Verification of a Fissile Material Cut-Off Treaty

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The potential benefits of a Fissile Material Cut-off Treaty (FMCT) are well known: it will put non-proliferation obligations on states outside the Non-Proliferation Treaty (NPT); it will reduce discrimination within the non-proliferation regime; it will introduce verification measures in states that are not currently subjected to full-scope safeguards, e.g. nuclear-weapon states (NWS) and states outside the NPT (SON), thereby further reducing proliferation dangers; and it will give a push to other initiatives aimed at similar goals, especially international collaboration on the security of fissile materials and nuclear disarmament.

While the benefits are clear and indisputable, there is less concordance on the shape that a FMCT verification regime will take. Many verification scenarios are possible, ranging from just a fence around former military production facilities to completely new global concepts. Verification must cover not only non-production but also non-diversion of (at least) civilian materials produced after entry into force. No material must be diverted for use in nuclear weapons, a commitment to be undertaken equally by all signatories of a FMCT. This is already being verified in non-nuclear-weapon states (NNWS) under full-scope safeguards. The difference under a FMCT verification regime would be that NNWS would not be allowed to possess unsafeguarded materials from earlier production, while NWS and SON would be allowed a “black box” of previously excluded materials.

It is not clear whether the scope of the treaty will cover only the future production of weapon-usable materials or if it will also include previously produced materials. Even if the scope is very limited, e.g. only a ban on future production, it must be ensured that material produced in the future is not falsely declared as earlier production. If civilian material were to be left out, it could eventually be declared as earlier production and diverted to military use. Therefore, all civilian and military materials produced after entry into force would need to be put under safeguards.

But why should the NPT and the FMCT have different verification standards when their verification tasks are almost the same? It can be argued that as long as a NWS has not disarmed down to zero, some warheads more or less do not make much difference. Additionally, as long as the black boxes of the NWS are not empty, it makes less of a difference if small diversions go undetected. However, the goal of verification is the deterrence of non-compliance through creation of a sufficiently high detection risk. Even in NNWS, there will always remain a low probability that non-compliance could remain undetected, and this probability is determined by a balance between trust and technical verification efforts and costs. The higher the trust, the lower the detection probability that can be tolerated. In relation to the NPT, the trust among the NNWS is not high

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enough for them to renounce full-scope safeguards or to lower standards. With this in mind, why should NWS be more trusted not to divert fissile materials for nuclear explosive purposes than NNWS? A provocative variant of this question is: who can be more trusted, those who have renounced nuclear weapons or those who continue to maintain nuclear arsenals and huge quantities of unsafeguarded weapon materials? This is not just a question of technical feasibility but, more principally, of the importance of treaty compliance. A FMCT would be discriminatory if there were two different classes of states parties who were granted two different degrees of trust. But we should keep in mind that the current non-proliferation regime is discriminatory, and the reduction of discrimination can only be achieved in steps, not all at once.

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The NWS have difficulty accepting full-scope safeguards on their entire civilian and converted fuel cycles for several reasons. Firstly, conservative inertia drives decision-makers towards viewing nuclear policies as exclusively national matters. Accepting full-scope safeguards is therefore a severe blow to national sovereignty. Secondly, installing a verification system is indeed a technical challenge.[1] Most production plants in NWS, especially from the early years, were not designed with safeguards. Neither did bookkeeping have the same priority as in NNWS because there was never the need for international justification. It is much more difficult to implement verification post-construction than at the time a facility is designed and built. Therefore, it is not surprising that many analysts from NWS envisage a progressive, step-by-step approach to verification.[2]

South Africa is the only case in history where a state possessing nuclear weapons converted to a NNWS and implemented comprehensive safeguards. The safeguards implementation was a success, but it also revealed technical challenges different than those known from previous safeguarding efforts.[3] As a second example, Britain brought a large reprocessing plant (B205) under Euratom safeguards some twenty years after it was designed. Although the safeguards applied there might not meet IAEA criteria, Euratom is satisfied that it can verify non-diversion from the plant. An interesting future study would be on how the United Kingdom brought B205 under safeguards.[4]

The Nuclear Fuel Cycle and Existing Safeguards

IAEA safeguards are a verification system within nuclear non-proliferation policy, the NPT and the Treaty of Tlatelolco to ensure that no nuclear material is diverted for use in nuclear weapons or other nuclear explosive devices. A state aiming at clandestine acquisition of direct-use nuclear material has several procurement strategies:[5]

- reusing already shut-down facilities;
- pursuing additional undeclared operations in operating declared facilities;
- diverting materials from declared inventories; or
- using clandestine undeclared production facilities.

