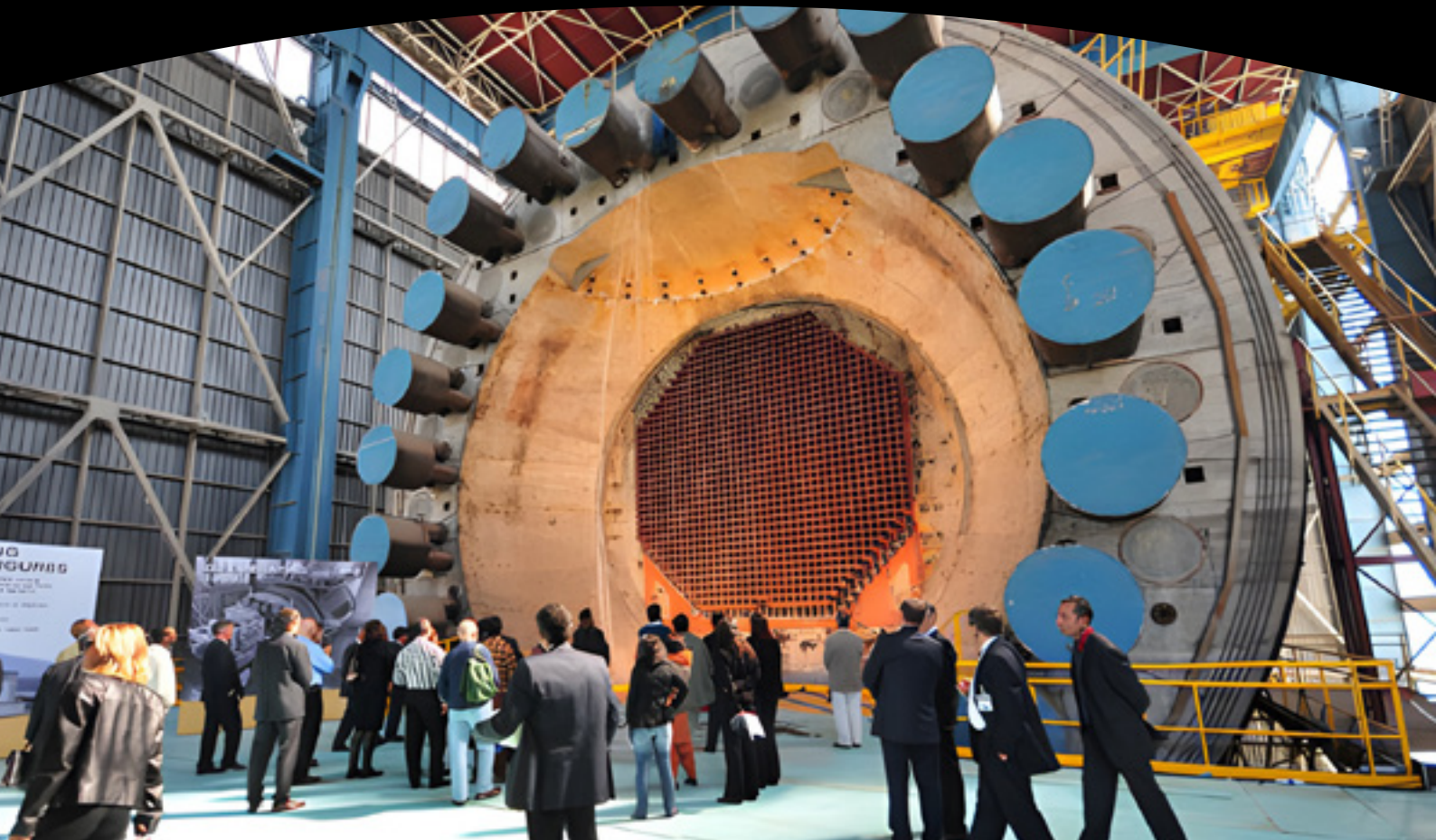




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# Taking stock of the fissile material cut-off treaty process

PAVEL PODVIG



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# About the author

**Pavel Podvig** is a Senior Researcher in the WMD Programme at UNIDIR. His current research focuses on nuclear disarmament, arms control and nuclear security. He is also a researcher with the Programme on Science and Global Security at Princeton University and a member of the International Panel on Fissile Materials. He runs his own research project on Russian Nuclear Forces. Podvig started his work at the Centre for Arms Control Studies of the Moscow Institute of Physics and Technology (MIPT). He holds a PhD in political science from the Institute of World Economy and International Relations (IMEMO), Moscow, and a degree in physics from MIPT.

## Abbreviations

<b>FMCT</b>	Fissile Material Cut-off Treaty
<b>ICJ</b>	Group of Governmental Experts
<b>HEU</b>	Highly enriched uranium
<b>IAEA</b>	International Atomic Energy Agency
<b>LEU</b>	Low-enriched uranium
<b>NPT</b>	Non-Proliferation Treaty
<b>PMDA</b>	Plutonium Management and Disposition Agreement

# Executive Summary

The pursuit of a treaty to ban the production of fissile materials for weapons and other nuclear explosive devices – commonly referred to as a Fissile Material Cut-off Treaty (FMCT) – has been an important element of efforts to advance nuclear disarmament and strengthen the nuclear non-proliferation regime for more than three decades.

Several initiatives over the past decade have advanced the discussions on an FMCT. In addition, several states have indicated strong support for beginning negotiations on an FMCT, including through a recent initiative led by the Government of Japan. In December 2023, the United Nations General Assembly adopted a resolution that urged the Conference on Disarmament to begin negotiating a treaty and urged states that possess or produce fissile materials for weapons to engage in transparency and confidence-building measures. However, the prospects for commencing negotiations in the Conference on Disarmament remain uncertain.

This paper outlines some of the issues that have complicated progress in the negotiation of an FMCT and lays out options for states to consider in seeking to revive discussions around this important concept. It covers some of the key questions regarding a future treaty, including whether or not the FMCT should be a disarmament treaty – that is, whether it should require the active elimination of fissile materials. The paper then lays out options for dealing with the related challenge of how to deal with existing stocks before considering issues related to transfers of fissile materials as well as options for transparency and confidence-building measures.

On the question of whether an FMCT would be a **disarmament treaty**, it is widely recognized that a world free of nuclear weapons would be impossible without an effective ban on the production of fissile materials for weapons. However, there is disagreement on the role of such a ban in the nuclear disarmament process. Important work encompassed in the 1995 Shannon report explicitly covered the future production of fissile materials; however, that report also noted that states can raise any other issues, including those related to past production or management of fissile materials, during the negotiations.

In terms of options for dealing with the related challenge of existing stocks, regardless of whether the treaty includes **existing stocks** in its scope, the elimination of weapon-related fissile materials is likely to follow the same route: it will focus on the materials released from the weapon programmes either unilaterally or as a result of bilateral or multilateral disarmament agreements. The most important contribution to this process that an FMCT could make would be establishing a mechanism for the verifiable elimination of weapon-related materials under international control. The treaty could also add a layer of accountability by requiring states parties to provide information about their fissile material holdings.

