i

Making the Grade?

International Fissile Material Control Efforts

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The management of fissile materials has traditionally been seen as ancillary to broader nuclear policy agendas—bilateral arms control, nonproliferation, international safeguards, anti-terrorism, and civil energy policy.

But that approach can mask problems. For example, many U.S.-Russian arms control agreements were negotiated with the underlying assumption that neither country's practices would negatively effect efforts to stop the spread of nuclear weapons. Now, however, weaknesses in Russia's control of its military stocks of fissile material may have a profound impact on nonproliferation efforts.

In an effort to highlight the importance of managing and controlling fissile materials, we decided to take a different approach by looking at fissile material controls across the board—and by awarding letter grades to the various efforts the international community has made to reduce the risk posed by civil and military

Table 1.1

Estimated Global Fissile Material Inventories

end of 1997 (in tonnes)*

	HEU (weapon-grade equivalent)**	Plutonium
Military	1,700	250
Civil	20	1,100
Total	**1,720**	**1,350**

stockpiles of plutonium and highly enriched uranium (HEU). This approach produces a more coherent and realistic vision of how the international community can reduce the risks posed by inadequately controlled fissile materials. And it can identify those controls that are in urgent need of improvement.

More than 3,000 tonnes of plutonium and HEU are now stockpiled in various civil and military programs (a tonne, or metric ton, equals 2,200 pounds) (see Table 1.1). In 1998, the total inventory grew by about 50 tonnes, representing a slowing in the rate of growth of fissile material stocks.

These huge inventories pose a variety of risks. And because it takes only a few kilograms of fissile material to make a nuclear explosive, those risks are not always directly proportional to the amount of fissile material each country has in stock. Five kilograms of separated plutonium in Iraqi hands

* Central estimates are updates of values in David Albright, Frans Berkhout, and William Walker, *Plutonium and Highly Enriched Uranium 1996: World Inventories, Capabilities, and Policies* (Oxford: Stockhom International Peace Research Institute [SIPRI] and Oxford University Press, 1997). Excludes highly enriched uranium (HEU) in naval fuel cycles (but includes naval reserves), Russian breeder reactors, and production reactors. Russian breeder reactors use 20–25 percent enriched uranium. If naval and production-reactor fuel cycles were included, it would increase the Russian uranium inventory by about 100 to 200 tonnes of mostly non-weapon-grade material—although Russian naval reactor fuel is significantly more enriched than Russian breeder fuel. Also excluded is the plutonium in the nuclear cores of power reactors. A crude estimate is that at the end of 1997 power reactor cores contained roughly 100 tonnes of plutonium. In addition, civil plutonium inventories have been reduced to account for the decay of plutonium 241. Uncertainties in these estimates are in the range of 10 percent for plutonium and about 20 percent for weapon-grade uranium equivalent.

** Because of uncertainties about the enrichment level of military stocks of enriched uranium, this study uses the convention of "weapon-grade uranium equivalent." For details, see *Plutonium and Highly Enriched Uranium 1996*. For example, the central estimate for Russia is 1,010±315 tonnes of weapon-grade uranium equivalent, as of the end of 1997. A fraction of Russia's stock is certainly less than weapon-grade, although not enough information is publicly available to derive an estimate of the average enrichment of Russia's military stock. But assuming the average enrichment of the actual stock is 80 percent, similar to the level of the U.S. HEU stock, Russia would have a stock of about 1,170±350 tonnes. See also Appendix 5.

may be far more dangerous than *five tonnes* of separated plutonium in Japan. Similarly, if physical security is weak at sites with only small amounts of fissile material, those sites can present significantly more danger than sites that are much larger. The amount of fissile material does relate, however, to the design of a specific physical protection system, the accurate determination of past production, and the cost of disposing of fissile material.

In this assessment, we grade the progress that has been made in meeting a set of specific goals to significantly reduce the risk posed by inventories of fissile materials. The goals are grouped in categories that relate to seven broad policy objectives:

- Ending the production of new fissile materials for nuclear weapons;
- Reducing and disposing of the military fissile material stockpiles of the nuclear weapon states;
- Protecting fissile material from theft;
- Increasing the "transparency" of military and civil stocks—thus determining a better baseline for the inventories of fissile materials worldwide;
- Stopping the spread of nuclear weapons;
- Improving civil fissile-material controls; and
- Establishing nuclear waste repositories.

One complicating factor in making this assessment concerns the characterization of India, Pakistan, and Israel. None of these states is classified as a nuclear weapon state as defined by the Nuclear Non-Proliferation Treaty (NPT), because they did not conduct a nuclear test before January 1, 1967. Technically, however, each must be considered a de facto nuclear weapon state—as India's and Pakistan's nuclear tests in May 1998 clearly demonstrated. As a result, these countries' activities are graded in areas that traditionally have been seen as the bailiwick of only the first five nuclear weapon states—Britain, China, France, Russia, and the United States.

