Nuclear Safeguards and the International Atomic Energy Agency

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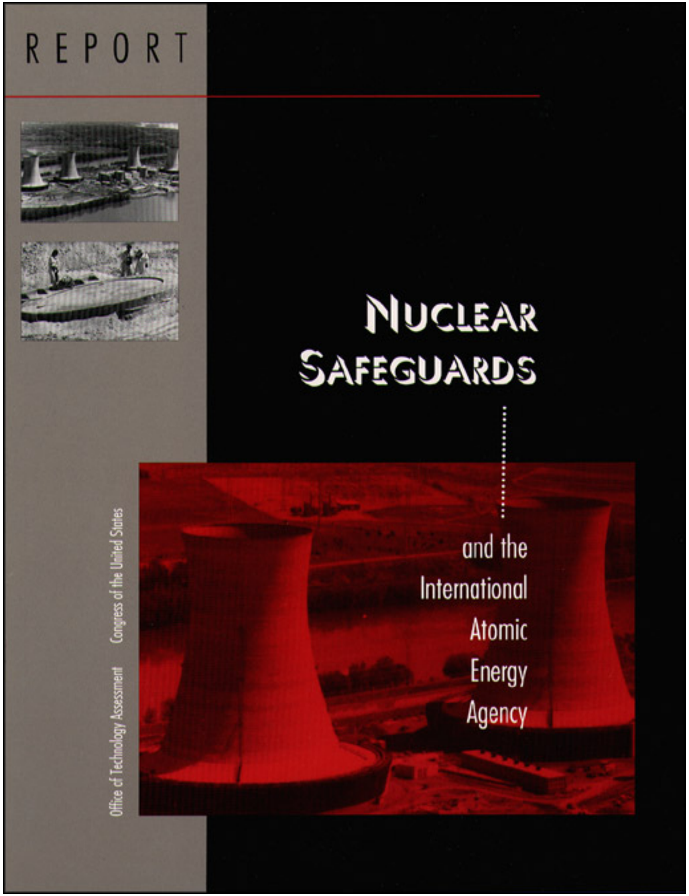

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Foreword

The International Atomic Energy Agency, which has primary responsibility for verifying compliance with the nuclear Non-Proliferation Treaty, plays a central role in preventing the spread of nuclear weapons. But the limitations of the IAEA's system of nuclear safeguards were highlighted in the aftermath of the 1991 Persian Gulf War, when it was revealed that Iraq had mounted an extensive, covert nuclear weapon program in addition to, and partly in proximity to, its open nuclear research activities that were under IAEA safeguards. The following year, IAEA investigations in North Korea revealed that the North Korean government was hiding information regarding the extent of its previous nuclear material production.

These cases showed that states could and did violate their Non-Proliferation Treaty commitments, offering concrete examples of what many had previously considered an abstract and distant threat. They also showed that the IAEA's traditional mission of detecting the misuse of safeguarded nuclear materials addressed only part—and probably not the most important part—of the proliferation problem. It became clear that if similar problems were to be avoided in the future, the IAEA would have to assume the task of ensuring that states do not possess covert nuclear facilities, a mission that it had previously not been granted the political support or the resources to conduct. Although the IAEA appears to be winning the political backing it needs to assume this broader responsibility, its member states have so far not granted it the funds to do so without impairing other safeguards functions.

This report analyzes what IAEA safeguards can and cannot be expected to accomplish, identifies areas where they might be broadened and improved, and presents options for doing so. It is the sixth publication of OTA's assessment on the proliferation of weapons of mass destruction, done at the request of the Senate Foreign Relations and Governmental Affairs Committees. That request was endorsed by the House Permanent Select Committee on Intelligence, the (then) House Committee on Armed Services, the Senate Committee on Banking, Housing, and Urban Affairs, and the (then) House Committee on Foreign Affairs.

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Note: OTA appreciates and is grateful for the valuable assistance and thoughtful critiques provided by the advisory panel members. The panel does not, however, necessarily approve, disapprove, or endorse this report. OTA assumes full responsibility for the report and the accuracy of its contents.

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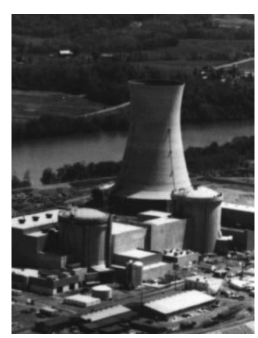

Summary 1

From the dawn of the nuclear age, nuclear power has been recognized as a "dual-use" technology. The same nuclear reactions that give bombs the destructive force of many thousands of tons of high explosive can, when harnessed in a controlled fashion, produce energy for peaceful purposes. The challenge for the international nuclear nonproliferation regime—the collection of policies, treaties, and institutions intended to stem the spread of nuclear weapons—is to prevent nuclear proliferation while at the same time permitting nuclear energy's peaceful applications to be realized. One of the key institutions involved in meeting these two objectives is the International Atomic Energy Agency (IAEA), an international organization created in 1957 as a direct outgrowth of President Eisenhower's "Atoms for Peace" program.

The IAEA Statute, which creates the legal framework for the agency, charges it to "accelerate and enlarge the contribution of atomic energy to peace, health, and prosperity throughout the world." At the same time, it gives the agency the authority to enter into so-called *safeguards agreements* with individual nations or groups of nations to ensure that nuclear materials, equipment, or facilities are not used to produce nuclear weapons. The IAEA's mission and its safeguards responsibilities were extended with the enactment in 1970 of the Treaty on the Non-Proliferation of Nuclear Weapons (also known as the Non-Proliferation Treaty, or NPT). The Treaty requires non-nuclear-weapon states that are parties to the accord to enter into safeguards agreements with the IAEA covering *all* nuclear materials on their territory (e.g., uranium and plutonium, whether in forms directly usable for weapons or forms that require additional processing before becoming usable in weapons).

Today, the IAEA has a central role in the international community's efforts to prevent the spread of nuclear weapons. It has come under increasing scrutiny since the Persian Gulf War of 1991, when it was revealed that Iraq had mounted a massive, covert nuclear weapon program in parallel with the public nuclear activities that were declared to, and inspected by, the IAEA. Discovery of Iraq's activities highlighted the need to ensure that other countries subject to IAEA safeguards were not also conducting nuclear weapon activities at facilities totally unknown to the IAEA. This assignment is considerably tougher than the one that the IAEA's member states had implicitly assigned the agency before the war: making sure that *known*, ostensibly peaceful facilities and materials were not being surreptitiously used for weapon purposes.

Over the following two years, the IAEA took a key role in exposing elements of North Korea's nuclear weapon program, and in verifying that South Africa had dismantled its own weapon program. These high-profile, high-stakes activities, in conjunction with a heightened interest in nuclear nonproliferation more generally, have focused additional attention on the IAEA and its system of nuclear safeguards. In addition to their direct contribution to nonproliferation, IAEA nuclear safeguards also affect the nuclear nonproliferation regime indirectly. For example, the confidence that parties to the Non-Proliferation Treaty have in safeguards is certainly one factor in determining their commitment to that Treaty, which is the centerpiece of the nonproliferation regime.

This report analyzes what the IAEA's system of nuclear safeguards can and cannot be expected to accomplish, identifies areas where it might be broadened and improved, and presents options for doing so. However, the focus here on nuclear safeguards should not be taken to imply that these safeguards are the only, or even the most important, nonproliferation tool. As discussed in an earlier Office of Technology Assessment (OTA) report, the nuclear nonproliferation regime also includes a host of other measures: export controls, international treaties, the extension of nuclear "umbrellas" by states having nuclear weapons to other states that might otherwise feel the need to develop their own, provision of other diplomatic and military commitments by nations to reassure their allies and warn potential foes, unilateral national polices, and so on.[1] This much wider set of issues is not addressed in this report. For further discussion, the reader is referred to that earlier report and to the other publications from OTA's assessment on the proliferation of weapons of mass destruction.

This chapter summarizes the issues and options for improving nuclear safeguards. Chapter 2 provides some background information about nuclear safeguards and the IAEA. Chapter 3 discusses various proposals for improving nuclear safeguards, or otherwise tightening control over nuclear materials, that could be implemented without making major changes to existing institutions or international agreements. These proposals generally address various changes in IAEA operations that the agency already has the authority to implement; indeed, many are already being implemented. Chapter 4 of this report addresses measures that go beyond existing institutions and agreements, whose implementation would require substantial changes or additions to the current regime (e.g., new treaties, or amendments to agreements such as the IAEA Statute or the NPT). Examples would include measures to address the actions of states not party to the NPT, or new

[1]See U.S. Congress, Office of Technology Assessment, *Proliferation of Weapons of Mass Destruction: Assessing the Risks*, OTA-ISC-559 (Washington, DC: Government Printing Office, August 1993). Other publications from this OTA assessment include *The Chemical Weapons Convention: Effects on the U.S. Chemical Industry*, OTA-BP-ISC-106, August 1993; *Technologies Underlying Weapons of Mass Destruction*, OTA-BP-ISC-115, December 1993; *Export Controls and Nonproliferation Policy*, OTA-ISS-596, May 1994; and *Proliferation and the Former Soviet Union*, OTA-ISC-605, September 1994.

agreements to place constraints on the production or use of nuclear materials that go well beyond the NPT.

OTA's major findings are presented below. Following that, this summary chapter mirrors the organization of the rest of this report: it provides some background information on IAEA safeguards, discusses various options to improve those safeguards that can be implemented largely within the existing regime, and concludes with some options to augment the regime.

FINDINGS ON IAEA SAFEGUARDS

- ***Some measure of subjectivity is inherent in any system of nuclear safeguards, and it is not possible to make an absolute determination of such a system's effectiveness.*** While *violations* of IAEA safeguards might be demonstrated unambiguously, *compliance can* never be established definitively.

  Although the purpose of IAEA safeguards—to verify that nuclear material "is not diverted to nuclear weapons or other explosive devices"[2]—may be simply stated, that goal does not automatically translate into the complex system of declarations, inspections, and evaluations that comprise the safeguards system. Assumptions must be made concerning the amount of material whose diversion should be detected (see discussion of "significant quantity" thresholds to follow), the period over which those diversions are conducted, and the statistical confidence needed to assert that a diversion might have taken place. No matter how small a diversion the IAEA intends to be able to detect in a certain period of time, for example, a state might still successfully divert the same amount of material by doing so over a longer period. Of course, even in such a case, there is value in delaying a proliferant's progress.

  Statistical methods such as those used by the IAEA to account for nuclear materials cannot give absolute answers. A measurement that a certain amount of nuclear material cannot be accounted for could mean that the material has been diverted out of a given facility—but it could also mean that the material remains within the facility but has for some reason escaped measurement, or even that all the material was in fact present and measured but that due to the inherent uncertainty in the measurement, some of the material *appeared* to be missing.

- ***The conventional "material accountancy" safeguards methods now in use by the IAEA appear unable to assure that the diversion of a bomb's worth of plutonium per year from a large plutonium reprocessing plant—e.g., one processing much over about 100 tons of spent fuel per year—would be detected with high confidence. No*** reprocessing plants this large are now under full IAEA safeguards, but one is under construction at Rokkasho-mura in Japan. (The operating reprocessing plant at Tokai in Japan has a capacity of about 90 tons spent fuel per year; whether or not it can meet this standard depends on the details of its material accountancy system and its annual throughput.)

  New techniques such as "near-real-time accountancy''-unproven at this scale by the IAEA—must be adopted for large reprocessing plants, and even these techniques may not be able to measure material flows and inventories accurately enough to detect the absence of as little as one bomb's worth of plutonium per year. In that case, if the IAEA could not demonstrate that safeguards methods *other than* the material accountancy techniques that form the core of its current safeguards approach can be relied on to detect diversion with a high degree of confidence, it would have to conclude that it could not safeguard such a plant to the same standards it applies at smaller facilities. *To date, the IAEA has not considered the possibil-*

[2] International Atomic Energy Agency, "Against the Spread of Nuclear Weapons: IAEA Safeguards in the 1990s," IAEA Division of Public Information, Vienna, Austria, December 1993, p. 11.

ity that it may be unable to safeguard large facilities such as the Rokkasho-mura reprocessing plant, but neither has it been able to demonstrate that it can.

- ***Evaluations of safeguards effectiveness that consider only the precision with which nuclear material inventories and flows can be measured underestimate the effectiveness of the overall safeguards system.*** Other techniques besides material accountancy—such as physical containment, surveillance, and review and verification of design information—can serve to prevent some diversion scenarios, and to make others less likely. These techniques make important contributions to safeguards, and the IAEA is improving its use of them. However, their contribution is very difficult to quantify, and it is hard to determine to what degree confidence in safeguards is improved through their use.
- ***IAEA safeguards alone cannot prevent states from developing nuclear weapons, but they make it much more difficult for states to use safeguarded nuclear facilities to make weapons without detection.*** IAEA safeguards are intended to detect—and therefore deter—diversion of civil nuclear materials into a weapon program. However, they cannot keep states from acquiring the technology needed to produce nuclear materials, or even from stockpiling fissionable material within civil programs and then withdrawing from safeguards to produce weapons.
- ***The most fundamental limit to improving the International Atomic Energy Agency's ability to detect nuclear proliferation is the extent to which the states that subscribe to nuclear safeguards are willing to cede additional sovereignty to the IAEA.*** Although any country subscribing to an international agreement such as the Non-Proliferation Treaty or a safeguards agreement with the IAEA is understood to have surrendered some sovereignty, states may not necessarily agree to new measures that they believe go beyond their original commitments. Therefore, the IAEA may not have the power to impose some measures it might otherwise wish to take to bolster its safeguards system. However, such measures could be voluntarily accepted by states subject to safeguards.
- ***The IAEA has no power on its own to compel states to comply with its inspection requests. However, it can refer disputes to the United Nations Security Council, which has the legal authority to enact and enforce resolutions that are binding on U.N. members.*** Thus, if the Security Council concludes that a state's refusal to cooperate with the IAEA threatens international peace and security, in principle it can demand that the state comply with IAEA requests or otherwise cease its provocative behavior, and the Security Council can ultimately back up its demands by authorizing the use of military force.

The IAEA's authority to inspect sites within a country is granted by the inspected country in the safeguards agreement that the country concludes with the IAEA. In the case of NPT parties, these agreements grant the IAEA the authority to determine that all nuclear materials in the state are exclusively in peaceful use.[3] They also give the IAEA—in consultation with the inspected state, and with its permission—the ability to inspect any site where the IAEA has reason to believe nuclear-related activities are being conducted, even if the inspected state has not admitted to conducting nuclear activities there. If the request for such a "special inspection" is refused, the IAEA can seek enforcement by the United Nations Security Council.

[3]The one exception is that nuclear materials that are in use for military, but nonexplosive, purposes such as naval propulsion are exempt from IAEA safeguards. However, a state may not create a separate fuel cycle outside of safeguards to produce nuclear materials for these purposes.

Nevertheless, safeguards agreements do not give the IAEA unlimited, "anytime-anywhere" access.

- ***Even though its access is limited, the IAEA can conduct inspections that individual states would not normally be permitted to undertake.*** For example, the IAEA took samples at North Korean nuclear facilities that the United States would almost certainly not have been able to visit. As an international organization, the IAEA is not generally thought of as pursuing the parochial interests of any single state, and strives to be seen as politically neutral.
- ***Ensuring the absence of undeclared nuclear facilities (i.e., those that a state hides from the IAEA, in violation of the requirement that all such facilities must be declared) is probably more important to the international nonproliferation regime than is incrementally improving safeguards at declared facilities*** (those that have been disclosed to and safeguarded by the IAEA). On the other hand, if safeguards at declared facilities deteriorate to the point where it becomes easy to divert materials without detection, diversion will become more attractive.
- ***The IAEA is exploring a number of means to improve its ability to determine whether states are pursuing undeclared nuclear weapon programs.*** However, it is not an intelligence organization, and its ability to discover undeclared activities that states wish to keep hidden from it will depend significantly on the willingness of other member states to share their own intelligence information with the IAEA, as well as on the ability of the IAEA to evaluate and analyze all such information.
- ***The steadily growing demands placed upon the IAEA cannot be accommodated without sacrificing effectiveness under the "no real growth" funding policy that has been imposed upon the agency since 1985. New*** responsibilities—including additional states subscribing to nuclear safeguards, expanded efforts to verify the absence of undeclared nuclear facilities in safeguarded states, and possible additional missions such as monitoring surplus nuclear weapon materials from the United States and Russia—need to be accompanied by new resources. However, *who* should pay and *how* the additional funds should be allocated remain controversial. For example, it will be politically difficult, if not impossible, to increase the safeguards budget without also increasing the funds the IAEA devotes to its technical assistance programs.

INTRODUCTION

Production of fissionable nuclear material (highly enriched uranium or plutonium) is the most difficult step in making a nuclear weapon. Consequently, constraining a would-be proliferant nation's ability to produce such materials has always been a central component of international nonproliferation efforts. One of the principal constraints is the requirement that countries joining the NPT as non-nuclear-weapon states accept international monitoring of all facilities that might produce, use, or otherwise handle nuclear materials. Such monitoring is conducted under the IAEA's system of nuclear safeguards.[4]

IAEA safeguards are intended to impede nuclear proliferation by ensuring that the diversion of nuclear materials from safeguarded nuclear facilities to weapon purposes will be caught and made known to the world community. To the extent that they can assure a country that its neighbors or adversaries are not developing nuclear weapons, safeguards lessen that country's perceived need to develop its own nuclear arsenal.

[4] IAEA safeguards can also constrain nuclear programs in non-NPT countries. Brazil, not party to the NPT, has nevertheless accepted IAEA safeguards over all its nuclear facilities. Moreover, additional states such as Israel, Pakistan, and India have placed certain nuclear facilities—usually imported ones—under safeguards as well, greatly complicating any attempt to use these facilities in their nuclear weapon programs. (India has a reprocessing plant that is under safeguards only when reprocessing safeguarded fuel; its activities at other times are not constrained by safeguards.)

In addition to imposing constraints on states' nuclear activities, the NPT also calls for the "fullest possible exchange of equipment, materials, and scientific and technological information for the peaceful uses of atomic energy," offering a reward to those states that subscribe to the Treaty and forego their option to produce nuclear weapons. In return for concessions by the non-nuclear-weapon states, the nuclear powers agree under the NPT to strive toward nuclear disarmament (Article VI of the Treaty), and (in conjunction with non-nuclear-weapon states who are in a position to contribute) to share information on the peaceful uses of atomic energy (Article IV). All NPT members are forbidden under Article III from exporting nuclear materials or facilities unless the recipients of those goods agree to place them under IAEA safeguards.

Origins of the IAEA Role in Nonproliferation

Pursuant to President Eisenhower's "Atoms for Peace" program, the United States in 1954 began to enter into bilateral nuclear cooperation agreements with other countries. These agreements included provisions, called safeguards, by which the United States could assure itself that its nuclear materials and technology were not being put to military use by other nations. At the same time, the United States entered into negotiations to create the International Atomic Energy Agency. These negotiations concluded in late 1956 with the drafting of the IAEA Statute. The agency itself was formed the following year as an independent intergovernmental organization affiliated with, but not a subunit of, the United Nations.

The IAEA was not given highly intrusive powers of inspection or enforcement over its member states, nor did it assert control over their nuclear activities. Rather, it was given the authority to enter into safeguards agreements with individual nations or groups of nations that would allow it to make certain inspections and measurements to ensure that nuclear activities were not being conducted for military purposes.

The first such agreement was concluded between the IAEA and Japan in 1959. By 1965, the IAEA adopted a comprehensive system of safeguards that was to be applied, upon request, to individual nuclear activities within a state, and to all activities receiving IAEA assistance. This type of safeguards, set forth in the IAEA publication known as INFCIRC/66, applies to individual plants, shipments of nuclear fuel, or supply agreements between importers and exporters of nuclear fuel or technology. It remains in use today as the basis for nearly all agreements between the IAEA and states that are not party to the Non-Proliferation Treaty.

The Non-Proliferation Treaty, which entered into force in 1970, extended the scope of the IAEA's safeguards activities. By joining the NPT, non-nuclear-weapon states—by definition, all those except the United States, the Soviet Union (now Russia), the United Kingdom, France, and China—commit themselves to refrain from manufacturing or otherwise acquiring nuclear weapons or explosive devices, and to submit to IAEA safeguards. Instead of covering only selected nuclear facilities as volunteered by the state, safeguards under the NPT—known as *full-scope* safeguards—are mandatory, and they must be applied to *all* nuclear materials in *all* peaceful nuclear activities within a country's territory or under its control.[5] To implement this charge, the IAEA developed a more comprehensive standard safeguards agreement—published in the IAEA document known as INFCIRC/153—encompassing a state's entire nuclear fuel cycle. All non-nuclear-weapon states that are parties to the NPT fall under IAEA safeguards, but the converse is not true. There are

[5]Non-Proliferation Treaty of 1970, Article III(1), with the exception noted earlier for material used for military, but nonexplosive, purposes (see footnote 3).

countries with safeguarded nuclear facilities, including a country (Brazil) about to conclude a full-scope safeguards agreement, that are not members of the NPT.

The NPT requires that any nuclear equipment exported by a member state be placed under safeguards by the recipient, even if the recipient is not an NPT member. However, the treaty does *not* oblige a member to require that countries receiving its nuclear exports adopt full-scope safeguards.

■ IAEA Safeguards

IAEA safeguards involve procedures for material accountancy, control, containment, surveillance, and verification of data, including onsite inspections, that are implemented through bilateral agreements between the IAEA and individual countries. They are designed primarily for two purposes: 1) to detect proliferation activities that involve diversion of materials from the civilian nuclear fuel cycle, and 2) to provide warning of any such occurrence to an international forum in a timely fashion. **Though they may deter proliferation by posing a risk of discovery, safeguards cannot predict a country's intent or future activity, nor can they by themselves prevent proliferation.**

The safeguards process consists of three stages:

1. *examination by the IAEA of state-provided information,* including a declaration to the IAEA of those facilities where nuclear materials will be handled, the design of those facilities, inventories of nuclear materials, and receipts formaterial transfers and shipments. States subject to safeguards must establish so-called state systems of accounting and control, or SSACs, to keep track of nuclear materials under their jurisdiction. The SSACs submit their records to the IAEA for independent verification, much like a bank auditor would be asked to provide independent confirmation of the accuracy of a bank's accounting.
2. *collection of data and independent information by IAEA inspectors* to verify material inventories, operating records, or design information, or, in special circumstances, to clarify unusual findings.
3. *evaluation by the IAEA* of this information for completeness and accuracy.

Any discrepancy of nuclear materials between the recorded (book) inventory and the physical inventory determined by measurements and inspections is called *material unaccounted for* (MUF). When MUF exceeds the amount attributable to measurement uncertainties, the possibility of diversion exists and must be resolved by the IAEA.

OPTIONS FOR ENHANCING THE SAFEGUARDS REGIME

OTA has explored a number of options for improving the nonproliferation regime, particularly regarding controls over nuclear materials. Some of these options can be implemented without making major changes to existing institutions or international agreements. Such proposals generally concern various aspects of IAEA operations and are discussed immediately below. Other options would involve making substantial changes or additions to the NPT or the IAEA Statute. These are discussed in the section titled "Beyond the Traditional NPT/IAEA Framework" that concludes this chapter.

■ Strengthening IAEA Capabilities

ISSUE: *Resources available for IAEA safeguards.*

In recent years, the demands placed upon the IAEA for safeguards services have increased substantially. For example, countries with substantial nuclear infrastructures have joined the NPT or otherwise come under safeguards, not only significantly increasing the number of facilities needing to be safeguarded but also requiring the IAEA to devote considerable resources to verify as best it can that all nuclear materials produced by the state in the past can be accounted for. Perhaps more significantly, the IAEA has significantly expanded its efforts to ensure that states under safeguards do not have secret or undeclared nuclear facilities.

Despite these growing demands, however, the IAEA's safeguards budget has essentially been held to zero real growth since 1985. A modest increase was approved in 1992, but was never realized due to the failure of the Soviet Union to make any contribution at all that year. Even though the United States interprets "zero real growth" as permitting increases to cover additional tasks that the IAEA has no ability to refuse—such as concluding new safeguards agreements and adding new facilities to existing agreements—the United States has been unable to convince other IAEA members to agree with this view. Therefore, every new country and new facility coming under safeguards squeezes the funding available for existing IAEA safeguards activities, let alone its new thrust to detect undeclared sites. In addition, the IAEA has constantly been subjected to late payments from member states, including the United States.

Even if agreement could be reached to increase funding for the IAEA, however, issues of fairness and proportionality—both with respect to *who* should pay more and *how* the added money should be allocated between safeguards and other IAEA programs such as technical assistance—complicate the debate over overall funding levels.

OPTION: *Increase U.S. contribution to the IAEA safeguards program.*

The United States, which provides just over 25 percent of the IAEA regular budget, is the IAEA's largest contributor. Its assessed contribution in 1994 totaled $49.9 million, with another $30 million provided in extrabudgetary contributions.[6] A total of $18.9 million of the U.S. assessed contribution went to fund safeguards activities. The largest portion of the U.S. extrabudgetary contribution—$14.6 million—was allocated to the IAEA's fund for technical cooperation and assistance in nuclear technology, a program integral to the IAEA's mission of promoting nuclear technology. Politically, this program is linked very strongly to the IAEA safeguards program, and there will be great resistance within the agency to increasing safeguards expenditures without corresponding increases in technical assistance. Some $9.4 million of the U.S. extrabudgetary contribution in 1994 was devoted to improving safeguards.

Those supporting increased U.S. funding for the IAEA believe that easing the fiscal pressures on the IAEA would enable it to better fulfill its current and future safeguards tasks and would be worth the added cost. Those opposed to a U.S. increase may place higher priority on competing needs for funds within the United States, or on the desire to reduce federal spending in general or contributions to international organizations in particular. Even if the United States were to increase its contribution, other IAEA member states may object to increasing their assessments or even to allowing the U.S. increase to be spent on safeguards without a corresponding increase in the technical assistance program.

OPTION: *Pay U.S. dues on time.*

Differences between the U.S. and the IAEA budget cycles mean that the U.S. contribution is consistently late, causing cash shortages for the IAEA and evoking criticism from the agency and from other member states. The United States could consider paying its dues on time. Moving the payment up, however, would incur a one-time charge equal to a year's dues because during that one fiscal year, two years' assessments would have to be paid.

ISSUE: *Allocation of inspection effort.*

Whether or not the overall safeguards budget is increased, efficiency in the use of IAEA resources is important. One inefficiency in present operations stems from the fact that safeguards are designed around nuclear material. Thus, much of the

[6] Safeguards constitute some one-third of the IAEA's regular budget—that part of the agency's activities funded by assessment on its member states. The United States and many other states have committed to make extrabudgetary contributions in addition to their assessments. Budgetary figures for 1994 are from the U.S. Department of State, March 1995.

safeguards effort has ended up being directed toward countries with large nuclear fuel cycles—Japan, Germany, and Canada-rather than states of greater proliferation concern. Furthermore, the majority of the safeguards effort gets applied to facilities with the greatest amount of material (i.e., those associated with civilian nuclear power production), rather than to other nuclear research activities that might be more likely to benefit a weapon program.

OPTION: *Reallocate inspection effort toward problem states.*

It would be desirable for the IAEA to focus greater safeguards efforts toward states either in regions of political tension or with only marginal nonproliferation records (where, for example, some effort might be directed at environmental monitoring to look for undeclared facilities). However, the IAEA is forbidden by its statute to discriminate against member states, making such proposals difficult to implement.

The IAEA already has some authority to adjust routine inspection requirements (subject to certain limits) based on a country's overall fuel-cycle characteristics. This authority might be exploited more fully, especially for *future* safeguards agreements. (Renegotiating safeguards agreements already in force would be much more difficult.) For instance, more emphasis could be placed on a country's overall amount of direct-use fissile material (i.e., material containing plutonium or highly enriched uranium, including their chemical compounds).[7] Or, if a country possesses enrichment or especially reprocessing facilities, additional inspection efforts might be justifiable even if amounts of fuel being irradiated in various reactors were small.

ISSUE: *Expansion of IAEA safeguards via "enhanced transparency" measures.*

"Transparency measures" refer to actions taken by a state to enhance the visibility and openness of its own activities in order to reassure others that it is not threatening their security. In the area of nuclear safeguards, such measures might include providing the IAEA with information, and offering access to inspectors, that is above and beyond what is required by a state safeguards agreement. Such actions can help a state assure others that it is not conducting secret nuclear activities, and they bolster the effectiveness of IAEA safeguards.

One technique that can take advantage of such transparency is the taking and analysis of environmental samples. The IAEA is exploring the potential for such environmental monitoring to detect and/or to characterize undeclared nuclear facilities. It is also accepting invitations by states such as Iran and South Africa for the IAEA to make "visits"—rather than formal inspections—to sites where questions may have been raised. As of August 1994, 20 states had agreed to participate in field trials of environmental monitoring or other techniques to strengthen safeguards. In addition to strengthening safeguards, transparency measures might allow the more efficient application of limited safeguards resources. In exchange for allowing IAEA inspectors much freer access to their territories, countries with large civilian fuel cycles, for example, might receive lessened routine inspection effort, while overall confidence in the absence of *undeclared* facilities could be increased. If the IAEA can satisfy itself that a state neither possesses nor has access to any undeclared facilities, it will have increased confidence that nuclear material at reactors and in storage has not been di-

[7] Direct-use material includes *unirradiated* direct-use material, which can be used to make weapon components with little additional processing (e.g., highly enriched uranium or separated plutonium), as well as irradiated direct-use material, such as the plutonium contained in spent fuel, which would have to be separated from the remainder of the fuel through chemical reprocessing before it could be used in weapon components.

verted to weapon use-even if the strict statistical confidence levels now required for material accountancy are somewhat relaxed.

OPTION: *Encourage states to make, and the IAEA to accept, offers to provide information and accept inspections not specifically required by safeguards agreements.*

NPT member states with nothing to hide might be willing to accept inspections and offer information above and beyond what they are required to provide, enhancing the IAEA's ability to apply safeguards. Moreover, such actions would reinforce a norm of openness for states wishing to demonstrate their compliance with nonproliferation commitments. To formalize their commitment to the IAEA to provide this transparency, states could add protocols to their safeguards agreements with the IAEA.

One possible limitation on a state's willingness to volunteer such access might be security, proprietary, or constitutional concerns that could argue against offering unlimited access. During the negotiation of the Chemical Weapons Convention, which provides for quite intrusive "challenge" inspections of suspect sites, such concerns lead to the development of "managed access" procedures that obligate the inspected state to address the concerns that motivated the inspection request, but ultimately give it the right to limit inspector access.

