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Fissile Material (Cut-off) Treaty: Definitions, Verification, and Scope

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UNIDIR RESOURCES

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About the author

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Overview

The negotiating mandate contained in the 1995 Shannon report that reflected a consensus regarding the framework for negotiations on the Fissile Material (Cutoff) Treaty, calls on the Conference on Disarmament 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.[1]

Among the central issues that the negotiations will have to deal with are those of definitions, verification, and scope. The term "fissile material" included in the negotiating mandate has not yet been defined in the context of international agreements. Different approaches to defining fissile material would shape the treaty verification provisions and determine the scope of the activities, facilities and materials covered by the treaty. These three closely linked elements of the future FM(C)T will eventually determine the effectiveness of the treaty in strengthening international security.

The issue of FM(C)T definitions has received significant attention; it has been a subject of discussions organized by the members of the Conference on Disarmament and position papers submitted by individual states.[2] Various aspects of FM(C)T verification arrangements also have been extensively considered in a number of studies.[3] Serious work has been done

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[1] 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, CD/1299 (Conference on Disarmament, 24 March 1995).

[2] Working Paper Submitted by Bulgaria, Germany, Mexico, Netherlands, Romania, Spain, Sweden and Turkey: Fissile Material Cut-Off Treaty, CD/1910 (FMCT) (Conference on Disarmament, 9 June 2011); Working Paper Submitted by Switzerland: A Pragmatic Approach to the Verification of a FMCT, by Bruno Pellaud, CD/1771 (Conference on Disarmament, 12 May 2006); Australia-Japan Experts Side Event on FMCT Definitions, Palais des Nations, Geneva, 16 February 2011. Report of the Chair, Ambassador Peter Woolcott of Australia, CD/1906 (Conference on Disarmament, 14 March 2011); Working Paper Submitted by Australia: Suggestions for the Substance of the Fissile Material Cut-Off Treaty, CD/1895 (Conference on Disarmament, 14 September 2010).

[3] Annette Schaper, "Principles of the Verification for a Future Fissile Material Cutoff Treaty (FMCT)" (PRIF, 2001), http://edoc.vifapol.de/opus/frontdoor.php?source_opus=273&la=de; Annette Schaper, "A Treaty on Fissile Material: Just Cutoff or More?" (PRIF, 2011); CD/1771; Japan-Australia Experts Side Event on FMCT Verification, Palais des Nations, Geneva, 30 May–1 June 2011. Report of the Chair, Ambassador Akio Suda of Japan, CD/1917 (Conference on Disarmament, 2 September 2011);

on examining political and technical questions related to the issue of scope and specifically to pre-existing stocks.[4]

Most importantly, the approaches to the future treaty were discussed by the Group of Governmental Experts (GGE) that worked in Geneva in 2014-2015. The GGE concluded that the Shannon report "remain[s] the most suitable basis on which future negotiations should proceed at the Conference on Disarmament" and considered a broad spectrum of technical and political issues associated with the future FM(C)T negotiations.[5]

This paper draws on the results of these earlier works and aims to present a summary of the issues related to definitions, verification and scope taking into account the most recent discussions that have taken place in the expert community. The structure of the paper follows this general outline: The first section considers various approaches to defining the term fissile material for FM(C)T purposes. The second section examines how different approaches to definitions would affect the treaty verification activities; its first part deals with downstream verification, the second looks into verification measures that would have to be implemented at production facilities (it also briefly considers verification at shutdown and converted facilities). The final section presents an overview of the measures that would be required to extend the scope of the treaty to pre-existing stocks and to ensure irreversible elimination of excess military material.

1. Definitions

A natural starting point for discussion of the definition of fissile material under FM(C)T is the scientific meaning of the term. In physics, fissile material is a material that can sustain an explosive nuclear chain reaction. This normally means that the material contains an appropriate amount of fissile isotopes and does not contain isotopes that prevent the chain reaction from developing, for example by capturing neutrons. Fissile isotopes are those that undergo fission after absorbing low-energy neutrons. A number of isotopes—such as uranium-235 and uranium-233, most long-lived isotopes of plutonium and americium, neptunium, curium and others—have this property, so the materials that contain these isotopes can theoretically be used in a nuclear explosive device.[6]

For a material composed of a single chemical element, isotopic composition would also play a role in determining the ability of that material to sustain an explosive chain reaction. For example, because of the physical properties of uranium nuclei, an isotopic mixture of uranium-238 and uranium-235 in which the concentration of uranium-235 is less than about

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John Carlson, "Proposed Fissile Material Cut-Off Treaty: Verification Issues" (Annual Meeting of the Institute of Nuclear Materials Management, Baltimore, Maryland, 11 July 2010).

[4] Working Paper Submitted by Canada: Elements of an Approach to Dealing with Stocks of Fissile Materials for Nuclear Weapons or Other Nuclear Explosive Devices, CD/1770 (Conference on Disarmament, 4 May 2006); *Global Fissile Material Report 2009: A Path to Nuclear Disarmament. Fourth Annual Report of the International Panel on Fissile Materials* (International Panel on Fissile Materials, 2009), http://ipfmlibrary.org/gfmr09.pdf; Annette Schaper, "A Treaty on the Cutoff of Fissile Material for Nuclear Weapons—What to Cover? How to Verify?" (PRIF, July 1997); Annette Schaper, "A Treaty on Fissile Material".

[5] Group of Governmental Experts to Make Recommendations on Possible Aspects That Could Contribute to but Not Negotiate a Treaty Banning the Production of Fissile Material for Nuclear Weapons or Other Nuclear Explosive Devices, A/70/81 (United Nations General Assembly, 7 May 2015).

[6] Attributes of Proliferation Resistance for Civilian Nuclear Power Systems (Nuclear Energy Research Advisory Committee (NERAC), October 2000), 4, ipfmlibrary.org/doe00b.pdf.

6% cannot be used to build an explosive nuclear device because of the neutron capture by uranium-238 nuclei.[7]

In addition to fundamental properties of nuclei that determine weapon-usability of a material, there are practical factors that could affect it as well. For example, while Pu-238 could in theory sustain an explosive chain reaction, because of the very high heat generated by this isotope, it would be highly impractical, if at all possible, to use it in a nuclear weapon.[8] Radioactive hazard is another factor that may complicate the use of certain materials in weapons.

There are other practical considerations as well, mostly determined by the relative ease of production of certain materials and their abundance in the nuclear fuel cycle. From that point of view, the range of fissile materials that are relevant for nuclear weapons use could be narrowed down to a relatively small number of isotopes and materials that contain them: uranium enriched in U-235 or U-233, plutonium, neptunium and americium. All these materials are present in the nuclear fuel cycle as it exists today; all of them have been produced and separated in substantial quantities.

These materials are included in most proposals that aim to define the subject of the FM(C)T.[9] Details of these proposals may vary quite considerably, but for the purposes of this analysis they could be combined into four distinct groups:

- Nuclear material (Article XX of the IAEA Statute),
- Unirradiated direct use material,
- Weapon-grade material,
- Intermediate-grade material.

Also, various approaches to defining fissile material in FM(C)T differ in the way they treat neptunium and americium. However, the verification procedures that would be required to monitor production and use of neptunium and americium do not depend on the choices made regarding other materials, so these two elements are considered separately.

1.1 Special fissionable material

The statute of the International Atomic Energy Agency (IAEA) contains definitions of categories of materials that are relevant from the point of view of safeguards administered by the Agency, including those that are implemented as part of the Nuclear Non-proliferation Treaty obligations. These categories are “special fissionable material” and “source material”, which are collectively referred to as “nuclear material” in the IAEA safeguards context.[10]

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[7] *Global Fissile Material Report 2008: Scope and Verification of a Fissile Material (Cutoff) Treaty* (International Panel on Fissile Materials, October 2008), 106, http://ipfmlibrary.org/gfmr08.pdf. However, it could be used to sustain a controlled chain reaction in a nuclear reactor.

[8] Attributes of Proliferation Resistance for Civilian Nuclear Power Systems, 4.

[9] For a comprehensive overview of various proposals suggested so far, see CD/1771.

[10] *IAEA Safeguards Glossary* (Vienna: International Atomic Energy Agency, 2002), 4.1.

Special fissionable material is defined as

> 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;[11]

Enriched uranium is then defined as uranium with the content of U-235 or/and U-233 that is higher than in natural uranium.[12] Source material is defined as natural or depleted uranium and thorium in various forms starting from ore concentrate.[13]

If the definition based on the concept of nuclear material is accepted for the FM(C)T purposes, the treaty verification arrangements would have to cover a wide range of materials in various forms at virtually all stages of the nuclear fuel cycle. FM(C)T could, in principle, exclude source material from its definition, but this does not seem to offer to any significant gains in terms of simplifying the structure of the treaty verification arrangements.

For the purposes of the FM(C)T, this definition could be expanded to include neptunium and americium. In this case, these isotopes would be covered in all forms, whether separated or not.

1.2 Unirradiated direct use material

The concept of unirradiated direct use material has been defined in the context of IAEA safeguards. The IAEA Safeguards Glossary defines direct use material as

> nuclear material that can be used for the manufacture of nuclear explosive devices without transmutation or further enrichment. It includes plutonium containing less than 80% 238Pu, high enriched uranium and 233U. Chemical compounds, mixtures of direct use materials (e.g. mixed oxide (MOX)), and plutonium in spent reactor fuel fall into this category. Unirradiated direct use material is direct use material which does not contain substantial amounts of fission products.[14]

The term “high enriched uranium” (commonly called highly enriched uranium, HEU) that is used in this definition refers to uranium with enrichment in U-235 that is higher than 20%.[15] Accordingly, low enriched uranium (LEU) that contains less than 20% of U-233 (or a combination of U-233 and U-235) would not be considered a direct-use material. It has been well understood that the 20% threshold between low and high enriched uranium is somewhat arbitrary, as uranium that contains less than 20% U-235 could theoretically sustain an explosive chain reaction (as long as the enrichment is higher than about 6% U-235). The 20% threshold first appeared in the context of the technical assistance provided by the United States to non-weapon states as the “Atoms for Peace” program in the 1950s. The United States determined at the time that this level of enrichment provides a reasonable balance between the weapon usability of the material and its suitability for use in research reactors.[16] In 1959, this understanding was used in agreements that regulated supply of

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[11] “International Atomic Energy Agency. Statute (as Amended up to 23 February 1989)” (IAEA, 1989), Article XX.1.

[12] Ibid., Article XX.2.

[13] Ibid., Article XX.3; *IAEA Safeguards Glossary*, 4.4.

[14] *IAEA Safeguards Glossary*, 4.25.

[15] Ibid., 4.13.

[16] Lawrence R. Hafstad, Research Reactors for Foreign Application, Report to the General Manager by the Director of Reactor Development (Atomic Energy Commission, 1954), http://fissilematerials.org/library/haf54.pdf.

material to the IAEA by the United States, the United Kingdom, and the Soviet Union, so the agency can use it in technical assistance programs.[17] However, at that time uranium enriched to 20% or higher in uranium-235 was not explicitly described as a direct use material at the time (and, accordingly, uranium with lower enrichments was not described as a material that cannot be used in nuclear weapons). This distinction was made later, in the context of safeguards that IAEA administers for the purposes of the Nuclear Non-proliferation Treaty (NPT). A model INFCIRC/153 safeguard agreement makes a clear distinction between uranium enriched to higher and lower than 20% of uranium-235, even though it does not refer to the potential weapon use of either material.[18] The description of uranium enriched to more than 20% uranium-235 as a direct use material appears in the IAEA Safeguard Glossary.[19]

Even though the 20% enrichment level does not necessarily provide a clear threshold for potential weapon use of enriched uranium, it is generally accepted that use of low enriched uranium in weapons would be impractical. The critical mass of 20% enriched uranium is as high as several hundred kilograms and is becoming much larger as lower enrichment levels. As noted earlier, uranium with less than about 6% uranium-235 cannot sustain explosive nuclear reaction.[20]

Plutonium that contains more than 80% of plutonium-238 is also excluded from the category of direct use materials on practical grounds. The very high heat generated by Pu-238 makes this material unusable for weapon purposes.

The IAEA definition does not specify the radiation level threshold that would be required to put direct use material in the category of irradiated material. However in its recommendations on the physical protection of nuclear material IAEA defines unirradiated material as:

> Material not irradiated in a reactor or material irradiated in a reactor but with a radiation level equal to or less than 1 Gy/hr (100 rad/hr) at one meter unshielded.[21]

For comparison, the corresponding radiation level of a spent fuel assembly of a power reactor is normally on the order of several thousand rad/hr when it is removed from the reactor; it reaches the level of 1 Gy/hr after about 100 years in storage.[22] At these radiation levels, handling of the material requires use of specialized equipment and facilities that provide a very high degree of radiation protection.

It should be noted that the IAEA safeguards definition of irradiated material explicitly refers to the radiation from fission products as the mechanism that increases the time and effort required to convert the material to weapon components. It does not take into account the radiation that may be present because of radioactive decay of isotopes contained or

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[17] The Texts of Three Agreements for the Supply of Materials to the Agency, INFCIRC/5 (International Atomic Energy Agency, 15 June 1959), https://www.iaea.org/sites/default/files/publications/documents/infcircs/1959/infcirc5.pdf.

