
5. US nuclear security cooperation with Russia and transparency

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I. Introduction

This chapter reviews the efforts of Russia and the United States to conclude agreements on the control or reduction of their inventories of nuclear warheads and military fissile materials. While some of the negotiations attempted to codify arms limitation and reduction measures, others were aimed at constraining the spread of fissile materials and technologies to the non-nuclear weapon states (NNWS). A number of the negotiations had elements of both arms control and non-proliferation.

Most of the monitoring provisions contained in nuclear agreements between Russia and the USA are in the category of *transparency measures*—those that give confidence that a state is fulfilling its obligations. Some transparency measures are unilateral and are intended to enhance confidence or goodwill. *Verification measures*, on the other hand, usually require more intrusive monitoring—enough to ensure a high likelihood that parties are in compliance with a treaty—and require formal, legally binding agreements. Taken together, these measures apply to parts of the parties' nuclear weapon complexes, with the conspicuous exception of warhead facilities. Nonetheless, the joint efforts of the past decade have laid the technical groundwork for extending the scope of monitoring to warheads.

II. Early efforts to control warheads and fissile materials

Proposals for controlling and accounting for warheads and fissile materials have a long history, dating back to the first meeting of the United Nations General Assembly, in January 1946. The first General Assembly resolution established the UN Atomic Energy Commission, with the mandate to 'make specific proposals . . . for the elimination from national armaments of atomic weapons and of all other major weapons adaptable to mass destruction'.¹ At the first meeting of this commission, in June 1946, US Representative Bernard Baruch put forward a proposal for international control with a call for the creation of an Inter-

¹ United Nations General Assembly Resolution 1 (I), 24 Jan. 1946; the resolution is reproduced in United Nations, *Yearbook of the United Nations, 1946–47* (UN: New York, 1947), pp. 64–66.

* The views expressed in this chapter are those of the author and do not necessarily reflect the views of the US National Academy of Sciences.

national Atomic Development Authority that would own or manage all nuclear activities for military applications. The proposal also called for the dismantlement of nuclear warheads under the following conditions.

When an adequate system for control of atomic energy, including the renunciation of the bomb as a weapon, has been agreed upon and put into effective operation and condign punishments set up for violations of the rules of control which are to be stigmatized as international crimes, we propose that: (1) manufacture of atomic bombs shall stop; (2) existing bombs shall be disposed of pursuant to the terms of the treaty; and (3) the Authority shall be in possession of full information as to the know-how for the production of atomic energy.²

Ultimately, the Baruch Plan failed because of the irreconcilable differences between the positions of the Soviet Union and the United States during the cold war. The Soviet Union would not accept the provision for sanctions against violations without the right of a veto by the five permanent members of the UN Security Council. It also wanted a prohibition on nuclear weapons before a verification system was put in place, which the United States would not accept.

Comprehensive nuclear disarmament remained on the UN agenda, but the reliance on nuclear weapons during the cold war blocked any attempt to achieve even modest measures. With the entry into force in 1970 of the 1968 Treaty on the Non-proliferation of Nuclear Weapons (Non-Proliferation Treaty, NPT), the role of the International Atomic Energy Agency (IAEA) in monitoring the compliance of the NNWS was expanded. However, the five states formally recognized as nuclear weapon states (NWS) under the NPT were not required to accept IAEA safeguards on their nuclear facilities.³ The international experience with implementing IAEA safeguards for non-proliferation purposes is nonetheless relevant for a number of the tasks that would be part of a comprehensive nuclear arms reduction regime.

Fissile materials and the 1967–69 dismantlement demonstration

In 1956 President Dwight D. Eisenhower proposed a ban on the production of fissile material for weapon purposes. In the following decade, the Warsaw Treaty Organization, the Western countries and many non-aligned states made similar proposals, but no serious negotiations took place.

In 1966 the USA made a proposal that was more limited but still remarkable for the times to the Conference on Disarmament (CD). Under this proposal the USA and the USSR would transfer highly enriched uranium (HEU) from weapons to peaceful uses under international safeguards. The USA offered to

² US Department of State, *Documents on Disarmament, 1945–1956* (US Government Printing Office: Washington, DC, 1960), pp. 10–15, available at URL <http://highered.mcgraw-hill.com/olc/dl/35265/2_3.html>.

³ The 5 NPT-recognized NWS are China, France, Russia (formerly the USSR), the UK and the USA. The NWS make some of their civilian facilities, but not their military facilities, eligible for IAEA monitoring under Voluntary Offer Agreements.

transfer 60 tonnes of HEU under the condition that the USSR would transfer 40 tonnes to peaceful uses. Both states were expected to demonstrate ‘the destruction of nuclear weapons to make HEU available for transfer to peaceful nuclear energy under international safeguards, and to halt the production of weapon-usable nuclear materials’.⁴

As part of the US Government’s assessment of the verifiability of this proposal, the Arms Control and Disarmament Agency (ACDA), working with the US Atomic Energy Commission and the Department of Defense (DOD), created Project Cloud Gap for demonstration inspections of dismantlement.⁵ The experiments were carried out at the Pantex (Texas), Rocky Flats (Colorado), Paducah (Kentucky) and Oak Ridge (Tennessee) facilities. Inspectors were given extensive access to the Pantex facility for close observation and monitoring of weapon dismantlement.⁶ At Rocky Flats they monitored the disassembly of warhead pits and separation of materials into plutonium, uranium and other residue. At Paducah they monitored the separation of materials into salvageable categories and the disposal of classified residue. At the Y-12 plant at Oak Ridge, they monitored the disassembly of HEU parts and the melting and casting of HEU into ingots. The inspectors carried minimal equipment, such as cameras, scales, Geiger counters, portable neutron counters and gamma-ray spectrometers, and collected samples for mass spectrometer measurements of the isotopic concentrations of the materials. The experiment monitored 40 warheads undergoing scheduled disassembly, along with 32 fake warheads.

The principle behind the experiments was to provide unrestricted visual access to the dismantlement process in order to ensure that warhead dismantlement was taking place. There was no attempt to conceal classified information.⁷ With this degree of open access, the ACDA report’s conclusion that classified information would be revealed came as no surprise. However, the report also concluded that information ‘could be protected by redesign of facilities and equipment’.⁸ This project highlighted the tension between obtaining the needed degree of confidence that weapons were being destroyed and protecting sensitive information—a tension that is still central to efforts to design effective monitoring arrangements.

⁴ Fisher, A. (Deputy Director, ACDA), Conference on Disarmament, *Documents on Disarmament*, 6 Mar. 1966, pp. 122–23. ‘We agree first to the demonstrated destruction of thousands of nuclear weapons by the United States and the Soviet Union; second, to the transfer to peaceful purposes under international safeguards of the large quantities of fissionable material obtained from this destruction; and third to a verified halt in the production of fissionable material for weapons purposes’.

⁵ Arms Control and Disarmament Agency (ACDA), ‘Final Report, vol. 1. Field Test FT-34: Demonstrated Destruction of Nuclear Weapons’ (Jan. 1969, released with deletions under the Freedom of Information Act). See also von Hippel, F., ‘The 1969 ACDA study on warhead dismantlement’, *Science & Global Security*, vol. 2, no. 1 (1990), pp. 103–108, available at URL <http://www.princeton.edu/%7Eglobsec/publications/pdf/2_1vonHippel.pdf>.

⁶ ACDA (note 5), pp. 51–56.

⁷ ACDA (note 5), p. 76.

⁸ ACDA (note 5), p. 10.

Warhead monitoring in cold war nuclear arms control agreements

INF and START

The major agreements to limit or reduce offensive nuclear arms that were negotiated by the two superpowers during and immediately after the cold war—the SALT I and II agreements, the INF Treaty, and the START I and II treaties⁹—focused on delivery vehicles and launchers. Warheads were dealt with mainly through ‘counting rules’ that attributed a certain number of deployed warheads to a particular delivery vehicle, for the following reasons.

1. Ballistic missiles are the major delivery vehicle for nuclear warheads.
2. Ballistic missiles, silos, submarines and bombers are much larger and easier to count than nuclear warheads. They are also far more difficult to hide than warheads or their fissile material components. Technologies such as templates, attributes and information barriers were not available at that time to properly verify warhead dismantlement without the risk of revealing sensitive design information, and national technical means (NTM) could only assess delivery vehicle inventories. Nor were the USA and the USSR willing to accept the level of intrusiveness required to verify limits on warheads.
3. The number and characteristics of the Soviet and US deployed strategic delivery vehicles and launchers provided better measures of the strategic significance of their nuclear arsenals than the size of their warhead or fissile-material stockpiles. The traditional concerns of both states were with warheads that can be delivered rapidly and accurately over long distances, although delivery by aircraft, ships and trucks was also a concern.
4. Modern strategic delivery vehicles are expensive, typically costing the USA, for example, 10 times more to develop, produce and maintain than the nuclear warheads they carry. The elimination of delivery vehicles therefore created a greater barrier to reconstituting deployable nuclear weapons.

The INF and START treaties nonetheless contain provisions relating to warheads.¹⁰

The INF Treaty preceded the winding down of the cold war.¹¹ It was the first Soviet–US agreement to eliminate an entire class of nuclear weapons, banning the possession and deployment of ground-launched missiles with ranges of 500–5500 kilometres. In carrying out its INF obligations, the USSR destroyed

⁹ The 1972 SALT I Interim Agreement, the 1979 Treaty on the Limitation of Strategic Offensive Arms (SALT II), the 1987 Treaty on the Elimination of Intermediate-Range and Shorter-Range Missiles (INF Treaty), the 1991 Treaty on the Reduction and Limitation of Strategic Offensive Arms (START I), and the 1993 Treaty on Further Reduction and Limitation of Strategic Offensive Arms (START II, not in force; on 14 June 2002, as a response to the expiration of the ABM Treaty on 13 June, Russia declared that it will no longer be bound by the START II Treaty).

¹⁰ The provisions of the START treaties are discussed in section III.

¹¹ *The INF Treaty*, US Senate Executive Report 100-15 (US Government Printing Office: Washington, DC, 14 Apr. 1988).

1800 missiles, capable of carrying over 3000 warheads, and the USA destroyed 850 single-warhead missiles.¹²

One of the most important verification issues was the need to determine that the banned SS-20 missile was no longer deployed by the Soviet Union.¹³ This was difficult, because the first stages of the permitted long-range (strategic) SS-25 intercontinental ballistic missile (ICBM) and the prohibited intermediate-range (theatre) SS-20 missile are similar.¹⁴ In addition, because SS-25 canisters are larger than SS-20 canisters, an SS-25 canister could contain an SS-20 missile.