By providing additional information, voluntary offers of openness will improve the IAEA's ability to do its job. However, they can also pose some risk to the IAEA. First of all, acting on them will require additional resources, exacerbating the IAEA's financial difficulties. Second, voluntary invitations to conduct such visits can be retracted at any time, as was demonstrated in North Korea. Although North Korea initially offered IAEA inspectors the ability to visit sites in addition to those that the North Koreans specifically declared to the IAEA as nuclear facilities, this openness rapidly broke down when the IAEA sought to investigate discrepancies concerning North Korean plutonium production. Finally, and perhaps most seriously, "technical visits" that do not uncover suspicious activities might be overinterpreted (by outside observers, even if not by the IAEA) to give the inspected state a "clean bill of health." All that such a visit should imply is that nothing untoward was discovered at that site at that time.

OPTION: *Encourage bilateral inspection regimes and regional arms-control and confidence-building measures.*

In addition to acting on offers made by individual states to make their nuclear activities more transparent, the IAEA can also work with groups of nations in tense regions of the world to encourage confidence-building measures and promote regional arms control agreements. The model for such regional nuclear inspection regimes has been established by Argentina and Brazil, which have implemented a quadripartite inspection regime involving the IAEA and a newly established agency called ABACC (the Argentine-Brazilian Agency for Accounting and Control of Nuclear Materials). Both countries have also completed the steps necessary to bring into force the Treaty of Tlatelolco, a regional agreement banning nuclear weapons in Latin America and imposing the same constraints on nuclear weapon ambitions as would the NPT. Arrangements involving mutual visits to military and nuclear installations have been discussed bilaterally in the Korean peninsula, but have been fraught with difficulties while North Korea continues to violate its safeguards obligations with the IAEA.

The regional inspection arrangements entered into by Brazil, Argentina, and (if their bilateral agreement comes into force) the Koreas all complement and extend these states' safeguards agreements with the IAEA. They have (or could have) some role in reducing tensions-or in ratifying the relaxation of tensions—in these regions. Similar agreements might also play a role in helping resolve tensions among key states that are not now under IAEA full-scope safeguards: Israel, India, and Pakistan. Granted, the accomplishments made so far in the in the Mideast peace process shows that inspection regimes related to weapons of mass destruction need not be among the first items addressed in regional security negotiations. It is difficult to imagine, however, that a long-term settlement can avoid addressing the issue of weapons of mass destruction in the region.

ISSUE: *Definition of "significant quantity"*

Many analysts have stated that the IAEA "significant quantity" (SQ) thresholds-the amounts of fissile material whose diversion the IAEA safeguards system is designed to detect—me probably higher than would be needed by nations attempting to make even their first nuclear explosive. (The significant quantity of plutonium is 8 kilograms; it is 25 kilograms for uranium enriched to 20 percent or more of the uranium-235 isotope.) The U.S. Department of Energy has all but confirmed this view in its recent declaration that 4 kilograms of plutonium are sufficient to make a nuclear weapon.[8]

OPTION: *Lower significant quantity thresholds.*

Lowering the significant quantity thresholds would call for greater inspection effort on the part of the IAEA, including increased inspection frequency at several small facilities in states not yet in possession of one SQ under the present definition. It would also make it more difficult in some cases for the IAEA to achieve its inspection goals, particularly at large "bulk handling" facilities—those that handle nuclear materials in bulk form (e.g., powders or solutions), rather than in discrete units such as fuel rods (see discussion immediately below). In those cases where the IAEA is close to or beyond the limits of its ability to verify diversion of one SQ in a timely manner, such as at large plutonium reprocessing plants, reducing the SQ would require the use of new safeguards techniques such as near-real-time-accountancy, and even these might not be sufficient.

A major cause for United States reluctance to press the IAEA to lower the definition of the significant quantity has been the increased resources that lowering this threshold would require. With financial pressures on the IAEA making it difficult for the agency to fulfill its growing responsibilities under the present definition of the SQ, lowering the SQ threshold without providing the necessary additional resources would exacerbate the IAEA's financial difficulties and weaken current safeguards. **Moreover, should the IAEA receive additional resources, it is not clear that lowering the SQ-which would primarily affect inspections at declared sites in those states with the largest nuclear programs-would be the most effective use of those added resources.**

OPTION: *Lower "timeliness" goals.*

For each type of nuclear material under safeguards, the IAEA has established "timeliness goals" to represent the maximum period of time after a diversion of material might take place before the IAEA would be able to detect that diversion. These goals are based on estimates of the nominal time it would take to convert a given type of safeguarded material into a finished metal component for a weapon. However, timeliness goals are not required to be less than these conversion times for producing weapon components, and in some cases they are longer. For example, although the IAEA estimates that it might take as little as one week to transform pure plutonium oxide into a weapon component, the IAEA's timeliness goal for this material is one month. In practice, these timeliness goals are at best an approximation, both with respect to the time needed by any given state to carry out a diversion of material and develop a weapon, and to the IAEA's ability to raise a clear warning flag in a particular instance of such diversion.

[8] Unclassified excerpt from U.S. Department of Energy, Classification Bulletin WNP-86, Feb. 8, 1994. This statement is not completely equivalent to stating that the SQ should beset equal to 4 kilograms, since the SQ makes an allowance for material lost in processing and machining the plutonium for use in a weapon. However, much of these processing losses can be recovered. No such statement has been issued with respect to uranium-235.

The IAEA could change its timeliness goals for various nuclear materials so that they were less than the corresponding conversion times. Such changes, however, would require considerably greater inspection resources, which would have to be weighed into the additional assurance that lessening these goals would provide. More significantly, the IAEA does not attain all of its timeliness thresholds today, due at least in part to financial pressures. **Achieving the timeliness criteria uniformly and comprehensively for all facilities—particularly those with "direct-use" nuclear materials containing highly enriched uranium or plutonium-is probably much more important than adopting even more stringent criteria as goals.**

ISSUE: *Safeguards uncertainties at nuclear material bulk-handling facilities.*

Large facilities that handle weapon-usable nuclear materials in bulk form-for example, nuclear reprocessing plants that produce plutonium, enrichment plants that produce (or could produce) highly-enriched uranium, and fuel-fabrication plants that process plutonium into "mixed-oxide" (MOX) reactor fuel—pose the toughest safeguards challenges. **For example, due to measurement uncertainties and the amount of plutonium handled per year in a large reprocessing plant such as that being built by Japan at Rokkasho-mura, conventional material accountancy techniques as currently practiced by the IAEA are not precise enough to ensure beyond a reasonable doubt that diversion of a bomb's worth of plutonium would be detected.** Even with expected improvements, new methods—unproven at this scale by the IAEA—must be adopted if plutonium throughputs in plants of this size are to be known accurately enough to detect the absence of as little as one significant quantity of plutonium per year.

The most difficult aspect of safeguarding a large reprocessing or MOX fuel fabrication plant is meeting the one-month timeliness goal, as discussed in the preceding section, for the materials processed in such plants. **The IAEA's ability to provide warning within its timeliness criteria of small but significant diversions from a large reprocessing plant is not proven, given the difficulty in making precise inventory measurements (particularly during plant operation), the time needed to identify anomalies in safeguards data that might indicate the diversion of nuclear material, and the time needed to investigate these anomalies to see whether they have a legitimate explanation. New** techniques that are substantially more intrusive than techniques in use for smaller plants will be required to detect the diversion of significant quantities of nuclear materials in a timely manner from large reprocessing plants; these methods are being explored but have yet to be demonstrated by the IAEA at the necessary scale.

Concerns about the Rokkasho-mura reprocessing plant, which because of its scale provides one of the greatest technical challenges for IAEA safeguards, largely derive from the precedent it sets. Even if Japan is judged unlikely to attempt to divert material from this plant (when it becomes operational) to a nuclear weapon, or to abrogate safeguards once a stockpile of plutonium has been amassed, many states would likely be much less sanguine about the effectiveness of safeguards if a developing country in a politically unstable region of the world were to build a plant even a fraction its size. By its obligation to be nondiscriminatory, the IAEA cannot make politically based judgments of trustworthiness, and it would have great difficulty in justifying more stringent safeguards in one country than in another.

It has been argued, on the other hand, that a country with a large reprocessing plant that wanted nuclear weapon materials would be less likely to divert a small amount than it would be to: 1) build a small clandestine nuclear infrastructure outside of safeguards, 2) attempt to buy or steal the nuclear material, now that there may well be an active market in it,[9] or 3) withdraw from the treaty after announcing that its vital interests were no longer served by NPT membership. In this view, the primary objective of safeguards at reprocessing plants is to deny states a quick and direct route to the production of large amounts of weapon-usable material in the course of a civil power program. **With safeguards, the risk of undetected diversion might not be eliminated entirely, but it is nevertheless greatly reduced in both the probability of undetected diversion and in the amount of material subject to diversion.**

OPTION: *Increase the use of containment and surveillance techniques.*

Containment and surveillance (C/S) techniques support the primary safeguards approach of material accountancy. After the nuclear material in an item such as a nuclear fuel assembly or a container of plutonium oxide powder has been measured, for example, verifiable, tamper-proof seals are put in place. So long as the seal is intact, the amount of nuclear material present will remain known and accounted for, avoiding the need to remeasure the item at a later date. Surveillance devices (cameras and motion detectors) are used to detect movement in facilities such as spent fuel ponds or other storage areas, indicating when nuclear materials might have been transferred in or out. C/S measures therefore can indicate how long a previous measurement or inventory should still be considered valid, and hence provide what is known as "continuity of knowledge."

New methods that can make C/S techniques even more effective, such as transmitting current surveillance data via telephone or satellite links, are technically feasible and have been demonstrated. Implementing them, however, faces significant obstacles, not the least of which is a state's willingness to be subjected to them. Surveillance techniques also suffer from the fact that their usefulness is difficult to assess quantitatively. Unambiguous evidence of nondiversion can only be obtained for the material or area within a given camera's or motion detector's line of sight, and then only in the case of uninterrupted coverage. Further, in cases where a large amount of legitimate activity is occurring, it may be difficult to detect some types of illegitimate activity. Further analysis of specific applications of enhanced containment and surveillance is therefore needed to determine whether cost-effective improvements in safeguards would result.

OPTION: *Institute near-real-time accountancy and surveillance.*

Various techniques have been proposed, and partially tested, for continuously monitoring and reporting the flow of materials through a bulk-handling plant. Such "near-real-time-accountancy" techniques permit more accurate measurement of plant inventories. They also permit alarms indicating anomalous situations or status of equipment to be sent in near-real time to the IAEA. A rapid response, including the introduction of inspectors, could be arranged, especially if there were resident inspectors near the monitored site. For example, Japan and the United States have been developing and testing a robotic system for monitoring nuclear materials. The system uses advanced sensors to monitor flows of nuclear materials at various locations and then transmit data by satellite to a remote control center.

Near-real-time accountancy techniques now under investigation, particularly at Britain's large THORP plutonium reprocessing plant, could provide inspectors with considerable information concerning actual plant operation. (However, since Britain is a nuclear-weapon state, most of the THORP plant is not under IAEA safeguards.) Such techniques, involving the provision to in-

[9] The German interception of 350 grams of apparently Russian-origin plutonium oxide in August 1994, and the Czech seizure of 3 kilograms of highly enriched uranium in December 1994, indicate that black market purchase of nuclear weapon material maybe more realistic than previously thought.

specters of *process information,* would help verify the non-diversion of nuclear material. However, some years of commercial operation—which have not yet taken place—will be required to fully prove these techniques. Moreover, plant operators might object to providing this degree of access to IAEA inspectors.

OPTION: *Declare that sufficiently large bulk-handling facilities cannot be adequately safeguarded.*

Near-real-time accountancy techniques notwithstanding, nuclear material accountancy and control might not be developed to the point where the amount of plutonium flowing through a large bulk-handling facility can be monitored accurately enough to reveal the diversion of one significant quantity per year. If material accountancy to this level of accuracy were to be the ultimate test of the adequacy of IAEA safeguards, plants above a certain size threshold (somewhere around 100 tons heavy metal capacity per year) could not be adequately safeguarded by the IAEA. In this view, the IAEA should then state that it could not apply safeguards to plants above this threshold unless states were prepared to accept declarations that the IAEA was unable to certify their compliance with their safeguards obligations.

On the other hand, many observers do not measure the adequacy of safeguards solely by their ability to achieve this level of material accountancy, and they fundamentally disagree with the premise that large reprocessing plants cannot be safeguarded adequately. Any material diverted from a plant has to be physically removed from it. Therefore, techniques such as the evaluation and verification of plant design, the adoption of containment and surveillance measures, and the monitoring of plant processes can provide additional—if not complete confidence that material is not being diverted. Moreover, the threshold of one "significant quantity" per year is a subjective one to begin with, as explained above, and it need not be taken as an absolute standard. Even if a material accountancy system does not provide high confidence that a diversion of one significant quantity per year will be detected, it nevertheless provides some probability of detecting small diversions, and it can provide high confidence that sufficiently large diversions would be caught. Therefore, the inability to meet rigorous material accountancy standards might not be considered to imply that a large bulk-handling facility could not be adequately safeguarded.

ISSUE: *Improve ability to detect undeclared facilities.*

Iraq's most serious violation of its Non-Proliferation Treaty commitment was not the diversion of safeguarded nuclear material into a weapon program (although it did reprocess a small amount of plutonium in violation of safeguards), but rather its covert development and construction of a massive *undeclared* complex of nuclear facilities to produce weapon materials. Discovery of this secret infrastructure highlighted the importance of verifying the absence of undeclared facilities—a mission that the IAEA's member states at the time had not given it the political backing or the means to conduct. **Providing the IAEA with the resources, the information, and the political support it needs to look for undeclared sites may turn out to be the most important aspect of a reinvigorated safeguards regime.**

OPTION: *Increase intelligence sharing with the IAEA.*

The IAEA has repeatedly stated that its activities will be significantly enhanced by increased access to information-both open source and national intelligence information. Such information is essential if the IAEA is to learn of undeclared facilities. Successful precedents in providing such information have now been set with respect to both Iraq and North Korea. The United States could continue and enhance its sharing of information with the IAEA, as well as encourage other nations to do so. Concomitantly, if this occurs, the IAEA will need to develop the capability to evaluate such information. Even when supplied with the best of intentions, intelligence information may be ambiguous. Moreover, the IAEA will also need to guard against the possibility that one state may wish to discredit another by supplying disinformation to the IAEA.

OPTION: *Increase the mandate and frequency of special inspections.*

The IAEA has some authority to demand "special inspections" of sites that have not been declared to the IAEA or formally placed under safeguards. Although no inspections at undeclared facilities had ever been requested or carried out before the upgrading of IAEA inspections following the Gulf War, the agency has the authority under its safeguards agreements to request inspections of undeclared sites if such inspections are needed to obtain further information or to carry out safeguards responsibilities.[10] Such inspections could help expose clandestine weapon programs, alleviate suspicions about such programs, or even deter member states from undertaking them.

The efficacy of the IAEA special inspections provision is limited by several factors, however. One is that special inspections must be carried out "in consultation" with the inspected state, which effectively precludes short-notice inspections unless they are explicitly permitted by the state in other agreements it has entered into with the IAEA. Another limitation is that special inspections can have considerable implications for IAEA credibility. Inspections have to be justified to the country and possibly also to the Board of Governors. Inspectors coming up empty-handed too many times could erode confidence in the IAEA's ability to identify suspect activities, could call into question the reliability or appropriateness of national sources of information (if such had been used), and could hinder the agency in conducting further special inspections.

A more fundamental limitation to the use of special inspections is getting states to accept them, a problem that has been highlighted by North Korea's refusal to permit IAEA special inspections at two suspected nuclear waste sites. Although the IAEA's powers of enforcement are quite limited, the agency's General Conference (consisting of representatives of all its member states) or its Board of Governors could declare that any failure to accept a special inspection will be referred immediately to the United Nations Security Council and will result in the suspension of a state's right to receive technical assistance from the IAEA. The IAEA Statute also provides that member states that have "persistently violated" the IAEA Statute, or any agreement (such as a safeguards agreement) entered into pursuant to the Statute, may be suspended from IAEA membership.[11] The U.N. Security Council could also declare in advance that failure to comply with a special inspection request would be considered a threat to international peace and security that could lead to enforcement actions under Chapter VII of the U.N. Charter. However, the significance of such a general declaration in the absence of a particular case is questionable, particularly given the Security Council's inaction to date against North Korea.

Even with limitations, the authority to carry out special inspections, together with access to national intelligence information, constitutes a formidable tool to detect clandestine activities. The recent examples of IAEA inspections in Iran and North Korea imply that both special inspections and "technical visits' '-combined with increased sharing of intelligence by member states—may become a more important tool than

[10] The IAEA's inspections in Iraq after the Gulf War were not conducted pursuant to its "special inspection" authority but rather under the far tougher provisions of United Nations Security Council Resolution 687, which formalized the cease-fire that ended the 1991 Gulf War. This resolution provides for "anytime, anywhere, no-right-of-refusal" inspections in Iraq and requires, inter alia, that Iraq nuclear weapon program and programs to develop other weapons of mass destruction be eliminated.

[11] *IAEA Statute, Article XIX.B.* Membership priveleges may be suspended if recommended by the Board of Governors, with the concurrence of two-thirds of those members of the General Conference present and voting.

they have been in the past. Some precedent has also been set within the Chemical Weapons Convention regarding challenge inspections, using "managed access" to set the terms of resulting inspections.[12] Although much of the information upon which special inspections or technical visits might be based will inevitably have to come from national intelligence sources, some could come from environmental sampling programs carried out by the IAEA itself.

Special inspections will require advanced or new kinds of portable instruments for field inspectors (e.g., compact multichannel analyzers) and additional training for inspectors to learn what they are looking for and how to react to unusual information they might discover. Increased member state support and voluntary contributions for equipment and training along these lines would be beneficial.

ISSUE: *Verifying initial inventories of nuclear materials.*

The IAEA has a responsibility to verify the completeness of the initial declaration of nuclear material inventories made by any state coming under fill-scope safeguards. That is, it must ensure that the state is not hiding nuclear materials, particularly those capable of being used in weapons. This task is a challenging one whenever the state has a substantial nuclear infrastructure, as is the case in Kazakhstan and Ukraine. It is particularly important if the state is suspected or known to have mounted a nuclear weapon program. Indeed, several such states have either come under or are about to come under full-scope IAEA safeguards, including Argentina, Brazil, South Africa, and North Korea.

To have confidence in the safeguards regime, it is important not only to be able to verify these states' initial declarations of nuclear materials, but also to ensure that any nuclear weapon programs they may have once pursued have been dismantled. South Africa's willingness to demonstrate the rollback of its nuclear weapon program, and the unprecedented access it granted the IAEA, offers a good example of how such confidence can be built. On the other hand, North Korea's refusal, as of this writing, to provide complete information as to the extent of its earlier nuclear activities is at the root of the current controversy concerning that country's nuclear program.

OPTION: *IAEA verification of the termination of a nuclear weapon program.*

Although IAEA safeguards are focused on nuclear materials, the IAEA might be called on (as it was in Iraq and, in a very different way, in South Africa) to verify the dismantlement or the conversion to peaceful uses of other elements of a nuclear weapon program. The United States, the IAEA, or the United Nations could make it clear that the former threshold or nuclear-weapon states have a special obligation to declare prior weapon-related activities and provide assurances that they have been ceased. Such assurances might include demonstrating that scientific teams had been reassigned, that facilities had been dismantled or converted to nonweapon purposes, and that any prior manufactured components and materials had been destroyed. If agreed to by the states in question, IAEA special inspections might then be used to verify the completion of these steps. Short-notice inspections could also be used to guard against the possibility of a state's transferring former bomb materials to new facilities in order to hide them from inspection, and thus enhance the confidence in determining initial inventories of previously unsafeguarded nuclear-weapon-usable material.

In opening its entire former nuclear weapon program to the IAEA, South Africa has established a precedent in this area and has enabled the IAEA to verify that its nuclear weapon program has indeed been demolished.

[12] See U.S. Congress, Office of Technology Assessment, *The Chemical Weapons Convention: Effects on the U.S. Chemical]ndustry,* OTA-BP-ISC-106 (Washington, DC: U.S. Government Printing Office, August 1993).

ISSUE: *IAEA institutional weaknesses.*

Some have argued that the IAEA has been excessively conservative and cautious, unable or unwilling to take on more vigorous safeguards activities. Part of this conservatism may be attributed to the resistance of member states represented on the Board of Governors to supporting a more aggressive IAEA agenda, and part may stem from a historically evolved institutional culture. Several options are available to the United States and other member states to try to strengthen the IAEA as an institution.

OPTION: *Encourage increased transparency on the part of the IAEA.*

Just as the IAEA requires access to facilities and information to achieve its safeguards objectives, so do those attempting to evaluate the adequacy of IAEA safeguards need detailed information about the functioning of the IAEA to determine how robust those safeguards objectives are, and how well it is implementing them. Public confidence in the IAEA's effectiveness is difficult to earn in a closed environment. Greater openness on the part of the IAEA itself might also allow outside experts to formulate more intelligent and constructive proposals for its improvement, which could ultimately serve to strengthen the overall safeguards regime.

Granted, the IAEA does deal with proliferation-sensitive and proprietary information. To its credit, the agency has earned the reputation of being able to keep this information closely held within its ranks. Nevertheless, the practice of protecting "safeguards confidential" information appears to extend into areas and types of information that may, in fact, offer benefits in increased public confidence in the safeguards system if they were to be made available. For instance, annual Safeguards Implementation Reports (SIRS) are unavailable to the public; these present both an overall assessment of how well the IAEA has met its safeguards goals for the year, including those associated with timeliness, and problems it has encountered with containment and surveillance and other equipment. Distribution of SIRS is restricted despite a substantial effort to protect the identities of any specific country or facility that is discussed.

OPTION: *Encourage states not to abuse their right to reject certain inspectors, and encourage states not to delay granting visas to inspectors.*

Under IAEA procedures, only those inspectors that have been "'designated" for a certain country can conduct inspections in that country, and states have the right to reject the designation of any inspector. In light of the IAEA's need to employ the best inspectors available, especially in less cooperative countries, this practice interferes with IAEA's ability to manage its safeguards inspections. In extreme cases, wholesale rejection of inspector designations could bring the credibility of inspections in that state into question. However, most states are reluctant to give up control over the entry of foreign nationals to their territory. The United States, for example, does not accept inspectors from states it does not have diplomatic relations with or from states that do not accept United States inspectors. Moreover, it reserves the right to deny access to inspectors found to be unacceptable, such as any that might have a serious criminal record or are otherwise not eligible to enter the United States.

The IAEA could discourage rejection of inspectors by imposing the highest allowed inspection frequencies in states that have a history of abusing inspector designations, or perhaps even by calling for a certain number of special inspections at *declared* sites while the state deliberates on accepting inspector designations. Alternatively, the IAEA might modify its guidelines to specify a maximum quota of such rejections, or a time limit upon which to respond to inspector designations.

■ Beyond the Traditional NPT/IAEA Framework

IAEA safeguards are only one element of the international nuclear nonproliferation regime. Many other policy options might be considered for strengthening nuclear nonproliferation, some of which would involve significant changes or additions to the existing regime. Even if safeguards are not the central focus of these measures, several of them could increase demands for IAEA services or otherwise affect the way the agency administers safeguards.

ISSUE: *Expanding safeguards by reinterpreting the Non-Proliferation Treaty*

Some of the limitations on the ability of nuclear safeguards to prevent nuclear proliferation are built into the Non-Proliferation Treaty, such as the fact that production and stockpiling of nuclear-weapon-capable materials are permitted as long as they are under safeguards. Although amending the NPT is, in theory, one way to address some of these limitations, it is probably not a viable option in practice for both procedural and political reasons. As an alternative approach, it might be possible for the signatories of the NPT collectively to agree to reinterpret some of the Treaty's provisions. Even though this approach may be nearly as difficult to implement as an amendment, it might be worth considering because such a reinterpretation could give considerably greater power to the IAEA, resulting in more effective safeguards. The problem, however, is that treaties, unlike domestic laws, generally have no authority that can issue definitive and binding interpretations; they mean what the states party to them agree that they mean, subject to constraints found in their negotiating record, in presentations made to legislatures during their ratification, and on past implementation practice. Coming up with a collective reinterpretation—particularly concerning politically controversial provisions—would be no easy feat.

OPTION: *Reinterpret Article Ill of the Non-Proliferation Treaty to give the IAEA a greater role in monitoring equipment and facilities beyond those directly related to nuclear materials.*

Article 111 of the Non-Proliferation Treaty explicitly requires non-nuclear-weapon state parties to the NPT to accept IAEA safeguards over all nuclear materials within their territory. This provision has generally been taken to limit the IAEA's purview to nuclear materials and the facilities used to process or store them. However, an alternate interpretation of that article would place greater weight on its requirement to apply safeguards ". . for the exclusive purpose of verification of the fulfillment of [a non-nuclear-weapon member state's] obligations. . .to preventing diversion of nuclear energy from peaceful uses to nuclear weapons." In this view, IAEA safeguards can justifiably cover a broader scope than just nuclear materials; instead, they might be applied to other activities that could be associated with a nuclear weapon program. Indeed, some of the Treaty's drafters have written that this interpretation was the one they had in mind. However, it has not been the one that has been implemented for the last 25 years, and it would be difficult to gain international consensus behind this new interpretation, particularly since implementing it would require renegotiation of every safeguards agreement between the IAEA and a non-nuclear-weapon NPT party.

As an alternative, and at risk of creating a "two-tiered" inspection system, this interpretation could be adopted only for new safeguards agreements, for revisions to existing ones, or for states that voluntarily accede to this new interpretation by amending or accepting protocols to their safeguards agreement.

ISSUE: *Problem NPT states.*

"Problem NPT states" are those non-nuclear-weapon state members of the NPT that are suspected of harboring nuclear weapon ambitions despite their treaty commitments. Any measures that strengthen safeguards, particularly at undeclared sites, will bolster the IAEA's ability to deter, or detect, NPT violations. However, as stated above, the NPT does not prohibit states from developing and building facilities that could produce weapon materials, or even from using these facilities to stockpile weapon-usable materials, under the guise of a civil program. Should such a state leave the NPT, those facilities and materials would provide a substantial head start toward obtaining nuclear weapons. Measures that made it more difficult to withdraw from the NPT, or penalized a state for doing so, might therefore impede such a scenario, or at least encourage the international community to respond more forcefully to it.

OPTION: *Seek to put additional constraints on the ability of states to withdraw from the NPT on 90 days' notice.*

The United Nations Security Council could goon record, for example, with a resolution declaring (well in advance of any particular case) that if a state withdrew from the NPT without surrendering all the direct-use nuclear materials it possessed under safeguards-and possibly any additional nuclear material or facilities that had originally been provided by NPT states—then that state would be considered a threat to international peace and security. Such a statement would open up the possibility that the Security Council would authorize coercive means—perhaps including military force—to remove that state's weapon potential. Such an approach could encounter difficulties, however; states maybe reluctant to take actions or set precedents that may limit their own freedom of action with respect to other treaties, even if they support the objective of making it more difficult to leave the NPT.

OPTION: *Attempt to implement general embargoes of nuclear technology for problem NPT states.*

Members of the Nuclear Suppliers Group have agreed to withhold nuclear technology from states that are not parties to the NPT and are not otherwise subject to full-scope IAEA safeguards. The United States is seeking similar agreement to withhold nuclear technology and many categories of dual-use technology from Iran, a party to the NPT whose nonproliferation credentials the United States nonetheless judges to be dubious. This policy is quite controversial. For example, Iran and other observers argue that it violates not only the spirit but the letter of Article IV, paragraph 2 of the NPT:

> All the Parties to the Treaty undertake to facilitate, and have the right to participate in, the fullest possible exchange of equipment, materials, and scientific and technological information for the peaceful uses of nuclear energy. Parties to the Treaty in a position to do so shall also co-operate in contributing. . . to the further development of the applications of nuclear energy for peaceful purposes, especially in the territories of the non-nuclear-weapon States Party to the Treaty, with due consideration for the needs of the developing areas of the world.

The United States response is that paragraph 1 of Article IV explicitly requires that technical cooperation be conducted "in conformity with Articles I and II," which ban the development of nuclear weapons by non-nuclear-weapon states. Although neither the United States nor the IAEA has provided evidence that Iran has violated its NPT commitments, the United States nevertheless believes Iran is seeking nuclear weapons. Therefore, the United States does not consider itself obligated to provide technical assistance.

ISSUE: *Capping nuclear weapon programs of non-NPT states.*

Some countries that are not prepared to admit to their nuclear weapon programs, or to formally reverse them by joining the NPT as non-nuclear-weapon states, may nevertheless become willing to limit or cap their unacknowledged activities. One approach to this end is the Clinton Administration's proposal, discussed below, to conclude a worldwide convention banning the production of nuclear materials for weapons or outside of safeguards. Other approaches are also presented below.

OPTION: *Expand the United Nations Security Council's ability to expose and even to render harmless clandestine nuclear weapon facilities worldwide.*

The IAEA has no authority to take coercive measures to expose or reverse nuclear proliferation. However, in their January 1992 declaration that proliferation of weapons of mass destruction constitutes a "threat to international peace and security," the heads of state of all the members of the U.N. Security Council raised the possibility that the Council might take forceful measures against proliferation under Chapter VII of the U.N. Charter. The IAEA could contribute inspectors and expertise to such an effort, as it did in the case of the U.N. Special Commission on Iraq. That commission's role might be extended, or a similar body created, to receive and evaluate national intelligence information concerning possible clandestine nuclear programs in other countries, and to interact with the IAEA. Such an organization would be in a position to bring matters directly to the Security Council, eliminating the time that the IAEA might require to evaluate evidence of a clandestine nuclear site or other safeguards violation, ask for a special inspection to resolve its concerns, bring allegations of noncompliance to its Board of Governors (which might direct it to repeat its request to the state), and only then forward its concerns to the Security Council.

Establishing such an organization would have far-reaching implications. Only in the case of Iraq, whose invasion of Kuwait unambiguously branded it a threat to international peace and security, has the Security Council asserted the power to forcibly disarm a state of its capability to produce weapons of mass destruction. It is extremely unlikely that the Security Council would (or even could) delegate this power to any other organization, even one subordinate to it. Therefore, any such situation in the future would almost certainly require a case-by-case determination by the Security Council. In the absence of a grievous violation of international norms, Security Council members might be very reluctant to impose such a sanction again, fearing that they themselves might some day face similar action. (Such an argument could also be made with respect to members of the IAEA's Board of Governors, although the powers of that body are far more limited.) The Security Council's five permanent members could protect themselves with their vetoes, but they might be very reluctant to take action that would be perceived as being so self-serving, and that would call attention to the Council's discriminatory structure.