[18] The Structure and Content of Agreements Between the Agency and States Required in Connection with the Treaty on the Non-Proliferation of Nuclear Weapons, INFCIRC/153 (Corrected) (International Atomic Energy Agency, 1972), para. 37.

[19] *IAEA Safeguards Glossary*, 4.13.

[20] The critical mass of a 20% enriched uranium sphere surrounded by a reflector is about 400 kg. *IPFM Report 2008: Scope and Verification of a FM(C)T*, 106.

[21] The Physical Protection of Nuclear Material and Nuclear Facilities, INFCIRC/225/Rev.4 (Corrected) (International Atomic Energy Agency, June 1999), 11, http://www.iaea.org/inis/collection/NCLCollectionStore/_Public/30/054/30054392.pdf.

[22] Charles E. Willingham, Radiation Dose Rates from Commercial PWR and BWR Spent Fuel Elements (Pacific Northwest Lab., Richland, WA (USA), 1981), vi, http://www.osti.gov/scitech/biblio/6052779.

accumulated in the material, such as americium-241 in plutonium or thallium-208 (Tl-208) in uranium-233.[23] Radiation levels associated with these isotopes could seriously complicate handling of the material, even though they are much lower than the IAEA physical protection threshold. However, there are mitigation strategies that could reduce these radiation levels; also, the unwanted isotopes could be removed in a chemical cleanup process.[24] This suggests that the direct use material that is not protected to the IAEA physical protection standard should be considered in the category of unirradiated direct use material.

A definition of fissile material in FM(C)T that is based on the IAEA concept of unirradiated direct use material could also include neptunium and americium, presumably separated from fission products.

1.3 Weapon-grade material

One possible approach to defining fissile material for the purposes of FM(C)T is to limit this definition to so-called weapon-grade material. In this case fissile material could include HEU with the U-235 contents of more than 90% and plutonium that contains more than 90-95% of Pu-239.[25] The key argument in support of this proposal is that these are the materials that are used in modern nuclear weapons and that there are few reasons for countries with pre-existing stocks of weapon-grade HEU and plutonium to produce other materials, such as U-233, or lower-grade HEU and plutonium for weapon purposes.

Although nuclear weapon states have not released information about composition of fissile materials that are used in active nuclear weapons, it does seem that most weapons in current nuclear arsenals and those produced in the past use weapon-grade HEU and/or plutonium. At the same time, the United States is known to have conducted a test of an explosive device that used lower-grade plutonium and may have tested designs that used U-233.[26] It is known that neptunium-237 can be used in nuclear weapons, although it is unclear if any neptunium-based devices have been ever tested.[27]

From the point of view of weapon design, there seems to be no special significance to the threshold of 90% U-235 in HEU or 90-95% Pu-239 in plutonium. These values reflect not only weapon design requirements, but also the practical choices that were made to maximize the efficiency of the weapon material production process. For example, the first uranium-based nuclear weapon that was dropped on Hiroshima in 1945, contained HEU

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[23] Americium is produced in a nuclear reactor or accumulated as a result of decay of Pu-241. Tl-208 is a decay product of U-232, which is produced alongside U-233 in a reactor. Jungmin Kang and Frank N. von Hippel, "U-232 and the Proliferation-Resistance of U-233 in Spent Fuel", *Science & Global Security* 9, no. 1 (2001), 1–32.

[24] *Comparison of Thorium and Uranium Fuel Cycles* (National Nuclear Laboratory, March 2012), 10, https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/65504/6300-comparison-fuel-cycles.pdf; Jungmin Kang and Frank N. von Hippel, "U-232 and the Proliferation-Resistance of U-233 in Spent Fuel".

[25] Different version of this proposal include different thresholds for Pu-239 contents, CD/1906.

[26] Gregory S. Jones, "What Was the Pu-240 Content of the Plutonium Used in the U.S. 1962 Nuclear Test of Reactor-Grade Plutonium?" (Nonproliferation Policy Education Center, 6 May 2013), http://nuclearpolicy101.org/wp-content/uploads/2013/05/Reactor-grade-plutonium.pdf; Robert Alvarez, "Managing the Uranium-233 Stockpile of the United States", *Science & Global Security* 21, no. 1 (2013), 53–69.

[27] The United States declassified "[t]he fact that Np237 can be used for a nuclear explosive device". "Restricted Data Declassification Decisions 1946 to the Present (RDD-8)" (U.S. Department of Energy, Office of Health, Safety and Security, Office of Classification, January 1, 2002), 18, http://fas.org/sgp/othergov/doe/decl/rdd-8.pdf.

enriched to 80% in uranium-235, primarily because of the difficulty of reaching higher enrichment levels at the time.

There is little information about the grade of fissile materials in the existing arsenals. The United States apparently considers plutonium with Pu-239 concentration of more than 93% to be weapon-grade material.[28] The United States also made a distinction between HEU enriched to 20-90% U-235 and that enriched to more than 90% in its report on the HEU production released in 2001.[29] Substantial amounts of HEU in the U.S. stock is enriched to 93% U-235. The United Kingdom appears to define weapon grade plutonium as having a Pu-240 content of 8% or less, which corresponds to about 92% Pu-239.[30] Russia's positions regarding the FM(C)T definitions indicate that it considers weapon grade plutonium as having more than 95% Pu-239 and weapon-grade HEU as uranium having more than 90% U-235.

An FM(C)T definition that defines fissile material as strictly weapon-grade material would exempt from the treaty obligations virtually all plutonium in civilian programs as well as significant amounts of enriched uranium that is used in civilian and non-explosive military applications.

1.4 Intermediate-grade material

The definition of fissile material as weapon-grade material has been criticized as too narrow, since HEU with enrichments of slightly less than 90% or plutonium with less than 90% Pu-239 could be used in nuclear weapon without problems. Indeed, the nuclear weapon that was used in Hiroshima contained uranium enriched to 80% U-235. Plutonium with less than 90% Pu-239 also was successfully used to build an explosive device.[31] At the same time, a definition based on the IAEA concept of direct-use material would cover a substantial portion of materials that are in use in the civilian nuclear fuel cycle, resulting in complex treaty verification arrangements. In an attempt to find a compromise between these two definitions, a number of proposals suggested defining fissile material as uranium and plutonium with, respectively, U-235 and Pu-239 content that is higher than a certain threshold. Specifics of these proposals vary, but the values are usually chosen around 40-60% of U-235 in uranium and about 60-80% of Pu-239 (or a sum of fissile isotopes—Pu-239 and Pu-241) for plutonium.[32]

In the case of enriched uranium, the argument is that 40-60% HEU is as an unlikely weapon material as the uranium enriched to 20% – while it could sustain an explosive chain reaction, the critical mass of this medium-enriched uranium is still rather large.[33] However, the difference may matter less if the uranium is used in the secondary stage of a thermonuclear device, which is the case for most HEU in modern designs. Indeed, some U.S. weapons apparently used intermediate enrichments of uranium (probably in addition to other fissile

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[28] *Nonproliferation and Arms Control Assessment of Weapons-Usable Fissile Material Storage and Excess Plutonium Disposition Alternatives* (The United States Department of Energy, January 1997), 38, http://ipfmlibrary.org/doe97.pdf.

[29] "Highly Enriched Uranium: Striking a Balance. A Historical Report on the United States Highly Enriched Uranium Production, Acquisition, and Utilization Activities from 1945 Through September 30, 1996" (U.S. Department of Energy, January 2001), http://fissilematerials.org/library/doe01.pdf.

[30] Gregory S. Jones, "Pu-240 Content of the Plutonium Used in the U.S. 1962 Nuclear Test", 6.

[31] Gregory S. Jones, "Pu-240 Content of the Plutonium Used in the U.S. 1962 Nuclear Test".

[32] CD/1771; CD/1906; CD/1895.

[33] Reflected critical mass for 40% and 60% HEU is about 120 kg and 70 kg respectively. *IPFM Report 2008: Scope and Verification of a FM(C)T*, 106.

materials).[34] Overall, it is not clear whether the difference between 20% HEU and 40-60% HEU is significant enough to justify a change in the definition that has been used by the IAEA for a long time.

Setting a threshold for enriched uranium at some intermediate level, however, would have some practical consequences for some of the uses of HEU in civilian as well as non-explosive military applications, such as the naval fuel cycle. For example, Russian naval reactors historically used fuels with uranium enriched to 21-28, 45, or 90%.[35] India is reportedly producing uranium with enrichment of 30-45 percent for its submarine reactors.[36] Depending on where the treaty sets the threshold for enriched uranium, this material and the activities that are associated with naval reactors may or may not be covered by the treaty provisions.

As for plutonium, setting the threshold at the level of about 60-70% of Pu-239 is supposed to exclude from the treaty almost all plutonium that is produced in the civilian nuclear fuel cycle.[37] The exact isotopic composition of plutonium produced in power reactors depends on the type of the reactor and burn-up of the fuel. Normally, plutonium in spent fuel of light-water reactors contains about 60% Pu-239. The presence of other plutonium isotopes, Pu-240 in particular, makes this plutonium, commonly referred to as “reactor-grade”, a somewhat more difficult material to work with in weapon applications.[38] An argument has been made that this renders reactor-grade plutonium unsuitable for nuclear weapons.[39] However, weapon-usability of reactor-grade plutonium has been recognized by IAEA, which classifies it as a direct use material.[40] Also a U.S. Department of Energy study conducted in 1997 concluded that the technical challenges of building a weapon using low-grade plutonium are not insurmountable:

> At the lowest level of sophistication, a potential proliferating state or subnational group using designs and technologies no more sophisticated than those used in first-generation 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 weapons-grade plutonium. […] Proliferating states using designs of intermediate sophistication could produce weapons with assured yields substantially higher than the kiloton-range possible with a simple, first-generation nuclear device.[41]

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[34] “Restricted Data Declassification Decisions 1946 to the Present (RDD-8)”, 69.

[35] *Global Fissile Material Report 2010: Balancing the Books: Production and Stocks* (International Panel on Fissile Materials, 2010), 62, http://ipfmlibrary.org/gfmr10.pdf.

[36] Ibid., 123.

[37] John Carlson et al., “Plutonium Isotopics—Non-Proliferation and Safeguards Issues” (Australian Safeguards Office, Canberra, Australia, n.d.), http://www.fas.org/nuke/intro/nuke/O_9705.htm; Fast neutron reactors can produce weapon-grade plutonium in their blankets. J. Carson Mark, “Explosive Properties of Reactor-Grade Plutonium”, *Science & Global Security* 4, no. 1 (1993), 111–28.

[38] J. Carson Mark, “Explosive Properties of Reactor-Grade Plutonium”.

[39] CD/1771, 4.

[40] An exception is made for plutonium that contains more than 80% Pu-238. *IAEA Safeguards Glossary*, 4.25.

[41] *Nonproliferation and Arms Control Assessment of Weapons-Usable Fissile Material Storage and Excess Plutonium Disposition Alternatives*, 38–39.

Overall, it appears that the intermediate-grade material option in defining fissile materials for FM(C)T purposes is largely redundant, as it may not be sufficiently different from the weapon-grade option to justify the complication in the structure of the treaty arrangements.

1.5 Americium and neptunium

Neptunium and americium are not included in the definitions of special fissionable material or source material in the IAEA Statute. Neither are they considered direct-use material for the purposes of IAEA safeguards. Instead, IAEA notes that americium and neptunium are sometimes referred to as “alternative nuclear materials”.[42]

Americium is a fissile material that theoretically could be used in a nuclear explosive device. However, its use for weapon purposes requires overcoming a number of serious engineering challenges as americium produces significant amount of heat. A study performed in the United States in the 1990s concluded that the problems posed by the heat could be overcome.[43] However, this does not necessarily mean that the United States would support including americium in the FM(C)T definition of fissile material.

Physical properties of neptunium that are relevant for weapon design are fairly close to those of highly-enriched uranium. It is not known if any of the nuclear weapon states tested neptunium-based explosive devices, but some reports suggest that they at least conducted experiments with the material.[44]

Most of the americium and neptunium have been produced so far are either in spent fuel or in high level reprocessing waste. However, substantial quantities of these materials have been separated, whether during reprocessing of spent fuel of power reactors or in the process of cleaning up civilian or military plutonium. According to one estimate, the total amount of separated americium is on the order of one tonne. As for neptunium, the United States reported having more than 300 kg of separated neptunium, which is used in Pu-238 production; Russia is believed to have hundreds of kilograms of separated neptunium as well.[45]

2. Verification

The main goal of the FM(C)T verification activities would be to ensure that no fissile material that is included in the scope of the treaty is produced for use in nuclear weapons or other explosive devices. The treaty, however, is expected to allow production of fissile materials for non-proscribed uses. It is reasonable to assume that any new treaty-obligated material produced for non-weapon purposes would be declared by a state and placed under the FM(C)T verification. These verification arrangements, which would ensure that no declared fissile material is used for weapons, could be referred to as downstream verification. Also, the FM(C)T verification system would have to ensure that no state is producing undeclared fissile material. For the purposes of this paper, this activity is referred to as verification of non-production.

