lesser instruments?

A "Complementary Presidential Statement" (CD/2007/CRP.6) was devised to accompany the proposed draft decision by the Conference, offering assurance that CD/2007/L.1 did not prejudice any past, present or future issue, nor did it set preconditions, or prescribe or preclude any outcome.[14] Once again, the complementary statement was intended to make the proposed work programme acceptable to those who sought legally binding outcomes on the remaining core issues (thus overcoming the linkages problem), as well as keeping options open for addressing contentious issues, most notably the issue of scope. However, consensus on the programme of work still remained out of reach—this proposal, like the Amorim and A5 proposals, was not submitted to the CD for a formal decision. In each case, it was the judgement of the president, based on extensive consultations, that although very widely supported, none of the proposals would have attracted the necessary consensus to be adopted.

In 2008 the six presidents for that year introduced in CD/1840 a further refinement aimed at improving the prospects for consensus on a programme of work. This document followed the comprehensive approach used in the previous drafts and proposals. It would appoint a coordinator to preside over "negotiations" on a fissile material treaty, and all delegations would have "the opportunity to actively pursue their respective positions and priorities, and to submit proposals on any issue they deem relevant in the course of the negotiations". This proposal sought to meet the needs of Members such as Pakistan that would not accept a mandate on fissile materials *without* mention of verification, and of the United States, which would not accept a mandate on fissile materials *with* mention of verification.

CD/1840 also would appoint individual coordinators to preside over "substantive discussions" on the three other core issues (disarmament, PAROS and NSAs). Moreover, in the cases of those other issues, CD/1840 kept the assurance of CD/2007/CRP.6 that the decision would not proscribe or preclude any outcome of the substantive discussions.[15] Again, due to lack of support the proposal was not submitted to the CD for decision.

## Breakthrough

In 29 May 2009, CD/1863, tabled by the presidency as a "draft decision for the establishment of a programme of work for the 2009 session", was submitted to the CD for decision by Algerian Ambassador Idriss Jazairy, on his final day as president, and drew no objections. It was adopted and became CD/1864.

Instead of Ad Hoc Committees or coordinators, the agreed programme of work established four Working Groups with the following mandates:

- to "negotiate a treaty banning the production of fissile material … on the basis of [the Shannon Mandate]";
- "to exchange views and information on practical steps for [nuclear disarmament], including on approaches toward potential future work of multilateral character";
- "to discuss substantively, without limitation, all issues related to the prevention of an arms race in outer space"; and
- "to discuss substantively, without limitation, with a view to elaborating recommendations dealing with all aspects of [NSAs], not excluding those related to an internationally legally binding instrument".[16]

All four mandates included the stipulation that each Working Group would "take into consideration all relevant views and proposals, past, present and future". Each Working Group was also required to report to the CD on the progress of its work before the conclusion of the current (annual) session.

Close perusal of the four mandates shows not only qualitative differences among them, but also how they have been refined over time. The evolution of mandates other than that dealing with fissile materials will not be considered here. But, given the linkages referred to earlier, it should be noted that consensus on a programme of work was made possible through compromises made over time in relation to non-insistence on a negotiating mandate for PAROS (China, Russia), non-insistence on a negotiating mandate on NSAs[17] by a number of Non-Aligned Group members, and revised instructions on verification (United States) following the election of US President Barack Obama.

### Return to the Shannon Mandate

The CD has, thus, returned to the Shannon Mandate, albeit as one of a number of other highly substantive and complex items on its programme of work for 2009. Whereas in 1998 the CD had two negotiating mandates to pursue, the decision in 2009 entailed only one negotiation but three other substantive undertakings and a further three issues to explore for further possible treatment. Given that the CD subsequently failed to implement its 2009 decision and that its Rules of Procedure require it to establish a programme of work annually, it remains to be seen whether the decision of 29 May 2009 will provide the basis for sustained work on fissile materials in 2010 through the adoption of a programme of work comparable to CD/1864 or whether CD/1864 will be as short-lived as CD/1547.

## OBJECTIVES, ELEMENTS AND CHARACTERISTICS OF AN FMT

### Possible objectives

It is worth bearing in mind the following considerations on the objectives of a fissile material treaty. The weight given to these factors by delegations or groups of delegations will determine the outcome of eventual negotiations:

- Banning the production of fissile materials for nuclear weapons will serve several ends. It will limit the pool of materials available for manufacturing such weapons, thereby benefiting the causes of horizontal and vertical non-proliferation, and lowering the risk of diversion to terrorists.[18]
- There exists a widespread expectation that an outcome of the negotiations will be the formalization of the longstanding **moratoria** on fissile material production declared unilaterally by France, Russia, the United Kingdom and the United States, extended to cover the other FM producers that possess, or are thought to possess or to be in the process of acquiring, nuclear weapons.
- A fissile materials treaty will also aid the cause of nuclear disarmament by making reductions in nuclear arsenals **irreversible**. This will be achieved through the manner in which the treaty ensures that fissile materials **declared** excess to weapons needs is prevented from any

future use in nuclear weapons. Such an outcome will serve two purposes. It will improve the climate of trust among the nuclear-weapon-possessing states, and at the same time it will help build confidence among non-nuclear-weapon states that real steps toward nuclear disarmament are being taken, provided that this excess fissile materials are placed under international safeguards.

- From the emphasis in the Shannon Mandate on the need for a "**non-discriminatory**" regime, it is clear that the final outcome will need to satisfy non-nuclear weapon states that a fissile material treaty would have no discrimination in favour of the nuclear-weapon states. This factor reflects the view among non-nuclear-weapon states that the bargain underpinning their agreement to the NPT is not being honoured by the nuclear weapon states.
- It would greatly boost the causes of nuclear disarmament and non-proliferation if a treaty covered **existing** stocks of fissile materials as well as **future** production. Even if agreement on existing stocks eludes negotiators, parallel measures outside of a treaty could enhance transparency and facilitate irreversibility.

## Elements of a treaty: questions of scope

This section breaks down the "design" choices (to use the words of the International Panel on Fissile Materials), that is, the possible elements on which a future agreement would be based. These elements will determine the ultimate scope of a fissile material treaty, and are relevant to the discussion of other issues, notably definitions and verification, and of possible negotiating scenarios.

For example, a treaty covering **existing** fissile material stocks as well as **future** stocks will affect the range of verification mechanisms needed to ensure compliance with the terms of the instrument. The success of the eventual treaty will be measured not only by the number of states that formally adhere to it but also by the clarity and effectiveness of the mechanisms through which compliance with its obligations is verifiably secured.

Moreover, some elements—especially the question of which stocks will be covered—will be settled only in conjunction with reaching agreement on **definition** of terms. In this regard, delegates will be able to draw on work conducted already, especially that by the International Atomic Energy Agency (IAEA) and the International Panel on Fissile Materials.

## Design choices

Clearly, the design choices made by the negotiators will determine to what extent the draft treaty can be considered a non-proliferation measure or one which addresses both non-proliferation and nuclear disarmament. The greater degree to which the treaty covers the categories of fissile materials identified in the following paragraph, the more the final product can be regarded as being both a non-proliferation and nuclear disarmament measure.

Fissile materials can be classified as follows:

a) Non-explosive:

(i) fissile material produced for civilian purposes (energy production, medicine, maritime propulsion and other uses in non-military facilities or vessels); and

(ii) fissile material produced for non-explosive military purposes (energy production, medicine, maritime propulsion and other such uses in military facilities or vessels).

b) Explosive:

(i) fissile material produced for explosive purposes and which is **already in use** in existing nuclear weapons or which is weapon-grade or weapon-usable[19] and has been **stockpiled** awaiting use in weapons;

(ii) fissile material declared in **excess** of weapons needs (i.e., weapon-grade or weapon-usable fissile material which is no longer required for nuclear weapons or which has been extracted from weapons retired from nuclear arsenals); and

(iii) **future production** of fissile material for use for explosive purposes. “Future” means from the date of entry into force of the treaty or such other date as may be determined by it.

The mandate given under the CD's 2009 Programme of Work (CD/1864) to the relevant Working Group is to negotiate a treaty to ban "the production of fissile material for nuclear weapons or other nuclear explosive devices". Bearing in mind that four of the five NPT-recognized nuclear-weapon states have unilaterally declared moratoria on the production of such fissile materials and that some have engaged in "down-blending" excess stocks, there is already some movement toward this objective.

It is also clear from the CD's 2009 mandate that fissile material that is produced for civilian (i.e. non-military, non-explosive) purposes is not intended to be covered by any prohibition. (The distinction between the types of fissile material that can be used in nuclear weapons and those than cannot is discussed below under "Definitions".) Fissile material produced for civilian and military non-explosive purposes would be covered by the future treaty to the extent that it would be necessary to provide that both types of material are subject to a regime in which they can be safeguarded, that is, subject to measures that verify the materials are not:

- **diverted** by a state for conversion within that state (e.g. through enrichment) for use in nuclear weapons or other nuclear explosive devices; or
- **transferred** to another state except through proper, safeguarded channels.

Materials already being used in weapons or stockpiled for future explosive use raise a complex and divisive set of considerations in terms of coverage by a treaty. Isolating or identifying fissile materials in weapons and stockpiles in existence when a treaty enters into force is a highly sensitive issue in political and practical terms. It would be difficult to reach consensus on a verification regime that was not seen by nuclear-weapon possessors as overly intrusive. The question which negotiators will face, therefore, is whether fissile material already embedded in existing nuclear weapons or in stock for future weapons use should be the subject of agreements other than fissile material treaty. In any event, while the **future production** of fissile material for explosive purposes would clearly be banned by a treaty, the question of how to deal with **existing** materials will be the central challenge of the negotiations.

## Managing excess

There would need to be the means to verify that excess weapon-grade fissile material was not being re-used in nuclear weapons or being stockpiled for such use. Inventories of what is excess to weapons needs would have to be established in order to provide a baseline against which to measure progress in the proper disposal of excess stocks. Accurate accounting of these stocks would help ensure that they have not been stolen by terrorists or others or diverted for proliferation or other purposes. The means of accounting would be through (unilateral) declarations or other reporting mechanisms. This will be developed below, but it should be noted here that existing models for reporting stocks such as IAEA's INFCIRC/549[20] can serve to assist delegations in developing approaches in increasing transparency.

The question of managing excess weapon-grade fissile materials is of fundamental importance given the NPT's obligations on the nuclear-weapon states and the moral and political pressures on the other possessors, i.e., those that are not party to the NPT. Given the obligations imposed by article VI, the international community is entitled to expect of a constant flow of declarations of excess fissile material resulting from steady processes for the de-commissioning of nuclear weapons. Future arms reductions accompanied by declarations that the material in these weapons would be placed under international safeguards, will diminish the global stock of fissile materials in an irreversible and transparent manner.[21]

## Future production

A fundamental step toward fulfilling a mandate such as CD/1864 is that the treaty would prohibit all future production of fissile material for explosive purposes and that strenuous efforts would be made after the negotiations to universalise the new agreement. Clearly, a producer of such materials that does not become party to the treaty will not legally be subject to the ban.

## Stockpiles

Strong resistance has been voiced, particularly by the nuclear-weapon states, to the inclusion of existing weapon-grade fissile materials (in warheads, stockpiled as reserves, or excess) within a future treaty. If this resistance is sustained and if delegations are unable to agree that a treaty should encompass existing stocks of weapon-grade fissile materials, the manner of addressing existing fissile materials will need to be rethought. That is not to say that addressing these materials in some shape and form must be abandoned entirely. A middle ground may be achieved, via a "phased" approach, as will be discussed in the section "Other approaches to the negotiations".

Alternative approaches to the negotiations are developed below, but warrant a brief mention here. In the absence of a fissile material treaty which addresses the question of existing military stocks, the relevant states might seek to address this issue in a separate manner following the conclusion of negotiations. These states might be required to:

- implement state **accounting practices** under which weapon-grade material would be controlled; and
- make unilateral **declarations** accounting for such stocks (and, consistent with the NPT, progressive reductions of them).

The International Panel on Fissile Materials envisages that initial declarations would simply state total holdings of HEU and plutonium. Ideally, declarations would specify the total quantities of HEU and plutonium in five categories of holdings:

1. Warheads, warhead components and associated working stocks in the warhead-production complexes overall and at individual sites;
2. Material that has been determined excess for military purposes but is still in weapons or weapon components;
3. Reserves for naval and other military-reactor use and in the naval fuel cycle (not including in spent fuel), divided into quantities in classified and unclassified forms;
4. Spent military-reactor fuel; and
5. Civilian stocks, divided into unirradiated and minimally irradiated forms (including in critical assemblies and pulsed reactor cores), and irradiated material in reactor cores and spent fuel.[22]

In the absence of mandatory declarations of such categories of stocks, other approaches that could be pursued include:

- urging nuclear-weapon states that have not already done so to make declarations of their total weapon-grade fissile material stockpiles;
- encouraging the conclusion of agreements to limit the number of national fissile material production facilities for civil applications (enrichment and reprocessing plants) through “multinational nuclear approaches”, incorporating the joint operation of such facilities in a regional context; and
- advocating near-total elimination of the use of HEU as a civilian reactor fuel, and rapid reduction of current civilian plutonium stockpiles through the recycling of mixed-oxide fuel (MOX) in nuclear power plants.

## Definitions

A fundamental issue is which materials should be covered by a fissile material treaty—or more precisely, what scientific criteria should be used to determine which materials were within the scope of the treaty and therefore banned. A subset of this issue is whether the production of certain materials could continue under international verification to ensure peaceful use. The main purpose of articles dealing with definitions will be to specify those fissile materials that will be banned and those that will not, distinguishing between fissile materials that have a strictly civilian application and those that are capable of being used in nuclear weapons.

Article XX of the IAEA Statute defines **Fissile material** as follows:

1. The term “special fissionable material” means plutonium-239; uranium-233; uranium enriched in the isotopes 235 or 233; any material containing one or more of the foregoing; and such other fissionable material as the Board of Governors shall from time to time determine; but the term “special fissionable material” does not include source material.
2. The term “uranium enriched in the isotopes 235 or 233” means uranium containing the isotopes 235 or 233 or both in an amount such that the abundance ratio of the sum of these isotopes to the isotope 238 is greater than the ratio of the isotope 235 to the isotope 238 occurring in nature.
3. The term “source material” means 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.[23]

**HEU**: U-235, in nature, makes up only 0.7% of natural uranium. The remainder is almost entirely U-238, which is fissionable but not fissile, that is, it cannot support a chain reaction. Although uranium enriched to 6% U-235 could, in principle, sustain an explosive chain reaction, uranium enriched to above 20% U-235, defined as "highly enriched uranium", is generally taken to be required for a weapon of practical size. The IAEA therefore considers HEU a "direct use" material, that is, material that can be used in a nuclear weapon without further enrichment. Actual weapons use higher enrichment, however, with "weapon-grade" uranium being enriched to over 90% U-235.

**Plutonium**: Plutonium is produced in a nuclear reactor when U-238 absorbs a neutron, creating U-239, which then decays to plutonium-239 (Pu-239). The longer an atom of Pu-239 stays in a reactor after it has been created, the greater the likelihood that it will absorb a second neutron and become Pu-240—or a third or fourth and become Pu-241 or Pu-242. Plutonium therefore comes in a variety of isotopic mixtures. Weapon designers prefer to work with a mixture that is as rich in Pu-239 as feasible because of its relatively low rate of radioactive heat generation and relatively low rate of spontaneous neutron and gamma ray emission. Weapon-grade plutonium contains more than 90% of the isotope Pu-239. Plutonium in spent fuel from a power reactor typically contains between 50 and 60% Pu-239, and about 25% Pu-240.

It was once believed that the plutonium generated in power reactors could not be used for weapons. It was thought that the large fraction of Pu-240 in "reactor-grade" plutonium would reduce the explosive yield of a weapon to insignificance. However, more modern weapon designs are not as sensitive to the isotopic mix in the plutonium and virtually any combination of plutonium isotopes can be used to make a nuclear weapon. While the higher neutron production rate from reactor-grade plutonium reduces the probable yield to an extent, the result is still a devastating weapon.

At the lowest level of sophistication, a potential proliferating state or non-state actor, using designs and technologies form the first-generation of nuclear weapons, could build a nuclear weapon from reactor-grade plutonium that would have an assured, reliable yield of one or a few kilotons (and a probable yield significantly higher than that). At the other end of the spectrum, advanced nuclear weapon states such as the United States and Russia, using modern designs, could produce weapons from reactor-grade plutonium having reliable explosive yields, weight, and other characteristics generally comparable to those of weapons made from weapon-grade plutonium.

**Other Fissile Materials**: In addition to plutonium, other weapon-useable fissile materials can be produced by irradiating different target materials in nuclear reactors or by the decay of certain isotopes of plutonium. Among these are U-233, neptunium-237, and americium-241. While Pu-239 and U-235 are the dominant fissile materials used in the weapons programmes of all the nuclear-weapon states, the United States, at least, has tested designs containing U-233. France, and perhaps other nuclear weapon states, may have experimented with neptunium-237 in nuclear tests.

## Verification

Options for mechanisms developed to verify that a fissile material production ban is being upheld depend on decisions on the scope of the proposed treaty. The following paragraphs discuss various approaches that could be taken, including whether negotiators should take a comprehensive approach similar to the Comprehensive Nuclear-Test-Ban Treaty (CTBT) and embed detailed articles on verification within the agreement, or rather simply develop a framework that would be built upon in a separate instrument.

### Verification mechanisms within the treaty

In a sense, the verification of the presence of nuclear materials is easier than the verification of chemical and biological agents, given the radioactivity emitted by fissile materials and the inherently **dual-use** capacity of biological and chemical products. Determining the purpose for which nuclear materials will be used, nonetheless, is far from straightforward given the secrecy with which nuclear weapons are produced and stockpiled.

While the production of some fissile materials will be banned, the production of others will not, although the latter are likely to be subject to a mechanism for ensuring that they will not be converted for use in weapons. It can thus be assumed that the primary focus of verification would be on **production facilities**. Which relevant facilities will need to be addressed? Determining the elements of the production chain that will be subject to the verification mechanism will need attention, both as a matter of scope and definition.

The key principles and requirements of verifying compliance with the terms of the treaty will also depend on a sound understanding of the technologies of fissile material production and the techniques and technologies available for verification. Issues such as monitoring of declared sites, required declarations, routine and random (or "challenge") inspections, inspection of undeclared sites, and the rights, responsibilities and protections of the inspected party as well as of the inspectors, must all be addressed in the negotiations.

### Verification mechanisms alongside the treaty

The negotiators must determine whether the treaty will be self-contained in regards to verification or, like the NPT, set out the basic principles, leaving the details for elaboration in an additional instrument or series of instruments.[24] However, it should be borne in mind that the future treaty will complement the NPT regime under which non-nuclear-weapon states are, in effect, already subject to a prohibition on producing fissile materials for explosive purposes,[25] with compliance verified by the IAEA.

If negotiators choose to subcontract the IAEA and draw on the existing verification tools utilized by the IAEA in fulfilling its mandate to verify nuclear material in states that have safeguards agreements with the Agency, a fissile material treaty could provide for the current IAEA-based NPT safeguards system to be used as a basis for demonstrating compliance of NPT non-nuclear weapon states with the treaty. This outcome presumes the willingness of states not party to the NPT to acquiesce in the inclusion of such an arrangement in a fissile material treaty, a factor that could be addressed by treating the IAEA's role under the new treaty as simply parallel—rather than formally related—to its NPT role.

The safeguards system for non-nuclear-weapon states is designed to enable the IAEA to draw conclusions concerning:

- the peaceful use of all declared nuclear material in a state; and
- the existence of undeclared nuclear material and activities in a state.

The IAEA's ability to draw the second of these two conclusions is heightened when a state has an Additional Protocol in place. Full implementation of the IAEA safeguards system in a state with which the IAEA has a comprehensive safeguards agreement and an Additional Protocol in place would permit the IAEA to make an annual determination of treaty compliance in terms of assuring that here has been no diversion of fissile materials from declared use and no undeclared activities.

If negotiators agreed to use the IAEA safeguards system as the verification mechanism for a fissile material treaty, non-nuclear-weapon states that do not currently have a comprehensive safeguards agreement and an Additional Protocol in place would have to adopt these standards in order to allow verification of their full compliance with the treaty. In the case of non-nuclear-weapon states which already have a comprehensive safeguards agreement and the Additional Protocol in place, a fissile material treaty is unlikely to impose burdensome new obligations.