Safeguards must be designed in a way that they are capable of detecting any of these operations with a sufficient probability. The basic objective of INFCIRC/153-type safeguards (those verifying the compliance of NNWS with the NPT) was “the timely detection of diversion of significant quantities of nuclear material from peaceful nuclear activities to the manufacture of nuclear weapons or for other nuclear explosive devices or for purposes unknown”,[6] i.e. the third procurement strategy.

Feed material (e.g. natural, depleted or low enriched uranium) and an enrichment facility are necessary to produce highly enriched uranium (HEU). Spent fuel and reprocessing technology are required for plutonium production. Therefore, the most proliferation relevant elements of the nuclear fuel cycle are enrichment and reprocessing. However, safeguarding only enrichment and reprocessing would leave too many loopholes, and therefore full-scope safeguards cover not only plutonium and HEU production facilities but also all other elements of the nuclear fuel cycle and nuclear reactors without exception — the respective intrusiveness depending on the technical hurdles to acquire direct-use material. In contrast, INFCIRC/66-type safeguards were designed to apply to individual shipments of plants and materials to SON. At a facility, the two types of safeguards often consist of similar control measures. However, large loopholes remain as long as the underlying verification approach does not cover systematically the entire fuel cycle. Safeguards agreements between NWS and the IAEA apply only to individual facilities, and there is always the legal possibility for a NWS to withdraw a facility from controls.

The number of facilities in NWS currently subjected to voluntary IAEA safeguards is small for three reasons:

- limited funds;
- not much sense had been seen in verifying non-diversion in states that are legally allowed to produce undeclared and military nuclear materials; and
- in these states, the assumption still prevails that their nuclear production is only a matter of national, not international, concern.

The obligation of NNWS to not divert nuclear materials for weapon purposes is already being verified by the IAEA. The agreements between the IAEA and the inspected state are based on a model agreement, INFCIRC/153.[7] It sets the principal requirements for full-scope safeguards. Full-scope safeguards are applied in all nuclear facilities, including normal power reactors. Yet recent experiences in Iraq, a NNWS according to the NPT, have demonstrated that even this is unsatisfactory. Iraq's proliferation has demonstrated that the objective of only detecting fissile material diversion is not enough, and has led to more emphasis on the additional goal of detecting clandestine acquisition activities. This has resulted in the IAEA's Strengthened Safeguards System (S^3), formerly called 93 + 2.

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S^3 goes beyond previous safeguards, with the additional goal of detecting undeclared production and even preparation for production. S^3 detection methods depend on the task and include: seals; monitors; special activity surveillance; design verification; independent measurements of inventories; various material accountancy measures; ad hoc, routine and special inspections; environmental sampling; remote monitoring; and inspector deployment. Now both nuclear materials and non-nuclear elements of the fuel cycle and R&D are affected by control or reporting measures. These measures are aimed at both the receiving and supplying ends of the technology transfer chain. Table 1 gives an overview of the most important fuel cycle elements, their significance for the acquisition of direct-use material, and the current status of IAEA safeguards.

The principle of universality is an important prerequisite for the success of the S^3 reform. It is logical that a similar verification system would be appropriate and necessary for effective FMCT verification. The IAEA sees itself as the appropriate agency for the verification of a FMCT.[8]

Table 1. Overview of the most important nuclear fuel cycle elements, their proliferation relevance and IAEA safeguards

Control and Detection of Direct-Use Material Production

Although IAEA safeguards cover the whole nuclear fuel cycle and the author believes that the same should be done in a FMCT, a closer look specifically at the production of direct-use materials is useful. In all likelihood, the NWS will start the FMCT negotiations with the position of limiting verification to direct-use material production.

The specific technological requirements of verification depend on the characteristics of the technical production process. HEU is produced through enrichment and plutonium through reprocessing. While there are some specific differences, the two processes have a lot in common.[9] Both techniques process nuclear materials flowing through a succession of stages. Diversion could take place at many locations, and verification must be able to detect it. Both processes also leak detectable characteristic traces of nuclear isotopes. Verification that a facility which has been declared "shut down" is truly closed or detection of clandestine activities makes use of this fact.