The problem was further complicated by the Soviet deployment of SS-25s at some former SS-20 bases. SS-25s have one warhead and SS-20s have three, so the patterns of neutron and gamma-ray emissions from the plutonium in the warheads are different for the two systems. Under the INF Treaty, this difference could be measured with radiation-detection equipment, which measures the flux of neutrons while the missile is in its canister but gives no critical information on warhead design.¹⁵ Under the INF Treaty the parties had the right to establish a permanent continuous monitoring system. The USA built a perimeter-portal continuous monitoring (PPCM) system at the Soviet Votkinsk Machine Building Plant, 500 km east of Moscow,¹⁶ and the USSR monitored the US Hercules Plant Number 1 at Magna, Utah, where Pershing II rocket engines were produced. The PPCM monitoring facility operated at Votkinsk for the duration of the treaty, from 1988 to 2001. Under the INF Treaty inspectors could measure the length and weight of all objects entering and leaving the missile factory. All road and rail shipping containers large enough to hold an SS-20 missile were made available at Votkinsk for X-ray imaging with a modified version of a commercial scanner, the CargoScan. The X-ray images showed the length and diameter of the first stages of the missiles to ensure that they were not SS-20 first stages. In addition, inspectors could visually inspect and measure a missile inside its canister eight times a year. This random inspection of canisters provided a great deterrent to cheating. US inspectors also patrolled the 5-km perimeter fences around Votkinsk.¹⁷

¹² *The START Treaty*, US Senate Executive Report 102-53 (US Government Printing Office: Washington, DC, 18 Sep. 1992). Under the INF Treaty, the USSR destroyed 654 SS-20 missiles capable of carrying 3 warheads each. In addition, the SS-4, SS-5, SS-12, SS-20, SS-23 and SSC-X missiles were destroyed. The USA destroyed 169 Pershing IAs, 234 Pershing IIs and 443 ground-launched cruise missiles.

¹³ Harahan, J. P., *On-Site Inspections Under the INF Treaty* (US On-Site Inspection Agency: Washington, DC, 1993), p. 145.

¹⁴ Strategic nuclear weapons are those with intercontinental range (>5500 km); theatre (also called tactical or non-strategic) nuclear weapons have less than intercontinental range (<5500 km).

¹⁵ Ewing, R. I. and Marlow, K.W., 'A fast-neutron detector used in verification of the INF Treaty', *Nuclear Instruments and Methods in Physics Research*, vol. A299 (1990), pp. 559-61. The detailed procedures for carrying out inspections with radiation detection equipment were too complex to negotiate into treaty language, so it was left to the INF Standing Verification Commission (SVC) to establish inspection procedures. The SVC agreed on the use of fast neutron detectors to determine the spatial pattern of radiation outside of canisters for field inspections.

¹⁶ Harahan (note 13), p. 67.

¹⁷ Similarly, the START I Treaty permitted the USA to build a PPCM at the Pavlograd plant in Ukraine, where the SS-24 ICBM was built, and permitted the USSR to build a PPCM at Promontory,

The Slava experiment

On 5 July 1989 a team of Soviet and US scientists measured the gamma-ray spectra from a Soviet warhead mounted on an SS-N-12 cruise missile on the *Slava* cruiser with a high-purity germanium detector.¹⁸ The most detectable gamma transitions showed the presence of uranium-235, plutonium-239 and uranium-232. The presence of uranium-232 indicated that the uranium in the Soviet warhead had resided in a nuclear reactor before being used as feedstock for an enrichment plant. The data also showed a transition, which the investigators interpreted as being induced by inelastic neutron scattering on the iron missile-support structure.¹⁹ Another transition was interpreted as coming from the absorption of neutrons by hydrogen. This was consistent with the considerable amount of hydrogen in the missile fuel and in the high explosives around the nuclear weapon.

The Soviet–US team also monitored neutron emissions from the warhead on the *Slava*.²⁰ A helicopter carrying neutron detectors flew at a distance of 30–80 metres from the warhead. The detectors were designed to observe a warhead at distances of 100–150 metres with the requirement that the signal must be more than three times the standard deviation (σ) of the background. The neutron data from the passage of the helicopter at 30 metres were about two to three times greater than the 3σ -background level.

III. Major post-cold war initiatives

The end of the cold war offered both great hope and great danger. Soviet/Russian and US leaders saw an opportunity to transform their relationship from a hostile to a cooperative one, reducing the risks that the two states' nuclear arsenals had posed to each other's forces and homelands, and to international security more broadly. The collapse of the Soviet Union also brought fears concerning the security of thousands of nuclear warheads and tonnes of fissile materials and the proliferation risks of 'loose nukes'.²¹ In responding to these risks and opportunities, leaders in Russia and the USA undertook remarkable

Utah, where the Peacekeeper ICBM was built. A PPCM facility houses *c.* 30 inspectors and costs about \$10 million per year.

¹⁸ Fetter, S. *et al.*, 'Gamma-ray measurements of a Soviet cruise-missile warhead', *Science*, vol. 248, (1990), pp. 828–34.

¹⁹ The gamma-ray detector had a resolution of 2 kilo-electronvolts (keV) (full-width at half-maximum) at 1000 keV, with a diameter of 5.9 cm and a length of 5.9 cm. The gamma-ray spectra from the weapon were measured for 24 minutes, followed by measurements of an empty missile tube for 10 minutes. Background measurements were carried out for 70 minutes. Inelastic collisions with neutrons can create gamma rays from excited states of stable nuclei. When fast neutrons collide with iron-56 nuclei, they can excite the 846.9 keV state of iron-56 while reducing the amount of total kinetic energy.

²⁰ Belyaev, S. *et al.*, 'The use of helicopter-borne neutron detectors to detect nuclear warheads in the USSR–US Black Sea Experiment', eds F. von Hippel and R. Sagdeev, *Reversing the Arms Race: How to Achieve and Verify Deep Reductions in the Nuclear Arsenals* (Gordon and Breach: New York, 1990), pp. 328–33.

²¹ Campbell, K. M. *et al.*, *Soviet Nuclear Fission: Control of the Nuclear Arsenal in a Disintegrating Soviet Union*, Belfer Center for Science and International Affairs, BCSIA Studies in International Security no. 1 (Harvard University: Cambridge, Mass., Nov. 1991).

Existing monitoring requirements: H = 1993 HEU Agreement; I = IAEA Voluntary Safeguards on select nuclear explosive materials (NEM), (in the process of ratification).

Monitoring requirements under discussion between Russia and the USA: A = Agreement for Cooperation for Russian Spent Fuel Repository (under discussion); F = Fissile Material Cut-off Treaty (first discussed in 1993, intermittently since then); M = 1996 Mayak Storage Facility Transparency Agreement; p = Processing and Packaging Implementation Agreement (discussed in 1997–99); P = 2000 Plutonium Disposition and Management Agreement (not in force); R = 1997 Agreement concerning Cooperation Regarding Production Reactors; S = START III accord (discussed in 2000); T = Trilateral Initiative (proposed in 1996, under discussion).

This figure represents the Russian cycle for the dismantlement of nuclear warheads and final disposition of excess NEM. (It should be noted that the US cycle is slightly different.) The figure does not show the re-manufacture of nuclear warheads, monitoring of deployed warheads under START or elimination of strategic nuclear delivery vehicles and launchers. Nor does it include the possibility of Russian reprocessing of US-origin spent fuel, but it does consider the possibility of the US import of Russian MOX.

Source: Adapted from Doyle, J. and Seitz, S., 'Applied monitoring and transparency initiatives for nuclear weapon fissile materials reductions', *Proceedings of the 42nd Annual Meeting of the Institute for Nuclear Materials Management (2001)* (on CD), available from the Institute of Nuclear Materials Management, email address inmm@inmm.org.

initiatives that have provided at least the basic foundations for much more cooperative and comprehensive arrangements to control nuclear warheads and materials. Figure 5.1 illustrates the sequence and context of the numerous technical and diplomatic initiatives and efforts in relation to different parts of the complex Russian nuclear weapon cycle.

Unilateral initiatives

Non-strategic nuclear weapons

In 1991 President George H. W. Bush announced the withdrawal of all US ground- and sea-launched tactical nuclear weapons to the USA. All of the ground-launched and about half of the sea-launched weapons would be destroyed. Soviet President Mikhail Gorbachev responded with the announcement that all Soviet tactical nuclear weapons would be withdrawn to the Russian Federation, and that nuclear artillery, ground-launched missile warheads and nuclear mines would be destroyed. In 1992 Russian President Boris Yeltsin confirmed and extended Gorbachev's pledges. In addition to destroying all ground-launched tactical warheads, he announced that Russia would destroy half of its air-launched tactical warheads, half of its nuclear warheads for anti-aircraft missiles and one-third of its tactical sea-launched nuclear warheads. Full implementation of the pledges in the 1991–92 Presidential Nuclear Initiatives (PNIs) would mean that approximately 5000 US tactical warheads would be destroyed.²² The number of Russian warheads scheduled for destruction is more difficult to judge; the US Central Intelligence Agency gave an estimate of

²² Excerpts from the PNIs are reproduced in *SIPRI Yearbook 1992: World Armaments and Disarmament* (Oxford University Press: Oxford, 1992), pp. 85–92.

5000–15 000 warheads.²³ Under the PNIs, the unilateral reductions were not subject to monitoring, nor were there meaningful transparency measures. It is therefore not known whether the reductions were carried out completely.

Fissile materials

The end of the cold war left Russia and the USA with large stockpiles of plutonium and HEU, far more than they could possibly need for nuclear weapon production or maintenance of stockpiles. Both governments gradually came to the conclusion that continued production of fissile material was unnecessary, and they took unilateral action during the late 1980s and early 1990s to close down the fissile material manufacturing facilities which were still in operation.²⁴ After the accident at the Chernobyl nuclear power facility in 1986, there was widespread public concern, particularly in the USA, about the environmental hazards associated with nuclear energy in general and plutonium production in particular. The resulting public pressure added further impetus to the decision to stop the production of fissile material.²⁵

In the USA the process of closing production facilities extended over more than two decades. Production of HEU for weapons ceased in 1964, although production of HEU continued for naval and research reactors until 1988.²⁶ The US Government announced in November 1991 that all HEU production would be suspended. Plutonium production reactors were closed beginning in 1964 as new reactor designs went on-line and as the need for plutonium diminished. The last two operating production reactors, located at Savannah River, South Carolina, were closed in 1988 because of safety concerns. The House of Representatives passed an amendment to the Defense Department budget in July of the following year urging the president to negotiate with the Soviet Union a bilateral ban on fissile material production for warheads. Finally, in July 1992 President Bush announced that, as part of a non-proliferation initiative, the USA would no longer produce fissile material.²⁷

The Soviet Union stopped the production of weapon-grade uranium in 1988 and of plutonium in 1994 (except at three reactors).²⁸ President Yeltsin, reiterating an offer made earlier by Gorbachev, suggested in January 1992 that Russia and the USA negotiate a bilateral fissile material production cut-off treaty. An

²³ Gershwin, L. (National Intelligence Officer for Strategic Programs), *DOD Appropriations for FY93*, Testimony before the House Committee on Appropriations, Part 5, 6 May 1992, p. 499.