The mandate for an FMCT is to end the production of fissile materials for weapons. However, production is not the only route to obtaining fissile materials as a state can acquire materials through a **transfer** from another state. An approach to banning the production of fissile materials for weapons should include a strategy for managing transfers of weapon-usable materials between nuclear-armed states. Such a strategy needs to consider both transfers of materials intended explicitly for weapon purposes and transfers of fissile materials for non-weapon military uses (e.g., naval propulsion or military research reactors).

Regarding the issue of **transparency and confidence-building measures**, several states have implemented transparency measures, including through declarations of fissile material stocks and the voluntary submission of data on amounts of separated plutonium. Such information provides an important insight into the status of stockpiles and material-management programmes. Although transparency and confidence-building measures are no substitute for a legally binding agreement, they can help create conditions for the commencement of negotiations. In contrast, the suspension of transparency measures can generate ambiguities, raise questions in relation to a state's activities and complicate the commencement of negotiations on an FMCT. To this end, states should be encouraged to report the size of their fissile material holdings and to expand on existing reporting practices through the submission of more detailed accounts of material stockpiles and related activities.

# 1 Introduction

A treaty to ban the production of fissile materials for weapons and other nuclear explosive devices – commonly referred to as a Fissile Material Cut-off Treaty (FMCT) – is widely seen as an important element of efforts to advance nuclear disarmament and strengthen the nuclear non-proliferation regime.<sup>1</sup> However, even though more than three decades have passed since the United Nations General Assembly started the process in 1993, the Conference on Disarmament – which has the mandate to negotiate the treaty – remains deadlocked.<sup>2</sup> Despite the Conference establishing subsidiary bodies in 2018 and again in 2022 – including one to deal with issues related to the FMCT – prospects for commencing FMCT negotiations in this forum remain uncertain.

With that said, significant progress has been made outside the Conference on Disarmament. In 2014–2015, a Group of Governmental Experts (GGE) and, in 2017–2018, a High-Level Expert Preparatory Group provided an opportunity for a detailed discussion of key elements of a treaty in a multinational setting.<sup>3</sup> These bodies advanced understandings of national positions on the key elements of a future treaty and the challenges of negotiating an FMCT.

More recently, several states have indicated strong support for advancing work on an FMCT. In 2023, the United Nations General Assembly urged the Conference on Disarmament to commence negotiation on a treaty banning the production of fissile materials for weapons. It also called on Member States to make contributions to facilitate the negotiations in all appropriate formal and informal forums.<sup>4</sup>

In addition, some states have taken the lead in seeking to realize an FMCT. The Government of Japan initiated efforts to revitalize the FMCT process, which was reflected in the Group of Seven (G7) Leaders' Hiroshima Vision on Nuclear Disarmament and the Commemorative High-Level Event on a Fissile Material Cut-Off Treaty co-hosted by Australia, Japan and the Philippines during the General Assembly session in September 2023.<sup>5</sup> Japan's initiatives have emphasized the importance of the early commencement of negotiations on an FMCT. In March 2024, in an address to the United Nations Security Council session on nuclear disarmament, Japan's Foreign Minister announced the establishment of the "FMCT Friends", a cross-regional group with the aim of maintaining and enhancing political attention on an FMCT and contributing to expand the support for the negotiation of an FMCT.<sup>6</sup>

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1 The use of the term "fissile material cut-off" to refer to the treaty should not be interpreted as implying that the treaty will necessarily be limited to a ban on future production.

2 General Assembly, A/RES/48/75, 16 December 1993, <https://undocs.org/A/RES/48/75>.

3 General Assembly, A/70/81, 7 May 2015, <https://undocs.org/A/70/81>; General Assembly, A/73/159, 13 July 2018, <https://undocs.org/A/73/159>.

4 General Assembly, A/RES/78/28, 4 December 2023, <https://undocs.org/A/RES/78/28>.

5 G7 Leaders' Hiroshima Vision on Nuclear Disarmament, 19 May 2023, <https://www.mofa.go.jp/files/100506518.pdf>; Japanese Ministry of Foreign Affairs, "The Commemorative High-Level Event on a Fissile Material Cut-Off Treaty (FMCT)", 28 September 2023, <https://www.youtube.com/watch?v=22RcoXPJNP8>.

6 Kamikawa Yōko, Japanese Foreign Minister, Statement at the Security Council Ministerial Briefing on Nuclear Disarmament and Nonproliferation, 18 March 2024, <https://www.mofa.go.jp/files/100643809.pdf>.

The main reason for the continuing interest in an FMCT is the fact that there is currently no international agreement limiting the production of fissile materials for use in weapons. Several states continue to produce fissile materials for weapons while others maintain the capability to do so. Another important factor is the existence of the large quantities of materials that were produced by various nuclear weapon programmes in the past. While there is no consensus on the issue, a significant number of states believe that an FMCT presents an opportunity to address these existing stocks and to advance nuclear disarmament.

The difficulty of commencing the negotiations on an FMCT testifies to the complexity of the issues involved in the relatively simple and seemingly uncontroversial idea of stopping the production of fissile materials for weapons. A ban on production could affect a variety of interests and may require some innovative technical, legal and institutional solutions.

This paper outlines some of the issues that have complicated progress towards an FMCT in an attempt to stimulate further discussion, help states clarify their differences and potentially find room for a compromise in the future. It draws on the expert discussions during the work of the GGE and the High-Level Expert Preparatory Group and in the Conference on Disarmament. It takes advantage of the draft treaty texts that have been introduced to the Conference on Disarmament by governments and expert groups, as well as an extensive body of research on various aspects of the FMCT, including UNIDIR's own work.<sup>7</sup>

The discussion focuses on the question of whether the FMCT should be a disarmament treaty – that is, whether it should require the active elimination of fissile materials – and the related issue of how the treaty should address existing fissile material stocks. The paper also considers the issue of transfers of fissile material and outlines some transparency and confidence-building measures that states have implemented in the past and could be considered today. The appendix contains an overview of the current status of fissile material stocks and fissile material-production capabilities.

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7 French Delegation to the Conference on Disarmament, “Projet français de Traité interdisant la production de matières fissiles pour les armes nucléaires ou d’autres dispositifs explosifs nucléaires (FMCT)” [French draft treaty banning the production of fissile materials for nuclear weapons or other nuclear explosive devices (FMCT)], 9 April 2015, [https://cd-geneve.delegfrance.org/IMG/pdf/2015-04-09\\_projet\\_traite\\_fmct\\_version\\_finale\\_fra.pdf](https://cd-geneve.delegfrance.org/IMG/pdf/2015-04-09_projet_traite_fmct_version_finale_fra.pdf); International Panel on Fissile Materials (IPFM), *Global Fissile Material Report 2008: Scope and Verification of a Fissile Material (Cutoff) Treaty* (Princeton, NJ: IPFM, 2008), <http://ipfmlibrary.org/gfmr08.pdf>; Conference on Disarmament, CD/1777, 19 May 2006, <https://undocs.org/CD/1777>; Pavel Podvig, “Fissile Material (Cut-off) Treaty: Elements of the Emerging Consensus”, UNIDIR, 2016, <https://unidir.org/files/publication/pdfs/fissile-material-cut-off-treaty-elements-of-the-emerg-ing-consensus-en-650.pdf>; Pavel Podvig, “Fissile Material (Cut-off) Treaty: Definitions, Verification, and Scope”, UNIDIR, 2016, <https://unidir.org/files/publication/pdfs/fmct-definitions-verification-and-scope-en-655.pdf>.