Uranium

There are several methods of HEU production.[10] The most common technologies are gaseous diffusion and centrifuge enrichment. The former is the most common method in the United States, the latter in Europe. Other methods are aerodynamic enrichment, for example the jet nozzle and helicon processes that were used by South Africa, electromagnetic separation (EMIS) that has been used by Iraq, and chemical isotope separation, which has only reached the stage of pilot plants in France and Japan. A new enrichment technology expected to be applied commercially in a few years is atomic vapour laser isotope separation (AVLIS). A test facility is running in the United States, and France's efforts are in the development stage.[11] In South Africa, R&D on a similar technology, molecular isotope separation (MLIS), is underway in cooperation with the French company Cogema.[12] Another technical variation is chemical reaction by selective laser activation.

The basic safeguards approach for uranium is material accountancy that verifies the report of a national system, the so-called State's System of Accounting for and Control (SSAC) of nuclear material, supplemented by containment and surveillance techniques. Analyzing samples of the various material streams is another routine safeguards measure in enrichment plants. Measuring equipment is installed at various points to check the isotopic composition of the streams. In plants not originally subjected to safeguards, such as former military production plants and other civilian plants in NWS and in the SON, such equipment must be installed. S^3 has also implemented the option of taking environmental samples to ensure that no additional undeclared HEU production has occurred. However, this method works only in LEU facilities where HEU has never been produced, since it would cause false alarms in former military facilities that have been converted to LEU production.

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Noteworthy is the Hexapartite Enrichment Project (HSP), whereby six countries (Germany, Netherlands, Japan, the United States, the United Kingdom and Australia) agreed to place all civil centrifuge plants under permanent IAEA safeguards. Initiated in 1989, the HSP was concerned primarily with devising a safeguards strategy to cover the new gas centrifuge enrichment facilities that began springing up in Western Europe and Japan during the 1970s. This project also entailed the development of special verification techniques that enabled the implementation of satisfactory measures and an agreement between the IAEA and Euratom.[13] One interesting option would be to widen this agreement to include the Russian Federation and China.[14]

Plutonium[15]

Plutonium does not occur naturally, rather it is produced in nuclear reactors. Spent fuel contains plutonium, highly radioactive fission products and their decay products, and unaffected uranium. Plutonium can be separated from spent fuel by a chemical means called reprocessing. Similar to enrichment plants, the basic safeguards approach at reprocessing plans is material accountancy that verifies the report of the SSAC, supplemented by containment and surveillance techniques.[16] Flows are checked at predetermined locations known as "key measurement points", and samples can be taken from various other areas.

In NNWS, safeguards implementation is taken into account at the planning stage of a plant, and design verification can take place during construction. This makes it much more difficult to pursue a path of unmonitored diversion. Adding safeguards at a civilian reprocessing plant not formerly under safeguards is difficult but not impossible. The first step of safeguards implementation is a thorough design analysis and a reconstruction of operation history. Verification that shut-down facilities remain so is comparably easy through on-site inspections with the use of technical methods. An additional verification task is the detection of undeclared production facilities.

General Limits

Although verification never can be 100% certain, a large detection risk implies deterrence. It is enhanced by national technical means (NTM). For this reason, it is planned within S^3 to grant the IAEA greater access to intelligence information. In relation to a FMCT, NTM can be implemented independently from the IAEA, as in several other arms control treaties.

Reprocessing and enrichment do not only require plants but also spent fuel or feed uranium. Verification of a FMCT would be much more reliable if the other elements of the nuclear fuel cycle were included in a safeguards regime, as currently is the case in NNWS. For example, safeguarding spent fuel is far simpler than safeguarding a reprocessing plant, because it consists of discrete items that can be counted and verified with uncomplicated measurement methods.

Different Degrees of Intrusiveness and their Costs

The IAEA has worked out several potential FMCT verification scenarios.[17] The first is comprehensive safeguards similar to those in NNWS including the measures contained within the Additional Protocol (INFCIRC/540), because "verification arrangements to anything less than a State's entire fuel cycle could not give the same level of assurance" of compliance.[18] Only a black box of previously excluded materials would be left out. The second scenario constrains the technical objective of verification to the provision that all production facilities of direct-use material are either shut down or converted to civilian use and subject to safeguards. This scenario is subdivided into three alternatives with various degrees of intrusiveness and varying cost estimates. A substantial period of time would be required for the implementation of any one of these scenarios, with different timelines for different participants. A prerequisite would be that SSACs in the NWS and the SON meet international standards. However, these do not exist everywhere and need extra time and effort to be built up.