²⁴ Fissile material used in nuclear weapons typically consists of plutonium-239 or uranium enriched in the isotope 233 or in the isotope 235. See chapter 7, section III, in this volume.

²⁵ Albright, D. and O'Neill, K. (eds), *The Challenges of Fissile Material Control* (Institute for Science and International Security: Washington, DC, 1999), pp. 100–101.

²⁶ Grand, C., 'A Fissile Material Cut-off Treaty and the future of nuclear arms control', ed. J. Cirincione, *Repairing the Regime: Preventing the Spread of Weapons of Mass Destruction* (Routledge: New York, 2000), p. 236.

²⁷ Albright and O'Neill (note 25), p. 101; and Lockwood, D., 'Nuclear arms control', *SIPRI Yearbook 1993: World Armaments and Disarmament* (Oxford University Press: Oxford, 1993), p. 571.

²⁸ Albright and O'Neill (note 25), p. 101; and Albright, D., Berkhout, F. and Walker, W., *Plutonium and Highly Enriched Uranium 1996: World Inventories, Capabilities and Policies* (Oxford University Press: Oxford, 1997).

announcement was made that same month that Russia would stop all production of weapon-grade plutonium by 2000 regardless of whether an agreement was reached. However, the three production reactors are still operating, to provide heat and power for local residents. The Russian and US governments are working together on a plan to replace the reactors with an alternative source of energy.²⁹

START: Russian–US agreements on strategic nuclear weapons

The end of the cold war enabled Russia and the USA to make genuine reductions in their strategic nuclear forces. The START I Treaty, which was signed on 31 July 1991 and entered into force on 5 December 1994, obligates Russia and the USA to limit their deployed strategic forces to 1600 strategic nuclear delivery vehicles each and 6000 treaty-accountable nuclear warheads each. START I covers only deployed strategic warheads and their delivery vehicles, not warheads after they have been removed from their delivery vehicles. START I was followed relatively quickly by the START II Treaty, signed by Presidents Bush and Yeltsin on 3 January 1993. START II contains the obligation for both signatories to ban intercontinental ballistic missiles with multiple independently targetable re-entry vehicles (MIRVed ICBMs) and to make further phased reductions to no more than 3500 deployed strategic warheads, approximately one-third of the size of the Soviet and US strategic arsenals at the time START I was signed. START II did not enter into force because of the US–Russian controversy over the future of the 1972 Treaty on the Limitation of Anti-Ballistic Missile Systems (ABM Treaty, expired as of 13 June 2002 owing to the US withdrawal).

The START process moved beyond reliance on NTM to introduce bilateral verification measures, some of which relate to deployed strategic warheads. The total number of START-accountable missile warheads is obtained by multiplying the number of deployed missiles by the number of warheads attributed to each missile under the treaty's counting rules. The individual warheads mounted on missiles are contained in re-entry vehicles. START I permits each party 10 re-entry vehicle on-site inspections each year to verify that the number of re-entry vehicles on a selected missile does not exceed the number attributed to that type of missile. If START II had been implemented, the number of such inspections would have increased to 14 per year.

In order to prevent inspectors from gaining access to classified information, the inspected party places an opaque cover over the warheads on the missile bus. The cover has protrusions that provide space for each re-entry vehicle; the number of protrusions must be less than or equal to the attributed number of re-entry vehicles. In cases of discrepancy, the inspected party can allow the use of radiation detection equipment to clarify whether the extra object is a war-

²⁹ Albright and O'Neill (note 25), p. 101; and Albright, Berkhout and Walker (note 28), pp. 80, 95.

head. The US Department of Energy (DOE) has also developed radiation imaging systems to count warheads.³⁰

The Biden Amendment and the START and SORT treaties

The September 1992 US Senate debate on ratification of the START I Treaty raised concerns about Russia's ability to rapidly redeploy warheads that have been removed from their delivery vehicles. There was also great concern about the security of nuclear weapons and materials. To address these concerns, an amendment proposed by Senator Joseph R. Biden, Jr was incorporated into the resolution of ratification.

Nuclear Stockpile Weapons Arrangement. Inasmuch as the prospect of a loss of control of nuclear weapons or fissile material in the former Soviet Union could pose a serious threat to the United States and to international peace and security, in connection with any further agreement reducing strategic offensive arms, the President shall seek an appropriate arrangement, including the use of reciprocal inspections, data exchanges, and other cooperative measures, to monitor (A) the numbers of nuclear stockpile weapons on the territory of the parties to this Treaty; and (B) the location and inventory of facilities on the territories of the parties to this treaty capable of producing or processing significant quantities of fissile materials.³¹

The Biden Amendment was interpreted to apply to a future START III accord, since the START II negotiations were moving to a conclusion at that time. The amendment provided a major impetus for the US Government to explore technical and policy approaches to monitoring warheads. In 2002, presidents George W. Bush and Vladimir Putin agreed to forego the START II and START III treaties. In its place, they signed the Strategic Offensive Reductions Treaty (SORT) with a limit of 1700–2200 *operational* warheads, which is the same limit as that proposed for START III, if *non-operational* submarines in maintenance are taken into account. The SORT negotiations and treaty did not consider the monitoring methods described in this volume.

³⁰ See, e.g., Ziock, K. P. 'Gamma-ray imaging spectrometry', *Science and Technology Review*, Oct. 1995, pp. 14–26; and Ziock, K. P. *et al.*, 'A Germanium-based coded aperture gamma-ray imager', *Proceedings of the 41st Annual Meeting of the Institute for Nuclear Materials Management (2000)* (on CD), available from the Institute of Nuclear Materials Management, email address inmm@inmm.org. The Gamma-Ray Imaging System uses a coded aperture to preferentially absorb gamma rays. The spatial pattern of surviving gamma rays is measured and analysed to count the number of warheads. Another approach is the Radiation Pattern Identification System, which uses directionally sensitive gamma-ray detectors and a segmented neutron detector with minimal directional sensitivity. These detectors are mounted on a platform that is moved around the periphery of the missile. The intensity patterns are Fourier-analysed to count warheads.

³¹ *The START Treaty*, US Senate Executive Report 102-53 (US Government Printing Office: Washington, DC, 18 Sep. 1992), resolution of ratification, p. 101.

The Cooperative Threat Reduction programme

The collapse of the Soviet Union raised fears of a loss of control over thousands of deployed strategic and non-strategic nuclear weapons and hundreds of tonnes of fissile material—the scenario for a proliferation nightmare. In the autumn of 1991 a bipartisan effort led by US Senators Sam Nunn and Richard Lugar addressed these dangers, and their proposal was passed by the Senate.³² The legislation authorized the president to transfer up to \$400 million from the appropriated defence budget for 1992, making the DOD the first major agency engaged in what became known as the Cooperative Threat Reduction (CTR) programme. US assistance for CTR and other programmes totalled \$5.5 billion in the 1990s.³³

In the early years, the CTR programme focused on assisting Belarus, Kazakhstan and Ukraine in their efforts to return all former Soviet nuclear warheads on their territories to Russia and to dismantle or destroy the associated strategic nuclear delivery vehicles and silos. It also provided assistance to Russia to eliminate strategic nuclear arms on its territory. Altogether, the programme facilitated the dismantlement of over 2000 former Soviet strategic missiles and launchers.³⁴ It also contributed to funding the construction of the nuclear materials storage facility at Mayak.³⁵ The CTR programme has funded such diverse activities as the provision of nuclear material containers, the refurbishment of Russian railway wagons for the transport of nuclear materials and the acquisition of nuclear accident response equipment.

The Russian and US governments soon recognized that the risks of theft or diversion of fissile material posed ‘a clear and present danger to national and international security’.³⁶ Russian–US programmes were developed to improve fissile materials protection, control and accounting (MPC&A) in the former Soviet Union. These programmes were shifted from the DOD to the DOE in order to more accurately identify facilities for MPC&A upgrades and define responsibilities for the participating organizations.

The CTR programme was a remarkable initiative undertaken in response to extraordinary circumstances. Engaging directly in programmes to ensure the security of nuclear warheads and fissile materials gave the USA unprecedented

³² Coombs, R., ‘US domestic politics and the Nunn–Lugar program’, eds J. M. Shields and W. C. Potter, *Dismantling the Cold War: US and NIS Perspectives on the Nunn–Lugar Cooperative Threat Program* (MIT Press: Cambridge, Mass., 1997).

³³ US General Accounting Office (GAO), *Nuclear Proliferation: Coordination of US Programs Designed to Reduce the Threat Posed by Weapons of Mass Destruction*, GAO-02-180T (GAO: Washington, DC, 2001), p. 2.

³⁴ US Defense Threat Reduction Agency, ‘Fact sheet on cooperative threat reduction’, Jan. 2002. The dismantled systems included 443 ICBMs, 409 ICBM launchers, 87 bombers, 483 air-launched cruise missiles, 209 submarine-launched ballistic missiles (SLBMs) and 368 SLBM launchers on 21 nuclear-powered ballistic-missile submarines.

³⁵ US General Accounting Office (GAO), *Weapons of Mass Destruction: Effort to Reduce Russian Arsenals May Cost More, Achieve Less than Planned*, GAO/NSIAD-99-76 (GAO: Washington, DC, 1999).

³⁶ National Academy of Sciences, Committee on International Security and Arms Control, *Management and Disposition of Excess Weapons Plutonium* (National Academy Press: Washington, DC, 1994), p. 1.

access to Russian facilities. Despite the difficulties involved in the implementation of many of its programmes, CTR nonetheless represents an essential part of the foundation for more comprehensive limits.

Laboratory-to-laboratory programmes

Not surprisingly, the implementation of new programmes proved slow, given the long tradition of secrecy in the Russian nuclear complex. To circumvent these difficulties and to take advantage of the potential to build trust through direct contacts between scientists, the DOE's national laboratories and their Russian counterpart institutions initiated a wide variety of contracts for joint research on technologies for the monitoring, physical security and accountancy of nuclear weapons and materials.³⁷ Established in 1999, the National Nuclear Security Administration (NNSA), a semi-autonomous agency within the DOE, now has responsibility for the DOE's cooperative security programmes, including MPC&A.

The laboratory-to-laboratory contracts are intended to transfer successful technologies between the parties in order to enhance transparency and arrive at the best monitoring options. The activities are wide-ranging and include: (a) physical security and containment of facilities; (b) radiation detection techniques; (c) fissile material accounting; (d) plutonium disposition in general; (e) plutonium storage at Mayak; (f) purchase of Russian HEU; and (g) monitoring warhead dismantlement.

