

Complete Cutoff: Designing a Comprehensive Fissile Material Treaty

President Barack Obama has pledged to “lead a global effort to negotiate a verifiable treaty ending the production of fissile materials for weapons purposes.”¹ Fissile materials are the chain-reacting fissionable materials that are the essential ingredients in nuclear weapons, in practice, highly enriched uranium (HEU) and separated plutonium.

Obama is not the first president to back the negotiation of such a treaty: President Bill Clinton did so after the UN General Assembly in 1993 adopted by consensus a resolution calling for negotiation of a “non-discriminatory, multilateral and internationally and effectively verifiable treaty banning the production of fissile material for nuclear weapons or other explosive devices.”² Even the administration of President George W. Bush tabled a draft treaty at the Geneva-

based Conference on Disarmament (CD), albeit without international verification.

Despite the passage of more than a decade since initial negotiations began and sputtered out, negotiations on a fissile material cutoff treaty (FMCT) have yet to be renewed, stalled largely over disagreements about the negotiating agenda of the CD. For years, many countries have supported a proposal to have a CD work program that included parallel negotiations on an FMCT,

nuclear disarmament, a binding agreement by the nuclear-weapon states not to use or threaten to use nuclear weapons against non-nuclear-weapon states, and the prevention of an arms race in outer space. The U.S. position, however, has been that negotiations on an FMCT should not be linked to negotiations on other issues.³ Because the CD operates by consensus, any single country can block agreement on the program of work. Should this logjam be broken and Obama be able to fulfill his pledge and begin talks, disputes about the scope of the treaty and its verification provisions would move to the fore.

Scope

Four of the five nuclear Nonproliferation Treaty (NPT) nuclear-weapon states (France, Russia, the United Kingdom, and the United States) announced in the 1990s that they had ended their production of fissile material for weapons. China has made no official announcement but is generally believed to have stopped producing during the same period. This means that the proposed FMCT primarily would constrain non-NPT states India, Israel, and Pakistan, all of which have nuclear arsenals.

Arend Meerburg retired from the Netherlands Foreign Ministry in 2004 after 34 years spent mostly working on multilateral arms control, including the Chemical Weapons Convention and the Comprehensive Test Ban Treaty. He was involved in the International Fuel Cycle Evaluation, international plutonium storage regime discussions, and the Nuclear Suppliers Group and served as a member of the International Atomic Energy Agency expert group on multinational nuclear approaches to sensitive parts of the nuclear fuel cycle. **Frank N. von Hippel** is a professor of public and international affairs at Princeton University. During 1993-1994, he was assistant director for national security of the White House Office of Science and Technology Policy. Both are members of the International Panel on Fissile Materials, and this article is based on the panel’s “Global Fissile Material Report 2008.”

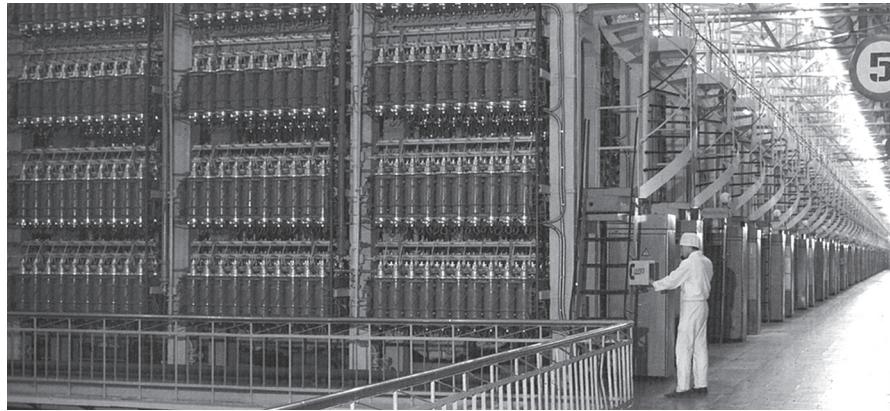
Many non-nuclear-weapon states, joined by Pakistan, argue that an FMCT should go beyond prohibiting the production of new fissile material for weapons. They point out that the existing stocks of fissile materials in some nuclear-weapon states are so large that a cutoff would have no practical effect on restricting the number of nuclear weapons that they could produce.

In fact, only about one-half of the global stockpile of HEU and about one-third of the global stockpile of separated plutonium is in weapons stockpiles (see figures 1 and 2). Beginning in the mid-1990s, Russia and the United States declared excess almost one-half the fissile materials in their weapons stocks. Even though more than one-half of the weapons HEU that was declared excess has since been blended down to low-enriched uranium (LEU), the amount that remains to be blended down or used as HEU constitutes about 20 percent of the global stock of HEU. Disposition of the weapons-grade plutonium that Russia and the United States declared excess has not even begun.

Among the nuclear-weapon states, Russia, the United Kingdom, and the United States fuel their naval reactors with HEU; India plans to do so as well.⁴ The United States is the only country thus far to declare a dedicated reserve of HEU for naval fuel, 128 metric tons of weapons-grade material. In the past, the United States has also supplied HEU to fuel British submarines.

France, Russia and the United Kingdom also have accumulated huge stocks of separated civilian plutonium; indeed, one-half of the global stock of separated plutonium is civilian. Surely, many non-nuclear-weapon states argue, an FMCT should capture all these stocks of non-weapon materials as well.