This option might also be opposed from two different directions: because it goes too far, or because it doesn't go far enough. Some would object that the IAEA already has the authority to conduct special inspections, and that creating a new organization for the same mission invites duplication, if not confusion. On the other hand, the United Nations' and the IAEA's memberships are largely overlapping. **If the IAEA is deemed institutionally incapable of taking forceful action against one of its members, the United Nations may not be much more successful.**

ISSUE: *Continued global production of materials usable for nuclear weapons.*

As long as stocks of materials usable in nuclear weapons are maintained and grow, the potential for nuclear weapon proliferation remains. Even nations that have agreed to the NPT may later decide to withdraw and use their formerly safeguarded fuels in weapons.

OPTION: *Push for multilateral agreements to end the production of nuclear materials for weapons or outside IAEA safeguards.*

The Clinton Administration has proposed such a ban in the hopes of at least capping, if not reversing, the production of nuclear materials for weapon purposes, especially among states not party to the NPT. Such states, including India, Israel, and Pakistan, might agree to join a global convention banning the production of any additional nuclear weapon materials provided that they were not required to admit to any previous production of such materials. (Making such a ban universal, binding nuclear-weapon states and non-nuclear-weapon states alike, would cap the arsenals of the acknowledged nuclear-weapon states as well as the threshold states, and it would also avoid the explictly discriminatory aspects of the NPT.[13]) Such a ban would not directly affect the U.S. nuclear weapon program, since the United States has already declared a moratorium on further production of weapon materials. A formal ban would make such a decision by the United States more difficult to reverse in the unlikely occurrence that the nation would not only seek to build new nuclear weapons in the future but would also require more than the tons of weapon material being made available by ongoing weapon dismantlements.

A critical issue, however, is whether such an agreement would have the effect of legitimizing any nuclear arsenal such states may have. For example, any verification regime for such an agreement would implicitly or explicitly have to exclude stockpiles of weapon materials, since the convention would only address future production. Critics of this proposal believe that such an arrangement would damage more than help the nonproliferation regime. They also won-y that any proposal that permitted the continued production of weapon-capable material under safeguards would enable states to amass a stockpile of such material and then to withdraw from the convention, converting the material into weapons. Worse still, they fear that the United States will aggravate this possibility by assuring states that the convention indeed would permit the production of such material under safeguards-in effect, creating an "entitlement" to pursue activities that the United States would be better off opposing.

If such a fissile material production limitation agreement were enacted, a mechanism for verifying compliance would have to be instituted. Under the Clinton Adminstration proposal, this mission would be given to the IAEA, which has longstanding experience monitoring the production of nuclear materials. However, this additional mission would require significantly greater resources for IAEA safeguards. It would also have to be implemented in such a way that whatever special verification procedures were adopted for the nuclear weapon and the nuclear threshold states did not set precedents that would weaken current IAEA safeguards in non-nuclear-weapon NPT states.

OPTION: *Discourage or ban the production worldwide of all material usable in nuclear weapons, even for civil applications.*

Such an agreement would close the loophole in existing safeguards, and in the cutoff convention discussed immediately above, that would permit states to develop production facilities and even to stockpile weapon-usable materials under safeguards. Since the United States has long renounced pursuit of a plutonium fuel-cycle for its commercial nuclear powerplants, a ban on producing plutonium for civil purposes (one component of a ban on the production of weapon-usable material) would not affect U.S. plans for nuclear power. However, under such a ban, the United States would not be able to develop new research reactors fueled with highly enriched uranium. (Banning the production of weapon materials entirely would have no more effect on the U.S. nuclear weapon program than banning their production outside safeguards, since both would prohibit the production of nuclear material explicitly for weapon purposes.)

Although this measure would not directly affect the United States, states with substantial investment in plutonium fuel cycles, including Russia, Japan, France, and the United Kingdom, would strenuously object to it. Despite the lack of any economic incentives to do so for the foreseeable future, Japan and Russia, in particular, still have active plans to pursue a plutonium fuel cycle

[13] Such a cutoff would not discriminate among states in terms of their future activities, but by not addressing their past activities would leave the discriminatory structure of the regime intact. Under such a cutoff, neither the declared nuclear states nor the undeclared threshold states (India, Israel, or Pakistan) would be forced to reveal the existence of any already produced weapons or weapon materials, nor would they have to place existing materials under safeguards.

for their nuclear industry. This measure would prevent them from doing so.

OPTION: *Explore the feasibility of internationalizing certain aspects of the nuclear fuel cycle.*

Some nonproliferation analysts maintain that no system of international inspection of nuclear production facilities can provide sufficient protection against or warning of a state's decision to use those facilities to produce nuclear weapons. Preventing nuclear proliferation in the long run, they argue, requires broad international operation of such facilities. Under such a proposal, individual states or small groups of states would be prohibited entirely from constructing or operating such facilities, and the many billions of dollars worth of such facilities would be internationalized or closed. Given the massive institutional changes from the existing status quo, such a policy decision would have far-reaching implications and would face tremendous resistance.

Introduction 2

Production of fissile nuclear material (highly enriched uranium or plutonium) is the most difficult step in making a nuclear weapon. Consequently, constraining a would-be proliferant nation's ability to produce such materials has always been a central component of international nonproliferation efforts. (For this reason, the widespread availability of nuclear weapon material from the former Soviet Union on the black market would deal a grievous blow to the nonproliferation regime.[1]) In particular, the Non-Proliferation Treaty (NPT) requires those countries that join the treaty as non-nuclear-weapon states to accept international monitoring of all their facilities that might produce, use, store, or otherwise handle nuclear materials. Such monitoring is conducted by the International Atomic Energy Agency (IAEA) through its system of nuclear safeguards.

Indeed, controls over nuclear materials and production facilities serve a number of purposes in nonproliferation policy. Safeguards play a role in each of the four basic categories of nonproliferation policies[2]:

1. **obstacles** to impede those working to acquire weapons of mass destruction;
2. **punitive measures** to deter or punish proliferants;

[1]Potential leakage of nuclear material from the former Soviet Union is discussed in some depth in U.S. Congress, Office of Technology Assessment, *Proliferation and the Former Soviet Union,* OTA-ISC-605 (Washington, DC: Government Printing Office, September 1994).

[2]These categories are described in detail in U.S. Congress, Office of Technology Assessment, *Proliferation of Weapons of Mass Destruction: Assessing the Risks,* OTA-ISC-559 (Washington, DC: Government Printing Office, August 1993), esp. pp. 5, 19-25, and 83-115.

3. **rewards** to increase the attractiveness of voluntarily forgoing these weapons; and, perhaps most important of all,
4. **regional or global security improvements** to reduce the perceived needs for the weapons.

IAEA safeguards are intended to impede nuclear proliferation by ensuring that the diversion of nuclear materials from safeguarded nuclear facilities to weapon purposes will be caught and made known to the world community. To the extent that they can assure a country that its neighbors or adversaries are not developing nuclear weapons, safeguards lessen that country's perceived need to develop its own nuclear arsenal.

Given the importance of the IAEA's system of nuclear safeguards to international nonproliferation efforts, this report analyzes what such safeguards can and cannot be expected to accomplish, identifies areas where they might be improved, and presents various options for accomplishing this. Options analyzed in this report fall into two broad categories: 1) those that could be implemented primarily within the current framework of NPT constraints and IAEA safeguards, thus improving on institutions and practices already in place; and 2) those that would extend beyond the current framework. The latter include measures to address actions of states not party to the NPT and policies that would have to be undertaken outside the domain of the NPT and IAEA safeguards.

The focus in this report on IAEA safeguards and nuclear materials should not be taken to imply that safeguards constitute the only nonproliferation tool. Many other measures, such as export controls, classification of weapon-related information and data, security assurances, diplomatic and military commitments, and international treaties, are also essential to international nonproliferation efforts.[3]

A HISTORY OF INTERNATIONAL CONTROL EFFORTS

Even before atomic weapons were first used at the end of World War II, some senior U.S. policymakers and scientific leaders realized that atomic energy might have to be controlled internationally. This conclusion followed because:

- atomic weapons made devastation possible on a scale that was not previously imagined;
- they derived from scientific knowledge that was or soon would be available worldwide, such that no nation would be able to maintain a monopoly in atomic weapons; and
- some of the knowledge and technology needed to produce atomic weapons was related to that needed to realize whatever peaceful applications atomic energy might provide.

In January 1946, the fledgling United Nations created a United Nations Atomic Energy Commission and charged it with preparing proposals for "the elimination from national armaments of atomic weapons and of all other major weapons adaptable to mass destruction," together with "effective safeguards by way of inspection and other means to protect complying States against the hazards of violation and evasion."[4] Anticipating this action, the U.S. Secretary of State had already

[3] See ibid. for a review of the array of policy tools that can be used to combat proliferation. For a discussion of evidence that might indicate the production of weapons of mass destruction and technical hurdles that might provide opportunities to control their spread, see U.S. Congress, Office of Technology Assessment, *Technologies Underlying Weapons of Mass Destruction*, OTA-BP-ISC-115 (Washington, DC: U.S. Government Printing Office, December 1993). Dual-use export controls are analyzed in U.S. Congress, Office of Technology Assessment, *Export Controls and Nonproliferation Policy*, OTA-ISS-596 (Washington, DC: U.S. Government Printing Office, May 1994). Proliferation issues arising from the breakup of the Soviet Union are addressed in *Proliferation and the Former Soviet Union*, op. cit., footnote 1.

[4] "Establishment of a Commission To Deal with the Problems Raised by the Discovery of Atomic Energy," United Nations General Assembly Resolution I, *Resolutions Adopted by the General Assembly During the First Part of Its First Session from 10 January to 14 February 1946*, United Nations Document A/64 (London, England: Church House, 1946), p. 9, quoted in Leniece N. Wu, *The Baruch Plan: U.S. Diplomacy Enters the Nuclear Age*, Foreign Affairs Division, Congressional Research Service, prepared for the Subcommittee on National Security Policy and Scientific Developments, House Committee on Foreign Affairs, August 1972, Committee Print, p. 8.

impaneled a commission chaired by Under Secretary of State Dean Acheson to "study the subject of controls and safeguards necessary" to protect United States interests under such a regime.

The Acheson-Lilienthal Report

In turn, the Acheson committee commissioned a panel of technical experts chaired by David Lilienthal, chairman of the Tennessee Valley Authority, to "apprais[e] all the relevant facts and formulat[e] proposals." The Lilienthal panel considered proposals by which nations would retain the capability to produce fissionable materials but would pledge not to do so for weapon purposes, and would submit to international inspections that would forestall and detect such prohibited activities. However, the panel found that no such approach was workable:

> We have concluded unanimously that there is no prospect of security against atomic warfare in a system of international agreements to outlaw such weapons controlled *only* by a system which relies on inspection and similar police-like methods.[5]

Verifiable nuclear disarmament, according to the panel, required that individual nations be completely prohibited from producing fissionable materials or conducting other "dangerous" activities that could directly support a weapon program. All such activities would be undertaken exclusively by an international organization established for that purpose. Using nuclear fuel provided by the international organization, nations would be permitted to operate nuclear reactors to produce power, or to use radioactive materials for research purposes, since such activities could not, according to the panel, lead to the production of weapon materials.[6] The scope of activity permitted to individual nations, however, would have to be strictly limited:

> So long as intrinsically dangerous activities may be carried on by nations, rivalries are inevitable and fears are engendered that place so great a pressure upon a system of international enforcement by police methods that no degree of ingenuity or technical competence could possibly hope to cope with them.[7]

Initial Failure of International Control

The Acheson-Lilienthal report was released in March 1946. In the same month, President Truman appointed financier Bernard M. Baruch to represent the United States at the U.N. Atomic Energy Commission's negotiations over the international control of nuclear energy. Baruch's proposal to the U.N. Commission in June 1946 was largely based on the Acheson-Lilienthal report but had some important differences, particularly regarding Baruch's insistence that the international control mechanism include specific provision for enforcement that would not be subject to Security Council veto. Known as the Baruch Plan, this proposal met a hostile reception from the Soviet Union. Ultimately, the United States and the So-

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[5] "A Report on the International Control of Atomic Energy," U.S. Government Printing Office, Washington, 1946, 79th Congress, 2d Session, House Document 709, prepared for The Secretary of State's Committee on Atomic Energy by a Board of Consultants: Chester I. Barnard, J.R. Oppenheimer, Charles A. Thomas, Harry A. Winne, David E. Lilienthal, Chairman, Mar. 16, 1946, p. 4.

[6] One of the assumptions of the Lilienthal panel was that nuclear materials suitable for nuclear power generation could be "denatured" so that they would not be usable in nuclear weapons. For uranium, which can only be used in a nuclear explosive if it is highly enriched in the uranium-233 or -235 isotopes, this assumption is true. However, although the panel believed that plutonium, too, could be produced in a form that would not be suitable for nuclear weapons without difficult additional processing, it is now known that so-called reactor-grade plutonium can still be used in nuclear explosives. For several reasons, such plutonium is somewhat less desirable for weapon use than so-called weapon-grade plutonium, but it is usable nonetheless. See *Technologies Underlying Weapons of Mass Destruction*, op. cit., footnote 3, pp. 131-133.

Indeed, the Lilienthal panel did anticipate that future developments might lessen or eliminate the barriers to using such "denatured" nuclear materials in weapons. They therefore stated that the distinction between "safe" activities and "dangerous" ones be continually revisited as technology advanced.

[7] "A Report on the International Control of Atomic Energy," op. cit., footnote 5.

viet Union could not agree on issues such as the process by which international control would be phased in and the U.S. nuclear arsenal phased out, the inspection rights that the international control organization would have, and the mechanism for enforcing the international control regime. Indeed, even had agreement on these issues been reached, the U.S. Senate's consent to the ratification of any such treaty would have been far from assured.

In the absence of international control, subsequent U.S. efforts to constrain the spread of nuclear weapons took place in a context completely different from that envisioned by the Acheson-Lilienthal and Baruch plans. Rather than basing its security on a binding international regime that would eliminate all nuclear weapons in national hands, the United States instead depended on the retention and further development of its own nuclear arsenal. So long as the United States could promise to respond to a nuclear attack with in-kind retribution, it could relax significantly the requirements that would otherwise have been placed on any international system to monitor and control nuclear technology. In lieu of any such system, proliferation did ensue; the Soviet Union detonated its first atomic bomb in 1949, and Britain followed in 1952. Later, three other countries would also carry out nuclear tests: France, in 1960; China, in 1964; and India, in 1974.

Atoms for Peace

In December 1953, with both U.S. and Soviet nuclear arsenals expanding, President Eisenhower proposed that both nations make contributions from their stocks of fissionable materials to a new international organization that would put these materials to peaceful use. This "Atoms for Peace" program was intended to serve the dual purpose of drawing down the stockpile of nuclear weapon materials among the superpowers as well as fostering peaceful applications of nuclear technology, such as producing electric power and contributing to agriculture, medicine, and other branches of science. In his speech before the United Nations outlining his proposal, President Eisenhower suggested that a new International Atomic Energy Agency be set up to take custody of nuclear material, ensure its security, and turn it to peaceful use.

In 1954, Congress amended the laws that severely restricted the transfer of nuclear materials and technology, and the United States began to enter into bilateral nuclear cooperation agreements with other countries. These agreements included provisions, called safeguards, by which the United States could assure itself that its nuclear materials and technology were not being put to military use. At the same time, the United States entered into negotiations to create the International Atomic Energy Agency. These negotiations concluded in late 1956 with the approval of the IAEA Statute, Article II of which gives the IAEA the mission to "accelerate and enlarge the contribution of atomic energy to peace, health, and prosperity throughout the world."[8] The IAEA was established the following year as an independent intergovernmental organization, affiliated with—but not a subunit of—the United Nations.[9]

The International Atomic Energy Agency

Created within the context of the existing international system, the International Atomic Energy Agency is necessarily far weaker than the supranational international control organization that would have been established under the Acheson-Lilienthal or Baruch plans. The IAEA was not given highly intrusive powers of inspection or enforcement over its member states, nor did it assert control over their nuclear activities or material.

[8]The IAEA Statute was approved October 23, 1956 and entered into force on July 29, 1957.

[9]*The Agreement Governing the Relationship Between the United Nations and the International Atomic Energy Agency*, INFCIRC/11, Oct. 30, 1959, specifies the affiliation between the two organizations, establishing various administrative and reporting linkages. The two bodies, however, are independently governed and have separate charters.

Rather, it was given the authority to enter into so-called safeguards agreements with individual nations to ensure that any nuclear materials, equipment, or facilities offered up for inspection were not used to produce nuclear weapons.

The first such agreement was concluded between the IAEA and Japan in 1959, but the agency did not adopt a comprehensive safeguards system until 1965.[10] Now set forth in IAEA document INFCIRC/66/Rev. 2, this system of safeguards was to be applied, upon request, to individual nuclear activities within a state and to all activities receiving IAEA assistance. INFCIRC/66 safeguards apply to individual plants, shipments of nuclear fuel, or supply agreements between states supplying nuclear fuel or technology and states importing it, and they are the basis for nearly all agreements between the IAEA and states that are not party to the nuclear Non-Proliferation Treaty.[11]

The Non-Proliferation Treaty, which entered into force in 1970, extended the scope of the IAEA's safeguards activities. By joining the NPT, non-nuclear-weapon states (e.g., all those except the United States, Russia, the United Kingdom, France, and China) commit themselves to refrain from manufacturing or otherwise acquiring nuclear weapons or explosive devices, and to submit to IAEA safeguards. Instead of applying only to selected nuclear activities on request, however, safeguards under the NPT—known as *full-scope* safeguards—are required of non-nuclear-weapon states on *all* nuclear materials in all peaceful nuclear activities within their territory or under their control.[12] To accommodate this new mission, the IAEA developed INFCIRC/153, a more comprehensive model safeguards agreement encompassing every aspect of a state's nuclear fuel cycle except the initial mining and milling of uranium ore. All non-nuclear-weapon states that are party to the NPT are obligated to conclude safeguards agreements with the IAEA, but the converse is not true. There are countries with safeguarded nuclear facilities, including one (Brazil) that has concluded a full-scope safeguards agreement, that are not members of the NPT. Box 2-1 distinguishes among states that are members of the Non-Proliferation Treaty, states that are members of the IAEA, and states that have concluded safeguards agreements with the IAEA.

IAEA SAFEGUARDS

IAEA safeguards are a system of procedures involving material control and accountancy, containment and surveillance, and verification (including onsite inspections at declared facilities) that are implemented through agreements between the IAEA and individual countries. They are designed primarily for two purposes: 1) to detect proliferation activities that involve diversion of materials from the civilian nuclear fuel cycle; and 2) to provide warning of any such occurrence to an international forum in a timely fashion. (Exactly what constitutes "timely" warning is somewhat controversial, as explained in the section on timeliness goals in chapter 3.) **Though they may deter proliferation by posing a risk of discovery, safeguards by themselves cannot prevent proliferation; nor can they predict a country's intent or future activity.**

The safeguards process consists of three stages:

1. *examination by the IAEA of state-provided information,* which covers design of facilities, inventories, and receipts for transfers and shipments of materials. States subject to safeguards must establish so-called state systems of accounting and control, or SSACs, to keep track

[10]David A.V. Fischer, *The International Non-Proliferation Regime, 1987* (New York: United Nations, 1987), pp. 4, 38

[11]Ibid., p. 38.

[12]Non-Proliferation Treaty of 1970, Article III(1). For non-nuclear-weapon states, nuclear materials that are in use for military, but nonexplosive, purposes such as naval propulsion are exempt from safeguards. However, a state may not create a separate fuel cycle outside safeguards to produce nuclear materials for these purposes. To date, this exemption has never been invoked.

BOX 2-1: NPT Members, IAEA Members, and Safeguards Agreements

Signing the Non-Proliferation Treaty, concluding a nuclear safeguards agreement with the international Atomic Energy Agency, and joining that agency are three independent actions. Taking any one of them does not automatically accomplish any of the others. Membership in the Non-Proliferation Treaty obligates a state to go on to conclude a so-called full-scope safeguards agreement with the IAEA, but many NPT members (all with no significant nuclear facilities in their territories) have not yet done so. In addition, neither of those actions depends on or affects a state's decision to become a member of the IAEA. Appendix B provides a list of countries in each of these three categories.

NPT Membership. States join the Non-Proliferation Treaty either as nuclear-weapon states or non-nuclear-weapon states. Nuclear-weapon states are defined in the NPT as those that had "manufactured and exploded a nuclear weapon or other nuclear explosive device" before January 1, 1967. The only states that have done so are the United States, Russia (successor of the Soviet Union), the United Kingdom, France, and China, all of which have joined the NPT. All other states are non-nuclear-weapon states. Joining the NPT imposes a number of binding obligations on a state, depending on whether it is a nuclear-weapon state or a non-nuclear-weapon state.

Safeguards Agreement. Non-nuclear-weapon states are required by the NPT to accept full-scope IAEA safeguards over all their nuclear activities. Such safeguards agreements are modeled upon a standard agreement known as INFCIRC/153 (see text). However, not all NPT members have concluded such agreements with the IAEA. Non-NPT members can also enter into safeguards agreements with the IAEA, either over all their nuclear activities as if they were NPT members, or (more often) over specific nuclear activities within their territories. The limited safeguards agreements that cover only a specified set of activities, materials, or facilities are modeled after a different IAEA standard known as INFCIRC/66.

Although not required to do so by the NPT, all the nuclear-weapon states have concluded so-called voluntary offers in which they provide the IAEA with a list of *civil* nuclear facilities at which they will voluntarily accept safeguards. From this list, the IAEA selects those facilities where safeguards will actually be applied. Due to resource constraints, it chooses to do so only at a few. Much of the text of these voluntary offers parallels the text of INFCIRC/1 53, with the very important difference that there is no obligation to place all nuclear facilities under safeguards, nor to refrain from using nuclear materials in nuclear weapons (except that those materials *under safeguards* must not be used for weapons). Consequently, military nuclear activities in the nuclear weapon states remain outside the scope of these offers.[1]

IAEA Membership. Membership in the IAEA gives a state a voice in the governance of the agency, including its role in implementing nuclear safeguards agreements between the agency and individual nations. It also makes a state eligible to participate in various IAEA programs, such as those that offer states technical assistance in peaceful applications of nuclear power. However, whether or not a state is a member of the IAEA is completely unrelated to any obligations a state may accept by joining the NPT or by concluding a safeguards agreement with the IAEA. States need not be members of the IAEA to join the NPT or to enter into safeguards, and a state may join the agency without joining the NPT or concluding a safeguards agreement.

[1]The United States has offered to accept safeguards at any of its civil nuclear facilities and also at facilities where nuclear material declared to be excess to its nuclear weapon program is stored.

of nuclear materials under their jurisdiction. The SSACs submit their records to the IAEA for independent verification, much as a bank auditor would be asked to provide independent confirmation of the accuracy of a bank's accounting.

2. *collection of data and independent information by IAEA inspectors,* either to verify material inventories, operating records, or design information, or, in special circumstances, to clarify unusual findings.
3. *evaluation by the IAEA* of this information for completeness and accuracy.[13]

Any discrepancy of nuclear materials between the recorded (book) inventory and the physical inventory determined by measurements and inspections is called *material unaccounted for* (MUF). When MUF exceeds the amount that the IAEA can reasonably attribute to measurement uncertainties, the possibility of diversion exists and must be resolved.[14]

Subjectivity of Safeguards

For each of the different types of facilities under safeguards (e.g., research reactors, power reactors, fuel fabrication facilities, enrichment plants, reprocessing plants), the IAEA has formulated a safeguards *approach* and developed safeguards *criteria* that, when successfully attained, permit the IAEA to assert that material has not been diverted from a given facility. **Despite the objective, systematic way in which the IAEA nuclear safeguards system has been codified and implemented, however, the underlying judgment as to what the safeguards system needs to be able to do and how well it needs to do it is inherently a subjective one.** The stated purpose for IAEA safeguards, as specified in the safeguards agreements between the IAEA and those countries that have accepted safeguards over all their nuclear facilities (usually as a consequence of adherence to the Non-Proliferation Treaty), is:

> ...the timely detection of diversion of significant quantities of nuclear material from peaceful nuclear activities to the manufacture of nuclear weapons or of other nuclear explosive devices or for purposes unknown, and deterrence of such diversion by risk of early detection.[15]

However, this statement, by itself, does not specify quantitative goals. What constitutes a "significant quantity"? How soon need diversion be detected to be "timely?" The answers to these questions, as explained in chapter 3, are controversial; different observers will set different standards. (Even apart from determining a reasonable estimate for the minimum amount of nuclear material necessary to make a bomb is the underlying decision as to whether the safeguards system need only be able to detect diversions of that size, or whether it has to be sensitive to fractions of that amount.) Over what period of time might a diversion take place before the IAEA deems it too slow to have much chance of being detected? (This is a different question from that of how soon after a diversion has been conducted should the IAEA be in a position to report it, which is the criteria for "timely detection.") Is it sufficient for the IAEA to attempt to detect diversions of one significant quantity per year, as it now sets out to do? Or does the agency need to meet the far higher (indeed, impracticably high) standard of assuring that a state has not been able to divert one "significant quantity" since the dawn of its nuclear program, no matter how long ago that may have been? **No matter what minimum rate of diversion the IAEA**

[13]Material in this section on IAEA safeguards is from *Technologies Underlying Weapons of Mass Destruction*, op. cit., footnote 3, pp. 185-189.

[14]This discussion is taken from ibid. For an extensive discussion of safeguards concepts and methodologies, see David A.V. Fischer and Paul Szasz, *Safeguarding the Atom: A Critical Appraisal* (London: SIPRI, Taylor and Francis, 1985); and Lawrence Scheinman, *The International Atomic Energy Agency and the World Nuclear Order* (Washington, DC: Resources for the Future, 1987), esp. ch. 4 and 5.

[15]INFCIRC/153, para. 28.

±**aims to detect, a state willing to wait a little longer might successfully divert material at a slower rate.**

Apart from determining parameters such as these upon which the rest of the safeguards system is built, the IAEA must also decide with what degree of confidence it needs to be able to assure that a diversion has not occurred. **No verification system can provide absolute certainty, and no safeguards system can prove that diversions have not occurred.** All that can be done is to provide some level of confidence—which can be quantified—that diversions have not taken place. The resources required of the safeguards system increase as the required confidence level increases; conversely, with given resources, the minimum detectable diversion grows as the required confidence level increases. Moreover, at some level, measurement uncertainties place fundamental limits on the sensitivity and the confidence levels that can be attained. **As discussed in chapter 3 and appendix A, large facilities such as the reprocessing plant now under construction in Japan will reach or exceed these limits, at least with the safeguards techniques now in use.**

The two objectives specified in INFCIRC/153 and quoted above make competing demands upon the safeguards system. Ensuring the "timely detection" of diversion of nuclear materials implies that the system must have a high likelihood of success, and the IAEA now sets out the goal of having a 90 percent probability of detecting diversions. However, the "deterrence of such diversion," which is also set out as a goal in INFCIRC/153, might be accomplished with a much less capable system. Even if the IAEA were to have as little as 50 percent confidence in detecting a diversion, anyone attempting to divert material would be as likely as not to get caught, and a system with only a 10 percent chance of detecting a diversion is sufficient to prevent a divertor from having more than 90 percent confidence that its activities would escape notice.

In particular, the difference between assured detection and deterrence affects how one interprets the significance of the measurement uncertainties that are unavoidable in making any inventory of nuclear materials. Critics of IAEA safeguards, particularly as applied to large plutonium reprocessing plants, imply that the uncertainty in a plant's measured inventory gives the amount of material that might be diverted without detection. In other words, they argue that if the amount of plutonium processed in the course of a year is only known, for example, to ±80 kilograms, a diversion of 80 kilograms might not be caught.[16] While it is true that in such a case, a diversion of that size could not be ruled out, it cannot be assumed that such a diversion would go undetected, either. Measurement uncertainties work both ways, *and nobody can know in advance which way the measurement will be off.* A diverting state might hope that an 80-kilogram diversion would be masked by a measurement that would otherwise have been 80 kilograms too high, yielding a measured throughput equal to what the value should have been had there not been any diversion. However, the error in measurement might equally likely go the other way, yielding a measurement that in the absence of diversion would have been 80 kilograms *below* the expected value. In this case, an 80-kilogram diversion would compound, rather than cancel, the 80-kilogram measurement error, resulting in a measurement 160 kilograms below what would be expected in the absence of diversion—a discrepancy likely to attract attention. Such odds would prevent a state from planning a diversion strategy with confidence.

[16]A measurement uncertainty of ±80 kg means that about 68 percent of the time, the *measured* value for annual plutonium throughput will lie within 80 kg of the true throughput. With such an uncertainty, there is about a 16 percent chance that the measured throughput would be more than 80 kg higher than the actual throughput, and an equal chance that the measured throughput would be less than 80 kg lower. This uncertainty of 80 kg—10 significant quantities—is chosen here purely for the sake of illustration. Chapter 3 and appendix A discuss the issues involved with measurement uncertainties at actual and proposed large reprocessing plants.

Since subjective determinations underlie any safeguards system, it is impossible to make an objective determination of effectiveness.

Limitations of Safeguards

Despite their value in detecting and deterring nuclear proliferation, IAEA safeguards—and the NPT regime that requires their adoption by non-nuclear-weapon states—have a number of limitations, from the perspective of preventing proliferation, that are difficult to remedy within the current framework (see box 2-2). Although these limitations have long been recognized, some of them have been brought into clearer focus by the Iraqi and North Korean violations of their safeguards obligations. These limitations include:

- ***States are not obligated to accept IAEA safeguards.*** Israel, Pakistan, and India, which have acquired nuclear weapon capability while remaining outside the NPT, are not subject to full-scope safeguards. Their nuclear weapon programs therefore face no real constraints under international law. States that are parties to the NPT can withdraw from the Treaty upon 90 days' notice, ending their legal obligations.[17]
- ***IAEA safeguards focus on nuclear materials*** and do not cover facilities unrelated to nuclear materials that could nevertheless be used by a nuclear weapon program. For example, they do not address research and development (R&D) for non-nuclear components of nuclear weapons, nor does the NPT explicitly ban such R&D. Although the NPT's prohibition against nuclear weapon "manufacture" has been widely interpreted to prohibit development of dedicated non-nuclear components, the Treaty provides no mechanism for verifying this prohibition.[18] Nevertheless, if discovered, such development would call into question a state's commitment to abide by safeguards on those facilities that were subject to them.
- ***The IAEA may face constraints on its ability to verify that the state's declaration is complete and accurate,*** even though NPT member states are required to declare all inventories of nuclear material to the IAEA, as well as all installations and locations that contain or are destined to contain nuclear material**.** The South African government granted the IAEA an extraordinary degree of access and cooperation, permitting the agency to verify independently that the South African declaration of its nuclear material inventory was reasonable. On the other hand, North Korea had made declarations that proved to be incompatible with the IAEA's independent measurements and analyses, and it has refused (in violation of its safeguards agreement) to permit the IAEA to conduct the inspections needed to resolve these discrepancies.
- ***Safeguards do not prohibit states from acquiring stockpiles of weapon-usable nuclear material*** (plutonium and highly enriched uranium) or the means to produce them, so long as the stocks and facilities are for peaceful purposes and are placed under safeguards. In fact, Article IV of the NPT explicitly allows for the indigenous development and sharing of technology for peaceful uses of nuclear energy. As such, the NPT embodies a nuclear "bargain": states gain access to peaceful nuclear technology in return for giving up their weapon options. Since much of the technology for developing nuclear energy is also applicable to nuclear weapons, however, it could be argued that this bargain is inherently self-defeating. Nevertheless, without it, many states would likely not have agreed to the international safeguards regime in the first place.