The total costs of a comprehensive verification system is estimated in the range of $140 million. The least intrusive alternative is estimated to cost about $40 million. This should be compared to the expenditure of $67.5 million by the IAEA's Department of Safeguards (1993 figure). Therefore the IAEA budget for safeguards must be about tripled in case of universal, full-scope safeguards. Sometimes NWS use the cost argument to oppose plans for universal coverage. On the other hand, the prospect of investing in safeguards may appeal to NWS, particularly because of the benefits that would accrue.[19] Judgements on costs are determined by priorities. For example, the United States has allocated several billion dollars for the maintenance of the Nevada test site in the context of negotiating and signing the CTBT, which far exceeds the amount the international community would annually spend on universal, full-scope safeguards.

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Specific Verification Challenges

Naval fuel

Reactors for naval propulsion are frequently fuelled with HEU because such reactor cores can be made especially small. Reactor fuel can be either military or civilian. NNWS are allowed to possess military HEU for non-explosive purposes without safeguards as long as it is not used for nuclear explosives, although this has not happened so far. In INFCIRC/153 (§14b), it is foreseen that verification of fuel is waived as long as the nuclear material is in a "non-proscribed military activity".

In case the scope of the FMCT covers only material produced after entry into force, it must be clarified whether or not unverified production of HEU or other fuel for military naval reactors will be banned. If allowed, the FMCT would contain an unacceptable loophole. It would be better to ban unverified HEU production altogether. This is likely to be agreeable to all participants because large stocks of HEU already exist that can be used as naval fuel. In case the scope of the FMCT requires placing all or some existing material under safeguards, special provisions must be found for naval fuel.

In principle, HEU is not always necessary for naval reactors because they can also be driven with LEU, similar to civilian research reactors. Because of proliferation concerns, most research reactors worldwide have been converted to non-weapon-usable fuel. It is likely that a similar conversion is also possible for submarines.

Tritium

Tritium is contained in all modern nuclear warheads. Since it does not occur in nature except in unretrievable traces, it must be produced artificially.[20] Its production gives rise to a difficulty because it might be confused with plutonium production. It is not possible to renounce the use of tritium for warheads, since this would require new warhead designs and the need for nuclear testing that is banned by the CTBT. Because tritium is a radioactive isotope of hydrogen with a half-life of about twelve years, nuclear disarmament does not abolish the need for new production, it only delays it. More precisely, each reduction of nuclear warheads by half would delay the need for new tritium for another twelve years.[21] A ban on military tritium production is therefore not acceptable to the NWS unless accompanied by comprehensive nuclear disarmament. Tritium is also used for several civilian applications, including scientific civilian fusion research. The wording of the FMCT negotiation mandate limits its scope to only fissile material, and excludes fusion material such as tritium.

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The most efficient and cost-effective tritium production method is by placing lithium in nuclear reactors. This procedure has been used by all NWS and it is the most probable method to be used in future. However, it is also the one that is the most likely to be mistaken for plutonium production. While exempting tritium production reactors from verification would weaken the treaty, a provision that allows states to withdraw military tritium production facilities is likely to be raised in negotiations. Again, this would create a big loophole. The IAEA agrees. Depending on whether or not naval fuel and tritium production facilities are placed under safeguards, the "level of assurance against the diversion of fissile material from amounts produced for such non-explosive uses permitted by the treaty could be high or low."[22]

Dual-use and military facilities

There is some reluctance to submit military facilities to extremely intrusive verification because sensitive information could be revealed. Sensitive facilities include former military production sites, maintenance facilities still in use, or dismantlement facilities for nuclear warheads. While closed facilities do not pose problems for verification, verification in maintenance and dismantlement facilities is unlikely to be acceptable to NWS. Additionally, the SON probably have facilities that raise similar problems. Examples of sensitive information include the following:

- *The isotopic composition of nuclear materials.* The Russian Federation is especially reluctant to reveal the exact isotopic composition of its weapon-grade HEU or plutonium.[23] It cannot be excluded that inspections and measurements on former military sites could find traces of weapon materials, even if their source had been removed prior to the start of inspections.
- *The amount of material needed for a single warhead.* It is also possible that at such sites material pieces or tools could be found that reveal the size of nuclear weapon pits. Such information is still regarded as sensitive, even after the end of the Cold War. An urgent task at such a facility is therefore the removal of these parts and tools as soon as possible in order to prepare it for the start of safeguards. This work, if necessary, is urgent anyway in order to minimize proliferation dangers.
- *Warhead design information*. In case a fissile material production facility or storage site is co-located with a warhead factory, machinery for pit fabrication and conventional explosive ignition technology could be around. This is believed to be the case at some Russian facilities.