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[42] *IAEA Safeguards Glossary*, 4.18, 4.19.

[43] David Albright and Kimberly Kramer, “Neptunium 237 and Americium: World Inventories and Proliferation Concerns”, Institute for Science and International Security (ISIS), 2005, 2–3, http://isis-online.org/uploads/isis-reports/documents/np_237_and_americium.pdf.

[44] Ibid., 2.

[45] Ibid., 5.

As stated in the mandate contained in the Shannon report, the FM(C)T negotiations are expected to produce an “effectively verifiable” treaty. Effectiveness, however, could be defined in a number of ways. The treaty, in fact, may not contain specific verification provisions, leaving the decision on details of the verification arrangements to the FM(C)T implementing body.

This approach has been accepted in the safeguards that are administered by IAEA for the NPT treaty. Neither the treaty itself nor the INFCIRC/153 Comprehensive Safeguard Agreements specifies all the details of safeguard arrangements. The objective of the INFCIRC/153-type safeguards is to assure

> the timely detection of diversion of significant quantities of nuclear material from peaceful nuclear activities to the manufacture of nuclear weapons or of other nuclear explosive devices or for purposes unknown, and deterrence of such diversion by the risk of early detection.[46]

It is left to the IAEA to determine what constitutes “timely detection” or “significant quantities”. To answer this question the IAEA adopted an approach that sets the safeguards objectives on the basis of time that would be required to manufacture a single nuclear explosive device from diverted material.[47]

In most cases, this approach could be applied to the FM(C)T as well. However, it has been argued that the verification approach based on the IAEA safeguards objectives is too stringent, as it does not take into account large quantities of weapon-usable materials that are already present in nuclear weapon states. This line of argument appears to follow a somewhat different approach to the effectiveness of verification, similar to the one that has been sometimes applied to arms control agreements. An arms control treaty would normally be considered effectively verifiable if significant violations that could undermine security of treaty participants are detected in time to allow the parties to respond and offset any threat that the violation may create.[48] Adopting this approach may not change the overall structure of the FM(C)T verification system, but it could affect specific timeliness or quantity components of the verification goal.[49]

In any event, if nuclear weapon states reduce their stocks of weapon materials, the FM(C)T verification system would be approaching the safeguards system established by the NPT.

2.1 Downstream verification

2.1.1 Special fissionable material

If the FM(C)T accepts a definition of fissile material based on the Article XX of the IAEA Statute, all special fissionable material produced in a country would be considered treaty obligated material and therefore would have to be followed throughout its life cycle to the point when it is consumed, diluted, or made practically irrecoverable.[50] The FM(C)T verification system would, in effect, extend the comprehensive safeguards system administered by IAEA

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[46] INFCIRC/153, Article 28.

[47] *IAEA Safeguards Glossary*, 3.13, 3.20.

[48] Amy F. Woolf, *Monitoring and Verification in Arms Control* (Congressional Research Service, 2011), 1, 7.

[49] Annette Schaper, “Principles of the Verification for a Future Fissile Material Cutoff Treaty (FMCT)”, 6.

[50] *IAEA Safeguards Glossary*, 2.12.

in non-nuclear weapon states under INFCIRC/153 agreements to all FM(C)T parties for all treaty-obligated fissile materials. However, the FM(C)T verification arrangements in this case would probably not cover "source material", such as natural uranium or thorium, which are formally subject to IAEA safeguards.

This arrangement would still allow production of new fissile material for non-proscribed military purposes, for example for use in naval reactors or research reactors that are used in defense research. To some extent, material from these military uses could come from the pre-existing stock, but since it is a finite resource, nuclear weapon states are likely to insist on keeping this option open.

The INFCIRC/153 agreement, in fact, already allows states to withdraw some material from IAEA safeguards provided that the material will be used for non-proscribed military activity.[51] No arrangements of this kind exist today and a development of a reliable verification system would present some technical challenges. However, it appears that these challenges could be overcome.[52]

Pre-existing stocks of fissile material that nuclear weapon states could reserve for weapon and other purposes should not pose any significant problems from the point of view of downstream verification as long as that material is not introduced to the production chain that is covered by the verification arrangements or mixed with fissile materials produced after the treaty comes into force.

2.1.2 Unirradiated direct use material

The IAEA category of unirradiated direct-use material is sufficiently broad to cover significant amounts of material that is routinely present in the civilian nuclear fuel cycle—HEU, plutonium, and U-233. All this material would have to be declared and placed under monitoring to verify that it is not used for weapon purposes.

2.1.2.1 HEU

There are a number of civilian applications that use HEU. Some fast neutron reactors use HEU fuel in their cores; more than hundred research reactors and other research facilities still use HEU fuel; relatively small quantities HEU are used in medical isotope production. Russia operates a number of civilian nuclear-powered ships that use HEU to fuel their reactors. It is difficult to estimate whether these civilian uses would require significant new production of HEU. Most of the demand could be covered by the existing HEU stock, but some applications may require new production. For example, in 2012 Russia resumed production of HEU, stating the need to supply its civilian reactor program.[53]

The amount of HEU that is involved in civilian activities is relatively small and few of these applications would present a significant verification challenge, with a possible exception of ship-propulsion reactors that could use some military-derived technology and that may therefore be declared sensitive. In any event, the use of HEU in civilian sector has been steadily decreasing in recent years and this trend is expected to continue, making verification easier with time.

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[51] INFCIRC/153, Article 14; *IAEA Safeguards Glossary*, 2.14.

[52] *IPFM Report 2008: Scope and Verification of a FM(C)T*, Chapter 7.

[53] "Russia Launches HEU Production Line", *IPFM Blog*, 29 October 2012, http://fissilematerials.org/blog/2012/10/russia_launches_heu_produ.html.

The military activities that involve HEU consume significant amounts of the material. At least four states operate naval reactors that use HEU fuel—the United States, the United Kingdom, Russia, and India (France is known to use LEU and China is believed to use LEU as well; Brazil is developing on a nuclear submarine that will be using LEU in its reactor—initially at least). These reactors are estimated to consume about 3,200 kg of HEU annually.[54] Also, there are defense-related uses of HEU in military research (weapon effects, weapon research) and tritium production reactors.

While there is no reason to believe that the use of HEU in these applications could not be effectively verified, procedures that would make it possible to do so are still to be developed.

2.1.2.2 Plutonium

Since the IAEA "direct-use material" definition covers plutonium of any isotopic content (with the exception of plutonium with more than 80% of Pu-238), separated plutonium of any grade would have to be covered by FM(C)T verification arrangements. This would mean that once the plutonium leaves a reprocessing plant, it would be followed through to a storage facility of fuel fabrication plant. Then, plutonium-containing fuel (e.g. MOX) would have to be monitored until it is irradiated in a nuclear reactor.

The scale of these operations could be quite substantial—the currently installed MOX fuel fabrication capacity is about 250 tons/year and it is projected to increase to 400 tons/year and perhaps higher in the next decade or so.[55]

There are number of reprocessing technologies currently under development that would produce plutonium still mixed with some transuranic elements and/or some fission products.[56] The plutonium that is mixed with some fission products could be considered an irradiated material; it may be therefore eligible for exemption from downstream verification. However, this exemption should depend on the level of radiation protection provided by the unseparated fission products. Neither of the processes that are currently under consideration appears to provide sufficient protection of the plutonium they produce.[57]

Some plutonium is used in civilian scientific applications—for example, in fast critical assemblies that are used to study physics of breeder reactors. However, the amounts involved are relatively small, on the order of hundreds of kilograms, and it is unlikely that these applications will require new production of plutonium.

2.1.2.3 Uranium-233

Although substantial amounts of separated U-233 exist today, it has not been used on an industrial scale yet. A number of countries, most prominently India, consider an option of developing a thorium-based fuel cycle, in which U-233 would be produced in dedicated

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[54] *IPFM Report 2008: Scope and Verification of a FM(C)T*, 76.

[55] "Mixed Oxide (MOX) Fuel", World Nuclear Association, May 2013, http://www.world-nuclear.org/info/Nuclear-Fuel-Cycle/Fuel-Recycling/Mixed-Oxide-Fuel-MOX/. Throughout this paper, tons refer to metric tons.

[56] R. Bari et al., "Proliferation Risk Reduction Study of Alternative Spent Fuel Processing" (Brookhaven National Laboratory, 2009), http://www.bnl.gov/isd/documents/70289.pdf.

[57] Jungmin Kang and Frank von Hippel, "Limited Proliferation-Resistance Benefits from Recycling Unseparated Transuranics and Lanthanides from Light-Water Reactor Spent Fuel", *Science & Global Security* 13, no. 3 (2005), 169–81.

reactors, and after separation from spent fuel will be used in nuclear fuel. Other fuel cycles that are based on U-233 are being explored as well.[58]

The general approach to the U-233 downstream verification would be no different from that applied to plutonium—the product of reprocessing facilities would have to be followed through storage, fuel manufacturing process, and irradiation in a reactor. In some prospective fuel cycles U-233 could be produced in a mix with U-238 (denatured). If the concentration of U-233 is less than 20% as a result, the U-233 containing mix would no longer be considered a direct-use material.[59]

There are no known uses of U-233 outside of the thorium-based fuel cycle, although some research facilities may have a small stock of the material. New production of U-233 for these purposes is unlikely.

2.1.3 Weapon-grade material

Limiting the definition of fissile material to weapon-grade HEU and plutonium would exempt from downstream verification activities the naval fuel cycles in Russia and India, but would still leave the naval cycle in the United States and the United Kingdom, who use uranium enriched to more than 90% in their naval reactors, covered.

Some research and specialized reactors that currently use weapon-grade HEU may continue to do so, at least for some time. In this case, HEU produced for use in these reactors will be subject to downstream verification.

Although a few civilian research facilities currently use weapon-grade plutonium, there seem to be no legitimate civilian or non-explosive military applications that would require new production of this material. Accordingly, no further production of separated weapon-grade plutonium is expected for non-weapons purposes.

Some plutonium of weapon-grade quality would be present in low-burn-up irradiated fuel and in blanket fuel assemblies of fast neutron reactors. However, these fuel assemblies would usually be processed together with other fuel, so under normal conditions, reprocessing plants would not be expected to have weapon-grade plutonium in their output stream.

2.1.4 Intermediate-grade material

From the point of view of downstream verification, the key difference between the "intermediate-grade" and "weapon-grade" options is the scope of naval fuel cycle activities that would have to be covered by the verification arrangements. Depending on the threshold set in the definition, parts of the naval fuel cycle (or, indeed, the entire cycle) in Russia and India may be exempt from downstream verification. The precise effect that various thresholds may have on the scale of verification activities is difficult to assess, since neither country officially disclosed the level of enrichment in the fuels of its naval and transport reactors.

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[58] *Thorium Fuel Cycle: Potential Benefits and Challenges*, IAEA-TECDOC-1450 (Vienna: International Atomic Energy Agency, 2005).

[59] Strictly speaking, the concentration of U-233 that would be equivalent to 20% U-235 in HEU is 12%. However, in the IAEA definition, concentration of either isotope is taken to be 20%. Jungmin Kang and Frank N. von Hippel, "U-232 and the Proliferation-Resistance of U-233 in Spent Fuel", 13; *IAEA Safeguards Glossary*, 4.25.

As far as plutonium is concerned, the intermediate-grade option is unlikely to be different from the weapon-grade one, as there are few, if any, uses for plutonium with Pu-239 contents between 60-70% and weapon-grade plutonium.

2.1.5 Neptunium and americium

2.1.5.1 Neptunium

Although neptunium could be separated from spent fuel of nuclear reactors in a standard PUREX process that is used for separation of plutonium, this has not been done on a large scale since the material has few applications that would justify its separation. Accordingly, neptunium is normally left in the high-level waste output stream.

The primary application that uses separated neptunium-237 is the production of Pu-238, which is used in thermoelectric generators. The United States is known to have a stock of hundreds of kilograms of neptunium that may be used for this purpose.[60] Russia is believed to have a comparable amount of the material, other states may have some material as well. Separation of neptunium for Pu-238 production may continue, but this activity is unlikely to pose any problems from the point of view of verification.

Separation of neptunium could also be done as part of the waste management strategy that seeks to remove minor actinides from the high-level waste to reduce its radiotoxicity. This strategy assumes that the separated elements would then be burned in reactors or accelerators.[61] If this approach to waste management takes hold, it could result in significant amounts of neptunium being separated and therefore being subject to verification.

Although neptunium is not included in the IAEA category of nuclear materials (i.e. it is not a special fissionable material or source material as defined in Article XX of the IAEA Statute), an FM(C)T definition that is based on Article XX may include neptunium. Consistency would require the definition to cover irradiated neptunium as well, just as it covers plutonium and other materials that are not separated from fission products. This means that high-level waste that contains neptunium would have to be subject of downstream verification, to rule out subsequent reprocessing of the waste for neptunium separation.

2.1.5.2 Americium

Like neptunium, americium that is produced in nuclear reactors is normally left in the high level waste stream during reprocessing of spent fuel. One isotope, Am-241, is also produced during radioactive decay of Pu-241, so it slowly accumulates in plutonium.