## 2 An FMCT as a disarmament treaty

One of the key questions regarding a future treaty is whether the FMCT should be a disarmament treaty. While it is widely recognized that a world free of nuclear weapons will be impossible without an effective ban on production of fissile materials for weapons, there is disagreement on the role of such a ban in the nuclear disarmament process.

In 1994, the Conference on Disarmament asked Ambassador Gerald Shannon of Canada to gather states' views on the best way to negotiate an FMCT. The mandate suggested in the Shannon report reflected an agreement to negotiate a “non-discriminatory, multilateral and internationally and effectively verifiable treaty banning the production of fissile material for nuclear weapons or other nuclear explosive devices”.<sup>8</sup> Although the mandate only explicitly covers future production of fissile materials, the report noted that the consensus regarding the mandate was made possible by an agreement that states can raise any other issues – including past production or management of fissile materials – during the negotiations.

One argument in favour of an international treaty only banning future production is that it would put a limit on the growth of nuclear arsenals. In particular, it would extend control over key parts of fissile material-production complexes, potentially including those of states that are not party to the existing nuclear non-proliferation regime. Even if such a treaty were not to include direct disarmament obligations, it could be an important stage in step-by-step progress towards nuclear disarmament. Moreover, such a treaty could open space for reduction of nuclear arsenals by contributing to an environment more conducive to nuclear disarmament. Proponents of this approach also point out that a disarmament FMCT would be more difficult to negotiate than a ban on future production and that disarmament obligations can be adopted separately, probably on a bilateral or multilateral basis.

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8 Conference on Disarmament, CD/1299, 24 March 1995, <https://undocs.org/en/CD/1299>.

Opponents of this point of view have expressed concerns that, in the absence of an obligation to reduce or eliminate existing stocks of fissile materials, an FMCT would create a situation in which non-nuclear-weapon states that have not produced fissile materials for weapons will have no leverage over the nuclear disarmament process. Some point to the precedent set by the 1968 Treaty on the Non-Proliferation of Nuclear Weapons (NPT), which gives non-nuclear-weapon states few options to influence the negotiations towards disarmament that the five NPT nuclear-weapon states – China, France, the Russian Federation, the United Kingdom and the United States – committed to pursue. Despite the significant differences between these two approaches, they are not necessarily irreconcilable. For example, a treaty might include a firm commitment to eliminate all fissile materials that could be used for weapons even if its specific prohibitions cover only future production. While such an obligation would be difficult to enforce, it can be made more specific than the arguably unenforceable disarmament obligation in the NPT. It would also present an opportunity to extend a disarmament obligation to states that are not party to the NPT, should they join the future FMCT. The obligation to eliminate fissile material stocks could be made even stronger if the FMCT were to create legal, institutional and technical mechanisms to support this process.

Developing these mechanisms is an important contribution that an FMCT could make to nuclear disarmament. Indeed, regardless of the details of a future treaty, it will have to include provisions for handling new fissile material produced for civilian or non-proscribed military purposes. These provisions will have to be implemented in nuclear-armed states to ensure that newly produced material is not diverted for use in nuclear weapons and that it is verifiably disposed of. These provisions could be readily applied to any existing material designated for elimination.<sup>9</sup> Designing a treaty with this goal in mind could make it more than a simple ban on future production and could create an effective instrument that can support a variety of nuclear disarmament processes.

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9 Podvig, “Fissile Material (Cut-off) Treaty: Elements of the Emerging Consensus”.

# 3 Existing stocks

The question of whether an FMCT becomes a disarmament treaty is closely linked to the question of how it should treat existing stocks of fissile materials. There are a variety of ways in which a treaty could address existing materials. In the simplest version of a treaty, existing stocks of fissile material would be left outside the scope of the agreement. In contrast, a more advanced disarmament-orientated FMCT could impose certain obligations regarding these stocks, such as their partial or even full elimination. Alternatively, the treaty could require its parties to declare their fissile material holdings but without necessarily assuming any other obligations. Regardless of whether the future FMCT is designed to be a disarmament treaty, these steps can be included in the treaty separately or in combination.

## Excess material

One approach would be to focus on the materials that states voluntarily identify as excess to their weapon or military needs. This would not require the treaty to explicitly mention the existing stocks and would not require parties to declare the amount of fissile materials or assume any legally binding obligations regarding these materials.

This approach draws on the post-Cold War experience of eliminating material declared excess for weapon (or military) purposes. Under a US–Russian agreement, the Russian Federation eliminated about 500 tonnes of weapon-origin highly enriched uranium (HEU), converting it to low-enriched uranium (LEU) for use as fuel for power reactors. The United States also eliminated or converted about 163 tonnes of its HEU and about 8 tonnes of plutonium for non-weapon uses. Separate to this, the United Kingdom declared about 5 tonnes of plutonium produced in its military programme to be excess and placed this material under civilian safeguards.<sup>10</sup>

Additionally, the United States and the Russian Federation each identified about 50 tonnes of weapon-related plutonium as excess and, under the bilateral 2010 Plutonium Management and Disposition Agreement (PMDA), each committed to eliminate 34 tonnes of this material in a cooperative process. The two states also worked with the International Atomic Energy Agency (IAEA) on a project known as the Trilateral Initiative to develop procedures that would allow them to place material awaiting disposal under safeguards. The Trilateral Initiative was concluded in 2002 without any material being committed to the safeguards process that it developed.<sup>11</sup> While the PMDA effectively ended after the Russian Federation suspended its participation in 2016, the United States and the Russian Federation confirmed their commitment not to use the PMDA material for military purposes.<sup>12</sup>

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10 International Panel on Fissile Materials (IPFM), *Global Fissile Material Report 2022: – Fifty Years of the Nuclear Non-Proliferation Treaty: Nuclear Weapons, Fissile Materials, and Nuclear Energy* (Princeton, NJ: IPFM, July 2022), <https://fissilematerials.org/library/gfmr22.pdf>.

11 Thomas E. Shea and Laura Rockwood, *IAEA Verification of Fissile Material in Support of Nuclear Disarmament* (Cambridge, MA: Belfer Center, May 2015), <https://www.belfercenter.org/sites/default/files/legacy/files/iaeaverification.pdf>, 2.