To fulfil any mandate requiring that fissile material treaty negotiations must result in a "non-discriminatory outcome", such as the Shannon Mandate or CD/1864, negotiators would need to adapt the IAEA safeguards system, or applicable elements of it, for use in states to which it is not currently applied, that is, NPT nuclear-weapon states and states not party to the NPT. Obligations that would be undertaken by these states would likely need to include the following:

- no diversion of fissile material to weapons programmes;
- no undeclared production of such material; and
- no transfer of fissile material.

Depending on the extent of the scope of the future treaty, other verification measures that go beyond the current IAEA safeguards system could also be developed within the treaty, or in parallel to it in a separate instrument or protocol, if there is consensus in the negotiations to do so. In any event, a fissile material verification regime should include measures to build a high level of confidence that all States Parties would be in compliance with their treaty-based commitment not to produce fissile material for nuclear weapons or other nuclear explosive devices.

### Alternative verification mechanisms and approaches

While the application of IAEA safeguards measures to states producing fissile materials would be advantageous, alternative verification measures could be considered as a fallback, drawing on experience gained in the negotiation and implementation of other nuclear non-proliferation, arms control and disarmament treaties and initiatives, for example the Intermediate Range Nuclear Forces (INF) Treaty, the Strategic Arms Limitation Talks (SALT), the Treaty on Strategic Offensive Arm (START) and the Trilateral Initiative. These verification measures could be pursued multilaterally, bilaterally or through "national technical means"[26] with the verification conclusions drawn from such activities being shared with all states parties to the treaty.

There are also several procedural options for articulating the verification obligations. For instance, if negotiators decide that only the principles and general considerations relating to verification need to be set out in the treaty, they may wish to leave the specification of technical details, procedures and technologies to be developed in a separate instrument with, or without, the same legal force as the framework, or head, agreement. Given that verification technologies are constantly evolving, it might be an inefficient use of negotiating time to follow the CTBT precedent of specifying them in the treaty text itself.

### Costs of verification

The costs of a verification mechanism will not be insignificant. Obviously, the more ambitious the mechanism, the greater will be its cost. For instance, the verification of all nuclear facilities in the nuclear-weapon-possessing states would entail a more comprehensive and intensive monitoring, inspection and surveillance system than is already required in non-nuclear-weapon states. Finding a formula to share such costs will be a fraught, time-consuming and highly political task.

Pursuing **existing** verification mechanisms, however, such as those just noted, would have the benefit of limiting the costs of verification. The verification system—whether specified in the treaty or in an ancillary instrument—could, at least initially, incorporate **existing** verification techniques and technologies in order to build upon approaches that are already in place and in which states have a high degree of confidence. The regime could be further supplemented through the use of tools akin to those developed, for example, under the Biological Weapons Convention, such as confidence building measures, that serve to promote transparency and thus compliance.

### Entry into force

The rules that govern the manner and time of a treaty's entry into force are sometimes crucial to its ultimate success. As the CTBT has shown, setting the threshold for the number and types of states parties that must adhere to an agreement in order to bring it into force as legally binding international instrument is a complex and politically sensitive calculation. With a fissile material treaty, that calculation will involve reaching consensus that the instrument will enter into force once a specified number of states in general have ratified or acceded to it—the orthodox approach in treaty law—or once a specified number of particular states have ratified or acceded to it (e.g. fissile material producers).

An agreement that imposes a production ban will have maximum effect if all producers bind themselves to imposing that ban. This does not necessarily mean that the article on entry into force needs to stipulate that all producers must adhere to the treaty before it can enter into force. On the other hand, the number of states that are regarded as producers might help to inform the decision on the appropriate threshold for entry into force. For example, with a total of around 40 states that currently produce fissile materials for civilian or military purposes, it would increase the effectiveness of the treaty if entry into force would not occur until 25 or 30 of those states had become party to it.

As for the starting date, the traditional approach is that binding legal obligations take effect from the date of the treaty's entry into force. That precise date for individual states parties is either:

- the date on which the treaty reaches a specified threshold of states (or specified states) adhering to it, including the individual state in question, thus entering into force; or
- the date on which that state lodges its instrument of ratification or accession or the date on which any period of delayed application expires. (For example, some treaties specify that they will enter into force for the new party six months after that state deposits its instrument of ratification or accession with the depositary.)

## Review

Advantages of including in the treaty a provision for its regular review are that:

- concerns about implementation can routinely be raised, debated and acted upon if necessary;
- provisions dealing with technical matters, such as the technology used for verification, can be revisited if the technology in question becomes obsolete or if new means and methods emerge; and
- more generally, any states that hold concerns about the manner in which the regime may unfold might find it easier to adhere to the treaty if it provides an assurance that its terms can be reviewed.

It is widespread practice in the disarmament arena to review the operation and implementation of treaties every five years, supplemented by annual meetings of states parties as a means of preparing for the five-year review.

## Compliance

A state party to a treaty is expected to—and must—comply with its terms as a matter of international law. Compliance provisions in a treaty can, nonetheless, serve two main purposes:

- they may establish a mechanism to handle potential or suspected breaches, such as through the circulation of a notice to states parties for consideration at a Review Conference or a regular or extraordinary meeting of states parties; and

- they may go further than that, providing a mechanism for the tasking of a fact-finding inquiry or an investigation, for example, by the UN Secretary-General.

### Amendment

An article establishing a procedure for amending the treaty may build in some flexibility to respond to unforeseen events or effects. Normally, however, an amendment does not come into formal effect until states individually signify their acceptance of it, resulting often in significant delays, although states can be expected to apply it informally in the meantime.[27]

## POSSIBLE NEGOTIATING SCENARIOS

The complex nature of the subject matter and the interdependencies among the key issues present a real challenge to the negotiation of a fissile material treaty. In his farewell statement in the CD on 2 July 2009, German Ambassador Bernhard Brasach observed that there is a triangular relationship between definitions, scope and verification, noting that these three issues will need to be "fine-tuned neatly to each other in parallel throughout the negotiations".[28]

These remarks arise from a concern to avoid focusing initially on definitions without having first explored the issues of scope and verification. Using the word "scope" in the broadest sense, clearly the way forward will be determined by gauging the parameters of the negotiations in the initial, general phase of negotiations. Definitions in treaties are normally a means to an end, that is, they are included in order to assist with interpreting matters of substance. They are of course substantive in their own right but they are generally not ends in themselves.

Ambassador Brasach's comments also allude to the linkage that exists between the scope of the production ban and verification. As mentioned earlier, the actual extent of the ban agreed by negotiators will determine the verification measures required to provide the level of effectiveness of the regime envisaged by the mandate.

The negotiators of the CTBT grappled on three fronts: with definitions, including that of nuclear explosions (the zero-yield issue); with scope, in terms of setting a threshold for the yield of tests and deciding whether to cover peaceful nuclear explosions; and with the relationship between scope and verification, and the resulting intrusiveness of verification. In the case of the CTBT, monitoring of the obligation to not carry out any nuclear explosion is clearly more effectively achieved than would have been the monitoring of nuclear explosions that were permitted so long as they did not exceed a specified yield.

Several considerations arise from the dilemma of where and how to begin the negotiations. First, there is the practical matter of how to stage the negotiations. There is the option of a triangular approach envisaged by the German Ambassador, in which the negotiations on definitions, scope and verification are carried out in a manner that recognizes their interrelatedness.

At one level, this entails that debate must identify, then resolve, the divergences emerging in the Working Group. On the one hand, it will be important not to let the debate go round circles among the three issues. On the other hand, it will be important that the negotiations are conducted in such a way as to avoid fixations, especially on definitions and scope. Clearly verification mechanisms can only sensibly be discussed when the scope of the proposed treaty becomes clearer. Avoiding these pitfalls will require close coordination and cooperation among those chairing the respective negotiations.

At another level, it will be necessary to identify and chart the main options at issue. For instance, once the debate has matured to a point where all initial negotiating positions have been tabled, it may be useful for the Working Group chair to produce a compilation which identifies the relationships among scope, definitions and verification for each of the major divergent positions of the delegations. The purpose would be to clarify things for the next round of the negotiations. The chair of the Working Group will from time to time need to pull together the interconnecting threads of these three areas, refining them as negotiations intensify.

Another major matter for consideration by negotiators is whether, and if so at what point, to designate “Friends of the Chair” or set up sub-groups on key issues. At issue is whether parallel negotiations on scope, definitions and verification—a division of effort comparable to that used in the CTBT negotiations—will reduce or heighten the risk of duplication of effort or wasted effort.

The need for technical and scientific inputs through the work of a group of experts has been raised by a number of delegations during past discussions on fissile materials. Such a device was viewed as helpful in laying foundations in the case of the CTBT negotiations. Expert inputs to the CTBT occurred over a number of years prior to the actual negotiation and were focused on verification mechanisms. Whether a similar level of work is required for a fissile material treaty, given the experience embodied in the IAEA, will depend on the extent to which there is agreement over the adoption of IAEA verification expertise in the fissile material regime. In any event, delegations would presumably wish to provide any such group of experts with a clear mandate and a time frame for the completion of its inputs.

### Other approaches to the negotiations

If consensus cannot be reached on the application of legally binding obligations to existing stocks of fissile materials, the negotiations will have reached a crossroads. While it will be clear in the treaty that the ban will prevent future production of fissile materials for explosive purposes after entry into force, a major loophole would exist if the prescribed verification regime were unable to differentiate between stocks held at the date of entry into force and stocks produced illegally after that date. What are the options?

These options could range from a legally binding duty contained within the treaty obliging nuclear-weapon-possessing states to declare their existing stocks and have these declarations subject to verification, to an outcome based only on trust. Or, there might be an initial political declaration by nuclear-weapon-possessing states to a moratorium on the production of fissile materials or, in the case of a state that already maintains a moratorium, to signify that it accepts that the moratorium will become legally binding. Realistically, the compromise seems likely to fall somewhere between these extremes, perhaps utilizing declarations based on state accounting and control that would establish inventories in which, as a minimum, fissile material deemed to be excess to weapons needs would come under international safeguards.

Such a compromise entails what has been described as a **phased**[29] approach. The significance of considering a phased approach to the negotiations lies in the potential for improving the prospects of consensus. Such an approach is one in which the eventual product of the CD and its fissile material Working Group is complemented by the parallel action of individual states. (Agreement to initiate preparatory work on fissile materials through a group of experts before the negotiations begin is another example of a phased approach.)

The outcome would be a framework treaty setting out general principles and basic norms of the new regime, together with provisions for transparency measures and possibly other mandatory or voluntary steps to be undertaken in a parallel or further phase of the process. That (final) phase might include implementation protocols covering verification and any aspect of scope not negotiated in detail for the framework treaty, perhaps including specific issues such as the use of fissile material for naval propulsion.[30]

Another way of approaching the negotiations is to adopt a **functional** perspective. This would entail looking at the *kinds* of ban that delegations might wish to pursue. In doing so, it would provide a ready focus for the negotiations, facilitating the ability to rise above potential deadlock on the issue of existing versus future stocks. This approach would concentrate on developing bans on activities that result in:

- the "reversion", or recommissioning, of production facilities that were once used for nuclear weapon purposes;
- the reversion of production facilities that were originally used for nuclear weapon purposes but which had subsequently been converted to non-nuclear-weapon purposes;
- the recycling for weapon use of fissile material that was once used for nuclear weapons but which had been declared excess. (It would be necessary, however, to permit recycling of plutonium removed from weapons as long as the this did not involve the production of new fissile material for weapon use);

- the diversion of fissile materials from non-weapon use to weapon use; and
- the transfer of fissile material having potential for weapon use. (Given the possibility that civilian-grade fissile material could be enriched for weapon use, it would be necessary to ban transfers to non-state parties not already bound under the NPT not to produce fissile material for nuclear weapons or nuclear explosive purposes.)

## CONCLUSION

While the negotiation of a fissile material treaty will not be straightforward, its successful conclusion will have significant international benefits. By limiting the pool of materials available for manufacturing nuclear weapons and by helping to make reductions in nuclear arsenals irreversible, the treaty will be a major boost to the causes of non-proliferation and nuclear disarmament. A non-discriminatory treaty also has the potential to strengthen the NPT, notably in the manner in which the nuclear-weapon states might be brought more formally into the IAEA safeguards system and in which nuclear-weapon-possessing states outside the NPT might be brought into closer cooperation with NPT states parties.

More broadly, a fissile material treaty would be a welcome, if belated, addition to the measures governing disarmament, non-proliferation and arms control, making a crucial contribution to improving the climate of trust at a time of high concern about the international security environment.

## VERIFIED CUT-OFF OF FISSILE MATERIAL PRODUCTION FOR WEAPONS

International Panel on Fissile Materials

*Note: this text is extracted from chapter 7 of the* Global Fissile Material Report 2009.

Setting up arrangements to verify a ban on the production of fissile materials for weapons is a part of the nuclear disarmament agenda that hopefully will soon be under negotiation at the UN Conference on Disarmament (CD) in Geneva. On 29 May 2009 the CD agreed to begin negotiations on "a non-discriminatory, multilateral and internationally and effectively verifiable treaty banning the production of fissile material for nuclear weapons or other nuclear explosive devices".[31] The proposed treaty is often referred to as the Fissile Material Cut-off Treaty (FMCT) and by the IPFM as the FM(C)T.[32]

Under a nuclear disarmament regime, the distinction between weapon and non-weapon states would disappear, and all fissile material would be under international safeguards. The question is how large a step in that direction will be taken under an FM(C)T. Specifically, negotiation of an FM(C)T will have to address two fundamental issues:

- whether and to what extent a treaty banning any new unsafeguarded production of fissile materials should also subject pre-existing non-weapons stocks of fissile material to international monitoring to verify that they are not converted to weapons use; and
- how such a treaty should be verified, including the extent to which safeguards obligations in the nuclear-weapon states and non-nuclear-weapon states will converge.

## AN INCOMPLETE MORATORIUM

Four of the five weapon states that are parties to the Non-Proliferation Treaty—France, Russia, The United Kingdom and the United States—

declared in the late 1980s and early 1990s that they had permanently ended production of fissile materials for nuclear weapons. China's government did not make such a public declaration but has let it be known unofficially since the early 1990s that it has suspended production and will only feel compelled to resume if it feels that the effectiveness and/or survivability of its deterrent is being eroded by a build-up of US missile defences and/or long-range precision-guided weapons.[33]

In South Asia, production of fissile materials is accelerating as India builds a "minimum deterrent" of unspecified size and Pakistan races to build up its fissile-material production capacity. Israel's policy of "opacity", that is not talking about its nuclear-weapon-related activities, has left unclear whether it is continuing to produce weapon-grade plutonium at its Dimona nuclear complex but, most likely it is, if only as a by-product of its tritium production.[34] Finally, on 24 September 2008, North Korea announced that it would resume separation of plutonium for weapons and, on 13 June 2009, announced that it was launching a programme to enrich uranium for weapons as well.[35]

As the world moves toward complete nuclear disarmament, however, all the nuclear-weapon states will have to halt production of fissile material for weapons and accept effective arrangements to verify this.

## VERIFICATION OF A BAN ON PRODUCTION OF FISSILE MATERIAL FOR WEAPONS

Verification of a ban on the production of fissile materials for weapons will require determinations that:

- production facilities that have been declared shut down are indeed shut down and remain so;
- all plutonium separated and high-enriched uranium (HEU) produced at declared production facilities after the ban comes into force are placed under International Atomic Energy Agency (IAEA) safeguards and remain under safeguards; and
- there are no undeclared enrichment or reprocessing facilities.

## Shutdown production facilities

Under an FM(C)T, countries would either convert production facilities (reprocessing plants, plutonium-production reactors, and enrichment plants) to safeguarded civilian use or shut them down and decommission them.

### Reprocessing plants

In practice, the facilities used to recover weapon-grade plutonium from the low-burnup[36] magnesium or aluminum-clad uranium metal used in production reactors are so different from those used to reprocess the high-burnup zirconium-clad uranium-oxide fuel used in most power reactors that no military reprocessing plant has been converted to civilian use. A few plutonium-production reactors have been operated as dual-purpose reactors, producing electricity as well as weapon-grade plutonium, but operating them for electricity production alone has been uneconomic and all such dual-purpose reactors have been decommissioned or soon will be.[37]

### Enrichment plants

In the United States, military gaseous diffusion enrichment plants were converted to civilian use but two out of the three have now been shut down and replacement capacity for the third is under construction. In China, it is believed that the two gaseous diffusion plants used to produce HEU for weapons have been shutdown. Low-enriched uranium (LEU) for China's power reactors is produced by centrifuge enrichment plants. In France, the Pierrelatte gaseous enrichment plant that produced France's HEU is being decommissioned. In Russia, three large centrifuge plants that produced HEU for weapons have been converted to producing LEU for nuclear power plants.[38] The United Kingdom's centrifuge enrichment plant that produced some of its HEU has similarly been converted.

Most facilities for producing fissile materials for weapons in the five NPT weapon states are therefore shut down and, in some cases, are in the process of being decommissioned.

The verification challenge at these sites will be minimal. It will only be necessary to confirm that key equipment necessary to the operation of the facility has been disabled or removed. Seals could be applied to assure that spent fuel is not introduced into reprocessing plants or uranium feedstock into enrichment plants and remotely monitored electronic cameras and other sensors could be set up to monitor any activity in key areas of the plants with periodic random unannounced on-site checks to make sure that the seals are intact and monitoring systems are functioning properly. Facilities for which there are no conversion plans should be decommissioned as quickly as possible to make their shutdown irreversible.

## Operating reprocessing and enrichment plants

The second element of verifying an FM(C)T would be to assure that any plutonium, HEU or other fissile material[39] produced in a declared reprocessing plant or enrichment plant after the treaty comes into force for a party is placed under IAEA safeguards.

### Reprocessing

Some weapon states (China, France, India, Russia and the United Kingdom) and one non-weapon state (Japan) are separating large quantities of weapon-usable plutonium from spent power-reactor fuel for civilian purposes. The original rationale was to provide start-up fuel for plutonium-breeder reactors. When those reactors were not commercialized, Belgium, France, Germany and Switzerland began to recycle their separated plutonium in light-water-reactor fuel.[40] Japan and China intend to do the same while India and Russia are still moving ahead with their breeder programmes, although at a glacial pace. The United Kingdom is winding down its reprocessing and is beginning to consider options for disposing of approximately 100t of separated power-reactor plutonium that it has accumulated.

Reprocessing and plutonium recycling are not economic, nor are plutonium breeder reactors. Nor do they simplify the problem of spent fuel disposal.[41] Furthermore, the spread of reprocessing has been closely associated with the spread of nuclear weapons programmes. Today, only one non-weapon state, Japan, reprocesses and twelve non-weapon states that in the past sent their spent fuel to France, Russia and the United Kingdom to be reprocessed have not renewed their contracts. For them, reprocessing simply exchanged the problem of storing and disposing of spent fuel for the equally politically challenging problem of storing and disposing of the solidified high-level reprocessing waste that the reprocessing countries insist on sending back to their foreign customers. Countries that have reprocessing plants have the political advantage that it does provide a single central location to which their nuclear power plants can ship their spent fuel.[42]

Modern civilian reprocessing plants are designed to separate annually 7–17t of plutonium—enough to make a thousand nuclear weapons or more.[43] Since plutonium is a directly weapon-usable material, this puts a tremendous burden on safeguards. Even with input and output measurement errors of plutonium from reprocessing and mixed-oxide (uranium–plutonium) fuel fabrication plants as low as 1%, it would be impossible to prove by mass balance checks alone that plutonium, sufficient to make tens of weapons had not been diverted. The IAEA, therefore, adds layers of expensive monitoring, containment and surveillance to increase its confidence that no significant diversions are occurring at Japan's reprocessing plants, especially at the large, recently completed plant at Rokkasho. This reprocessing plant plus a smaller pilot plant, the only reprocessing facilities in a non-weapon state, account for about 20% of the IAEA's total safeguards budget.[44]

At Rokkasho, the IAEA was able to verify the design of the reprocessing plant and installed independent measuring instrumentation before some areas of the plant were embedded in concrete or became contaminated. For pre-existing plants, the IAEA would not have this luxury. Nevertheless, it should be possible to design safeguards procedures, including the use of short-notice random inspections that would make it difficult to operate the plant improperly and make it possible to detect a diversion of plutonium larger than the measurement errors in the plant plutonium throughput.[45]

It would be better for verification of an FM(C)T, however, if reprocessing was phased out altogether. This would also have the advantage of allowing attention to be focused on the elimination of the existing large stockpiles of civilian and excess weapons plutonium. Given that civilian spent-fuel reprocessing is neither economic nor necessary to nuclear power for the foreseeable future, such a phase-out does not appear an unreasonable goal.