Grades have been awarded on a scale of A, B, C, D, and F, where A is excellent and F is failing. For averaging purposes, an

A corresponds to a numerical grade of 4, and an F, to zero. When averaging, each sub-category is weighed equally. The assignment of letter grades was accomplished by ISIS staff. Their judgments are based on extensive experience and research in these areas and

Table 1.2

Scorecard Summary

Category	Grade
I. Ending the production of fissile material for nuclear weapons	**C**
a. Unilateral initiatives to end the production of new materials for weapons in Britain, China, France, Russia, and the United States	A-
b. Ending production in other states	D
c. Obtaining a fissile material cutoff treaty	B-
II. Protecting and reducing military stocks of fissile materials in the nuclear weapon states	**C**
a. Declaring military stocks to be excess	C-
b. Placing excess military stocks under international safeguards or verification	B
c. Disposing of excess HEU	B-
d. Disposing of excess plutonium	D+
e. Establishing verifiable warhead dismantlement	C-
III. Protecting fissile materials from theft	**C+**
a. Improving protection and accounting systems in the former Soviet Union	D+
b. Improving physical protection worldwide	B+
IV. Creating inventory transparency	**C+**
a. Military stocks of plutonium and HEU	D+
b. Civil stocks	B+
V. Ending the proliferation of nuclear weapons	**C+**
a. Strengthened IAEA safeguards	A-
b. Working towards NPT universality and nuclear-weapon-free zones	B-
c. Dealing with violators of international nonproliferation commitments or inspections	D
d. Improving export controls	C+
VI. Reducing the threat posed by civil stocks of fissile material	**C-**
a. Minimizing stocks of separated civil plutonium	D+
b. Eliminating civil HEU	C
VII. Establishing acceptable nuclear waste repositories	**F**
Overall Grade	**C**

a series of fissile-material workshops ISIS sponsored in 1997 and 1998 in Washington, D.C., Geneva, and Vienna.

Results in Brief

ISIS awards an overall grade of “C” to international efforts to reduce the risk posed by fissile materials. This grade reflects an average performance—an uninspiring mark given the threat posed by fissile materials and the expectations of the early 1990s. Considerable efforts are needed to improve this overall grade. Table 1.2 summarizes grades in individual categories, which vary widely. Our main conclusions are as follows:

Despite years of effort, the Geneva-based Conference on Disarmament (CD) has yet to produce a treaty banning the production of fissile materials for nuclear weapons. Negotiations are finally starting, however, following India’s and Pakistan’s reversal of their long-standing opposition to the treaty. But negotiations are likely to be long and complicated. Meanwhile, Israel, India, and Pakistan are continuing to produce weapons materials. And India and Pakistan’s recent nuclear tests may have caused them to increase production for weapons.

Effectively dealing with countries, such as Iraq and North Korea, that violate international nonproliferation treaties and norms remains a serious problem. International Atomic Energy Agency (IAEA) safeguards have been significantly improved. But the challenges of funding and implementing improved safeguards systems must be confronted.

The physical protection of Russian stocks of fissile material remains inadequate, creating a significant risk that some material will be diverted. However, the goal of adequate physical protection of nuclear materials is accepted internationally.

The nuclear weapon states are still reluctant to make realistic declarations of their excess stocks of fissile material. Their resistance reflects overly pessimistic projections about future reductions in nuclear arsenals and extremely generous calculations of future needs for HEU to fuel naval reactors. Some excess military HEU is being disposed of, although not as rapidly as it might be. Russia and the United States have agreed that converting HEU into low-enriched uranium (LEU) to be used as commercial reactor fuel is the best option, but there have been recurring difficulties in implementing this approach.

Proposed programs to dispose of excess military plutonium, which would take many years, have not yet gotten off the ground. In the meantime, more emphasis should be placed on converting plutonium to unclassified forms and putting those forms in safeguarded storage.

Civil supplies of separated plutonium continue to grow, and the prospects for significantly reducing civil inventories will be limited as long as even a few major countries remain committed to civil reprocessing.

Finally, the lack of politically and technically acceptable nuclear waste repositories complicates the development of solutions to a wide range of fissile material control issues.

The Report Card

I. Ending the Production of Fissile Material for Nuclear Weapons: *Overall grade: C*

Although Britain, China, France, Russia, and the United States have halted production, India, Israel, and Pakistan continue to produce weapon-grade material. Table 1.3 lists the status of military stocks of plutonium and highly enriched uranium in all eight countries.