In 1995, Canadian Ambassador Gerald Shannon was tasked with finding a way to accommodate the various views concerning the scope of an FMCT. His report became a CD-backed consensus proposal known as the Shannon Mandate. It called for moving forward with the talks without first deciding the issue of fissile material stocks: “[I]t has been agreed by delegations that the mandate for the establishment of the ad hoc Committee does not preclude any delegation from raising for consideration in the ad Hoc Committee any of the above noted issues [pre-existing stocks and management of fissile material].”⁵



Russian Ministry of Atomic Energy

Interior view of a cascade hall of Russia's Novouralsk centrifuge enrichment plant. The facility has a capacity of more than 10 million separative work units per year.

IPFM Draft Treaty

To facilitate negotiations when they are finally launched, the International Panel on Fissile Materials (IPFM), of which we are members, decided to produce an alternative to the U.S. draft FMCT. This draft treaty, which may be found on the IPFM Web site,⁶ would prohibit using all or nearly all pre-existing stocks of non-weapons fissile materials for nuclear weapons and include verification. Such a broader treaty is necessary because an FMCT that banned the production of new fissile material for weapons but allowed production of new weapons from the massive existing stocks of civilian, excess weapons, and naval fissile material would not effectively cap nuclear arsenals or make reductions irreversible. Because it goes beyond a cutoff of future production, we designate the IPFM draft treaty as a fissile material (cutoff) treaty [FM(C)T].⁷ On the date the treaty entered into force, all fissile material in the civilian sector and any material produced after that date would be subject to safeguards. Some material that had been declared excess for military purposes might not be immediately transferable to the civilian sector because it was still in weapons components. It could be subjected to International Atomic Energy Agency (IAEA) monitoring, however, by an approach similar to that of the Trilateral Initiative.

One issue to be addressed early would be the IAEA monitoring of pre-existing stocks of HEU reserved for future naval purposes. This possibility is likely to be resisted fiercely by the British and U.S. nuclear navies. As a result, in the absence of a presidential-level commitment to inclusion, the negotiators may quickly jettison such monitoring. For any HEU newly produced for naval reactors, however, veri-

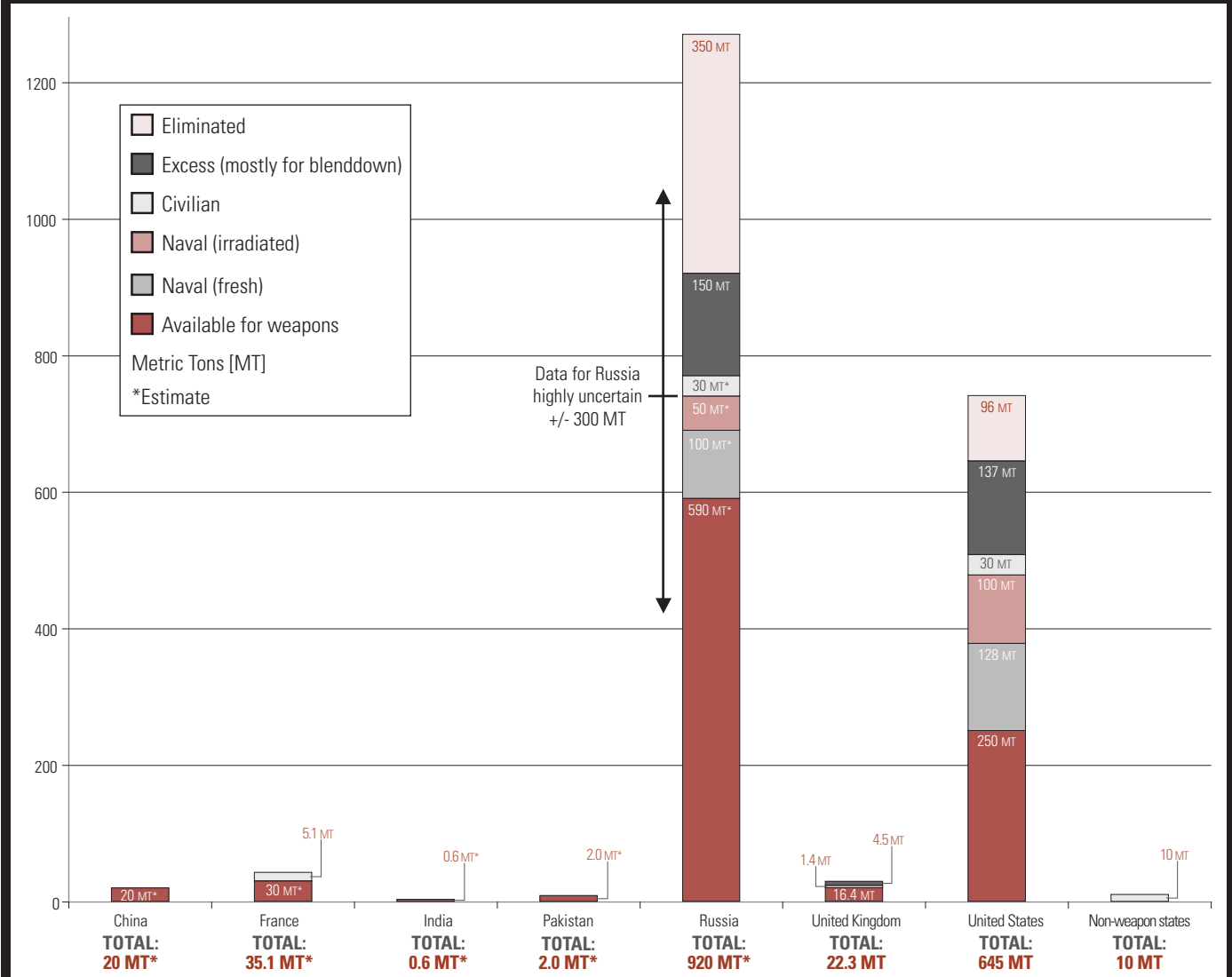
fication arrangements for nondiversion of HEU from naval fuel cycles will have to be developed. The only way to avoid such verification arrangements would be to convert HEU to LEU fuel before the stockpiles of pre-existing HEU are depleted. For Russia and the United States, existing stocks of excess weapons HEU will last for many decades. Other countries, notably India, could face the need to make HEU for naval fuel much earlier.