## Enrichment

Only one country, India, is known to be producing HEU for non-weapon purposes today. India is building naval reactors that reportedly are fuelled with HEU enriched to between 20% and 40% uranium-235.[46] Other countries (Russia, the United Kingdom and the United States) are known to use HEU in naval-reactor fuel but their requirements could be satisfied for many decades using excess Cold War weapons HEU. France has already shifted its naval reactors to LEU. HEU is also used as a research reactor fuel but, outside Russia at least, it is being replaced by LEU.

Thus the major challenge in the near term would be to verify that all operating enrichment plants except India's are indeed not producing HEU. In principle, the enrichment of the uranium in the key collector or "header" pipes in the enrichment plants could be monitored. This may be impractical in Russia's huge enrichment plants, however, because they have hundreds of thousands of relatively low-capacity centrifuges and complex piping arrangements.

A supplementary approach to detect clandestine HEU production in a large enrichment plant would be to look for traces of leaked HEU. The IAEA has used this technique with remarkable effect in Iran and elsewhere. It involves taking "swipes" of surfaces inside a facility and then inspecting the dust picked up by the swipe for particles of uranium. When such particles are identified, they can be bombarded by a beam of atoms that will knock off uranium ions that can be passed through a mass spectrometer to determine the percentages of uranium-235 and uranium-238.

The complication for the case of Russia's centrifuge enrichment facilities is that there could be old particles of HEU dating back to when Russia was producing HEU before 1989. These particles would have to be distinguished from possible new particles of HEU. One approach, age dating the particles using the in-built clock associated with the decay of uranium-234 into thorium-230 is discussed in *Global Fissile Material Report 2008*, chapter 4.[47]

India may continue producing HEU but its enrichment plant is small enough so that its output of HEU could be accurately monitored.

## Non-weapon use of fissile materials

Once HEU or plutonium is under safeguards, it must be carefully monitored until, in the case of HEU, it is down-blended to LEU, and, in the case of plutonium, it is embedded in a radioactive matrix equivalent to the plutonium in spent power reactor fuel.[48] In most cases, effective approaches for doing this have been worked out for NPT safeguards in non-weapon states.

A new safeguards issue for the weapon states, however, will be the fact that many of them have HEU-fuelled military reactors. Most of these are naval reactors but Russia, for example, also uses HEU-fuelled reactors to produce tritium for its nuclear weapons.[49]

Any new production of HEU for reactor fuel would have to be safeguarded under an FM(C)T and, depending upon the scope of the FM(C)T, some pre-existing stocks of HEU also could come under safeguards. The quantity of HEU in military-reactor fuel cycles is substantial. The United States, for example, uses an average of about 2,000kg of weapon-grade uranium annually to fuel the reactors that propel its submarines and aircraft carriers. If converted to first-generation Nagasaki-type implosion weapons at 25kg per weapon, that would be enough to produce 80 nuclear weapons a year.

The non-weapon use of HEU produced or reserved for naval and tritium-production reactor fuel could be verified by measuring the quantity of HEU produced or withdrawn from stocks to make HEU fuel and then confirming that it was actually put into a reactor. Verification procedures that have been developed for HEU-fuelled research reactors might have to be altered if, as appears likely, some of the weapon states will consider the designs of their military reactors and their fuel to be sensitive information. The International Panel on Fissile Materials (IPFM) has been exploring various technical approaches that could help, but the IAEA and the weapon states would have to work out compromises under which the most sensitive design and operating information would be concealed while still enabling the IAEA to obtain enough information to verify that no significant amount of HEU was being diverted. The best solution, however, would be for the weapon states to switch to LEU-fuelled reactors. The international community then would not have to worry about possible diversions of HEU from the naval fuel cycles and the nuclear navies could preserve military secrets.

## Clandestine production

Finally, there is the challenge of detecting clandestine reprocessing or enrichment activities. This is a challenge that is already faced in non-weapon states that are parties to the NPT. Iraq mounted a clandestine enrichment programme as did Libya and Iran. In all three cases, the programmes were discovered before they went into operation. For Iraq, the discovery was as a result of that country having to accept intrusive inspections after its defeat in the 1991 Gulf War. This helped lay the basis for the Additional Protocol under which non-weapon states commit to declare to the IAEA all significant nuclear-related activities and allow the IAEA to check those declarations.[50] Iran voluntarily complied with the Additional Protocol for two and a half years between 2003 and 2006. During that period, the IAEA was able to visit suspect sites and detected undeclared enrichment-related activities.

The Additional Protocol also creates the possibility that the IAEA, if authorized by the IAEA Board, could carry out wide-area environmental monitoring to detect evidence of clandestine reprocessing or enrichment. There is a long Cold War history of atmospheric measurements of the concentration of the 11-year half-life fission product krypton-85 to detect foreign reprocessing activities.[51]

The gaseous releases from centrifuge enrichment plants are very small. The uranium hexafluoride ($UF_6$) gas in the system is at less than atmospheric pressure with the result that leakage is generally of air into the system rather than $UF_6$ outward except when natural-uranium feed and enriched-uranium product cylinders are detached from the system. Air filtration systems are also standard equipment. Still, the degradation products of $UF_6$ in the environment, molecules containing both uranium and fluorine, do not occur naturally. It is therefore worthwhile to determine if extremely sensitive detection techniques could be developed for such molecules. Furthermore, if tight controls could be established on $UF_6$ at declared production plants, then a clandestine enrichment plant would require a clandestine $UF_6$ production plant. Such plants produce the $UF_6$ at above atmospheric pressure and therefore leak more $UF_6$ than centrifuge enrichment plants.[52]

When there is an indication of possible clandestine reprocessing or enrichment activity, the IAEA has the right to request an inspection. In a non-weapon state—and presumably in a nuclear-weapon-free world—inspectors would be free to take and analyse swipes. During the transition, at military nuclear sites in a weapon state, however, swipes could reveal information that a state considers sensitive: the isotopic makeup of or alloying material used in its weapon-grade plutonium, for example.

This is a familiar situation for the verification of the Chemical Weapons Convention (CWC) since chemical manufacturers wish to protect proprietary processes. Nevertheless, the Organization for the Prohibition of Chemical Weapons (OPCW), which is responsible for the verification of the CWC, uses sensitive instruments, notably gas-chromatograph mass spectrometers (GCMS) that are capable of identifying millions of chemical species and could be used for industrial espionage. For purposes of verifying the CWC, however, the chemical manufacturers and the OPCW have devised a “managed access” approach under which the library of chemical signatures inside the GCMS memory is purged of all information other than that relating to chemical-weapon agents, their precursors and degradation products.

The IAEA could similarly use instruments that have been rendered incapable of detecting anything beyond information required by the inspectors. Laser breakdown spectroscopy, for example could be used to turn particles on a surface into ionized plasma that would emit light with wavelengths characteristic of the particles’ constituent atoms. If spectral lines characteristic of uranium and fluorine were found together, that would be an indicator of gas centrifuge enrichment. The lines of all other elements could be blocked.

Thus, under an FM(C)T, the safeguards obligations of the nuclear-weapon states and the non-weapon states would begin to converge, with the IAEA having the responsibility of verifying non-production of fissile materials for weapons at both declared and suspect nuclear sites in all states. The authority of the IAEA to check for undeclared nuclear activities has been strengthened and codified in the Additional Protocol. It will be critical to the verifiability of nuclear disarmament that both weapon and non-weapon states ratify this Protocol.

In a nuclear-weapon-free world, several of the verification problems that will have to be dealt with today under an FM(C)T would be considerably eased. For one, there would be no stocks of fissile material not under international safeguards. Secondly, all states, including the nuclear-weapon states, would have to adhere to a strict and strengthened Additional Protocol. Finally, managed access procedures could be greatly simplified because the nuclear-weapon states would no longer need to protect nuclear weapon-design information.

# A VERIFIED BAN ON FISSILE MATERIAL PRODUCTION

Andreas Persbo

*Note: this text is taken from a presentation given by Mr. Persbo in Geneva on 21 August 2009.*[53]

## THE PRESENT STATE OF AFFAIRS

Today's vast stockpiles of fissile material are largely a legacy of the Cold War. The production of fissile material did not fully end until the early 1990s following the fall of the Soviet Union. At present, many hundreds of tons of weapons-usable fissile material remain in storage around the world. Most of the material is in the United States and Russia, although large quantities also remain in China, France and the United Kingdom. This equates to tens of thousands of nuclear warheads.

While the recognized nuclear weapon states have ceased production, a new arms race has emerged elsewhere. Fissile material production is ongoing in South Asia, where India and Pakistan are trying to define how much material they would need in order to maintain their own deterrence. In these two countries, fissile material control measures are often viewed with grave suspicion. Some argue that too much transparency in material holdings could expose military weaknesses and that an imbalance in stocks could tilt the military balance in one country's favour.

A legal prohibition on the production of fissile material for weapons purposes would do nothing to reduce already accumulated stocks of material and would consequently help to preserve the status quo in nuclear arms levels. The impact on nuclear disarmament from this perspective is limited, since the declared nuclear weapon states are in possession of large stocks of usable material. It is often expected that India and Pakistan would opt to produce a comfortable cushion of material before signing any control regime. However, a ban on the production of fissile material for weapons purposes would be more than just symbolism. Under a treaty, no new material can be produced, which means that reductions would be the only lawful change in stockpiles. This is why several statesmen around the world argue that a Fissile Material Cut-off Treaty (FMCT) is the logical first step toward nuclear abolition.

A large amount of work has been produced on an FMCT over the last twenty years. Most analysts and academics tend to agree that a treaty *with* a verification regime is preferable over a treaty *without* one. A minority argues that verification is not necessary, since the P5 moratorium on the production of fissile material has been in effect for two decades without seemingly being breached. The minority view, however, understates the symbolic significance of verification of a treaty, especially for non-nuclear-weapon states. For them, verification measures would in effect bring the nuclear-weapon states' obligations closer to those of non-nuclear-weapon states thus making the non-proliferation regime less discriminatory. The minority view also supposes that the nuclear-weapon states trust each other well, and this is a clear overstatement.

What verification measures should be put in place, if a treaty is to be verified? It is generally assumed that verification techniques applicable to an FMCT are available *off the shelf*—those advocating this sometimes claim that the solution is as simple as applying full-scope safeguards on the nuclear-weapon states. This is beyond doubt a workable solution, but is it really a necessary one?

After all, while the parties to an FMCT would enter into a commitment similar to that for the non-nuclear-weapon states, several important differences remain. An FMCT would not alter the nuclear-weapon states' right to manufacture, store and deploy nuclear arms. Therefore, large amounts of legitimate fissile material will be present on the territories of the states parties. There is little point in monitoring this pool of material, since the state is free to make use of it as it sees fit. This is an argument in support for the idea that a treaty, and its verification regime, should be focusing on the back-end of the weapons fuel cycle rather than on the entirety of the fissile material manufacturing line. This is often referred to as a "focused approach".

In addition, is a full-scope approach economically viable? It is certainly possible to safeguard reactors, spent fuel ponds, conversion activities, heavy water production and fuel fabrication operations. Likewise, it is possible to build a picture of the total capacity of an individual state (through declarations on associated infrastructure such as uranium mining and milling). But since the majority of the world's nuclear activity is conducted in the recognized nuclear-weapon states, this is likely to be a human- and capital-intensive exercise. Budget estimates indicate a doubling, or perhaps even a tripling, of the present International Atomic Energy Agency (IAEA) safeguards budget. Most of the activities monitored would not be relevant for the production of nuclear weapons, and therefore would bring few marginal benefits to the verification endeavour.

## THE MAIN PROHIBITION

Let us turn to the proposed scope of a treaty. There is a tendency in the literature to discuss FMCT verification without linking it to what the cut-off is actually going to cover. Papers tend to enumerate "off-the-shelf" verification techniques and technologies without properly putting them into context. While this is not surprising, the scope has after all not been decided, and it leads to a slightly fractured debate. The questions asked should either be "how can we verify scope A" or "what scope can be verified by verification technique B"? The impact of any verification proposal will necessarily be limited unless there is a clear relationship to the obligation to be verified.

Indeed, the goal of any verification regime is to determine whether "Party A" is compliant with a defined obligation that it has undertaken either unilaterally or bilaterally. The certainty with which the verification regime can make this determination depends on the clarity and precision of the undertaking itself. Consider the following statement: It is easier to verify that a declared item remains in its declared place than it is to verify that all items that should have been declared are in fact declared.

The verification regime is a product of the scope of a treaty, not the other way around. The question "what should the system verify" needs to be answered before the verification designer can examine the questions "where to verify", "when to verify", "how to verify" and "who should verify". This poses a problem for anyone examining cut-off verification. Unless the researcher makes a number of assumptions on the scope of the proposed treaty at the outset of his or her paper, he or she would need to propose several alternative verification regimes. Once the researcher has decided on the question "what should be verified", the rest of the exercise becomes relatively straightforward.

If, for instance, the goal of the verification regime is to verify that "special fissionable material is not diverted to military uses", the researcher needs to identify where special fissionable material is produced, used and stored, and focus on putting monitoring measures in place at all those locations. If, on the other hand, the goal of the verification regime is to verify that "special fissionable material is being used as declared", the verification regime needs only to focus on locations where declared material is present. A regime focusing on the verification that material is being "used as declared" may require the employment of different verification techniques than a regime looking at material "not being diverted to military purposes".

## NON-COMPLIANCE SCENARIOS

There are two possible instances of non-compliance:

- diverting material from a declared facility; and
- producing material in undeclared facilities.

The first scenario is serious, albeit not very likely. Today's material accountancy and control techniques are more than adequate for effective verification. There are some problems relating to material accountancy at reprocessing facilities, but somewhat relaxing the timeliness criterion can overcome these. Likewise, a new safeguards approach for uranium enrichment plants is probably necessary to solve some of the accountancy problems at large-scale facilities. These are significant but not insurmountable challenges to a focused verification regime.

The second scenario poses most challenges under a fissile material control regime. The main problem with a focused verification approach is that it makes the construction of a clandestine fuel cycle a relatively cheap affair.

The focused approach would exclude pre-enrichment conversion. Consequently, the non-compliant state only needs to construct a clandestine uranium enrichment plant if it desires to resume production. This is not beyond the reach of the recognized nuclear-weapon states. These facilities would be very difficult to detect.

Consider the following scenario. A state wants to construct a clandestine enrichment plant capable of producing some 100kg of weapon grade uranium per year. Here, a plant comprising 400 URENCO TC-12 centrifuges would do the job. The centrifuges would need some 1,200$m^2$ of floor space to operate, and the total energy consumption to run the machines would be less than 150kW. The plant itself would draw more energy but not enough to distinguish it from any other industrial plant. Consequently, the facility could be hidden in small and non-descript buildings and would be very difficult to detect from the outside. Indeed, it would have few emissions and would require very little power infrastructure, it would look more like a warehouse than an industrial site.

What about shipments of material? The plant would only need to be supplied with about 19t of uranium hexafluoride gas per year. This would constitute a diversion of less than 0.3% of the total conversion capacity of British Nuclear Fuels Limited and less than 0.1% of Minatom's. The plant could be supplied by trucks, and would therefore only need access to the road network. Access to a rail network would not be required.

On the other hand, if pre-enrichment conversion facilities are envisioned to fall under safeguards, the state must either divert the 19t from one of their declared facilities or build a small undeclared conversion facility (with a capacity of some 50t per year) to supply the enrichment plant. Diverting from a declared facility, where safeguards are applied, entails a significant risk of detection. Especially since the early 2000s, when the starting point of safeguards was moved from the shipping area to the receipt area of the facility, making it possible to match input with output.

Building a new conversion facility is obviously also not beyond the capability of any recognized nuclear-weapon state, but would increase the financial burden of non-compliance. According to some academics, conversion facilities could possibly be detected at a significant distance but it is relatively simple to avoid detection by, for instance, co-location with a declared conversion facility. However, this increased risk for detection would factor into the state's non-compliance strategy, and make cheating a bit more burdensome.

## CHALLENGE INSPECTIONS

Undeclared nuclear fuel cycles cannot be detected by routine inspections, and the deployment of remote sensors able to detect various plant signatures on the territory of states parties are likely to be too costly and highly unpractical. The question is whether to rectify the problem through requiring safeguards on larger swathes of the nuclear fuel cycle or to implement a challenge or special inspection regime to handle suspicions of non-compliance.

A challenge inspection regime has weaknesses. Normally, some sort of evidence would be required pointing towards non-compliance in order to get the necessary political support for inspections. This evidence alone tends to create a presumption of guilt. Related to that, if the challenge inspection fails to produce any evidence due to the absence of undeclared activities, it is quite possible that the requesting state will not be convinced by the outcome. This relates to the well-known problem of *proving a negative*.

## DIMINISHING RETURNS OF VERIFICATION

How much verification will be enough for the purpose of a fissile material control regime? Sadly, there is no technical answer to this question. Rather, a political judgement by the negotiating parties will decide whether proposed verification measures are adequate to the task.

Economic theory can possibly provide some answers. It is reasonable to assume that the marginal benefit of verification measures will decrease with each layer of additional verification (so-called *diminishing returns*). Even if the marginal cost of deploying an additional layer of verification were constant, there would be a point where the marginal benefit meets the marginal costs. It is possible to envision an optimal verification system, or verification equilibrium, at that point.

The only developments that would shift that equilibrium are the introduction of more effective techniques, hence increasing the marginal benefit of one additional layer of verification, or lower marginal costs. The introduction of so-called integrated safeguards in the IAEA safeguards system aims to maintain the current state of assurance, but at a lower marginal cost, thus increasing the overall utility of the system.

## CONCLUDING THOUGHTS

In respect to an FMCT, the verification designer needs to consider the object and purpose of the regime. Presently, few weapon states would consider a treaty that encompasses reductions in stocks. Rather, the idea is to formalize the 20-year-old fissile material production moratoria already in effect among the P-5 and to introduce a legally binding moratorium in South Asia and the Middle East. The nuclear-weapon states would have little incentive to place their stocks on the negotiation table. After all, it was the accumulation of stocks that made them consider a treaty in the first place.

Past production of fissile material is also significant from another angle. Given the large uncertainties in historical production in some weapon states, it will be near impossible to establish baseline inventories of nuclear material. There will not be any meaningful way, consequently, to monitor changes in state inventories of fissile material. This means that a full-scope verification regime will yield few benefits on the margin. A focused approach, simply looking at carefully defined materials, compounds and processes should be sufficient to assure the nuclear-weapon states that no militarily significant production of fissile material is occurring.

This low-assurance verification scheme will by no means be foolproof, but given the object and purpose of an FMCT, it may be viewed as sufficient. It may also reduce costs in treaty implementation.

# A TREATY ON FISSILE MATERIALS—JUST CUT-OFF OR MORE?

Annette Schaper[54]

## WHY A TREATY IS IMPORTANT—FOUR GOALS

A Fissile Material (Cut-off) Treaty, or FM(C)T, will have many benefits, on which states place somewhat different emphasis. As a result of the diverging goals, we must expect different positions on scope and verification. Each delegation will try to push its priorities, for example in language on the preamble, in scope, on verification, or on entry into force (EIF). A historic example are the Comprehensive Nuclear-Test-Ban Treaty (CTBT) negotiations when disagreements on EIF were a result of different priorities. Some delegations saw the major benefit in the participation of states outside the Treaty on the Non-Proliferation of Nuclear Weapons (NPT); others wanted to strengthen the disarmament potential of the CTBT. Unfortunately, some delegations viewed these goals as contradictory instead of reinforcing. Therefore, during the upcoming negotiations on an FM(C)T, the same mistake should not be repeated. Instead, care should be taken to view the various benefits as reinforcing each other. In the following, four goals of the treaty will be presented.

### Goal I: Irreversibility of nuclear disarmament and implementation of Article VI of the NPT

The uncontested minimum goal of an FM(C)T is a ban on future production of fissile material for explosive purposes. This means that the quantities can only be reduced, not increased. The FM(C)T can be compared to the CTBT: while the CTBT can be regarded as a tool to cap the *qualitative* nuclear arms race, for example to hinder the future development of qualitatively new nuclear explosives, the FM(C)T can be seen as its *quantitative* counterpart, capping the amount of material available for new nuclear weapons.[55]

Therefore, both treaties were labelled as "nuclear disarmament measures" in terms of article VI of the NPT and were included in the list of Principles and Objectives for Nuclear Non-proliferation and Disarmament at the NPT

Review and Extension Conference 1995. Successful FM(C)T negotiations therefore would strengthen the NPT.