This kind of information is highly sensitive and therefore must be protected. An urgent task for the owning state is the physical separation of fissile material production, storage sites (at least those for future civilian material) and weapon manufacture sites, in order to prepare for future inspections. In case such different facilities are co-located very closely, special arrangements will be necessary to protect the sensitive areas. Also transport to and from such special buildings must be exempted.

Implementing MC&A and SSACs

As previously mentioned, most plants in the United States, the Russian Federation, China and in the SON were not designed with safeguards in mind. Therefore, infrastructure for the installation of control equipment might be lacking. Before a SSAC can work effectively, technical material control and accountancy (MC&A) at the facilities must be implemented. Improvements are necessary and underway independent of the cut-off, at least in the Russian Federation, in the context of the various international collaborative projects for the improvement of nuclear security. A similar though smaller effort was necessary for the implementation of full-scope safeguards in South Africa.

Steps that must be taken in order to create a SSAC that is compatible with IAEA standards include: implementing regulations containing technical, organizational and reporting requirements for MC&A; implementing the interaction between the MC&A in a facility and the SSAC; installing measurement systems at facilities; preparing the initial technical physical inventory and implementing the according regulations; training personnel; and moving from the old to the new system. There are many problems that must be overcome, both of a financial and an organizational nature. In most NWS and SON, different authorities are responsible for the control of the military and civilian nuclear cycles. These states might anticipate problems in the transition of material and facilities from military to civilian use. It is recommended that they collaborate to solve such challenges.

Time will be necessary after entry into force for implementation of verification. However, it is strongly encouraged that such time be specified. Vague treaty language, like "as soon as practicable", could delay success indefinitely. It would be advisable to negotiate a timetable for specific steps, perhaps combined with technical collaboration programmes among states, the IAEA, Euratom or other SSAC agencies.

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A Universal Verification System?

An effective and non-discriminatory FMCT will need universal, full-scope safeguards. However, there are several political and technical hurdles. Paving the way for universal acceptance within the NWS and SON is a political problem and will take time, implementing material accountancy systems in these countries is a technical problem and will take time and money, implementing the safeguards is also a technical problem and will take more time and even more money.

In the long term, it will be necessary to work on fundamental reforms, moving towards a universal system without distinction between NWS and NNWS. Such a future system will be different, characterized by a new safeguards culture based more on technical and political judgement than on the current ad hoc and often political arrangements. This reform will have to encompass several areas: finances, organization, decision-making, effectiveness, concern about non-compliance, as well as underlying principles. A reform will be necessary even without a FMCT because of the various non-proliferation and disarmament problems that need new solutions. Verification activities are already underway and more will come, starting with the implementation of S^3 and safeguards on declared excess weapon materials. A new global approach could potentially lay the basis for a future nuclear-weapon-free world. To quote William Walker, "the regulatory situation in all countries, including the NWS, should be approached *as if the world is preparing for total nuclear disarmament*, whether or not that is a desirable or realistic prospect".[24]