For years there have been calls to start negotiating an international, verified ban on fissile material production for weapons, but progress toward achieving a ban has been disappointing. Following the Indian and Pakistani nuclear tests in May 1998, however, the international community exerted intense pressure on both countries to reverse their opposition to several measures that might cap their nuclear arms race, including a fissile material cutoff treaty (FMCT). In the case of a cutoff treaty, these efforts have succeeded (see Appendices 1, 2, and

Table 1.3

Production and Status of Military Stocks of Fissile Material, end of 1997 (in tonnes)*

	Plutonium	Weapon-grade uranium equivalent	
United States	100	635	production halted
Russia	130	1,010	production halted
Britain**	7.6	15	production halted; but could purchase HEU from U.S.
France	5	24	production halted
China	4	20	production believed halted
Subtotal	**247**	**1,704**	
Israel	0.46	?	production continues
India	0.35	small quantity	production continues
Pakistan	negligible	0.21	production likely accelerated in 1998
North Korea	0.03	———	production frozen
South Africa	———	0.4***	production halted
Subtotal	0.8	0.6	
Total (rounded)	**250**	**1,700**	

* Central extimates are updates of values in *Plutonium and Highly Enriched Uranium 1996*. Excludes stocks used in naval fuel cycles (not naval reserves) or production reactors or located in reactor cores, but about 20 tonnes of fuel- and reactor-grade plutonium, a fraction of which is in spent fuel, is included. Unless otherwise noted, the uncertainties in the estimates are identical to those in *Plutonium and Highly Enriched Uranium 1996.*

** Recently declassified British figures are published in the British government publication *Strategic Defense Review: Modern Forces for the Modern World*. Britain has declared 4.4 tonnes of plutonium to be excess. Britain's official declared military HEU total is 21.9 tonnes, including HEU dedicated to the naval program. The British government did not release data on the average enrichment of its HEU. Britain's total inventory was previously estimated at 13.6 tonnes of weapon-grade uranium equivalent, including naval HEU but reflecting losses and drawdowns for nuclear testing. This value appears to be an underestimate of as much as 8.3 tonnes. Not enough information is yet available for a thorough reassessment, but an additional amount appears to have been purchased from the United States under an enrichment services contract in the 1980s and 1990s. It was earlier estimated that about 4 tonnes had been purchased under this contract; now the estimate is closer to 7 tonnes. However, this adjustment still leaves about 4 tonnes of HEU unexplained. Recent British government statements—that HEU was transferred from the Dounreay reprocessing plant to the weapons program—reportedly involve a quantity far too small to explain the discrepancy. In any case, it is assumed that most of the HEU purchased under the enrichment contract was for naval reactors. But the exact purpose, source, and specific enrichment of the 4 tonnes of HEU remains unclear.

*** Not converted to weapon-grade equivalent. This value is the amount of HEU originally dedicated to the nuclear weapons program. Roughly, 25 percent is HEU enriched to about 80 percent; the rest is enriched to 90–95 percent. South Africa has used an unknown fraction of its stock of HEU from its dismantled nuclear weapons program to fuel the Safari research reactor.

3). But it remains to be seen whether Indian and Pakistani agreement will lead to successful negotiations.

Unilateral Initiatives to End the Production of New Materials for Weapons in Britain, China, France, Russia, and the United States *Grade: A-*

The five acknowledged nuclear weapon states have made great progress in halting the production of plutonium and HEU for nuclear weapons. The United States, Russia, Britain, and France have all officially announced a halt to the production of both materials for nuclear weapons. Only China has not officially declared a halt, although unofficial reports indicate that it has also stopped producing weapons materials. Russia has announced that it will convert its three remaining plutonium-production reactors so they no longer produce weapon-grade plutonium.

Ending Production in Other States *Grade: D*

Although Pakistan was believed to have "frozen" its production of HEU in 1991, it probably resumed production in response to increased tensions in South Asia. It also started producing unsafeguarded plutonium in a new reactor in early 1998. India is also producing unsafeguarded plutonium and possibly HEU. In addition, India and Pakistan may embark on a nuclear arms race that could lead them both to significantly increase their stocks of unsafeguarded fissile material. If production for weapons continues, by 2005 India could have enough weapon-grade plutonium for 100 nuclear weapons. Pakistan could have enough fissile material for about half as many.

Finally, Israel is expected to slowly increase its supply of fissile materials. Production, however, is not thought to be accelerating.

No country other than the above eight states is known to be producing fissile materials for nuclear weapons. Suspicions, however, remain about activities or intentions in Iraq, Iran, and North Korea. As a result, these countries are under intense international scrutiny.

Obtaining a Fissile Material Cutoff Treaty
Grade: B-

Although the Geneva Conference on Disarmament (the "CD") was given the mandate to negotiate a cutoff treaty in 1995, efforts to start—much less conclude—the negotiations completely failed in 1996, in 1997, and again in the first half of 1998. Now, however, prospects for success are improving.