FMCT Verification

By calling for a verifiable treaty, the Obama administration appears to have rejected the Bush administration's position that an FMCT could not be effectively verified. The draft FMCT that the Bush administration submitted on May 18, 2006—the only draft FMCT that any government has submitted thus far—did not contain any provisions for international verification.⁸ It was accompanied with a white paper that put forward the administration's position on the verifiability of an FMCT: “[E]ven with extensive verification mechanisms and provisions—so extensive that they could compromise the core national security interests of key signatories, and so costly that many countries would be hesitant to implement them—we still would not have high confidence in our ability to monitor compliance with an FMCT.”⁹ The two primary concerns behind this conclusion appear to have been the difficulty of determining without unacceptable intrusiveness that HEU is not being diverted to weapons from the naval-reactor fuel cycle and whether undeclared fissile material production capabilities might be present in nuclear-weapon-related facilities.¹⁰ The discussion of FM(C)T verification that follows therefore begins with these challenges.

Figure 1: National Stocks of Highly Enriched Uranium

As states seek to define a fissile material (cutoff) treaty, they are debating whether the treaty should encompass some preexisting stocks of fissile material that are used today for non-weapons purposes. One such material is highly enriched uranium (HEU). Current global stocks of HEU could make about 50,000 warheads based on the International Atomic Energy Agency assumption that 25 kilograms of U-235 in HEU is needed to provide the explosive material for a nuclear weapon. Almost half of the stockpile of unirradiated HEU in the nuclear-weapon states is outside their weapon complexes. This includes about 300 tons that have been declared excess for military use and are being blended down to low-enriched uranium (LEU) for power-reactor fuel. A comparable quantity has been reserved to fuel naval, isotope-production, civilian research and Russia's icebreaker-propulsion reactors.



SOURCES: The numbers without asterisks are based on declarations by the relevant governments. Non-weapon states declare their stockpiles to the IAEA and some of the weapon states declare their civilian stocks. Only the United Kingdom and the United States have declared their military stocks. The numbers with asterisks are non-governmental estimates. Most of the numbers are for the end of 2007.
 * David Albright, Frans Berkhout, and William Walker, *Plutonium and Highly Enriched Uranium 1996* (Oxford University Press, 1997); Institute for Science and International Security, "Global Stocks of Nuclear Explosive Materials," available online; and International Panel on Fissile Materials, "Global Fissile Material Report 2008," pp. 7-20.

Safeguarding Naval HEU

One of the challenges to the verification of a broad FM(C)T would be detecting any significant diversion of HEU in naval fuel cycles to weapons.

Naval reactors are a challenge to the verification of the NPT as well because that treaty allows non-nuclear-weapon states to acquire nuclear-powered ships and submarines and its associated safeguards regime and has a potential loophole that could be exploited vis-à-vis fuel for such military vessels.¹¹ Brazil is the

first non-nuclear-weapon state that is developing a propulsion reactor for a nuclear submarine. Fortunately, it is to be fueled with LEU.

The best solution from many points of view would be for LEU fuel to become the norm.¹² France already has shifted its naval reactors to LEU fuel. In 1994 the U.S. Congress requested a study from the Department of Energy's Office of Naval Propulsion of the costs and benefits of shifting to LEU.¹³ More recently, the Senate Armed Services Committee directed "the Office of

Naval Reactors to review carefully options for using low-enriched uranium fuel in new or modified reactor plants for surface ships and submarines."¹⁴ The National Academy of Sciences should be commissioned to do an independent cost-benefit analysis.

In the meantime, however, the problem of HEU-fueled naval reactors must be addressed. The IPFM has not solved the problem of safeguarding this HEU but has developed some ideas that could be useful.¹⁵

To begin, the IAEA should monitor any HEU stockpiles reserved for naval fuel use,

and the owner countries should inform the IAEA when they need to withdraw specific amounts for specified propulsion reactors. The IAEA could do a rough check of the reasonableness of these numbers by comparing them with published estimates of the amounts of HEU used in the cores of different types of naval vessels.¹⁶ The IAEA would then verify the amount of HEU being removed from the safeguarded store and shipped to a naval fuel fabrication facility.