Notes

1. On the technical abilities of the IAEA to verify a cut-off see: T.E. Shea, *Verifying a Fissile Material Production Cut-Off: Safeguarding Reprocessing and Enrichment Plants*. Current and Future Practices, Seminar on Safeguards and Non-Proliferation, IAEA Headquarters, 16–17 November 1995.
2. "The burden of a comprehensive verification system might be mitigated if the intensity of safeguards in the declared NWS were relaxed somewhat from that applied in the NNWS." See F. Berkhout, O. Bukharin, H. Feiveson and M. Miller, A Cutoff in the Production of Fissile Material, *International Security*, Winter 1994/95 (vol. 19, no. 3), pp. 167–22, quotation on p. 183; S. Fetter and F. von Hippel, A Step-By Step Approach to a Global Fissile Materials Cutoff, *Arms Control Today*, October 1995, pp. 3–8.; Zhu Qiangguo, *A Cutoff of Fissile Material Production for Nuclear Weapon Purposes and Its Concerned Issues*, Paper presented at the 8th International Summer Symposium on Science and World Affairs, Beijing, China, 23–31 July 1996. Jin Huimin maintains that the objective of a FMCT is just to shut down military facilities, so verification of civilian activities has little to do with it. See Jin Huimin, *On Verification of the Cut-Off Treaty*, Paper for the 5th ISODARCO-Beijing Seminar on Arms Control, 11–16 November 1996, Cheng-Du, China.
3. S. Fetter, *Verifying Nuclear Disarmament*, Stimson Center, Occasional Paper No. 29, October 1996.
4. W. Walker, personal communication.
5. T.E. Shea, see note 1.
6. § 28 of INFCIRC/153 (Corrected), June 1972. For explanations of the terms timely detection, significant quantities, detection probability, and false alarm probability see *IAEA Safeguards Glossary*, 1987 edition.
7. European Union members have transferred the sovereignty of owning civilian nuclear materials including accountancy authority to Euratom. In this case, there is a safeguards agreement between Euratom and the IAEA (INFCIRC/193). For a description of IAEA safeguards see: D.A.V. Fischer, The International Atomic Energy Agency and Nuclear Safeguards, in: D. Howlett, J. Simpson (eds.), *Nuclear Non-Proliferation – A Reference Handbook*, Longman, Harlow, 1992.
8. This is also the expectation of the IAEA. See S. Thorstensen, *Fissile Material and Verification – IAEA Capability and Infrastructure for Verification of Fissile Material*, presentation at the Cut-Off Convention Workshop, Toronto, Canada, 17–18 January 1995.
9. T.E. Shea, see note 1.
10. A comprehensive overview on enrichment technologies and their significance for proliferation is A.S. Krass, P. Poskma, B. Elzen and W.A. Smit, *Uranium Enrichment and Nuclear Weapon Proliferation*, SIPRI, Taylor & Francis Ltd, London and New York, 1983.
11. A. MacLachlan, France 'on schedule' to show feasibility of SILVA in 1997, *Nuclear Fuel*, 11 March 1996.
12. A. MacLachlan, Cogema to help South Africa's AEC develop MLIS enrichment process, *Nuclear Fuel*, 11 March 1996.
13. D.A. Howlett, *Euratom and Nuclear Safeguards*, Macmillan, Southampton, 1990. See p. 225 ff.
14. W. Walker, personal communication.
15. On technical properties of plutonium see: *Nuclear Energy Agency, Plutonium Fuel – An Assessment*, OECD, Paris, 1989.
16. T.E. Shea, note 1; T.E. Shea et al., Safeguarding Reprocessing Plants: Principles, Past Experience, Current Practice and Future Trends, *Journal of Nuclear Materials Management*, July 1993; United States Congress, Office of Technology Assessment, *Nuclear Safeguards and the International Atomic Energy Agency*, Appendix A: Safeguarding Reprocessing Facilities, OTA-ISS-615, Washington, 1995.
17. IAEA, *A Cut-Off Treaty and Associated Costs – An IAEA Secretariat Working Paper on Different Alternatives for the Verification of a Fissile Material Production Cut-Off Treaty and Preliminary Cost Estimates Required for the Verification*

of these Alternatives, presented at the Cut-Off Convention Workshop, Toronto, Canada, 17–18 January 1995.
18. Ibid., p. 6.
19. F. McGoldrick (United States State Department) said in 1994: "Some argue that the benefits of safeguards in nuclear weapon states are not commensurate with the costs. I think they are, and many share this view." F. McGoldrick, *U.S. Fissile Material Initiatives – Implications for the IAEA,* invited paper, Proceedings of the Symposium on International Nuclear Safeguards, Vienna, 14–18 March 1994, vol. I, quotation on p. 20.
20. For a detailed overview on tritium uses, production and eventual control see M. Kalinowski and L. Colschen, International Control of Tritium to Prevent its Horizontal Proliferation and to Foster Nuclear Disarmament, *Science and Global Security*, vol. 5, no. 2, 1994/95, p. 130.
21. Arms reductions are releasing large amounts of tritium — decades worth — that the United States and the Russian Federation can stockpile. If comprehensive disarmament were envisaged in a comparable time, they might live with a ban on tritium production. The United Kingdom and France may have a greater problem because their reductions are smaller percentage-wise.
22. S. Thorstensen, note 8, p. 4.
23. In the United States, the isotopic composition is classified as long as the material is in warhead component form. As soon as this form is modified, the masses and isotopic composition can be revealed. See J.T. Markin and W.D. Stanbro, Policy and technical issues for international safeguards in nuclear weapon states, in: *International Nuclear Safeguards 1994*, Proceedings of the Symposium on International Nuclear Safeguards, Vienna, 14–18 March 1994, vol. II, p. 639. In the Russian Federation, the isotopic composition of disarmament materials remains classified.
24. D. Albright, F. Berkhout and W. Walker, ibid.; see Chapter 15, The control and disposition of fissile materials: the new policy agenda.