On August 11, 1998, the CD agreed to start negotiations. This move followed dramatic change in India's and Pakistan's position on the FMCT after international economic sanctions were imposed on them as a consequence of their nuclear tests in May. Shortly after testing, India signaled its willingness to join the cutoff negotiations, dropping its insistence on linking cutoff talks to negotiations on a general nuclear disarmament treaty. In late July, Pakistan's ambassador to the conference announced that Pakistan was ready to join other members in promoting the creation of an ad hoc committee to negotiate a cutoff treaty, reversing Pakistan's long-standing and often bitter opposition. However, the ambassador made clear Pakistan's intentions to seek a solution to the problem of "unequal stockpiles," an approach rejected by the United States and other states. Pakistan believes that India's stock is significantly larger than its own, an imbalance that Pakistan has said it will not tolerate. For these and other reasons, agreement will be difficult to achieve even after serious negotiations start in early 1999.

II. Protecting and Reducing the Military Stocks of Fissile Materials in Nuclear Weapon States
Overall Grade: C

Close to 2,000 tonnes of plutonium and HEU have been produced for military purposes (see Table 1.3). About 1,900 tonnes were produced by the United States and Russia, and they will need less than 400 tonnes to sustain their nuclear arsenals at START II levels (see Table 2.1, page 31). If further reductions are agreed, even more fissile material will not be unneeded.

Nevertheless, the nuclear weapon states are reluctant to admit how much military plutonium and HEU is “excess” to their realistic military requirements. To date, only about one-third of military stocks have been declared excess (see Table 1.4).

The United States, Britain, and Russia are willing to allow international verification of the stocks they have labeled excess, and they have pledged to no longer use these materials in nuclear weapons or explosives. However, financial and classification issues have limited the amount of material actually subject to inspection by the IAEA. However, in September 1998, the United States, Russia, and the IAEA announced that they had made substantial progress in overcoming problems in verifying classified forms of plutonium.

Disposing of these materials is a thorny problem, and plutonium disposition is intensely controversial. Only about 50 tonnes of weapons uranium and insignificant quantities of military plutonium have been disposed of so far. Disposing of fissile material will require significant political, legal, and financial commitments by the United States, Russia, and other countries over many years. And coordinating the efforts of many countries and private corporations will take considerable skill.

Table 1.4

Fissile Material Declared Excess, as of July 1997 (in tonnes)

	Plutonium	Highly enriched uranium	
Britain	4.4	0	
China	0	0	
France	0	0	
Russia	50	500	(assumed weapon-grade)
U.S.	52.5	174	(100 tonnes WGU-eq)
Total	**107**	**674**	(600 tonnes WGU-eq)
Already disposed of	**0**	**56**	(53 tonnes WGU-eq)
Remaining to dispose of	**107**	**618**	(547 tonnes WGU-eq)

Irreversible nuclear arms reductions also require the establishment of systems to verify that nuclear weapons have been dismantled. Until March 1997, when Presidents Bill Clinton and Boris Yeltsin declared that warhead dismantlement would be included in the next round of negotiations to reduce strategic arms, arms control had all but ignored verified warhead dismantlement. The significance of the Clinton-Yeltsin statement is unknown, because key issues related to the types and numbers of warheads have yet to be settled.

We have evaluated five issues related to military stocks. Most of the discussion on these issues is limited to the five official nuclear weapon states. India, Israel, and Pakistan rarely if ever discuss these issues. One reason is the ambiguous status of their nuclear arsenals; another, the relatively small size of their stocks.

Declaring Military Stocks to be Excess *Grade: C-*

Russia and the United States have declared portions of their stocks to be excess to military requirements, but they could safely declare much larger quantities. Currently, we estimate that almost 1,500 tonnes, or 75 percent, of military fissile material in Russia and the United States is outside active nuclear weapons. But less than one-half of the material outside active weapons has been declared excess. Britain recently declared a portion of its military plutonium stock as excess; France and China have not declared any excess materials.

Placing Excess Materials under International Safeguards or Verification *Grade: B*

Verifiably removing excess materials from military stocks is a key aspect of irreversible nuclear arms reductions. But only a small fraction of excess stocks has been placed under IAEA or Euratom inspections so far, mainly because of financial and classification problems. Nonetheless, efforts to place additional U.S. and Russian materials under international inspections are progressing (see Appendix 4). In addition, Britain recently announced that it will place its excess plutonium under international safeguards.

The original nuclear weapon states have not codified their commitment not to use excess fissile material stocks in nuclear weapons. Although the states declaring excess have committed these materials to nonexplosive purposes, including naval reactor programs, their commitments lack legal standing and are essentially unverified. However, under the Trilateral Initiative of the United States, Russia, and the IAEA, they are working to create a model verification agreement that would allow the IAEA to verify a country's commitment to keep excess fissile material outside nuclear explosives, at least until the materials are determined to be unusable for the manufacture of nuclear weapons.