Because of its high radioactivity, in the current nuclear fuel cycle americium is largely treated as an unwanted isotope and is separated primarily to remove it from other materials, such as plutonium. This activity, which could be done with military as well as civilian material, is a potential source of substantial amounts of separated americium. One estimate suggested that the total amount of separated americium, mostly from military plutonium, is on the order of one tonne.[62]

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[60] "Draft Environmental Impact Statement for the Proposed Consolidation of Nuclear Operations Related to Production of Radioisotope Power Systems" (U.S. Department of Energy, Office of Nuclear Energy, Science and Technology, June 2005), S–3, http://www.doeal.gov/SWEIS/DOEDocuments/048%20DOE%20EIS-0373D.pdf.

[61] David Albright and Kimberly Kramer, "Neptunium 237 and Americium", 7–10.

[62] Ibid., 7.

Should americium be included in the FM(C)T definition of fissile material, the activities associated with cleanup of military plutonium may present a verification challenge for the treaty, since they are likely to involve military material in weapon use that is outside of the scope of the treaty. However, there is little information about these cleanup operations or indeed about whether any of these activities take place today.

Americium could also be separated from plutonium during MOX fuel fabrication process to reduce radiation doses to the workers. Although it does not seem to be a widespread practice today, the corresponding facilities do exist. A large MOX fabrication facility could separate up to several hundred kilograms of Am-241 annually, depending on the age of plutonium processed at the plant.[63]

Like neptunium, americium is not defined as a nuclear material by IAEA. However, if the FM(C)T definition of fissile material based on Article XX of the statute includes americium, then americium-containing high-level waste would probably have to be covered by the downstream verification arrangements.

Finally, americium could be separated from high-level waste as part of waste-management strategy. This process could result in significant amounts of separated americium that would have to be covered by verification arrangements.

2.2 Verification of non-production

The FM(C)T downstream verification arrangements would ensure that no fissile material that is covered by the treaty is used for weapons or other explosive purposes. To be effective, they would have to be complemented by verification measures that ensure that no undeclared production of fissile material takes place. This would require developing a verification approach that would provide the necessary assurances at the broad range of facilities that are involved in the nuclear fuel cycle. Specific verification procedures and the number of facilities where these procedures are applied would depend on the definition of the fissile material adopted by the treaty and on the degree of confidence in the absence of production that the treaty will seek.

As a starting point for facilities verification, it is reasonable to assume that the treaty would require all its parties to submit initial declarations of relevant facilities. Ideally, these declarations would include all facilities that are capable of handling nuclear materials or handled them in the past, irrespective of the specific definition of fissile material that would be adopted by the treaty. For example, this list might include information about LEU enrichment plants or fuel manufacturing facilities whether or not LEU itself is included in the treaty scope. Based on this information, the FM(C)T implementing body would determine the appropriate level of verification measures that should be applied to each individual facility or exempt some of them from verification. It would also ask states to submit design information for those facilities that are chosen for verification. Strictly speaking, no facility should be completely exempt from the verification process, but the level of verification activity would vary quite substantially depending on the individual facility.

As discussed later in this section, the verification system would probably have to include provisions for detecting undeclared facilities. Without these provisions, effectiveness of many verification activities would be fairly low. The scope of these activities would depend

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[63] Based on ibid., 6–7. A Rokkasho-size MOX fabrication plant that produces 130 MT of fuel could separate about 300 kg of Am-241 a year.

on the degree of confidence in the absence of undeclared material production that the treaty would seek to achieve.

This section examines various components of the fuel cycle from the point of view of verification arrangements that would be required to ensure non-production of undeclared fissile material.

2.2.1 Facilities verification: HEU

Most of the currently deployed industrial enrichment facilities produce low enriched uranium (normally with U-235 content of less than 5%) for fuel of light water reactors. All these facilities use gas centrifuges, although other technologies have been used in the past—most notably gaseous diffusion. Centrifuges are arranged in a series of cascades that could be configured to optimize performance of the plant and, if necessary, to produce uranium with higher enrichments.[64]

Although IAEA has some experience with safeguarding centrifuge enrichment plants that use current technology, some facilities, especially those designed without safeguards in mind, could pose a certain challenge for verification. Also, undeclared centrifuge facilities are virtually impossible to detect.[65] Facilities that will employ new technologies, such as laser enrichment, could be even more difficult to safeguard and detect than centrifuges.[66]

All this requires a careful consideration of verification arrangements that would be applied to the front end of the fuel cycle that includes uranium enrichment.

The basic approach to safeguarding gas centrifuge enrichment plants was developed by the Hexapartite Safeguards Project (HSP).[67] The procedures developed by the project could be applied to the enrichment plants that use URENCO technology. They are believed to provide reliable detection of diversion of low-enriched uranium from declared feed and of covert production of HEU. Later, these procedures were amended to include environmental sampling, which makes covert production of HEU virtually impossible to hide. However, the HSP procedures do not guarantee detection of covert excess production of LEU from undeclared feed.[68] In order to increase confidence in its ability to detect undeclared production, the IAEA implements some additional measures that involve analysis of the facility long-term production plans, export declarations, and other documents. However, the reliability of this information remains limited.[69]

The HSP procedures may not be fully applicable to enrichment facilities that are based on Russian-origin centrifuges. These facilities are designed to allow easy change of the cascade configuration, which could seriously complicate detection of undeclared production. IAEA

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[64] *IPFM Report 2008: Scope and Verification of a FM(C)T*, Chapter 4.

[65] R. Scott Kemp, "The Nonproliferation Emperor Has No Clothes: The Gas Centrifuge, Supply-Side Controls, and the Future of Nuclear Proliferation", *International Security* 38, no. 4 (April 1, 2014), 39–78, doi:10.1162/ISEC_a_00159.

[66] Francis Slakey and Linda R. Cohen, "Stop Laser Uranium Enrichment", *Nature* 464, no. 7285 (March 4, 2010), 32–33, doi:10.1038/464032a.

[67] Australia, Germany, the Netherlands, Japan, the United Kingdom, and the United States. The IAEA and Euratom participated as observers. *IPFM Report 2008: Scope and Verification of a FM(C)T*, 42.

[68] Ibid., 43.

[69] Scientific Experts Meeting on Technical Issues Related to a Treaty Banning the Production of Fissile Material for Nuclear Weapons or Other Nuclear Explosive Devices Based on Resolution 66/44 of the General Assembly of the United Nations, Geneva, 28/29 August 2012, CD/1943 (Conference on Disarmament, 13 September 2012), para. 42.

has some experience of safeguarding the Russia-supplied enrichment plant in Shaanxi, China.[70] However, there is little information about the degree of confidence IAEA has in achieving its safeguards objectives there.[71]

The challenge of detecting excess production from undeclared feed is likely to be common for all centrifuge enrichment plants, regardless of the specific technology they use. While environmental sampling could deter production of HEU at a facility, undeclared production of LEU could still pose a problem. Theoretically, the excess LEU product could be diverted to a relatively small undeclared facility for further enrichment to HEU. To close this possibility, some degree of verification of the flow of source material (natural uranium) in the feed as well as of its output, probably in combination with measures to detect undeclared facilities, might be necessary.[72]

Environmental sampling that could detect the presence of HEU at a facility could be an extremely powerful tool in deterring covert production of the material. However, if a facility has been recently involved in HEU production, sampling might be ineffective. For legacy facilities that were involved in HEU production in the past, it is generally possible to determine the absence of fresh production by age-dating the particles in a swipe sample. But this technique works only for particles that are at least several years old, and preferably much older, so if a facility periodically produces HEU for non-proscribed uses reliable detection of covert HEU production might be difficult.[73] Most enrichment facilities would not be affected, as the scale of new HEU production is expected to be relatively small and could be restricted to a small number of dedicated centrifuge cascades.

The challenges of detecting undeclared flows of material and undeclared facilities mean that the range of verification activities applied to the facilities of the uranium enrichment chain—from uranium mining to enrichment itself—would be the same regardless of the specific FM(C)T definition.

The "nuclear material" definitions in the Article XX of the IAEA statute cover both the input and the output of any enrichment facility. The natural uranium feed as well as depleted uranium tails would be covered by verification arrangements as source material; enriched uranium product would be covered as special fissionable material. This means that the verification system would be able to determine the material flow through the facility and detect any discrepancies that may indicate diversion of the material.

As discussed earlier, IAEA safeguards at gas centrifuge facilities may not be able to detect excess production from undeclared source material. In non-weapon states, it is reasonable to assume that there is no undeclared material that could be used as such a feed. However, this possibility cannot be completely ruled out in the case of INFCIRC/153 safeguards alone as they assume that the safeguards are applied only to the uranium that is converted to UF6 at a (declared) conversion facility.[74] To address the issue of undeclared nuclear material, the Additional Protocol (INFCIRC/540) requires states to provide information about source

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[70] A. Panasyuk et al., "Tripartite Enrichment Project: Safeguards at Enrichment Plants Equipped with Russian Centrifuges", in *IAEA Symposium on International Safeguards*, Vienna, 2001, http://www-pub.iaea.org/MTCD/publications/PDF/ss-2001/PDF%20files/Session%208/Paper%208-02.pdf.

[71] *IPFM Report 2008: Scope and Verification of a FM(C)T*, 43.

[72] See also CD/1917, para. 32–34.

[73] *IPFM Report 2008: Scope and Verification of a FM(C)T*, 48–49.

[74] *IAEA Safeguards Glossary*, 2.11.

material at much earlier stage.[75] The Additional Protocol also includes measures that allow IAEA to make a determination about the absence of undeclared facilities in a state. According to IAEA (emphasis added),

> it is only for those States with both CSAs [INFCIRC/153] and APs [INFCIRC/540] in force that the Agency draws the broader conclusion that *all nuclear material* remains in peaceful activities in the State. For those States with CSAs but without APs, the Agency draws the conclusion that *declared nuclear material* remains in peaceful activities, as the Agency does not have the measures available under an AP to enable it to provide credible assurance of the absence of undeclared nuclear material and activities.[76]

This shows that a high degree of confidence in the absence of undeclared material or facilities would require a fairly intrusive measures similar to those implemented under the Additional Protocol. At lower levels of confidence these measures could be made less intrusive, but some degree of monitoring of the flow of source material and some ability to detect undeclared facilities would still be necessary.

If FM(C)T adopts the definition based on either of the other concepts—unirradiated direct use material, weapon-grade or intermediate-grade HEU—uranium enriched to the level lower than the definition threshold would not be covered by the treaty provisions. However, to ensure non-production of treaty-obligated HEU, verification arrangements would have to be extended to all enrichment plants, regardless of the level of enrichment in their product. Ideally, these arrangements would also provide a certain degree of assurance of non-diversion of uranium enriched to the below-the-threshold levels, since LEU could be a very high-quality feed for an undeclared enrichment facility.

Overall, it appears that in order to achieve a high degree of confidence in the absence of undeclared production of HEU, the FM(C)T verification system would probably have to include measures similar to those implemented in the Additional Protocol. Without arrangements that would monitor material flow through the entire enrichment cycle and some fairly robust capability to detect undeclared facilities, the level of confidence in the absence of production of treaty-obligated material could be rather low.

2.2.2. Facilities verification: Reprocessing

The most common reprocessing technology that is used to separate plutonium from fission products in spent fuel of nuclear reactors, known as PUREX, was developed as part of weapon programs. All industrial reprocessing facilities that are operational or under construction today use the PUREX process.[77] All known reprocessing facilities are located in nuclear weapon States, whether they are party to the NPT or not, with the single exception of Japan, which is the only non-nuclear weapon state that currently has reprocessing facilities. States that are outside of NPT are believed to maintain operational military or dual-use reprocessing plants. Other states do not have military reprocessing plants—the operational facilities are dedicated civilian reprocessing plants, such as La Hague in France or Rokkasho in Japan, or old military reprocessing plants that have been converted to non-

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[75] Model Protocol Additional to the Agreement (s) between State (s) and the International Atomic Energy Agency for the Application of Safeguards, INFCIRC/540 (Corrected) (International Atomic Energy Agency, May 1997), Article 2.a.vi.

[76] "GOV/2013/38: The Conceptualization and Development of Safeguards Implementation at the State Level" (IAEA Board of Governors, 12 August 2013), Para 8.