To illustrate the range of activities, over 50 contracts involving warhead dismantlement transparency have been implemented by scientists at the US DOE and the Russian Ministry of Atomic Energy (Minatom). They have involved radiation measurements, computer modelling of dismantlement facilities and measurements to confirm the removal of high explosives from nuclear weapons.

The participating laboratories in the USA are the DOE nuclear weapon laboratories (Los Alamos, Livermore and Sandia) and other DOE laboratories (Argonne, Brookhaven, Oak Ridge/Y-12, Pacific Northwest and Pantex). About 12 Russian laboratories participate, including the All-Russian Scientific Research Institute of Experimental Physics in Arzamas-16 (Vserossiyskiy Nauchno-Issledovatel'skiy Institut Eksperimental'noy Fiziki, VNIIEF), the All-Russian Scientific Research Institute of Technical Physics in Chelyabinsk-70 (Vserossiyskiy Nauchno-Issledovatel'skiy Institut Tekhnicheskoy Fiziki, VNIITF), and the All-Russian Scientific Research Institute of Automatics (Vserossiyskiy Nauchno-Issledovatel'skiy Institut Avtomatiki, VNIIA) and the Research Institute of Pulse Technique (RIPT), both in Moscow.

In general, the laboratory-to-laboratory exchanges have helped the technical experts of both states to become familiar and confident with monitoring techniques and information barriers. For example, cooperative gamma-ray mea-

³⁷ Bieniawski, A. and Irwin, P., 'Overview of the US-Russian laboratory-to-laboratory warhead dismantlement transparency program: a US perspective', *Proceedings of the 41st Annual Meeting of the Institute for Nuclear Materials Management (2000)* (note 30).

surements of classified objects were carried out without releasing classified information. Many believe that such programmes progressed successfully because they developed away from the political spotlight and engaged technical experts who shared both knowledge and an appreciation of the issues at the technical level.

IV. The 1990s: initiatives to limit warheads and fissile materials

In order to carry out the broad initiatives put forward for the control and reduction of nuclear weapons and stockpiles and to take advantage of the results, specific proposals and programmes for Russian–US activities were implemented in the 1990s.³⁸ This section outlines some of the most important programmes. It does not cover them all; for example, the important programmes that sought to provide support and alternative employment for Russian nuclear scientists and alternative, commercial activities for the former closed nuclear cities are only mentioned briefly.³⁹

The programmes are discussed under four headings: (a) the diplomatic framework; (b) the production and disposition of fissile material; (c) the improvement of fissile material MPC&A; and (d) the monitoring of warheads.

The diplomatic framework

Agreements for cooperation

Beyond the formidable, but less formal, barriers raised by strong traditions of secrecy in nuclear matters, any serious effort to increase transparency in the Russian and US nuclear warhead and fissile material inventories must overcome significant legal hurdles in each state. In the USA, the Atomic Energy Act

³⁸ There are many accounts and assessments of this period. See, e.g., Bunn, M., *The Next Wave: Urgently Needed New Steps to Control Warheads and Fissile Material* (Carnegie Endowment for International Peace: Washington, DC, and Harvard University: Cambridge, Mass. 2000), available at URL <<http://www.ceip.org/files/projects/npp/pdf/NextWave.pdf>>; Goodby, J. E., ‘Transparency and irreversibility in nuclear warhead disarmament’, ed. H. A. Feiveson, *The Nuclear Turning Point: A Blueprint for Deep Cuts and De-Alerting of Nuclear Weapons* (Brookings Institution Press: Washington, DC, 1999), pp. 171–92; Thomson, D. B., *A Guide to Nuclear Arms Control Treaties*, LA-UR-99-3173 (Los Alamos National Laboratory: Los Alamos, N. Mex., July 1999); Office of Under Secretary of Defense (Acquisition, Technology and Logistics), US Department of Defense, *Arms Control Program Plan, Fiscal Years 2000-2001* (DOD: Washington, DC, 7 July 2000); Bukharin, O. and Luongo, K., *US–Russian Warhead Dismantlement Transparency: The Status, Problems, and Proposals*, PU/CEES-314 (Center for Energy and Environmental Studies, Princeton University: Princeton, N.J., Apr. 1999); Bukharin, O., Bunn, M. and Luongo, K., *Renewing the Partnership: Recommendations for Accelerated Action to Secure Nuclear Material in the Former Soviet Union* (Russian American Nuclear Security Advisory Council: Princeton, N.J., Aug. 2000); and Luongo, K. N., ‘The uncertain future of US–Russian cooperative nuclear security’, *Arms Control Today*, vol. 31, no. 1 (Jan./Feb. 2001), pp. 3–10.

³⁹ More detailed accounts of these programmes can be found in Bunn (note 38); Desmond, W., ‘What is the Nuclear Cities Initiative?’, *Proceedings of the 41st Annual Meeting of the Institute for Nuclear Materials Management* (2000) (note 30); Schweitzer, G. E., *Swords into Market Shares: Technology, Economics and Security in Russia* (John Henry Press: Washington, DC, 2000); and US General Accounting Office (GAO), *Nuclear Proliferation: Concerns with DOE’s Efforts to Reduce the Risks Posed by Russia’s Unemployed Weapons Scientists*, GAO/RCED-99-54 (GAO: Washington, DC, Feb. 1999).

of 1954 prohibits the release of restricted data and the sharing of such data with other states, except for mutual defence purposes. The DOE must negotiate a formal bilateral Agreement for Cooperation in order to share restricted data with a state with which the USA does not have a mutual defence agreement. The DOD and the DOE share the classification authority for information on the basing of nuclear weapons and other related matters.⁴⁰

To support the initiatives of the early 1990s, the fiscal year (FY) 1993 and 1994 Defense Authorization Acts amended the Atomic Energy Act, granting authority to negotiate an Agreement for Cooperation with Russia to allow the sharing of limited amounts of national security information as mutually agreed by the parties to be useful for monitoring arrangements. This provided the legal basis for an ambitious effort to create broad transparency between the two states. It should be noted that Russia's nuclear exports and imports could also cause complications for the legal completion of an Agreement for Cooperation. Section 129 of the Atomic Energy Act requires that the president must determine whether Russian nuclear exports can assist the nuclear weapon programmes of other states, such as India and Iran.⁴¹ The Iranian Government intends to complete the unfinished German nuclear power plant in Bushehr that was begun under the Shah. In 1992 Russia agreed to finish the Bushehr plant and in 1995 agreed to build a new commercial nuclear power plant for Iran with water–water power reactors, the VVER-1000 (Vodo-Vodyanoy Energeticheskiy Reaktor). The export of commercial, non-military reactors is permitted under the NPT, but the US Government contends that such exports provide knowledge of and access to the Russian nuclear complex that could assist Iran's alleged efforts to acquire nuclear weapons.⁴² In addition, Russian fuel exports for the Indian Tarapur reactors violate the provision of the 1978 Nuclear Suppliers Group (NSG) Guidelines not to export to states that do not have full-scope safeguards,⁴³ although Russia maintains that these exports are needed for safety reasons. Finally, if Russia imports US-origin spent fuel for the proposed international spent-fuel repository, this will require an Agreement for Coopera-

⁴⁰ Habiger, E. (Commander, US Strategic Command), Department of Defense News Briefing, 16 June 1998, URL <http://www.defenselink.mil/news/Jun1998/t06231998_t616hab2.html>.

⁴¹ Section 129 (Chapter 11) prohibits the export of any nuclear materials and equipment or sensitive nuclear technology to 'any nation or group of nations that is found by the President to have . . . assisted, encouraged, or induced any non-nuclear-weapon state to engage in activities involving source or special nuclear material and having direct significance for the manufacture or acquisition of nuclear explosive devices, and has failed to take steps which, in the President's judgment, represent sufficient progress toward terminating such assistance, encouragement, or inducement'. The Atomic Energy Act is available on the Internet site of the US Nuclear Regulatory Commission at URL <<http://www.nrc.gov/reading-rm/doc-collections/nuregs/staff/sr0980/>>.

⁴² Eisenstadt, M., 'Russian arms and technology transfers to Iran: policy challenges for the United States', *Arms Control Today*, vol. 31, no. 2 (Mar. 2001), pp. 15–22.

⁴³ The NSG Guidelines for Transfers of Nuclear-Related Dual-Use Equipment, Materials, Software, and Related Technology, as they are now called, are incorporated in IAEA document INFCIRC/254. They have been revised several times since 1978. See URL <<http://www.iaea.org/worldatom/Documents/Infcirc/Others/infcirc254.shtml>>.

tion with the USA as well as US consent for the reprocessing and re-transfer of spent fuel.

The Safeguards, Transparency and Irreversibility Initiative

In January 1994 presidents Bill Clinton and Boris Yeltsin agreed to establish a joint working group to consider steps to ensure the ‘transparency and irreversibility’ of nuclear weapon reductions. In May 1994 the working group agreed to examine options for: (a) declaring all stocks and locations of weapon-usable fissile material; (b) carrying out reciprocal inspections of storage facilities containing fissile materials removed from dismantled warheads; and (c) making irreversible transfers of fissile material to peaceful purposes. These terms of reference were strengthened at their September 1994 summit meeting, where they agreed to: (a) exchange detailed information on the aggregate stockpiles of nuclear warheads and weapon-usable nuclear materials; (b) develop a regular process for exchanging this information; and (c) direct the joint working group to develop measures to improve confidence in and increase the transparency and irreversibility of nuclear weapon reductions.⁴⁴

The USA envisaged a transparency and irreversibility regime that provided for the exchange of detailed information and reciprocal inspections to confirm that HEU and plutonium had been removed from nuclear warheads. The regime was also intended to include cooperative measures to confirm the existence of excess warheads awaiting dismantlement as well as cooperative measures to confirm and clarify declared weapon-usable material stocks, but not to include materials in weapons or in naval fuel. In addition, the regime was to include exchange visits to the fissile material production sites and exchanges of production records.

In response to the progress of the joint Russian–US working group, presidents Clinton and Yeltsin agreed in May 1995 to negotiate agreements on the following measures: (a) a regular exchange of detailed information on aggregate stockpiles of nuclear warheads, on stocks of weapons-usable fissile materials and on their safety and security; (b) a cooperative arrangement for reciprocal monitoring at storage facilities of weapon-usable fissile materials removed from nuclear warheads; and (c) other cooperative measures as necessary to enhance confidence in the reciprocal declarations on fissile material stockpiles.⁴⁵ The Clinton–Yeltsin statement also declared that: (a) fissile materials removed from nuclear weapons being eliminated and excess to national security requirements will not be used to manufacture new nuclear weapons; (b) no newly produced

⁴⁴ Goodby (note 38), p. 182; and Joint Statement on Strategic Stability and Nuclear Security by the Presidents of the United States of America and the Russian Federation (The White House, Office of the Press Secretary: Washington, DC, 28 Sep. 1994), available at URL <<http://csf.colorado.edu/dfax/npn/npn13.htm>>. The meeting took place under the auspices of the US–Russian Joint Commission on Economic and Technological Cooperation, known as the Gore–Chernomyrdin Commission, which was established in 1993.

