A Treaty on Fissile Materials *Just a Cut-off or More?*

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

Why a treaty is important—four goals

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

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

The uncontested minimum goal of an FM(C)T is a ban on future production of fissile material for explosive purposes. This means that the quantities can only be reduced, not increased. The FM(C)T can be compared to the CTBT: while the CTBT can be regarded as a tool to cap the *qualitative* nuclear arms race, for example to hinder the future development of qualitatively new nuclear explosives, the FM(C)T can be seen as its *quantitative* counterpart, capping the amount of material available for new nuclear weapons.[1]

Therefore, both treaties were labelled as "nuclear disarmament measures" in terms of article VI of the NPT and were included in the list of Principles and Objectives for Nuclear Non-proliferation and Disarmament at the NPT Review and Extension Conference 1995. Successful FM(C)T negotiations therefore would strengthen the NPT.

Critics maintain that this is not enough, since large quantities of fissile materials are excess. They are owned by the nuclear-weapon states and exceed the quantities needed for a potential rearmament up to numbers of the peak of the Cold War. Therefore, they claim, it is necessary to reduce the existing quantities. Only then would a treaty have the effect of nuclear disarmament. This view is rejected by several

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

delegations. This conflict played a central role already during the negotiations of the Shannon Mandate, and similarly it will play a central role in the negotiations on scope.

Goal II: Reducing the discrimination of the NPT

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

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

Goal III: Drawing in states outside the NPT

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

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

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

The topic of the negotiations: "Fissile materials"

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

Fissile materials can be classified according to various categories. The most appropriate categorization for an FM(C)T is the criterion of ease of use in nuclear explosives. Similarly, the IAEA defines various categories according to this criterion. These categories are "direct use material", "indirect use material", "special fissionable material", "nuclear material" and "other material". They imply different regulations for safeguards—the less technical effort necessary to use a given material for nuclear explosives, the more frequent and intrusive are the safeguards. Direct use material, for example plutonium or highly enriched uranium (HEU), can be used with only little technical effort. Special fissionable material, for example spent fuel, natural uranium or low enriched uranium (LEU), needs reprocessing or enrichment in order to transform it into direct use material. The effort required for the other categories of materials is even higher.[2]

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

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

Plutonium

Plutonium is categorized as a direct use material. It does not occur naturally but is the product of nuclear reactions, mostly when uranium-238 is hit by neutrons. This can happen in a nuclear reactor or with any other neutron source. The plutonium isotopes are separated from the spent fuel by "reprocessing". It is a combination of mechanical and chemical methods and radiation shielding technologies. The quantity of material needed for one warhead can be one to a few kilograms.[3]

Presumably, some delegations will advocate the position that only so-called "weapon grade plutonium" should be subjected to the treaty, and the so-called "reactor grade" plutonium should be left out. But this would create a fatal gap into the treaty. Normally, plutonium consists of a mix of various isotopes whose composition depends on the type of production facility. The IAEA definition of direct use material includes all plutonium isotopes and compositions except plutonium containing more than 80% plutonium-238, which is highly radioactive. It

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

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

also includes chemical mixtures containing plutonium. In the past, the usability in weapons of different isotopic compositions has been subject to debate because different categorization implies different safeguards and non-proliferation measures.[4] Plutonium that has remained in a power reactor for a long time consists of a substantial fraction of “higher” isotopes that are more radioactive than the comparatively stable plutonium-239. Reactor-grade plutonium therefore emits more unwanted radiation, including neutrons, and develops unwanted heat. These effects pose technical challenges in all uses, be they nuclear weapons or civilian fuel.

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

Since the nuclear-weapon states prefer weapon-grade to reactor-grade plutonium for warhead construction, it had been reasoned that the latter cannot be used at all for nuclear explosives. These debates have largely ceased, thanks to publications of plausible technical arguments that illustrate the feasibility of nuclear explosives made from reactor-grade plutonium.[5] Today, it is widely recognized that all kinds of plutonium can be used for nuclear explosives and must be safeguarded accordingly, except plutonium-238. Nevertheless, most existing nuclear warheads are made from weapon-grade plutonium. Explosives made from reactor-grade plutonium would need a different design. The plutonium arising and used in civilian nuclear industry is mainly reactor-grade plutonium.