[77] *Global Fissile Material Report 2013: Increasing Transparency of Nuclear Warhead and Fissile Material Stocks as a Step toward Disarmament* (International Panel on Fissile Materials, 2013), 25, http://ipfmlibrary.org/gfmr13.pdf.

plutonium applications (Seversk plant in Russia) or deactivated (F-canyon at Savannah River Site), or decommissioned military plants (for example, Marcoule in France). Some old civilian plants, for example, Mol in Belgium or Karlsruhe in Germany, have been decommissioned as well. Some operational facilities handle tens of tons of spent fuel (measured in metric tons of heavy metal) a year. The largest facilities, such as UP2 and UP3 reprocessing plants at La Hague, are designed to handle 1000 MTHM/year. A number of new reprocessing technologies, such as pyroprocessing, are under development, but none has reached the construction stage, so PUREX remains the dominant reprocessing technology.[78]

One of the main challenges of verifying the production of plutonium at a reprocessing facility is the difficulty of accurate measurements of plutonium content in the material handled by the plant.[79] At new facilities that are designed with safeguard requirements in mind, such as the Rokkasho plant in Japan, IAEA has demonstrated that it could achieve its safeguards objectives by introducing additional containment and surveillance measures that involve considerable cost. But implementing this approach at already-operating facilities or at new facilities that are not designed for safeguards would be in most cases impossible. There are, however, a number of well-developed proposals of an FM(C)T safeguard approach that could be applied to older plants and that would reduce the uncertainty in plutonium measurements to a reasonable level, comparable, but higher than that achieved at Rokkasho.[80]

Since both IAEA safeguards and the proposed FM(C)T approach rely on measuring plutonium contents in the spent fuel entering a reprocessing facility, they assume that plutonium in irradiated fuel assemblies is covered by the FM(C)T definition of fissile material. This would be the case should the FM(C)T accepts the nuclear material concept of Article XX of the IAEA Statute.

If the FM(C)T definition is limited to unirradiated direct use material or weapon- or intermediate-grade material, spent fuel assemblies would technically be outside of the treaty scope.

In the weapon-grade and intermediate-grade cases, this may not present a serious problem, as it would be sufficient to demonstrate that no plutonium with the Pu-239 contents above a certain level (90-95% or 60-70% respectively) is entering the dissolver of the reprocessing plant. This would not require material accounting measures and could probably be done relatively easily. Since the isotopic composition of plutonium does not change during reprocessing, this would guarantee that the plant is not producing treaty-obligated plutonium.

If the FM(C)T accepts the concept of unirradiated direct use material, plutonium of any isotopic composition (with less than 80% Pu-238) would be treaty-obligated, so the treaty would have to verify that no diversion of plutonium takes place during reprocessing. Without the ability to measure plutonium contents in the spent fuel entering the plant, the confidence in the absence of diversion would be extremely low. In this case, about the only way to address the diversion issue would be to conduct detailed design verification inspections of the plant to determine potential diversion paths. But it is not clear if this

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[78] See, for example R. Bari et al., "Proliferation Risk Reduction Study of Alternative Spent Fuel Processing"; "Spent Nuclear Fuel Reprocessing Flowsheet" (OECD NUCLEAR ENERGY AGENCY, n.d.).

[79] Shirley Johnson, "The Safeguards at Reprocessing Plants under a Fissile Material (Cutoff) Treaty" (International Panel on Fissile Materials, 2009), http://fissilematerials.org/library/rr06.pdf.

[80] Ibid., 10.

determination could be reliably made for large reprocessing facilities and especially for those that are already in operation.

Another option is to extend the coverage of treaty verification system to the spent fuel that is arriving to the reprocessing facility, even though formally the treaty would not cover irradiated plutonium. In fact, it would be logical to extend it even further—to spent fuel assemblies that are removed from reactors and placed in storage. These measures would be relatively inexpensive and easy to implement.

Indeed, some degree of monitoring of irradiated fuel assemblies after they are unloaded from a reactor would be required in all cases to guard against diversion of spent fuel for reprocessing at a clandestine facility. Some of these fuel assemblies, for example, those exposed to low burn-up or blanket assemblies of a fast reactor, could contain plutonium of weapon- or intermediate-grade quality. Also, a verification system should include some measures that would allow detection of undeclared reprocessing facilities. Diversion of spent fuel or construction of a clandestine reprocessing plants would be much easier to detect than diversion of uranium feed or construction of clandestine enrichment facilities, so these measures should not significantly increase the complexity and cost of the verification system. Even simple measures could provide a significant deterrence against undeclared reprocessing activity.

One possibility that was mentioned in the context of limiting the definition of fissile material to weapon-grade material only is that some reprocessing facilities could be exempt from verification if it is determined that they cannot produce weapon-grade material. For example, theoretically, some reprocessing plants may be designed to handle only reactor-grade plutonium because of the criticality safety considerations. If this is the case, the issue should be decided on a facility-by-facility basis. However, a facility like this would not be fully exempt from verification. Some very detailed initial design verification would be required in any case, as well as periodic inspections to confirm that the design has not been altered.

Another exemption proposal suggests that facilities that employ a process in which plutonium in the output stream is not separated from some transuranic elements and/or from some fission products would not require verification. One example of such process is pyrorpocessing that is developed in South Korea. However, as discussed earlier, in most cases these processes do not seem to offer a high degree of protection of plutonium.[81] Also, while the specific procedures that would be implemented at such facilities may be different from those at PUREX plants, it has been demonstrated that virtually all reprocessing facilities can be reconfigured to produce a separate plutonium stream, so no facility should be exempt from verification.[82]

2.2.3 Facilities verification: Uranium-233

The use of U-233 in the nuclear fuel cycle would normally require chemical reprocessing of thorium-containing fuel irradiated in a nuclear reactor.[83] Like U-238 in the plutonium fuel cycle, Th-232 is a fertile material that is used to produce a fissile isotope. After irradiation, U-233 could be separated from the fission products in a radiochemical process. A process

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[81] Jungmin Kang and Frank von Hippel, “Limited Proliferation-Resistance Benefits from Recycling Unseparated Transuranics and Lanthanides from Light-Water Reactor Spent Fuel”.

[82] R. Bari et al., “Proliferation Risk Reduction Study of Alternative Spent Fuel Processing”.

[83] In some “open cycle” concepts, U-233 would be produced and used in situ and then disposed without reprocessing. *Thorium Fuel Cycle*, 10–11.

that has been developed to handle the separation is known as THOREX; it is similar to PUREX process that is used to separate plutonium.[84] Most THOREX reprocessing so far has been done on laboratory and pilot-scale scale, so there is no experience with industrial-scale operations of the THOREX reprocessing plants.[85] There are also projects to build molten-salt reactors, in which reprocessing unit is deeply integrated with the reactor.[86] These projects are still on the experimental stage.

Since uranium-233 is identified as a special fissionable material in the IAEA Statute, should the FM(C)T adopt the definition based on the IAEA concept of "nuclear material" all irradiated fuel that contains U-233 would be covered by the FM(C)T verification provisions. Reprocessing and fuel fabrication facilities as well as irradiated U-233 containing fuel (until it is reprocessed or disposed of) would also have to be covered. Although IAEA does not have practical experience with safeguarding thorium-based fuel cycle, it is likely that the general approach to uranium-plutonium/PUREX cycle could be used in the thorium/THOREX cycle. Advanced fuel cycle concepts could present some additional challenges, but there is no reason to believe that these could not be addressed, especially if the facilities are designed with IAEA safeguards or FM(C)T verification in mind.

If the FM(C)T definition is based on the "unirradiated direct-use material", then spent fuel assemblies would not, strictly speaking, be covered by the treaty. However, it would be important to include them in the scope of the verification activities in order to detect possible diversion of the material.

It might also be possible to design a cycle in which thorium in fuel is mixed with U-238 (denatured), so the U-233 that is produced during irradiation would be contained in an isotopic mixture of U-233 and U-238. At U-233 concentrations of less than 20% this mixture would not be considered a direct-use material and therefore would be exempt from the treaty verification arrangements after separation.[87]

In the narrowly defined concept of "weapon-grade" material, U-233 would be completely exempt from verification. If it is included in that definition or if U-233 is considered an "intermediate-grade" material, most verification activities described above would not change. The only exception would be those that involve denatured U-233.

2.2.4 Facilities verification: Neptunium and americium

In most radiochemical processes neptunium and americium are not extracted in a separate output stream. In the PUREX process they are normally sent to the high-level waste stream, where they are subsequently disposed of with the waste. Since neither neptunium or americium is considered a special fissionable material in the IAEA Statute, they are not formally covered by the IAEA safeguards. However, these materials are monitored by the IAEA "under voluntary arrangements with relevant states".[88] The basic method, "flow sheet verification", can ensure that neptunium and americium are not separated during

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[84] *Thorium Fuel Cycle*; "Comparison of Thorium and Uranium Fuel Cycles", 18.

[85] *Thorium Fuel Cycle*, 65; One industrial facility, PRTRF, is being constructed in India. Thomas B. Kingery, *Nuclear Energy Encyclopedia: Science, Technology, and Applications* (John Wiley & Sons, 2011), 98.

[86] *Thorium Fuel Cycle*, 30.

[87] Ibid., 82.

[88] *IAEA Safeguards Glossary*, 4.18, 4.19.

reprocessing, but more accurate methods that could provide some information about material balance are being considered as well.[89]

With some modification of the radiochemical process, neptunium and americium could be extracted in a separate stream or mixed with other products, such as plutonium.[90] Also, if these materials are sent to waste stream, it would be necessary to ensure that no further reprocessing of the waste is done downstream.

Verification procedures that would be applied to facilities capable of separating neptunium and americium would likely to be similar to those used to monitor plutonium, although they may require development of new measurement technologies.

Americium may present a unique challenge from the point of view of verification at radiochemical facilities. The reason is that some separation of americium may take place as part of the process of cleanup of military plutonium. Accordingly, it may not be possible to use certain measurement techniques as they might reveal information about the military material that may be considered sensitive. At least one proposal, put forward by Australia, suggested that FM(C)T should explicitly allow the military cleanup activities.[91]

2.2.5 Shutdown, closed down, decommissioned, or converted facilities

In addition to operational facilities, the FM(C)T verification measures would need to cover those facilities that have been involved in production of fissile materials in the past. The IAEA practice recognizes several relevant categories of facilities:

> A shutdown facility is one that contains nuclear materials and could be restarted. A closed-down facility has been cleaned out but has not yet begun decommissioning. In non-weapon states, facilities that have been either shutdown or closed-down continue to be categorized as facilities, irrespective of inventory, and remain under IAEA safeguards. Inspection and design verification activities are conducted for the purpose of assuring that no new nuclear material has been introduced, that the current inventory (if any) remains as declared and that operations of the facility have not been restarted.[92]

A decommissioned facility is defined as

> an installation or location at which residual structures and equipment essential for its use have been removed or rendered inoperable so that it is not used to store and can no longer be used to handle, process or utilize nuclear material.[93]

The procedures that were developed by the IAEA to monitor shutdown and closed down facilities and to certify decommissioned status of a facility could be used in the FM(C)T context without major modifications.[94] The only potential problem is that at the former

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[89] H. Ottmar et al., "Demonstration of Measurement Technologies for Neptunium and Americium Verification in Reprocessing", in *International Safeguards Verification and Nuclear Material Security* (Vienna: IAEA, 2001), 307–8, http://www.iaea.org/inis/collection/NCLCollectionStore/_Public/33/007/33007049.pdf.

[90] "Spent Nuclear Fuel Reprocessing Flowsheet"; R. Bari et al., "Proliferation Risk Reduction Study of Alternative Spent Fuel Processing".

[91] CD/1895, para. 23.

[92] Shirley Johnson, "The Safeguards at Reprocessing Plants under a Fissile Material (Cutoff) Treaty", 15; For definitions, see *IAEA Safeguards Glossary*, 5.29, 5.30.

[93] *IAEA Safeguards Glossary*, 5.31; "INFCIRC/540", Article 18.c.

[94] Technical Issues Related to a Fissile Material Cut-Off Treaty (FMCT). Report of the Co-Chairs Ambassador Hellmut Hoffmann, Permanent Representative of Germany to the Conference on Disarmament, and Ambassador Paul van Den IJssel, Permanent Representative of the Netherlands

military facilities the decommissioning process should take into account possible presence of sensitive information or equipment on the site.

The FM(C)T may also consider a category of converted facilities, defined as those that participated in production of treaty-relevant fissile material in the past, but since then were redesigned in such a way that they are no longer capable of serving this function. For example, Russia's reprocessing plants that were producing weapon-grade plutonium have been converted to other uses that do not involve plutonium. Depending on the specifics of the conversion process, these plant may or may not be subject to monitoring under FM(C)T.

One possible approach to dealing with converted facilities in FM(C)T is to require member states to submit declarations about all facilities that handled treaty obligated materials in the past. Then, each facility would be examined in order to determine the appropriate level of monitoring that should be applied to it.

3. Scope

The issue of scope adds another level of complexity to the structure of the future fissile material control treaty. The central question here is whether the treaty should cover pre-existing stocks of fissile materials. Also, there are different points of view regarding the treatment of the material that is declared excess for weapon uses, the material that is released in the process of reductions of nuclear arsenals, transparency measures that should cover these categories of fissile material, and whether the treaty should require member states to actively pursue reductions of their holdings of weapon-usable materials.[95]

A narrow interpretation of the mandate contained in the Shannon report may suggest that the future treaty should only cover "the production of fissile material for nuclear weapons or other nuclear explosive devices". However, the consensus regarding this mandate was achieved only with understanding that it does not preclude any state from raising the issue of stocks during negotiations.[96]

Various options for addressing the issue of existing stocks, from increased transparency to disposition of fissile materials have been already discussed in great detail. The options include declaration of the current holdings, which would be an important transparency measure and serve as a baseline for future reductions, declarations of excess military material, placing excess material under verification, and creating a mechanism for disposition of the excess material.[97] The discussion in this section will summarize various options that have been discussed so far and consider them from the from the point of view of definitions and verification arrangements. It will then discuss approaches to weapon material declared excess and the material released in the process of nuclear disarmament.