⁴⁵ Joint Statement on the Transparency and Irreversibility of the Process of Reducing Nuclear Weapons (The White House, Office of the Press Secretary: Washington, DC, 10 May 1995).

fissile materials will be used in nuclear weapons; and (c) fissile materials from or within civil nuclear programmes will not be used to manufacture nuclear weapons.

Although Russia and the USA appeared to be moving towards an initial regime for warhead and fissile material reductions, Russia broke off the talks in late 1995 and they were not resumed. Some US experts believe that the agenda was simply too broad and ambitious for the time and circumstances. Matthew Bunn cites three reasons for ‘the transparency that never happened’.⁴⁶

1. The historical legacy of tsarist and communist secrecy made the Russian Government ‘extraordinarily reluctant to open nuclear secrets’.

2. Many in the US Government were equally unwilling to make US facilities accessible to Russia.

3. The US Government never offered significant strategic or financial incentives to overcome Russian reluctance.

Even in the absence of high-level negotiations, extensive and innovative technical discussions and experiments between Russian and US laboratories have continued as part of the laboratory-to-laboratory programme. Significant progress has been made in the joint development of approaches for monitoring warhead dismantlement and the storage of fissile components, as well as on arrangements for fissile materials. Since information barriers block the transfer of information containing restricted data, it would seem that an Agreement for Cooperation would not be needed for the collection of such data.

The production and disposition of fissile materials

General approaches

The Fissile Material Cut-off Treaty. Four of the NPT-recognized NWS have officially declared that they have stopped the production of HEU and plutonium for nuclear weapon purposes.⁴⁷ In a major initiative, the 1992 Russian–US informal agreement to ban the production of fissile materials was expanded to create the concept of a multilateral Fissile Material Cut-off Treaty (FMCT). On 27 September 1993, President Clinton proposed at the United Nations a multilateral agreement to halt the production of HEU and plutonium for nuclear explosives. In December 1993 the General Assembly adopted by consensus a resolution calling for the initiation of negotiations.⁴⁸ The January 1994 Clinton–Yeltsin summit meeting produced a joint statement calling for ‘the most rapid conclusion’ of the FMCT.

⁴⁶ Bunn (note 38), pp. 46–47.

⁴⁷ Grand (note 26). The cut-off dates for HEU and Pu production for weapons were as follows: France (1996/1992), Russia (1987/1994, except for 3 reactors), the UK (1963/1995) and the USA (1988/1964).

⁴⁸ United Nations General Assembly Resolution 48/75L, Dec. 1993.

The FMCT concept focuses primarily on the five NPT-recognized NWS and the three de facto NWS (India, Israel and Pakistan), but all other states would be invited to join the regime.⁴⁹ In 1995 the CD agreed by consensus to establish an ad hoc committee to negotiate a treaty, but progress stalled over a number of issues. For example, India and a few other states have declared that they would not sign an FMCT unless a strict deadline was set for the NWS to fulfil their NPT Article VI obligations to eliminate their nuclear weapons. Issues of ballistic missile defence, the weaponization of outer space (raised by China) and the no-first-use of nuclear weapons have also blocked progress. Since the CD operates on a consensus basis, a deadlock can easily be created, as happened in this case.

The cost of verifying an FMCT would vary greatly depending on the approach adopted.⁵⁰ It is unlikely that the treaty's monitoring provisions would apply to stockpiles of fissile material produced in the NWS before it entered into force. The FMCT could establish safeguards at all the power plants in the NWS, which would raise the costs since there are about as many nuclear power plants in the NWS as there are in the NNWS. However, safeguarding all reactors worldwide would not double the IAEA's burden since the IAEA also performs other tasks. It is envisaged that the IAEA would conduct routine FMCT inspections at plutonium and HEU production and storage sites in the NWS.

Precedents and experience relevant to an FMCT. A number of international arrangements offer precedents and experience that could be useful for an FMCT. A ban on the production of HEU is monitored under the 1989 Hexapartite Enrichment Project, in which six states—Australia, Germany, Japan, the Netherlands, the UK and the USA—place all their civil centrifuge plants under IAEA safeguards.⁵¹ Monitoring to distinguish between HEU and low-enriched uranium (LEU) is an integral part of this arrangement. This type of monitoring could be extended to all types of enrichment plant. States which have nuclear-powered submarines have asked for an exemption for HEU fuels for naval propulsion. This issue could be avoided by designing the next generation of naval power plants to operate at levels well below 90 per cent uranium-235 enrichment, which several states have already done.⁵²

Most of the NWS have sufficient weapon-grade plutonium, so they no longer reprocess military spent fuel. This is easy to monitor on a permanent basis

⁴⁹ Albright and O'Neill (note 25).

⁵⁰ Koyama, K., 'What the verification regime under a Fissile Material Cut-off Treaty could be like: a preliminary view', *Journal of Nuclear Materials Management*, vol. 27 (winter 1999), pp. 48–52; and Bragin, V. and Carlson, J., 'An introduction to focused approach to verification under FMCT', *Journal of Nuclear Materials Management*, vol. 28 (winter 2000), pp. 39–45. Some have speculated that the budgets needed would be about the size of the annual IAEA safeguards budget of \$80 million, but this would clearly depend on the regime.

⁵¹ von Baeckmann, A., 'Implementation of IAEA safeguards in centrifuge enrichment plants', *Proceedings of the Fourth International Conference on Facility Operations—Safeguards Interface*, 29 Sep.–4 Oct. 1991 (American Nuclear Society: LaGrange Park, Ill., 1991), pp. 185–90.

⁵² Ma, C. and von Hippel, F., 'Ending the production of highly enriched uranium for naval reactors', *Nonproliferation Review*, vol. 8, no. 1 (spring 2001), pp. 86–101. France uses HEU containing 90% U-235, but is switching to 7%.

when plants have been closed, but it is more complicated if the plants continue to be used to reprocess civilian spent fuel to obtain separated plutonium for fabrication into mixed oxide (MOX) fuel. The reprocessing plants in the NNWS were originally designed to accommodate IAEA material accounting measurements, but plants in the NWS were not. The monitoring of plutonium under an FMCT would also have to ensure that new plutonium remained inside the civilian nuclear fuel cycle and not in weapons. In order to obtain accurate material balances and track the material throughout its use, it would be necessary to measure flow rates at predetermined key measurement points in the plant.

In order to be confident that clandestine production of HEU or plutonium is not taking place in the NNWS, the IAEA has instituted the Strengthened Safeguards System under INFCIRC/540, by which states are required to make declarations about their research and development for enrichment and reprocessing technologies.⁵³ INFCIRC/540 also establishes environmental monitoring to detect clandestine plants. Special inspections under traditional INFCIRC/153-type measures already allow further inspection of a declared site to confirm declarations.⁵⁴ Special inspections can also be applied at undeclared sites. (The IAEA had requested such inspections in North Korea.) The inspection regime under INFCIRC/540 will allow managed access to undeclared facilities in order to confirm the absence of undeclared production.

Russian–US programmes and initiatives

The HEU Agreement. HEU poses a more serious proliferation danger than plutonium does since it is easier to use to manufacture nuclear warheads. HEU is not a significant spontaneous neutron emitter and can be fabricated for use in a nuclear warhead with the simpler gun-type design. At the same time, HEU has the great advantage that it can be relatively easily converted into LEU fuels that have considerable commercial value. By contrast, the use of plutonium in MOX fuels is very costly. For these basic economic reasons, significant progress has been made in reducing the Russian and US excess HEU stockpiles, while very little progress has been made in disposing of excess plutonium.

Under the 1993 HEU Agreement the USA agreed to purchase 500 tonnes of Russian HEU down-blended to LEU.⁵⁵ From June 1995 to 31 December 2002, Russia received about \$2.5 billion (of the new 2002 projected \$8 billion total)

⁵³ IAEA, Model Protocol Additional to the Agreement(s) between State(s) and the International Atomic Energy Agency for the Application of Safeguards, INFCIRC/540, Sep. 1997, and subsequent corrections, available at URL <<http://www.iaea.org/worldatom/Documents/Infcircs/Numbers/nr501-550.shtml>>.

⁵⁴ IAEA, The Structure and Content of Agreements Between the Agency and States Required in Connection with the Treaty on the Non-Proliferation of Nuclear Weapons (NPT Model Safeguards Agreement), INFCIRC/153 (Corrected), June 1972, available at URL <<http://www.iaea.org/worldatom/Documents/Infcircs/Others/inf153.shtml>>. Comprehensive IAEA safeguards agreements are based on this document.

⁵⁵ The text of the HEU Agreement is reproduced in *SIPRI Yearbook 1994* (Oxford University Press: Oxford, 1994), pp. 673–75.

for 5027 tonnes of LEU down-blended from 171 tonnes of HEU.⁵⁶ The contract value has varied over time, depending on market prices.

The USA declared 174 tonnes of its HEU as excess, with some to be down-blended into reactor fuel and some to be disposed of as waste. In addition, Minatom and the US NNSA are working together to down-blend excess HEU that resides outside of the Russian military complex. So far, the programme has down-blended 2 tonnes of HEU, with additional plans to down-blend more.⁵⁷

The ability to monitor the weapon usability and origin of the HEU feedstock has taken time to evolve.⁵⁸ The US–Russian Transparency Review Committee has established monitoring procedures at the three relevant Russian facilities: Russian and US personnel have the right to visit processing facilities to check tags/seals, verify supporting documents, observe critical processing steps, and take measurements of uranium isotopic content and mass. The committee established the certification process for US instruments, such as the HEU/LEU Blend-Down Monitoring System.⁵⁹ The acceptance of enhanced monitoring was facilitated by a prepayment of \$100 million, which gives the USA inspection privileges at Russian facilities. These inspections are necessary to assure the USA that the LEU is derived from weapon-grade HEU.

Up to 24 inspections are allowed each year along with a permanent monitoring office. Adequate set-ups for providing assurances that the uranium feedstock for down-blending comes from a weapon-grade uranium feed exist at one of the facilities, but not at the other two, where the monitoring equipment is not yet in place.⁶⁰ The FY 2001 budget for the NNSA called for monitoring equipment to be installed at Zelenogorsk in FY 2002 and for discussions to be initiated in FY 2002 on the installation of a down-blend monitoring system at Seversk in FY 2003. The USA does not monitor the complete chain of custody of HEU, from warhead to arrival at the down-blending facilities, but spot checks have given confidence that the material comes from dismantled warheads.⁶¹

In July 1998 the US Government purchasing agent, the US Enrichment Corporation (USEC), was privatized. This placed market considerations in conflict

⁵⁶ United States Enrichment Corporation (USEC), ‘US–Russian Megatons to Megawatts Program: turning nuclear warheads into electricity (as of 31 December 2002)’, URL <<http://www.usec.com/>>.