The IPFM's effort has been focused pri-

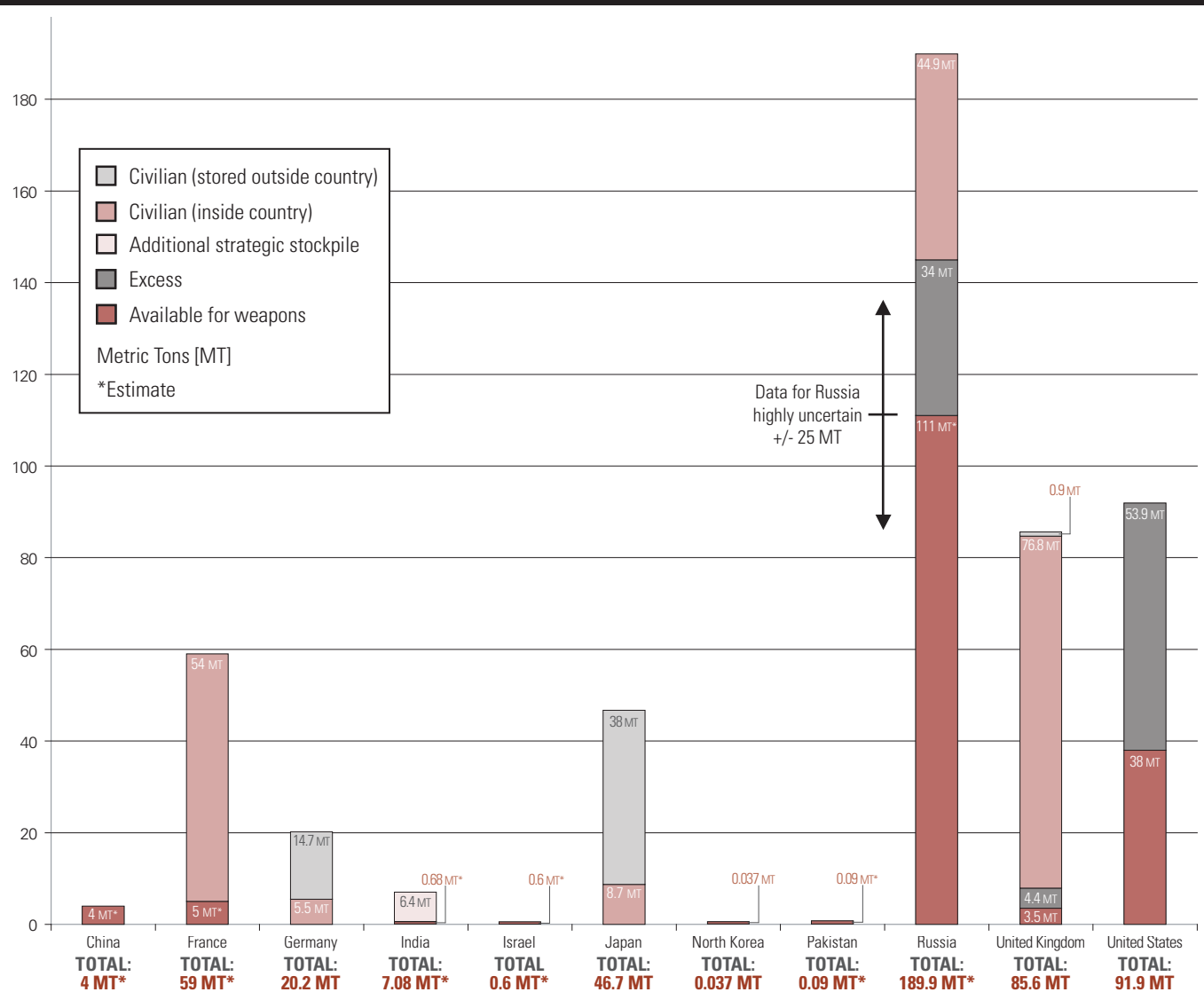
marily on determining whether it would be possible for the IAEA to verify the amount of HEU coming out of the fuel fabrication facility in the form of fuel in a sealed container. In doing so, we have patterned our approach on that of the Trilateral Initiative within which Russia and the United States discussed with the IAEA from 1996 to 2002 how to monitor the fissile material in excess weapons components until they could be converted to unclassified form. The initiative proposed that the IAEA monitor plutonium-con-

taining weapon "pits" by measuring the emissions of neutrons and energies of the gamma rays coming out of their containers and then processing the data through a computer "information barrier" that would indicate to the IAEA only whether a container held more than a threshold quantity (e.g., two kilograms) of weapons-grade plutonium.¹⁷

For the naval fuel, the question is whether it would be possible for the IAEA to determine the amount of uranium-235 in HEU in a container without determin-

Figure 2: National Stocks of Separated Plutonium

As states seek to define a fissile material (cutoff) treaty, they are debating whether the treaty should encompass preexisting stocks of fissile material, some of which is used today for non-weapons purposes. One such material is plutonium. Two thirds of the separated plutonium in the nuclear-weapon states is either civilian or has been declared excess for weapons use as a result of the downsizing of Cold War stockpiles. Civilian plutonium has been separated mostly from spent power-reactor fuel. Originally, it was to be used to provide startup fuel for plutonium breeder reactors that were never commercialized. Today, it is being recycled in France but is simply stockpiled in Russia and the United Kingdom. Were all the separated plutonium in the world to be used for nuclear weapons and assuming that four kilograms of weapon-grade plutonium or eight kilograms of civilian plutonium is needed per warhead, there is enough separated plutonium in the world to make about 90,000 warheads.



SOURCES: The numbers without asterisks are based on declarations by the relevant governments. Non-weapon states declare their stockpiles to the IAEA and some of the weapon states declare their civilian stocks. Only the United Kingdom and the United States have declared their military stocks. The numbers with asterisks are non-governmental estimates. Most of the numbers are for the end of 2007.

ing additional design information about the fuel (e.g., alloying material, cladding, fuel rod or plate thickness). Our current idea is to shoot a beam of neutrons into the canister holding the fuel and to look for events in which many more neutrons are emitted than could be attributed to a single fission. This would be an indicator of chain reactions and therefore a

quires a country to declare all of its nuclear-related activities, including, for example, centrifuge research and development and manufacture, and allows the IAEA access to check on the declaration's "correctness and completeness." From mid-July 2003 until February 2006, while Iran was complying voluntarily with the protocol, the IAEA successfully used the access that it provided to

Department has instructed the managers at all its sites, and the NRC has similarly instructed the owners of the sites it regulates, to prepare managed access plans in case the IAEA requests an on-site inspection.²⁴ It is very encouraging that even the Bush administration was not inclined to simply invoke the national security exemption at all of its military nuclear sites.