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to the Conference on Disarmament, CD/1935 (Conference on Disarmament, June 26, 2012), para. 32-48.

95 Annex I. Report on the Informal Meetings of the Conference on Disarmament with a General Focus on FMCT, CD/1918 (Geneva, 17 and 18 May 2011) (Conference on Disarmament, 7 September 2011).

96 CD/1299.

97 CD/1770; Annette Schaper, "A Treaty on the Cutoff of Fissile Material for Nuclear Weapons—What to Cover? How to Verify?"; William Walker and Frans Berkhout, *Fissile Material Stocks: Characteristics, Measures and Policy Options* (Geneva: UNIDIR, 1999); CD/1918, 18.

3.1 Pre-existing stocks

The minimum FM(C)T option is a treaty that does not deal with the stocks of fissile materials that exist at the time the treaty enters into force. This position is supported by most nuclear weapon states; some of non-nuclear weapon states also take a view that it would be impractical to include existing stocks in the future treaty.[98] Among the arguments in support of this position is the notion that inclusion of existing stocks would make a consensus regarding FM(C)T more difficult, and that it would be impossible to apply verification measures to fissile materials contained in weapons.

A number of states appear to support the non-inclusion of existing stocks, but would like to see some transparency measures applied to the current fissile material holdings. Specifically, member states could be asked to make declarations of fissile material for use in nuclear weapons or other explosive devices.[99] It has been suggested that these declarations could be voluntary, at least during a transitional period. One option is to have a separate protocol that would be added to the treaty at some later date and that would deal with existing stocks.[100] The idea of a parallel voluntary arrangement outside of the treaty, a Fissile Material Control Initiative, that would address various issues related to existing stocks, such as transparency, nuclear security, and others, also has gained some considerable support.[101]

At the other end of the spectrum lies an option of submitting "all stocks of weapon-usable materials … to international verification and control".[102] This proposal appears to be supported by some states, although only a few explicitly stated their preference for complete elimination of all weapon-usable materials as part of the future treaty.[103] More often, states express their preference for addressing the issue of existing stocks without suggesting specific measures to do so.[104]

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[98] Working Paper Submitted by the United States of America. Draft Treaty on the Cessation of Production of Fissile Material for Use in Nuclear Weapons or Other Nuclear Explosive Devices, CD/1777 (Conference on Disarmament, 19 May 2006); Working Paper Submitted by Japan: FMCT: A Contribution to Constructive Discussions, CD/1774 (Conference on Disarmament, 16 May 2006); Working Paper Submitted by Australia: Suggestions for Progressing the Fissile Material Cut-Off Treaty, CD/1775: (Conference on Disarmament, 17 May 2006); CD/1895; Working Paper Submitted by South Africa: The Possible Scope and Requirements of the Fissile Material Treaty (FMT), CD/1671 (Conference on Disarmament, 28 May 2002); Working Paper Submitted by South Africa: The Possible Scope and Requirements of the Fissile Material Treaty (FMT), Addendum, CD/1671/Add.1 (Conference on Disarmament, 23 August 2002); "Fissile Material Cutoff Treaty: Views of the United States of America, pursuant to UNGAR 67/53 (2012)", 2012, http://www.unog.ch/80256EDD006B8954/(httpAssets)/BD142DD9E3BA954BC1257B7C00321B78/$file/USA.pdf; Foreign and Commonwealth Office, "Fissile Material Cut-Off Treaty", 16 May 2013, http://www.unog.ch/80256EDD006B8954/(httpAssets)/E1CAF1118D2E8675C1257B7C0032245B/$file/United+Kingdom.pdf.

[99] CD/1770, 3.

[100] CD/1910.

[101] Robert J. Einhorn, "Controlling Fissile Materials and Ending Nuclear Testing" (Achieving the Vision of a World Free of Nuclear Weapons. International Conference on Nuclear Disarmament, Oslo, 26 February 2008), http://www.ctbto.org/fileadmin/user_upload/pdf/External_Reports/paper-einhorn.pdf; CD/1910.

[102] "Time for a Comprehensive Fissile Material Treaty" (Greenpeace, 21 February 2006), Draft treaty, Article II.6, http://www.greenpeace.org/international/Global/international/planet-2/report/2006/4/comprehensive-fissile-material.pdf.

[103] CD/1910; "Views of the Islamic Republic of Iran pursuant to Paragraph 2 of Resolution A/RES/67/53 on Treaty Banning the Production of Fissile Material for Nuclear Weapons or Other Nuclear Explosive Devices", n.d., http://www.unog.ch/80256EDD006B8954/(httpAssets)/3E37E9422483CF79C1257B8E0029B1D3/$file/IRAN.pdf.

[104] See "Member States' Views", *The United Nations Office at Geneva*, accessed July 14, 2014, http://www.unog.ch/unog/website/disarmament.nsf/(httpPages)/384E4AAF5A1D7189C

The variety of intermediate positions between these two extreme options could be reduced to two key groups of proposals that would allow member states to exclude certain amounts of weapon-usable material from the scope of the future treaty while setting some limits on the way the fissile material stocks are managed.

The less restrictive proposals would permit nuclear weapon states to retain essentially any amount of fissile materials outside of the treaty scope, but would prohibit the use in weapons of any material that has been declared excess. In addition, the material that has been released in the process of nuclear disarmament could also be prohibited for weapons use. These proposals might also require that pre-existing stocks of civilian materials and the material that was designated for military non-weapon uses (in naval or military research reactors) to be included in the scope of the treaty.[105] This would provide fairly strong assurances of irreversibility of reductions of weapon-usable holdings of fissile materials, while still providing nuclear weapon states with considerable degree of flexibility in determining the structure of their stocks. Some proposals in this category would require nuclear weapon states to conduct periodic reviews of their fissile material needs and declare as much excess material as practically possible.[106]

The more restrictive proposals in this category would allow nuclear weapon states to exclude from the treaty coverage only those materials that are "contained in a nuclear weapon or in any other nuclear explosive device" at the time the treaty enters into force.[107] At least one proposal would also allow retaining some reserve to maintain safety and security of the operational arsenal.[108] All other material would have to be declared excess and placed under FM(C)T verification. It should be noted, however, that none of these proposals contains specific provisions that would suggest an effective verification mechanism to ensure that all material that is outside of nuclear weapons has been declared excess.

3.2 Scope and definitions

Depending on the definition of fissile material adopted by FM(C)T, resolving the issue of scope would have different consequences for the fissile material control regime established by the treaty. This section attempts to describe how various categories of fissile materials would be affected by different choices of definitions and scope.

3.2.1 Weapon-grade and intermediate-grade material

An FM(C)T definition of fissile material based on the concept of weapon-grade or intermediate-grade material would mostly cover military stocks. However, for the purposes of the scope discussion it is useful to consider various sub-categories within the broad category of weapon-grade (and intermediate-grade) material.

1257B7C003140CA?OpenDocument&unid=B8A3 B48A3FB7185EC1257B280045DBE3.

[105] *IPFM Report 2008: Scope and Verification of a FM(C)T*; CD/1774; CD/1671; CD/1770; CD/1775.

[106] CD/1770.

[107] Working Paper Submitted by Brazil: Proposal on the Structure of a Treaty on Fissile Material for Nuclear Weapons or Other Nuclear Explosive Devices, CD/1888 (Conference on Disarmament, 14 June 2010); CD/1910.

[108] "Statement by Ambassador Zamir Akram, Permanent Representative at the Conference on Disarmament. General Exchange of Views" (Geneva: Pakistan Permanent Mission to the United Nations, 4 June 2014).

A. Material in operational warheads

This sub-category includes weapon-grade material in nuclear weapons that are considered to be operational, meaning that they are either deployed or are ready to be deployed. Specific definitions vary from country to country, and in most cases the exact status of warheads that are considered operationally deployed is not known.

The United States, the only country that provides information about its stockpile, defines two categories of weapons that would be considered operational—active and inactive warheads. Active warheads are those that are "maintained in an operational, ready-for-use configuration;" the warheads "that must be ready for possible deployment within a short timeframe, and logistics spares" are also included in this category. The defining feature of active warheads is that they "have tritium bottles and other Limited Life Components installed". The United States defines inactive warheads as those that have their tritium bottles removed.[109] Presumably, bringing these warheads to operational state, while possible, would take some considerable time.

Other nuclear weapon states may handle their operational stockpiles differently, so U.S. definitions is probably not applicable to all nuclear arsenals. For example, Pakistan appears to maintain at least some of its weapons as components placed in storage.[110] However, these weapons would be considered operational, since they could be made ready for use in a short period of time.

B. Retired warheads

This category would include warheads that have been removed from service. These warheads would be still intact, although they would definitely have tritium bottles and other limited life components removed. However, unlike inactive warheads in the operational stockpile, which also have these components removed, retired weapons could not be easily brought back into service. This would be the case, for example, for warheads of missiles that have been withdrawn from service and eliminated.

Since retired warheads cannot be returned to service, they are probably placed in a dismantlement queue. Normally, they would be moved to dedicated storage facilities that handle weapons awaiting dismantlement. Various states appear to handle dismantlement process differently, but in general it seems that unless a weapon has a known safety issue, it could be stored intact for a long period of time. In most cases, the rate of dismantlement is determined by the capabilities of the weapon disassembly facilities. Some countries, e.g. Russia and France, are known to refurbish their nuclear warheads, so old weapons are disassembled as part of a process that produces new warheads ready for deployment.[111]

C. Warhead components

Once a nuclear warhead has been disassembled, its fissile material components could be kept intact and stored without further disassembly. Some components could probably be reused in new warheads, if necessary. In U.S. weapons these components are plutonium

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[109] "Fact Sheet: Transparency in the U.S. Nuclear Weapons Stockpile", 29 April 2014, http://ipfmlibrary.org/usg14.pdf.

[110] "Statement by Ambassador Zamir Akram, Permanent Representative at the Conference on Disarmament. General Exchange of Views".

[111] *Global Fissile Material Report 2011: Nuclear Weapon and Fissile Material Stockpiles and Production* (International Panel on Fissile Materials, 2011), 5, http://ipfmlibrary.org/gfmr11.pdf; "Rapport d'Information Déposé en Application de l'Article 145 du Règlement par la Commission de la Défense Nationale et des Forces Armées sur La Fin de Vie des équipements Militaires et Présenté par M. Michel Grall, Député" (Paris: National Assembly, 16 March 2009), 11.

pits and so-called canned subassemblies that contain HEU. These components are probably present in most modern thermonuclear weapons, although some non-U.S. weapons may have different design. National practices of handling fissile material components are likely to be different as well. It is known that in the United States almost half of all fissile materials are stored in plutonium and HEU components.[112] This is not necessarily the case in other states—for example, Russia reportedly does not have significant number of plutonium pits in storage. One important feature of weapon components is that their geometrical shape and mass are likely to be considered sensitive information.

D. Bulk material

This subcategory of material would include HEU and plutonium in storage or in the weapon assembly/disassembly process in the form of metal or oxide powder. There is little publicly available information about how nuclear weapon states handle and store their bulk material, but it appears that it constitutes a significant fraction of all weapon-related stocks.

E. Material in naval fuel cycle and naval reserve

At least two states—the United Kingdom and the United States—use weapon-grade HEU to fuel their naval reactors. Depending on the specific threshold, the material used in naval fuel of two countries that use HEU, Russia and India, could also be considered intermediate-grade material. Some of this material is directly involved in the naval fuel cycle—for example, HEU contained in fresh fuel or held up in the fuel manufacturing process. Also, some HEU may be assigned to naval fuel reserve, which implies a commitment not to use this material for weapon purposes.

So far, only the United States made a specific commitment to use some of its HEU—about 152 tons—for naval fuel.[113] However, this does not necessarily mean that all this material has been physically placed in a separate storage. Substantial amount of this material could still be in weapon components.[114] The United Kingdom is reported to have a naval reserve, but it has not officially declared its size or committed to use it exclusively for naval reactors.[115] Russia has never made public its policy regarding the use of HEU in naval reactors. India appears to have a de-facto naval reserve policy, since its naval reactors will use intermediate-grade HEU that is not intended for weapons use. France and China are believed to use LEU in their submarine reactors.

F. Safeguarded material

Some weapon-grade (or intermediate-grade) material is covered by existing obligations and therefore will not be available for use in weapons. This, of course, includes all fissile material in non-nuclear weapon states that are parties to the NPT. Some of these states have weapon-grade HEU or plutonium, which is under IAEA comprehensive (INFCIRC/153) safeguards. Any material that is under IAEA facility-specific (INFCIRC/66) safeguards or safeguards administered under the INFCIRC/754 agreement between IAEA and India would have to remain in non-weapon use.

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[112] About 40 metric tons of US plutonium are stored as pits at the Pantex plant and about 280 metric tons of HEU are stored as HEU components at the Y-12 National Security Complex. This estimate is based on the data in *Global Fissile Material Report 2011*, 9; "Highly Enriched Uranium Inventory: Amounts of Highly Enriched Uranium in the United States" (DOE, Office of Security and Safety Performance Assurance, January 2006), 3, http://ipfmlibrary.org/doe06f.pdf.