⁵⁷ Wander, T. *et al.*, ‘Model and pilot projects on HEU consolidation and converting into LEU in SRI SIA “Luch” [Scientific Research Institute, Scientific Industrial Association ‘Luch’, Russian Ministry of Atomic Energy]’, *Proceedings of the 41st Annual Meeting of the Institute for Nuclear Materials Management (2000)* (note 30).

⁵⁸ US General Accounting Office (GAO), *Nuclear Proliferation: Status of Transparency Measures for US Purchase of Russian Highly Enriched Uranium*, GAO/RCED-99-194 (GAO: Washington, DC, Sep. 1999).

⁵⁹ Mastal, E. *et al.*, ‘Certification of US instrumentation in Russian nuclear processing facilities’, *Proceedings of the 41st Annual Meeting of the Institute for Nuclear Materials Management (2000)* (note 30).

⁶⁰ Mastal, E. *et al.*, ‘Current and future directions for the implementation of the US/Russian Intergovernmental Agreement: transparency and the natural feed component’, *Proceedings of the 41st Annual Meeting of the Institute for Nuclear Materials Management (2000)* (note 30).

⁶¹ GAO (note 58).

with the broader goals of arms control.⁶² The HEU Agreement has been close to collapse on several occasions, but the differences have been resolved or resolution postponed.⁶³ Funding has been further complicated by the drop in natural uranium prices. Roughly speaking, the original price of \$12 billion was based on about \$8 billion for enrichment services in separative work units (SWUs) and about \$4 billion for the natural uranium feed component. The spot market price for uranium dropped by more than half from 1996 to 2000, reducing the payments to Russia. About 50 per cent of the USEC's sales of LEU in the USA are from Russian imports and about 40 per cent of its total sales are Russian LEU. The implementing contract expires at the end of each year.⁶⁴ Critics of the new contract that begins in January 2003 claim that Russia is being underpaid for the uranium going into the enrichment services that are used by the USEC to keep its uneconomical Paducah plant functioning.⁶⁵ The USEC states that the \$12 billion contract is now worth \$8 billion because natural uranium will be returned to Russia and the market-based enrichment price will begin at \$90.42 per SWU.

Management and disposition of excess weapon plutonium. Recognizing the greater proliferation risks posed by excess weapon-grade plutonium, in 1992 President George H. W. Bush's National Security Advisor, General Brent Scowcroft, asked the National Academy of Sciences to study the options for plutonium management and disposition. In a two-volume study released in 1994 and 1995, the Academy's Committee on International Security and Arms Control (CISAC) recommended that Russian and US excess weapon plutonium be converted into a form that is at least as inaccessible for weapon use as the plutonium in spent-fuel rods from civilian nuclear power production.⁶⁶ This would put weapon plutonium in the category of risks posed by spent fuel, which the CISAC also strongly recommended addressing. The CISAC determined that two approaches were acceptable to fulfil the 'spent-fuel standard': (a) the encapsulation of diluted plutonium in a radioactive matrix (immobilization) for eventual geological disposal with other high-level nuclear waste; and (b) the

⁶² Neff, T., 'Privatizing US national security: the US–Russian HEU deal at risk', *Arms Control Today*, vol. 28, no. 6 (Aug./Sep. 1998), pp. 8–14.

⁶³ Bieniawski, A., Bussurin, Y. and Bystrov, A., 'Cooperation under the US–Russian Intergovernmental Agreement on the Disposition of Highly-Enriched Uranium from Nuclear Weapons and transparency arrangements under the HEU Purchase Agreement', *Proceedings of the 41st Annual Meeting of the Institute for Nuclear Materials Management (2000)* (note 30).

⁶⁴ United States Enrichment Corporation, 'Implementation of the US–Russian HEU Purchase Program', Hearing on Department of Energy Nonproliferation Programs with Russia, Committee on Foreign Relations, US Senate, 28 Mar. 2001.

⁶⁵ US General Accounting Office (GAO), *Nuclear Nonproliferation: Implications of the US Purchase of Russian Highly Enriched Uranium*, GAO-01-148 (GAO: Washington, DC, 2000); Neff, T., 'Decision time for the HEU deal: US security vs. private interests', *Arms Control Today*, vol. 31, no. 5 (June 2001), pp. 12–17; and Sewell, P., 'A response to Thomas Neff's "Decision time for the HEU deal"', *Arms Control Today*, vol. 31, no. 6 (July/Aug. 2001), pp. 14–16.

⁶⁶ US National Academy of Sciences (NAS), Committee on International Security and Arms Control (CISAC), *Management and Disposition of Excess Weapons Plutonium* (National Academy Press: Washington, DC, 1994); and NAS/CISAC, *Management and Disposition of Excess Weapons Plutonium: Reactor Related Options* (National Academy Press: Washington, DC, 1995).

use of plutonium as MOX fuel in existing reactors without subsequent reprocessing.

To encourage the disposition of large stocks of plutonium, the two governments formed the US–Russian Joint Steering Committee on Plutonium Management. In January 1997 the DOE announced that it would use either immobilization or the MOX route for the US disposition programme. On 2 September 1998, Clinton and Yeltsin signed a joint statement of principles for the disposition of 50 tonnes of plutonium by each state using either the immobilization or the MOX approach.⁶⁷ They also agreed to develop acceptable methods for transparency measures, including international verification and stringent standards of MPC&A.

On 1 September 2000 Russia and the USA signed the Plutonium Management and Disposition Agreement (PMDA), according to which each party must remove 34 tonnes of plutonium from its nuclear weapon programme and convert it into forms that will be irreversibly removed from military purposes.⁶⁸ The agreement is to remain in effect until the plutonium is irradiated to a specified level or is immobilized for geological storage. In January 2002 the George W. Bush Administration supported the MOX disposition programme, but did not provide a budget, while it halted the immobilization programme. Although the agreement does not specify a monitoring approach, each state is responsible for accounting for its materials, with reciprocal rights of inspection and specific monitoring arrangements to be negotiated. The agreement calls for ‘an appropriate arrangement’ between the IAEA, Russia and the USA.⁶⁹ Uncertainties about funding in both Russia and the USA make the planning of plutonium disposition difficult.

The Mayak Storage Facility Transparency Agreement. In 1991 Minatom Minister Viktor Mikhailov stated that the former Soviet Union would need a large facility near Tomsk in which to store excess weapon-usable materials under secure conditions. In January 1996 US Secretary of Defense William Perry and Mikhailov agreed on the construction of a storage facility for excess weapon-usable fissile materials at Mayak (Chelyabinsk-65).⁷⁰

The Mayak facility was designed in 1996 to accommodate 50 000 canisters filled with 66 tonnes of plutonium and 536 tonnes of HEU at a cost of

⁶⁷ Office of Fissile Materials Disposition, US Department of Energy, ‘Record of decision issues for surplus plutonium disposition’, URL <<http://www.doe-md.com>>. The decision allows for the disposition of 50 tonnes of plutonium—33 tonnes as MOX and 17 tonnes as immobilized waste. The 1 Sep. 2000 Russian–US agreement provides for 34 of the 50 tonnes. Holgate, L., ‘US/Russian cooperation for plutonium disposition—update’, *Proceedings of the 41st Annual Meeting of the Institute for Nuclear Materials Management (2000)* (note 30). The programme is expected to cost about \$4 billion without immobilization for the USA and \$1.75 billion for Russia. The USA will contribute \$200 million to assist the Russian effort and both countries plan to ask for additional assistance from the G8.

⁶⁸ The Agreement concerning the Management and Disposition of Plutonium Designated as No Longer Required for Defense Purposes and Related Cooperation, 1 Sep. 2000, available at URL <<http://www.ransac.org/new-web-site/related/agree/bilat/pudisp-agree.html>>. The PMDA had not entered into force as of Dec. 2002

⁶⁹ Such an arrangement is being considered under the Trilateral Initiative, described in chapter 11 in this volume.

⁷⁰ US General Accounting Office (note 33), p. 8.

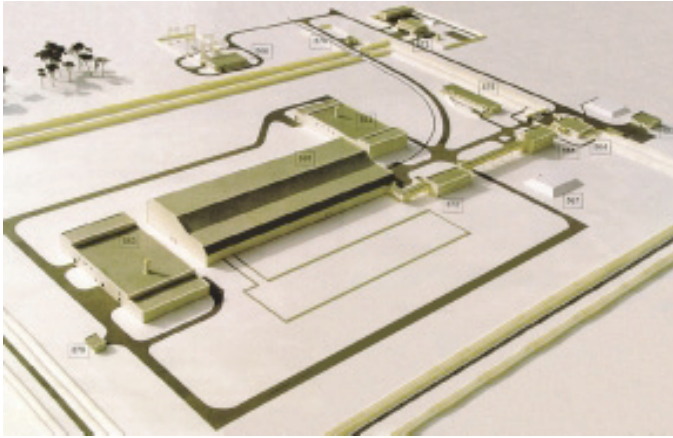


Figure 5.2. A model of the Mayak Fissile Material Storage Facility, under construction at Ozersk, Russia

Source: US Defense Threat Reduction Agency, *Technology Research and Development for Arms Control* (Office of Nonproliferation Research and Engineering, National Nuclear Security Agency: Washington, DC, spring 2001).

\$275 million.⁷¹ The first wing has been rescheduled to open in 2003 and estimated to cost about \$500 million, with the USA paying 90 per cent of this sum. This wing is designed to keep 25 000 containers, holding a total of 50 tonnes of plutonium and perhaps as much as 200 tonnes of HEU.⁷² A second wing of the same size could have been opened by 2010, but the \$250 million in funding was not obtained.⁷³

The two states agreed on ‘joint accountability and transparency measures’ that would permit the USA to confirm Mayak’s holdings. The US Congress expects confirmation that the materials are weapon-usable, but it will be much more difficult to verify that the plutonium originated from dismantled warheads. This would require measuring the attributes of the plutonium pits when they are brought to the Russian pit processing and packaging facility for conversion into spheres or hockey-puck shapes, but this requirement appears to have been relaxed.

The draft monitoring arrangement grants the USA considerable access to the Mayak storage facility, but the type of monitoring and the number of attributes

⁷¹ Under the Nunn–Lugar Cooperative Threat Reduction programme, the DOE spent \$63 million for 32 700 canisters for Mayak. See US General Accounting Office (note 33), p. 4.

⁷² HEU produces little heat and was to be used as heat spacers between the plutonium containers. The heat output from plutonium has caused some design problems, reducing storage capacity. Forced convection will be used to reduce plutonium heating.

⁷³ US General Accounting Office (note 33), pp. 5–7.