Disposing of Excess HEU *Grade: B-*

The final step in controlling fissile material is to render it benign or unusable in weapons. Highly enriched uranium can be converted into low-enriched uranium, which is usable as fuel in nuclear power reactors but not as a nuclear explosive. The material is converted by diluting it—"blending down" HEU with slightly enriched or natural uranium. The United States and Russia are already disposing of excess HEU by blending down the HEU to LEU.

The largest amount of HEU scheduled for conversion into LEU is covered by a U.S.-Russian agreement in which the United States pledged to purchase 500 tonnes of Russia's HEU recovered from nuclear weapons (the material contains about 100 million "separative work units," or SWUs, or enough to fuel the world's power reactors for around three years). However, the deal has encountered difficulties in its commercial implementation. And the recent privatization of the U.S. Enrichment Corporation (USEC) has created further difficulties and delays. Purchasing Russian HEU, which is then turned into LEU, will conflict with the company's incentive to maximize profits—it can produce LEU at its two domestic gaseous diffusion plants at a lower cost.

The amount of weapons uranium scheduled for blending down in 1998 was 24 tonnes, but only 14.5 tonnes was actually blended down and received by USEC. From 1999 through

2005, about 40 tonnes per year of weapons uranium are scheduled for dilution to LEU. Thirty tonnes of this total is Russian in origin and the rest is U.S. in origin.

Not all military HEU can be blended down or used commercially. Some of the material will have to be disposed of at an acceptable nuclear waste site. Progress in developing such sites has been slow (see section VII of this chapter).

Disposing of Excess Plutonium *Grade: D+*

Plutonium cannot be made non-usable by blending it down with another plutonium isotope—except for plutonium 238, which is far too scarce and expensive to produce to result in a realistic option. Plutonium is also far more radioactive than uranium. As a result, great controversy surrounds its disposition. Two disposal options have emerged: immobilizing it with high-level waste, or converting it into "spent fuel"—burning it in mixed oxide—"MOX"—fuel in commercial power reactors. Both of these options face serious technical, economic, and political obstacles, and as yet no significant quantity of plutonium has been disposed of by either method. Russia's current economic crisis only makes building the necessary facilities less likely.

Finding little concrete support for the MOX option in Russia or among European nuclear companies, Senator Pete Domenici, a major supporter of the idea, recommended before the current economic crisis that, as an interim measure, the United States and Russia convert their excess stores of weapon-grade plutonium into "unclassified forms" before putting them in safeguarded storage.

Establishing Verifiable Warhead Dismantlement *Grade: C-*

Technical talks between Russian and U.S. scientists have made progress, but there is no political motivation to begin formal negotiations on verifying warhead dismantlement until the Russian Duma ratifies the START II Treaty. Even then, an agreement would place significant controls on U.S. and Russian fissile materials only if a large portion of warheads were covered, a prospect that seems unlikely.

III. Protecting Fissile Materials from Theft
Overall Grade: C+

Improving Protection and Accounting Systems in the Former Soviet Union *Grade: D+*

Plutonium and highly enriched uranium in former Soviet states remain insecure. The Soviet Union produced the largest stockpile of plutonium and HEU, most of which is now in Russia. Despite recent efforts, systems to adequately protect and account for much of the fissile material remain far below international standards, making the stocks possible targets of theft by terrorists, proliferant states, or criminal groups.

Through international cooperation, particularly with the United States, Russia and the rest of the Newly Independent States are greatly improving physical security at many sites containing fissile materials. But it remains to be seen whether these improvements will be sustained in the long term, particularly given the inadequate physical protection and accounting "culture" inherited from the old system. Moreover, many key facilities containing large quantities of fissile material have yet to be addressed.

Improving Physical Protection Worldwide
Grade: B+

All nuclear facilities require physical protection against unauthorized theft or seizure. Responsibility for establishing and operating physical protection systems rests with national authorities. During the last two decades, states have cooperated, however, in producing the International Convention on the Physical Protection of Nuclear Material and international guidelines on physical protection, and national physical protection systems have been improved throughout the world, particularly in Europe and Japan. Physical protection and accounting in the U.S. nuclear weapons complex have undergone dramatic improvements in the last 25 years. More recently, governments have worked together to stop illicit trafficking in nuclear and radioactive materials. Much remains to be done, however. The Convention on Physical Protection requires additional strengthening, including expanding the convention to create an international, legally binding obligation to protect nuclear material in domestic use. Civil HEU stocks are widely dispersed and may require special attention.