Uranium

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

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

5 Kankeleit made his calculations by using historic quotations from open sources; ibid. Later, his arguments were confirmed by former nuclear weapon designer J. Carson Mark, “Explosive Properties of Reactor-Grade Plutonium”, *Science & Global Security*, vol. 4, p. 111, 1993; and by the Committee on International Security and Arms Control, *Management and Disposition of Excess Weapons Plutonium*, National Academy of Sciences, 1994; Committee on International Security and Arms Control, *Management and Disposition of Excess Weapons Plutonium: Reactor Related Options*, National Academy of Sciences, 1995; and Committee on International Security and Arms Control, *Monitoring Nuclear Weapons and Nuclear-Explosive Materials*, National Academy of Sciences, 2005.

Presumably, some delegations will advocate the position that at only HEU enriched above 90% should be subjected to a treaty. But this would create a fatal gap into the treaty. Firstly, a crude nuclear explosive could be constructed with a uranium-235 content well below this value. Secondly, the effort required to further enrich HEU is far lower than the effort required to enrich LEU or natural uranium. And thirdly, a new interpretation would undermine respect of the IAEA definitions and its safeguards for the NPT. It would also undermine current efforts to phase out any civilian use of HEU. [6]

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

Ordinary power reactors use LEU or natural uranium. The only civilian application of HEU is in research reactors. In order reduce proliferation dangers, successful international projects have been underway for years on the conversion of research reactors from HEU fuel to LEU fuel.[7] However, another non-weapon application is as fuel for naval propulsion. It is strongly recommended to subject naval propulsion reactors to similar conversion.

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

Other isotopes and other mixtures

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

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

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

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

fuel or LEU fall into the broader category of special fissionable materials, which is defined as all those materials that contain any fissile isotopes.

Variations of scope

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

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

The 2009 report by the International Panel on Fissile Materials (IPFM) gives an overview on the quantities of stocks in the various categories.[8]

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

No regulations at all

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

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

Comprehensive disarmament

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

Irreversibility by a ban on redesignation to explosive needs

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

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

Declarations of excess fissile material

Some nuclear-weapon states possess large quantities of excess fissile materials without safeguards. Most of it is from dismantled nuclear weapons or from nuclear weapon fabrication processes. Some civilian direct-use material comes from use in civilian reactors all over the world in the context of the US "take-back" programme.[9]

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

What is transparency of stocks? There is a broad spectrum of variants. Information that is useful for the preparation of safeguards and disarmament and could potentially be published includes quantities of plutonium and HEU in nuclear weapons and reserves, excess or civilian stocks, and information on isotopics and physical properties, for example how much is still in the form of pits (nuclear weapon cores) and how much is in other forms. Other information includes locations, for example storage, maintenance or disposition facilities. It would be helpful to provide documentation of the production history for a future comprehensive accountancy of all stocks. Those states that call for the inclusion of previously fabricated

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

material should be among the first to provide such information. A promising example is the publication in February 1996 by the United States of its plutonium production and use from 1944 through 1994.[10] In 2001, the United States also published its HEU production and use from 1945 to 1996.[11] In 2000, the United Kingdom published information on its plutonium production.[12] Taking an inventory by national means is the first step to prepare for international verification.

Safeguards on declared excess fissile materials

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

The United States and Russia cooperate with some other states in order to dispose of excess fissile materials. There is a plan to dilute excess HEU to LEU for civilian nuclear industry. The methods of how to dispose of excess plutonium have been discussed and studied for years. The most realistic scenario seems to be the option to fabricate MOX for civilian nuclear energy. But the successful accomplishment of these plans will take decades, mainly for technical and economic reasons. In the meantime, the material will be stored, bearing the risk of rearmament or proliferation. Therefore, irreversible safeguards would be a quick disarmament measure the implementation of which is comparatively easy. On various occasions, Russia, the United States and various international groups have declared their wish to place excess weapons material under international safeguards, however, "as soon as practicable".[13]

Another variant of scope would be the commitment to set high standards of physical protection and material accountancy. The call for universal safeguards and more transparency is not new, but its implementation is still at its very beginning. The opposition has various reasons: the first is the claim that too much sensitive information would be revealed. Initially, excess fissile material would be in forms that would reveal too much on the construction of warheads. Before safeguards can be implemented, the material must be transformed. It is also recommended that nuclear-weapon states pursue a detailed analysis of their secrecy regulations and decide whether some information that would be useful for transparency and verification could be revealed. A prominent example of such an endeavour is the "Openness Initiative" that the United States undertook in the mid-1990s and that led to great efforts to be accountable for the whereabouts of US fissile material both to the international community and to the American people.[14]