Figure 5.3. A crane at the Mayak Fissile Material Storage Facility, lowering fissile material into a ‘nest’

Note: A nest is a cylindrical space several metres in length, in which the AT-400R canisters are stacked.

Source: US Defense Threat Reduction Agency, *Technology Research and Development for Arms Control* (Office of Nonproliferation Research and Engineering, National Nuclear Security Agency: Washington, DC, spring 2001).

to be measured have not yet been finalized.⁷⁴ The DOE is currently developing a ‘single suite of equipment’ for use in several monitoring arrangements.

⁷⁴ US General Accounting Office (note 33), p. 10. The technical options under consideration are addressed in chapter 11 in this volume. Russia pledges not to remove any material from the Mayak facility, other than for emergency purposes, without first negotiating provisions to assure the USA that the material would not be reused for weapons. US inspectors could monitor Mayak 6 times per year and use data from Mayak’s material control and accounting system. US monitors could spend up to 5 days conducting the initial inspection. During each inspection, the monitors could download recorded data from sensors used by Russia to identify, scan and track each container as it passes through Mayak’s unloading and incoming control rooms. Annually, US monitors could randomly select up to 120 storage shafts (4% of Mayak’s capacity) and verify the identifying tags on containers against Mayak’s records. US monitors have the right to scan 1 container from each of the selected shafts to determine its contents. Russia would be required to inventory a random number of containers twice a year with US participation.

The Plutonium Production Reactor Agreement (PPRA). Russia and the USA agreed in 1994 to stop producing plutonium and HEU for weapons. However, Russia continues to operate three plutonium-producing reactors, at Seversk and Zelenogorsk, because they supply heat and power to nearby communities. In addition, Russia has insisted that it is necessary to reprocess the spent fuel since it suffers serious corrosion problems. It was agreed that the resulting plutonium (about 1 tonne per year) would be stored in oxide form and the USA agreed to provide assistance to replace or convert these reactors so that they would no longer produce weapon-grade plutonium. According to the agreement signed by Prime Minister Chernomyrdin and Vice-President Gore on 23 June 1994, the reactors were to be closed down by 31 December 2000.⁷⁵ The plutonium produced between 1994 and 2000 was to be placed under bilateral monitoring to ensure that it would not be used in nuclear weapons. This agreement has not yet been implemented because of a failure to agree on the ultimate plans for alternatives to provide power to the communities.

The Processing and Packaging Implementation Agreement (PPIA). The implementation of the PPIA, proposed in 1997, has also faltered, but its provisions are often referred to in discussions of plutonium storage at the Mayak facility. Russian and US pits would be processed into new shapes or amorphous forms to render them unusable for weapons. The USA has considered the Advanced Recovery and Integrated Extraction System (ARIES) to convert plutonium from excess pits into oxide form. A facility for this purpose, the Pit Disassembly and Conversion Facility, was scheduled to be built at Savannah River by 2005. The ARIES operations will be unclassified once the pits are converted into plutonium oxide powder. The Russian facility at Mayak is expected to make 2-kg plutonium sphere ingots, placing two ingots in each canister. Figures 5.2 and 5.3 show a model of the exterior of the Mayak facility and the process for lowering fissile material into cylinders inside the facility, respectively. Since the ingots will be in an unclassified shape, they could be accessible to limited IAEA monitoring. However, Russia considers the isotopic ratio (Pu-240/Pu-239) to be secret and will protect it by blending plutonium stocks before measurements are allowed. The US DOD indicated that it would provide \$650 million for construction of this facility, but so far Russia has rejected the offer, probably because of a need to protect classified information.⁷⁶

A spent-fuel repository in Russia. Another approach is to build a global spent-fuel repository in Russia. A repository that could hold 10 000–20 000 tonnes of spent fuel might raise some \$20 billion for Russia. The availability of such a repository could reduce the pressure to reprocess, but Russia appears to be planning to store its spent fuel for 10 years before reprocessing it to make MOX fuel. In addition, a geological repository is needed for 32 000 tonnes of US-

⁷⁵ von Hippel, F. and Bunn, M., *Saga of the Siberian Plutonium-Production Reactors*, FAS Public Interest Report 53, Nov./Dec. 2000, pp. 1–10.

⁷⁶ US General Accounting Office (note 33), p. 5; and US Department of Energy (DOE), *Warhead and Fissile Material Transparency Program Strategic Plan* (DOE: Washington, DC, Feb. 2000), pp. 12–13. The DOD would assist with transportation but not with operation and maintenance.

origin spent fuel, as there will otherwise be pressure to reprocess and thus obtain 300 tonnes of plutonium. In July 2001 President Vladimir Putin signed a law that allows Russia to import spent fuel for storage and reprocessing.⁷⁷ However, this presents many legal and political difficulties. The US Nuclear Non-proliferation Act of 1978 constrains the transfer and reprocessing of US-origin spent fuel and requires that some form of safeguards are maintained over it.⁷⁸ Russia's civil nuclear exports to India and Iran could also complicate an approval from the USA.

Improving MPC&A

The origins of the MPC&A programmes are described above. The purpose of the US programme is to help Russia with the MPC&A tools needed to strengthen its monitoring of nuclear materials. It is generally assumed that a viable transparency and monitoring plan for fissile materials and warheads would encourage the host states to improve their indigenous MPC&A programmes. The declaration and inspection processes would uncover problems which could be rectified.

The Russian HEU and plutonium that exist outside weapons are of greatest concern because these materials are subjected to the least accountancy and physical protection. The NNSA's FY 2002 budget proposal stated that 850 tonnes of military and civilian fissile materials stored at 95 sites in the former Soviet Union were probably in need of security upgrades.⁷⁹ The NNSA identified 11 Minatom sites that account for about 500 tonnes of fissile materials and 53 Russian Navy sites that contain 315 tonnes in warheads and fuel which probably need security upgrades. The civilian nuclear complex consists of 31 sites (18 in Russia and 13 in the newly independent states) which hold about 32 tonnes of material.

Because of the continuing uncertainties regarding Russia's MPC&A programme, the DOE asked the US National Research Council to review it. The Council's study concluded that there had been significant progress, but that there was much more work to be done.⁸⁰ It also concluded that the Russian

⁷⁷ Bleek, P. C., 'Russian Duma passes bill allowing import of spent fuel', *Arms Control Today*, vol. 31, no. 6 (July/Aug. 2001), p. 25; and Guinnessy, P., 'Russia banks on importing nuclear waste', *Physics Today*, vol. 54, no. 9 (Sep. 2001), pp. 24–25.

⁷⁸ McGoldrick, F., 'Proposals for an international spent fuel facility: US law and policy', Carnegie Endowment for International Peace Non-Proliferation Conference 2000, URL <<http://www.ceip.org/files/events/Conf2000McGoldrick.asp?>>; and Bunn, M., 'Russian import of foreign spent fuel: status and policy implications', *Proceedings of the 41st Annual Meeting of the Institute for Nuclear Materials Management (2000)* (note 30).

⁷⁹ The NNSA projected that 50% of the 95 sites would have 'comprehensive upgrades completed' by the end of FY 2002. Its projections for the end of FY 2002 were that, of 850 tonnes of fissile materials, 29% would have had 'comprehensive upgrades completed', 53% will have had 'rapid upgrades completed' and 67% will have had 'upgrades underway'. US General Accounting Office (GAO), *Nuclear Proliferation, Security of Russia's Nuclear Material Improving: Further Enhancements Needed*, GAO-01-312 (GAO: Washington, DC, 2001).

⁸⁰ National Research Council, *Protecting Nuclear Weapons Materials in Russia* (National Academy Press: Washington, DC, 1999); and Bukharin, Bunn and Luongo (note 38).

MPC&A programme would be a 'high-priority national security imperative for the United States for at least a decade'. The MPC&A programme addressed the following deficiencies in Russia: (a) a lack of unified physical protection standards and inadequate defences within sites; (b) a lack of perimeter-portal monitors to detect nuclear materials leaving sites; (c) inadequate central alarms and assessment and display capabilities; (d) inadequate protection of guards from weapons and an inadequate guard force; (e) a lack of material accounting procedures to detect and localize nuclear losses; (f) inadequate measurements of waste and scrap nuclear materials during reprocessing, manufacture and transport; and (g) antiquated tamper-indicating seals and tags that fail to provide timely detection.

The study recommended long-term indigenization of MPC&A activities and stressed the importance of nurturing Russian ownership of the technical solutions resulting from the Russian-US programmes.⁸¹ While the DOE has made substantial headway in implementation, administrative problems in Russia have impeded progress. In some cases US specialists have been denied routine access, there has been confusion as to Russian certification requirements for MPC&A equipment, or there has been indecision on the part of Russia. The study concluded that neither Russia nor the USA has developed a long-term strategy to ensure the sustainability of MPC&A systems. Storage areas must be further consolidated, transportation programmes need to be expanded, and additional US funds should be made available for the indigenization of Russian MPC&A equipment. In the related area of technology exports, the USA is sponsoring training programmes in the USA for officials of Russia and the newly independent states in order to strengthen controls.⁸²

Programmes to assist weapon scientists

Former Soviet nuclear weapon scientists are faced with the stark choices of unemployment, work in a non-nuclear government job, emigration to another country or conversion of their skills for work in the civilian sector.⁸³ The 1994 Initiatives for Proliferation Prevention (IPP) programme is a cooperative Minatom-DOE programme to assist scientists with nuclear weapon expertise to apply their skills to development and product manufacturing in the commercial sector. The NNSA has claimed that the programme has provided alternative, peaceful employment to roughly 8000 former Soviet specialists on weapons of mass destruction. Another programme is the 1998 Nuclear Cities Initiative (NCI), which is directed at improving the commercial sector in Russia's 10 formerly secret and still closed nuclear cities. The NNSA states that '30 civilian projects [were] funded through NCI, potentially employing more

⁸¹ US Department of Energy (DOE), *MPC&A Program Strategic Plan* (DOE: Washington, DC, Jan. 1998).

⁸² Bertsch, G. and Potter, W. (eds), *Dangerous Weapons, Desperate States* (Routledge: London, 1999).

⁸³ Schweitzer (note 39).

than 700 people'. The goal is to assist in planning and with loans to establish new industries. International development centres and open computing centres have been established in Sarov, Snezhinsk and Zheleznogorsk, but US funding may be limited in the future.⁸⁴ Congress combined the IPP and NCI programmes in November 2001.⁸⁵ A broader approach reaches out to the US commercial sector directly through the US Industry Coalition, an association of US companies and universities. As of December 1998 the IPP programmes had funded over 400 projects in Belarus, Kazakhstan, Russia and Ukraine. The US Industry Coalition has brought together the newly independent states and US commercial entities to collaborate on projects involving about \$164 million.⁸⁶

The International Science and Technology Centre in Moscow and the Science and Technology Centre in Ukraine have been established to provide former Soviet nuclear weapon scientists with opportunities in non-military research.⁸⁷ The US Department of State manages the science and technology centres, which have funded 840 non-military scientific projects and engaged over 30 000 scientists between 1994 and 2000. These programmes have experienced some start-up problems, but they have helped former weapon scientists as Russia downsizes its complex.