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[17]Note that international agreements besides the NPT may also constrain nuclear weapon programs. For example, both the bilateral denuclearization agreement between North and South Korea (which has not been implemented yet) and the bilateral Agreed Framework between North Korea and the United States contain provisions that impose stricter constraints than the NPT does on North Korean nuclear activities.

[18]See, e.g., George Bunn and Roland Timerbaev, "Avoiding the 'Definition' Pitfall to a Comprehensive Test Ban," *Arms Control Today,* vol. 23, No. 4, May 1993, pp. 16-17.

BOX 2-2: Compromises and Limitations of IAEA Safeguards from a Nonproliferation Perspective

It is not appropriate to evaluate nuclear safeguards solely from a nonproliferation perspective, since they were never intended to serve only nonproliferation objectives. The basic bargain underlying the nuclear nonproliferation regime is that non-nuclear-weapon states agree to forego weapon programs in return for assistance and encouragement in pursuing civil nuclear programs under safeguards. Therefore, safeguards represent an answer to "How can applications of civil nuclear energy be pursued without contributing to weapon programs?" rather than "How can nuclear proliferation best be opposed?" From a nonproliferation perspective, rolling back the spread of nuclear technology would be preferable to encouraging the spread of that technology under safeguards. However, that choice was not an available option. At the time that IAEA safeguards were being established, the alternative to the spread of *safeguarded* nuclear technology would more likely have been the spread of *unsafeguarded* nuclear technology.

Therefore, it is clear that even a perfectly functioning safeguards system has limitations from the perspective of its ability to forestall proliferation. Recognizing the caveats above, these limitations include the following:

- Safeguards are directed primarily to declared facilities.[1]
- Special inspections undertaken to resolve ambiguities must first gain cooperation of the inspected state.
- States have the right to reject particular inspectors designated for their country by the IAEA.
- Development of nuclear fuel-cycle activities is encouraged (by NPT Article IV).
- Production and possession of weapon-usable nuclear materials (plutonium and highly enriched uranium) are neither prohibited nor discouraged by either the NPT or the IAEA.
- Diversion of fractions of a "significant quantity" (SQ) from different locations can be difficult to detect.
- Less than one SQ can be sufficient for a nuclear device.[2]
- Exemptions from safeguards are allowed for material for military, nonexplosive applications (e.g., ship propulsion), as well as other purposes of less concern for potential diversion such as the manufacture of ceramics and alloys, and scientific research in amounts too small to pose threat of significant diversion to weapon purposes.
- Safeguards are not applied at the very front end of the fuel cycle, that is, to material in mining or ore processing activities.

[1]This represents the situation under "routine" application of safeguards. However, if the agency determines that it requires additional information to ensure that safeguards commitments are being honored, its built-in authority allows it to request both further access to areas within declared facilities and special inspections at declared or undeclared facilities. If irreconcilable conflicts remain, the IAEA can take the issue to the U.N. Security Council, leading ultimately to the possibility that enforcement action be taken under Chapter Vll of the U.N. Charter.

[2]Although the IAEA significant quantity for plutonium is 8 kilograms, the U.S. Department of Energy has stated that "Hypothetically, a mass of 4 kilograms of plutonium or uranium-233 is sufficient for one nuclear explosive device. " (U.S. Department of Energy, Classification Bulletin WNP-86, February 8, 1994. Although this sentence is unclassified, the full text of the bulletin is classified.) This statement is not completely equivalent to stating that the SQ should be set equal to 4 kilograms, since the SQ makes an allowance for material lost in processing and machining the plutonium for use in a weapon. However, much of these processing losses can be recovered. No such statement equivalent to this Classification Bulletin has been issued with respect to uranium-235.

SOURCE: Office of Technology Assessment, 1995.

- ***Under safeguards, states can operate reprocessing plants to extract and store plutonium from spent fuel, import highly enriched uranium for use in research reactors, and build enrichment facilities capable of being converted to produce weapon-grade uranium.*** Such activities bring states into close contact with weapon-usable material and give them experience in its properties and handling.[19] Many countries unilaterally choose to withhold assistance in these nominally peaceful activities from states whose motives are suspect, but they are not required by the NPT to do so. Sometimes, states are even pressured within the IAEA context *not* to withhold such aid.
- ***The IAEA, by itself, lacks an effective means of enforcement.*** There are no agreed provisions that would allow the IAEA or the United Nations Security Council to forcibly destroy nuclear facilities or render them useless, even if found to be in violation of the NPT or safeguards. The Security Council, however, could take such measures on an ad hoc basis, as it has done in Iraq.
- ***The IAEA is subject to diplomatic, legal, and political pressures to treat all states equally,*** making it difficult to select some as being of particular proliferation concern and subjecting them to closer scrutiny. As a consequence, much of the IAEA safeguards budget today is spent on the well-developed fuel cycles in Japan, Germany, and Canada, which are not generally regarded as countries of current proliferation concern.

In summary, the demise of the post-World War II efforts to internationalize the control of atomic energy, and the ensuing development of a far weaker system of nuclear safeguards in which states voluntarily yield some measure of sovereignty to submit their individual nuclear activities to outside inspection, has put severe limitations on the ability of any international institution such as the IAEA to prevent nuclear proliferation. In such a world, attempts to deny a country possession of nuclear materials and technology though safeguards, export control, and other means will not always work. As one analyst has stated:

> Given the circumscribed powers and limited resources granted the IAEA by the international community...blaming this institution for failing to stop proliferation is patently absurd.[20]

Recent Events

In the last few years, several factors have coalesced to raise the profile of the nuclear nonproliferation regime. As mentioned above, IAEA inspections in North Korea in 1992 proved that North Korea's declarations about its past plutonium reprocessing activities were, at best, incomplete and misleading. For many observers, these revelations confirmed suspicions that North Korea was developing nuclear weapons in violation of its NPT commitment not to do so, and that it may, in fact, have already built one or more weapons. The year before, in the aftermath of the Persian Gulf War, international inspections discovered an extensive clandestine nuclear weapon program in Iraq, an NPT member state for which

[19] Reprocessing technology, for example, was declassified decades ago and is well described in the open literature. For an assessment of technical hurdles facing a potential nuclear proliferant, see *Technologies Underlying Weapons of Mass Destruction*, op. cit., footnote 3, ch. 4.

[20] Janne Nolan, testimony before the Subcommittee on Technology and National Security, Joint Economic Committee, U.S. Congress, 102d Congress, 2d session, part 2, "Arms Trade and Nonproliferation in the Middle East," S.Hrg. 102-1021, Pt. 2, Mar. 13, 1992, p. 38.

no safeguards violations had been discovered or reported by the IAEA before the war.[21] The chief impact of these discoveries will be, and to some extent already has been:

> ...to focus the nonproliferation regime more sharply on the risks of proliferation in the politically tense regions of the Developing World, to find ways of enhancing the IAEA's ability to detect clandestine programs, and to stress the role of the U.N. Security Council as the supreme international authority for enforcing non-proliferation obligations.[22]

In April 1992, little more than a year after that war, the major nuclear exporting countries (the Nuclear Suppliers Group or "London Group") agreed to a major new set of export guidelines restricting trade in a wide range of dual-use technologies pertaining to nuclear weapons (e.g., technologies useful for producing nuclear weapons that also have legitimate civil applications), and linking approvals for such trade to a country's overall nonproliferation credentials. Still more important was the Nuclear Suppliers Group's agreement to prohibit exports of explicitly nuclear-related goods to states that were not subject to full-scope IAEA safeguards (i.e., those covering every nuclear facility in the state's territory). This new policy had the effect of blocking a possible Russian sale of reactors to India and a French project to sell one to Pakistan.[23]

Within the same period, the breakup of the former Soviet Union, with its vast nuclear weapon stockpile and infrastructure spread among several republics, presented dangerous new complications to the nonproliferation regime. At least three republics other than Russia (Belarus, Kazakhstan, and Ukraine) had nuclear warheads and nuclear materials on their territories. With all these republics having become non-nuclear-weapon states party to the NPT, they have committed to return all nuclear weapons on their territories to Russia and to place all of their nuclear facilities under safeguards.[24]

In addition, the conference held in April and May 1995 to review and extend the NPT drew worldwide attention to the treaty itself and to the nuclear safeguards that it requires its non-nuclear-weapon state parties to adopt. The outcome of this conference—a consensus decision to extend the NPT indefinitely—will shape the nonproliferation regime into the next century.

Despite its weaknesses and the discrimination between the nuclear "haves" and "have-nots," the nonproliferation regime, centered as it is on the NPT, has largely been successful. The total number of declared or de facto nuclear weapon states, including the five which had declared their nuclear weapon status before the NPT's signing, has

[21]Although carried out by the IAEA, the intrusive nuclear inspections conducted in Iraq since 1991 were mandated by U.N. Security Council resolutions 687, 707, and 715 and did not follow directly from Iraq's safeguards agreements. The IAEA has long had the authority under its full-scope safeguards agreements to conduct "special inspections" of undeclared sites. However, before 1991 it did virtually nothing regarding such sites, primarily due to the lack of political support in the international community for such intrusions on the national sovereignty of member states. It has since paid more attention to such sites, making its first—and so far its only—formal request for a special inspection of an undeclared site in 1992. North Korea, the target of the request, refused to allow it. On the other hand, several nations have permitted the IAEA to make less formal "visits" to undeclared sites.

[22]David Fischer, "Innovations in IAEA Safeguards To Meet the Challenges of the 1990s," in *The New Nuclear Triad: The Non-Proliferation of Nuclear Weapons, International Verification and the International Atomic Energy Agency* (Southampton, UK: Programme for Promoting Nuclear Non-Proliferation, Sept. 1992), p. 27.

[23]Refusing to export explicitly nuclear-related goods to states that are not under full-scope safeguards amounts to imposing an economic sanction on states unwilling to forego the nuclear weapon option. China has not agreed to abide by this policy, and it continues to export nuclear technology to states that are not under full-scope safeguards. However, China is obligated under the NPT to insist that IAEA safeguards be applied to nuclear-related items and facilities it exports, even if the recipient has not accepted safeguards on all its facilities.

[24]For further discussion of the former Soviet Union, see *Proliferation and the Former Soviet Union*, op. cit., footnote 1.

remained at eight or nine, a fraction of what some in the early 1970s were predicting. Forty states succeeded, ratified, or acceded to the NPT between January 1, 1991 and May 25, 1995, including France, China, Russia (as successor to the U.S.S.R.), and all of the other former Soviet republics, bringing the total number of parties to 178 (see appendix B).

Argentina and Brazil, two former "threshold" states that had been thought to be pursuing nuclear weapon programs in the past, have adopted strong nonproliferation measures through their commitments to the Treaty of Tlatelolco, which requires the implementation of comprehensive IAEA safeguards plus bilateral inspections of each other's nuclear activities through a newly formed agency called ABACC (the Argentine-Brazilian Agency for Accounting and Control of Nuclear Materials). Argentina has also gone on to join the NPT. Finally, a major advance for the nuclear nonproliferation regime was achieved in South Africa's accession to the NPT, for which it first dismantled its small clandestine nuclear arsenal and subsequently opened all of its nuclear facilities (including its ex-weapon facilities) to international inspection.

Despite growing adherence, however, the international safeguards regime has a number of shortcomings, as summarized in this chapter. The remainder of this report addresses various policy options for remedying these shortcomings.

Enhancing the Traditional IAEA Safeguards Regime 3

The traditional International Atomic Energy Agency safeguards regime can be strengthened in two ways. One approach is to improve the IAEA's ability to detect the diversion of "declared" nuclear materials—those materials that a state makes known to the IAEA and processes at facilities open to IAEA inspection. The other approach is to strengthen the IAEA's ability to detect undeclared materials and facilities where a state may be attempting to conduct nuclear weapon activities in secret. Until recently, international safeguards were restricted in practice to the first of these approaches, dealing only with declared materials at known sites. Now, however, steps are being taken to enhance the IAEA's ability to discover undeclared nuclear facilities.

To improve its chances of detecting covert nuclear facilities, the IAEA has already begun to incorporate new sources of information into its framework of implementing safeguards. It is studying the use of environmental sampling to detect covert sites[1] and is placing considerably more emphasis on determining the completeness and accuracy of the initial inventory of nuclear material that a state must declare to the IAEA when first coming under safeguards. In particular, it has made heavy use of "ad hoc" inspections for this purpose in states such as South Africa and North Korea, which entered the Non-Proliferation Treaty (NPT) after having already developed a substantial nuclear infrastructure. ("Ad hoc" inspections are those conducted before the

[1]See forthcoming OTA background paper on detecting nuclear facilities through environmental sampling (anticipated summer 1995), which examines the prospect of using environmental samples to identify or characterize covert nuclear weapon facilities by detecting radioactive or other characteristic substances they might emit.

completion of the formal attachments to a state's safeguards agreement with the IAEA that govern routine inspections at specific facilities.) With its new emphasis on determining the completeness of a state's initial declaration, the IAEA has apparently been successful in verifying the consistency of the South African case while uncovering clear discrepancies in the North Korean one. **It remains to be seen, however, whether the enhanced efforts and projected capabilities will be effective in states that refuse to cooperate fully with the IAEA's call for increased access and transparency, which has the potential to go well beyond the full-scope, NPT-type safeguards specified in INFCIRC/153.**

OVERALL CONFIDENCE IN SAFEGUARDS

Through 1990, official IAEA statements all tended to reflect the conviction that safeguards had continued to provide assurance that states were complying with their safeguards agreements. The only exceptions were two cases in 1981 and 1982, when the IAEA was unable to confirm compliance with safeguards at a Pakistani reactor and an Indian reactor due to the need to install additional equipment and take other measures to assure the absence of diversion.[2] Safeguards were, therefore, credited with playing a key role in preventing the proliferation of nuclear weapons and other nuclear explosive devices.[3] The IAEA has been cautious to place its capability into the proper perspective, deliberately calling attention to the fact that its statements were limited to *declared* nuclear material, and that categorical statements about the absence of undeclared installations could not be made on the basis of IAEA verification activities. It has also pointed out that the safeguards system is not so finely meshed that it would be likely to detect diversion of less than a "significant quantity" (SQ),[4] which it defines as "the approximate quantity of nuclear material in respect of which, taking into account any conversion process involved, the possibility of manufacturing a nuclear explosive device cannot be excluded."[5]

The most serious known violations of safeguards or NPT obligations—such as those uncovered in Iraq after the 1991 Gulf War—have involved not diversion from safeguarded facilities, but *undeclared* activities falling outside the domain of safeguards as it was then understood. Only in Iraq, North Korea, and Romania has the IAEA found violations that involved diversion of nuclear material or improper activities at a *declared* facility (i.e., one that has been disclosed to the IAEA and placed under safeguards). In Iraq and Romania, the violations at declared facilities involved quantities of nuclear materials that were substantially less than the amount whose diversion the IAEA would consider a serious proliferation risk. In North Korea, where the quantities in question could be significant, the concern is not the diversion of material from safeguarded facilities but rather the failure to declare all existing nuclear materials to the IAEA before safeguards were initiated. See box 3-1.

[2]The Indian situation was cleared up quickly, but Pakistan resisted installing the necessary equipment at its KANUPP power reactor for two years before agreeing to do so. During this period, the IAEA was careful not to imply that material had indeed been diverted, although the possibility existed. David A.V. Fischer and Paul Szasz, *Safeguarding the Atom: A Critical Appraisal* (London: SIPRI, Taylor and Francis, 1985), pp. 16-17; and David A.V. Fischer, *The International Non-Proliferation Regime, 1987* (New York: United Nations, 1987), p. 41.

[3]For example, see the draft document of the 1990 NPT review conference, NPT/CONF/DC/1/Add.3(a), Article III and preamble paragraphs 4 and 5, as cited in Lawrence Scheinman, *Assuring the Nuclear Nonproliferation Safeguards System* (Washington, DC: The Atlantic Council, October 1992), p. 7.

[4]See statement by Hans Blix, Director General of the IAEA, to the General Conference of the IAEA, GC(XXXVII)/OR.353, Oct. 11, 1993, p. 26.

[5]The definition also says that "significant quantities should not be confused with critical masses; the former take into account unavoidable losses of conversion and manufacturing processes." International Atomic Energy Agency, *IAEA Safeguards Glossary, 1987 Edition* (Vienna, Austria: IAEA, 1987), p. 23. The definition of significant quantities of various weapon materials is discussed later in this report.

BOX 3-1: Some Cases of Violation of Safeguards, or Inability To Certify Compliance with Safeguards

Iraq. Iraq's extensive violations of the Non-Proliferation Treaty—by building and operating a number of undeclared nuclear facilities and accumulating undeclared stocks of nuclear materials—have been the most notorious breach of international nuclear safeguards. In addition, Iraq violated its safeguards agreement with the IAEA by producing a small quantity of plutonium through the irradiation of indigenous, undeclared uranium fuel at an installation that was subject to IAEA inspection. Iraq's safeguards violations were detected only by inspections after the Gulf War.

North Korea. At best, North Korea made an incomplete declaration of its initial plutonium inventory when it concluded its full-scope safeguards agreement with the IAEA. At worst, the undeclared plutonium is evidence of a nuclear weapon program in violation of NPT and safeguards commitments. North Korea did not conclude its safeguards agreement with the IAEA for six years following its ratification of the NPT, in apparent violation of the treaty. (Safeguards agreements are to be completed within 18 months. Many other NPT parties have not met this deadline either, but they have no significant nuclear facilities and certainly no facilities for production of weapon-usable nuclear materials.) North Korea has refused to allow access to IAEA inspectors, both for routine inspections at declared facilities and for special inspections at two suspected waste sites. Having first announced and then suspended its withdrawal from the NPT, North Korea has asserted that it has a unique status under the NPT and is not subject to standard safeguards requirements. However, neither the IAEA nor other NPT parties recognize such a status.

The IAEA was able to discover discrepancies in the North Korean declaration of its initial inventory on the basis of its own sampling and analysis. Information supplied by member states contributed to the IAEA's request to conduct special inspections of two undeclared sites.

Romania. Following the ouster of the Ceaucescu regime, Romania acknowledged producing small amounts of plutonium without notifying the IAEA as required. In addition, it has admitted selling Norwegian-origin heavy water to India without requiring IAEA safeguards on the sale (it should have negotiated an INFCIRC/66 agreement with India) or reporting the sale to the IAEA, apparently in violation of the NPT requirement for such transfers.

Pakistan. In the early 1980s, when Pakistan became able to produce its own fuel for its KANUPP nuclear reactor, which was under IAEA INFCIRC/66 (non-NPT party) safeguards, the IAEA was unable to certify that Pakistan had not diverted nuclear material from this reactor. For two years, until Pakistan allowed additional equipment to be installed and procedures taken, the IAEA stated that it could not rule out the possibility of diversion there. During this period, the IAEA was careful not to imply that material had indeed been diverted, although the possibility existed.

All the instances above relating to NPT parties (i.e., the Iraqi, North Korean, and Romanian cases) became known to the IAEA after the Gulf War. Thus some argue that before Iraq's clandestine nuclear program was discovered, the IAEA not only remained free from pressure from its member states to be more intrusive and forceful (in fact, some member states objected to any additional intrusiveness), but had little incentive in this direction since no significant safeguards violations were known to have occurred.

SOURCE: David Fischer and Paul Szasz, *Safeguarding the Atom* (London and Philadelphia: Taylor and Francis, 1985) and Office of Technology Assessment, 1995.

IAEA

IAEA inspectors visiting a nuclear reactor in North Korea. By analyzing samples taken during its inspections, the IAEA determined that the North Koreans had not revealed all of their plutonium production.

If IAEA safeguards did not exist, the diversion of nuclear material from ostensibly civil facilities would pose serious dangers to the nonproliferation regime. Given the existence of safeguards, however, diversion of material from civil facilities is probably not the easiest or the most efficient route to obtaining weapon materials.[6] Moreover, in the past, states pursuing nuclear weapons such as India, Israel, Pakistan, Iraq, and South Africa have produced their weapon materials at undeclared-and therefore unsafeguarded-facilities.[7] **Therefore, ensuring the absence of *undeclared* facilities for producing nuclear materials is probably even more important to the international nonproliferation regime than is verifying with very high confidence that not even a single bomb's worth of nuclear material could have been diverted from *decklared* facilities.** Nevertheless, achieving a high probability that the diversion of a significant quantity of fissionable nuclear material from a declared facility will be detected—while maintaining a manageable false alarm rate—underlies the vast majority of NPT international verification activities. Both the application of safeguards to declared facilities and the detection of undeclared facilities are important to the nonproliferation regime, and the IAEA has a key role to play in both missions.

■ IAEA Organizational Culture and "Mindset"

Many feel that the IAEA is more conservative and more cautious than it should be or needs to be, and that it cannot easily adapt to a new, more ambitious agenda.[8] This attitude may stem from IAEA practice before the 1991 Gulf War, when it was not encouraged by its member states to seek undeclared facilities. Ten years earlier, former IAEA inspector Roger Richter testified in a widely publicized congressional hearing that the IAEA actively *discouraged* inquiries into undeclared activities. He asserted that an inspector "must prepare [oneself] mentally to ignore the many signs that may indicate the presence of clandestine activities going on in the facilities adjacent to the reactor

[6] Office of Technology Assessment, *Technologies Underlying Weapons of Mass Destruction,* OTA-BP-ISC-115 (Washington, DC: U.S. Government Printing Office, December 1993), pp. 181-183. This statement is based on the existence of safeguards, on the fact that the vast majority of nuclear material in the civil sector is in forms that are not directly usable or, if usable, not optimal for weapons, and on the uneconomic operating conditions that production of weapon materials would require in most commercial facilities.

[7] Iraq's undeclared activities violated its NPT commitments. The other states listed were not NPT members when they pursued their weapon programs and were, therefore, under no legal obligation to declare their nuclear activities or place them under safeguards.

[8] Lawrence Scheinman, *Assuring the Nuclear Non-Proliferation Safeguards System,* op. cit., footnote 3, p. *26*. See also, Gary Milhollin, "The New Arms Race: The Iraqi Bomb," *The New Yorker,* Feb. 1, 1993, pp. 47-55; and David Kay, "The IAEA—How Can It Be Strengthened?" paper presented at the conference *Nuclear Proliferation in the 1990s: Challenges and Opportunities,* Woodrow Wilson Center, Washington, DC, Dec. 1-2, 1992, especially pp. 9-14.

[under IAEA inspection]."[9] After the revelation of Iraq's covert nuclear weapon program, an unnamed IAEA official was quoted as stating that "we may have been too narrow" in the training provided for IAEA inspectors in the past, implying that to some extent the earlier criticism may have been warranted.[10]

As Lawrence Scheinman explains, there are institutional pressures within the IAEA that have acted to oppose the strengthening of safeguards:

> Historically—and even in the present political context—there has been a continuing reluctance of the [IAEA] board members to agree to new safeguards measures that will be any burden on themselves. Some member states accept safeguards grudgingly, but even non-nuclear-weapon states which are strongly committed to effective safeguards and to non-proliferation are chary of accepting new measures, even when it is not their behavior that necessitates these measures in the first place.[11]

Moreover, he argues, "sovereignty remains a vigorous and contradictory force against empowering international institutions with far-reaching authority."[12] However, Scheinman ultimately concludes that "with proper political leadership there is no reason that the IAEA should not be able to implement a more far-reaching and more intrusive safeguards regime. The basic responsibility for ensuring this task rests in the hands of the governments of its key member states, especially the United States."[13] It also rests with the Security Council and its relationship to the IAEA. Indeed, a number of potentially far-reaching steps have been taken since the 1991 Persian Gulf war to strengthen the IAEA, improve its nuclear safeguards, and otherwise bolster the nuclear nonproliferation regime.

Recent Improvements

In January 1992, a communiqué was issued by the U.N. Security Council in which its members, through their respective heads of state, declared that 1) "the proliferation of all weapons of mass destruction constitutes a threat to international peace and security"; 2) fully effective IAEA safeguards are integral to the implementation of the NPT; and 3) Security Council members "will take appropriate measures in the case of any violations notified to them by the IAEA."[14] This statement significantly strengthened U.N. support for the goals of IAEA safeguards and implied firmer actions by the United Nations in the future.

In late 1991, IAEA Director General Hans Blix called for several improvements to safeguards, including the need to incorporate outside intelligence about undeclared facilities, the need for inspectors to have the right to go anywhere unimpeded, and the value of "powerful support," such as that provided by the Security Council. Blix also established procedures within the IAEA to receive information from outside sources. At its meeting in February 1992, the IAEA's Board of Governors explicitly reaffirmed the IAEA's "right to obtain and to have access to additional information and locations in accordance with the IAEA Statute and all comprehensive safeguards agreements." Specifically included in this reaffirmation was the IAEA's right to use information derived

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[9] "The Israeli Air Strike," Hearings before the Committee on Foreign Relations, United States Senate, 97th Congress, 1st Session, June 18, 19, and 25, 1981, p. 112.

[10] Mark Hibbs, " 'Special Inspections:' A Transatlantic Turf War for Post-Iraq Powers: Nonproliferation After the Gulf War," *Nucleonics Week*, vol. 33, No. 5, Jan. 30, 1992, p. 14.

[11] Scheinman, op. cit., footnote 3, p. 42.

[12] Ibid., p. 28.

[13] Ibid.

[14] U.N. Security Council Press Release, SC/536, Jan. 31, 1992, as cited in Scheinman, op. cit., footnote 3, p. 6.

both from nonsafeguards activities (technical cooperation, safety, and research activities) and from non-IAEA or political sources.[15]

The Board also reaffirmed the IAEA's right to undertake "special inspections," including their use to ensure that *all* appropriate nuclear materials have in fact been placed under safeguards. In doing so, the Board declared that the requirement to engage in "consultation" with the state in question (pursuant to INFCIRC/153, paragraph 77) did not allow the state ultimately to deny the agency's right to special inspections.[16] (In practice, of course, the requirement for consultation can be used by states to delay inspections, making short-notice inspections impossible.) The IAEA had always had the authority to conduct special inspections, but before the Persian Gulf War of 1991, none had ever been conducted at an undeclared site. (The "anytime, anywhere, no-right-of-refusal" inspections conducted by the IAEA in Iraq were not conducted under its special inspection authority but rather under U.N. Security Council Resolution 687, which was imposed on Iraq under threat of force.)

Despite the Board's affirmations, intrusive inspections and reliance by the IAEA on national intelligence sources are unwelcome by many countries. **Since the IAEA has a strong institutional commitment to maintaining political support within its ranks, it will take some time to determine how successful proposals will be for increasing the scope of inspections or for the agency to act upon additional amounts of national intelligence information.** However, states provided the IAEA with much of the information it needed in the cases of Iraq and North Korea. In the latter case, the IAEA proved able to act on such information (in conjunction with its own sampling and analysis) to request a special inspection of two undeclared waste disposal sites.

In 1992, the IAEA took additional steps to improve the quality of the information available to it concerning safeguards-related activities. In February, the Board of Governors endorsed an IAEA proposal that design information be provided *at the time of the decision to construct or to authorize construction* of any nuclear facility, or to modify an existing facility. Such information is to be provided at least 180 days before construction starts. (This is a much stronger requirement than the prior practice, which held that such information be provided 180 days *before fissile material was to be introduced* at the site.) With this additional notice, the IAEA will be better able to plan for effective implementation of safeguards for the facility.

The importance of early design information was particularly stressed by the LASCAR (LArge SCAle Reprocessing plant) study, a four-year analysis of safeguards for future large-scale plutonium reprocessing plants. LASCAR, conducted by representatives from France, Germany, Japan, the United Kingdom, the United States, IAEA, and the European Atomic Energy Community (EURATOM), was an initiative that was proposed and financed by Japan. Acting in an advisory capacity to the IAEA, the LASCAR forum formulated new guidelines for IAEA safeguards on such facilities in May 1992.

[15]Some board members, however, argued that use of foreign intelligence information as the basis for inspections could be challenged, and some developing states would consider Agency use of such as a violation of their sovereignty. The adopted text dropped an explicit reference to foreign intelligence. The Board also declined to support establishment of a formal unit within the IAEA to process intelligence information.

[16]If a request by the Director General for a special inspection is refused, the Director General may bring the matter to the Board of Governors, who can request the state to take the required action without delay. If the matter remains unresolved, the Board has the obligation to report to the Security Council the inability of the Agency to verify "that there has been no diversion of nuclear material required to be safeguarded" (INFCIRC/153, paragraph 19). The Security Council can then determine if the situation threatens international peace and security, in response to which it could invoke options under Chapter VII of the U.N. Charter. The initial decision to call for a special inspection, however, rests with the Director General alone, and does not require action by the Board (though the latter can also request such an inspection). Scheinman, op. cit., footnote 3, pp. 12-13.

To further enhance its information-analysis capabilities, the IAEA's Board of Governors took steps at its February and June 1992 meetings toward adopting universal reporting of: 1) exports and imports of certain equipment and non-nuclear material, and 2) exports, imports, production, and inventories of nuclear material. However, these measures did not cover production of non-nuclear material and did not envisage routine verification other than cross-checks within the IAEA.[17] At the September 1992 meeting of the IAEA's General Conference in Vienna—the annual plenary of representatives from all the IAEA's member states—Hans Blix announced that states able to begin such reporting should do so on a voluntary basis. At the February 1993 meeting, the Board of Governors authorized the secretariat to implement proposals for such a system of universal reporting, including *production* of nuclear materials, specified equipment, and non-nuclear material commonly used in the nuclear industry.[18]

If a substantial number of states comply, increased reporting to the IAEA of their imports and exports of nuclear material and equipment will significantly strengthen the safeguards regime. Blix has claimed that if such data for Iraq had been available, the IAEA would probably have requested special explanations and visits to Iraq.[19] Many argue that such collection and analysis of information is one of the most important parts of the control system for weapons of mass destruction.[20] Nevertheless, the plan for universal reporting is still in its infancy, and only a handful of states provided information in 1992 and 1993, although many major suppliers are expected to comply eventually.