[113] *Global Fissile Material Report 2013*, 12.

[114] "Highly Enriched Uranium: Striking a Balance", 38; "Highly Enriched Uranium Inventory", 3.

[115] *Global Fissile Material Report 2010*, 72.

The United Kingdom and France have placed their civilian material, that includes some HEU and civilian plutonium, under Euratom safeguards.[116] The United Kingdom submitted to IAEA/Euratom safeguards about 0.3 tons of weapon-grade plutonium declared excess.[117] The United States has submitted about 2 tons of weapon-grade plutonium for IAEA safeguards.[118] The terms of these voluntary offers allow withdrawal of the material from safeguards, but it is unlikely that these state would do so should FM(C)T enter into force. In the absence of FM(C)T obligations, however, the material can be returned to military use at any time—the United States withdrew 10 tons of HEU that was earlier placed under IAEA safeguards.[119] The material was transferred to the naval reserve.

Russia has not placed any of its weapon-grade material under IAEA safeguards. However, under the terms of its bilateral agreement with the United States, it cannot use about 18 tons of weapon-grade plutonium that was separated after January 1997 for weapon purposes. This plutonium is placed in storage at two sites in Russia that are subject to periodic inspections by the United States.[120] The IAEA is not taking part in these inspection activities.

G. Civilian weapon-grade material

Civilian activities in nuclear weapon states may involve weapon-grade HEU and plutonium that is not safeguarded or otherwise obligated. In absolute terms, the quantity of this materials could be rather large – for example, one research facility in Russia has several tons of weapon-grade plutonium and HEU in various forms.[121] However, relative to the size of weapon stocks these quantities are fairly small.

If FM(C)T does not cover any of the material produced before the treaty's entry into force, none of the categories of material describe above would be affected. All existing obligations regarding the use of material would remain in force and no new commitments would be assumed. The existing weapon materials would remain largely separated from the civilian nuclear fuel cycle. If a state would choose to exercise its right to produce fissile material for non-weapon purposes, for example for naval fuel, the new material would be covered by FM(C)T verification arrangements and therefore would have to be handled separately from the material that comes from pre-existing stock. This may complicate the treaty verification system, but is unlikely to create serious problems.

If the FM(C)T includes provisions for handling voluntary declarations of excess material, the structure of the verification arrangements could be simplified. This would require states to

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[116] *Global Fissile Material Report 2007: Developing the Technical Basis for Policy Initiatives to Secure and Irreversibly Reduce Stocks of Nuclear Weapons and Fissile Materials* (International Panel on Fissile Materials, 2007), 73, http://ipfmlibrary.org/gfmr07.pdf.

[117] *Global Fissile Material Report 2013*, 21.

[118] *Global Fissile Material Report 2007*, 72.

[119] Ibid.

[120] "Agreement Between the Government of the United States of America and the Government of the Russian Federation Concerning Cooperation Regarding Plutonium Production Reactors", 23 September 1997, http://ipfmlibrary.org/gov97.pdf; Anatoly Dyakov, "Nuclear Warheads and Weapons-Grade Materials", in Nuclear Reset: Arms Reductions and Nonproliferation, ed. Alexei Arbatov, Vladimir Dvorkin, and Natalia Bubnova (Moscow: Carnegie Moscow Center, 2012), 249–251, http://armscontrol.ru/pubs/en/Diakov-NucWarheads.pdf; "Plutonium from Last Russian Production Reactors—IPFM Blog", accessed 17 July 2014, http://www.fissilematerials.org/blog/2008/07/plutonium_from_last_russian_pr.html.

[121] I. P. Matveyenko, V. G. Dvukhsherstnov, V. F. Yefimenko, et al., "Physical Inventory of Nuclear Materials on BFS Facility" (MPC&A-2000, Obninsk, Russian Federation, 2000).

agree that the material that enters any non-weapon production chain (for example, naval fuel fabrication facility) would be automatically covered by FM(C)T verification arrangements just as newly produced material. In addition, states could choose to submit any additional amounts of material from their weapon stock to FM(C)T downstream verification arrangements.

In the case the future treaty includes provisions that would require states to declare excess material, most of the categories listed in this section would have to come under FM(C)T verification. Essentially, states would be allowed to keep outside of remit of the treaty only the material contained in operational warheads. It is not clear how this distinction could be implemented in practice, especially given that the procedures used to maintain the operational arsenal may vary significantly from country to country.

Finally, if FM(C)T imposes an obligation to eliminate all existing stocks of weapon-grade materials, the treaty would have to find a way to bring all operational weapons as well as all retired weapons and fissile material in reserve, under verification arrangements. There are no technical reasons why a system like that could not be implemented; however, it would require an unprecedented degree of openness on the part of nuclear weapon states.

3.2.2 Unirradiated direct-use material

Extending the FM(C)T definition to include all unirradiated direct-use material would create additional categories of material that would have to be taken into account in considering the issue of pre-existing stocks.

A. Highly enriched uranium

While highly enriched uranium is used in a number of civilian applications, the quantity of this material outside of military stocks is relatively small—only about 40 tons of the approximately 1390 tons in the global HEU stock are considered civilian. However, substantial amounts of HEU are used in ship-propulsion programs—primarily in submarine reactors, but on some civilian ships as well. As discussed earlier, naval reactors in Russia and India are believed to use HEU with enrichment in the 21-45% range. If the FM(C)T definition of fissile material includes all uranium enriched to more than 20%, the material that has been produced for these two programs would have to be considered as well, in addition to the weapon-grade HEU stocks (other countries use either weapon-grade HEU or LEU in their naval reactors). There is no reliable information about the quantity of HEU that Russia has produced for use in naval fuel, but it has been estimated that it may need about 16 tons of HEU (90% enrichment equivalent) to fuel its naval reactors in the next ten years. India has produced about 1 tonne of HEU for naval reactors so far and may increase this amount somewhat in the coming years.[122]

B. Separated civilian plutonium

Separated plutonium accumulated in civilian programs would be a large component of pre-existing stocks of fissile material—in 2013 the total amount of separated civilian plutonium was estimated to be 260 tons (as compared to about 234 tons of military material).[123] Some of this plutonium is already under IAEA or Euratom safeguards, but a substantial amount of the material is not currently safeguarded. Civilian plutonium under safeguards includes all the material that belongs to non-nuclear weapon states and the civilian plutonium in France

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[122] *Global Fissile Material Report 2013*, 13.

[123] This number does not include 49 tons of separated plutonium that the United States has declares to be civilian.

and the United Kingdom.[124] This leaves four countries that have plutonium produced by reprocessing fuel of power reactors or explicitly declared as civilian material—China, India, Russia, the United States.

Although China is working to build a domestic civilian reprocessing program, the amount of plutonium it has separated so far is fairly small—in 2014 China declared having 25.4 kg of the material.[125] However, the amount of civilian plutonium would increase, probably to several tons, in about a decade if the domestic reprocessing program reaches its intended capacity.

In India, there are two categories of plutonium separated from power reactor fuel. About 240 kg of plutonium separated from fuel of safeguarded reactors is currently under safeguards. In addition to this, India has separated about 5 tons of plutonium from fuel of unsafeguarded reactors. It is unlikely that this plutonium is intended to be used directly for weapon purposes; rather, it could be used as fuel in reactors to produce more unsafeguarded plutonium in the future.[126]

Russia has been operating a reprocessing facility that extracts plutonium from fuel of some of the power reactors of Soviet design (as well as of naval and research reactors). It also has a plan to expand its civilian reprocessing program. As of 2013, this program has produced 50.7 tons of separated unirradiated plutonium.[127]

The United States has no domestic civilian reprocessing program. However, it reports 49.0 tons of separated plutonium as civilian in its submissions to the IAEA. This amount is part of the 61.5 tons of the plutonium that the United States declared excess to its military needs—the rest is irradiated, decayed or disposed of material.[128] Most of the separated plutonium declared by the United States as civilian is probably weapon-grade material; most of it is still contained in weapons or weapon components.[129] As mentioned earlier, about two tons of this plutonium has been placed under IAEA safeguards.[130]

C. Uranium-233, neptunium and americium

The amounts of separated U-233 that may be affected by the FM(C)T is unknown, but the existing stocks appear to fairly small. The United States has separated about 1.5 tons of U-233; it plans to dispose of about a third of this material as waste.[131] There is no information about the U-233 stocks in other states, but they are unlikely to be significantly larger.

The quantities of separated neptunium and americium are also relatively small. The global stock of separated americium is estimated to be about one tonne, the amount of separated neptunium is probably of the same order of magnitude. Although some americium has been

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[124] *Global Fissile Material Report 2007*, 73–74.

[125] Communication Received from China Concerning Its Policies Regarding the Management of Plutonium, INFCIRC/549/Add.7/14 (IAEA, 28 August 2015).

[126] "India—International Panel on Fissile Materials", accessed 18 July 2014, http://fissilematerials.org/countries/india.html.

[127] Communication Received from the Russian Federation Concerning Its Policies Regarding the Management of Plutonium, INFCIRC/549/Add.9/15 (IAEA, 23 May 2014).

[128] Communication Received from the United States of America Concerning Its Policies Regarding the Management of Plutonium, INFCIRC/549/Add.6/16 (IAEA, 2 April 2014), http://www.iaea.org/Publications/Documents/Infcircs/2014/infcirc549a6-16.pdf.

[129] *Global Fissile Material Report 2010*, 37.

[130] *Global Fissile Material Report 2007*, 72.

[131] Robert Alvarez, "Managing the Uranium-233 Stockpile of the United States".

produced during cleanup of weapon plutonium, neither of these materials is considered to be part of the military fissile material stockpile.

Should the FM(C)T define fissile material as unirradiated direct-use material, most of the issues related to scope would focus on weapon-grade materials that have been produced for weapon programs, rather than on the existing civilian stocks. Nevertheless, it would be important to take these stocks into account when considering the issue of scope.

If the treaty does not cover any pre-existing stocks, then the HEU with enrichment below the weapon-grade (or intermediate-grade) would not be covered by verification arrangements. It is rather unlikely that this HEU would be directly used in nuclear weapons. However, it could theoretically be used as a feed material for clandestine production of HEU for weapon programs. A robust FM(C)T verification system should be able to detect this kind of clandestine production, but the presence of an unaccountable stock of HEU would make this task more difficult (however, a similar challenge would be posed by the LEU with enrichments just below the 20% HEU threshold).

The situation with civilian plutonium is somewhat different. As discussed earlier, this plutonium can be used directly in nuclear weapons. Since the production of civilian plutonium is unlikely to stop, the FM(C)T verification system would have to deal with two categories of this material—produced before and after the treaty's entry into force. This could seriously complicate the verification arrangements and reduce the effectiveness of the verification system.

Most of these problems could be avoided if the FM(C)T requires member states to submit all their pre-existing stocks of civilian material to verification. This decision, suggested in some proposals, could be made even if the treaty leaves the stocks of military fissile materials outside of its scope.[132] This measure should be uncontroversial since most countries already treat their civilian and military fissile materials separately. Under this arrangement, the HEU reserved for naval reactors could be placed under FM(C)T verification or declared part of the military stock. . The unsafeguarded reactor-grade plutonium in India could be brought under FM(C)T verification as well, since once FM(C)T is in force the main rationale for keeping it outside of safeguards—production of new weapon material—would no longer be valid. The plutonium declared by the United States as civilian may have to be included in the military stock, at least initially, to be dealt with later as excess material.

3.2.3 Nuclear material

If the FM(C)T parties agree that the treaty should cover all categories of nuclear material as defined in the Article XX of the IAEA Statute, then placing all pre-existing stocks under verification appears to be the only practical solution of the scope issue. Otherwise, the treaty verification arrangements, having to deal separately with material produced before and after entry into force in every category, would become extremely complicated. Also, if the negotiators agree on a broad definition of fissile material, reaching an agreement on the scope should be relatively easy. A much more important issue related to scope would be whether the materials in weapons and weapon reserve would be exempt from the treaty coverage.

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[132] *IPFM Report 2008: Scope and Verification of a FM(C)T*, 34.

3.3 Transparency

Transparency of fissile materials holdings is an important element of most proposals that deal with the scope of a fissile material control regime. The options that have been suggested so far call for a variety of transparency measures that could be applied to the existing materials, including those that would be left outside of the treaty scope. It is not surprising that transparency of weapon stocks has been at the focus of the discussion, although other categories of fissile materials would be affected by the transparency provisions as well.

If the FM(C)T does not cover existing stocks of fissile materials, it would be logical to assume that member states would have no obligation to report the size and composition of the stocks that have been created before the treaty's entry into force. However, a number of states, while supporting limiting the scope of the FM(C)T to future production, expressed their preference for implementing transparency measures, most likely as a separate arrangement (such as the Fissile Material Control Initiative).[133] This approach would require member states to make declarations of fissile materials for use in nuclear weapons even if these materials are not covered by the treaty. Two nuclear weapon states—the United States and the United Kingdom—have published detailed accounts of their military stocks of plutonium and HEU.[134] These accounts set an example that other states could follow. At the same time, the information in these publicly released accounts does not disclose some information that would be important in the FM(C)T context. For example, neither country has released data on the amount of material assigned to active nuclear warheads. Even though voluntary declarations could be an valuable confidence-building tool, it would be difficult to include them in the treaty if it does not explicitly cover the existing stocks. Also, without a verification mechanism, the value of these declarations would be uncertain.