A broader treaty is necessary because a fissile material cutoff treaty that banned the production of new fissile material for weapons **but allowed production of new weapons from the massive existing stocks of civilian, excess weapons, and naval fissile material would not effectively cap nuclear arsenals or make reductions irreversible.**

measure of the density of U-235. Work on such an approach has been initiated at Princeton University.¹⁸ A related approach is being pursued at the Oak Ridge National Laboratory.¹⁹

If it is possible to verify the amount of HEU in a fuel container, it will also be necessary to have confidence that the fuel actually is installed in a naval reactor. This is done routinely by the IAEA for light-water power reactors, where the owner installs the fuel in the presence of IAEA inspectors and then the pressure vessel is closed and sealed by the IAEA. There would be sensitivities, however, about having the IAEA present during the fueling of naval ships and submarines.

The challenge would be similar to that which confronted the negotiators of START when they had to negotiate procedures that would allow verification of the declared number of warheads deployed on strategic missiles. We believe that, as the saying goes, "if there is a [political] will, there is a way."

Challenge Inspections

The other major challenge to FM(C)T verification would be the possibility of undeclared production of HEU or plutonium. The same challenge exists under the NPT. Since the discovery of Iraq's undeclared enrichment program in 1991, the IAEA's capabilities to detect undeclared activities have been strengthened in those states that have ratified versions of the 1997 Model Additional Protocol.²⁰ This protocol re-

quires a country to declare all of its nuclear-related activities, including, for example, centrifuge research and development and manufacture, and allows the IAEA access to check on the declaration's "correctness and completeness." From mid-July 2003 until February 2006, while Iran was complying voluntarily with the protocol, the IAEA successfully used the access that it provided to

surface activities that Iran had tried to conceal, such as its enrichment experiments at the Kalayeh Electric Company.²¹ For the IAEA to be able to detect clandestine fissile material production under an FM(C)T, the nuclear-weapon states would have to agree to something like the Model Additional Protocol. In fact, the United States already has a version of the Model Additional Protocol with the IAEA.²² The U.S. additional protocol is identical to the model for non-nuclear-weapon states except that it contains an added clause (Article 1b) that allows the U.S. government to exclude the IAEA in circumstances where the application of the additional protocol "would result in access by the Agency to activities of direct national security significance to the United States or in connection with locations or information associated with such activities."

The United States delayed depositing its instrument of ratification of its additional protocol to the very end of the Bush administration while it worked out in advance how it would handle challenge inspections at every nuclear facility in the United States.²³

Facilities that could conceivably conceal clandestine fissile material production activities are the Energy Department sites where spent fuel reprocessing and uranium-enrichment research and development are carried out and Nuclear Regulatory Commission (NRC)-licensed sites, including those where nuclear fuel is fabricated for naval propulsion reactors. The Energy

The Department of Defense, however, has demanded a blanket exemption of all its sites from reporting or inspections under the U.S. additional protocol.²⁵ Hopefully, the Obama administration will reconsider this Pentagon position. Japan and all non-nuclear-weapon states in western Europe have ratified versions of the Model Additional Protocol, which would allow IAEA inspectors to have managed access to their defense facilities.²⁶ The U.S. defense establishment differs from its counterparts only by virtue of having nuclear weapons and nuclear-powered ships, but neither could credibly conceal clandestine fissile material production activities.

In any case, all defense-related sites already are subject to challenge inspections under the Chemical Weapons Convention by inspectors of the Organization for the Prohibition of Chemical Weapons (OPCW). IAEA inspectors would be looking for different activities than OPCW inspectors, but the elaborate procedures that have been developed for OPCW inspections would provide useful templates for IAEA inspections of sensitive nuclear sites. One OPCW instrument, for example, a gas-chromatograph mass spectrometer, includes a database that allows inspectors to identify 3,000 specified chemical weapons agents, precursors, and degradation products but no other chemicals. The IAEA is examining instrumentation that could similarly identify surface deposits containing uranium and fluorine, an indicator of the presence of uranium hexafluoride, the chemical form of uranium that is used in

centrifuge enrichment plants, while not revealing the isotopic makeup of the uranium. Similarly, Geiger counters could be used to detect the presence of highly radioactive fission products, an indicator of reprocessing activities, without providing any information about the isotopic composition of any uranium or plutonium that is present.²⁷

Problems With the Focused Approach to Verification

Some diplomats have proposed a “focused approach” to verification for an FMCT that only banned new production of fissile materials.²⁸ This would involve IAEA monitoring of only enrichment and reprocessing plants initially. For enrichment plants, if they were determined not to be producing HEU, that would be the end of the story. Plutonium newly separated at reprocessing plants and any newly produced HEU would be subject to IAEA safeguards in storage and through processing into fuel until the fuel was irradiated in a reactor.

This focused approach would minimize IAEA inspection costs incurred as a result of an FMCT. It also has attractions for some of the nuclear-weapon states because it would allow them to limit routine entry by IAEA inspectors to facilities into which “new” fissile material had been introduced, i.e., material produced after an FMCT came into force for that country.