The 27 members of the Nuclear Suppliers Group (NSG) adopted new Dual-Use Export Guidelines in April 1992, extending international export controls on items useful for manufacturing nuclear weapons or weapon material.[21] These guidelines will tighten export restrictions on thousands of items in 65 categories of equipment and materials related to producing nuclear weapons, including specific types of lasers, carbon fibers, oscilloscopes, certain high-purity materials used in the nuclear industry or for weapon components, and computer-numerically-controlled machine tools. The NSG members also agreed not to export explicitly nuclear-related goods to states that are not subject to full-scope safeguards. According to officials from the Foreign and Trade Ministries of Japan, which has become the NSG's de facto secretariat, the emerging regime would become the largest international regulatory framework for the export of dual-use items.[22]

The most significant nuclear supplier that has not committed to adhere to the Nuclear Suppliers Group restraints is China. As a party to the Non-Proliferation Treaty, China is obligated to notify the IAEA of exports to a non-nuclear-weapon state of any nuclear materials, equipment, or facilities, and to place them under IAEA safeguards. Beyond its NPT obligations, China has pledged to

[17]Some of the enhanced reporting requirements that are being considered would require reporting of *any* amount of plutonium or enriched uranium transferred to or from either nuclear-weapon states or non-nuclear-weapon states (nuclear-weapon states already voluntarily report transactions in excess of 1 effective kilogram—see glossary—of nuclear material for peaceful purposes), and they include reporting of inventories and transfers of material not yet suitable for fuel fabrication or enrichment (such as uranium ore concentrates, U_3O_8) even if exported for peaceful *non*-nuclear purposes. Scheinman, op. cit., footnote 3, pp. 16-17.

[18]Programme for Promoting Nuclear Nonproliferation, *Newsbrief*, No. 21, First Quarter, 1993, p. 6.

[19]IAEA Press Release, Oct. 21, 1992, on Blix's statement to the U.N. General Assembly.

[20]See U.S. Congress, Office of Technology Assessment, *Export Controls and Nonproliferation Policy,* OTA-ISS-596 (Washington, DC: U.S. Government Printing Office, May 1994).

[21]See U.S. Congress, Office of Technology Assessment, *Technologies Underlying Weapons of Mass Destruction,* OTA-BP-ISC-115 (Washington, DC: U.S. Government Printing Office, December 1993), app. 4-D.

[22]*Arms Control Reporter*, 1992, p. 602.B.219.

exercise restraint on nuclear exports. However, the United States has repeatedly approached China concerning its nuclear export activities, particularly with respect to Iran. Argentina, like China not a participant in the April 1992 NSG meeting, declared that it would establish effective controls over its exports of nuclear equipment and materials, and has committed to this under its quadripartite agreement with Brazil, the Argentine-Brazilian Agency for Accounting and Control of Nuclear Materials (ABACC), and the IAEA.[23]

Current IAEA Thinking on Improving Safeguards: "Programme 93 + 2"

With an eye toward strengthening and streamlining IAEA safeguards in the post-Gulf War political environment, the IAEA undertook a broad-ranging, internal evaluation of its safeguards regime. In 1993, it put forth "Programme 93 + 2," a number of recommendations for improving the efficiency and effectiveness of safeguards to be addressed in the two years before the 1995 NPT review and extension conference. This proposal consists of six parts plus an integration phase:[24]

1. increased transparency measures,
2. increased use of states' systems of accounting and control (SSACs),
3. environmental sampling,
4. use of "anytime, anyplace" inspections,
5. analysis of additional sources of information, and
6. expanded training of the inspectorate.

The intention is to integrate these improvements into the present system of safeguards in a coherent way. The proposal is motivated both by the need for cost savings and by a desire to increase the IAEA's access to relevant facilities and information sufficiently to provide assurances not only that a country's declared materials remain in peaceful use, but also that it has no *undeclared* nuclear facilities.

Under 93+2, a number of avenues to strengthen safeguards would be examined for their feasibility and utility. The implications of changing the definition of "significant quantity" thresholds for nuclear materials would also be reexamined. Options for increased utilization of the SSACs include using them to make the IAEA's work more efficient, sharing equipment and analytic capabilities, thus lessening the inspector's workload, and relegating some verification activities (e.g., for natural or depleted uranium) almost entirely to the state system.[25] Investigation of environmental sampling under 93+2 to detect undeclared facilities or activities would primarily be directed at applications where most believe it would be useful—in short-range monitoring of specific types of activity in a small number of countries.[26] In the short term, it will concentrate on performing background calibrations at various distances from known sites, developing a cleanroom analytic capability, and documenting various signatures from reprocessing, enrichment, and reactor operations. Increased access and the concept of unan-

[23]IAEA document INFCIRC/404, as cited in ibid.

[24]International Atomic Energy Agency, "Strengthening the Effectiveness and Improving the Efficiency of the Safeguards System: A Report by the Director General," GC(XXXVIII)/17, Aug. 29, 1994.

[25]The IAEA has also reached a new understanding with EURATOM for streamlining its relationship and procedures for carrying out their overlapping safeguards responsibilities in Europe. This "New Partnership Approach" is intended to reduce significantly the inspection resources that IAEA must devote to EURATOM countries, while maintaining the IAEA's ability to arrive at independent safeguards conclusions.

[26]As of August 1994, 20 states had agreed to participate in field trials of environmental monitoring or other techniques to strengthen safeguards. See IAEA General Conference, "Strengthening the Effectiveness and Improving the Efficiency of the Safeguards System," op. cit, footnote 24, p. 5. Field trials have shown that nuclear operations in coastal areas can be detected in water and sediment samples up to 20 kilometers from the facility (p. 17).

nounced inspections will be studied on a voluntary basis in countries such as Australia, Canada, Iran, Japan, South Korea, and Sweden, the eventual goal being in part to reduce some inspection activities (e.g., on spent fuel storage in Canada) while maintaining or increasing overall effectiveness. Finally, various open source databases and programs for organizing the kinds of information most relevant to safeguards will be explored.[27] Such data retrieval and analysis will be used to increase the utility of environmental sampling as well as arrangements for voluntary access.

The 93+2 program is ambitious and will address many important areas needing improvement within the IAEA. Nevertheless, a number of important issues remain to be addressed. These can be divided into techniques and procedures for implementing safeguards themselves, and institutional issues concerning the IAEA broadly.

STRENGTHENING SAFEGUARDS

Safeguards Objectives

The IAEA seeks to detect diversion of so-called significant quantities of nuclear material, defined as 8 kilograms of plutonium, or 25 kilograms of uranium-235 when in the form of highly enriched uranium. It has set its detection goals at 90 percent, with a false alarm rate of 5 percent (see box 3-2).[28] The IAEA safeguards system does not attempt to disguise the fact that diversion of lesser quantities may be more difficult to detect. Moreover, it does not aim to detect diversion of a significant quantity instantly, but rather to do so in a "timely manner," defined variously as monthly, every three months, or yearly, depending on the particular type of material and roughly the time required for it to be converted into a weapon. Detection thresholds are set at 90 percent for fissionable

BOX 3-2: Detection Probabilities and False Alarm Rates

Safeguards measurements for material accountancy and control are used by the IAEA to determine the amount of nuclear material at a facility that is unaccounted for ("material unaccounted for," or MUF) and to compare it to the value reported by the facility's operator. A sufficiently large MUF could indicate that nuclear material had been diverted. Alternatively, it could reflect an unrecorded process loss. Ideally, one would like measurements to result in a zero value for the MUF, thereby closing the books with all of a facility's nuclear material fully accounted for. However, measurement errors will, in general, produce nonzero estimates of MUF, *even if no material has been lost or diverted.* Given the known or estimated uncertainties in the measurements used to calculate MUF, it can be determined whether the MUF value is significantly different from zero (i.e., a magnitude that measurement errors alone would be unlikely to explain). Thresholds at which MUF is considered significant are determined after choosing acceptable levels for two types of errors:

- *Fake alarms, or "Type I" errors.* Claims of a diversion or loss of material when none has occurred. The probability of a false alarm, meaning that analysis of material accountancy measurements will indicate that material is missing when none in fact has been diverted or lost, is represented by α.
- *Missed diversion,* or *"Type II" errors.* Failure to conclude that a diversion or loss has occurred when in fact it has. The probability that a true diversion or loss will be not be detected is denoted by β (see figure a).

(continued)

[27] One such program, called INSIST, has been developed by the U.S. Department of Energy's Pacific Northwest Laboratory to help implement long-term monitoring in Iraq. It incorporates and manages multimedia data including photographs, maps, and facility layouts.

[28] Such goals apply to the conclusions reached at the end of a material balance period, when the IAEA verifies a physical inventory (e.g., monthly, every 3 months, or yearly, depending on the type of material).

BOX 3-2 (Cont'd.): Detection Probabilities and False Alarm Rates

If either type of error occurs too frequently, it could seriously erode the credibility of the entire system used to make judgments. False alarms can have political and procedural costs and might sometimes require extensive consultations to resolve. It is thus very important for the IAEA to maintain a low false alarm rate, and $\alpha = 0.05$ has been chosen as the maximum acceptable value.[1] Similarly, missed diversions can be very costly in terms of their consequences for proliferation. The IAEA uses 90 percent detection probability for detecting a "significant quantity" of diverted U-235 or plutonium in a form directly usable for weapons, thus defining β by $0.90 = (1- \beta)$, or $\beta = 0.10$.

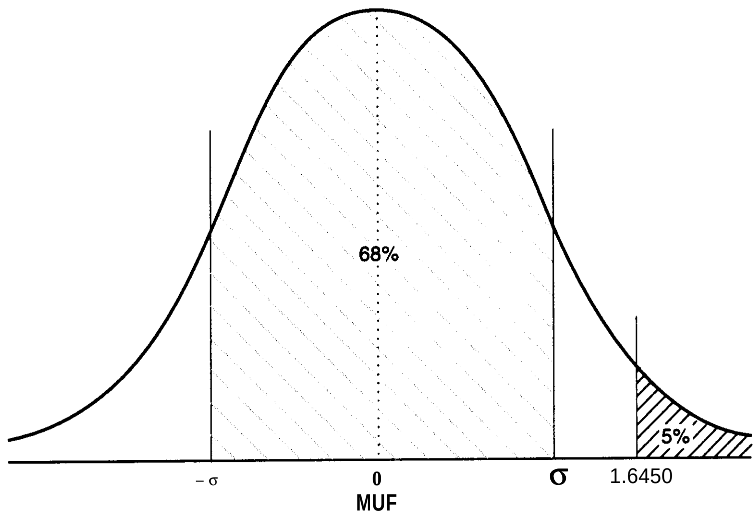

Figure a. Expected probability distribution of MUF (material unaccounted for) measurements from a system with an overall uncertainty of σ, assuming that no diversion of material has taken place and that no systematic errors act uniformly to shift all the measurements to one side or the other. Measurements will fall between - σ and + σ 68 percent of the time. Measurements will fall above +1 .64505 percent of the time.

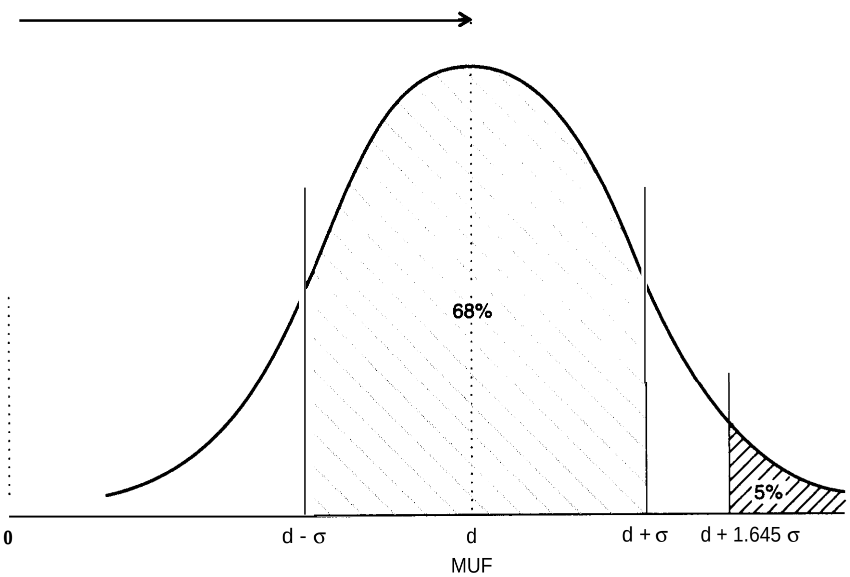

Figure b. Expected probability distribution of MUF measurements from the same system as figure a) in the event that amount "d" of nuclear material has been diverted. Measurements of missing or unaccounted-for material are most likely to be near d, falling between d-a and d+ σ 68 percent of the time.

[1] According to the IAEA, the false-alarm rate in practice is much smaller than 5 percent, even for material in bulk form, but especially for safeguards procedures that only require identifying and counting complete items (known as item accountancy). (See letter in response to Office of Technology Assessment questions, signed by Jan Priest, Division of External Relations, IAEA, and addressed to Marvin Peterson, United States Mission to the United Nations System Organizations in Vienna, Jan. 17, 1995, p, 5.) Each alarm requires additional investigation, credible explanation by plant operators, or other procedures to try to resolve the discrepancy and determine whether the alarm is warranted.

(continued)

BOX 3-2 (Cont'd.): Detection Probabilities and False Alarm Rates

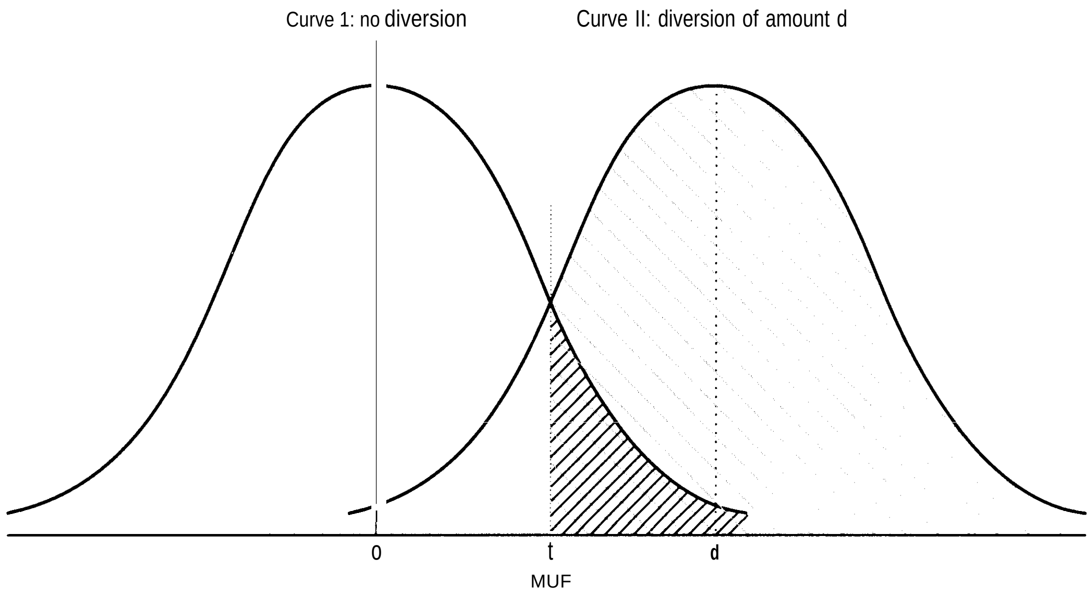

Figure c. To tell the difference between a measurement that indicates material is actually unaccounted for and a measurement that might be due solely to measurement error, a threshold is typically established. Measurements greater than the threshold—shown in this figure as "t''-are assumed to represent the absence of material, whereas measurements below the threshold are assumed to be consistent with all material being accounted for. Probability distributions for two different cases are shown here: curve I represents the case where no material is actually missing, and curve II represents the case where a diversion of amount "d" has been made. Therefore, the shaded area under curve I that is to the right of "t" represents the false alarm rate: the probability that measurements will appear to indicate diversion even when none has occurred. At the same time, the shaded area under curve II that is to the right of "t" represents the probability for detecting diversion of size "d, since it gives the probability that a measurement will show that more than "t" material is missing when "d" has actually been taken.

In sum, uncertainties associated with numerical measurements directly affect the uncertainty (and the false alarm rate) of conclusions based on those measurements. No system can provide absolute certainty in detecting loss of material or the absence of loss. The best that can be done is to design a system that has high detection probability and low false alarm rate. **However, these two goals are in opposition, forcing a balance to be struck between them.** For a given measurement system, detection probability can always be raised, but only at the expense of generating more false alarms.

Statistical analysis shows that by sounding an alarm when MUF values exceed 1.645a (where σ is the uncertainty, or "standard deviation, " with which MUF can be computed), the false alarm rate will be held to 5 percent or less, while true diversions or losses of twice the alarm threshold (3.290) would be detected with 95 percent probability. There would be a 90 percent chance of catching diversions over 2.93a. For example, if a plutonium measurement system were characterized by a one-standard-deviation uncertainty of ± 2 kg, sounding an alarm when MUF values exceeded 3.29 kg would have a 95 percent chance of detecting diversions as big as 6.58 kg of plutonium. Similarly, false alarms would occur only 5 percent of the time (see figures a through c).

However, even smaller diversions would also have some chance of being detected, using the same threshold and thus the same (low) 5 percent false-alarm probability. If a diversion equal to 3.290 has a 95 percent chance of being detected, for example, diversions at levels of 1 σ or 2 σ would have a 26

(continued)

BOX 3-2 (Cont'd.): Detection Probabilities and False Alarm Rates

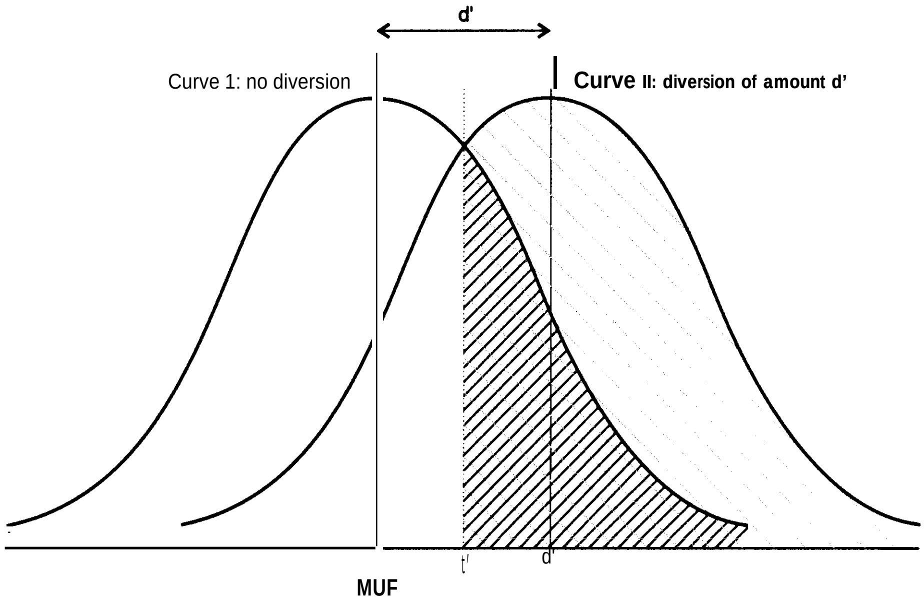

Figure d. The size of the diversion to be detected can be reduced by lowering the alarm threshold. **At the same time,** however, the false alarm rate will go **up. In this figure, an alarm threshold t' is used that is equal to half of the threshold t** shown **in figure c. The area under curve I to the right of t' is larger** than it **was in figure c, indicating that the false alarm rate will be higher in this case. Moreover, since less of the area under curve** II is to the right of the threshold t' in this picture, the chances are lower that an actual diversion will be caught. In other **words, the detection probability will be lower.**

percent or 64 percent chance, respectively, of being detected as well. Thus a plant operator who deliberately diverts *any* amount of material always has some chance of being discovered.[2] This assumes, of course, that the data used by the IAEA have not been falsified in some way by the operator

One option that has been considered for bulk-handling facilities (e.g., facilities that handle nuclear material in bulk form, such as solution or powder—these plants are among the hardest to safeguard) is to allow an increase in false alarm rate (e.g., to 20 percent or even 30 percent) in order to attain additional detection sensitivity.[3] Given that a MUF value higher than the detection threshold does not automatically imply (nor is it ever immediately assumed to imply) that material has *actually* been diverted anyway, these higher false alarm rates would be expected only to set in motion a more rigorous search for other sources of the anomalous readings, and not to trigger a crisis. Such an increase in allowable false alarm rates would be the result of lowering the detection threshold for sounding the alarm by about a factor of two, thus making half-size diversions detectable with higher confidence.[4] The disadvantage of such an adjustment is that considerably more work would be required to investigate all the false alarms. If so many false alarms lulled the inspectors into not taking this investigative effort seriously, the detection sensitivity could in effect degrade to a condition worse than before the detection threshold were lowered.

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[2] Even if he diverts nothing at all, there is still a 5 percent chance that measurements will indicate a diversion or loss—this is the meaning of the false alarm rate. Therefore, during 5 percent of the accountancy periods, steps would have to be taken to resolve apparently discrepant measurements.

[3] See, e.g., R.D. Marsh and R.W. Foulkes, "Design of Safeguards Systems for Commercial Plutonium Processing Facilities," in *Nuclear Safeguards Technology* 1986, Proc. IAEA Symposium, vol. 1, Nov. 10-14, 1986 (Vienna, Austria: IAEA, 1987), pp. 31-46.

[4] For instance, if a given reprocessing plant's measurement system can achieve a 95 percent detection capability with 5 Percent false alarm rate only for diversions as large as 16 kilograms of plutonium, a 79 percent detection capability could be achieved for losses of just 8 kilograms if one could tolerate a false alarm rate of 21 percent. Such a change in detection capability would be accomplished simply by halving the threshold for sounding the alarm from 1.645 σ, which has 5 percent of the normal probability distribution curve to its right, to 0.823σ, which has 21 percent to the right. See figured.

nuclear material not only to facilitate catching the great majority of diversions, should they be taking place, but also to *deter* them in the first place. Nevertheless, safeguards can neither predict diversions ahead of time, nor physically prevent them, nor be guaranteed to detect them 100 percent of the time, **and they should not be expected to do so.**

Difficulties and Limitations

Technical difficulties can interfere with safeguards operations. For example, camera failure, delays in taking samples or inventorying materials, or staffing limitations may prevent the IAEA from fulfilling its safeguards objectives at particular facilities. In 1979, the IAEA was only able to completely attain 27 percent of the inspection goals it set for itself, although for material directly usable in weapons its goal attainment was 60 percent. By 1984, this record had improved to 53 percent for all materials and 71 percent for weapon-usable materials.[29] At major facilities, the IAEA attained 63 percent of its inspection goals in 1986 and 81 percent in 1990 before dropping back to 69 percent in 1992.[30]

Even if inspection goals are missed, the IAEA may still be able to certify that materials have not been diverted. However, it may not be in a position to do so within the deadlines it has established. All instances where missing information might prevent the IAEA from detecting diversion of material are investigated. Typically, additional information, such as from a subsequent inventory, provides proof that material was not in fact diverted during the period when inspection goals were unmet. Except for the Indian and Pakistani cases mentioned above, the IAEA ultimately certified the nondiversion of safeguarded material, even though it has not always met its inspection goals.

Two other fundamental limits on the ability of the safeguards system to detect diversions are the need for cooperation by the state and the IAEA's limited resources. Allowing international inspectors to regularly visit a country's nuclear facilities requires a country to relinquish some sovereignty, and the allowed routine inspection effort is spelled out in the comprehensive safeguards agreement a country negotiates with the IAEA. There are specific provisions for stepping beyond the constraints of such routine inspections, but these are also restricted in certain ways and do not provide the IAEA with a "hunting license" to search within the country arbitrarily. Although states are usually receptive to IAEA requests to visit other sites, they have no legal obligation to permit such access beyond their requirement to accept these restricted "special inspections" in cases where the IAEA considers that the information made available to it by the inspected state "is not adequate for the Agency to fulfill its responsibilities."[31]

The limits imposed by finite resources are most easily seen by a few comparisons. In the multibillion-dollar reprocessing plant to be built at Rokkasho-mura in Japan, tens of millions of dollars will be spent on equipment to comply with safeguards requirements, a substantial portion of which will be used to construct an onsite analytic lab and the rest for in-plant design features and measuring

[29]Fischer, op. cit., footnote 2, p. 42.

[30]D. Schriefer, D. Perricos, and S. Thorstensen, "IAEA Safeguards Experience," Symposium Proceedings, *International Nuclear Safeguards 1994*, March 14-18, 1994, Vol. 1, p. 40.

[31]INFCIRC/153, Article 73(b)

equipment.[32] Comparing this capital expenditure with the total annual IAEA safeguards budget of about $70 million for carrying out safeguards worldwide-covering over 40 countries, some 900 installations, and parts of at least four other reprocessing plants—indicates why the IAEA relies on the basic structure of verifying the *states'* systems of accounting and control and cannot install complete monitoring and measurement systems of its own.

The IAEA chose long ago to employ this strategy of exploiting the states' own systems of accounting and control, while carrying out certain procedures and independent measurements to *authenticate and verify* the state's measurement systems and thus the state's reports.[33] **The IAEA is thus dependent on the quality of the SSAC and the cooperation of the state in implementing safeguards.** If the SSAC is very sloppy, suspicions will be raised, and the IAEA may even call into question the validity of the state's measurement systems or reject the reports. The IAEA is not permitted to play the role of plant operator, however, and would not have the resources to do so even if it were.

■ Resources Available for Safeguards

OPTION: *Increase the financial resources available to the IAEA for carrying out safeguards.*

Under pressure from those countries providing the bulk of its funding, the IAEA has been held to virtually a zero-real-growth budget since 1985. In addition, since 1991, the Soviet Union's successor states have been unable to maintain the U.S.S.R. previous level of contributions, about 13 percent of the agency's budget.[34] Meanwhile, the IAEA is constantly subjected to late payments from member states, including the United States.[35] Despite its financial difficulties, the agency's safeguards responsibilities have been increasing:

- Several countries with significant nuclear infrastructures, such as Argentina, Brazil,[36] South Africa, Ukraine, and Kazakhstan, have

[32] For example, Rokksho will have ove,25 tanks and several separate buildings between the initial dissolver tank and the final Plutonium output stream-all connected by piping and monitored by various process-specific equipment. According to press accounts, construction of Rokkasho is expected to cost between 1.8 trillion and 2 trillion yen, or roughly $18 billion to $20 billion. See N. Usui and A. MacLachlan, "Japan AEC Looking at Delay in Startup of Reprocessing Plants," Nuclear Fuel, Feb. 14, 1994, pp. 10-11.

Rokkasho will be the only reprocessing plant of this size under complete IAEA safeguards. The THORP reprocessing plant in the United Kingdom and the French reprocessing plant at La Hague, which are even larger than Rokkasho, will have IAEA safeguards applied only to their product-storage areas. Since both are located in nuclear weapon states, neither is required to be completely safeguarded by the IAEA.

[33] Though the IAEA can perform some measurements independently by taking samples from the site (destructive assays) or by carrying portable equipment to it (nondestructive assays), other measurements can only be "authenticated" by IAEA personnl, by verifying the integrity of plant measurement equipment, and by watching to see that plant operators do their job properly. IAEA inspectors can also verify the emplacement of the equipment during construction and may install tamper-resistant devices.

The THORP reprocessing plant in the United Kingdom and the French reprocessing plant at La Hague will have IAEA safeguards applied only to their product-storage areas, and not to the entire plants, which is permissible since they are located in nuclear-weapon states.

[34] As of December 31, 1994, the payment status of those former Soviet republics that are members of the IAEA is as follows: Armenia, Kazakhstan, and Uzbekistan have made no payments. Belarus and Ukraine, which had formally been members of the IAEA even while the Soviet Union existed, are fully paid for 1991 but have not paid since then. Russia is fully paid for 1991 and 1992 and has paid 23 percent of its 1993 assessment and none of its 1994 assessment. Estonia has made a partial payment and Lithuania is fully paid for 1993 and 1994. From letter of Jan. 17, 1995 from Jan Priest, Division of External Relations, IAEA, addressed to Marvin Peterson, United States Mission to the United Nations System Organizations in Vienna, responding to Office of Technology Assessment questions, p. 3.

[35] At just over 25 percent of the total, the U.S. contribution is the largest single contribution to the IAEA of any member state.

[36] The 1991 agreement between Brazil, Argentina, the Argentine-Brazilian Agency for Accounting and Control of Nuclear Materials (ABACC), and the IAEA will add over $2 million yearly to the IAEA's safeguards costs upon entry into force. David Fischer, "Innovations in IAEA Safeguards to Meet the Challenges of the 1990s," in *The New Nuclear Triad: The Non-Proliferation of Nuclear Weapons, International Verification and the International Atomic Energy Agency* (Southampton, U.K.: Programme for Promoting Nuclear Non-Proliferation, Sept. 1992), p. 29.

recently concluded or are concluding full-scope safeguards agreements with the IAEA, as required by the Treaty of Tlatelolco (in the case of Argentina and Brazil) or the nuclear Non-Proliferation Treaty (the others). These safeguards agreements require the IAEA to apply safeguards to all nuclear facilities in these countries, noticeably expanding the IAEA's total workload.

- In the 1990s, almost a dozen safeguarded facilities will be handling plutonium. These activities, including reprocessing as well as fabrication of MOX (mixed oxide, consisting of uranium oxide combined with plutonium oxide) fuel, make special demands on safeguards. Total costs to the IAEA for safeguarding these facilities will likely increase to $50 million per year and require a "quantum leap" in inspection effort.[37]
- The IAEA has greatly increased the attention and resources devoted to finding undeclared nuclear facilities, a mission it had not undertaken before the Gulf War.

Mitigating these additional expenses somewhat is the 50 percent reduction in IAEA inspection expenditures devoted to EURATOM states that has been made possible through closer collaboration and coordination between EURATOM and the IAEA. Through the New Partnership Approach, the IAEA and EURATOM intend to reduce redundancy in inspections of the same facilities while retaining the IAEA's ability to make its own independent assessments.[38] Even with these savings, however, **a zero-growth budget makes almost no sense in this environment.** The IAEA's current responsibilities do not lessen when it concludes new safeguards agreements, or when new facilities are added to existing safeguards agreements.