12 International Panel on Fissile Materials (IPFM), “Russia Suspends Implementation of Plutonium Disposition Agreement”, IPFM Blog, 3 October 2016, [http://fissilematerials.org/blog/2016/10/russia\\_suspends\\_implement.html](http://fissilematerials.org/blog/2016/10/russia_suspends_implement.html).

Despite the problems encountered by the plutonium-disposition programmes, their approach to eliminating existing fissile materials based on identifying excess material can be considered fairly successful. It has the advantage of not requiring a declaration of the size of a stockpile (although the United States and the United Kingdom both provided accounts of their holdings).

At the same time, this approach has serious limitations. The main problem is that the concept of excess material relies on the judgment made by each state as to the amount of material that is sufficient for military needs. Attempts to define excess material in a formal, legally binding manner are unlikely to be successful as states could refer to their unique security requirements and circumstances in order to justify maintaining a fissile material stock of virtually any size. There is also strong criticism of the very concept of excess material as it confers legitimacy on the use of fissile materials for weapons. This criticism notwithstanding, the approach to the elimination of fissile materials based on voluntary declarations of excess material has its place in the nuclear disarmament toolkit.

## **Disarmament material**

A somewhat different scenario in which an FMCT can effectively deal with existing stocks, even if they are not directly mentioned in the treaty, is related to the concept of “disarmament material.” Under this scenario, fissile material that is released in a separate disarmament process – for example, an agreement that reduces the number of deployed nuclear weapons or eliminates an entire category of weapons – could be verifiably eliminated under the FMCT. The disarmament agreement would need to include a provision that requires the parties to eliminate the material contained in these weapons (or an agreed equivalent amount) using FMCT mechanisms.

Even though any such elimination agreement would be concluded separately from the FMCT, the latter treaty would play a very important role in the process. It would provide parties with established mechanisms and procedures for eliminating the disarmament material under international control. For example, had these mechanisms existed, the United States and the Russian Federation could have agreed to submit the 34 tonnes of plutonium that each committed to eliminate to the FMCT elimination process instead of negotiating the PMDA.

It should be emphasized that the elimination of weapon materials through the disarmament material concept would not require an FMCT to explicitly cover existing stocks, nor would it require states parties to declare the sizes of their respective material holdings.

## Declared material

If the FMCT were to include existing stocks within its scope, there are several ways of dealing with such stocks. At the very least, the states parties could commit to dispose of or convert to peaceful uses the materials that they have already identified as excess. This would strengthen the pledges made by the United States and the Russian Federation, the only two states that have made such a commitment. A treaty could also develop elimination procedures that would be applied to these materials and potentially, in time, additional excess materials. This approach, however, leaves the designation of excess materials to its owners and therefore does not provide a clear path towards consistently identifying additional material for disposal.

A more important step towards full accountability for existing stocks would involve the parties declaring the amount of material in their possession. This declaration would establish a baseline for any future reduction measures that an FMCT might include. Verification of such declarations would be hard since a significant portion of the material is used in weapons or weapon-related applications, and it should be expected that no state will permit the close access to its weapons that would be required for verification. Moreover, even the material declared excess usually retains characteristics that states consider sensitive, as some of it is in weapons that are awaiting dismantlement or in weapon components. These challenges, however, are not insurmountable. The “deferred verification” arrangement, which allows for a separate declaration of sensitive stock, offers a method for making verifiable declarations of fissile material stocks even when access to the material involved in weapon-related activities is not possible.<sup>13</sup> It is also possible to design a procedure for dismantling weapons and disposing of weapon-origin materials without having access to sensitive information.<sup>14</sup>

A more serious challenge lies in developing a mechanism that would determine which materials should be designated for disposal. A declaration would probably include a breakdown of the material holdings by categories, one of which would be material in weapons or reserved for weapons. It is the material in this category that a disarmament FMCT would aim to eliminate; a consistent disarmament approach would mandate the elimination of all weapon-related materials. If such a mandate proves impossible, the treaty would need to develop a procedure to determine which portion of the overall stock must be eliminated. Such a procedure, however, would have to make certain assumptions about the characteristics of nuclear arsenals, such as the number of warheads (active and in reserve), the fissile material content of such warheads, and the amount of reserve material required to sustain an arsenal of a certain size. Even if this information was available, which is highly unlikely, it is difficult to imagine an acceptable mechanism that would dictate to states parties how much material they must designate as excess.

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13 Pavel Podvig and Joseph Rodgers, “Deferred Verification: Verifiable Declarations of Fissile Material Stocks”, UNIDIR, 2017, <https://unidir.org/sites/default/files/publication/pdfs/deferred-verification-verifiable-declarations-of-fissile-material-stocks-en-694.pdf>.

14 Pavel Podvig and Ryan Snyder, *Watch Them Go: Simplifying the Elimination of Fissile Materials and Nuclear Weapons* (Geneva: UNIDIR, 2019), <https://doi.org/10.37559/WMD/19/NuclearVer01>.

## Practical considerations

These examples show that some mechanisms for eliminating weapon-related stocks of fissile materials are independent of whether the FMCT explicitly includes these stocks within its scope. With the exception of a case in which the treaty would mandate the full elimination of all weapon-related fissile materials within a defined time frame, the approach to elimination would essentially remain the same. States will either voluntarily identify the material to be eliminated or designate disarmament material for elimination based on bilateral or multilateral disarmament agreements. The treaty's value would be in creating the framework for eliminating this material under international control, rather than in specifically requiring its disposal.

The effectiveness of an FMCT as a disarmament instrument would greatly increase if the treaty were to require its parties to declare the size of their fissile material holdings. These declarations would add an important level of accountability in the disarmament process and would provide a baseline for future reductions.

## 4 Material transfers

Understood narrowly, the FMCT mandate is to end the production of fissile materials for weapons. Production, however, is not the only route to obtaining fissile materials as a state can acquire materials through a transfer from another state.<sup>15</sup> NPT prohibits states parties from transferring nuclear material to non-nuclear-weapon states for non-peaceful purposes. Transfers between the five NPT nuclear-weapon states, however, are not prohibited. And, of course, states that are not party to the NPT are not bound by this restriction.

Most transfers of nuclear material between states are related to peaceful nuclear activities. For example, significant amounts of HEU and some plutonium were provided by the United States and the Soviet Union and later the Russian Federation to fuel research reactors. This material was subject to IAEA safeguards in the receiving state. Also, the NPT nuclear-weapon states have made commitments to report any export of nuclear material to non-nuclear-weapon states to the IAEA.<sup>16</sup> Transfers of nuclear material for peaceful purposes between nuclear-weapon states are also quite common. Even though these transfers are not covered by the reporting commitment and the material is often not subject to safeguards at the destination, information about these transactions is normally publicly available. For example, the Russian Federation has supplied some HEU to West European states, where it was used to produce fuel for research reactors, subject to Euratom safeguards.<sup>17</sup> Some of this material was new HEU, part of it of weapons-grade quality, produced specifically for export. Another recent example of a transfer of newly produced HEU was the supply of fuel by the Russian Federation to the two fast neutron reactors that China is constructing.<sup>18</sup> While this transfer was reasonably transparent, there is no obligation to place this material under safeguards. However, the fuel-supply agreement prohibits any military use of this material as well as any material that can be produced with its help.<sup>19</sup>

Based on public sources, the practice of transferring fissile materials for military purposes is limited mainly to the cooperation between the United States and the United Kingdom. Transfers between these states are regulated by a mutual cooperation agreement signed in 1958 and renewed regularly since then. The agreement allows for the transfer of material for a range of military purposes,

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15 See, for example, Japanese Permanent Mission to the United Nations, “Japan’s Views on a Fissile Material Cut-off Treaty (Submitted Pursuant to UNGA Resolution 67/53 Paragraph 2)”, 13 May 2013, <https://documents.unoda.org/wp-content/uploads/2021/04/778B94BEAE525FAFC1257B7C0041839DJAPAN.pdf>, paragraph 21.