The cost savings from the focused approach are often exaggerated, however, because the IAEA inspection effort re-

quired to safeguard a reprocessing plant in a non-nuclear-weapon state is about 100 times greater than at a reactor fueled by LEU. In 2007 the IAEA had 924 facilities under safeguards in non-nuclear-weapon states,²⁹ but two reprocessing plants in Japan account for 20 percent of the global IAEA safeguards budget.³⁰ A 1996 Brookhaven study found that just safeguarding reprocessing and enrichment plants would account for two-thirds of the cost of safeguarding all nuclear facilities in the nuclear-weapon states, including 364 power reactors and 419 other facilities such as fuel fabrication facilities and research reactors.³¹

The focused approach would be insufficient in any case for the more extensive treaty we envision, which should capture as much fissile material as possible, not only that newly produced.³² Monitoring existing civilian and weapons excess stocks as well as HEU for naval or other military reactors would require more extensive verification measures.

Of course, the IAEA would have to prioritize, at least while it was building up its capabilities. The highest priority targets should be reprocessing and enrichment plants and facilities with large stocks of fissile materials. Monitoring the fuel cycles of reactors fueled with LEU, i.e., most power reactors and an increasing fraction of research reactors, should be a lower priority.

Two particular challenges for inspectors would be employing safeguards at pre-

existing reprocessing plants and detecting undeclared HEU production at enrichment plants that produced this material in the past.

Safeguards at Pre-existing Reprocessing Plants

The size of the flow of plutonium through a large commercial reprocessing plant is so large that, if inspectors solely apply mass measurements, a country might well be able to divert enough plutonium for one nuclear bomb or several without being detected. At Japan’s new Rokkasho reprocessing plant, for example, the design throughput is 8,000 kilograms of plutonium per year. With measurement errors on the order of 1 percent, which is 80 kilograms per year, and the “significant quantity” of plutonium required to make a nuclear weapon being eight kilograms or less, the IAEA cannot certify on the basis of measurements alone that a significant quantity has not been diverted. Mass measurements are therefore supplemented with process monitoring to detect anomalous flows and concentrations and with “containment and surveillance” to detect activities that might be associated with diversions. Whether these measures are adequate has been questioned.³³ Furthermore, at pre-existing reprocessing plants, surveillance measures necessarily would be more limited than at a new reprocessing plant, where the IAEA can verify the declared locations of pipes before concrete is poured and install independent measuring instruments in reprocessing cells before high levels of radiation makes them inaccessible.

Shirley Johnson, who oversaw the development, installation, and implementation of IAEA safeguards at Rokkasho, has proposed a design for safeguards at pre-existing reprocessing plants that would require real-time declarations of the operations being performed within the plant and input of these declarations into a detailed computer model of the plant’s internal configuration. Inspectors would then compare the predicted flows and concentrations with continuous measurements by automated instrumentation at strategic points and by IAEA inspectors during six to eight random unannounced visits each year. Finally, the plant would be cleaned out annually to check whether, within measurement uncertainties, the amount of separated plutonium oxide that came



AFP/Getty Images

Control room of Japan’s spent fuel reprocessing plant at Rokkasho, Dec. 21, 2004. The facility has a design throughput of 8,000 kilograms of plutonium per year.

out of the reprocessing plant matched the amount of plutonium measured in the input accountability tank.

By eliminating the costly resident inspection team and on-site safeguards laboratory that account for a major part of the IAEA costs at Rokkasho, Johnson was able to drive estimated IAEA safeguards costs down to about one-fifth of those at the Rokkasho plant, or about \$2 million per year.³⁴ Safeguarding reprocessing plants and the associated fuel fabrication plants for uranium-plutonium mixed-oxide fuel, however, will be problematic under an FM(C)T just as it is under the NPT.

Detecting Undeclared HEU Production at Enrichment Plants

A sense of the challenge of safeguarding a large pre-existing enrichment plant to ensure that it is not being used to produce HEU is conveyed by the picture from inside the centrifuge hall of one of Russia's huge centrifuge enrichment plants.

Perhaps the most potent tool the IAEA has to check for HEU production is to take swipes of surfaces and then look for microscopic HEU-containing particles in the dust collected. Yet, three out of four of Russia's existing enrichment plants produced HEU in the past. To our knowledge, Russia ended

HEU production in these facilities in 1987 or 1988. It therefore would be necessary to look for new HEU particles against a background of pre-1988 particles.

Alexander Glaser has done a review of progress in age-dating small particles of HEU and believes that the state of the art has progressed to the point where it should be possible to distinguish new particles from pre-1988 particles.³⁵ This approach would not work for the enrichment plants currently producing HEU in India and Pakistan, but those plants are small. Monitoring the flows and enrichment of uranium hexafluoride within their cascades would be feasible.

Key Countries and a Fissile Material (Cutoff) Treaty

If U.S. negotiators should embark on negotiations on a fissile material (cutoff) treaty (FM(C)T), they will have to keep in mind the quite different perspectives of some of the key countries that would have to be involved in the talks.¹ There are also several related steps that they and representatives from other countries could take to make talks more successful.

First and foremost, bringing about a treaty will require China, India, and Pakistan to decide that they have enough nuclear weapons materials. Indeed, some of the nuclear Nonproliferation Treaty (NPT) nuclear-weapon states question the point of an FM(C)T if non-NPT states India and Pakistan, which are in the process of accelerating the rate at which they are producing fissile material for weapons, refuse to join. France, Russia, the United Kingdom, and the United States have declared that they have ended their production of fissile materials for weapons.

China is believed to have halted its production of fissile material for weapons around 1990 but has not declared a permanent halt because of concerns that U.S. long-range conventional precision-guided missiles and missile defense programs could eventually threaten the deterrence value of China's small ICBM force. If the Obama administration were to reconsider the Bush administration's open-ended and unconditional commitment to strategic missile defense and prompt global strike, that might mitigate China's concerns.