Critics maintain that this is not enough, since large quantities of fissile materials are excess. They are owned by the nuclear-weapon states and exceed the quantities needed for a potential rearmament up to numbers of the peak of the Cold War. Therefore, they claim, it is necessary to reduce the existing quantities. Only then would a treaty have the effect of nuclear disarmament. This view is rejected by several delegations. This conflict played a central role already during the negotiations of the Shannon Mandate, and similarly it will play a central role in the negotiations on scope.

### Goal II: Reducing the discrimination of the NPT

Unlike the NPT, an FM(C)T would not discriminate between nuclear- and non-nuclear weapon states. Rights and duties would be the same for all parties. Furthermore, it is unlikely that there will be any duties for non-nuclear-weapon states that go beyond those of the NPT. Therefore, the additional duties for the nuclear-weapon states would be a reduction of the discrimination in the non-proliferation regime. Nuclear industry in the non-nuclear-weapon states sometimes claims that they perceive a competitive disadvantage in comparison to their competitors in the nuclear-weapon states. Whether this claim is true or not, an FM(C)T will insert some duties for nuclear industry in the nuclear-weapon states and will appease such complaints.

Nevertheless, discrimination will not be totally eliminated because the FM(C)T will not be a “Global Zero” treaty, that is, a treaty for a world without nuclear weapons. Some disarmament advocates criticize this. They maintain that an FM(C)T would serve only as an alibi, because the nuclear-weapon states would still be allowed large quantities of fuel for weapons while the non-nuclear-weapon states would not , should the duties for the nuclear-weapon states be too minor. On the contrary, this would legitimize the status quo. Indeed, there are constituencies in the nuclear-weapon states that have no interest in reducing the discrimination.

### Goal III: Drawing in states outside the NPT

A benefit of a treaty would be its potential to draw in those states outside the NPT—India, Pakistan, Israel and North Korea. For some states, this is the major motivation, because they want to cap the number of warheads in these states. Similarly, this was the motivation of some states during the CTBT negotiations, for some delegations by far the most important one, but not so for others. This has led to the conflict on EIF of the CTBT. A repetition of this conflict must not be allowed to similar stalemates this time. This means that a FM(C)T must offer enough incentives for states outside the NPT, and all states should accept that in an initial phase some delegations might still abstain.

### Goal IV: Reducing the risk of nuclear terrorism and promoting a culture of "international responsibility"

In non-nuclear-weapon states, nuclear industry has responsibilities to the IAEA. Material accountancy is precisely maintained so that it can be presented to the IAEA any time. The technical equipment for safeguards and security is installed in all plants, and international duties promote a culture of responsibility and transparency. In contrast, in some nuclear-weapon states and states outside the NPT, nuclear industry is perceived as a matter of national concern. Verification of an FM(C)T would introduce standards of security and accountancy discipline and would replace the notion of "national concern" with the notion of "international responsibility". This would lessen the risks of illegal diversion.

## THE TOPIC OF THE NEGOTIATIONS: "FISSILE MATERIALS"

The Shannon Mandate uses the term "fissile material for nuclear weapons or other nuclear explosive devices". There is no official definition for the term "fissile material", and therefore there is a margin for different interpretations, which will play a role during the negotiations. In this section, I want to explain various fissile materials that will be the central topic during the negotiations.

Fissile materials can be classified according to various categories. The most appropriate categorization for an FM(C)T is the criterion of ease of use in nuclear explosives. Similarly, the IAEA defines various categories according to this criterion. These categories are "direct use material", "indirect use material", "special fissionable material", "nuclear material" and "other material". They imply different regulations for safeguards—the less technical effort necessary to use a given material for nuclear explosives, the more frequent and intrusive are the safeguards. Direct use material, for example plutonium or highly enriched uranium (HEU), can be used with only little technical effort. Special fissionable material, for example spent fuel, natural uranium or low enriched uranium (LEU), needs reprocessing or enrichment in order to transform it into direct use material. The effort required for the other categories of materials is even higher.[56]

The table in annex B gives an overview various isotopes and some mixtures, their different categories according to the IAEA, their technical roles in nuclear explosives, their production methods and their civilian use or occurrence.

The diagram in annex C shows an example of common fuel cycles. It includes material streams containing uranium and plutonium, the current IAEA definition of material classes and the related technical processes.

### Plutonium

Plutonium is categorized as a direct use material. It does not occur naturally but is the product of nuclear reactions, mostly when uranium-238 is hit by neutrons. This can happen in a nuclear reactor or with any other neutron source. The plutonium isotopes are separated from the spent fuel by "reprocessing". It is a combination of mechanical and chemical methods and radiation shielding technologies. The quantity of material needed for one warhead can be one to a few kilograms.[57]

Presumably, some delegations will advocate the position that only so-called "weapon grade plutonium" should be subjected to the treaty, and the so-called "reactor grade" plutonium should be left out. But this would create a fatal gap into the treaty. Normally, plutonium consists of a mix of various isotopes whose composition depends on the type of production facility. The IAEA definition of direct use material includes all plutonium isotopes and compositions except plutonium containing more than 80% plutonium-238, which is highly radioactive. It also includes chemical mixtures containing plutonium. In the past, the usability in weapons of different isotopic compositions has been subject to debate because different categorization implies different safeguards and non-proliferation measures.[58] Plutonium that has remained in a power reactor for a long time consists of a substantial fraction of “higher” isotopes that are more radioactive than the comparatively stable plutonium-239. Reactor-grade plutonium therefore emits more unwanted radiation, including neutrons, and develops unwanted heat. These effects pose technical challenges in all uses, be they nuclear weapons or civilian fuel.

In contrast, weapon-grade plutonium consists of a large fraction of plutonium-239 and only small proportions of higher isotopes. Therefore, the unwanted side effects, for example radiation and heat, are smaller. It can be obtained by exposing fuel in a reactor for a short time, with the side effect that the quantity produced is small. This is not economic for the civilian nuclear industry, whose main goal is the profitable production of energy. But for warhead production in the nuclear-weapons states, this was the major method. Weapon-grade plutonium is also a by-product in fast breeder reactors, due to the different nuclear processes; theoretically it could also be produced with the aid of other advanced fast-neutron generators.

Since the nuclear-weapon states prefer weapon-grade to reactor-grade plutonium for warhead construction, it had been reasoned that the latter cannot be used at all for nuclear explosives. These debates have largely ceased, thanks to publications of plausible technical arguments that illustrate the feasibility of nuclear explosives made from reactor-grade plutonium.[59] Today, it is widely recognized that all kinds of plutonium can be used for nuclear explosives and must be safeguarded accordingly, except plutonium-238. Nevertheless, most existing nuclear warheads are made from weapon-grade plutonium. Explosives made from reactor-grade plutonium would need a different design. The plutonium arising and used in civilian nuclear industry is mainly reactor-grade plutonium.

### Uranium

The other isotope that has been used on a large scale for nuclear weapons is uranium-235. Natural uranium contains 0.7% uranium-235 and 99.3% uranium-238, which is not fissile. For nuclear explosives, the uranium-235 content must be much higher, which is achieved with the aid of enrichment technology. The lower the uranium-235 content, the larger is the mass needed for explosive use. Nuclear-weapon states prefer a uranium-235 content well above 90%. The IAEA considers uranium enriched to 20% or more as HEU, and enriched below 20% as LEU. HEU is classified as a direct use material. LEU and natural uranium cannot be used for nuclear weapons.

Presumably, some delegations will advocate the position that at only HEU enriched above 90% should be subjected to a treaty. But this would create a fatal gap into the treaty. Firstly, a crude nuclear explosive could be constructed with a uranium-235 content well below this value. Secondly, the effort required to further enrich HEU is far lower than the effort required to enrich LEU or natural uranium. And thirdly, a new interpretation would undermine respect of the IAEA definitions and its safeguards for the NPT. It would also undermine current efforts to phase out any civilian use of HEU.[60]

In contrast to plutonium, uranium is less radioactive and emits less spontaneous fission neutrons. For these reasons, criminals would have fewer problems stealing and smuggling HEU. It therefore poses special proliferation dangers and needs careful safeguarding.

Ordinary power reactors use LEU or natural uranium. The only civilian application of HEU is in research reactors. In order reduce proliferation dangers, successful international projects have been underway for years on the conversion of research reactors from HEU fuel to LEU fuel.[61] However, another non-weapon application is as fuel for naval propulsion. It is strongly recommended to subject the naval propulsion reactors to similar conversion.

Another fissile uranium isotope is uranium-233. It does not occur naturally but, analogous to plutonium, is produced as a result of nuclear reactions when neutrons hit thorium. There are concepts for civilian nuclear fuel cycles using thorium and uranium-233, which principally could also be abused to make nuclear explosives. But up to now, uranium-233 has not been produced on an industrial scale.

### Other isotopes and other mixtures

There are other isotopes that potentially could be used for nuclear warheads, namely neptunium. The usability of americium for nuclear explosives is disputed because it is very radioactive. Both neptunium and americium arise in light water reactor spent fuel, but none has been separated in larger quantities, unlike plutonium. Reprocessing would yield considerable quantities of these isotopes, but so far they have not been produced on an industrial scale. Nevertheless, they are included in IAEA safeguards regulations because they have the potential to become a proliferation danger. It is recommended to include the IAEA definitions into an FM(C)T because this would create an automatic adaption to the latest insights. In case new isotopes are identified to be weapons usable, the IAEA adapts its classification of materials.

The isotopes discussed so far can be found in various mixtures, some of which can be used directly in nuclear weapons or with only moderate technical effort. The IAEA classifies these as direct use materials. This includes not only HEU and separated plutonium but also plutonium contained in mixed-oxide fuel (MOX) for nuclear reactors. As long as MOX is not irradiated, the plutonium can be extracted rather easily (it should be noted that IAEA classifications do not differentiate between isotopes and the chemical compounds of those isotopes). Spent fuel or LEU fall into the broader category of special fissionable materials, which is defined as all those materials that contain any fissile isotopes.

## VARIATIONS OF SCOPE

In the preceding section, we have looked at various types of fissile materials. But in the centre of discussions on the scope is a disagreement—whether a treaty should cover only future production or whether it should also include existing materials produced prior to EIF. During the negotiations of the Shannon Mandate, several states called for the inclusion of materials produced prior to EIF. It was the consensus, however, that production for civilian nuclear industry should not be banned.

Nuclear material existing today is devoted to several purposes, and it is subject to different regulations. In the nuclear-weapon states and states outside the NPT, there is nuclear material in nuclear weapons and in the technical pipeline for their maintenance. Some nuclear-weapon states have declared some material excess to needs. Probably there is even more excess material that has not yet been declared so because, since the end of the Cold War, many thousands of warheads have been disarmed setting free hundreds of tons of fissile material. Some HEU is reserved as fuel for nuclear-propelled military vessels. And there are stocks for civilian nuclear industry. In the non-nuclear weapon states, this is the only category of material. It is subject to IAEA safeguards and is accounted for. The civilian nuclear material of France and the United Kingdom is subject to Euratom safeguards that are as intrusive and precise as IAEA safeguards. The civilian nuclear material in other nuclear-weapon states and states outside the NPT is not subject to safeguards.

The 2009 report by the International Panel on Fissile Materials (IPFM) gives an overview on the quantities of stocks in the various categories.[62]

Mostly, the calls for an inclusion of already existing materials into an FM(C)T are rather vague. There are many variations of possible regulations for material produced prior to EIF and the scope of an FM(C)T. In the following, some of these are illustrated.

### No regulations at all

One extreme in the debates is the view that a treaty should deal only with materials produced after EIF. This is equivalent with the view that, in future, the nuclear-weapon states and the states outside the NPT will deal at their pleasure with their stocks produced prior to EIF, for example their civilian, excess and military materials, without need to justify their actions to the international community. Theoretically, they could use these stocks for future armament beyond the maximum of the Cold War. This would be a contradiction of the “Global Zero” that US President Obama invoked at his famous speech in Prague, which has been applauded by many states. Disappointment and criticism at future NPT Review Conferences would be almost unavoidable.

### Comprehensive disarmament

The other extreme of scope would be a ban of all fissile material for explosive use, which would be equivalent to a treaty for comprehensive disarmament. In this case, a treaty would set a timetable according to which the use of fissile materials for nuclear weapons would be phased out, and this would be verified. Warheads would be dismantled and the fissile material subjected to safeguards. It is unlikely that any delegation believes that, at the time being, this scenario would be acceptable to all delegations in the Conference on Disarmament.

### Irreversibility by a ban on redesignation to explosive needs

Between these two extremes, there are many variants. A minimum demand would be irreversibility, a view that is shared by many. This means to create a one-way road for disarmament. Firstly, nuclear material that is declared as “excess” or “civilian” must never be reused for explosive purposes, even if it had been produced prior to EIF. Secondly, material that has been submitted to safeguards must never been withdrawn. Once civilian, forever civilian; once under safeguards, forever under safeguards. These are demands that are easy to comply with.

Currently, all nuclear-weapon states could submit nuclear material and plants to safeguards, but they also have the right to withdraw them. In the past, only few IAEA safeguards have been installed in nuclear-weapon states. The United Kingdom and the United States are the only states that have submitted excess plutonium to IAEA safeguards. The quantities are just a few tons, although the quantities of excess material are much higher. These are examples of safeguards that must become irreversible.

### Declarations of excess fissile material

Some nuclear-weapon states possess large quantities of excess fissile materials without safeguards. Most of it is from dismantled nuclear weapons or from nuclear weapon fabrication processes. Some civilian direct-use material comes from use in civilian reactors all over the world in the context of the US “take-back” programme.[63]

The nuclear-weapon states have not declared all their excess stocks. Declarations and transparency of data are the first prerequisite of international safeguards and should be a goal of diplomacy anyway. The call for more transparency of stocks will play an important role during the negotiations.

What is transparency of stocks? There is a broad spectrum of variants. Information that is useful for the preparation of safeguards and disarmament and could potentially be published includes quantities of plutonium and HEU in nuclear weapons and reserves, excess or civilian stocks, and information on isotopics and physical properties, for example how much is still in the form of pits (nuclear weapon cores) and how much is in other forms. Other information includes locations, for example storage, maintenance or disposition facilities. It would be helpful to provide documentation of the production history for a future comprehensive accountancy of all stocks. Those states that call for the inclusion of previously fabricated material should be among the first to provide such information. A promising example is the publication in February 1996 by the United States of its plutonium production and use from 1944 through 1994.[64] In 2001, the United States also published its HEU production and use from 1945 to 1996.[65] In 2000, the United Kingdom published information on its plutonium production.[66] Taking an inventory by national means is the first step to prepare for international verification.

### Safeguards on declared excess fissile materials

What is "disarmed" or "civil" fissile material? In terms of the NPT, this is fissile material under IAEA safeguards. In the case of a Global Zero, no fissile materials without safeguards would be left, and disarmament would mean to submit all nuclear materials to safeguards. It is conceivable that an FM(C)T could have a regulation that strives at increasing the quantities of fissile materials under safeguards. A start could be with fissile materials that are already civilian.

The United States and Russia cooperate with some other states in order to dispose of excess fissile materials. There is a plan to dilute excess HEU to LEU for civilian nuclear industry. The methods of how to dispose of excess plutonium have been discussed and studied for years. The most realistic scenario seems to be the option to fabricate MOX for civilian nuclear energy. But the successful accomplishment of these plans will take decades, mainly for technical and economic reasons. In the meantime, the material will be stored, bearing the risk of rearmament or proliferation. Therefore, irreversible safeguards would be a quick disarmament measure the implementation of which is comparatively easy. On various occasions, Russia, the United States and various international groups have declared their wish to place excess weapons material under international safeguards, however, "as soon as practicable".[67]

Another variant of scope would be the commitment to set high standards of physical protection and material accountancy. The call for universal safeguards and more transparency is not new, but its implementation is still at its very beginning. The opposition has various reasons: the first is the claim that too much sensitive information would be revealed. Initially, excess fissile material would be in forms that would reveal too much on the construction of warheads. Before safeguards can be implemented, the material must be transformed. It is also recommended that nuclear-weapon states pursue a detailed analysis of their secrecy regulations and decide whether some information that would be useful for transparency and verification could be revealed. A prominent example of such an endeavour is the "Openness Initiative" that the United States undertook in the mid-1990s and that led to great efforts to be accountable for the whereabouts of US fissile material both to the international community and to the American people.[68]

### A ban on production of HEU for submarines and naval vessels

Some nuclear-weapon states have nuclear submarines that utilize HEU, which could be used directly for nuclear weapons. The United States has reserved more than 100t for this purpose. Military submarines are propelled with HEU because reactors make no noise, and the reactors can use be used for many years without refuelling. Using HEU instead of LEU allows the reactors to be smaller.

In discussions during the last years, the call had been heard that the FM(C)T should allow the production of HEU for this purpose. But this would create a severe loophole, for several reasons.

Firstly, the HEU and the submarines are kept extremely secret. Should this secrecy be maintained, it would not be possible to verify that the HEU is indeed used as fuel. Theoretically, non-nuclear-weapon states under the NPT would be allowed to withdraw HEU for use in military naval vessels: in INFCIRC/153 (§14b), it is foreseen that verification of fuel in a "non-proscribed military activity" is renounced as long as the nuclear material is used in such an activity. The Agency and the state shall make an arrangement that identifies "to the extent possible, the period or circumstances during which safeguards will not be applied". This implies that so far it is not clearly defined under which conditions safeguards of the fuel are interrupted. The interruption could be limited only to fuel in the reactor, or it could also be applied to specific naval fuel storage sites. "In any event, the safeguards provided for in the Agreement shall again apply as soon as the nuclear material is reintroduced into a peaceful nuclear activity", and verification procedures still would have to be developed to ensure that it is not diverted for other purposes. This has never happened and there is no practical experience on how to provide assurance on the one hand but to maintain the secrecy on the other.[69] It is incomprehensible why the owners maintain such extreme secrecy on their naval fuel. While many educated discussions take place in academic and diplomatic fora on the nuclear disarmament of fissile materials, for civilian as well as for explosive purposes, only few discussions on naval fuel take place, and they probe only vaguely at the surface of the problem.

Secondly, the question must be asked why submarine reactors cannot be converted to less enriched fuel, similarly to many civilian research reactors. Despite the secrecy, it may be assumed that some principal approaches to converting HEU-fuelled research reactors to LEU fuel could be applied to HEU-fuelled naval reactors.

Thirdly, the huge stocks of HEU reserved for submarines are sufficient for many decades. Even more HEU will become excess, and thus available, as nuclear disarmament continues. In case it would not be possible to convert the existing submarine reactors, these decades would be more than enough time to develop new reactors that use less enriched fuel.

Fourthly, the major role of military submarines is deterrence of nuclear first strikes. The demand to be allowed to produce HEU after many decades is equivalent to the concession that nuclear deterrence will still be needed after this long time. In other words, those who believe that they need to produce new nuclear submarine fuel in the far future do not think that comprehensive nuclear disarmament will ever be possible or should be strived for. This would be a contradiction of article VI of the NPT and would also be a contradiction of the spirit of the FM(C)T that is officially declared as "nuclear disarmament measures" in terms of article VI, in the list of Principles and Objectives for Nuclear Non-proliferation and Disarmament.

## PROSPECTS

There are many benefits of an FM(C)T, and there are many variations of scope for a treaty that more or less promote the benefits. Another topic that has not been covered in this paper but is as important is verification. Again, there is a broad spectrum of possibilities, ranging from a thorough approach which would be quite similar to verification of the NPT in non-nuclear-weapon states, and that would make use of material accountancy, to the so-called “focused approach”, that concentrates only on reprocessing and enrichment plants. In any case, there will be several specific problems, for example how to cope with “sensitive” information, how to adapt former military production plants converted to civilian use to verification, how to detect clandestine production, and how to distinguish between military tritium production and civilian plutonium production. There are ideas on how to approach these problems, but they must be explored in more detail. A lot of work is ahead of us, and probably many disagreements will have to be resolved. Should the Conference on Disarmament be successful, everyone will benefit.