IV. Creating Inventory Transparency
Overall Grade: C+

Military Stocks of Plutonium and HEU *Grade: D+*

Despite the leadership of the United States and recent actions by Britain, military stocks are insufficiently transparent. The United States has produced a comprehensive history of its military plutonium production, and it has produced a similar study of military HEU which, as of the end of 1998, is under declassification review. Britain was the first country to reveal both its military plutonium and HEU inventories, and it is producing a history of its production of military fissile material. Russia and the United States have agreed in principle to share information about their inventories, but this effort has floundered because of the lack of an agreement for cooperation. France and China have released little information about their military fissile material stocks.

It is troubling that most of the nuclear weapon states cannot cite precise figures for their own inventories. In addition, assessments that have been conducted—of historical fissile material production in the United States and South Africa—have demonstrated the importance of conducting investigations as soon as possible, while historical records still exist and key personnel are still alive.

Civil Stocks *Grade: B+*

States involved in civil reprocessing programs have made significant progress in declaring their stocks of civil plutonium. Nine countries agreed in the spring of 1998 on a common set of guidelines for civil plutonium management, including publishing regularly their holdings of civil plutonium. Table 1.5 lists the declarations of these nine states. (India remains outside this process, as are former Soviet states that inherited significant separated plutonium inventories.)

Civil HEU stocks are much less transparent. The management of civil HEU should be subject to similar guidelines.

Table 1.5

Unirradiated Civil Plutonium, 1996 (in tonnes)[a]

	Holdings in country
Belgium	2.7
Britain[b]	54.0
China	0.0
France[c]	65.0
Germany[d]	5.0
India[e]	0.5
Japan[f]	5.0
Russia[g]	28.0
Switzerland[h]	0.1
United States[i]	5.0
Total	165.3

a. Except for India, the source of this information is INFCIRC/549 and its associated declarations. Complete data exist for only 1996. Russian data is for July 1, 1996; the rest is for the end of 1996. The values represent amounts held in each country, not necessarily all unirradiated plutonium owned by a country.

b. Of the total value for Britain, 3.8 tonnes is owned by foreign countries. The total declared value at the end of 1997 is 59 tonnes, of which 6.1 tonnes is foreign-owned.

c. Of this quantity, 30 tonnes is owned by foreign countries. In 1997, France's stock of unirradiated civil plutonium increased to 72 tonnes, of which about 34 tonnes is foreign-owned.

d. Germany did not declare its stock of plutonium held overseas. This stock is estimated at about 16 tonnes and is included under listings for Britain and France. See Mark Hibbs, "Schroeder Will Allow Reprocessing But Push for At-Reactor Storage," *Nuclear Fuel,* August 10, 1998. In 1997, Germany's stock in-country grew by one tonne.

e. Estimated. This value reflects only plutonium separated at the PREFRE reprocessing plant that has not been assigned to the weapons program.

f. Japan also has about 15 tonnes of unirradiated plutonium held overseas.

g. Excess military stocks of up to 50 tonnes of plutonium are not included here.

h. Switzerland's inventory grew to 0.7 tonnes in 1997.

i. The United States also declared 40.4 tonnes held in the United States but not at a reprocessing plant. This plutonium represents formerly military plutonium transferred to civil use and is part of the roughly 50 tonnes declared excess to military requirements by the United States. As a result, it is not included in this table (see Table I.4).

V. Ending the Proliferation of Nuclear Weapons *Overall Grade: C+*

Controls on fissile materials or on the means to make them are at the heart of efforts to stop the spread of nuclear weapons to additional countries. Although these controls are not sufficient to stop proliferation—several countries have secretly acquired plutonium separation or uranium enrichment facilities—

they have limited the spread of fissile material. Controls are a key component in reducing the threat of proliferation.

Two major tools to control fissile materials are international safeguards and export controls. A major purpose of safeguards is to create transparency in the production and use of fissile materials. Export controls seek to create uniform national and international rules that can inhibit the spread of fissile material production capabilities, providing time for remedies to work.

The primary focus of concern about proliferation lies in the Middle East and South and Northeast Asia. Conflicts in these regions remain a major motivation for states to seek nuclear weapons or unsafeguarded stocks of plutonium and HEU.

At the same time, efforts to curb proliferation of nuclear weapons have achieved several notable successes. Argentina, Brazil, and South Africa have backed away from nuclear weapons and signed the NPT. South Africa revealed information about its former nuclear weapons stockpile. Argentina and Brazil created a regional safeguards system that complements the IAEA regime. Belarus, Kazakhstan, and Ukraine successfully removed all nuclear weapons on their soil and joined the NPT as non-nuclear weapon states.

Israel, India and Pakistan continue to hold out against international controls. They each have significant stocks of fissile material outside IAEA inspections that are part of their nuclear weapons programs. India and Pakistan both tested nuclear explosives in May 1998, sharply intensifying tensions in the region.