The United States has suggested "real growth" be interpreted to mean added expenditure *above and beyond that required to address these mandatory obligations*. In this way, the IAEA would not suffer financially from the imposition of new safeguards responsibilities that it does not have the ability to avoid. However, the United States has not been able to persuade other IAEA members to accept its view. Fiscal hardliners, including close U.S. allies such as Japan, Germany, the United Kingdom, and France, are not willing to make provision in the IAEA budget for these nondiscretionary increases.

Even if agreement could be reached to increase funding for the IAEA, issues of fairness and proportionality—both with respect to *who* should pay more and *how* the added money should be allocated between safeguards and technical cooperation programs—tend to complicate the debate over overall funding levels, as discussed below.

Options for the United States:

- **Pay IAEA dues on time.** Although IAEA assessments for a given calendar year are due on January 1, the United States delays its payment at least nine months, until the following fiscal year begins on October 1. (Delaying the payment from January 1 to October 1 had the effect of creating a one-time reduction in the federal budget the year the shift took place; moving the payment back would require a corresponding one-time increase.) This nine-month delay aggravates IAEA cash flow problems.
- **Raise the U.S. extrabudgetary contribution and level of technical assistance to safe-**

[37] See, e.g., Frans Berkhout et al., "Disposition of Separated Plutonium," *Science & Global Security*, vol. 3, Nos. 3-4, 1993, pp. 161-214.

[38] S. Thorstensen and K. Chitumbo, "Increased Co-operation Between IAEA and Euratom: The New Partnership Approach," Symposium Proceedings, *International Nuclear Safeguards 1994*, op. cit., footnote 30, p. 271

guards. The IAEA's formal safeguards budget, $68.6 million in 1994, is quite modest. It represents about one-third of the IAEA's regular assessed budget, which that year totaled $200.1 million.[39] In addition to the regular budget, the IAEA also receives extrabudgetary contributions, some of which are devoted to safeguards. Total United States funding for the IAEA in 1994 consisted of a $49.9 million assessment and a $30.0 million extrabudgetary contribution. Of this $30.0 million, $14.6 million was paid into the IAEA's Technical Cooperation and Assistance Fund, or TACF (see box 3-3).

Another $6 million went to specific technical cooperation activities that were not funded from the TACF, and the remainder—$9.4 million—provided extrabudgetary support for safeguards.[40] Therefore, the United States contributed $28.3 million towards IAEA safeguards in 1994, an amount on the order of one ten-thousandth of the United States national security and international relations budget.[41]

Given the extensive and increasing responsibilities of the IAEA safeguards program, and the U.S. interest in strengthening them, the United States might wish to consider greatly increasing its safeguards contributions. It has already pledged to increase its extrabudgetary contribution for 1995 to $40.0 million, of which $16.2 million will be devoted to safeguards.[42] Even at $100 million per year, this contribution would be a tiny share of the U.S. national security budget. Greatly increased safeguards budgets would allow the maintenance or even expansion of rigorous safeguards on "non-problem" states as well as increased attention to "problem" states. In this way, the IAEA could get around the major political difficulty of targeting safeguards efforts on the basis of any judgment of proliferation risk.

Even if the United States were to increase its own contribution, however, the IAEA faces institutional barriers to accepting the additional funds entirely for safeguards purposes. First is the pressure from many member states to balance the IAEA's safeguards activities with nuclear promotion and technical assistance activities. Raising one will almost certainly require raising the other (see the option on removing the linkage between safeguards and assistance, below). Second is the reluctance of many states—including advanced industrial states with large nuclear programs—to increase the safeguards effort devoted to their own nuclear facilities, particularly if they are required to pay for it. Third is the perception that safeguards only matter to those few states that are paying the bulk of its expenses, and that therefore the rest of the IAEA's membership need not pay for or care very much about them.

Options available to the IAEA:

- **Relax safeguards standards (significant quantities, timeliness goals, or achievement of inspection goals).** This is not an option any party would like to see implemented, but rather could be the de facto consequence of the increased demands that have been placed on the IAEA if additional funds or efficiencies in operation are not found.
- **Increase overall assessments charged to IAEA member states**. Over the past decade, and particularly since the Gulf War, the IAEA's member states have been extremely reluctant to

[39] To minimize the effect of exchange rate fluctuations, the IAEA budget is assessed in a mix of U.S. dollars and Austrian schillings. However, changes in exchange rates may nevertheless introduce disparities between budget figures for different years, or between budgetary assessments and actual payments.

[40] 1994 budget figures are from "IAEA Funding in 1994," provided by the U.S. Department of State, March 1995.

[41] The $28.3 million for safeguards breaks down into $18.9 million from the U.S. formal assessment, which represents 28.1 percent of the IAEA's regular safeguards budget, plus the $9.4 million in extrabudgetary safeguards support.

[42] "IAEA Funding in 1994," op. cit., footnote 40. In recent years, the United States has provided over 70 percent of the total extrabudgetary cash contributions for safeguards. This percentage can be expected to increase significantly for 1995, given the increase in the U.S. extrabudgetary safeguards contribution.

BOX 3-3: Technical Assistance Programs[1]

The IAEA has engaged in technical assistance and cooperation with member states since 1958, at first in accordance with the "Atoms for Peace" program suggested by the United States and later in accordance with Article IV of the Non-Proliferation Treaty. That Article gives all NPT parties "the right to participate in the fullest possible exchange of equipment, materials, and scientific and technological information for the peaceful uses of nuclear energy ., . especially in the territories of non-nuclear-weapon States Party to the Treaty, with due consideration to the needs of the developing areas of the world." Its inclusion in the NPT was one of the *quids pro quo* for the IAEA's right to inspect sites containing nuclear material, under Article Ill.

In 1993, technical assistance funding supported 1,373 projects in 86 countries at a level totaling $45 million, an amount about two-thirds the size of that year's safeguards budget. The largest share, or just over 20 percent, of technical assistance funding was devoted to food and agriculture.[2] Just under 20 percent went to nuclear safety programs: radioactive waste management, radiation protection, and safety of nuclear installations. Assistance in physical and chemical sciences came to 18 percent of the total, followed by industry and earth sciences at 14 percent, human health at 14 percent, and nuclear power and the nuclear fuel cycle (other than the safety program mentioned above), together at 9 percent. The bulk of these funds, or $36,7 million, came from the IAEA's Technical Assistance and Cooperation Fund, consisting of voluntary contributions made by Member States (aimed at a target established by the Board of Governors) beyond their yearly assessed contributions to the IAEA. Member states also provided $5.6 million in cash in addition to their contributions to the Technical Assistance and Cooperation Fund, as well as $1.6 million in in-kind contributions. Finally, the United Nations Development Program provided $1,4 million for a number of specific projects.

Top recipients of IAEA Technical Assistance, 1958-93

Country	**$ millions**
Egypt	24,7
Brazil	18.5
Thailand	16,1
Indonesia	15.0
Peru	13.8
Pakistan	12.7
Philippines	12.4
Bangladesh	11.8
South Korea	11.7
Yugoslavia	11.7
Total of top 10 recipients	148.4
Total of all recipients	617.5

(continued)

[1] IAEA budgetary figures in this box are from International Atomic Energy Agency, *The Agency's Technical Cooperation Activities in 7993,* Report by the Director General, GC(XXXVlll)/lNF/3, August 1994, tables on pp. 9, 10; table 7, Financial Summary, 1993, pp. 66-68; and table 8, Financial Summary: 1958-1993, pp. 69-71,

[2] Agriculture programs include a variety of projects based on the ability of radioactive isotopes to be traced as they Pass through Iiving organisms. For example, radioisotopes are used to examine the abilityof different crops to fix nitrogen from the atmosphere, thus reducing dependence on chemical fertilizers. Another agricultural area of study IS the development of superior strains of food plants through radiation-induced mutations and subsequent selection. A third is pest control using nuclear techniques, such as using high radiation doses to render insects sterile. When released into the environment in large numbers, these resects can overwhelm preexisting, fertile insects in competing for mates. In this way, further reproduction of the pest can be greatly reduced, A fourth area of research is the use of radiation to preserve food by killing pathogens and other organisms responsible for causing it to spoil.

BOX 3-3 (Cont'd.): Technical Assistance Programs

From its inception through 1993, the IAEA has provided $617 million worth of technical assistance in three broad categories: expert advice, equipment, and fellowships and training programs. The table lists the countries that received the most IAEA technical assistance through 1993.

Assistance programs in the areas of nuclear fuel cycle studies, and in physical and chemical sciences, have given rise to some concern regarding the potential for proliferation. One recent example would be a relatively large program of assistance ($0.8 million in 1993; $8.2 million total through 1993) to Iran, much of which was devoted to development of a major cyclotron laboratory. Iran recently imported a cyclotron from China for isotope production. Cyclotron-based techniques can also be used to separate isotopes on a small scale, Such separation is necessary to produce radioisotopes for research and can also be used to analyze how these isotopes are taken up by organisms. However, on a larger scale, this technology (electromagnetic isotope separation) is the very one used by Iraq in 1990 to produce highly enriched uranium for its nuclear weapon program, If uninterrupted, Iraq would have produced enough material within a few years to make nuclear weapons.

In general, assistance at the level and for the purposes provided by the IAEA makes little direct contribution to a nuclear weapon program. However, the skills and expertise that might be acquired by a state through such assistance could be relevant, both in terms of basic knowledge in dealing with nuclear materials and nuclear technology, and also possibly in terms of extrapolating techniques a state first learns through IAEA technical assistance, Even if such assistance might lend indirect support to a nuclear weapon program, though, the IAEA may not be able to refuse to provide it to a state that appears to be in full compliance with its nonproliferation commitments. Both Article IV of the NPT and the IAEA Statute itself mandate that assistance be provided to Member States. For example, although the United States believes that Iran is pursuing nuclear weapons, neither the United States nor the IAEA has provided public evidence that Iran has violated its Non-Proliferation Treaty commitments. Therefore, the IAEA has no basis on which to deny technical assistance to Iran.

More generically, questions could be raised about this sort of dual-use assistance to other states, whether or not the United States considers them to be of special proliferation concern, For example, cyclotron help is provided to several states, including South Korea, Indonesia, Turkey, Egypt, and, somewhat disturbingly, North Korea. North Korea received $266,000 in technical assistance from the IAEA in 1993, and a total of $6,4 million through 1993, before the IAEA's Board of Governors suspended technical cooperation in June, 1994 over North Korea's refusal to accept IAEA special inspections. Soon afterwards, North Korea withdrew from the IAEA. According to the IAEA and to the NPT's member states, North Korea remains legally bound by the terms of the NPT and its safeguards agreement. However, North Korea does not consider itself so bound, and it is not in full compliance with this agreement as of this writing.

raise its budget despite the growing demands. Even if they should agree to increase their respective assessments, they would still need to deal with balancing safeguards against technical promotion, and safeguards on the developing world against those on the industrialized states.

The reluctance of member states to accept increased assessments for many United Nations organizations stems at least in part from the perception that these organizations do not spend their funds efficiently. Increased efficiencies should be sought, in this view, before assessments are increased. The IAEA, however, does not appear to share the widespread reputation attributed to U.N. agencies in general for fiscal and managerial laxity. *A* 1993 *study of the IAEA safeguards program by the U.S. General Accounting Office, an organization that among other things investigates allega -*

tions of waste, fraud, or mismanagement, did not raise such questions regarding the IAEA.[43]

- **Weaken or remove the linkage between the safeguards budget and technical assistance programs.** Many developing states view their commitments to accept nuclear safeguards as balanced by the provision of technical assistance in nuclear energy and other peaceful applications of nuclear technology—one of the bargains built into the IAEA from its outset. These states continue to apply pressure to maintain a rough parity between the IAEA's allocations for safeguards and those for promotional activities and "technical cooperation" (see box 3-3).[44] Since pledges and actual payments to the technical cooperation program have declined, while demands on the safeguards budget have increased, it becomes increasingly difficult to maintain the "target ratio" between cooperation and safeguards. Therefore, it has become correspondingly difficult to contemplate a significant redirection of funds toward safeguards in developing states, even if such funds were to become available.

  The linkage between safeguards and technical cooperation, however, has been challenged on a number of grounds. First, there is no inherent relationship between the risks of diversion of nuclear materials worldwide—and the consequent demands on the safeguards budget—and the need for technical assistance and promotion in the fields of nuclear science and technology. Second, it is not clear that technical assistance in nuclear-related technologies is the most appropriate way to meet the needs of developing countries. Article IV of the NPT, which calls for contributions "to the further development of the applications of nuclear energy for peaceful purposes," holds that due consideration should be given to "the needs of the developing areas of the world." If those needs are not appropriately served by nuclear technology, Article IV would not seem to require nuclear solutions.

  Despite these questions, the linkage between safeguards and technical cooperation will be difficult, if not impossible, to break. Without the provision of technical assistance in nuclear fields, many states would never have agreed to submit to the safeguards regime at all. *International organizations whose very existence depends on compromises that were made years ago will not have an easy time reformulating those compromises.*

  One possible solution would be to find some mechanism to provide technical assistance in energy technologies, medical technologies, or agricultural technologies generally to supplement the narrower assistance provided by the IAEA in the nuclear-related aspects of these fields. The IAEA would probably not be the appropriate vehicle to provide this type of general assistance, since its expertise and mission specifically involve nuclear technology. Moreover, the total amount of technical assistance the IAEA can provide is very small compared with funding available for development assistance in general. However, political agreements or understandings might be made between donor and recipient states in which non-IAEA sources of technical assistance would be increased at the same time that pressures that tied the IAEA's safeguards budget directly to technical assistance were relaxed.

Reallocation of Inspection Effort

Whether or not overall resources devoted to safeguards are increased, it is important to use the

[43] United States General Accounting Office, *Nuclear Nonproliferation and Safety: Challenges Facing the International Atomic Energy Agency,* GAO/NSIAD/RCED-93-284 (Washington, DC: U.S. General Accounting Office, September 1993).

[44] The total value of the Technical Assistance and Co-operation Funds contributions delivered in 1993 amounted to $36.7 million. Total assistance provided that year, including U.N. Development Program funds, member state extrabudgetary contributions, and member-state "in-kind" contributions, totaled $45.3 million.

available resources efficiently. In the case of safeguards, efficiency means getting the most value toward detecting safeguards violations and thereby deterring-or providing warning of—proliferation. Since IAEA inspection efforts depend on the amount and type of nuclear material under safeguards and the size of the facilities processing it, a large portion of the total IAEA safeguards budget (some 46 percent at present) is spent on Germany, Japan, and Canada, the states with the largest and most advanced nuclear programs under safeguards.[45] None of these countries is regarded by most observers as a current proliferation risk, especially with respect to cheating on safeguards or attempting to divert material from civilian fuel cycles.[46] In addition, the majority of the safeguards effort is applied to facilities involving the greatest amount of material—those associated with civilian nuclear power production—rather than to other nuclear activities, such as research reactors, that are more likely to benefit a weapon program. Various proposals for saving money within the IAEA have thus focused on redirecting effort to countries that are thought to pose a greater risk.

OPTION: *Reallocate inspection effort toward problem states.*

Many feel that, given the constraints of a zero-real-growth budget, there is a need to focus greater safeguards efforts (including environmental monitoring to look for undeclared facilities) toward states either in regions of political tension or with only marginal nonproliferation records.

There is already some authority within INFCIRC/153 to adjust routine inspection requirements (subject to certain limits) based on a country's overall fuel-cycle characteristics (see box 3-4).[47] **This authority might be exploited more fully, especially for *future* safeguards agreements,** although renegotiating safeguards agreements already in force would be much more difficult. For instance, more emphasis could be placed on a country's overall amount of "direct-use" fissile material (e.g., material containing highly enriched uranium or plutonium). If a country possesses enrichment or (especially) reprocessing facilities, additional inspection efforts might be justifiable even if amounts of fuel being irradiated in various reactors were small. (See the following option for discussion of the converse approach of reducing inspection effort in states that offer the IAEA widespread access and technical visits, with the aim of providing assurance that they do not possess undeclared facilities.) Some have taken this argument even further, suggesting that several measures in addition to the INFCIRC/153 provisions mentioned above be used in determining a country's level of inspection effort. These measures might include the size or growth of a state's military forces, its possession or development of vehicles suitable for delivering weapons of mass destruction, its import of key dual-use technologies, its involvement in regional tensions, or even its human-rights record.[48]

However, the IAEA is forbidden by its statute to discriminate against member states. Therefore, **unless a reallocation of inspection effort could**

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[45] The 46 peercent share is stated in the Jan. 17, 1995 letter from Jan Priest, IAEA, in response to Office of Technology Assessment questions, op. cit., footnote 34, p. 3. Earlier estimates of the fraction of safeguards resources devoted to Japan, Germany and Canada had been higher; it was given as 55 percent in Scheinman, op. cit., footnote 3, p. 20.

[46] Even if governments seekking nuclear weapons were to come to power in such countries, they would probably be more likely to withdraw from the NPT, which would permit the development of a large arsenal, than mount an expensive, difficult, and risky attempt to divert as little as one bomb's worth of fissionable material per year from safeguarded facilities.

[47] See paragraph 81, INFCIRC/153.

48 For example, see David Kay, "The IAEA—How can It Be Strengthened?" paper presented at the conference *Nuclear Proliferation in the 1990s: Challenges and Opportunities,* Woodrow Wilson Center, Washington, DC, Dec. 1-2, 1992, p. 16.

BOX 3-4: Legal Limits on IAEA Routine Inspection Effort[1]

The model safeguards agreement for NPT states, INFCIRC/153, lays out general guidelines for the routine inspection effort that should be applied to various types of facilities, based on the type and amount of nuclear material they use. Such guidelines are primarily in the form of ceilings on inspector effort, called "maximum routine inspection effort" or MRIE (see definitions below).

The *actual* routine inspection effort (ARIE) for a given facility is negotiated by IAEA and the state separately for each safeguarded facility.[2] In practice, inspection frequencies are then chosen so that the IAEA can meet its goals for detection times—i.e., so that it can detect the diversion of nuclear material on a time scale roughly comparable to what it would take to fabricate that material into a weapon—according to the following:

Unirradiated direct-use material:	one month
Irradiated direct-use material:	three months
Indirect-use material:	one year

MRIE. As specified in paragraphs 79 and 80 of INFCIRC/153, the "maximum routine inspection effort (MRIE)" is the maximum number of person-days of inspection work (up to 8 hours of access to a facility during one day) per annum allowable for a given facility. This limit depends on the larger of its inventory, annual throughput, or maximum potential annual production of nuclear material, which is denoted L and expressed in effective kilograms (see definition below).

L <5 effective kilogram (ekg): one routine inspection per year

L >5 ekg:

Reactors and sealed stores: 50 Person-Days-Inspection (PDI)/year[3]

Facilities containing Pu or U enriched to more than 5 percent:

$MRIE = 30 \times L^{1/2}$ PD1/y, but not less than 450 PDI/y

All other cases: MRIE = (100 + 0.4L) PDI/y.

ARIE. "Actual routine inspection effort" is the estimated annual inspection effort under an INFCIRC/153 agreement, based on a plant operating fully according to its design data The ARIE is negotiated and included in the facility attachment. It cannot exceed the MRIE above. In accordance with paragraph 81 of INFCIRC/153, due consideration of the following factors should be given to the following when the ARIE is being established:

1. The form and accessibility of the nuclear material (bulk form v. discrete items, chemical composition, enrichment);
2. The effectiveness of the State System of Accounting and Control (SSAC), the extent to which the operator is functionally independent of the SSAC, the promptness and consistency of the State's reports, and the value and accuracy of the MUF as verified by the Agency;
3. The characteristics of the State's nuclear fuel cycle, in particular the number and types of facilities and the characteristics of such facilities relevant to safeguards (e.g., containment and ability to correlate information from different material balance areas);

[1] *IAEA Safeguards Glossary,* 1987 *Edition,* op. cit , PP. 65-66

[2] The ARIE is usually significantly less than the MRIE for some types of facility, but facility-specific values are safeguards-confidential.

[3] Small research reactors typically contain less than 5 effective kilograms of HEU, but larger ones, such as the approximately 40 MW(th) Osirak reactor in Iraq, can contain more. The latter was being inspected 3 times per year prior to its being attacked by Israel in 1981, and inspection efforts would have increased had it become operational.

(continued)

BOX 3-4 (Cont'd.): Legal Limits on IAEA Routine Inspection Effort

4. The international interdependence of nuclear activities involved and any relevant IAEA verification activities; and

5. Technical developments in the field of safeguards (e.g., statistical and random sampling techniques).

In practice, since the ARIE cannot exceed the MRIE, these factors can only be used to reduce the inspection effort, not to increase it. For instance, agreed ARIE person-days of inspection at reactors vary and can be set at levels up to 50, but normally do not exceed an upper limit of 10 or 15.[4] In addition, actual person-days of inspection can be less than the ARIE if there are extended shutdowns of the facility,

Effective kilograms (ekg). The number of "effective kilograms (ekg)" for plutonium and uranium-233 is equal to their mass in kilograms. For uranium enriched to at least 1 percent uranium-235, the ekg is the total amount of uranium times the square of the enrichment level. Thus 10 kilograms of 90 percent uranium-235 is 8.1 ekg, 10 kg of 20 percent uranium-235 is 0.4 ekg, and 10 kg of 5 percent uranium-235 is 0.025 ekg. Thus, the actual mass of uranium-235 present at lower enrichments is considerably more than the ekg value.

Time Allowed Before Safeguards Must Come into Effect. Article Ill of the NPT requires a state's safeguards agreement to "enter into force" within 18 months of its ratification or accession to the NPT. INFCIRC/153, paragraph 40, requires that Subsidiary Arrangements, which include Facility Attachments specifying actual inspection procedures for each safeguarded installation, enter into force within 90 days of entry into force of a state's safeguards agreement. Thus, there is no legal requirement for routine inspections to begin until 21 months after a state joins the NPT. However, the IAEA may conduct ad hoc inspections of any facilities declared in a state's safeguards agreement before, during, or after Subsidiary Arrangements are completed. Thus, inspections usually begin no later than up to about 18 months after a state joins the NPT.

[4] J.E. Lovett, "Nuclear Materials Safeguards for Reprocessing," International Atomic Energy Agency Report STR-151/152 (December 1987), pp. 208. Lovett also asserts that verification and sealing of spent fuel shipping casks at reactors would require levels of effort that are neither possible within agreed ARIE levels nor feasible with currently available inspector staff levels

be justified under some objective criteria, the IAEA would face serious institutional difficulties in making what would be perceived to be a political determination that some states are more trustworthy than others. Moreover, subjective criteria would be considered vulnerable to political distortions, making them nearly impossible for the IAEA to use when negotiating safeguards agreements. Certain member states might feel that they were being unjustly singled out. For instance, some states represented on the Board of Governors have been known to take a very conservative approach to such matters, fearing that any more stringent requirements that they allowed in another state might eventually come back and be applied to them. Adding another discriminatory practice on top of the already-existing distinction in the NPT between nuclear "haves" and "have nets" might damage the political consensus behind that treaty itself.

If reallocating safeguards effort away from states not thought to pose near-term proliferation threats had the effect of relaxing safeguards standards there, long-term risks could arise-particularly for states with extensive nuclear fuel-cycle infrastructures involving enrichment or reprocessing. If the continuity of safeguards were lost in one of these countries and a new government that sought nuclear weapons came to power, the IAEA could have a great deal of difficulty reestablishing a strict full-scope safeguards regime.

It remains to be seen how far the IAEA can push already existing authority to focus more of its resources on states of greater proliferation concern, especially in countries whose safeguards agreements have been in force for some time. However, the United States, being one of the most influential members of the IAEA, could try to push the agency in this direction, if it chose. INFCIRC/153 also gives the IAEA authority to conduct "special inspections" if reasonably justified to carry out its safeguards obligations, and these could also be used more effectively in problem countries. Some increased efforts along these lines have already been taken in North Korea and South Africa, two countries that have recently completed their safeguards agreements (albeit under extremely different circumstances).[49] Since special inspections can be requested "if the Agency considers that information made available by the State, including explanations from the State and information obtained from routine inspections, is not adequate for the Agency to fulfill its responsibilities under the [safeguards] Agreement," some flexibility would certainly seem authorized in invoking this provision, and greater use could probably be justified in less cooperative states without overstepping this authority.

■ Expansion of Safeguards via "Enhanced Transparency"

Transparency measures refer to actions taken by a state to enhance the visibility and openness of its own activities in order to reassure others that it is not threatening their security, or in order to make it more difficult for other states to hide their own activities. In the area of nuclear safeguards, such measures might include providing access to IAEA inspectors above and beyond what is required by a state's safeguards agreement. Making *transparency* a norm of international behavior might enable the IAEA-or the world community-to become aware more easily of undeclared nuclear facilities or other state practices that could indicate the existence of a nuclear weapon program. As a result, IAEA safeguards would be bolstered, and states would gain added assurance that their neighbors were not mounting nuclear weapon programs. Increased transparency might also be associated with reduced routine inspection effort, permitting more efficient application of the IAEA's limited safeguards resources.[50]

One technique that can take advantage of additional transparency is the taking and analysis of environmental samples, which the IAEA is exploring as a means for detecting and/or characterizing undeclared nuclear facilities. The IAEA is also accepting invitations by states such as Iran and South Africa to conduct "visits' '-rather than formal inspections—to sites where questions may have been raised.

OPTION: *The United States could encourage states to make, and the IAEA to accept, offers to provide information and accept inspections not specifically required by safeguards agreements.*

If greater transparency by inspected states can help the IAEA satisfy itself that all facilities capable of processing or producing fissile material are safeguarded (i.e., that a given state lacks even the potential to operate any undeclared facilities and does not have access to such facilities anywhere else), then the agency can have confidence that nuclear material at reactors and in storage has not been diverted for weapon use-even if it has not been accounted for with the high statistical confidence levels and timelines now required.[51] The idea would be to move away from the traditional

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[49] Since South Africa volunteered very broad access to its territory, the IAEA was able to make so-called ad hoc visits to all the sites it wanted to see without having to invoke the "special inspection" machinery of its safeguards agreement with that country. Lack of North Korean cooperation, on the other hand, forced the IAEA to demand special inspections there. As of this writing, these requests have not been granted.

[50] See, e.g., David Fischer, op. cit., footnote 36, and Scheinman, op. cit., footnote 3.

[51] Scheinman, op. cit., footnote 3, p. 41.

focus on strictly quantitative material accountancy methods (which are increasingly difficult to apply rigorously as facility throughputs get larger) toward an approach that can also utilize the less quantitative types of information that are volunteered through transparency measures. For instance, the requirement for inspections every three months of spent fuel containing significant amounts of irradiated plutonium might be relaxed, perhaps in conjunction with real-time, automated monitoring of the spent fuel pond, if the IAEA could be assured that a country had no reprocessing facilities nor access to any. As Scheinman explains,

> [The value of these measures] lies not in the ability of the agency to draw conclusions identical to those drawn from the system of material accountancy—which it well may not be able to do. Rather, [it] lie[s] in the contribution that a flexible verification system makes to the **perception** of both the inspected party and outside states about the risk of detection, and, consequently, the willingness of a would-be proliferator to take the risk in the first place.[52]

The right to tailor safeguards procedures to an individual state's facilities, control systems, and behavior is implicitly incorporated into the original model safeguards agreement. Provisions for modifying the frequency and notification requirements for safeguards inspections based on various qualitative and quantitative aspects of a state's fuel cycle and reporting practices, as well as on developments in statistical techniques and random sampling, are contained in INFCIRC/153 (paragraphs 81 and 84). Nevertheless, such safeguards modifications have never been fully exploited, since the factors upon which they would be justified are not easily quantifiable.

Apart from seeking to reduce their inspection burden, states with nothing to hide may be willing to accept inspections and volunteer information not specifically required by their safeguards agreements. In so doing, they not only provide added assurance that they are complying with their own commitments, but also encourage others to do likewise. However, they may also need to balance such transparency against security, proprietary, or constitutional concerns that could argue against providing unlimited access. During the negotiation of the Chemical Weapons Convention (CWC), which provides for quite intrusive "challenge inspections" of suspect sites, such concerns led to the development of "managed access" provisions. These provisions specify negotiation procedures and timeliness by which inspectors must be granted some access to the requested site, and they obligate the inspected state to address whatever concerns have motivated an inspection request. However, they ultimately give the inspected state the right to limit access (see box 3-5). Similar protections would probably be associated, implicitly or explicitly, with any offers of additional access to the IAEA.

In principle, the signature of the Chemical Weapons Convention by 159 countries (as of this writing) indicates widespread international acceptance of its monitoring and inspection provisions, offering the prospect that CWC signatories may be willing to grant the IAEA a corresponding degree of openness. However, this apparent acceptance is tempered by the much slower rate at which the CWC signatories are ratifying it. (As of the same date, only 27 countries had deposited their instruments of ratification.) Moreover, since the convention has not yet entered into force, no inspections have been carried out, and nobody can tell how its commitment to transparency will be realized in practice.

By providing additional information, voluntary offers of openness improve the IAEA's ability to do its job. However, they can also pose some risk to the IAEA. First of all, acting on them will require additional resources, exacerbating the IAEA's financial difficulties. Second, voluntary

[52]Ibid., p. 23. Emphasis in original.

BOX 3-5: Challenge Inspections Under the Chemical Weapons Convention[1]

Under the Chemical Weapons Convention (CWC), a state party that suspects another party of violating the treaty's provisions can call for a *challenge inspection* of any site within the suspected violator's territory. The treaty and its associated Verification Annex specify a sequence of procedures and timelines under which the inspected state must give international inspectors access to the suspect site, and they also provide for a series of negotiations to determine how much access the inspected country must provide. The fact that 159 countries have signed the Chemical Weapons Convention (as of February 1995) shows that these provisions have gained widespread international acceptance, and it *may* indicate-although does not guarantee-that states would be willing to grant equivalent access to IAEA inspectors. On the other hand, the true commitment of states to these provisions has not been tested; as of the same date, over 25 countries had deposited their instruments of ratification for the CWC, but well short of the 65 ratifications needed to bring the treaty into force. Therefore, no experience has yet been gathered in conducting such inspections or in gauging states' reactions to them.