If the treaty definition of fissile material is broader than weapon-grade (or intermediate-grade) material, the transparency arrangements would affect nuclear-weapon as well as non-nuclear weapon states. It should be noted that today no state has an obligation to publicly declare the amount of nuclear materials in its possession. Non-nuclear weapon states make this information available to IAEA as part of their safeguards obligations. However, IAEA has no authority to disclose this information. A number of states release data on their nuclear material holdings on a voluntary basis. For example, a number of states submit to IAEA annual declarations, released as INFCIRC/549 documents, of their civilian plutonium (and, in some cases, HEU) stocks.[135] States may also publish national reports—for example, Japan is making public information about its plutonium stock.[136] It has been suggested that these reports could become a model for universal declarations of fissile material holdings.[137]

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[133] CD/1770; CD/1910; CD/1918; Robert J. Einhorn, "Controlling Fissile Materials and Ending Nuclear Testing".

[134] "Plutonium: The First 50 Years. United States Plutonium Production, Acquisition, and Utilization from 1944 through 1994" (U.S. Department of Energy, February 1996); "The United States Plutonium Balance, 1944–2009. An Update of Plutonium: The First 50 Years, DOE/DP-0137, February 1996" (Department of Energy, June 2012), http://fissilematerials.org/library/doe12.pdf; "Highly Enriched Uranium: Striking a Balance"; "Historical Accounting for UK Defence Highly Enriched Uranium. A Report by the Ministry of Defence on the Role of Historical Accounting for Highly Enriched Uranium for the United Kingdom's Defence Nuclear Programmes" (UK Ministry of Defence, March 2006), http://fissilematerials.org/library/mod06.pdf; "The United Kingdom's Defence Nuclear Weapons Programme", n.d., www.ipfmlibrary.org/mod00b.pdf.

[135] INFCIRC/549 reports are submitted by Japan, Germany, Belgium, Switzerland, France, the United States, China, the United Kingdom, and the Russian Federation. Germany, France, and the United Kingdom include information about their civilian HEU stocks.

[136] "Current Situation of Plutonium Management in Japan", Japan Atomic Energy Commission (JAEC), accessed 19 July 2014, http://www.aec.go.jp/jicst/NC/iinkai/teirei/plutonium_management.htm.

[137] CD/1770.

However, the experience with the INFCIRC/549 reports has demonstrated the limits of voluntary declarations. Even though the participating states agreed on a standard reporting form, there is no consistency in the information submitted by individual states. For example, the United States includes its excess military plutonium in the report (as well as the material that has decayed or disposed of), while Russia does not. Also, states differ in their approach to reporting holdings of separated plutonium. Since there is no verification mechanism, the submitted information may contain errors.[138]

As a more limited transparency measure, nuclear weapon states could be asked to provide reports on the amount of their weapon-grade material declared excess to weapon needs. This requirement could be a natural part of the approach to FM(C)T scope that includes voluntary or mandatory declarations of excess material. In this case, the reporting requirement as well as the specific reporting guidelines could be included in the treaty. Non-nuclear weapon states would probably have to submit these declarations as well, as their fissile materials would have the same status as the excess material in nuclear weapon states.

3.4 Excess and disarmament material

Whether or not the FM(C)T covers the existing stocks of weapon material, it is widely accepted that the treaty could include measures to ensure that any material that has been declared excess is no longer available for weapon (or, more generally, to military) purposes. In some proposals the treaty should make excess declarations mandatory, in others member states would be allowed to make them an a voluntary basis.

Once the excess material is made available in a form that could be placed under verification, it should be relatively easy to ensure that it cannot be returned for use in weapons. The FM(C)T verification system could handle this material just as it would any new material produced for non-proscribed uses. However, the experience with excess material declarations made by nuclear weapon states indicates that implementation of this initial step—making the material available for verification—would require dealing with a number of serious challenges.

As of 2016, three states—Russia, the United States, and the United Kingdom—declared parts of their fissile material stock excess for weapon or military purposes. The United States declared 61.5 tons of plutonium and 174 tons of HEU excess to military purposes and an additional 200 tons of HEU as excess to weapon purposes. The excess stock includes a range of categories of fissile materials: only 49 tons of plutonium is separated unirradiated plutonium. About 211 tons of HEU, most of which with less than 90% enrichment, was designated for down-blending or geologic disposal, 152 tons of weapon-grade HEU is reserved for naval fuel. As of the end of 2012, approximately 141 tons had been downblended.[139] Russia has declared up to 50 tons of its weapon-grade plutonium and 500 tons of its weapon-grade HEU excess for military purposes. By the end of 2013, all 500 tons of excess HEU had been down-blended as part of the U.S.-Russian bilateral HEU-LEU

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[138] "An Error in Japan's Civilian Plutonium Declarations", *IPFM Blog*, 7 June 2014, http://fissilematerials.org/blog/2014/06/an_error_in_japans_civili.html.

[139] *Global Fissile Material Report 2013*, 11–12.

agreement.[140] The United Kingdom declared excess and placed under safeguards 4.4 tons of plutonium, of which only 0.3 tons comes from the weapon stock.[141]

With the exception of the 4.4 tons of excess U.K. plutonium and 2 tons of plutonium that has be placed under IAEA safeguards in the United States, none of the excess material is under international safeguards. Some Russian excess plutonium is being monitored by the United States under a bilateral agreement that does not involve the IAEA. Moreover, most of the excess material is apparently still contained in weapons, weapon components, or in other classified forms and therefore is not immediately available for verification. This situation shows that in order to deal with excess weapon material, the FM(C)T should probably make a distinction between a general commitment to designate a certain amount of material as excess (sometimes called unverified excess material) and actual availability of the material that could be submitted to FM(C)T verification (verified excess material).[142]

Experience of dealing with excess material suggests that it would be difficult to convert it to a form suitable for verification. As a rule, fissile materials are converted to this form only in connection with the disposition process. This was the case with the 500 tons of Russian excess HEU—the material, which came from the military stock, was made available for verification only after it entered the down-blending process.[143] It took almost 20 years to complete the program. In the United States, the rate of HEU down-blending is apparently set by the progress in weapon disassembly activities.

The structure of the U.S.-Russian plutonium disposition program also suggests that no material will be made available for verification or safeguards unless it enters the disposition process. Under the Plutonium Management and Disposition Agreement, finalized in 2010, Russia and the United States committed to eliminate 34 tons of weapon-grade plutonium each.[144] The parties agreed to implement verification measures with respect to their disposition programs and submitted a formal request to the IAEA.[145] However, it appears that IAEA will be involved only when the material enters fuel fabrication facilities and at no point the stock of excess plutonium will be placed under safeguards.[146] The actual disposition activities are not expected to begin until at least 2018; they will end no earlier than 2030—more than 30 years after the plutonium was declared excess.

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140 “Last HEU-LEU Program Shipment to Leave Russia—IPFM Blog”, accessed 20 July 2014, http://fissilematerials.org/blog/2013/11/last_shipment_of_heu-leu_.html; “The Agreement between the Government of the United States of America and the Government of the Russian Federation Concerning the Disposition of Highly Enriched Uranium Extracted from Nuclear Weapons”, 18 February 1993, http://ipfmlibrary.org/heuleu93.pdf.

141 *Global Fissile Material Report 2010*, 78.

142 William Walker and Frans Berkhout, *Fissile Material Stocks*, 6; CD/1906.

143 Oleg Bukharin, “Understanding Russia’s Uranium Enrichment Complex”, *Science & Global Security* 12, no. 3 (2004), 211–213.

144 “U.S.-Russian Plutonium Management and Disposition Agreement”, *IPFM Blog*, 11 May 2010, http://fissilematerials.org/blog/2010/05/us-russian_plutonium_mana.html; “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 (as Amended by 2010 Protocol)”, 13 April 2010, http://ipfmlibrary.org/PMDA2010.pdf.

145 Communication from the Permanent Missions of the Russian Federation and the United States of America Regarding a Joint Letter Regarding the Agreement Concerning the Management and Disposition of Plutonium Designated as No Longer Required for Defense Purposes and Related Cooperation, INFCIRC/806 (IAEA, 16 September 2010), http://www.iaea.org/Publications/Documents/Infcircs/2010/infcirc806.pdf.

146 Anatoly Dyakov, “Nuclear Warheads and Weapons-Grade Materials”, 6.

Attempts to place weapon-origin excess material under verification before it enters the disposition process have been largely unsuccessful. In the 1990s, the United States and Russia tried to reach an agreement on verification measures that would apply to plutonium stored in the Mayak Fissile Material Storage Facility, build in Russia with U.S. assistance. While some technical issues have been resolved, in the end the parties were unable to agree on procedures that would allow to verify that the plutonium in storage is weapon-origin.[147] The facility was put into operation in 2006 with no verification arrangements; it reportedly contains about 25 tons of Russia's excess weapon-grade plutonium. Since the material appears to be in classified form, it is unclear if Russia would be ready to submit it to verification.

The United States has also considered the idea of placing its excess plutonium under safeguards while the material is still in weapon components. At some point in the 1990s, it examined a possibility of giving the IAEA access to parts of the Pantex Plant in Texas, which stores plutonium weapon components. This idea was later abandoned.

In 1996, the United States, Russia, and the IAEA launched a Trilateral Initiative, specifically aimed at developing a mechanism that would allow the IAEA to monitor stocks of fissile materials in classified form.[148] Even though the project demonstrated feasibility of dealing with classified forms of material, it was terminated in 2002. It appears that the United States and Russia were satisfied with the level of transparency in their excess material disposition programs they achieved by that time. It should be noted that the initiative dealt only with weapon-origin plutonium. As for HEU, the some verification measures have been implemented in the HEU-LEU agreement. Specifically, the United States was able to verity that the HEU that enters the down-blending process is weapon-grade and that is not a freshly produced material, suggesting that the material is weapon-origin.[149]

The issue of excess stocks is closely related to the issue of so-called disarmament material. A great number of states strongly support measures that would ensure that fissile materials released in the process of nuclear disarmament process could not be used again for weapon purposes. From the point of view of FM(C)T implementation, these measures should not present any problems as long as the material produced in the process of warhead dismantlement is declared excess and submitted to the FM(C)T verification. This process should be fairly straightforward since the disarmament material would be produced as verified excess material.

The main problem with disarmament material is getting nuclear weapon states agree on disarmament measures that would include elimination of warheads as part of reductions of their nuclear arsenals. So far, no arms control and disarmament agreement required its parties to eliminate nuclear warheads. The only known attempt to include warhead elimination in the disarmament process was made in 1997, when Russia and the United States agreed to address these issues in the START II follow-on treaty.[150] However, this effort did not produce any result and was abandoned when the United States and Russia decided not to continue the START II process in 2002. The prospects for a new agreement of this kind, whether bilateral or multilateral, seem remote. Although the FM(C)T could include procedures for verified elimination of warheads, it may not be the best forum to do so, as these issues are

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[147] Ibid., 250.

[148] *IPFM Report 2008: Scope and Verification of a FM(C)T*, Chapter 6.

[149] Oleg Bukharin, "Understanding Russia's Uranium Enrichment Complex", 211–213.

[150] "Joint Statement on Parameters on Future Reductions in Nuclear Forces, Helsinki Summit", 21 March 1997.

closely linked to other aspects of nuclear disarmament that are far outside of the scope of the treaty—elimination of launchers, strategic stability, and others. Instead, the treaty could leave these issues to the weapon states involved in nuclear disarmament and concentrate on handling the material released from the warheads to ensure irreversibility of the reductions.

4. Conclusion

As this overview demonstrates, there is a wide range of options for dealing with the issues of definitions, verification, and scope in the future treaty. However, regardless of the specific choices that are made regarding these issues, an FM(C)T would be a valuable new element of the international security architecture. In addition to stopping production of fissile materials for weapons, it would create a verification system that would cover all fissile material production facilities and provide a mechanism that could support nuclear disarmament. It is important to underscore that regardless of whether the future FM(C)T includes specific provisions for dealing with existing stocks, the treaty will create the legal and organizational framework able to handle all categories of existing fissile materials—the material declared excess, the disarmament material, as well as the material that is currently in weapons. Even if at the early stages of its implementation an FM(C)T only addresses the material produced after entry into force, its verification system could be later expanded to accept the existing stocks and ensure their safe and secure disposition under international control.

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Fissile Material (Cut-off) Treaty: Definitions, Verification, and Scope

This paper aims to present a summary of the issues related to definitions, verification and scope taking into account the most recent discussions that have taken place in the expert community. The first section considers various approaches to defining the term fissile material for FM(C)T purposes. The second section examines how different approaches to definitions would affect the treaty verification activities; both downstream verification as well as verification measures that would have to be implemented at production facilities. The final section presents an overview of the measures that would be required to extend the scope of the treaty to pre-existing stocks and to ensure irreversible elimination of excess military material.