## TREATMENT OF PRE-EXISTING FISSILE MATERIAL STOCKS IN AN FM(C)T

Harold A. Feiveson

All parties to the forthcoming Conference on Disarmament (CD) negotiations on a Fissile Material (Cut-off) Treaty, or FM(C)T,[70] agree that a treaty should prohibit any further production of fissile materials for weapons once the treaty comes into force. It also is expected that the treaty will permit production under safeguards of fissile materials for non-weapon purposes. This includes separating plutonium for civilian nuclear energy programmes and producing highly enriched uranium (HEU) to fuel reactors for nuclear-powered submarines and ships. There is disagreement, however, about whether *any* pre-existing stockpiles of fissile materials weapons in the Treaty on the Non-Proliferation of Nuclear Weapons (NPT) nuclear-weapon states and non-NPT states should be placed under international safeguards.

Pre-existing stocks can be divided according to whether the fissile materials are:

- **In the nuclear-weapon sector**. HEU and plutonium currently in assembled nuclear weapons, in weapon components in storage, in process or otherwise being held for weapon programme purposes;
- **Weapon-origin fissile material declared by states as excess to any military purpose**. Excess weapon HEU and plutonium committed for use in fuel in civilian reactors or disposition in such a manner that would require either enrichment or reprocessing or both to reverse;
- **Civilian**. HEU used or reserved to fuel research reactors or Russia's nuclear-powered icebreakers or for other civilian purposes;[71] plutonium separated from power-reactor fuel and declared to be reserved for future use in civilian power reactors or other disposition; and
- **Military-reactor fuel**. HEU used in or reserved to fuel nuclear-powered naval submarines and ships and tritium-production reactors.[72]

Annex D shows the approximate quantities of these stocks held by the individual NPT nuclear-weapon states and non-NPT states as of the end of 2007—either based on government declarations or, where governments have not declared stocks, non-governmental estimates.[73] In round numbers, the total fissile material stocks in these states, in metric tons (t), are as follows:

| | |
|---|---|
| In weapons programmes | 900t HEU and 160t separated plutonium |
| Declared excess | 250t HEU and 90t separated plutonium |
| In civilian programmes | 70t HEU and 180t separated plutonium |
| In military, non-weapon programmes | 380t HEU |

In weapon equivalents, the quantity of weapon-usable fissile material outside of weapon stocks is staggering. The HEU stocks translate to the equivalent of over 25,000 nuclear weapons and the plutonium stocks translate to 30,000–60,000 nuclear weapons (assuming 25kg of weapon-grade uranium or 4–8kg of plutonium for a nuclear weapon).

Although, under current conditions, there is little likelihood that much of the material in the pre-existing non-weapon stocks will be converted to weapons use, the reason to subject these stocks to international monitoring in an FM(C)T is to maintain the current situation. This is the same rationale for safeguards under the NPT where non-nuclear-weapon states accept international monitoring to assure that materials that they have declared to be for non-weapons use remain that way.

International monitoring in the nuclear-weapon states also would strengthen international confidence that their nuclear weapon stockpile reductions are irreversible. Nuclear disarmament would not be irreversible if the huge stockpiles of pre-existing civilian and excess weapon materials were available for weapon manufacture. The importance of irreversibility in disarmament was agreed to in the final document of the NPT 2000 Review Conference where a commitment was made:

> by all [NPT] nuclear-weapon States to place, as soon as practicable, fissile material designated by each of them as no longer required for military purposes under IAEA [International Atomic Energy Agency]

> or other relevant international verification and arrangements for the disposition of such material for peaceful purposes, to ensure that such material remains permanently outside of military programmes.[74]

Russia and the United States account for more than 95% of the global stockpile of non-weapon HEU and about half of the global stockpile of non-weapon separated plutonium. It is therefore significant that, already in 1995, the two states had committed that "Fissile materials removed from nuclear weapons being eliminated and excess to national security requirements will not be used to manufacture nuclear weapons; … Fissile materials from or within civil nuclear programs will not be used to manufacture nuclear weapons".[75]

A year later, at the Moscow Nuclear Safety Summit, the leaders of the other G-8 states, including France and the United Kingdom, joined the Presidents of Russia and the United States in the following statement:

> We pledge our support for efforts to ensure that all sensitive nuclear material (separated plutonium and highly enriched uranium) designated as not intended for use for meeting defence requirements is safely stored, protected *and placed under IAEA safeguards* (in the Nuclear Weapon States, under the relevant voluntary offer IAEA-safeguards agreements) as soon as it is practicable to do so.[76]

Nevertheless, today, the argument is often made that inclusion of pre-existing stocks in the FM(C)T negotiations would complicate negotiations and make verification intrusive and difficult. Even the recent report of the International Commission on Nuclear Non-proliferation and Disarmament (ICNND) argued that:

> The difficulty of making the treatment of stocks a formal part of the treaty negotiations now starting—such that the objective would, in effect, be an "FMT" (Fissile Material Treaty) rather than an FMCT—is that this would be a far more complicated exercise, needing altogether more intrusive and sensitive verification arrangements, involving close scrutiny of military facilities.[77]

The purpose of this briefing paper is to clarify some misunderstandings relating to the inclusion of pre-existing stocks of fissile materials in an FM(C)T. In particular, the following points are stressed:

- an FM(C)T that placed civilian, excess and naval stocks under IAEA safeguards need not constrain the use of materials already in weapons or reserved for weapon purposes;
- the inclusion of pre-existing civilian stocks of fissile material would not make IAEA monitoring significantly more difficult, nor would it require access by international inspectors to weapons facilities;
- the inclusion of weapon-origin fissile materials that nuclear-weapon states have declared excess would not involve unprecedented new undertakings by those states, nor involve a significant increase in IAEA monitoring after the materials have been reduced to unclassified forms beyond that required for the monitoring of civilian stocks; and
- naval stocks of HEU cannot indefinitely be kept out of safeguards under an FM(C)T.

### An FM(C)T that placed civilian, excess and naval stocks under IAEA safeguards need not constrain the use of materials already in weapons or reserved for weapon purposes

This would seem obvious. As the ICNND statement quoted above illustrates, however, when "pre-existing" stocks are referred to, many assume that *all* pre-existing stocks, including weapon stocks, are being put on the table. For some proposals, this may be true but it is not true for the International Panel on Fissile Materials (IPFM) Draft Fissile Material (Cut-off) Treaty.[78]

### The inclusion of pre-existing civilian stocks of fissile material would not make IAEA monitoring significantly more difficult, nor would it require access by international inspectors to weapons facilities

Even in the absence of an FM(C)T, several nuclear-weapon states have already accepted, either in practice or in principle, international or regional safeguards on their civilian stocks:

- France and the United Kingdom have accepted Euratom safeguards on their civilian fissile materials. As the end of 2007, the two states had declared publicly through the IAEA stocks of 55t and 81t of civilian separated plutonium—enough for about 7,000 and 10,000 nuclear weapons respectively;[79] and

- China, France, Russia/the Soviet Union, the United Kingdom and the United States have all made voluntary offers to allow IAEA safeguards on source or special fissionable material in peaceful nuclear facilities to be designated by those governments.[80] The US voluntary offer is the most expansive of these.[81] Because of severe limitations on its resources and the priority it gives to safeguards in the non-nuclear-weapon states, however, the IAEA has taken advantage of the offers from the nuclear-weapon states only when the facilities offered were of a type unfamiliar to its inspectors that would broaden their experience base.

Under any verified FM(C)T, all future production of fissile material for weapons would be banned. This would require IAEA safeguards at least on all spent-fuel-reprocessing and uranium-enrichment plants. It would also require safeguards to follow any fissile material produced at these facilities. This would result in IAEA safeguards on mixed-oxide (MOX, plutonium–uranium) fuel-fabrication plants during their fabrication of fuel containing plutonium produced after the FM(C)T comes into force. Safeguards on reprocessing plants in the nuclear-weapon states probably would dominate the safeguards burden of the FM(C)T in the NPT nuclear-weapon states and non-NPT states.[82]

If safeguards were *not* applied to pre-existing civilian plutonium, states and the IAEA would face the complication at MOX-fabrication facilities and MOX-using reactors of having to keep separate two classes of plutonium after the FM(C)T comes into force: pre-existing unsafeguarded, and newly produced safeguarded.[83]

As long as military and civilian nuclear activities are segregated in different facilities, subjecting civilian fissile materials to IAEA monitoring would not require access to military nuclear sites.

In a few cases, applying IAEA safeguards to civilian fissile materials would require states to segregate civilian and non-weapon military nuclear activities that currently take place in the same facilities. For example, in some states, HEU fuel for civilian reactors is produced in the same facilities as HEU fuel for submarines. This overlap is decreasing, however, as civilian HEU-fuelled reactors are shut down or converted to low-enriched uranium (LEU) fuel. By the time that an FM(C)T comes into force, the cost of segregating the fabrication of civilian HEU fuel should not be great.

**The inclusion of weapon-origin fissile materials that nuclear-weapon states have declared excess would not involve unprecedented new undertakings by those states, nor involve a significant increase in IAEA monitoring after the materials have been reduced to unclassified forms beyond that required for the monitoring of civilian stocks**

Russia and the United States have each declared excess to their future military needs hundreds of tons of fissile material from Cold War weapons. In 2000, in their Agreement Concerning the Management and Disposition of Plutonium Designated as No Longer Required for Defense Purposes, Russia and the United States committed to:

> begin consultations with the International Atomic Energy Agency (IAEA) at an early date and undertake all other necessary steps to conclude appropriate agreements with the IAEA to allow it to implement verification measures beginning not later in the disposition process than: (a) when disposition plutonium or disposition plutonium mixed with blend stock is placed into the post-processing storage location of a conversion or conversion/blending facility; or (b) when disposition plutonium is received at a fuel fabrication or an immobilization facility, whichever (a) or (b) occurs first for any given disposition plutonium.[84]

In effect, this is a commitment to subject the disposition of excess weapon plutonium to IAEA safeguards once the plutonium is in unclassified form. In the case of their excess weapon-grade HEU, Russia and the United States have a bilateral transparency agreement in their "HEU Deal" under which the United States is purchasing 500t of Russian weapon-grade HEU after it is blended down to LEU:

> In order to ensure that the objectives of the Agreement are fulfilled, the Parties shall implement transparency and access measures to guarantee, inter alia: that the HEU subject to the Agreement is extracted from nuclear weapons and that this same HEU enters the oxidation facility and is oxidized therein; that the declared quantity of HEU is blended down to LEU; and, that the LEU delivered to the United States of America pursuant to the Agreement is fabricated into fuel for commercial nuclear reactors.[85]

The IAEA could be made a party to this transparency agreement at least at the blend-down point. In fact, the United States invited the IAEA to verify the blend-down to LEU of 13t of excess HEU at the Portsmouth enrichment plant, where it had produced much of its HEU,[86] and 50t of HEU at the BWXT plant in Lynchburg, where the United States produces naval and research reactor HEU fuel.[87]

Furthermore, in 1996, Russia and the United States joined with the IAEA in launching a Trilateral Initiative "concerning the application of IAEA verification of weapon origin fissile materials"[88] even before they had been reduced to unclassified form. The effort was a technical success but the two states lost interest after Presidents Bush and Putin succeeded Presidents Clinton and Yeltsin, respectively.[89]

### Naval HEU fuel cycles cannot be kept free of IAEA monitoring indefinitely

The United States is the only state that has publically declared a separate stockpile of HEU for naval reactor fuel: about 128t of weapon-grade HEU.[90] Historically, the United States has supplied HEU for UK naval-propulsion reactors. A substantial UK reserve can be inferred because the United Kingdom has declared 17.4t of military HEU, which is considerably more than would be required to support its declared nuclear arsenal of less than 200 warheads. In any case, the US stockpile alone would suffice to supply the current needs of the US and UK navies for about 60 years.[91] Russia has not publicly declared a separate stockpile of HEU for naval-reactor fuel but probably has a comparable reserve for future naval-reactor use. France has shifted to LEU fuel for its naval reactors. It is not known whether China uses LEU or HEU. India is believed to use HEU in its prototype submarine propulsion reactor and currently does not have a large HEU stockpile.

Under an FM(C)T, freshly produced HEU for naval reactors will have to be subjected to some sort of IAEA monitoring to ensure that it is not diverted to weapon use. As indicated above, for Russia, the United Kingdom and the United States, such production may not be necessary for several decades.

Nevertheless, during this period, the pre-existing stocks of HEU will constitute a potential source of weapon-grade material that could be diverted to weapons. This diversion potential from naval HEU reserves will loom increasingly significant as Russia, the United States and eventually the other nuclear-weapon-possessing states draw down their nuclear-weapon arsenals and dispose of their excess fissile materials. Annex E shows the relative size of current naval HEU reserves to the HEU in weapons if the nuclear-weapon-possessing states moves to smaller numbers of nuclear weapons and declare excess the HEU no longer needed for weapons. Disarmament therefore would be stabilized by shifting naval reactors from HEU to LEU fuel, which would make it possible to shrink the global naval HEU stockpile in parallel with the nuclear-weapon HEU stockpile. In the meantime, monitoring of the naval HEU reserves would be helpful.

This would be easiest to do once the naval HEU reserves were in unclassified form—although non-intrusive monitoring of excess HEU components in sealed canisters might also be developed as was the case for excess plutonium components in the Trilateral Initiative.

If international monitoring of naval HEU stockpiles were agreed, when HEU was required to fabricate new naval-reactor cores, a state would have to declare to the IAEA the amount of HEU that it required for the purpose. This would require states to be willing to declare to the IAEA the quantities of HEU in specific cores. Although some states currently classify this information, revealing it would not appear to reveal sensitive performance characteristics, such as the maximum power output of the core or how rapidly the power output can change or how resistant the core would be to damage resulting from the explosions of nearby torpedoes or depth charges. The verification challenge, which has not been completely worked out yet, would be to be able to determine non-intrusively that the fabricated “cores” contained the agreed amount of HEU and that the objects designated as “cores” were installed and sealed into naval reactor pressure vessels.[92]

# FOCUSING ON FMCT VERIFICATION

Bruno Pellaud

Many of the possible building blocks of a Fissile Material Cut-off Treaty (FMCT) have been thoroughly presented and analysed since the formulation of the Shannon mandate in 1995 at the Conference on Disarmament (CD). In the technical environment, not much has changed since that time, thanks to the decision of most states with nuclear weapons to voluntarily suspend the production of the corresponding fissile materials. The earlier UN General Assembly resolution mandate of December 1993 formed the basis 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".[93] Each part of that sentence—as clear as it seems—is open to different interpretations. "Non-discriminatory" will be an issue when the broad structure of a FMCT has been defined. "Multilateral", *not* "universal", would allow a treaty among few parties or a series of bilateral treaties, but "international" verification would go beyond the participating parties.

But what is "effective verification"? The International Atomic Energy Agency (IAEA) makes a distinction between effectiveness and efficiency. The effectiveness of safeguards is deemed to be satisfactory if the applied safeguards are capable of providing a sufficiently high degree of assurance of compliance. This implies that technical and control measures are available, and used with sufficiently high intensity or frequency on the facilities and materials being verified. Efficiency is more administrative, since it concerns minimizing the use of resources to achieve a given level of effectiveness. Even though the UN mandate did not say an "effectively and efficiently verifiable treaty", there is no doubt that efficiency plays an important role in the negotiation of treaties. In the case of the Biological Weapons Convention, the parties could not agree on the verification component of the treaty, because of the resources needed to achieve a stated and satisfactory level of assurance of compliance.

Is a future FMCT effectively and efficiently verifiable? Some governments were inclined to answer "no" to both accounts during the last decade. However, today, like in the 1990s, the answer could be "yes". Currently, the IAEA safeguards system is used to verify some 1,100 facilities around the world. If the IAEA can do so in non-nuclear weapons states, an effective and efficient verification can also be carried out elsewhere under a FMCT for fewer facilities of a comparable technical nature. Yet, one might imagine that the efficiency would be somewhat less under an FMCT because of the greater complexity of dealing with military facilities. Effectiveness would likely be much less than in the IAEA safeguards system as well, particularly given the need to protect the confidentially of certain weapon-related information.

Verification—this is the bottom line, this is what will make a treaty possible or not—this is the measure of success. The effectiveness of a treaty and the cost of verification will depend on the choices made for the well-known core issues:

- The **objective**: the freezing of the status-quo (non-proliferation) or partial disarmament, as well;
- The **scope**: the inclusion (immediately or at some point in the future) of stocks, of all nuclear facilities or just a subset to be verified, and (immediately or at some point in the future) of potential undeclared facilities;
- The **definitions** of fissile materials: whether unirradiated fissile materials only, or more or less strictly defined weapon-usable separated isotopic mixtures, etc.
- The assurances of compliance being sought for: should they be beyond doubt, reasonable, credible? In other words, what should be the intensity/frequency of verification measures to provide the world community with a politically significant degree of assurance.

## SHIFTING FOCUS: FROM THE IAEA TO AN FMCT

An FMCT will deal with nuclear facilities and materials. So does the IAEA. There is thus a direct analogy between the two verification regimes.

The **objective** of the IAEA under the Treaty on the Non-Proliferation of Nuclear Weapons (NPT) is broader (not to acquire nuclear weapons) than that intended for an FMCT, but it does contain the notion of not producing nuclear materials for weapon purposes and of knowing the whereabouts of stocks of nuclear materials of any kind.

The **scope of verification** varies according to the task expected from the IAEA and the type of agreement prevailing between IAEA and a given state:

- **IAEA inspection of a single facility**: a single, well-identified facility is verified with standard accounting and technical means, from item counting to indoor environment sampling;
- **IAEA inspection of all declared facilities**: all facilities are verified with standard accounting and technical means, from item counting to outdoor environment sampling;
- **IAEA inspection under Additional Protocol**: as above, plus verification of potential unidentified, undeclared facilities with expanded information gathering, and more intrusive access and technologies.

All three cases would deserve consideration during the negotiation of an FMCT: a collection of single facilities in individual states, a comprehensive list of facilities, or more ambitiously the consideration of potential undeclared facilities.

Unambiguous **definitions** of what are fissile materials have been adopted by the IAEA from the very beginning, and offer a tried example for following in the FMCT negotiations. However, less demanding definitions may be more appropriate for an FMCT.

By defining maximum frequencies of inspection for various kinds of facilities, the Model Safeguards Agreement of INFCIRC/153 had specified a minimum **degree of assurance.** This level was sometimes too low as revealed by the failure of the IAEA to uncover the Iraq nuclear programme prior to 1990. Triggered by this failure, the new technical measures adopted by the IAEA in 1995 (environmental sampling, satellite imagery, etc.), and the adoption by many States since 1997 of the more intrusive Additional Protocol, have increased the degree of assurance markedly. When addressing these same core issues for an FMCT, most relevant lessons can be learned from the rich experience of the IAEA. In particular, all the verification tools used by the IAEA are almost directly applicable to the FMCT, should scope and definitions overlap.

Thus, this overview shall focus on scope and definitions, leaving the objectives aside. Regarding the degree of assurance, this mostly depends, for a given scope and given definitions, on the intensity of application of the verification techniques.

The scope of an FMCT remains to be decided. At the very minimum, one could expect the inclusion of declared facilities previously dedicated to weapon programmes and the consideration of strictly weapon-usable materials—thus giving an estimated total of 100 facilities in the states possessing nuclear weapons. On the other hand, a maximum scope would include all nuclear facilities in those states, giving a total of 1,000 facilities or more.

Again, FMCT verification efforts will depend on the scope, on the definitions and also on the desired degree of assurance.

## FOCUSED VERIFICATION SCOPE

A “focused” scope could concentrate on the most proliferation-sensitive fissile material production facilities—that is, spent fuel reprocessing facilities and enrichment facilities—and the relevant ongoing production from those facilities, regardless of operational status (operating or shut down). This would require verification measures at downstream facilities handling the processed materials. Fissile materials subject to an FMCT, and exactly defined in the treaty, would be separated plutonium, uranium-233, high-enriched and low-enriched uranium and separated neptunium.

Irradiated fuel, which contains unseparated fissile materials, would be deemed of no further strategic value until reprocessed, and therefore would not be subject to FMCT.

Altogether, an estimated 195 facilities would fall under verification in the states possessing nuclear weapons. Such a scope could also include measures aimed at the detection of related undeclared production activities in or around the declared facilities. Such a model was proposed by Australia a few years ago.[94] The IAEA considered this model in the studies carried out in the 1990s.[95]

Such a scope could provide a **reasonable level of assurance**.