CWC Challenge Inspections

The Chemical Weapons Convention creates a new international organization, the Organization for the Prohibition of Chemical Weapons (OPCW), to implement the CWC's provisions. In a role somewhat analogous to the IAEA, the OPCW will contain a Technical Secretariat to compile the data that member states must submit under the CWC, and to conduct routine and challenge inspections. Any treaty party can initiate a challenge inspection by providing specific information about the site in question to the Director General of the OPCW's Technical Secretariat, who then passes it to the OPCW's Executive Council. To prevent abuses of the challenge inspection provisions, a 3/4 vote of the Executive Council can block an inspection request judged to be "frivolous, abusive, or beyond the scope of the treaty."[2] Otherwise, the Director-General is obligated to conduct the inspection without delay. Unlike an IAEA special inspection, which must be negotiated with the state to be inspected and therefore can at least be delayed, if not stalled indefinitely, a challenge inspection under the CWC cannot legitimatly be delayed or blocked by state being challenged. The inspected state must be notified of the location of the site to be inspected at least 12 hours before an inspection team is to arrive at a point of entry.

Within 36 hours of the team's arrival, the host state must transport it to the perimeter of the suspect site, where it will be allowed to examine traffic logs, take photographs and videos, and visit other portions of the perimeter. If the site perimeter requested by the inspection team is not acceptable to the host nation, the host (with some conditions) can propose an alternate. Negotiations over the final perimeter can continue for up to 72 hours from the team's arrival at the perimeter, at which point—if agreement has not been reached—the alternate perimeter will become the final perimeter. When the final perimeter is determined, the inspection team will be allowed to take air, water, and effluent samples, and use monitoring instruments.

Managed Access

Within 108 hours of the inspection team's arrival at the host nation's point of entry, it must be allowed access within the perimeter of the suspect site. The degree of access granted is to be negotiated between inspectors and host under the principle of "managed access, " by which the host state is obligated to allow the "greatest degree of access" consistent with any "constitutional obligations it may have with regard to

(continued)

[1] This box is based on U.S. Congress, Office of Technology Assessment, *The Chemical Weapons Convention: Effects on the U.S. Chemical Industry,* OTA-BP-ISC-106 (Washington, DC: U.S. Government Printing Office, August 1993), pp. 5-6 and 27-28; on Amy Smithson (cd.), *The Chemical Weapons Convention Handbook,* Handbook No. 2 (Washington, DC: The Henry L. Stimson Center, September 1993), pp. 31-34; and on the Chemical Weapons Convention itself, formally known as the *Convention on the Prohibition of the Development, Production, Stockpiling, and Use of Chemical Weapons and on Their Destruction* (denoted here as *CWC),* United Nations, 1993.

[2] CWC, Article IX ("Consultations, Cooperation, and Fact-Finding"), paragraph 17.

BOX 3-5 (Cont'd.): Challenge Inspections Under the Chemical Weapons Convention

proprietary rights or searches and seizures" and with the protection of national security information.[3] The inspection team is required to conduct its inspection "in the least intrusive manner possible" that will permit it to accomplish its mission.[4] To protect sensitive installations or information, the host state may take measures such as removing sensitive papers from offices, shrouding displays or equipment, turning off computer systems, restricting sample analysis to determining the presence or absence of compounds indicative of treaty violation, or permitting access to a randomly selected fraction of buildings or rooms. In those areas where full access is not granted, the host nation is obligated to make "every reasonable effort" to provide alternate means to address the concerns that prompted the challenge inspection request.[5] The inspection itself may not last more than 84 hours, unless extended by agreement with the host.

After review by the inspected state, the inspection team's report will be transmitted to the Executive Council and to all other CWC members, with the provision that certain sensitive information may be retained within the Technical Secretariat. The inspection report is to include "an assessment by the inspection team of the degree and nature of access and cooperation granted to the inspectors, "[6] Consequently, the Executive Council and member states can draw their own conclusions from a determined effort by the inspected party to frustrate the inspection, even if no overt evidence of violation is found.

[3] CWC, Annex on Implementation and Verification, Part X ("Challenge Inspections Pursuant to Article IX"), paragraph 41,
[4] Ibid., paragraph 45.
[5] Ibid., paragraph **42.**
[6] Ibid., paragraph 59.

invitations to conduct such visits can be retracted at any time, as was demonstrated in North Korea (see box 3-6). Finally, and perhaps most seriously, visits that do not uncover suspicious activities might be overinterpreted to give the inspected state a "clean bill of health." All that such a visit should imply is that nothing untoward was discovered at that site at that time.

OPTION: *Encourage the IAEA to support bilateral nuclear inspection regimes and regional arms-control and confidence-building measures.*

In addition to accepting offers by individual states to make their nuclear activities more transparent, the IAEA can also work with groups of nations in tense regions of the world to encourage confidence-building measures and promote regional arms control agreements. The model for such regional nuclear inspection regimes has been established by Argentina and Brazil, which have implemented a quadripartite inspection agreement involving themselves, the IAEA, and the newly established bilateral agency ABACC. Both countries have completed the steps necessary to bring into force the Treaty of Tlatelolco, a regional agreement banning nuclear weapons in Latin America and imposing the same constraints on nuclear weapon ambitions as does the NPT.[53] Largely due to the change from military to civilian regimes in these two countries, both seem to have renounced any nuclear weapon ambitions, making such disarmament measures possible.

On the Korean peninsula, arrangements involving mutual visits to military and nuclear installa-

[53] For discussion of how a nuclear-free zone in the Middle East might be implemented and verified, see United Nations, "Establishment of a Nuclear Weapons-Free Zone in the Region of the Middle East," Report of the Secretary-General, A/45/435, October 1990. Note that the verification requirements insisted on by states in the region would go likely go beyond those provided by the IAEA's model full-scope safeguards agreement, INFCIRC/153.

BOX 3-6: Safeguards Transparency[1]

In considering ways to improve the effectiveness of safeguards while reducing overall inspection efforts, tradeoffs are often discussed between increased transparency and reduced (and possibly more randomized) inspection frequency, The rationale for such an approach is that a state that has no access to undeclared enrichment or reprocessing plants has no way to process some types of safeguarded nuclear material (e.g., low-enriched uranium or spent fuel) to the point where it could be used in a weapon, Therefore, diversion of such materials becomes less important, and inspection effort devoted to ensuring its lack of diversion can be somewhat relaxed. For example, a possible regime could provide that a state that agreed in advance to some or all of the following measures could be a candidate for substantial reductions in routine safeguards inspections:

- Giving the IAEA the unrestricted right to carry out inspections and technical visits at short notice and at any location at which the IAEA has reason to believe that there may be undeclared nuclear material. (The state would be informed of such an inspection, but its prior right of consent would not be sought.) **From the IAEA's perspective, a state would be much more persuasive in demonstrating the absence of undeclared facilities by giving the IAEA such an unlimited right of access than by simply allowing a finite number of "special inspections" when requested.** Special inspections are a specific provision within IAEA authority, but frequent special inspections that failed to find anything suspicious could have serious repercussions on the credibility of the safeguards regime. Pre-accepted inspection provisions could be used more freely, resulting in stronger assurances overall. As many IAEA officials stress, improving access would be the single biggest help in strengthening safeguards.[2]
- Inviting the IAEA to utilize a similar, unrestricted right to make "surprise" (unannounced) inspections at any facility that contains safeguarded nuclear material.[3]
- Permitting the IAEA to take environmental samples at locations of its choosing in the inspected state.
- Providing the IAEA with full information in advance about its nuclear program and, in particular, about plans for the construction or export of any new nuclear plant, and consulting with the IAEA before taking action so that any such plant may be designed in an easily safeguardable manner.
- Permitting IAEA inspection of all nuclear facilities during construction.
- Waiving visa requirements (or issuing long-term, multiple-entry visas) to IAEA inspectors carrying appropriate travel documents or, in appropriate cases, accepting resident inspectors.

Such a package of concessions in a given country could be met with a reduced inspection effort, possibly combined with more randomized routine inspections.[4] In principle, this may significantly reduce the overall costs of applying safeguards in countries willing to be extremely cooperative with the IAEA. It might be particularly attractive for states that have substantial nuclear programs, but that lack

(continued)

[1]Material in this section is drawn from David Fischer, "Innovations in IAEA Safeguards to Meet the Challenges of the 1990s, " in *The New Nuclear Triad: The Non-Proliferation of Nuclear Weapons, International Verification and the International Atomic Energy Agency* (Southampton, U. K.: Programme for Promoting Nuclear Non-Proliferation, Sept. 1992), pp. 32-33.

[2]Some within the IAEA advocate widening the safeguards net to include uranium mines, which now fall outside the legal domain of safeguards. It is claimed that such access would significantly help in ruling out undeclared facilities and, as an example, would have helped in determining the extent of Iraq's nuclear program. Placing mines under safeguards could also allow the IAEA to use isotopic techniques to trace the origin of nuclear materials back to individual mines, aiding in the verification of certain types of material transfers within a country's fuel cycle

[3]INFCIRC/153, paragraph 84 already provides the IAEA the authority to "carry out without notification a portion of the routine insections," and such unannounced inspections are now part of the system of procedures known as the Hexapartite agreement for safeguarding gas centrifuge enrichment facilities. Although not implemented, unannounced inspections have also been included as an option in the Safeguards Criteria for low-enrichment fuel fabrication plants. Afield test of such inspections has been completed, preliminary results may be found in L.G. Fishbone et al., "Field Test of Short Notice Random Inspections for Inventory Change Verification at a Low Enriched Fuel Fabrication Plant. Preliminary Summary," Symposium Proceedings (IAEA-SM-334/164), International Nuclear Safeguards 1994, 14-18 March 1994.

[4]Such a system is currently being discussed within the IAEA, and Sweden has volunteered to serve as a test case.

BOX 3-6 (Cont'd.): Safeguards Transparency

facilities for producing unirradiated direct-use nuclear materials (separated plutonium or highly-enriched uranium), such as Canada, Sweden, Switzerland, and the Czech and Slovak Republics. It might also provide a framework for eventually subjecting the nuclear facilities of *nuclear-weapon states* to safeguards, without putting undue burden on the safeguards budget. The drawback to such proposals, however, is that relaxation of routine inspection effort will translate, in quantitative terms, to lower confidence that an SQ or more of materials has not been diverted. Unless these transparency measures actually provide the IAEA with high confidence that the inspected states have not built and do not have access to covert enrichment or reprocessing facilities with which to process any diverted materials, diversion could still pose a proliferation risk.

Transparency measures have precedents in a number of other arms control agreements and proposals, including the treaty on Conventional Forces in Europe (CFE), "Open Skies, " and the Chemical Weapons Convention.

Nevertheless, details would have to be worked out to determine an equitable means of reducing the inspection effort in any given country. Objections over fairness might be raised by countries with only rudimentary fuel cycles if benefits were seen to favor the larger industrialized states in Europe. An approach that reduced overall inspection effort might also be inappropriate for Japan, since it is the only NPT non-nuclear-weapon state operating a reprocessing plant that produces significant quantities of separated plutonium (and is building a second very large plant).

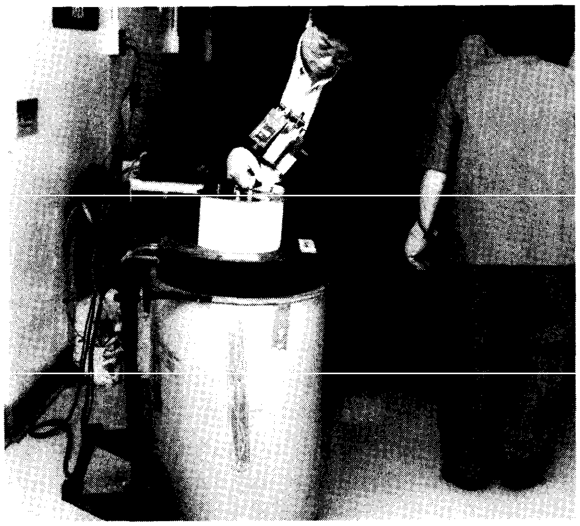
Iran, South Africa, Libya, North Korea, and other states have made statements at one time or other volunteering to accept IAEA visits more intrusive than required by NPT safeguards (in some cases, practically amounting to "anytime/anywhere" inspections). The IAEA has taken advantage of these offers in Iran and South Africa and, and, prior to March 1993, it had been permitted to visit undeclared sites in North Korea. However, as the North Korean example shows, behavior and intentions can change, and such promises must be born out in practice. Despite its pledge, North Korea threatened withdrawal from the NPT when the IAEA pressed for access to two undeclared sites suspected of storing nuclear waste. Iran poses another sort of problem. Its fuel cycle is still in its early stages, and even if it were planning to develop nuclear weapons, as the United States and other countries allege, it might not have reached the point where it had built facilities it would wish to hide. Some countries, particularly the United States, would probably remain skeptical of Iran's long-term commitment to nonproliferation even if it allowed greatly expanded rights of inspection in the near term.[5]

Many in the IAEA feel that additional voluntary offers by states allowing relatively unrestricted '(technical visits" of their facilities would be beneficial and should thus be encouraged in a number of countries, including countries such as South Korea, Sweden, Switzerland, and Taiwan, which have admitted or have at one time been suspected by other nations to have considered nuclear options. Visits to a variety of facilities, such as production facilities for armor-piercing shaped-charges or nuclear research centers based at universities, could help add needed transparency to a country's overall activities.

On the other hand, the IAEA's Standing Advisory Group on Safeguards Implementation (SAGSI), in informal comments, has strongly opposed placing substantial emphasis on such visits (although not to them per se), since they can be manipulated by the country for propaganda purposes. In any case, such offers should probably not be accepted unless made unconditionally and accompanied by a waiver of a country's right to reject IAEA designated inspectors, if not a waiver as well of the right to reject additional personnel that the IAEA might like to include in such delegations, The latter could be particularly important for technical visits to any undeclared facilities, including those for nonnuclear activities, since it could be advantageous for the IAEA to include experts (perhaps with some nuclear weapon knowledge) not regularly assigned to inspections in those countries.

[5] This does not imply however, that the United States would oppose such transparency by Iran; on the contrary, it could be expected to welcome it.

MARTIN MARIETTA ENERGY SYSTEMS



IAEA inspectors making measurements on some of the highly enriched uranium that the United States has placed under safeguards at the Y-12 facility in Oak Ridge, Tennessee.

U.S. DEPARTMENT OF ENERGY, RICHLAND OPERATIONS OFFICE

IAEA inspector and Hanford employee handle a canister of plutonium oxide during an IAEA safeguards inspection at the Hanford plutonium storage facility Hanford, Washington.

tions have been discussed bilaterally, but progress remains stalled so long as North Korea continues to violate its safeguards obligations to the IAEA.

OPTION: *Expand the scope of the nuclear facilities subject to the United States' "voluntary offer" to accept safeguards not required by the Non-Proliferation Treaty and encourage other nuclear-weapon states to do the same.*

The United States is taking a number of steps to increase safeguards transparency. Since 1968, it has volunteered to accept safeguards at its own civil nuclear facilities, even though it is not required to do so under the Non-Proliferation Treaty.[54] In the past, however, due to both resource constraints and lack of urgency, the IAEA has chosen to place only a few U.S. nuclear facilities under safeguards, and very few inspections had been conducted in recent years.

In 1993, the United States for the first time agreed to place under safeguards nuclear material determined to be excess to its nuclear weapon program, and in 1994 it invited the IAEA to monitor some highly enriched uranium stored at Oak Ridge, Tennessee, and plutonium stored at Hanford, Washington. The IAEA agreed to do so, and monthly inspections began in January 1995. Through its extrabudgetary contribution to the IAEA, the United States is providing resources to conduct these additional inspections so that they do not detract from safeguards activities elsewhere in the world.

The United States could increase the scope of its nuclear facilities and materials subject to its voluntary safeguards offer, urge the IAEA to inspect a greater number of them, provide the resources to do so, and encourage other nuclear weapon states to follow its lead. If a convention to freeze the production of fissile material were implemented, the United States and other weapon states could allow the IAEA to have access to former weapon-material-production facilities. Such steps would reinforce the spirit of Article VI of the

[54] As a nuclear-weapon state, the United States is not obligated by the NIT to place its nuclear facilities under IAEA safeguards. However, to assuage concerns from non-nuclear-weapon states that this exemption placed the U.S. nuclear industry at an unfair advantage, the United States has voluntarily offered to place any of its civil nuclear facilities under safeguards. (The other nuclear-weapon states have since made similar offers, although sometimes—as in the case of China and Russia—to a much more limited extent.) From the list of civil facilities that the United States offers, the IAEA decides which to accept for application of safeguards.

NPT that calls for progress toward nuclear disarmament, making it harder for other states to refuse to follow suit.

OPTION: *The IAEA could expand the use of import and export information submitted by member states.*

As part of the enhanced safeguards activities initiated after the Gulf War, the IAEA has established a registry of imports and exports of certain equipment and non-nuclear material, and of imports, exports, production, and inventories of nuclear material. States supplying such information make it harder for their trading partners to mount covert nuclear activities. The IAEA could attempt to cross-check and verify these submissions. Other options include broadening the scope of information to be reported to the IAEA, encouraging states more strongly to participate, and making the information more widely available than just within the IAEA. However, this last point would likely raise proprietary concerns among the reporting parties.[55] Moreover, if such reporting were not mandatory and universal, those states choosing to report might suffer a disadvantage with respect to those who do not.

OPTION: *Expand the scope of safeguards to include uranium mining and milling activities that are not now subject to safeguards.*

Some observers have proposed expanding the domain of safeguards to include monitoring a state's uranium mining and milling activities. Currently, these activities fall outside of the IAEA's responsibility (see box 3-7), and they are not addressed in existing full-scope safeguards agreements. Further, while non-nuclear-weapon states party to the NPT are required to inform the IAEA of the export of yellowcake (U_3O_8, produced when uranium ore is refined), there is no requirement to verify or keep track of the shipment after its importation. Placing uranium ore and yellowcake under safeguards would require either the renegotiation of safeguards agreements or the voluntary acceptance of such safeguards on the part of states conducting mining and milling activities.

Since it is very difficult to monitor and keep track of the exact quantity of nuclear material produced by these activities (quantities of ore, in particular, can be very large), this concept might be limited to mandatory reporting of all production and transfers, perhaps with spot checks but without attempting to account rigorously for all mined materials. While such measures would not satisfy material accountancy requirements, they would at least add transparency to the entirety of a state's nuclear activities and provide a rough idea of the amount of uranium available from domestic sources, thereby making it more difficult in some cases for a clandestine program to be developed. The cost of such an addition to safeguards efforts would have to be weighed against whatever improvement in effectiveness was thereby achieved.

■ Improving the IAEA's Technical Capability

Lowering "SQ" or Timeliness Thresholds

OPTION: *The United States could encourage and support the IAEA to lower "significant quantity" thresholds.*

The IAEA significant quantity thresholds-the amount of fissile material whose diversion the IAEA safeguards system is designed to detect (e.g., 8 kilograms of plutonium, or 25 kilograms of uranium-235 in a form enriched to 20 percent or more)—represent the approximate amounts that the IAEA considers to be needed for a state to make its first nuclear explosive.

Many analysts have stated that these quantities are probably too high, and that even states attempting to make their first nuclear explosive

[55] See U.S. Congress, Office of Technology Assessment, *Export Controls and Nonproliferation* Policy, OTA-ISS-596 (Washington, DC: U.S. Government Printing Office, May 1994), especially pp. 34-35, for discussion of some of the issues involved with making export data public.

BOX 3-7: What Is Exempted from Safeguards?

- Uranium mining and milling activities, including active mines, uranium-bearing ore, and (from inspection, but not from reporting exports) yellowcake before it is in a form suitable for further enrichment or fuel fabrication (INFCIRC/153, paragraphs 33-34).
- Nuclear material for use in non-nuclear activities (such as production of alloys or ceramics) or in military non-explosive uses (such as naval propulsion, although only when actually in the ship's reactor), provided its removal from the nuclear fuel cycle is declared and specified in advance (paragraphs 13-14).[1]
- Special fissionable material in gram quantities for use in sensing instruments, or plutonium containing more than 80 percent Pu-238 (paragraph 36 of INFCIRC/153).
- Up to 1 kg total of plutonium or highly enriched uranium (by uranium-235 content) or greater amounts of low-enriched, natural, or depleted uranium, as specified by paragraph 37 of INFCIRC/153, if requested by the state to be exempted from safeguards.
- Records of plant operation and inventories more than 5 years old (paragraph 53). The IAEA would therefore normally be prevented from examining or re-checking records of production more than five years into the past (although South Africa voluntarily provided operating records as far back as 15 years in order to help the IAEA verify the accuracy and completion of its initial inventories of nuclear material).
- Detailed knowledge of the capabilities of equipment within material balance areas (such as centrifuge design information) and *access* to such areas (implied by paragraphs 5, 8, and 76c, calling for protection of commercial and industrial secrets, for using only minimum information required for carrying out purposes of safeguards, and for carrying out routine inspections only at predetermined strategic points).

[1] On this issue, INFCIRC/66 is more restrictive than INFCIRC/153, since the former does not allow any military use of nuclear materials,

might be able to do so with less.[56] Indeed, the U.S. Department of Energy has all but confirmed this view, at least in the case of plutonium, in its recent declaration that 4 kilograms of plutonium is sufficient to make a nuclear weapon.[57] Lowering these thresholds would call for increased inspection effort and correspondingly greater inspection resources, and it would make it harder for the IAEA to meet its inspection goals—particularly at bulk-handling facilities. (Large bulk-handling facilities are difficult to safeguard even under the existing definition of the SQ; see discussion below). Lowering the SQ would also require increased inspection frequency at several small facilities in states not yet in possession of 1 SQ under the present definition. If the IAEA could not meet its inspection goals with a lowered SQ, and if it were unable to demonstrate that other safeguards techniques could compensate for that inability, the agency might have to "sound the alarm" more frequently

[56] See, e.g., Fischer, op. cit. footnote 36, p. 39; and Brian G. Chow and Kenneth A. Solomon, *Limiting the Spread of Weapon-Usable Fissile Materials* (Santa Monica, CA: Rand Corp., 1993), p. xiv. Note, however, that the SQ has never been meant to correspond to the minimum amount of fissionable material needed in a weapon, since: 1) it includes provision for estimated material losses during manufacture (even though much of this processing loss can be recovered), and 2) advanced weapon states with considerable experience and sophisticated designs might be expected to get the same results with less material. See Fischer and Szasz, op. cit., footnote 2, p. xix.

[57] U.S. Department of Energy, classification Bulletin WNP-86, February 8, 1994, states that "Hypothetically, a mass of 4 kilograms of Plutonium or uranium-233 is sufficient for one nuclear explosive device." (Although this sentence is unclassified, the full text of the Bulletin is classified.) No such statement has been issued with respect to uranium-235.

that it is unable to assure the nondiversion of an SQ of materials—even if no diversion had actually taken place.

To the extent that the SQ overstates the amount of nuclear material needed for a weapon, the actual diversion of even a fraction of an SQ should warrant a loud alarm-yet the IAEA might not readily notice such a diversion today. (Diversion of less than 1 SQ can still be detected, but with a lower probability than diversion of larger amounts.) The possibility of a state's obtaining 1 SQ or more by diverting lesser quantities from multiple facilities must also be considered, since such a scenario is in general more difficult to safeguard against. Indeed, new statements by the IAEA in 1993 asserted the goal of detecting a cumulative diversion of an SQ or more from all of a state's facilities taken collectively. As a result, the IAEA increased the inspection frequency from once to four times per year for sites containing less than 1 SQ of "direct-use" material (e.g., material containing highly enriched uranium or plutonium) in states where the total amount of material in such facilities exceeds 0.5 SQ. Otherwise, however, the safeguards criteria and approaches used to achieve safeguards goals are still based on individual facilities and thresholds of 1 SQ for each of the material balance areas within them.

Since the IAEA has no direct nuclear weapon expertise, it relies on the nuclear-weapon states for technical advice on matters such as the appropriate definition of an SQ. Existing definitions date back to information provided by the nuclear-weapon states in the mid- 1960s; in the absence of subsequent guidance, the IAEA had no basis to revise them. In recent years, however, the IAEA has become more concerned about this issue. In 1990, Director General Blix asked the nuclear-weapon states to provide updated guidance on whether the definitions should be revised. He received no response.

This question is also being examined to some extent within the 93+2 program. Now that the United States has declassified the fact that 4 kilograms of plutonium could be sufficient for a nuclear weapon, it may be easier for the United States to engage in a discussion with the IAEA on lowering the SQ. However, the United States has been reluctant to contemplate this step in the past, at least in part because doing so would place yet additional demands on a safeguards system that is already squeezed between increased responsibilities and fixed resources. Even if safeguards resources were to be increased, it is not clear that lowering the SQ would be the most effective way to use them.

OPTION: *The United States could encourage and support the IAEA to reexamine timeliness thresholds.*

The IAEA's timeliness criteria are based on estimates of the time it would take a state to convert a given safeguarded material into a finished metal weapon component, once such material were diverted (see table 3-l). These conversion times range from about a week for plutonium, uranium-235, or uranium-233 already in metal form, to months for such material in irradiated fuel, to about a year for thorium or uranium enriched to less than 20 percent.[58] Based on these conversion times, the IAEA has established timeliness goals for the maximum amount of time that may elapse between diversion and its detection.

To detect diversion before the diverted material could be fabricated into a weapon, timeliness goals for various types of nuclear material would have to be less than their corresponding conversion times. However, the only requirement be-

[58] Intemational Atomic Energy Agency, *IAEA Safeguards Glossary,* op cit., footnote 2, paragraph 105, p. 23, and table II, p. 24. Conversion time estimates do not include the time needed to accomplish the diversion or to move the diverted material to the site(s) where it is further processed. The estimates also assume that all facilities needed to produce weapons from the diverted material exist and that all non-nuclear components of such weapons have been made or can be completed in less time than it will take to process the nuclear materials into weapon components.

TABLE 3-1: Estimated Material Conversion Times for Finished Plutonium or Highly Enriched Uranium Metal Components

Conversion time	Beginning material form
Order of days (7-10)	Plutonium (Pu), highly enriched uranium (HEU), or uranium-233 metal
Order of weeks (1-3)[a]	PuO_2, $Pu(NO_3)_4$, or other pure plutonium compounds
	HEU or uranium-233 oxide or other pure uranium compounds
	Mixed-oxide fuel (MOX, consisting of plutonium and uranium oxides) or other unirradiated pure mixtures containing plutonium and uranium (uranium-233 or highly enriched uranium); or
	Pu, HEU, and/or uranium-233 in scrap or other miscellaneous impure compounds
Order of months (1 -3)	Pu, HEU, or uranium-233 in irradiated fuel
Order of one year	Uranium containing <20 percent uranium-235 and uranium-233, or thorium

[a]This range is not determined by any single factor, but the pure plutonium and uranium compounds will tend to be at the lower end of the range and the mixtures and scrap at the higher end.

SOURCE: *IAEA Safeguards Glossary, 1987* Ed., IAEA/SG/INF/1 (Rev. 1) (Vienna, Austria: International Atomic Energy Agency, December 1987), P. 24.

tween the two is that they should correspond "in order of magnitude," meaning they should be within about a factor of 3 of each other.[59] In practice, timeliness goals can exceed conversion times. For example, according to the IAEA, fresh reactor fuel containing plutonium or highly enriched uranium can be converted into weapon components in one to three weeks (for highly enriched uranium [HEU] or plutonium oxides or other chemical compounds) or seven to ten days (for HEU or plutonium metal). However, the timeliness goal for such material is one month. Spent (irradiated) fuel containing plutonium or HEU, which would have to be chemically reprocessed to yield HEU or plutonium, could be converted to weapon components in one to three months, but the timeliness goal for spent fuel is at the upper end of this range, at three months. Therefore, in some cases, the IAEA's timeliness goals for detecting diversion of nuclear material can exceed the amount of time it would take to convert that diverted material into weapon components.

Some argue that it is not even sufficient for the IAEA to be able to announce the diversion (or the inability to certify nondiversion) of nuclear materials before that material could be made into a bomb. Instead, they state that the international community must be warned of a potential diversion *far enough in advance so* that pressure could be applied to prevent the diverting state from making the weapon in the first place.[60] Such a requirement is impossible to achieve in any safeguards regime that permits nations to produce,

[59]Ibid., paragraphs 108 and 109, P. 25, and paragraph 123, p. 29.

[60]This more restrictive definition is the one adopted by the ''timely warning''language in the U.S. Nuclear Non-Proliferation Act (NNPA) of 1978, which governs United States nuclear cooperation with other countries. In particular, the NNPA sets the conditions under which U.S.-supplied nuclear material can be reprocessed. See, e.g., Leonard Weiss, "The Concept of 'Timely Warning' in the Nuclear Nonproliferation Act of 1978," unpublished paper distributed by the Senate Governmental Affairs Committee, Apr. 1, 1985.

stockpile, and use nuclear materials, such as plutonium or HEU, that can be converted into weapon components in less time than almost any conceivable international response could be mounted. Formulating, deliberating, approving, and implementing such a response would almost certainly take weeks to months, if not longer. In such cases, detecting the diversion of nuclear materials the instant it happened would not provide sufficient notice.

To make possible the degree of warning that this definition would require, a much stronger system of international control would be required that prohibited individual nations from producing or stockpiling any nuclear materials that could be converted to weapons on short notice. Such a system would resemble the Acheson-Lilienthal plan more than it would the present system of IAEA safeguards.

It might also be argued that the international community does not possess—or at least would never be willing to use-diplomatic, economic, or military measures strong enough to prevent a state from making a weapon out of diverted nuclear material. If this were indeed the case, no amount of notice would suffice, and the only way to guarantee that proliferation could not occur would be to prevent non-nuclear-weapon states from pursuing certain elements of the nuclear fuel cycle. These activities would have to be either banned completely, reserved for nuclear-weapon states alone, or internationalized. Although some indeed urge the banning of spent fuel reprocessing, enrichment could not be banned without shutting down most civil nuclear power plants. **Reserving enrichment and reprocessing for the nuclear-weapon states would so badly aggravate the existing discriminatory nature of the international nonproliferation regime that this option must be considered politically untenable.** Internationalization is addressed in chapter 4.

Unlike changes in the definition of significant quantities, which generally affect only the *intensio* of each individual inspection (e.g., the number of samples taken or measurements conducted on a certain batch of material stored in many containers), changes in the timeliness criteria require increased inspection *frequency.* Shorter timeliness criteria, therefore, would have a large effect on the safeguards efforts needed to achieve them.[61] **Moreover, achieving the existing timeliness criteria uniformly and comprehensively for all facilities-particularly those containing direct-use materials-is probably much more important than adopting even more stringent criteria as goals.** For example, in 1993, the timeliness goal for direct-use material was fully met at only 63 percent of the facilities containing such material, and either partially met or not met at 37 percent.[62] (See also the discussion of near-real-time accountancy, below).