16 International Atomic Energy Agency, INFCIRC/207, 26 July 1974, <https://www.iaea.org/sites/default/files/publications/documents/infcircs/1974/infcirc207.pdf>.

17 International Panel on Fissile Materials (IPFM), “Supply of Russian HEU to Western Europe”, IPFM Blog, 27 July 2010, [http://fissilematerials.org/blog/2010/07/supply\\_of\\_russian\\_heu\\_to\\_.html](http://fissilematerials.org/blog/2010/07/supply_of_russian_heu_to_.html); Alexander Glaser and Pavel Podvig, “Production of New Highly Enriched Uranium in Russia for the FRM-II in Germany”, IPFM Blog, 8 November 2017, [http://fissilematerials.org/blog/2017/11/production\\_of\\_new\\_highly\\_.html](http://fissilematerials.org/blog/2017/11/production_of_new_highly_.html).

18 International Panel on Fissile Materials (IPFM), “Russia Delivers Fuel for China’s CFR-600 Reactor”, IPFM Blog, 28 December 2022, [https://fissilematerials.org/blog/2022/12/russia\\_delivers\\_fuel\\_for\\_.html](https://fissilematerials.org/blog/2022/12/russia_delivers_fuel_for_.html).

19 International Panel on Fissile Materials (IPFM), “Russian Laws Prohibit Military Use of HEU Supplied to China”, IPFM Blog, 15 May 2024, [https://fissilematerials.org/blog/2024/05/russian\\_export\\_laws\\_prohi.html](https://fissilematerials.org/blog/2024/05/russian_export_laws_prohi.html).

including, it appears, for nuclear weapons.<sup>20</sup> At the same time, the transfer of nuclear weapons is explicitly prohibited.<sup>21</sup> Independent estimates suggest that more than half of the United Kingdom's stockpile of HEU originated from the United States. The United Kingdom, however, has enough indigenously produced HEU to maintain its current nuclear warhead stockpile.<sup>22</sup> Shipments of material apparently continue, although the amounts transferred have not been disclosed.<sup>23</sup> It is possible that this material is HEU used in naval reactors or for research applications. In the past, the United States also shipped about 0.5 tonnes of HEU to France for a prototype naval reactor fuel.<sup>24</sup>

A consistent approach to banning the production of fissile materials for weapons should include a strategy for managing transfers of weapon-usable materials between nuclear-armed states. This strategy needs to address two distinct issues: transfers of materials intended explicitly for weapon purposes; and transfers of fissile materials for non-weapon military uses, such as naval propulsion or military research reactors.

It is well recognized that a potential ban on transfers of materials reserved for weapons would be virtually impossible to verify without having access to the stocks of these materials. Nonetheless, such a ban could establish a norm against such transfers, and the "deferred verification" arrangement might deter them.<sup>25</sup>

Transfers of material for non-proscribed military activities, naval reactors in particular, will require developing a verification arrangement that would ensure that the material is not diverted from its declared use. It is important to recognize that, under an FMCT, this kind of arrangement would have to be developed in any event to cover domestic production of fissile material for non-proscribed military uses. Such an arrangement could subsequently be applied to potential transfers of this material to other states.

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20 Agreement Between the Government of the United Kingdom of Great Britain and Northern Ireland and the Government of the United States of America for Cooperation on the Uses of Atomic Energy for Mutual Defense Purposes, 22 July 2014, <https://fissilematerials.org/library/mda2014.pdf>, Article III bis.A.3.

21 Ibid., Article V.B.

22 The United Kingdom reported that, as of 2002, it had 21.38 tonnes of HEU in its stockpile. The amount of HEU in nuclear warheads is estimated to be about 2.5 tonnes. International Panel on Fissile Materials (IPFM), *Global Fissile Material Report 2010 – Balancing the Books: Production and Stocks* (Princeton, NJ: IPFM, 2010), <https://ipfmlibrary.org/gfmr10.pdf>, 71, 72–73, 78.

23 International Panel on Fissile Materials (IPFM), "Ongoing Transfers of Weapon Materials between the United States and the Kingdom", IPFM Blog, 1 March 2016, [http://fissilematerials.org/blog/2016/03/ongoing\\_transfers\\_of\\_weap.html](http://fissilematerials.org/blog/2016/03/ongoing_transfers_of_weap.html).

24 International Panel on Fissile Materials, *Global Fissile Material Report 2010*, 31.

25 Podvig and Rodgers, *Deferred Verification*.



One advantage of having a verification arrangement of this kind in an FMCT is that it would strengthen the safeguards in cases where fissile material is transferred to a non-nuclear-weapon state for non-proscribed military uses. In the typical Comprehensive Safeguards Agreement that states sign with the IAEA, Article 14 provides for the possibility of non-application of safeguards to this material in the recipient state.<sup>26</sup> While the IAEA can develop effective arrangements to ensure that the material is not diverted, this task is made more complex by the requirements to protect sensitive design information related to reactors and fuel. By adding supply-side verification measures to the IAEA procedures, the FMCT could strengthen the overall arrangement.

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26 International Atomic Energy Agency, INFCIRC/153 (Corrected), June 1972, <https://www.iaea.org/sites/default/files/publications/documents/infcircs/1972/infcirc153.pdf>, paragraph 14.

# 5 Transparency and confidence-building measures

Despite the production of fissile materials being an area traditionally closed to outside scrutiny, past experiences relating to transparency are important and should be taken into account by the future FMCT. While transparency and confidence-building measures cannot replace legally binding obligations under a treaty, they can help create conditions for the commencement of negotiations. They also provide an opportunity to develop, demonstrate and evaluate various practical measures and tools that could be incorporated into an FMCT.

The value of transparency and confidence building has been recognized by the United Nations General Assembly. In its regular resolution on an FMCT, in December 2023, it added a paragraph calling on those states “that possess or produce fissile material for nuclear weapons... to engage in transparency and confidence-building measures among themselves”.<sup>27</sup> Even though this call was not universally supported by nuclear-armed states, it could potentially provide an impulse for dialogue regarding fissile materials.