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

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

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

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

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

A ban on production of HEU for submarines and naval vessels

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

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

Firstly, the HEU and the submarines are kept extremely secret. Should this secrecy be maintained, it would not be possible to verify that the HEU is indeed used as fuel. Theoretically, non-nuclear-weapon states under the NPT would be allowed to withdraw HEU for use in military naval vessels: in INFCIRC/153 (§14b), it is foreseen that verification of fuel in a "non-proscribed military activity" is renounced as long as the nuclear material is used in such an activity. The Agency and the state shall make an arrangement that identifies "to the extent possible, the period or circumstances during which safeguards will not be applied". This implies that so far it is not clearly defined under which conditions safeguards of the fuel are interrupted. The interruption could be limited only to fuel in the reactor, or it could also be applied to specific naval fuel storage sites. "In any event, the safeguards provided for in the Agreement shall again apply as soon as the nuclear material is reintroduced into a peaceful nuclear activity", and verification procedures still would have to be developed to ensure that it is not diverted for other purposes. This has never happened and there is no practical experience on how to provide assurance on the one hand but to maintain the secrecy on the other.[15] It is incomprehensible why the owners maintain such extreme secrecy on their naval fuel. While many educated discussions take place in academic and diplomatic fora on the nuclear disarmament of fissile materials, for civilian as well as for explosive purposes, only few discussions on naval fuel take place, and they probe only vaguely at the surface of the problem.

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

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

Fourthly, the major role of military submarines is deterrence of nuclear first strikes. The demand to be allowed to produce HEU after many decades is equivalent to the concession that nuclear deterrence will still be needed after this long time. In other words, those who believe that they need to produce new nuclear submarine fuel in the far future do not think that comprehensive nuclear disarmament will ever be possible or should be strived for. This would be a contradiction of article VI of the NPT and would also be a contradiction of the spirit

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

of the FM(C)T that is officially declared as “nuclear disarmament measures” in terms of article VI, in the list of Principles and Objectives for Nuclear Non-proliferation and Disarmament.

Prospects

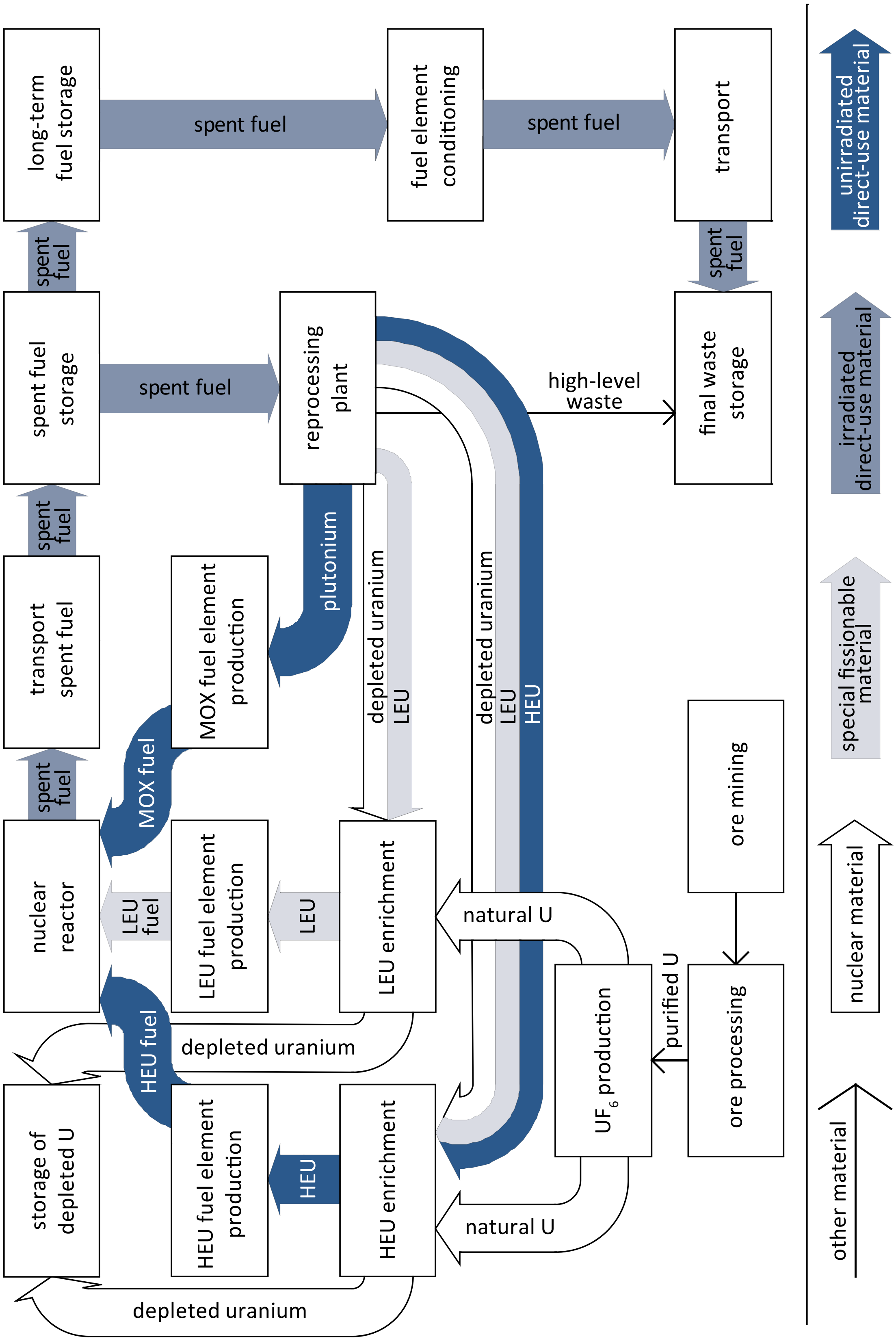
There are many benefits of an FM(C)T, and there are many variations of scope for a treaty that more or less promote the benefits. Another topic that has not been covered in this paper but is as important is verification. Again, there is a broad spectrum of possibilities, ranging from a thorough approach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