## BROAD VERIFICATION SCOPE

Some observers believe that the above scope is insufficient, since it would deal only with sensitive facilities and separated fissile materials. In addition, some wish from the outset to include civilian nuclear power plants, and irradiated spent fuel from civilian plants. This would bring the total number of facilities under verification to 645 in the states possessing nuclear weapons.

While taking into account many more facilities and materials, it should be noted that this particular scope does not include matters felt to be of less concern, for example the diversion, misuse and verification of low enriched, natural or depleted plutonium, and thorium (these being considered under the comprehensive scope).

Such a scope could provide for a **high level of assurance**.

## COMPREHENSIVE SCOPE

"Comprehensive" scope would mean applying IAEA safeguards-type measures to all nuclear facilities and materials in a state or territory under its control, except those acknowledged as military stocks of fissile material which would be in existence at the date of entry into force of the treaty. For the states in possession of nuclear weapons, this would corresponds to 995 facilities.

Such a scope would correspond to that of safeguards applied in the non-nuclear weapons states, and could provide for a **very high level of assurance**.

## COSTS: THREE LEVELS OF VERIFICATION

The cost studies done by the IAEA in the early 1990s (see note 2) correspond closely to the assumptions made in the above three levels of verification scope. Detailed estimates of the verification efforts in the various facilities present in the states possessing nuclear weapons were made, in terms of Person-Days of Inspections (PDIs). The third column in table 1 shows the original case from the studies and the estimated PDIs in

1995. These figures were then multiplied by a PDI unit cost at the time for each type of facility and geographical location. (Incidentally, the results in dollars were very close to the cost figures in euros shown in the third column.)

**Table 1.** Verification cost estimates

| | | |
|---|---|---|
| **Level 1** | Australia's model—enrichment and reprocessing facilities, and those facilities containing separated fissile materials (an estimated 195 facilities in the states possessing nuclear weapons) | **€90 million per year**<br>16,271 PDIs<br>IAEA Case B |
| **Level 2** | All the above facilities and separated materials, with, in addition, all large nuclear plants and reactors and all irradiated spent fuel (645 facilities) | **€130 million per year**<br>22,113 PDIs<br>IAEA Case C |
| **Level 3** | Comprehensive, that is everything, in Level 2, with, in addition, thorium and low-enriched, natural and depleted uranium (995 facilities) | **€150 million per year**<br>25,398 PDIs<br>IAEA Base Case |

In the table, some adjustments have been made by the author to update the 1995 IAEA figures: the dollar-to-euro shift (since 2006, the IAEA uses the euro as its basic currency), the PDI unit costs and more importantly the new PDI efficiency. PDI indicates work out in the field, out in the facilities. Thanks to remote monitoring, the IAEA can now provide the same degree of assurances with fewer PDIs, with inspectors doing much work from headquarters. The 1995 PDI estimates would be considerably lower today, but with a higher PDI unit cost.

For comparison, the 2008 IAEA budget was €96 million, supporting 8,220 PDIs per year at a total of 1,131 facilities. By this rough estimate, the verification of a similar number of facilities under an FMCT would be some 30% to 50% more expensive than the IAEA system, due to a number of factors: older, more complex facilities, confidentiality constraints, the partial inapplicability of modern techniques such as environmental sampling due to the presence of materials excluded from verification, etc.

## BOTTOM LINE: COSTS VERSUS ASSURANCES

The negotiations of an FMCT will bring together valid considerations and priorities for the balancing act between the degree of assurances brought by a verification model and the associated costs:

**Extreme low model**—for example, the consideration of only the 100 core facilities in the states possessing nuclear weapons. Limited scope and low assurance mean limited verification and low costs. But, such a treaty may have little political relevance.

**Extreme high model**—comprehensive scope coupled with demand for very high assurance would mean stringent verification and thus very high costs. But, political demands that are too high could halt FMCT negotiations.

The negotiations will need to find **the right balance**, the right compromise!

## AFTERTHOUGHTS

### ON THE NEGOTIATING APPROACHES AND FMCT TREATY CONTENTS

Like most other treaties negotiated under the umbrella of the Conference on Disarmament, the FMCT will reflect an intricate pattern of technical, economical, legal and political factors. In order to facilitate the negotiations, it could be worthwhile to segregate in space and in time the most important factors, in particular those related to verification. One could consider two alternatives, two negotiating approaches:

First alternative: A **single treaty** containing both the basic treaty objectives and the details of the verification system—this is the approach taken with the Chemical Weapons Convention (CWC). With this alternative, it would be difficult to negotiate a balanced treaty and to structure it with a certain degree of flexibility in order to accommodate future changes in the technical and political contexts.

Second alternative: Basic political commitments in a **principal treaty**, with the verification system in a **secondary agreement**—as done in the

NPT's case, where the safeguards agreement with the IAEA is negotiated separately, but based on the model INFCIRC/153. This approach separates largely political from largely technical subject matters, and allows for an adaptable verification system. The NPT was concluded in 1968, entered into force in 1970, while the model safeguards agreement, INFCIRC/153, was not concluded until 1972 and the model Additional Protocol (INFCIRC/540) introduced in 1997. The NPT setup is flexible and allows for major updates of the verification system (see note 1).

## On the verification agency under the FMCT

Who should be entrusted with the verification of an FMCT?

It appears relatively obvious that the FMCT agency should be in Vienna in order to build on the synergies with the IAEA NPT activities. Should it be the IAEA itself or a new agency? The response will depend on a political issue. The choice will depend on the negotiated composition of the FMCT Board of Governors/Executive Council (same or different for NPT and FMCT) and of the funding mechanisms behind these treaties. In reality, the IAEA Board composition and the funding of safeguards correspond to a system unrelated to and predating the NPT, in which the level of economic development and the status of nuclear energy in selected non-nuclear weapons states are taken into account. Yet, many observers feel that the states possessing nuclear weapons (except for Israel, which is not on the Board) exercise an excessive influence in the Board. Under a FMCT, the states possessing nuclear weapons could seek to play an even stronger role than in the IAEA Board, since they will be the focus of the treaty. Yet, the FMCT negotiations could bring an opposite view to the surface.

# IAEA SAFEGUARDS AND VERIFICATION ACTIVITIES

International Atomic Energy Agency

*Note: this text is a summary of a presentation by the International Atomic Energy Agency to the Conference on Disarmament on 24 August 2006 in Geneva, entitled "A cut-off of production of weapon-usable fissionable material: considerations, requirements and IAEA capabilities". The full presentation is available in all UN languages in CD/1795, dated 24 September 2006.*

*Recognizing the differing views of states on the scope and verification of a Fissile Material Cut-off Treaty (FMCT), the IAEA stressed that it did not wish to prejudge the discussion of such issues in the Conference on Disarmament. Its paper offered an overview of the Agency's safeguards system and verification activities for the information of states taking part in the work of the Conference on Disarmament and identified activities that could be of relevance to a discussion on verification of a future FMCT.*

## INTRODUCTION

The UN General Assembly adopted resolution A/RES/48/75/L on 16 December 1993 which, inter alia, requested the 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 analyse 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 Treaty on the Non-Proliferation of Nuclear Weapons

(NPT) states parties would include an undertaking neither 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 for nuclear weapon purposes. Thus there would be the need to ensure that stocks of plutonium and high-enriched uranium (HEU) 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 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 production facilities, or should the verification activities be comprehensive?
- How, and to what extent, should verification ensure that stockpiles of fissile material 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.

## 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.[96] Following the conclusion of the 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.

The non-nuclear-weapon states (NNWS) parties to the NPT have undertaken treaty commitments that include not to manufacture or otherwise acquire nuclear weapons or other nuclear explosive devices. Such states have undertaken to conclude a comprehensive safeguards agreement (CSA, see INFCIRC/153 (Corr.)) with the IAEA to fulfil their obligation under Article III of the NPT. In accordance, they submit all nuclear material in all nuclear activities to IAEA safeguards to ensure that such material is not diverted to nuclear weapons or other nuclear explosive devices.

The five nuclear-weapon states (NWS) parties to the NPT have concluded voluntary offer safeguards agreements (VOAs) 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.

In the 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 (see INFCIRC/66/Rev.2).

All states having a safeguards agreement with the IAEA can also conclude an Additional Protocol (AP, see INFCIRC/540 (Corr.)) in order to strengthen the effectiveness and efficiency of the safeguards system.

## SAFEGUARDS FOR NNWS

IAEA safeguards are regarded as a cornerstone of the international nuclear non-proliferation regime, and comprehensive safeguards agreements based on INFCIRC/153 (Corr.) are the cornerstone of IAEA safeguards. Twenty-two NPT NNWS have yet to bring into force their CSAs, as required by Article III of the NPT. CSAs obligate NNWS to submit all nuclear material to IAEA safeguards and 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 misuse scenarios involving both declared nuclear material and undeclared material and activities; they are intended to confirm that all nuclear material is submitted to safeguards and remain committed to peaceful use.

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

- to detect the diversion of significant quantities (SQs) of nuclear material 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 as well as the presence of undeclared nuclear activities in the state as a whole.

Over the years, standard criteria have been adopted to guide the implementation of safeguards at declared facilities, affecting 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. "Significant quantity" is defined by the IAEA as follows: 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; and for 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 to other states as 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 nuclear material" (referred to as an SSAC) must be created to be responsible for implementing, inter alia, effective nuclear material accountancy arrangements. States must make extensive declarations regarding their nuclear activities at safeguarded facilities and report at specified periods on their nuclear material inventories and flows, including imports and exports of nuclear material. When a CSA first enters into force, the initial report of all nuclear material holdings 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 NNWS with a CSA, demonstrated that a safeguards system that mechanistically 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 the limitations of CSAs. Additional Protocols to CSAs, based on INFCIRC/540 (Corr.), extend the authority of the IAEA to require states to provide additional information and access to locations, enabling the IAEA to verify not only the "correctness" but also the "completeness" of states' declarations under CSAs. The goal is to have APs in force universally, so that the Agency's expanded rights of access apply equally in all states with CSAs. To date the progress on the conclusion and entry into force of APs has been slow. APs have been signed by 128 states and are in force in 94 states.

The provisions of APs to CSAs require states to provide information on their nuclear programmes including research and development not involving nuclear material, 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, to resolve questions or inconsistencies pertaining to activities or materials, or to confirm the decommissioned status of facilities. Provisions for managed access are included 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. Assurances regarding the absence of clandestine facilities or undeclared activities in declared facilities provided through APs has allowed the IAEA to optimize its verification requirements at declared facilities.

For states with both a CSA and an AP in force and for which the IAEA has drawn the "broader conclusion" that all their nuclear material remains in peaceful activities, the IAEA is able to apply "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 APs. 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 January 2010, the IAEA is applying integrated safeguards for 47 states, including in Japan and Canada, which have the two largest programmes under safeguards.

## SAFEGUARDS FOR NON-NPT STATES

IAEA safeguards implementation in India, Israel and Pakistan are applied under safeguards agreements based on INFCIRC/66/Rev.2 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. Of the non-NPT states, India has signed an AP but it is not yet in force.

## SAFEGUARDS FOR NWS

The five NPT NWS—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 serve two purposes: to broaden the IAEA's safeguards experience by allowing for inspection at advanced facilities, and to demonstrate that NWS are not commercially advantaged by being exempt from safeguards on their peaceful nuclear activities.

These VOAs place no obligation on the state in relation to the nuclear material to be subject to safeguards and they permit the state to withdraw nuclear material and to remove facilities from the list of those 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. 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.

All five NPT NWS have signed and brought into force APs that include certain measures provided for in INFCIRC/540. For the most part, the APs adopted by the NWS are intended to provide the IAEA with additional information to assist the IAEA in safeguarding nuclear activities in NNWS. The APs 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 routine 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 UN Security Council resolution 687 and related resolutions, 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 Democratic People's Republic of Korea in relation to an Agreed Framework concluded between the Democratic People's Republic of Korea and the United States, including monitoring a freeze on operations at the reprocessing plant at Nyongbyon, which was maintained at operational stand-by. In addition, under the Six Party Talks, from July 2007 to April 2009, the IAEA carried out ad hoc monitoring and verification of the shut down of the Nyongbyon nuclear facilities. Again, the experience gained may be of benefit in considering provisions for inspections under an FMCT; and
- The IAEA participated with the Russian Federation and the United States in a project called the Trilateral Initiative to develop a verification

system for excess defence fissile materials in those states, as briefly described below.

## 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 a 17 September 1996 meeting. The aim of the initiative was to fulfil 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 Trilateral Initiative 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. The task entrusted to the Trilateral Initiative Working Group was declared concluded on 16 September 2002. The IAEA stands ready to place under verification any material that would be made available by the two states.

## 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 review of IAEA experience in applying safeguards at reprocessing and enrichment plants to date might be useful.

IAEA safeguards both at reprocessing and enrichment 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.

### Declared reprocessing plants

Plutonium produced in nuclear reactors is separated from the uranium, fission products and other actinides in reprocessing plants. 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 process, make the application of safeguards complex and more expensive than any other safeguards application.

The safeguards approach for a reprocessing plant depends on a range of considerations, chief among which is its operational status—whether it is in operation, stand-by mode, decommissioned or abandoned. 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.

The verification equipment used at reprocessing plants includes standard seals and surveillance equipment, plus specialized systems, including process monitoring, pneumatic measurement systems, secure sample containers, densitometry equipment and—in large-scale plants—on-site analytical laboratories.

Safeguards at reprocessing plants include the taking of samples for analysis at the IAEA Safeguards Analytical Laboratory, located in Seibersdorf, Austria. Shipping such samples is expensive and requires appropriate radiation protection measures.

In a CSA state, any undeclared reprocessing would constitute a clear violation of the provisions of the agreement and the AP. 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 AP, 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 analyses the information provided and compares that information with information obtained from a range of other sources.

*Complementary access*: Under the provisions of the AP, 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 AP at locations where complementary access is carried out. Procedural arrangements for wide-area environmental sampling (WAES) would require approval by the Board of Governors before this feature of the AP 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 low-enriched uranium (LEU) production (that might subsequently be further enriched at a clandestine plant or within a plant under safeguards, with a higher risk of detection); 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.

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.

Environmental sampling has proven to be an extremely sensitive 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 an HEU plant, environmental sampling may be less useful. The safeguards approach in such facilities would require greater emphasis on other elements of the approach, 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.

The methods used to detect *undeclared* enrichment plants are essentially as for undeclared reprocessing: enhanced information analysis, complementary access and environmental sampling. 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 only likely to be effective close to such facilities.

## VERIFICATION OPTIONS

In the mid-1990s, the IAEA 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 CSAs 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 CSAs, 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 IAEA safeguards system. IAEA safeguards 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 (e.g. 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 Chemical Weapons Convention or the Conventional Forces in Europe Treaty, “managed access” arrangements similar to those adopted under the Model Additional Protocol or the Chemical Weapons Convention 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. Some of these measures are already employed by the IAEA within the framework of strengthened safeguards or have been used during other, case-specific verification missions.

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 deactivate 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.

In some states, the military and civilian nuclear fuel cycles are not entirely separate 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 over-flight 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.

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 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 detected decrease, as the timeliness requirements increase, and as the confidence associated with conclusions increases, the verification costs commensurately go up and the level of assurance provided by the system increases.

The third of the parameters just mentioned in relation to 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.

## 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 a 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 database 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 of America). Depending on the parameters, the IAEA estimated in 2006 that the costs of verifying an FMCT could vary between €50 million to €150 million, updating its earlier estimates based on the 1995 study.

### 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 1,000 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 CSAs (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 €115 million supplemented by €21 million in extra-budgetary contributions, more than 250 IAEA inspectors carry out nearly 2,100 inspections representing more than 8,000 person-days of inspection work each year, using more than 100 different verification systems. As of 31 December 2008 (data for 2009 will be available in June 2010), Agency safeguards were applied to 1,131 facilities, including 232 power reactor units (including 197 light water reactors and 30 on-load reactors), 156 research reactors and critical assemblies, 16 enrichment plants, 13 reprocessing plants, 20 conversion plants, 46 fuel fabrication facilities and 158,670 SQs of nuclear material (comprising 11,443 SQs of unirradiated plutonium, including MOX, outside reactor cores; 121,881 SQs of plutonium contained in irradiated fuel, including plutonium in fuel elements in reactor cores; 317 SQs of HEU and 19 SQs of U-233; 15,947 SQs of LEU; and 9,063 SQs of source material). Of the 1,131 facilities noted above, 597 (containing more than 99% of the total material), were inspected in 2008. Approximately 634,000 accounting reports were provided to the Agency for processing. 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 FMCT 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 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.

# ANNEX A

## RELEVANT CD DOCUMENTS

Shannon report
CD/1299, 24 March 1995

Canada: transmitting papers of a workshop held in Toronto, 16–19 January 1995
CD/1302, 30 March 1995

Canada: transmitting a publication on verification
CD/1304, 4 April 1995

USA: Statement by President Clinton
CD/1441, 22 January 1997

Canada: Working paper on an Ad Hoc Committee on an FMCT
CD/1485, 21 January 1998

USA: Statement from the President
CD/1490, 28 January 1998

Draft Decision on the establishment of an Ad Hoc Committee
CD/1492, 3 February 1998

Report of a seminar on FMCT held in Geneva, 11–12 May 1998
CD/1516, 28 May 1998

Sweden: Joint declaration
CD/1542, 11 June 1998

Algeria: proposal under agenda item 1
CD/1545, 31 July 1998

Decision on the establishment of an Ad Hoc Committee under agenda item 1
CD/1547, 11 August 1998

Statement by the President following adoption of CD/1547
CD/1548, 11 August 1998

Statement by the G21
CD/1549, 12 August 1998

Austria: Statement by the Foreign Minister
CD/1550, 12 August 1998

The Philippines: Statement by the Foreign Minister
CD/1551, 18 August 1998

Report of the Ad Hoc Committee under agenda item 1
CD/1555, 1 September 1998

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CD/1578, 18 March 1999

Japan: Report of the Tokyo Forum
CD/1590, 19 August 1999

Finland: Declaration by the EU on fissile materials
CD/1593, 6 September 1999

Mexico: portion of text adopted at the 2000 NPT RevCon
CD/1614, 25 May 2000

South Africa: Working paper: possible scope and requirements of the FMT
CD/1671, 28 May 2002

Addendum to CD/1671
CD/1671/Add.1, 23 August

The Netherlands: Summary of an informal meeting on fissile materials held in Geneva, 7 June 2002
CD/1676, 19 June 2002

Ireland: paper submitted by the New Agenda Coalition (NAC) to the first PrepCom of the 2005 NPT RevCon
CD/1683*, 3 September 2002

The Netherlands: Summary of a second informal meeting on fissile materials held in Geneva, 25 September 2002
CD/1691, 13 January 2003

The Netherlands: Summary of a fourth informal meeting on fissile materials held in Geneva, 4 April 2003
CD/1705, 26 May 2003

New Zealand: paper submitted by the NAC to the second PrepCom of the 2005 NPT RevCon
CD/1707, 26 May 2003

UK: Working paper submitted to the second PrepCom of the 2005 NPT RevCon
CD/1709, 17 June 2003

Japan: Working paper on a FMCT treaty
CD/1714, 19 August 2003

The Netherlands: Summary of a fifth informal meeting on fissile materials held in Geneva, 26 September 2003
CD/1719, 9 October 2003

Italy: EU strategy against proliferation of WMD
CD/1724, 31 December 2003

The Netherlands: Summary of a sixth informal meeting on fissile materials held in Geneva, 2 April 2004
CD/1734, 7 May 2004

The Netherlands: Common position of the EU to the 2005 NPT RevCon
CD/1751, 10 June 2005

Malaysia: Working paper by the NAM to the 2005 NPT RevCon
CD/1752, 27 June 2005

Canada: Elements of an approach to dealing with stocks of fissile materials for nuclear weapons or other nuclear explosive devices
CD/1770, 4 May 2006

Switzerland: A pragmatic approach to the verification of an FMCT
CD/1771, 12 May 2006

Italy: Banning the production of fissile material to prevent catastrophic nuclear terrorism
CD/1772, 15 May 2006

Italy: FMCT's entry into force: possible options
CD/1773, 15 May 2006

Japan: FMCT: a contribution to constructive discussions
CD/1774, 16 May 2006

Australia: Suggestions for progressing the FMCT
CD/1775, 17 May 2006

USA: Draft mandate for an Ad Hoc Committee on a FMCT
CD/1776, 19 May 2006

USA: Draft FMCT
CD/1777, 19 May 2006

USA: White paper on a Fissile Material Cutoff Treaty
CD/1782, 22 May 2006

Canada: An FMCT scope–verification arrangement
CD/1819, 21 March 2007

Reports of the seven Coordinators on the work done during the 2007 session
CD/1827, 16 August 2007