Some of the most notable transparency measures implemented so far include the declarations of fissile material stocks made by the United States and the United Kingdom. The United States has also published information about its nuclear arsenal and provided updates of the status of its HEU holdings. It has considered allowing the IAEA to monitor its plutonium-disposition process.

Significant progress has been made in shutting down and dismantling the facilities that were involved in fissile material production for weapons, both as unilateral initiatives and as part of bilateral processes. France has dismantled its plutonium-production and uranium-enrichment facilities and invited observers to witness the process.<sup>28</sup> The United States and the Russian Federation verifiably shut down their plutonium-production reactors as part of a bilateral agreement that included verification provisions.

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27 General Assembly, A/RES/78/28, paragraph 4. Note that 5 states, including China, India, Pakistan and the Russian Federation, voted against this paragraph. See United Nations Meetings Coverage and Press Releases, “General Assembly Adopts 56 First Committee Texts as Geopolitical Realities Test Sustainability of Non-Proliferation Regime, Scuttle Consensus”, 4 December 2023, <https://press.un.org/en/2023/ga12568.doc.htm>.

28 FranceTNP, “Visite des anciennes installations de Pierrelatte et Marcoule” [A tour of the former Pierrelatte and Marcoule facilities], 2009, <https://www.francetnp.gouv.fr/visite-des-anciennes-installations-de-475>.

Among other transparency measures are those related to the civilian nuclear industry. Most states that use plutonium in their nuclear power industries publish annual declarations about the status of their civilian plutonium stock. These documents – which are published as IAEA information circulars, numbered INFCIRC/549 – provide data about the amount of separated plutonium in various forms as well as about plutonium in irradiated fuel.<sup>29</sup> While these submissions are voluntary, they provide an important insight into the status of various plutonium-management programmes.

The example of INFCIRC/549 declarations illustrates the value as well as the limits of transparency measures. On the one hand, they offer states a mechanism to demonstrate compliance with certain obligations that they have assumed, even if the information provided by states cannot be verified. The suspension of implementation by any state could therefore indicate a change in a state's policy. The voluntary nature of transparency measures, however, does not provide outside parties with a recourse in such cases, potentially complicating assessments of the seriousness of any change in policy.

To illustrate this point, China suspended publication of its INFCIRC/549 declarations in 2017, shortly after it started operations of its first civilian reprocessing facility. While the facility appears to have been built to support the civilian nuclear power programme, it may also have the capability to reprocess irradiated fuel from the two new fast-neutron reactors.<sup>30</sup> Since these reactors can produce weapons-grade plutonium, the suspension of the INFCIRC/549 reporting has raised questions about the direction of China's fissile material-production programme.<sup>31</sup> In this case, the existence of a well-established INFCIRC/549 reporting mechanism would provide a straightforward way to address these questions.

Transparency can also help address issues that may complicate the initiation of FMCT negotiations. As discussed above, there are several different ways in which an FMCT could address the issue of existing stocks. It is possible that a treaty could be negotiated in a way that does not obligate states to eliminate existing materials, thereby freezing the disparities that exist today. This may not be a problem for some nuclear-armed states that believe their existing stocks can cover all conceivable future needs. Other states, however, may see the existing disparities differently. For example, Pakistan has expressed concerns about a “serious asymmetry in fissile material stockpiles, especially in South Asia”.<sup>32</sup> A number of experts in Pakistan have argued that India has a significant stock of plutonium that can be potentially used to produce nuclear weapons (see the appendix). Since the plutonium in question is reactor-grade material, its direct use in weapons is unlikely, even if theoretically possible. In this case, it might be possible to design a transparency arrangement that ensures this particular material is not used in weapons without constraining India's options for using this material in non-weapon applications, such as in fuel for its fast-neutron reactor.

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29 International Atomic Energy Agency, INFCIRC/549, 16 March 1998, <https://www.iaea.org/publications/documents/infcircs/communication-received-certain-member-states-concerning-their-policies-regarding-management-plutonium>.

30 The first of these two reactors began operations in December 2023. Zhang Hui, “China Started Operation of Its First CFR-600 Breeder Reactor”, IPFM Blog, 15 December 2023, [https://fissilematerials.org/blog/2023/12/china\\_started\\_operation\\_o.html](https://fissilematerials.org/blog/2023/12/china_started_operation_o.html).

31 G7 Leaders' Hiroshima Vision, 3–4.

32 General Assembly, A/68/154, 16 July 2013, <https://undocs.org/en/A/68/154>, 21.

There are a number of steps that can contribute to strengthening the existing transparency and confidence-building measures. The United States and the United Kingdom, the two nuclear-weapon states that declared the size of their fissile material holdings, could provide regular updates of these declarations. Other states should be encouraged to report the size of their fissile material holdings, even if not to the level of detail provided by the United States and the United Kingdom. While this step may seem ambitious, especially given concerns about the lack of reciprocity expressed by some states, releasing some information could be an extremely important transparency and confidence-building measure, particularly if it is done in a coordinated manner.

It is important that the practice of submitting INFCIRC/549 declarations on civilian plutonium continues, that China resumes the submission of declarations, and that all states that have civilian plutonium stocks join the arrangement. The reporting states can also expand this practice, building on the experience of Japan, which provides a more detailed account of the status of its plutonium programme.<sup>33</sup>

Non-nuclear-weapon states can also make an important contribution to the transparency regime. For example, they can report the status of their HEU holdings using the INFCIRC/912 mechanism established by a group of states in 2017.<sup>34</sup> So far, only two states – Norway and Australia – have submitted such declarations.<sup>35</sup> While these reports are intended to cover only civilian HEU, the principle of transparency that they help establish is very important to uphold. Nuclear-armed states that do not provide this information should also be encouraged to do so.

As these examples demonstrate, while transparency and confidence-building measures would benefit from cooperation among states that possess fissile material produced for weapons, there is also significant scope for unilateral measures. Non-nuclear-weapon states can also contribute to this process by strengthening the existing transparency mechanisms.

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33 Japanese Cabinet Office, Office of Atomic Energy Policy, “The Status Report of Plutonium Management in Japan – 2022”, Provisional translation, 18 July 2023, [http://www.aec.go.jp/jicst/NC/sitemap/pdf/kanri230718\\_e.pdf](http://www.aec.go.jp/jicst/NC/sitemap/pdf/kanri230718_e.pdf).

33 International Atomic Energy Agency, INFCIRC/912, 16 February 2017, <https://www.iaea.org/sites/default/files/publications/documents/infcircs/2017/infcirc912.pdf>.

33 France, Germany, and the United Kingdom provide this information in their INFCIRC/549 reports.

# 6 Conclusion

The path toward a treaty banning the production of fissile material for weapons and other nuclear explosive devices has proven to be more complex than was anticipated when the United Nations General Assembly initiated the process, in December 1993.<sup>36</sup> Although the international community has made significant progress in developing the concept of the treaty and identifying its key elements, differences remain and the prospects for commencing negotiations look distant.