Annex A. Materials, their IAEA categories and their role for nuclear explosives

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

<table>
<tr><th>Material</th><th colspan="4">IAEA Category
(sfm = special fissionable material)</th><th>Role for nuclear explosives</th></tr>
<tr><td>weapon-grade plutonium
high content of Pu-239</td><td rowspan="2">nuclear material</td><td rowspan="2">“plutonium” with no legal distinction</td><td rowspan="2">direct-use material</td><td rowspan="2">sfm</td><td>as explosive</td></tr>
<tr><td>reactor-grade plutonium
Pu-239 and substantial fractions of other plutonium isotopes</td><td>as explosive, but with technical disadvantages</td></tr>
<tr><td>Pu-238 mixtures (> 80%)</td><td colspan="4">none</td><td>none</td></tr>
<tr><td>weapon-grade HEU
high content of U-235
(> 90 %)</td><td rowspan="13">nuclear material</td><td rowspan="2">HEU with no legal distinction</td><td rowspan="2">direct-use material</td><td rowspan="3">sfm</td><td>as explosive</td></tr>
<tr><td>lower grades of HEU</td><td>as explosive, but this is more difficult than with weapon-grade HEU</td></tr>
<tr><td>LEU
U-235 enriched to < 20%</td><td colspan="2"></td><td rowspan="3">enrichment necessary to produce HEU, or irradiation to produce plutonium</td></tr>
<tr><td>natural uranium
U-238 with U-235 content = 0.7 %</td><td colspan="3" rowspan="2">source material</td></tr>
<tr><td>depleted uranium
U-235 content < 0.7 %</td></tr>
<tr><td>U-233</td><td colspan="2" rowspan="2">direct-use material</td><td rowspan="2">sfm</td><td>as explosive</td></tr>
<tr><td>mixtures containing U-233</td><td>separation produces U-233</td></tr>
<tr><td>thorium (Th-232)</td><td colspan="3">source material</td><td>can be irradiated to produce U-233</td></tr>
<tr><td>neptunium (Np-237)</td><td colspan="3">No categorization, but material accountancy</td><td>as explosive</td></tr>
<tr><td>americium (Am-241)</td><td colspan="3">No categorization, but reporting</td><td>as explosive, but only with extreme technical sophistication</td></tr>
<tr><td>MOX
mixture of uranium and plutonium</td><td rowspan="3">direct-use material</td><td rowspan="2">unirradiated</td><td rowspan="3">sfm</td><td>plutonium must first be chemically separated</td></tr>
<tr><td>Fresh spent fuel
U-238, U235, plutonium and highly radioactive isotopes</td><td>reprocessing produces plutonium</td></tr>
<tr><td>Older spent fuel (> 10–20 years)
U-238, U-235, plutonium and less radioactive isotopes</td><td>irradiated</td><td>reprocessing and handling is easier</td></tr>
<tr><td>ore, ore residue (e.g. yellow cake)</td><td colspan="4">none</td><td>yields natural uranium</td></tr>
<tr><td>tritium</td><td colspan="4">none</td><td>for fusion processes during a nuclear explosion</td></tr>
</table>

Annex B. Facilities and material flows in nuclear fuel cycles with IAEA classification



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Note

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