Reports of the seven Coordinators on the work done during the 2008 session
CD/1846, 15 August 2008

Canada, Japan, the Netherlands: Draft treaty text prepared by the IPFM
CD/1878, 16 September 2009

# ANNEX B

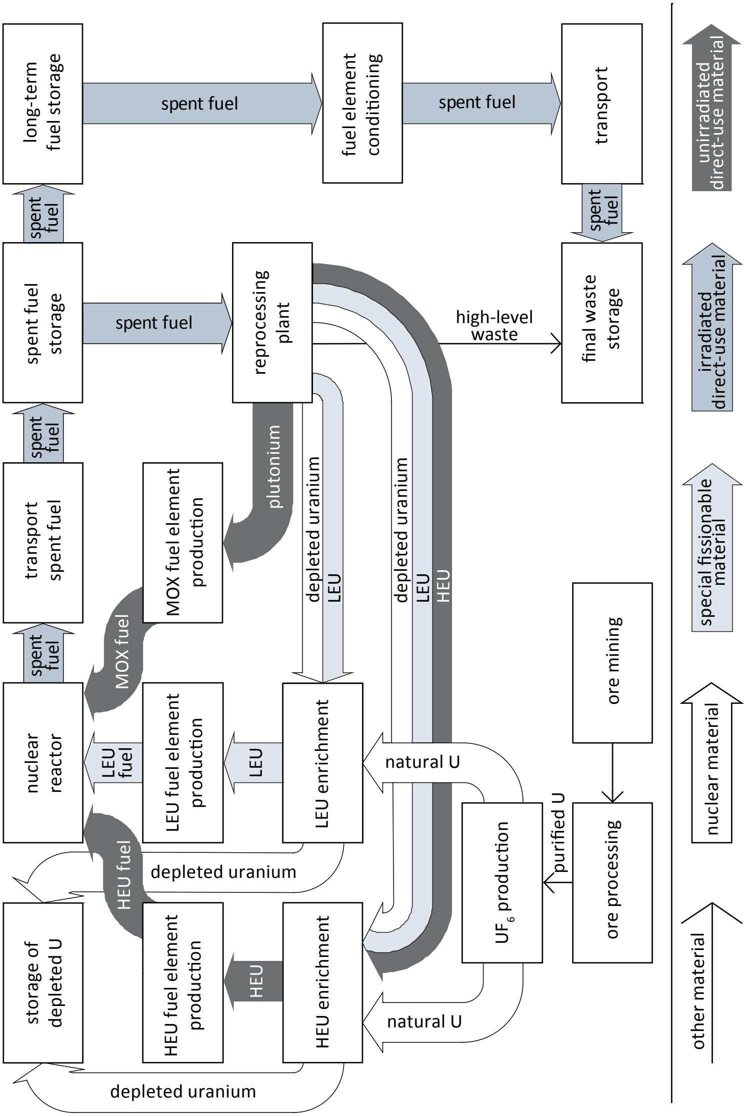
## MATERIALS, THEIR IAEA CATEGORIES AND THEIR ROLE FOR NUCLEAR EXPLOSIVES

For technical details on the use of various nuclear materials for nuclear explosives, see Annette Schaper, *Principles of the Verification for a Future Fissile Material Cutoff Treaty (FMCT)*, PRIF-Report no. 58, Peace Research Institute Frankfurt, 2001, <http://hsfk.de/fileadmin/downloads/prif58.pdf>.

| **Material** | **IAEA Category**<br>(sfm = special fissionable material) | **Role for nuclear explosives** |
|---|---|---|
| weapon-grade plutonium<br>high content of Pu-239 | nuclear material; "plutonium" with no legal distinction; direct-use material; sfm | as explosive |
| reactor-grade plutonium<br>Pu-239 and substantial fractions of other plutonium isotopes | | as explosive, but with technical disadvantages |
| Pu-238 mixtures (> 80%) | none | none |
| weapon-grade HEU<br>high content of U-235<br>(> 90%) | nuclear material; HEU with no legal distinction; direct-use material; sfm | as explosive |
| lower grades of HEU | | as explosive, but this is more difficult than with weapon-grade HEU |
| LEU<br>U-235 enriched to < 20% | | enrichment necessary to produce HEU, or irradiation to produce plutonium |
| natural uranium<br>U-238 with U-235 content = 0.7% | source material | |
| depleted uranium<br>U-235 content < 0.7% | | |
| U-233 | direct-use material; sfm | as explosive |
| mixtures containing U-233 | | separation produces U-233 |
| thorium (Th-232) | source material | can be irradiated to produce U-233 |
| neptunium (Np-237) | no categorization, but material accountancy | as explosive |
| americium (Am-241) | no categorization, but reporting | as explosive, but only with extreme technical sophistication |
| MOX<br>mixture of uranium & plutonium | direct-use material; unirradiated; sfm | plutonium must first be chemically separated |
| Fresh spent fuel<br>U-238, U-235, plutonium and highly radioactive isotopes | | reprocessing produces plutonium |
| Older spent fuel (> 10–20 years)<br>U-238, U-235, plutonium & less radioactive isotopes | irradiated | reprocessing and handling is easier |
| ore, ore residue (e.g. yellow cake) | none | yields natural uranium |
| tritium | none | for fusion processes during a nuclear explosion |

## ANNEX C

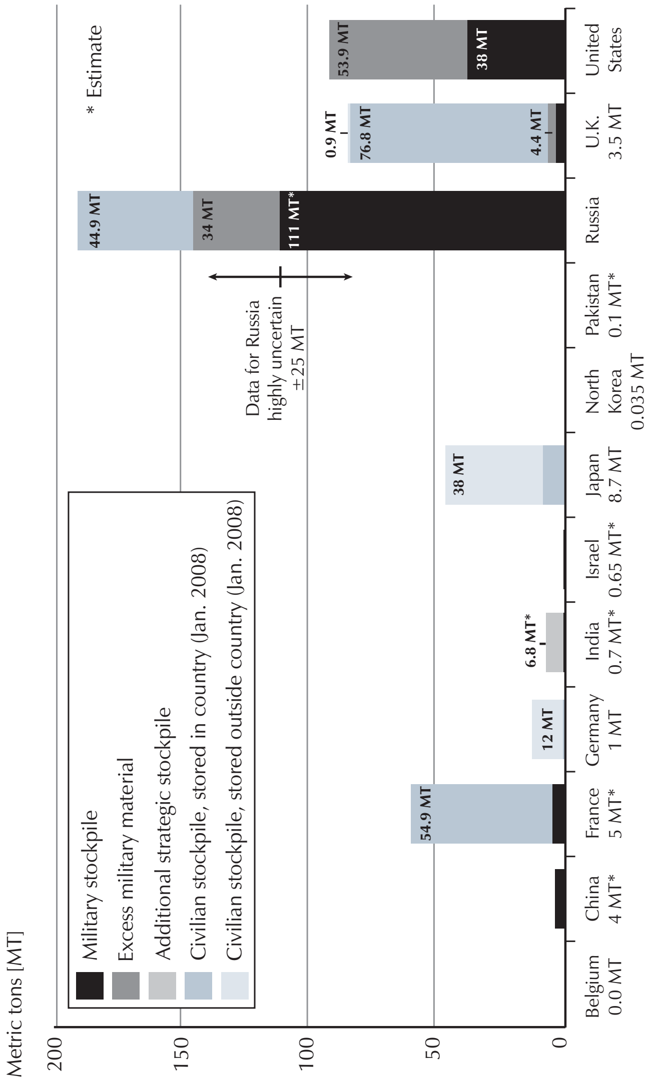
# FACILITIES AND MATERIAL FLOWS IN NUCLEAR FUEL CYCLES WITH IAEA CLASSIFICATION



## ANNEX D

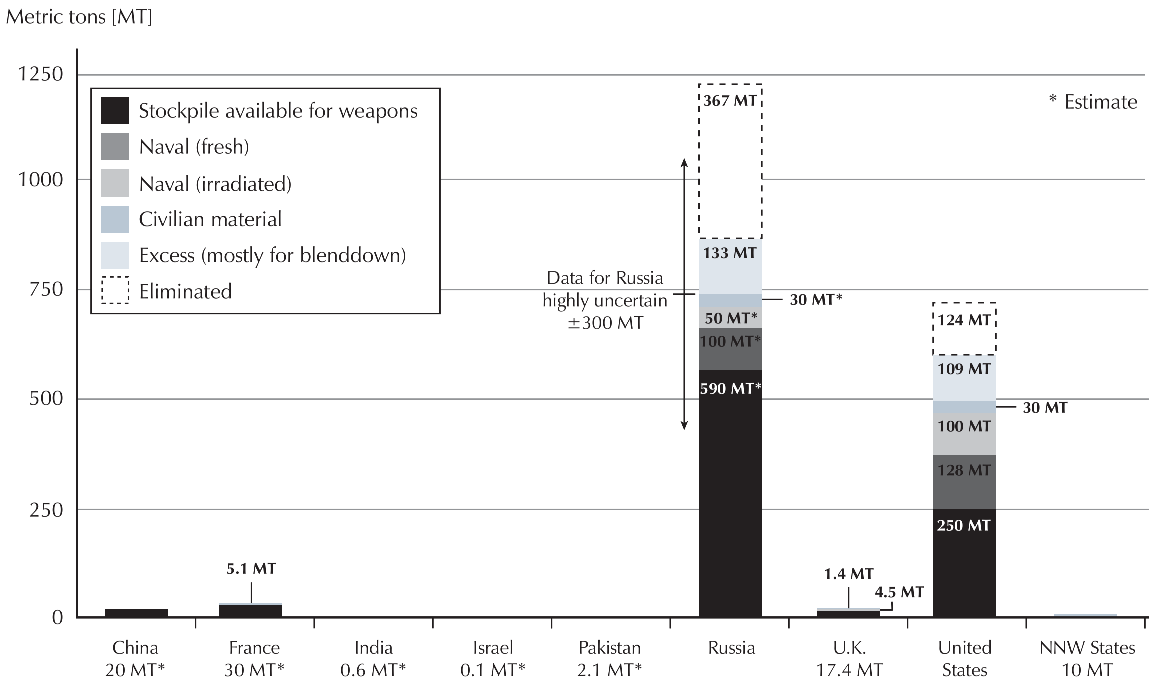
# NATIONAL STOCKPILES OF FISSILE MATERIALS

**Figure 1.** National stocks of separated plutonium




*Source*: Global Fissile Material Report 2009, *IPFM*, *2009*, *p. 16*.

**Figure 2.** National stocks of HEU as of mid-2009

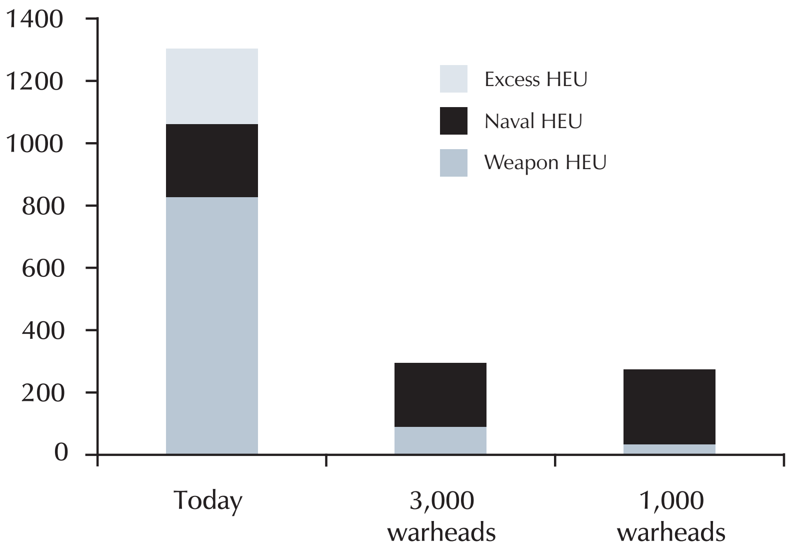



*Source*: Global Fissile Material Report 2009, *IPFM, 2009, p. 13.*

## ANNEX E

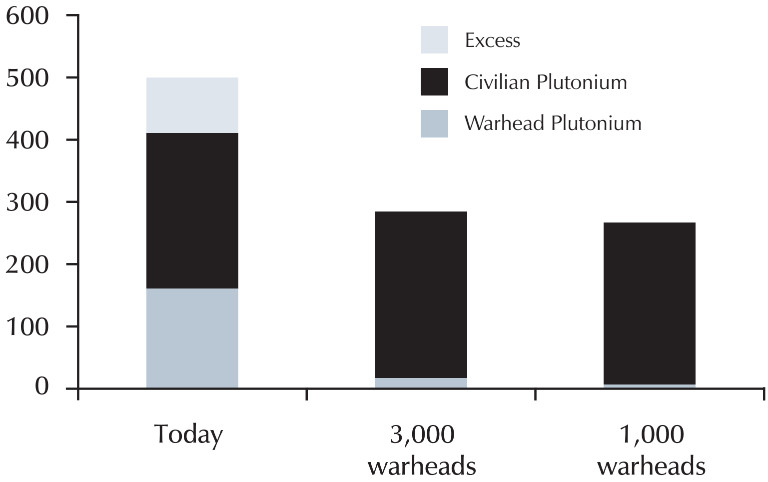
# FISSILE MATERIAL STOCKPILES IN A DISARMING WORLD

**Figure 1.** Global stockpiles of HEU in metric tons, today and in the future




The shadow on nuclear disarmament thrown by naval reserves of HEU will grow as the weapon stockpiles are reduced. The amount of weapon-grade HEU in naval use (250t) would be sufficient to make approximately 10,000 nuclear warheads (the vertical axis of the chart represents metric tons).

**Figure 2.** Global stockpiles of plutonium in metric tons, today and in the future




The shadow thrown over nuclear disarmament by today's civilian plutonium stocks would also be huge. The amount of reactor-grade plutonium in civilian use (240t) would be sufficient for 40,000 first-generation Nagasaki-type bombs (the vertical axis of the chart represents metric tons).

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International Atomic Energy Agency

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International Panel on Fissile Materials

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Dedicated to research and training to combat the proliferation of nuclear weapons. Publisher of *The Nonproliferation Review*. <cns.miis.edu/index.htm>

Nuclear Suppliers Group

A group of nuclear supplier countries which seeks to contribute to the non-proliferation of nuclear weapons through the implementation of guidelines for nuclear exports and nuclear-related exports. <www.nuclearsuppliersgroup.org>

Verification Research, Training and Information Centre

VERTIC promotes effective and efficient verification as a means of ensuring confidence in the implementation of international agreements and intra-national agreements with international involvement. <www.vertic.org>

## Notes

[1] *Global Fissile Material Report 2009*, International Panel of Fissile Materials, 2009, p. 124.

[2] Rule 23 of the CD's Rules of Procedure reads: "Whenever the Conference deems it advisable for the effective performance of its functions, including when it appears that there is a basis to negotiate a draft treaty or other draft texts, the Conference may establish subsidiary bodies, such as ad hoc sub committees, working groups, technical groups or groups of governmental experts, open to all member States of the Conference unless the Conference decides otherwise. The Conference shall define the mandate for each of such subsidiary bodies and provide appropriate support for their work".

[3] Conference on Disarmament, *Report of Ambassador Gerald E. Shannon of Canada on Consultations on the Most Appropriate Arrangement to Negotiate a Treaty Banning the Production of Fissile Material for Nuclear Weapons or Other Nuclear Explosive Devices*, document CD/1299, 24 March 1995.

[4] Ibid.

[5] F. Barnaby, "The FMCT Handbook: A Guide to a Fissile Material Cut-off Treaty", Oxford Research Group, 2003, p. 13.

[6] Rule 28 requires the CD to establish its programme of work annually, on the basis of its agenda which is also agreed annually.

[7] J. Rissanen, "Time for a Fissban—or Farewell?", *Disarmament Diplomacy*, no. 83, 2006.

[8] "Banning the Production of Fissile Materials for Nuclear Weapons: Country Perspectives on the Challenges to a Fissile Material (Cutoff) Treaty", International Panel on Fissile Materials, 2008, p. 9.

[9] Conference on Disarmament, *Proposal by the President on the Programme of Work for the 2000 Session of the Conference on Disarmament*, document CD/1624, 24 August 2000.

[10] Ibid.

[11] Algeria (Dembri), Belgium (Lint), Chile (Vega), Colombia (Reyes) and Sweden (Salander).

[12] Item 5 is "new types of weapons of mass destruction and new systems of such weapons; radiological weapons", item 6 is "comprehensive programme of disarmament", and item 7 is "transparency in armaments".

[13] Conference on Disarmament, *Presidential Draft Decision*, document CD/2007/L.1, 29 June 2007.

[14] Conference on Disarmament, *Draft Decision by the Conference*, document CD/2007/CRP.6, 30 August 2007.

[15] Conference on Disarmament, *Draft Decision by the Presidents of the 2008 Session of the Conference of Disarmament*, document CD/1840, 13 March 2008.

[16] Conference on Disarmament, *Decision for the Establishment of a Programme of Work for the 2009 Session*, document CD/1864, 29 May 2009.

[17] See CD/1624, para. 4 and CD/1693/Rev.1, para. 1.

[18] Since 1998, the last occasion on which the CD set up a Working Group on fissile materials, the question of scope has been complicated by concerns about terrorism, giving rise to the question of the wisdom of confining a prohibition merely to the production of highly enriched uranium for explosive purposes.

[19] "Weapons-grade" and "weapons-usable" indicate fissile material that is currently, or capable of being, in use in a nuclear weapon.

[20] Since 1997, Belgium, China, France, Germany, Japan, Russia, Switzerland, the United Kingdom and United States have been declaring publicly their stocks of civilian plutonium annually to the IAEA. These declarations (INFCIRC/549) are publicly available at the IAEA website. Some countries now add civilian HEU to their declarations. All the INFCIRC/549 declarations detail the fissile material stocks at reprocessing plants, fuel-fabrication plants, reactors and elsewhere, divided into non-irradiated forms and irradiated fuel.

[21] See for instance President Eisenhower's "Atoms for Peace" proposal http://www.iaea.org/About/history_speech.html.

[22] *Global Fissile Material Report 2009*, International Panel of Fissile Materials, 2009, p. 35.

[23] Interpretations and background information on the IAEA definition can be found on the website of the International Panel on Fissile Materials at <www.fissilematerials.org/ipfm/pages_us_en/fissile/fissile/fissile.php>.

[24] For example, such instruments could be similar to safeguards agreements concluded between non-nuclear-weapon states and the IAEA via that Agency's Comprehensive Safeguards Agreement (INFCIRC/153) and the Model Additional Protocol (INFCIRC/540). See also INFCIRC/66 (which established the pre-NPT safeguards regime) in its application to non-NPT nuclear weapon states. "Safeguard", a term for verifying that a material and its use are indeed what they purport to be, is a concept that stems from the NPT and the IAEA.

[25] Article III, paragraphs 1 and 2 of the NPT read (emphasis added):

> **1. Each non-nuclear-weapon State Party to the Treaty undertakes to accept safeguards, as set forth in an agreement to be negotiated and concluded with the International Atomic Energy Agency in accordance with the Statute of the International Atomic Energy Agency and the Agency's safeguards system, for the exclusive purpose of verification of the fulfillment of its obligations assumed under this Treaty with a view to preventing diversion of nuclear energy from peaceful uses to nuclear weapons or other nuclear explosive devices.** Procedures for the safeguards required by this article shall be followed with respect to source or special fissionable material whether it is being produced, processed or used in any principal nuclear facility or is outside any

such facility. The safeguards required by this article shall be applied to all source or special fissionable material in all peaceful nuclear activities within the territory of such State, under its jurisdiction, or carried out under its control anywhere.

2. Each State Party to the Treaty undertakes not to provide: (a) source or special fissionable material, or (b) equipment or material especially designed or prepared for the processing, use or production of special fissionable material, to any non-nuclear-weapon State for peaceful purposes, unless the source or special fissionable material shall be subject to the safeguards required by this article.