Iraq remains a nuclear weapons “wannabe.” It is the only country in the world prohibited from possessing separated plutonium and HEU. Although its pre–Gulf War facilities have been destroyed, it retains extensive expertise and ambition to reconstitute its nuclear weapons program.

Iran is also a concern. And Iran may now be more strongly motivated to acquire nuclear weapons as a result of the

Indian and Pakistani nuclear tests. Weakening sanctions and inspections in Iraq may lead Iran to accelerate its nuclear weapons program.

North Korea's plutonium inventory remains unknown. North Korea's nuclear program is "frozen" under the 1994 Agreed Framework, and a U.S.-initiated international consortium has started preparations to construct two light-water reactors. The final outcome of this process will depend on the North allowing the IAEA to investigate the history of its plutonium production program, to determine if it could have hidden a stock of weapon-grade plutonium. In addition, given the economic problems confronting East Asia, concern grew in 1998 about the ability of consortium members South Korea and Japan to shoulder most of the costs of building the two reactors. North Korea's ballistic missile program and its refusal to allow inspections of a suspicious underground construction site are other factors working against the Agreed Framework.

Strengthened IAEA Safeguards *Grade: A-*

After Iraq's secret nuclear weapons program was revealed, the IAEA sought to strengthen its nuclear safeguards and inspection procedures in non-nuclear weapon states with comprehensive safeguards agreements in a new program called "Programme 93+2." Five years of study and negotiation have led to an overhaul of safeguards that emphasizes more openness and the detection of undeclared activities. These new arrangements, including the new safeguards protocol, INFCIRC/540, are major accomplishments. But additional measures are needed, and implementation will take considerable time and face many challenges. Some states are expected to resist the new protocol unless tangible rewards are offered. Financing the improved regime may be a major problem.

In the early 1990s, the IAEA conducted an unprecedented verification of South Africa's abandonment of its nuclear weapons program. This IAEA investigation included a historical evaluation of South Africa's past weapons program, which generated a much deeper understanding of the effort needed to verify the size of fissile material inventories in nuclear weapon states.

The five legally recognized nuclear weapon states are accepting more IAEA safeguards over their civil programs, but coverage in Russia and China remains fragmentary. Britain and France are covered by Euratom and its safeguards, which has historically monitored more civil activities than the IAEA.

Working Toward NPT Universality and Nuclear-Weapon-Free Zones *Grade: B-*

The NPT is the foundation of the nonproliferation regime. During the last several years, many nations have joined the treaty, making it nearly universal. Most significantly, South Africa, Argentina, and Brazil have joined. However, Cuba and the de facto nuclear weapon states, India, Pakistan, and Israel, remain outside the treaty.

Regional regimes now complement the NPT. The strengthened Latin American Nuclear-Weapons-Free Zone (NWFZ) helped to end a potential Argentine-Brazilian race for "peaceful nuclear explosives." The Pelindaba Treaty locked a denuclearized South Africa into an African NWFZ, which is currently awaiting ratification by its members and the nuclear weapon states. An additional zone is being negotiated for Central Asia, and a Middle East NWFZ awaits that region's "comprehensive peace."

Dealing with Violators of International Nonproliferation Commitments or Inspections *Grade: D*

Various agreements constrain nations from acquiring nuclear weapons capabilities, but the international community's response to violations of these agreements has been uneven and inconsistent. There is no international consensus on how to deal with treaty violators.

Many see the reactor deal as rewarding rather than punishing

North Korea for flouting the NPT. In addition, North Korea is still not cooperating with the IAEA in preserving the information needed to verify its past nuclear activities. Iraq often resists Security Council resolutions, and balks at IAEA Action Team and U.N. Special Commission inspections. The Security Council may be unable to enforce a rigorous inspection regime in Iraq. Some fear other NPT parties may be cheating.

Unilateral military action against illicit nuclear activities are increasingly seen as ineffective or counterproductive. The lesson of Iraq is that a united Security Council can work effectively to enforce international laws and norms, but unified Security Council action remains the exception, not the rule.

Improving Export Controls *Grade: C+*

International export control guidelines on fissile material production technologies, including "dual-use" technologies, were expanded following the Persian Gulf War. However, "cheaters" and other "bad apples" may turn to the former Soviet Union and China, where the enforcement of export controls is perceived to be weak. The United States and the European Union also have shown signs of dropping their guard.

VI. Reducing the Threat Posed by Civil Stocks of Fissile Material *Overall Grade: C-*

Unlike military stocks, civil plutonium stocks are growing rapidly. About 1,100 tonnes of plutonium had been produced in commercial power reactors by the end of 1997. These stocks will continue to grow at the rate of about 75 tonnes annually. More than 80 percent of this material remains in spent nuclear fuel stored in more than 30 countries, but a growing amount is being separated at reprocessing plants in France, Britain, Russia, Japan, and India. Separated or unirradiated plutonium is far more accessible for nuclear weapons use, but plutonium in spent fuel represents a long-term proliferation concern.