Countries also have differing perspectives on whether a treaty should cover pre-existing materials. For the most part, the nuclear-weapon states want a treaty that simply cuts off further production of fissile material for weapons and does not cover pre-existing stockpiles of fissile materials. The non-nuclear-weapon states, in contrast, want an FM(C)T to serve as a significant step toward the eventual elimination of nuclear weapons. They therefore want a cutoff treaty that includes deep cuts in existing weapons stockpiles, at least in those of Russia and the United States, and would prevent the conversion to nuclear weapons of pre-existing stockpiles of civilian and other fissile material declared excess to weapon needs.

Pakistan is in the camp of countries interested in reductions in existing stocks because it fears that a cutoff treaty could lock it into a position of disadvantage relative to India. Whether Pakistan actually has a significantly smaller stockpile than India, however, depends in large part on whether India's separated reactor-grade plutonium is considered civilian or weapon material. India exempted its separated reactor-grade plutonium and the fuel cycle of its

plutonium-breeder reactor program from international safeguards under the recently approved U.S.-Indian nuclear agreement. It would mitigate Pakistan's concern if India declared these materials civilian and subject to International Atomic Energy Agency (IAEA) safeguards under an FM(C)T.

With regard to verification, all the nuclear-armed states appear to worry to a greater or lesser degree about the intrusiveness and cost of inspections. That makes the "focused approach" to verification of a minimal treaty a lowest-common-denominator compromise. Under this approach, IAEA inspections would focus initially on enrichment and reprocessing plants and then expand only to follow newly produced highly enriched uranium and plutonium until they were irradiated. Much of the value of an FM(C)T would be lost in such a compromise.

Among the nuclear-weapon states, France and the United Kingdom should be the least nervous about international inspections because all their civilian nuclear facilities are already subject to Euratom inspections. The United States has included all of its civilian nuclear facilities in its "voluntary offer" for IAEA inspections, but the IAEA has not had enough funding to mount inspections at more than a very few U.S. facilities of special interest.²

Finally, there is Israel. Its current production rate is not publicly known, and it fears that an FM(C)T would force its nuclear weapons program out of the closet and strengthen pressures on it to disarm. Israel also sees discussion of an FM(C)T as a distraction to the effort to end Iran's uranium-enrichment program.

Given these complexities, negotiations on an FM(C)T could last several years. It would therefore be desirable in the meantime for more countries to join the current voluntary production moratorium and offer their production facilities and major civilian and excess military stocks of fissile materials for voluntary IAEA safeguards. —AREND MEERBURG and FRANK VON HIPPEL

ENDNOTES

1. See Jean-Marie Collin et al., "Country Perspectives on the Challenges to a Fissile Material (Cutoff) Treaty," International Panel on Fissile Materials (IPFM), 2008.
2. IPFM, "Global Fissile Material Report 2007," pp. 67-81, www.fissilematerials.org/ipfm/site_down/gfmr07.pdf.

Conclusion

The work done by the IPFM thus far encourages us to believe that it should be feasible technically for an FMCT to capture under IAEA safeguards pre-existing stocks of fissile material in civilian use, declared excess for military use, and in naval fuel reserves and to verify the treaty about as well as the NPT can be verified in non-nuclear-weapon states. Such a verified treaty would be a vital building block for further nuclear disarmament measures. The political task of persuading states to agree to such constraints and access, however, may be the more difficult challenge (see previous page). **ACT**