26 "… all nuclear arms control agreements are likely to depend, at least to begin with, upon relatively non-intrusive verification techniques. It was the development of 'national technical means of verification' that helped pave the way for SALT I, the chief means being satellite observation (photographic, electronic, early warning, and radiation) coupled with agreement by each state not to interfere with the other's "national technical means". While such techniques gather information of great military significance, they do not require the physical presence of the verifying state in the state whose activities are being verified"; D.A.V. Fischer, "Safeguards—a model for general arms control?", *IAEA Bulletin*, vol. 24, no. 2, 1982, p. 48.

27 See, for example, article VIII of the NPT.

28 The full statement can be found at <www.unog.ch/80256EDD006B8954/(httpAssets)/3AB4598F0FD5D9BAC12575E7004E33CB/$file/1146_Germany.pdf>.

29 See P. Meyer, "A Fissile Material (Cut-off) Treaty: some observations on scope and verification", *Disarmament Diplomacy*, no. 91, 2009.

30 See Germany, *Creating a new momentum for a fissile material cut-off treaty (FMCT)*, document NPT/CONF.2010/PC.II/WP.21, 30 April 2008.

31 Conference on Disarmament, *Decision for the Establishment of a Programme of Work for the 2009 Session*, CD document CD/1864, 29 May 2009, decides inter alia to "establish a Working Group under agenda Item 1 entitled 'Cessation of the nuclear arms race and nuclear disarmament' which shall negotiate a treaty banning the production of fissile material for nuclear weapons or other nuclear explosive devices, on the basis of the document CD/1299 of 24 March 1995 and the mandate contained therein". The quote characterizing the treaty is from CD/1299.

32 Most non-weapon states and some weapon states would like to see the treaty capture under IAEA safeguards some pre-existing fissile materials as well. This could include plutonium and HEU used in the fuel of nuclear-power and civilian research reactors and fissile materials formerly in weapons that have been declared excess for weapons use. Advocates of such a broadened FMCT often characterize it as a Fissile Material Treaty. The IPFM has tried to capture both positions by calling it a Fissile Material (Cut-off) Treaty.

33 See for example the Chinese perspective in IPFM, *Banning the Production of Fissile Materials for Nuclear Weapons: Country Perspectives on the Challenges to a Fissile Material (Cutoff) Treaty, Companion Volume to the Global Fissile Material Report 2008*, 2008, <www.ipfmlibrary.org/gfmr08cv.pdf>.

34 Tritium is made by neutron capture in lithium-6 in reactors. But, the natural-uranium fuel of Israel's Dimona reactor contains 140 uranium-238 atoms for every chain-reacting uranium-235 atom. Many neutrons therefore would be captured in uranium-238 nuclei, converting them to uranium-239 nuclei that then decay into plutonium-239. Also, the fuel of the Dimona reactor, which was originally designed for plutonium production, is probably uranium metal clad with aluminum or magnesium alloy for ease of reprocessing. Such fuel, unlike the zirconium-clad uranium-oxide fuel used in power reactors cannot be easily stored for a long time in water and is therefore usually reprocessed. It is therefore likely that, even if Israel thinks that it has produced enough separated plutonium, it is probably still producing more as a by-product of tritium production.

35 "DPR Korea cuts off UN atomic watchdog agency's access to nuclear facilities", *UN News Center*, 24 September 2009; B. Harden, "North Korea Says It Will Start Enriching Uranium: Weapons Move Is 'Retaliation' for Sanctions", *Washington Post*, 14 June 2009.

36 "Burnup" is a measure of the percentage of the fuel that has been fissioned. Most weapon-grade plutonium has been produced in graphite or heavy-water-moderated reactors by irradiating natural uranium to a level where roughly one gram of uranium-235 in a kilogram of natural uranium has been fissioned. This produces plutonium that is more than 90% plutonium-239. With further irradiation, neutron captures in the plutonium cause losses through fission and fissionless neutron capture increases the percentage of Pu-240, Pu-241 and Pu-242 in the plutonium. In light-water reactor fuel, today about 50 grams of uranium and plutonium are fissioned per kilogram of low-enriched uranium fuel.

37 The ADE-2 reactor in the Siberian plutonium city of Zheleznogorsk near Krasnoyarsk is the last dual-purpose reactor. It is scheduled to be shutdown by the Summer of 2009 or 2010 when a replacement coal-fired plant is completed under a programme financed by the United States. As part of the financing agreement, Russia's government agreed that the weapon-grade plutonium produced after 1994 by this reactor and two other dual-purpose production reactors that operated at a second plutonium city, Seversk, would not be used for nuclear weapons and would be subject to US monitoring; see <www.ransac.org/new-web-site/related/agree/bilat/core-conv.html>.

38 One of these, the Novouralsk enrichment plant, is still licensed to produce uranium enriched up to 30% in U-235.

39 Although there is no report that any fissile material other than plutonium or HEU is currently in use in nuclear weapons, in principle, uranium-233,

neptunium-237, americium-241 and -243 and other fissile isotopes all could be so used.

40 Belgium and Germany both had their own pilot reprocessing plants but they were shut down in 1979 and 1991 respectively. Most of the plutonium that has been recycled in Belgium and Germany—and all of the plutonium recycled in Swiss reactors—was separated in French and UK commercial reprocessing plants.

41 See for example M. Schneider and Y. Marignac, *Spent Nuclear Fuel Reprocessing in France*, IPFM, Research Report no. 4, 2008; and M. Forwood, *The Legacy of Reprocessing in the United Kingdom*, IPFM, Research Report no. 5, 2008.

42 F. von Hippel, "Why Reprocessing Persists in Some Countries and not in Others: The Costs and Benefits of Reprocessing", in H. Sokolski (ed.), *Expanding Nuclear Power: Weighing the Costs and Risks*, Non-proliferation Education Center, 2009, forthcoming.

43 The modern reprocessing plants in France, Japan and the United Kingdom are licensed to annually reprocess 1,700, 800 and 700 tons of spent fuel respectively. In actuality, today, after the loss of virtually all its foreign customers, France's plant is reprocessing 1000t annually, Japan's plant has not begun commercial operation because of a serious design problem, and the UK reprocessing plant has endured a series of prolonged shutdowns since 2005 because of equipment failures. Typically, spent light-water reactor fuel is about 1% plutonium, so roughly 17,000, 8,000 and 7,000 kilograms of plutonium would be recovered if the plants operated at full capacity. The Nagasaki bomb contained 6kg of weapon-grade plutonium. Eight kilograms of power-reactor plutonium would have the same critical mass.

44 In addition to the commercial Rokkasho reprocessing plant, Japan also operates the pilot-scale Tokai Reprocessing Plant; see <www.jaea.go.jp/english/04/tokai-cycle/02.htm>.

45 See S. Johnson, *Safeguards at Reprocessing Plants Under a Fissile Material Cutoff Treaty*, IPFM, Research Report No. 6, 2009; and IPFM, *Global Fissile Material Report 2008*, chp. 5.

46 D. Albright and S. Basu, "India's Gas Centrifuge Enrichment Program: Growing Capacity for Military Purposes", Institute for Science and International Security, 18 January 2007, p. 9, <www.isis-online.org/publications/southasia/indiagrowingcapacity.pdf>.

47 Uranium-234 is a decay product of uranium-238.

48 Spent fuel is monitored under the NPT to protect against the possibility of clandestine reprocessing. Under the FM(C)T, it would probably be sufficient—initially at least—to verify declarations of spent fuel with a small number of random spot checks.

49 A gas of tritium (T), mixed with deuterium (D), is injected into the hollow plutonium "pit" of a modern nuclear weapon when the weapon is triggered. The energy released by the fission chain reactions in the plutonium heat the

gas up to temperatures where the thermonuclear reaction, D + T $\rightarrow$ helium + neutron, takes place. The resulting burst of neutrons causes an additional burst of fissions that "boosts" the power of the explosion more than ten-fold. The United States formerly produced tritium for its nuclear weapons using the HEU-fuelled production reactors at the Department of Energy's Savannah River Site but has shifted to inserting lithium-6 "targets" in LEU-fuelled power reactors.

50 *Model Protocol Additional to the Agreement(s) Between State(s) and the International Atomic Energy Agency for the Application Of Safeguards*, IAEA document INFCIRC/540 (Corrected), September 1997.

51 Some declassified documents relating to the US programme have been compiled in W. Burr, *Documents on the U.S. Atomic Energy Detection System [AEDS]*, National Security Archive Electronic Briefing Book No. 7, <www.gwu.edu/~nsarchiv/NSAEBB/NSAEBB7/nsaebb7.htm>.

52 R.S. Kemp, "Initial Analysis of the Detectability of $UO_2F_2$ Aerosols Produced by UF6 Released from Uranium Conversion Plants", *Science and Global Security*, vol. 16, no. 3, 2008, p. 115.

53 For more information on the conference, see <www.unidir.org/bdd/fiche-activite.php?ref_activite=471>.

54 The views in this paper are the author's personal views and do not imply any official German position.

55 Part of the reasoning in this paper has already been elaborated in A. Schaper, *A Treaty on the Cutoff of Fissile Material for Nuclear Weapons. What to Cover? How to Verify?*, PRIF-Report no. 48, Peace Research Institute Frankfurt, 1997.

56 For details of IAEA definitions, see *IAEA Safeguards Glossary, 2001 Edition*, IAEA, 2002.

57 The IAEA currently defines a "significant quantity" of plutonium as 8kg. This is a legal term with consequences for safeguards regulations. It is a compromise between high confidence in verification on the one hand, and costs on the other. The "critical mass" of a bare sphere is a technical term, it describes the mass of a sphere of normal density in which the number of neutrons during a chain reaction is just constant. For plutonium-239, this is 10kg. The fissile material in a warhead, however, is compressed and surrounded by a reflector. Therefore, the quantity needed for one warhead is probably less.

58 For a historic overview, see E. Kankeleit, C. Küppers, U. Imkeller, "Bericht zur Waffentauglichkeit von Reaktorplutonium" [Report on the Weapon Usability of Reactor-Grade Plutonium], Interdisciplinary Research Group in Science, Technology and Security, Technical University Darmstadt, 1989. This report is available in English at <www.ianus.tu-darmstadt.de/kankeleit/1989ReactorPuUseab.pdf>.

59 Kankeleit made his calculations by using historic quotations from open sources; ibid. Later, his arguments were confirmed by former nuclear weapon designer J.C. Mark, "Explosive Properties of Reactor-Grade Plutonium", *Science & Global Security*, vol. 4, p. 111, 1993; and by the Committee on

International Security and Arms Control, *Management and Disposition of Excess Weapons Plutonium*, National Academy of Sciences, 1994; Committee on International Security and Arms Control, *Management and Disposition of Excess Weapons Plutonium: Reactor Related Options*, National Academy of Sciences, 1995; and Committee on International Security and Arms Control, Monitoring Nuclear Weapons and Nuclear-Explosive Materials, National Academy of Sciences, 2005.

60 Within this effort, research reactors are being converted from HEU to LEU use. Some use HEU enriched far below 90% but are nevertheless being converted. The need for this would be difficult to justify if the FM(C)T defines fissile materials for nuclear weapons only as that enriched above 90%.

61 O. Reistad and S. Hustveit, "HEU Fuel Cycle Inventories and Progress on Global Minimization", *Nonproliferation Review*, vol. 15, no. 2, 2008, pp. 265–87.

62 For details see "Nuclear weapon and fissile material stocks and production", in *Global Fissile Material Report 2009*, IPFM, chp. 1.

63 D. Albright and K. Kramer, "The Disposition of Excess US and Russian Military Highly Enriched Uranium (HEU)", Institute for Science and International Security, 2005.

64 *Plutonium: The First 50 Years: United States Plutonium Production, Acquisition, and Utilization from 1944 through 1994*, US Department of Energy, 1996, <http://apollo.osti.gov/html/osti/opennet/document/pu50yrs/pu50y.html>.

65 *Highly Enriched Uranium: Striking a Balance*, US Department of Energy, 2001, <www.fas.org/sgp/othergov/doe/heu/index.html>.

66 *Plutonium and Aldermaston—An Historical Account*, UK Ministry of Defence, 2000, <www.fas.org/news/uk/000414-uk2.htm>.

67 A list of quotations can be found in Annette Schaper, *Looking for a Demarcation between Nuclear Transparency and Nuclear Secrecy*, PRIF-Report no. 68, Peace Research Institute Frankfurt, 2004, pp. 33–4.

68 *Draft Public Guidelines to Department of Energy Classification of Information*, US Department of Energy, 27 June 1994, <www.fas.org/irp/doddir/doe/pubg.html>.

69 As an example, INFCIRC/193 (between the IAEA and Euratom) is no more specific than IINFCIRC/153.

70 Disagreement over the whether the treaty should affect pre-existing stocks is reflected in the name used for the treaty by different states. States that prefer a treaty in which safeguards apply only to fissile material produced after the treaty comes into force refer to it as a "Fissile Material Cutoff Treaty." Some states that would like the treaty to place some pre-existing stocks under safeguards call it a "Fissile Material Treaty." The IPFM use of FM(C)T reflects both options.

71 A small amount of HEU is used in targets that are irradiated with neutrons to produce medical isotopes. It is expected that, within a decade, this use of HEU will be substituted by low-enriched uranium.

72 Tritium is used in nuclear weapons as a fusion fuel. It is made by neutron capture and has a half-life of about 12 years.

73 See "Nuclear weapon and fissile material stocks and production", in *Global Fissile Material Report 2009*, IPFM, 2009, chp. 1.

74 *2000 Review Conference of the Parties to the Treaty on the Non-Proliferation of Nuclear Weapons, Final Document*, document NPT/CONF.2000/28 (Parts I and II), p. 15, para. 10.

75 "Joint Statement on the Transparency and Irreversibility of the Process of Reducing Nuclear Weapons", White House, Office of the Press Secretary, 10 May 1995, <www.presidency.ucsb.edu/ws/index.php?pid=51341>.

76 "Moscow Nuclear Safety and Security Summit Declaration", 20 April 1996, <www.g7.utoronto.ca/summit/1996moscow/declaration.html>, emphasis added.

77 *Eliminating Nuclear Threats: A Practical Agenda for Global Policymakers*, ICNND, 2009, p. 111, para. 12.17.

78 "A Fissile Material (Cut-Off) Treaty: A Treaty Banning the Production of Fissile Materials for Nuclear Weapons or Other Nuclear Explosive Devices", IPFM, 15 September 2009, <www.fissilematerials.org/ipfm/site_down/fmct-ipfm-sep2009.pdf>.

79 *Global Fissile Material Report 2009*, IPFM, 2009, appendix 1C, assuming 8kg of plutonium per nuclear weapon.

80 "International safeguards in the nuclear weapon states", in *Global Fissile Material Report 2007*, IPFM, 2007, chp. 6.

81 Under its voluntary offer to the IAEA, the United States has committed "to permit the Agency to apply safeguards, in accordance with the terms of this Agreement, on all source or special fissionable material in all facilities within the United States, excluding only those facilities associated with activities with direct national security significance to the United States, with a view to enabling the Agency to verify that such material is not withdrawn, except as provided for in this Agreement, from activities in facilities while such material is being safeguarded under this Agreement"; *Agreement of 18 November 1977 Between the United States of America and the Agency for the Application of Safeguards in the United States of America*, IAEA document INFCIRC/288, December 1981, art. 1.

82 The IAEA had 924 facilities under safeguards in the non-nuclear-weapon states at the end of 2007 (see *Annual Report 2007*, IAEA, p. 88), but the two operating reprocessing plants in Japan accounted for 20% of its safeguards budget; S. Johnson, *Safeguards at Reprocessing Plants under a Fissile Material (Cutoff) Treaty*, Research Report no. 6, IPFM. 2009, p. 1. Japan is the only non-nuclear-weapon state with operating reprocessing plants but five of the nine nuclear-weapon and non-NPT states have civilian reprocessing plants: China, France, India, Russia and the United Kingdom.

83 The problem of having to segregate pre-existing from new HEU in civilian use is less likely to arise, since it is unlikely that new HEU will be made for civilian

use. There are also a few plutonium-fuelled civilian critical assemblies in the nuclear-weapon states that could escape monitoring in an FM(C)T focused just on newly separated plutonium, since they do not require make-up plutonium. That is, unlike power reactors, relatively little plutonium is fissioned in the critical assemblies, and so there is no need for fresh plutonium replacement fuel. But the savings in verification costs would not be great—perhaps a few percent.

84 *Agreement between the Government of the United States of America and the Government of the Russian Federation Concerning the Management and Disposition of Plutonium Designated as No Longer Required for Defense Purposes and Related Cooperation*, 2000, art. VII.3, <www.state.gov/documents/organization/18557.pdf>.

85 *Memorandum of Understanding Between the Government of the United States of America and the Government of the Russian Federation Relating to Transparency and Additional Arrangements Concerning the Agreement Between the United States of America and the Government of the Russian Federation Concerning the Disposition of Highly Enriched Uranium Extracted from Nuclear Weapons*, 1993, <www.ipfmlibrary.org/heu93b.pdf>, p. 8, art. I.2.

86 D. Gordon et al., "IAEA Verification Experiment at the Portsmouth Gaseous Diffusion Plant", Brookhaven National Laboratory, 1998, <www.osti.gov/bridge/purl.cover.jsp?purl=/639787-wpGE11/webviewable/>.

87 R. Thiele et al., "The SAPPHIRE and 50 MT Projects at BWXT, Lynchburg, VA", IAEA document SM-367/8/01/P, 2001, <www-pub.iaea.org/MTCD/publications/PDF/SS-2001/PDF files/Session 8/Poster 8-01-P.pdf>.

88 "Trilateral Statement to the Press", IAEA document PR 96/19, 17 September 1996.

89 "Weapon-origin Fissile Material: The Trilateral Initiative", in *Global Fissile Material Report 2008*, IPFM, 2008, chp. 6.

90 "Remarks Prepared for Energy Secretary Sam Bodman", 2005 Carnegie International Nonproliferation Conference, Washington DC, 7 November 2005, p. 11, <www.carnegieendowment.org/static/npp/2005conference/presentations/bodman_remarks.pdf>. Bodman originally declared that 160t of excess weapon material would be allocated to the naval stockpile but more recently it was estimated that only 128t of this material will meet the US Navy's standards; Robert M. George, Department of Energy, Office of Fissile Materials Disposition Program, "U.S. HEU Disposition", 50th Annual Meeting of the Institute of Nuclear Materials Management, Tucson, July 2009.

91 O. Reistad and S. Hustveit, "HEU Fuel Cycle Inventories and Progress on Global Minimization", *Nonproliferation Review*, vol. 15, no. 2, 2008, pp. 265–87.

92 "HEU in the naval-reactor fuel cycle", *Global Fissile Material Report 2008*, IPFM, 2008, chp. 7.

93 General Assembly, *General and Complete Disarmament*, UN document A/RES/48/75, 16 December 1993.

94 J. Carlson, “Can a Fissile Material Cutoff Treaty be Effectively Verified?”, *Arms Control Today*, vol. 35, no. 1, 2005.

95 IAEA, “A Cut-off Treaty and Associated Costs—An IAEA Secretariat Working Paper on Different Alternatives for the Verification of a Fissile Material Production Cut-Off Treaty and Preliminary Cost Estimates Required for the Verification of these Alternatives”, presented at the Workshop on a Cut-Off Treaty, Toronto, 17–18 January 1995.

96 See “The Safeguards System of the IAEA” at <www.iaea.org/OurWork/SV/Safeguards/safeg_system.pdf>.

# ABBREVIATIONS

| | |
|---|---|
| AP | Additional Protocol |
| CD | Conference on Disarmament |
| CSA | comprehensive safeguards agreement |
| CTBT | Comprehensive Nuclear-Test-Ban Treaty |
| EIF | entry into force |
| FMCT | Fissile Material Cut-off Treaty |
| FMT | Fissile Material Treaty |
| HEU | high-enriched uranium |
| IAEA | International Atomic Energy Agency |
| ICNND | International Commission on Nuclear Non-proliferation and Disarmament |
| IPFM | International Panel on Fissile Materials |
| LEU | low-enriched uranium |
| MOX | mixed plutonium–uranium oxide fuel |
| NNWS | non-nuclear-weapon state |
| NPT | Treaty on the Non-Proliferation of Nuclear Weapons |
| NSAs | negative security assurances |
| NWS | nuclear-weapon state |
| PAROS | prevention of an arms race in outer space |
| PDI | person-day of inspection |
| SQ | significant quantity (of nuclear material) |
| VOA | voluntary offer agreement |