Meanwhile, the treaty's relevance has only increased. As Japan's Minister of Foreign Affairs, Kamikawa Yōko, noted at the recent session of the United Nations Security Council on nuclear disarmament, "the importance of an FMCT in limiting the quantitative improvement of nuclear weapons by banning the production of fissile materials is indisputable".<sup>37</sup> It is also indisputable that a ban on the production of fissile materials for weapons is an absolutely essential element of a nuclear weapon-free world. An FMCT could become an important step towards the elimination of nuclear weapons by creating a legal, institutional and technical foundation to constrain stocks of weapon-usable fissile materials and establishing a mechanism for their verifiable elimination under international control.

While some of the issues that hold back the FMCT negotiations may present a serious challenge, the differences are not necessarily irreconcilable and virtually all technical problems can be adequately addressed. Given the benefits that an FMCT could generate, it is essential to continue the discussion and engage in a cooperative search for solutions that can give new momentum to the FMCT process.

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36 General Assembly, A/RES/48/75.

37 Kamikawa, Statement at the Security Council.

# Appendix

## Current status of fissile material stocks and production capacities

### Fissile material stocks

As of 2023, the global stock of fissile materials was estimated to include about 1245 tonnes of highly enriched uranium and about 560 tonnes of separated plutonium, the two key materials that are used in nuclear weapons (see Table 1).<sup>38</sup> However, not all of this material can be used for weapons or other non-peaceful activities. About 420 tonnes of separated plutonium have been produced outside of military programmes or are covered by various obligations not to use it for military purposes. Some of this material is under international or bilateral safeguards. This leaves about 140 tonnes of plutonium that is either in weapons or available for weapons. Most HEU, about 1100 tonnes, is available for weapons.

All materials in NPT non-nuclear-weapon states are under IAEA safeguards in accordance with safeguard agreements concluded by these states. The situation in nuclear-armed states varies from state to state.

Plutonium stocks in the Russian Federation and the United States include 34 tonnes of weapons-grade plutonium in each state that they have committed to eliminate under the bilateral 2010 Plutonium Management and Disposition Agreement. Even though the agreement has been suspended, both states have reconfirmed the commitment not to use this material for military purposes. Some weapons-grade HEU in the United States is also covered by a voluntary obligation not to use it for weapon purposes. The United States has also designated some non-weapons-grade plutonium for disposal. The material that the Russian Federation and the United States pledged to eliminate is normally not covered by safeguards or monitoring arrangement, and for the most part is still in classified forms. However, about 15 tonnes of weapons-grade plutonium in the Russian Federation is covered by a bilateral US–Russian monitoring agreement; 3 tonnes of US weapons-grade plutonium is under IAEA safeguards.

The Russian Federation's stock of separated plutonium also includes about 65 tonnes of plutonium produced as part of its civilian programme. Although this material is not under safeguards or an obligation not to use it for military purposes, it is considered as material not available for weapons.

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38 The estimates used in this section are based on the information collected by the International Panel on Fissile Materials (IPFM). They can be accessed from the IPFM website, International Panel on Fissile Materials, “Fissile Material Stocks”, 13 April 2024, <http://fissilematerials.org>. They will be also published in Friederike Frieß et al., “Global Stocks and Production of Fissile Materials, 2023”, in *SIPRI Yearbook 2024: Armaments, Disarmament and International Security* (Oxford: Oxford University Press, forthcoming 2024). The total amounts in the last line are rounded to 5 tonnes.

Table 1. Stocks of highly enriched uranium and separated plutonium

COUNTRY	HIGHLY ENRICHED URANIUM (TONNES)		SEPARATED PLUTONIUM (TONNES)	
	TOTAL	AVAILABLE FOR WEAPONS	TOTAL	AVAILABLE FOR WEAPONS
Russia	680	672	193	88
United States	483	361	87.6	38.4
United Kingdom	23	22	119.6	3.2
France	29	25	98	6
China	14	14	3	2.9
India	5	–	10	0.7
Pakistan	5	5	0.5	0.5
Israel	0.3	0.3	0.9	0.9
DPRK	0.7	0.7	0.04	0.04
Others	4	–	47.6	–
<b>TOTAL</b>	<b>1245</b>	<b>1100</b>	<b>560</b>	<b>140</b>

Most of the separated plutonium produced by the United Kingdom and France is in their civilian programmes. In addition, some of their HEU is used in civilian applications. Both states report this material as civilian in their annual reports to the IAEA. These reports also include information about foreign-owned material that is temporarily stored in these states.

The estimate of China’s fissile material stock includes only the material that was produced for its military programme in the past. China may also have separated some plutonium from fuel from civilian power reactors in recent years. Since China stopped submitting information about its civilian plutonium in 2017, no data about plutonium separated after 2016 is available. Plutonium extracted from spent fuel of light-water reactors would normally not be considered directly available for weapons. However, if the reprocessing programme is configured to process material irradiated in breeder reactors, then it can produce weapons-grade plutonium. It should be noted that this plutonium will be obligated material: it cannot be used in a weapon programme as long as the reactor uses fuel supplied by the Russian Federation.<sup>39</sup>

39 International Panel on Fissile Materials, “Russian Laws Prohibit Military Use of HEU Supplied to China”.

Information about fissile materials in non-NPT nuclear-armed states is scarce, so the estimates are characterized by significant uncertainties. Almost all these materials are not safeguarded and are believed to be used in weapon programmes. One notable exception is India. It is believed that India's HEU is being produced for its military naval propulsion programme and is therefore not available for weapons. As for plutonium, most of the material in India's stock is the reactor-grade plutonium separated from unsafeguarded power reactors. Although this material has not been placed under safeguards and is not covered by a commitment not to use it for military purposes, it is considered not directly available for weapons. It can, however, be used in a breeder reactor to produce weapons-grade plutonium.

Fissile materials owned by non-nuclear-weapon NPT states parties are placed under IAEA safeguards. In cases where these materials are transferred to a nuclear-weapon state, as is the case with irradiated fuel from civilian reactors sent for reprocessing and the plutonium separated from this fuel, the IAEA ensures application of safeguards in accordance with its agreement with the host state. If this material is returned to the owner (for example, in fuel for power reactors), it is placed under safeguards in accordance with the NPT obligations of the owner state.

## Fissile material production

Almost any state that operates a nuclear reactor or uranium-enrichment facility has some capability to produce fissile materials for weapons. In practice, however, this capability is constrained by a number of factors. In NPT non-nuclear-weapon states, all relevant facilities and materials are placed under IAEA safeguards to ensure that all nuclear materials remain in peaceful use.

The IAEA normally does not apply safeguards to materials and facilities in NPT nuclear-weapon states, even when it has an option of doing so under the terms of voluntary offer agreements. Some facilities in non-NPT nuclear-armed states are covered by item-specific safeguards or similar arrangements.

All five NPT nuclear-weapon states stopped the production of fissile materials for weapon purposes between the late 1980s and early 1990s. Four of them – France, the Russian Federation, the United Kingdom and the United States – formally announced a moratorium on such production and undertook steps to dismantle dedicated production facilities.