Warhead monitoring

START III

The Joint Statement issued at the conclusion of the March 1997 Helsinki summit meeting called for a START III agreement that included 'measures relating to the transparency of strategic nuclear warhead inventories and the destruction of strategic nuclear warheads . . . to promote the irreversibility of deep reductions including prevention of a rapid increase in the number of warheads'.⁸⁸ Presidents Clinton and Yeltsin also agreed to 'explore, as separate issues, possible measures relating to . . . tactical nuclear systems, to include appropriate confidence-building and transparency measures', and to 'consider the issues related to transparency in nuclear materials'.

The statement linked the US concern about Russian tactical weapons with the Russian concern about a potential US breakout from the START treaties. However, the statement could be interpreted in a another way. For example, meas-

⁸⁴ Desmond (note 39).

⁸⁵ US General Accounting Office (note 33); and Bleek, P. C., 'DOE threat reduction funding cut, programs reorganized', *Arms Control Today*, vol. 31, no. 8 (Dec. 2001), p. 23.

⁸⁶ Bell, D. *et al.*, 'Progress in nonproliferation: Initiatives for Proliferation Prevention, the US Industry Coalition, and other international programs', *Proceedings of the 41st Annual Meeting of the Institute for Nuclear Materials Management (2000)* (note 30).

⁸⁷ US General Accounting Office (GAO), *Weapons of Mass Destruction: State Department Oversight of Science Centers Program*, GAO-01-582 (GAO: Washington, DC, 2001).

⁸⁸ Joint Statement on Parameters on Future Reductions in Nuclear Forces, The White House, Office of the Press Secretary, Washington, DC, 21 Mar. 1997, available on the Carnegie Endowment for International Peace Internet site at URL <<http://www.ceip.org/files/projects/npp/resources/summits6.htm#parameters>>.

ures relating to the destruction of warheads might be interpreted to apply only to those warheads that are to be removed under a START III accord or only to those warheads declared excess to military needs. Although it is important to dismantle warheads removed from delivery vehicles that are scheduled for elimination, this is not sufficient. Little would be gained by verifying the dismantlement of certain warheads if other warheads in the stockpile could take their place or if new warheads could be produced to replace them. Warheads can be interchangeable if the delivery systems are modified.⁸⁹ To improve security benefits, transparency measures must be comprehensive. With the exception of the monitoring provisions specified in the INF and START treaties, as described above, warheads remain outside the bounds of any transparency or verification measures. In the years to come, this will be the greatest challenge in the development of a comprehensive regime to control warheads and fissile materials.

Joint technical work

The degree to which warheads are not subjected to any controls or transparency measures is offset somewhat by the degree to which the DOE laboratory-to-laboratory programme made significant progress in engaging Russian and US scientists in exploring the challenges of warhead monitoring.⁹⁰ The 2000 Warhead Safety and Security Exchange Agreement was extended in 2001 for five years to continue exchanges of unclassified warhead data, to enhance the safety and security of nuclear weapons, and to continue the laboratory-to-laboratory contracts which support research in this area. There has been considerable progress on this work, as described in appendix 8A, but more advances could have been made with greater political cooperation at the highest levels of both governments.

V. Conclusions

The negotiations on and initiatives for reducing cold war nuclear arsenals and for strengthening transparency have led to the establishment of cooperative programmes and measures that would have been inconceivable a decade earlier. In the area of enhancing controls over fissile materials and establishing mutual monitoring rights, the progress has been without precedent. Security at Russian nuclear facilities is being enhanced through the MPC&A programme, and

⁸⁹ E.g., US Minuteman ICBMs carry the W87 warhead developed for the MX missile, but they could also be armed with the W62 or W78 warhead developed for the Minuteman, large numbers of which are maintained in storage. The Trident II SLBM can carry either the W76 or the W88 warhead, or both; large numbers of W76 warheads are maintained in storage. With modifications, the Minuteman could carry the SLBM warheads and the Trident II could carry the ICBM warheads. Different types of weapons often share the same nuclear components, so 1 type could be used as the basis for another, just as the USA used W85 warheads from eliminated Pershing II missiles to build new B61 bombs. Russia reportedly has an even greater degree of interchangeability within its warhead stockpile.

⁹⁰ Bieniawski and Irwin (note 37).

excess fissile materials are being constrained with the construction of the Mayak storage facility and the HEU Agreement. However, much more work remains to be done. This section summarizes the lessons of the past decade.

The Russian Advisory Task Force appointed by US Secretary of Energy Bill Richardson argued for considerably increased funding and stronger directions in a report in 2001. The findings of the panel, chaired by former Senator Howard Baker and former Presidential Counsellor Lloyd Cutler, should be closely examined because of the high calibre of its membership and its bipartisan nature.⁹¹

1. The most urgent national security threat to the United States is the danger that weapons of mass destruction, or weapon-usable material in Russia, could be stolen and sold to terrorists or hostile states and used against US troops abroad or citizens at home.

2. The current non-proliferation programmes of the DOE, the DOD and related agencies have achieved impressive results, but their limited mandate and funding fall short of what is required to adequately address the threat.

3. The president and congress face the urgent national security challenge of devising an enhanced response proportionate to the threat.

The panel declared that Russia and the USA should agree at high levels of government on the degree of transparency needed to ensure that US-funded activities will have measurable impacts. It recommended \$30 billion in additional funding over the next decade, which would be 1 per cent of the projected US defence budget for this period.

Lessons

The past decade began with a high degree of cooperation between Russia and the USA on enhancing physical security, improving fissile material accounting, developing new monitoring approaches and providing for the irreversible disposition of excess nuclear warheads and materials. Over the past few years, however, progress has waned as competing pressures in each state have caused delays. These problems must be resolved if progress is to be renewed.

Access rights and reciprocity

The lack of access to critical facilities in both states has adversely affected the ability to win consensus on monitoring regimes. US officials have made many more visits to Russia than Russian officials have to the USA since Russia has more excess material, some of which is not adequately guarded, and more

⁹¹ Baker, H. and Cutler, L. (Co-Chairs, Russian Task Force, Secretary of Energy Advisory Board), *A Report Card on the Department of Energy's Nonproliferation Programs with Russia* (US Department of Energy: Washington, DC, 10 Jan. 2001), pp. 2-3, available at URL <<http://www.ceip.org/files/projects/npp/pdf/doetaskforceappendices.pdf>>.

MPC&A measures are needed. The USA is asking for and feels entitled to access rights because it is purchasing Russian HEU and funding the Mayak storage complex. For the overall benefit of their cooperation, it is clear that the USA should ensure the development of as much symmetry as possible between the two sides.

Degree of monitoring

The level of monitoring can rise with increased experience and trust, as in the case of monitoring under the HEU Agreement.

Secrecy

The former Soviet Union was often obsessed with secrecy, but the USA also exhibits this tendency. Segments of the US Government are negative towards the constraints of mutual monitoring. The recent concerns about the loss of secret information from Los Alamos sparked the creation of the National Nuclear Security Administration and the introduction of lie-detector tests at the national laboratories, which has affected staff morale. While there are legitimate reasons for keeping national security information secret, relatively harmless facts are also kept secret, which can impede Russian-US progress in reducing the nuclear threat. The USA favours 'transparency measures' in general, but in Russia there is a fear that they would allow the stronger party to spy on the weaker one. The USA has learned a great deal about the Russian nuclear complex. Although this knowledge may not be of great assistance to the US military, it is often hard to convince Russian officials of this.

Entanglement with other issues

Cooperation and progress have been slowed by other, unrelated issues, such as the US involvement in the wars in Bosnia and Herzegovina and Kosovo, the enlargement of NATO, the abandonment of the ABM Treaty and the planned deployment of missile defences. To the extent that these issues adversely affect Russian-US relations, they make the task of improving controls over nuclear weapons and materials harder to achieve.

Diplomatic strategy

The eagerness of the USA to move forward on a large and complex agenda may in 1995 have frightened Russia into pulling out of the negotiations on the Agreement for Cooperation and taking a more hesitant position concerning transparency and irreversibility. The USA has more personnel available to conduct negotiations, thus causing Russia to suffer from 'negotiation fatigue'. This may be one of the reasons why Russia prefers a slow, 'step-by-step' approach. Ultimately, both states will act only when they view a particular arrangement as beneficial to their national security.

Incentives

The financial assistance which the USA provided to Russia in exchange for monitoring rights has created an incentive that has sometimes helped move the agenda forward. Unless Russia and the USA return to their former level of cooperation, the availability of funds will be a less effective incentive in the future. Once the USA has completed its purchase of the Russian HEU, paid for the Mayak facility and helped with MPC&A, it is less clear what type of financial arrangements can promote mutual monitoring. National pride, the fear of revealing secret information and the rising price of Russian oil all contribute to reducing the incentives Russia has had from financial aid. Funding alone will not be enough to determine the best approach to devising the best arrangements, and there are reasons to believe that this approach should be gradual, with a negotiation strategy based on unilateral measures and executive agreements.

Leadership

Between 1994 and 1997, presidents Clinton and Yeltsin agreed on four occasions to broad measures for the enhancement of transparency, irreversibility and safeguards on excess nuclear warheads and materials. One agreement was to exchange stockpile data, but thus far only the USA has responded and only with data on its plutonium stockpile. In general, while technology experts in both states agree on the usefulness and value of the monitoring technologies, this does not always translate into policy. There is concern that support for these programmes may diminish unless there is a commitment from leaders at the highest level.⁹² The Bush Administration's withdrawal from the ABM Treaty, its rejection of the stronger verification measures of the proposed START III accord and the downgrading of some cooperative programmes with Russia, taken together, is not a hopeful sign.

An integrated approach

The programmes outlined in this chapter are complex and difficult to analyse. US Government proposals and budget requests have often seemed to be overly detailed and lacking in coherence. Acceptance of these programmes overall has been negatively affected by such complexities. It is obvious that a more integrated approach is necessary. One attempt in this direction has been made by Siegfried Hecker, former Director of the Los Alamos National Laboratory, who has called for an integrated strategy of nuclear cooperation with Russia.⁹³ It is to be hoped that more proposals for strategies of this type will be made and will gain momentum in the near future.

⁹² Luongo (note 38).

⁹³ Hecker, S., 'Thoughts about an integrated strategy for nuclear cooperation with Russia', *Nonproliferation Review*, vol. 8, no. 2 (summer 2001), pp. 1–24. Hecker developed an integrated approach for 33 issues, under 6 generic topics, for 3 situations. In the first, Russia is an ally of the USA, in the second Russia's status remains unchanged, and in the third Russia re-emerges as an adversary.