By the end of 1996, about 170 tonnes of unirradiated plutonium had been separated from civil spent fuel (see Table 1.5).

This is expected to grow to about 250 tonnes over the next decade unless steps are taken now to reverse the trend. This stock of plutonium is growing so rapidly because plutonium separation in reprocessing plants is not being matched by plutonium disposition by recycling it as fuel. France, Britain, and Russia hold the largest inventories of civil plutonium, but an increasing amount of this material will be owned by non-weapon states in Europe and by Japan.

The civil plutonium imbalance has reduced enthusiasm within the European nuclear industry for burning Russian military plutonium. With only a limited capacity to fabricate plutonium fuel, Europeans fear that turning Russia's excess military plutonium into MOX fuel would only increase the size of their surplus stocks. In addition, Russia is increasing its stock of civil plutonium, essentially at an annual rate that would match the amount of military plutonium proposed for disposal each year.

Highly enriched uranium, unlike plutonium, is not a byproduct of civil nuclear power programs. As a result, the international community has had an easier time in its attempt to reach the consensus that HEU fuels should be eliminated. HEU already plays a diminishing role in civil research programs and almost no role in power programs, although over the years nearly 40 countries have used HEU fuels. The complete elimination of civil HEU fuels in research programs remains a long-term goal, and the attempt to further this goal continues to generate controversy. Research programs now have a stock estimated at about 20 tonnes, but this estimate is highly uncertain—principally because of the excessive secrecy of Europe's and Russia's civil research programs.

Minimizing Stocks of Separated Civil Plutonium

Grade: D+

Most utilities would prefer to store spent fuel, pending its direct disposal in a geological repository. But the transition away from reprocessing is hindered by binding contracts with reprocessors and by the uncertainty of long-term spent-fuel storage policies.

Several key states refuse to reassess their civil reprocessing and plutonium management policies. Instead of piling up surpluses, reprocessing decisions should be dependent on reaching zero. If utilities possess or anticipate surplus stocks, further reprocessing of spent fuels should be deferred until a balance between supply and demand has been established. These policies should take into account the disposition of plutonium from surplus civil and military stocks.

Eliminating Civil HEU *Grade: C*

Efforts to eliminate HEU in civil research programs have progressed slowly, encountering resilient opposition in many countries, including Germany, Belgium, South Africa, France, China, and Russia. The United States has strongly resisted converting several of its own research reactors to LEU fuel. All of these countries have or are building civil research reactors that they claim depend on a continuing supply of highly enriched fuels.

The United States continues to lead international efforts to develop new low-enriched uranium fuels that can replace highly enriched ones. However, U.S. efforts to convert several European research reactors have been set back by Russia's recent emergence as a new, long-term supplier of HEU to France, Germany, and possibly the Netherlands. The United States was the main supplier for decades, but decided against supplying foreign reactor owners with any more HEU fuel without a firm plan to convert to LEU fuels.

An important step in reducing the amount of civil HEU overseas has been the U.S. decision to take back spent fuel from overseas reactors containing U.S.-origin uranium. However, Russia has been unwilling to take back large stocks of irradiated, Russian-origin HEU fuel that is now stored principally in Eastern Europe. Russia did take a small, but strategically important, quantity of Russian- and French-origin HEU fuel from Iraq after the Persian Gulf War. After Iraq invaded Kuwait, it decided to divert safeguarded HEU to its nuclear weapons program.

VII. Establishing Acceptable Nuclear Waste Repositories *Grade: F*

Intense controversy surrounds efforts to develop politically and technically acceptable nuclear waste repositories. As a result, more than 50 years into the nuclear age, not a single country has built and successfully operated a geological repository for storing irradiated fuel or high-level waste. Technologies to somehow transmute dangerous, long-lived radionuclides are in their infancy.

The lack of repositories for civil spent fuel or other civil high-level waste enormously complicates efforts to reduce the incentives to separate plutonium and to eliminate HEU fuels. The absence of a viable plan to create international or regional waste repositories creates hardships for small countries with irradiated fuel to dispose of but no nuclear power programs to pay for building a repository. Lack of a repository also complicates the disposal of military plutonium.

Countries are increasingly united in their agreement to institute strategies aimed at long-term storage of spent fuel, either at reactors or at away-from-reactor storage sites. Many countries are also realizing that more resources are required to stabilize and safely store irradiated research reactor fuel. In some cases, the hazardous conditions of the fuel could pose health and safety risks, or encourage reprocessing to separate HEU or plutonium.