The United States has shut down all of its military production facilities and, as a result, does not have facilities that could be used to produce fissile materials for weapons. The only large uranium-enrichment facility on US soil, in Eunice, New Mexico, is operated by the British–Dutch–German URENCO consortium and is limited to producing uranium for peaceful non-explosive purposes.<sup>40</sup>

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40 Agreement between the Government of the United States of America and the Four Governments of the French Republic, the United Kingdom of Great Britain and Northern Ireland, the Kingdom of the Netherlands, and the Federal Republic of Germany regarding the Establishment, Construction and Operation of Uranium Enrichment Installations using Gas Centrifuge Technology in the United States of America (Treaty of Paris), 24 February 2011, <https://fissilematerials.org/library/urenco11.pdf>, Article III.



The United States is reconstituting its indigenous uranium-enrichment programme, but it will be limited to producing LEU for advanced civilian reactors. There are no plans to resume production of weapons-grade HEU in the United States. As for plutonium, the United States operates a small-scale reprocessing facility, but it is limited to special operations. All dedicated plutonium-production reactors in the United States have been shut down.

The United Kingdom has no capability to produce weapons-grade plutonium or to separate plutonium from irradiated fuel. The only enrichment plant in the United Kingdom, in Capenhurst, is operated by URENCO and is therefore limited to producing uranium for peaceful purposes. While it is no longer under Euratom safeguards, this facility is bound by the terms of the Treaty of Almelo, which created the consortium, under which the parties commit not to produce “weapons grade uranium for the manufacture of nuclear weapons or other nuclear explosive devices”.<sup>41</sup>

France operates two fissile material-production facilities: a large reprocessing facility and a centrifuge enrichment plant. They are placed under Euratom safeguards, which ensure that the material they produce is used only for peaceful purposes. The facilities that were used to produce materials for weapons – the enrichment plant in Pierrelatte and the plutonium-production complex in Marcoule – have been shut down and dismantled. France made a special effort to introduce transparency in the dismantlement process.<sup>42</sup>

Although the Russian Federation has stopped production of fissile materials for weapons, it has converted rather than dismantled some elements of its production infrastructure. It has shut down the plutonium-production reactors and converted the reprocessing facilities that separated weapons-grade plutonium. At the same time, the Russian Federation continues to operate large civilian reprocessing facilities. The Russian Federation’s nuclear complex also includes several large uranium-enrichment facilities that produce LEU for power reactors but are capable of producing HEU as well. Indeed, in 2012 the Russian Federation resumed production of HEU at one of its enrichment facilities for use in breeder reactors and some civilian naval reactors.<sup>43</sup>

The situation with China’s fissile material-production capability is somewhat uncertain. It is believed that China has shut down the production facilities that supported its nuclear weapon programme in the past. In recent years, however, it has been expanding its uranium-enrichment and reprocessing programmes.<sup>44</sup> It is possible that the new production facilities are being built to support China’s

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41 Agreement between the United Kingdom of Great Britain and Northern Ireland the Federal Republic of Germany and the Kingdom of the Netherlands on Collaboration in the Development and Exploitation of the Gas Centrifuge Process for producing Enriched Uranium (Treaty of Almelo), 4 March 1970, <https://fissilematerials.org/library/urenc070.pdf>, Article VI(2).

42 FranceTNP, “Visite des anciennes installations”.

43 International Panel on Fissile Materials (IPFM), “Russia Launches HEU Production Line”, IPFM Blog, 29 October 2012, [http://fissilematerials.org/blog/2012/10/russia\\_launches\\_heu\\_produ.html](http://fissilematerials.org/blog/2012/10/russia_launches_heu_produ.html).

44 Zhang Hui, “China Starts Construction of a Second 200 MT/Year Reprocessing Plant”, *IPFM Blog*, 21 March 2021, [https://fissilematerials.org/blog/2021/03/china\\_starts\\_construction.html](https://fissilematerials.org/blog/2021/03/china_starts_construction.html); Zhang Hui, “China Started Operation of Two New Enrichment Plants in 2023”, IPFM Blog, 15 December 2023, [https://fissilematerials.org/blog/2023/12/china\\_started\\_operation\\_o\\_1.html](https://fissilematerials.org/blog/2023/12/china_started_operation_o_1.html).

growing civilian nuclear power programme. Some of China's power reactors and enrichment plants are under IAEA safeguards, but most new production facilities are not safeguarded or monitored. Theoretically, they can be used to produce material for military purposes.

All nuclear-armed states outside the NPT – with one possible exception – retain the capability to produce fissile materials for nuclear weapons and could potentially expand this capability in the future.

The possible exception is Israel, which appears to operate its Dimona plutonium-production reactor in tritium-production mode.<sup>45</sup> Around 2019, Israel began some construction activity at the site, but its purpose is not clear.<sup>46</sup>

Pakistan operates four plutonium-production reactors at Khushab. Together these reactors could add as much as 40 kilogrammes of plutonium annually to Pakistan's stock, which is estimated to comprise about 500 kg of material. Pakistan also has a uranium-enrichment programme that includes one or two facilities that can produce HEU. The capacities and operational histories of these facilities, however, are not well known, limiting the reliability of the estimate of Pakistan's HEU stock.

India produced most of its weapons-grade plutonium in the CIRUS reactor, which was permanently shut down in 2010. It is believed to continue plutonium production in the Dhruva reactor, which is also used as a research reactor. During the 2010s, it had a plan to build another Dhruva-type reactor, but this seems to have been put on hold. India is building the Prototype Fast Breeder Reactor, which is expected to begin operation in 2024.<sup>47</sup> Once operational, this reactor will be able to produce weapons-grade plutonium. To be able to use this plutonium in its weapons programme, India would have to use unsafeguarded reactor-grade plutonium in its fuel. India also operates a uranium-enrichment plant. It is believed that the plant is producing HEU for India's naval reactors, rather than weapons-grade HEU that can be used in weapons.

Finally, the Democratic People's Republic of Korea (DPRK) is known to have plutonium-production and uranium-enrichment programmes. Both programmes appear to be active, although the estimates of the HEU-production capacity are highly uncertain.

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45 Alexander Glaser and Julien de Troullioud de Lanversin, "Plutonium and Tritium Production in Israel's Dimona Reactor, 1964–2020", *Science & Global Security*, vol. 29, no. 2 (2021): 90–107, <https://doi.org/10.1080/08929882.2021.1988325>.

46 International Panel on Fissile Materials (IPFM), "Significant New Construction at the Dimona Site", IPFM Blog, 18 February 2021, [https://fissilematerials.org/blog/2021/02/significant\\_new\\_construct.html](https://fissilematerials.org/blog/2021/02/significant_new_construct.html).

47 International Panel on Fissile Materials (IPFM), "India Begins Loading Fuel in Prototype Fast Breeder Reactor", IPFM Blog, 4 March 2024, [https://fissilematerials.org/blog/2024/03/india\\_begins\\_loading\\_fuel.html](https://fissilematerials.org/blog/2024/03/india_begins_loading_fuel.html).

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