ENDNOTES

1. "Arms Control Today 2008 Presidential Q&A: President-elect Barack Obama," *Arms Control Today*, December 2008, special section.
2. UN General Assembly, Resolution 48/75L, 1993.
3. Reaching Critical Will, "Governmental Positions on the Core Issues at the Conference on Disarmament, Publicly Stated Positions Since 1 January 2003," June 19, 2008, www.reachingcriticalwill.org/political/cd/positions_matrix.html.
4. We are aware of no definitive public information on the enrichment of the fuel used in China's nuclear-powered submarines.
5. "Report of Ambassador Gerald E. Shannon of Canada on Consultations on the Most Appropriate Arrangement to Negotiate a Treaty Banning the Production of Fissile Material for Nuclear Weapons or Other Nuclear Explosive Devices," CD/1299, March 24, 1995.
6. International Panel on Fissile Materials (IPFM), "Draft Fissile Material (Cut-Off) Treaty," January 23, 2009, www.ipfmlibrary.org/fmct-ipfm_feb2009draft.pdf.
7. We found very valuable in our work a draft treaty developed by Thomas Shea, which is still broader, including commitments on proliferation resistance and materials security.
8. "U.S. Tables Draft FMCT Text at Conference on Disarmament," May 18, 2006, geneva.usmission.gov/Press2006/0518DraftFMCT.html.
9. "United States of America: White Paper on a Fissile Material Cutoff Treaty — Conference on Disarmament," May 18, 2006, geneva.usmission.gov/Press2006/0518WhitePaper.html.
10. These positions are attributed to "one delegation" in "Report to the President of the Conference on Disarmament on the Informal Meetings During the First Part of the 2008 Session by the Permanent Representative of Japan to the Conference on Disarmament, Ambassador Sumio Tarui, Coordinator on Agenda Items 1 and 2 With a General Focus on the Prohibition of Production of Fissile Material for Nuclear Weapons or Other Nuclear Explosive Devices," CD/1846, August 15, 2008, p. 15 (app. III).
11. Paragraph 14 of INFCIRC/153 (corrected), June 1972, the model safeguards agreement between the IAEA and non-nuclear-weapon states that are parties to the NPT, permits a country to remove nuclear material from safeguards for use "in a non-proscribed military activity," i.e., for fuel in naval propulsion or other military reactors, as long as the state makes clear that "during the period of non-application of safeguards the nuclear material will not be used for the production of nuclear weapons or other nuclear explosive devices."
12. Ma Chunyan and Frank von Hippel, "Ending the Production of Highly Enriched Uranium for Naval Reactors," *Nonproliferation Review*, Spring 2001, p. 86.
13. Director, Naval Nuclear Propulsion, "Report on Use of Low Enriched Uranium in Naval Nuclear Propulsion," June 1995, www.ipfmlibrary.org/onnp95.pdf.
14. Senate Committee on Armed Services, "National Defense Authorization Act for Fiscal Year 2009," 110th Cong. 2d sess., 2008, S. Rep. 355, p. 515, http://frwebgate.access.gpo.gov/cgi-bin/getdoc.cgi?dbname=110_cong_reports&docid=fsr335.110.pdf.
15. Ferenc Dalnoki-Veress, Alexander Glaser, and Frank von Hippel, "HEU in the Naval Fuel Cycle," in IPFM, "Global Fissile Material Report 2008: Scope and Verification of a Fissile Material (Cutoff) Treaty," September 2008, pp. 76-85, www.fissile-materials.org/ipfm/site_down/gfmr08.pdf.
16. These estimates are based on public information on the shaft horsepower of the ships and the refueling frequency of their reactors, standard assumptions concerning the efficiency of conversion of the thermal energy released by fission into mechanical power and the percentage burn-up of the U-235 in the fuel, and estimates of the average fractional power output of the reactor. See for example, Ole Reistad and Styrrkaar Hustveit, "HEU Fuel Cycle Inventories and Progress on Global Minimization," *Nonproliferation Review*, No. 15 (2008), p. 265.
17. Thomas Shea, "Weapon-Origin Fissile Material: The Trilateral Initiative," in IPFM, "Global Fissile Material Report 2008," pp. 62-75. For excerpts of this material, see "The Trilateral Initiative: A Model for the Future," *Arms Control Today*, May 2008, p. 17.
18. Ferenc Dalnoki-Veress, Alexander Glaser and Frank von Hippel, "A Dedicated Detector for the Verification of Highly Enriched Uranium in Naval Reactors" (paper, Institute of Nuclear Materials Management, Tucson, July 12-16, 2009).
19. The Oak Ridge group has focused on the problem of verifying fissile material in the sealed cores of small transportable power reactors. Brandon Grogan and John Mihalcz, "Simulated Verification of Fuel Element Inventory in a Small Reactor Core Using the Nuclear Materials Identification System (NMIS)" (paper, Institute of Nuclear Materials Management, Tucson, July 12-16, 2009); Brandon Grogan and John Mihalcz, "Simulated Verification of Fuel Enrichment in a Small Reactor Core Using the Nuclear Materials Identification System (NMIS)" (paper, Institute of Nuclear Materials Management, Tucson, July 12-16, 2009).
20. IAEA, "Model Protocol Additional to the Agreement(s) Between State(s) and the International Atomic Energy Agency for the Application of Safeguards," INFCIRC/540 (corrected), 1997.
21. IAEA, "Implementation of the NPT Safeguards Agreement in the Islamic Republic of Iran: Report of the Director General to the IAEA Board of Governors," November 10, 2003, annex 1, para. 21.
22. The full name is "Protocol Additional to the Agreement Between the United States of America and the International Atomic Energy Agency for the Application of Safeguards in the United States of America." The U.S. Senate approved the protocol on March 31, 2004, as Title II of the Hyde Act.
23. U.S. Department of State, "The President Approves Ratification of the U.S.-IAEA Additional Protocol," December 31, 2008.
24. U.S. Congressional Budget Office, "The Cost of Implementing the Additional Protocol to the Treaty on the Non-Proliferation of Nuclear Weapons," March 5, 2004, table 1.
25. Ibid.
26. IAEA, "Strengthened Safeguards System: States With Additional Protocols," January 21, 2009, www.iaea.org/OurWork/SV/Safeguards/sg_protocol.html.
27. Frank von Hippel, "Challenge Inspections at Military Nuclear Sites," in IPFM, "Global Fissile Material Report 2008," pp. 86-95.
28. See John Carlson, "Can a Fissile Material Cutoff Treaty Be Effectively Verified?" *Arms Control Today*, January/February 2005, p. 25-29.
29. IAEA, *Annual Report 2007*, table A5.
30. Shirley Johnson, "Reprocessing Plants," in IPFM, "Global Fissile Material Report 2008," pp. 50-61.
31. David Dougherty et al., "Routine Inspection Effort Required for Verification of a Nuclear Material Production Cutoff Convention," BNL-63744 (1996), table 1.
32. In addition to HEU and plutonium, neptunium-237, americium-241, americium-243, and any other fissionable isotope suitable for the manufacture of nuclear weapons are classified as fissile materials in the IPFM draft treaty.
33. See for example, Marvin M. Miller, "Are IAEA Safeguards on Plutonium Bulk-Handling Facilities Effective?" Nuclear Control Institute, 1990, www.nci.org/k-m/mmsgrds.htm.
34. IPFM, "Global Fissile Material Report 2008," pp. 50-61.
35. Alexander Glaser, "Uranium Enrichment Plants," in "Global Fissile Material Report 2008," pp. 40-49.