Safeguards Uncertainties at Nuclear Material Bulk-Handling Facilities

OPTION: *The United States could encourage and support efforts to decrease uncertainty limits at bulk-handling facilities.*

Facilities that process nuclear material in bulk form include those for enrichment, fuel fabrication, and reprocessing. Though each type of facility poses unique challenges for safeguards, enrichment safeguards are probably the most developed and easiest to implement of the three (see box 3-8). One of the most difficult types of facility to safeguard effectively is the spent fuel reprocessing plant, because:

1. the plutonium produced is directly usable in nuclear weapons;
2. plutonium in a reprocessing plant is somewhat more difficult to assay accurately (on a kilo-

[61] Lowering the definition of the significant quantity (SQ) will increase the inspection frequency for facilities that have less than 1 SQ under the old definition but more than one under the new one.

[62] Letter of Jan. 17, 1995 from Jan West, IAEA, in response to Office of Technology Assessment questions, op. cit., footnote 34, p. 2.

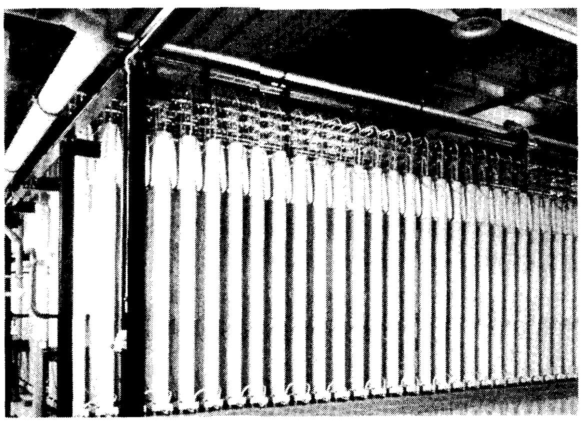
BOX 3-8: Enrichment Plant Safeguards

Enrichment plants, like reprocessing facilities, are bulk-handling facilities that can potentially produce material directly usable in weapons: in this case, highly enriched uranium.[1] Currently, the IAEA applies safeguards only to the following 7 enrichment facilities: Brazil (Resende)[2]; Germany (URENCO, Gronau); Japan (Ningyo, and Rokkasho-mura enrichment plants); Netherlands (URENCO, Almelo); South Africa (Pelindaba); and the United Kingdom (BNFL centrifuge plant at Capenhurst).[3] Of these, the Resende enrichment facility (using Becker nozzle technology) is unlikely to operate in the future. However, Brazil's Ipero gas centrifuge plant will be coming under safeguards now that Brazil has agreed to apply safeguards to all its nuclear fuel cycle facilities. Since the United Kingdom is a weapon state, its facilities are safeguarded under voluntary agreements. Of the remaining facilities, Germany, the Netherlands, and Japan operate centrifuge plants and South Africa operates an aerodynamic separation process called Helikon. The latter technology had never been safeguarded by the IAEA prior to South Africa's accession to the NPT, but it shares some characteristics with gas centrifuge and some with gaseous diffusion technology.

Gas Centrifuge Enrichment Plant Safeguards

If covert reconfiguration of gas centrifuge plants can be detected, such plants can be safeguarded with high confidence. Using well-established measurement techniques, input and output quantities of uranium hexafluoride can be assayed very accurately, both for amount and for isotopic content.[4] It is harder to measure the amount of uranium hexafluoride contained in gas form within the centrifuge cascade than it is to determine inputs and outputs, but this "gas phase inventory" is relatively small, Given present measurement uncertainties, plants with up to *2,000,000* separative work units per year enrichment capacity (which contain roughly 75 kilograms of uranium-235 in the process stream at any given moment) appear safeguardable using current practices. A plant this size can produce enough low-enriched uranium to fuel some 20 large commercial power reactors. Urenco plants are half this size, although Russian centrifuge plants are of this scale or slightly larger.

URENCO



Gas centrifuge cascade at a URENCO uranium enrichment plant. URENCO operates enrichment facilities in Almelo in the Netherlands, Capenhurst in the United Kingdom, and Gronau in Germany.

(continued)

1 For discussion of different types of enrichment technologies, see US. Congress, Office of Technology Assessment, *Technologies Underlying Weapons of Mass Destruction,* OTA-BP-ISC-115 (Washington, DC: Government Printing Office, December 1993), appendix 4-B.

2 This facility had been covered by an INFCIRC/66 safeguards agreement prior to implementation of full-scope safeguards under the ABACC agreement and the Treaty of Tlatelolco.

3 *IAEA Annual Report for* 1992, op. cit., p. 161.

4 2.5 ton (t) cylinders of UF_6 gas are routinely measured to within +/-0,5 kilogram (kg), and 14 t cylinders to within +/- 1 kg. Uranium purity (grams uranium per grams material) has a 1-o uncertainty of only O.05 percent, and isotopic assay for low-enriched uranium at IAEA's Seibersdorf Analytical Laboratory (based on the characteristic 186-keVgamma emission) has an uncertainty of 0.2 to 0.3 percent. David Gordon, group leader, Arms Control and Nonproliferation division, Brookhaven National Laboratory, private communication, 1993.

BOX 3-8 (Cont'd.): Enrichment Plant Safeguards

The principal safeguards concerns associated with centrifuge plants involve the possibility of reconfiguring the cascade to produce higher enrichments, which is a particular concern because of the speed at which such plants would start producing the higher enrichments after such a conversion. Covert production of highly enriched uranium would require the use of unsafeguarded feedstock in addition to reconfiguration of the cascade. Material imbalances would result if safeguarded feedstock did not show up again as safeguarded, low-enriched output. To protect against either reconfiguration or operation of the plant with undeclared material or in an undeclared manner, a consortium of centrifuge technology holders in 1981 agreed with the IAEA and Euratom to implement a set of procedures for safeguards, known as the Hexapartite agreement. This agreement represented a compromise between protecting proprietary information relating to the technology and configuration of the cascade itself, and restricting the opportunities for altering plant operation between inspections. Its principal strength is its providing for short notice inspections *within* the cascade area of the plant, under guidelines called "limited frequency unannounced access" (LFUA),[5] and for portable assay equipment to be taken into the cascade area for determining whether the plant is producing HEU.[6] In addition, uranium flows in and out of the plant are monitored and controlled, with samples of the output measured for enrichment.

LFUA inspections inside the cascade area are allowed from 4 to 12 times per year, depending on the size of the facility, Their degree of surprise can range from a totally unannounced arrival of inspectors at the plant (at which point operators would be allowed no more than 2 hours to hide from view any proprietary equipment that might be exposed within the cascade) to unexpectedly calling for an inspection inside the cascade area during one of the routine monthly inspections at the plant. Although there is no explicit routine verification measurement that can guarantee detection of undeclared feed being introduced into the cascade, LFUA inspections area deterrent against such scenarios since they add a probabilistic chance of spotting such material.[7]

Gaseous Diffusion Enrichment Plant Safeguards

The principal difficulties of safeguarding gaseous diffusion enrichment plants involve the large amount of material normally present *within* the cascade (as much as 4 tonnes of uranium-235 in a large plant), and the occurrence of some of that material "plating out" on the inside surfaces of pipes due to small leaks.[8] Both factors involve holdup material and thus lead to measurement inaccuracies and uncertainties in MUF. Argentina has the only gaseous diffusion facility under safeguards outside the nuclear weapon states, and its small size should make it relatively easy to safeguard effectively.

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[5]Part of the agreed procedures involves safekeeping at the plant of original photographs Of the interior cascade area so that inspectors can compare them with the current layout. With the myriad of pipes, valves, and connections inside a cascade, however, the visual acuity of the inspector can limit the utility of such comparisons.

[6]This equipment involves gamma analysis and x-ray fluorescence equipment using a portable cobalt-57 source. The software for this instrument has been "blinded" so that it indicates only whether enrichment Ievels are greater than or less than 20 percent and does not reveal the actual enrichment As with the LFUA compromise, the decision to Iimit the measurement equipment to this simple HEU/LEU reading was made to protect sensitive plant information, such as the separative capacity of individual centrifuges or specific portions of the cascade.

[7]The IAEA also has the option during routine inspections to require that every feed, product, and tail cylinder be verified before it is fed into or shipped from the plant. A more reasonable plan would be a sampling program that would have a high probability of detecting a significant diversion.

[8]Unlike centrifuge plants, which run at low pressures and whose fast-spinning vacuum-encased rotors can easily crash if there are leaks, diffusion plants can tolerate small leaks without major damage. (Sampling, which can introduce leaks, is thus done at many places, whereas there are no inter-cascade sampling points in centrifuge plants.) Plating out is the result of water vapor reacting with the fluorine in UF_6 gas.

nium, yet is significant in quantities less than one-third that of HEU;
3. the material is in "bulk" form (e.g., in solution or in the form of powder) throughout plant operations; and
4. extremely large quantities of plutonium (up to 8 tonnes per year, or 1,000 significant quantities) can routinely be separated in large commercial plants.

Mixed-oxide fuel fabrication plants share many of the safeguards difficulties of plutonium reprocessing plants. However, MOX plants that are now under safeguards have considerably smaller plutonium inventories and throughputs than the large commercial reprocessing facilities built or under construction in England, France, and Japan. Moreover, the IAEA has amassed considerably more experience to date with MOX facilities than with reprocessing plants.

Up until about 1990, IAEA criteria for safeguarding reprocessing plants had used as their standard not the "significant quantity" but a quantity called the "accountancy verification goal" (AVG). The AVG, which might be several times larger than an SQ, was based on a realistic assessment of what then-current measurement techniques applied to a given facility could actually detect. As analytic techniques and safeguards practices have improved, however, the IAEA has phased out use of the AVG, and the revised Safeguards Criteria introduced in 1991 make no reference to the concept.

Even though the AVG is no longer in use, conventional material accountancy methods alone appear unable to verify the absence of diversion or loss of material from large reprocessing plants to within annual uncertainty levels of 1 significant quantity of plutonium. At present, this conclusion is moot, since the reprocessing plants that have come under full-time IAEA safeguards to date are relatively small. However, Japan is building a large reprocessing plant at Rokkasho-mura that, when completed, cannot be safeguarded with a simple extrapolation of techniques in use at smaller facilities. While several new methods being studied appear to hold promise and are likely to improve detection sensitivity by a significant amount, the IAEA has not been able to demonstrate that material accountancy methods at large reprocessing plants will be able to assure, say, a 90 percent probability of detecting the diversion of as little as one weapon's worth of plutonium per year.

Reprocessing plants of this scale, therefore, pose difficulties for the IAEA. Either the agency will need to demonstrate that safeguards methods *other than* the inventory measurements that form the core of its existing safeguards approach can be relied on to detect diversion with a high degree of confidence, or it will have to conclude that it cannot safeguard such a plant to the same standards it applies at smaller facilities. **To date, the IAEA has not considered the possibility that it cannot safeguard large facilities such as the Rokkasho-mura reprocessing plant, but neither has it been able to demonstrate that it can.[63]**

Various techniques to improve the capability of conventional material accountancy methods at large-scale reprocessing plants have been proposed and tested over the last 10 to 15 years. Many of these new techniques involve a concept known as "near-real-time" accountancy (NRTA—see next section), or the use of ongoing, continuous measurements to keep track of nuclear materials as opposed to the periodic taking of discrete inventories. Improved safeguards methods also apply various statistical models to the large amount of process data (e.g., flows and concentrations of nuclear materials and volumes of solutions in

[63] Rokkasho is the only reprocessing plant now envisioned to come under full-time IAEA safeguards with an annual plutonium production rate as large as a few tonnes per year. The only other civil reprocessing plants of this size now operating are in nuclear weapon states: the United Kingdom, France, and Russia.

tanks) available from such plants.[64] Other improvements to supplement material accountancy involve verification of design information and increased use of containment and surveillance (C/S) measures.[65] Application of these methods to safeguarding reprocessing plants is discussed in more detail in appendix A.

Part of the difficulty in safeguarding large reprocessing plants is that the IAEA has no real experience doing so (though it has safeguarded several smaller ones in the past, such as Tokai in Japan). Many of the measurement studies must therefore rely, at least in part, on assumptions about the actual plant operation and the obtainable measurement uncertainties. Another problem is that although the effectiveness of various safeguards techniques as applied to generic facilities is discussed in the open research literature, the effectiveness of the specific statistical tests the IAEA plans to use in a given case is facility-dependent. IAEA confidentiality would, therefore, prevent it from being shared even with member governments or the Board of Governors, let alone with the public. **Without knowing the specific characteristics of the data set on which statistical models are to be applied, however, the effectiveness of those models cannot be assessed by outside observers**.

Since the Office of Technology Assessment (OTA) last examined this issue in 1977, substantial improvements have been made in IAEA safeguards practices, including those at reprocessing facilities.[66] Moreover, the level of concern that should be attached to the material-accountancy limits at large bulk-handling plants depends on subjective judgments of what constitutes adequate deterrence against diversion. Many argue that the primary value of safeguards at a large reprocessing plant in a country such as Japan is to detect whether such a facility is being used to fuel a large nuclear weapon program with many weapons' worth of plutonium per year. No matter how effective they may or may not be at the margins, safeguards are well capable of detecting diversion of plutonium on that scale. It could be argued that the diversion of only a small amount of low-quality plutonium is very unlikely, given both the risks of detection with even an imperfect safeguards system and the political consequences for Japan of being caught developing nuclear weapons.

Those holding this view speculate that if Japan ever felt the need to develop a nuclear weapon option, it would be much more likely to: 1) build a small clandestine nuclear infrastructure outside of safeguards, 2) buy or steal the nuclear material, now that there may well be an active market in it,[67] or 3) simply withdraw from the NPT after announcing that the Treaty no longer served Japan's vital interests. Given the tremendous value that safeguards have in helping deny states a quick and direct way to produce large amounts of weapon-usable material during civil power program, the added value of tightening the threshold at which small diversions from a reprocessing plant would be detected with high confidence might be considered significantly less important. In other words,

[64]Near-real-time accountancy techniques are used at THORP in the United Kingdom and UP-3 in France.

[65]Containment and surveillance measures include items such as use of cameras and seals to ensure that a given storage location or piece of equipment has not been disturbed. For reprocessing plants, C/S measures are quite useful and can be used to block many diversion paths—perhaps all of them if the plant's flows are completely and correctly known by the inspectors. The IAEA has always considered, however, that C/S measures supplement—but do not replace—material control and accountancy, and that absence of diversion can only be positively demonstrated by the latter.

[66]See U.S. Congress, Office of Technology Assessment, *Nuclear Proliferation and Safeguards*, OTA-E-48 (Washington, DC: Office of Technology Assessment, July 1977); and B. Judson, "Needs and Obstacles in the International Safeguards of Large Reprocessing Plants," NTIS No. PB95-199170, OTA contractor report, December 1993.

[67]The German interception of 350 grams of apparently Russian-origin plutonium oxide in August 1994 and the Czech seizure of 3 kilograms of highly enriched uranium in December 1994 indicate that black market purchase of nuclear weapon material may be more realistic than previously thought.

safeguards might not eliminate the risk of diversion (see appendix A), **but those risks are nevertheless greatly reduced in both the probability of diversion of any kind and in the amount of material subject to diversion.**

Others, however, object to the above reasoning. First, even a very small nuclear arsenal can have a very large political and military effect. Second, even if Japan is judged very unlikely to skim a small amount of plutonium from a large reprocessing plant, the United States and other countries would probably be much less sanguine if a developing country in a politically unstable region of the world were to build a plant even a fraction the size of Rokkasho. Since the IAEA is required not to discriminate among its member states, it would have great difficulty in justifying more stringent safeguards in some places than in others.[68] Therefore, the existence of safeguarded reprocessing plants—even in countries not thought to pose proliferation risks—leaves the IAEA with few grounds on which to discourage the development of reprocessing plants in more questionable locations, or to require any additional safeguards measures to be applied there.

OPTION: *The United States could encourage and support the implementation of automated near-real-time accountancy and alarm capability by the IAEA at more facilities.*

The concept of near-real-time accountancy has traditionally been focused on reprocessing and fuel-fabrication facilities in which the amount of in-process inventory is large enough that timeliness goals are difficult to meet by conventional material control and accountancy (MC&A) methods. MC&A practice at reprocessing plants traditionally has required physical inventories to be taken and verified only once a year during a complete plant shutdown and cleanout. Monthly "interim inventories," which do not require plant shutdown, are less precise because of the difficulty in estimating in-process inventories. **In any case, interim inventories do not always meet the one-month timeliness goal for detecting diversion of material, including the investigation and resolution of anomalies.**

One facility already incorporating the NRTA approach is Japan's Tokai Plutonium Fuel Production Facility (PFPF), where MOX fuel has been fabricated for Japan's Joyo and Monju fast-breeder reactors at a rate of 5 tonnes per year since 1988.[69] Unattended, tamper-proof instruments, such as neutron coincidence counters in glove boxes, measure plutonium levels at various locations, even in the absence of human inspectors. Unmanned instrumentation allows safeguards measurements in areas where worker-safety regulations restrict manned inspections, such as between plutonium-storage and fuel-assembly areas in MOX plants. It is also intended to reduce manpower costs, although whether it will or not will depend on factors such as the details of the installation, its monitoring objectives, and so on.

Despite its use of NRTA, allegations questioning the adequacy of safeguards at the PFPF have been publicized, particularly concerning the

[68] Even though the IAEA cannot apply different safeguards standards to different nations, the rationale for pursuing reprocessing and the risk of plutonium diversion is not uniform around the world. Energy-poor Japan—a nation that traditionally has taken a very long-term view—argues that the plutonium fuel cycle is essential to achieving some measure of security for its energy supplies in the future, and that it is worth utilizing even if it generates electricity that is significantly more expensive than electricity from other sources. Further, having a domestic plutonium supply would eliminate the need to reprocess plutonium overseas and then return it to Japan via highly visible and politically contentious shipments. To ease concerns elsewhere, Japan has cooperated extensively with the IAEA in finding ways to make plants such as Rokkasho as safeguardable as possible. As noted earlier in the text, LASCAR was a Japanese initiative, financed by Japan. In less cooperative states, the IAEA's job could be made much more difficult.

[69] Power Reactor and Nuclear Fuel Development Corp. promotional brochure, Tokyo, Japan, August 1992, p. 7.

amount of plutonium—claimed to be 70 kilograms, or roughly 9 significant quantities-presumed to be held up in plant equipment.[70] One critic has concluded from this episode that this plant cannot be safeguarded effectively.[71] The IAEA responded that the plutonium in question has been measured in situ on a monthly basis, and that to improve the quality of these measurements the IAEA is discussing a schedule with Japanese authorities for the recovery of this material from this plant equipment where it is trapped.[72] The case does illustrate, however, the diffilculties of performing in-process measurements in bulk-handling facilities.

OPTION: *The United States could encourage and support the increased use of containment and surveillance techniques by the IAEA.*

Containment and surveillance techniques are used to supplement, rather than substitute for, the primary safeguards approach of material accountancy. Once the quantity of nuclear material stored in a particular location has been measured, for example, C/S measures such as cameras, motion detectors, or tamper-proof seals can be used to ensure that no material is added or removed, drastically reducing the need to repeat the measurements at a later date.

C/S techniques as applied in safeguards, however, should not be confused with similarly named methods to physically prevent material from being diverted by unauthorized intruders or seized, either at facilities or during transport between facilities (although such events would very likely be detected by C/S methods or by subsequent IAEA inspections). ***Prevention* of these activities falls within the domain of "physical protection," which is the responsibility of the state, not the IAEA.**[73] **C/S** techniques used by the IAEA are employed mainly to reduce the need for inspectors tore-assay material in storage or re-certify the integrity of previously inspected items—to maintain "continuity of knowledge."

C/S techniques are being improved. For example, videotape-based Modular Integrated Video Systems (MIVS) have already been installed to replace many of the older Minolta 8-mm cameras, which are movie cameras modified to take one frame every 10 to 20 minutes.[74] In addition, an improved, digital-based surveillance system called GEMINI is also being developed. New seals have already been developed that can be read

IAEA

Verification of seals using laser disk recording. With this equipment, IAEA inspectors can determine whether seals placed at safeguarded facilities have been tampered with.

70 Ppaul L. Leventhal, "The New Nuclear Threat," *The Wall Street Journal,* June 8, 1994, op-ed page, and Nuclear Control Institute, " 'Astounding' Discrepancy of 70 Kilograms of Plutonium Warrants Shutdown of Troubled Nuclear Fuel Plant in Japan, ''press release, May 9, 1994.

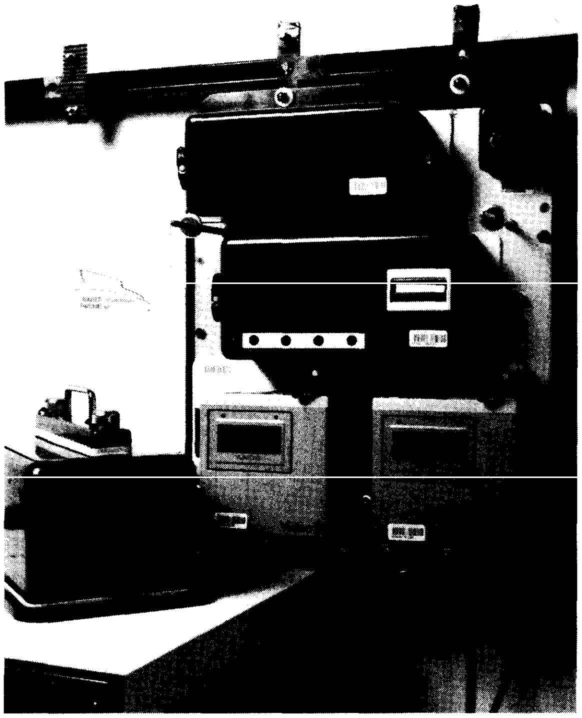
71 Ibid.

72 Intemational Atomic Energy Agency, "Japanese Material Under Full Safeguards," press release, PR 94/23, May 25, 1993. Specific safeguards-related data concerning PFPF-and all other safeguarded facilities—are considered "safeguards-confidential" by the IAEA and are not made public (see section on "Increase transparency within the IAEA itself," below).

73 General guidelines for such measures are published by the IAEA as INFCIRC/225/Rev.3, "The Physical Protection of Nuclear Material." These guidelines form the basis of the Convention on the Physical Protection of Nuclear Materials, which came into force on February 8,1987 and has a membership similar to that of the Nuclear Suppliers Group.

74 In 1990, for instance, 43 Modular Integrated Video system closed-circuit TV systems were being installed at 19 facilities.

AQUILA TECHNOLOGIES GROUP



The Modular Integrated Video System (MIVS) surveillance unit now jn use by the IAEA.

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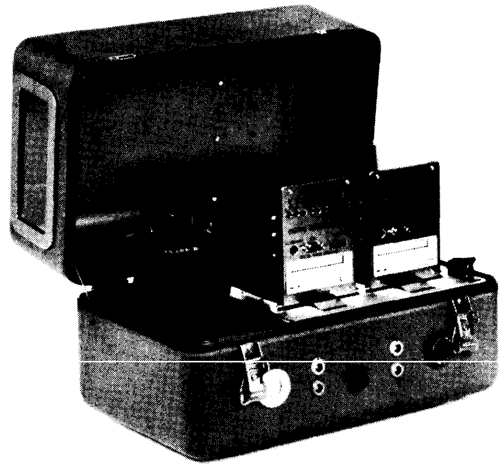


The digital-based Gemini surveillance system, an improvement over the MIVS system.

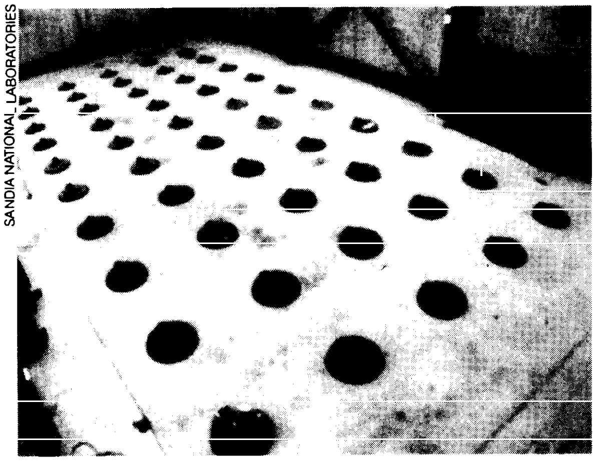
in the field for signs of tampering, rather than needing to be sent back to IAEA headquarters in Vienna.

Furthermore, there are several proposals for increasing the use of IAEA C/S techniques for nuclear facilities.[75] In the early 1980s, the RECOVER program tested the concept of transmitting information on the status of C/S equipment directly to Vienna by telephone lines, but the concept never gained IAEA acceptance.[76] More recently, the IAEA has conducted and is evaluating test operations in Sweden, Finland, and Hungary, in which state operators have been allowed to change videotape or film and send it to the IAEA, with special techniques used to prevent tampering or substitution. This procedure saves inspector effort in the collection of such tapes. A remote-monitoring project being developed at the U.S. Department of Energy's Sandia National Laboratories-originally designed to demonstrate remote monitoring of a deactivated chemical facility—is examining the use of cameras and satellite links for real-time C/S. A system has already been installed in Australia, and other sites are being examined. Private companies such as a Hughes-Canberra consortium and Unisys have also begun to examine concepts for remote-monitoring techniques using satellite links that could be used both for implementing better containment and surveillance and for enhancing near-real-time accountancy methods.

To improve the instrumentation available for remote monitoring of nuclear materials, Japan and the United States have been developing and testing the Containment and Surveillance Data Authenticated Communication System at Sandia Na-

[75] For a survey of ideas being discussed in the context of the European fuel cycle, see M. Cuypers and R. Haas, *"Can Containment and Surveillance Play a More Important Role in Safeguards?"* in *Proceedings of the Third International Conference on Facility Operations-Safeguards Interface,* San Diego, CA, Nov. 24-Dee. 4, 1987 (La Grange Park, IL: American Nuclear Society, 1988), pp. 341-348.

[76] The RECOVER system was not found to be cost-effective, among other reasons because it transmitted only status information about safeguards instrumentation, rather than the actual data from those instruments.



SANDIA NATIONAL LABORATORIES

Dry spent-fuel storage facilitu in Australia, monitored from Sandia National Laboratories, Albuquerque, New Mexico. Part of the International Remote Monitoring Project, this demonstration is a collaborative effort between the U.S. Department of Energy Sandia National Laboratories, and the Australian Safeguards Office.

tional Laboratories in New Mexico since mid-1992. The system uses advanced sensors to monitor flows of nuclear materials at various locations and then transmits this data by satellite to a control center in Japan. If such a system were used in a safeguarded facility, anomalous situations could immediately trigger alarms in a local control center, or back at IAEA headquarters. These alarms, in turn, could initiate a rapid response.

Such proposals face significant obstacles, not the least of which is a state's willingness to be subjected to measures going beyond the traditional requirements of safeguards, especially when data from one of their facilities is to be transmitted outside the country without the government right to vet the data first. Some of the techniques could even lead to an increase in safeguards effort, rather than a savings, through the need for site visits to resolve ambiguous indicators, such as unexpected motion, or to repair failed equipment.[77] On the other hand, to the extent that remote surveillance does eliminate the need for site visits, it will also lessen the opportunity to gain the "on-the-ground" presence that human inspectors provide. Many argue that this presence cannot be overestimated.

Containment and surveillance techniques also suffer from the fact that their usefulness is difficult to quantify. Unambiguous evidence of nondiversion can only be obtained for the material or area within a given camera's or motion detector's line of sight, and then only in the case of uninterrupted coverage. Nevertheless, initial reports **overall** have been promising. Further analysis of specific applications of enhanced C/S is, therefore, needed to determine whether it could result in cost-effective improvements in safeguards.

■ Improving the Ability To Detect Undeclared Facilities

OPTION: *The United States could encourage states to share intelligence information on potential safeguards violations with the IAEA.*

The IAEA has repeatedly stated that its activities will be significantly enhanced by increased access to information—both open source and national intelligence information. Before the Gulf War, member states neither pressed the IAEA to be aggressive in ferreting out clandestine facilities nor supplied the IAEA with information that would assist in such efforts. Nevertheless, successful precedents in providing such information have now been set with respect to Iraq, North Korea, South Africa, and other countries. The IAEA has also shown in South Africa that it has been

[77] The anomaly and false alarm rates with C/S measures are usually significantly higher than with material accountancy, but these anomalies would almost never be expected to give evidence of an actual diversion. Normally these false alarms can be appropriately resolved through further investigation, which in the extreme case can involve taking a special physical inventory. When that occurs, the C/S measures would in effect have contributed only to timely detection of the need for taking another material balance. J.E. Lovett, "Nuclear Materials Safeguards for Reprocessing," International Atomic Energy Agency Report STR-151/152 (December 1987), pp. 218-219.

able to independently verify the "completeness" of a state's declared inventory *without* being tied to conclusions reached by national sources.[78]

While it is generally agreed that sharing intelligence with the IAEA is a good idea, member states considering such sharing need to explore several overlapping issues:

- the form in which the information should be shared (e.g., photographs, written communications, informal briefings, or isolated tips),
- the means by which it can be assured that sensitive information is protected,
- the confidence that the IAEA can have in information that is provided to it, especially if the sources and methods by which it was derived are not shared with the agency,
- the mechanism for defending against planted disinformation directed against a particular state, and
- the use that the IAEA makes of the information once obtained.

Unlike national governments, which may agree to participate in reciprocal exchanges of information, the IAEA is required to maintain strict confidentiality and cannot offer any return flow of information. **As the recipient of information, the IAEA must develop policies for evaluating it as well as for shielding itself against charges of being manipulated for political purposes by being given information only selectively.** It must also be able to keep sensitive information about a state out of the hands of nationals or sympathizers of that state.

The fact that the IAEA is now receiving and using information supplied by member states, including the United States, represents a sea change in behavior that is absolutely necessary if the IAEA is to make a serious attempt to ensure that states have not built and are not using clandestine, undeclared nuclear facilities. The IAEA's best defense against charges of "selective provision" of intelligence is to accept information from any party, to balance these charges against the quality and implications of the information it is being provided, and to use its own judgment in coming to any conclusions before acting on them. **This will require the agency to develop some expertise in judging or in performing some analysis of the information presented to it.**

OPTION: *Increase the mandate and frequency of special inspections, to include "anytime, anywhere" inspections.*

In contrast to safeguards transparency measures, which would be completely voluntary, the IAEA also has some authority to demand "special inspections." Although no special inspections at undeclared facilities had ever been requested or carried out before the IAEA's investigations in North Korea, INFCIRC/153 provides for them if needed in order for the IAEA to obtain further information or to carry out its safeguards responsibilities.[79] The efficacy of this provision is limited by several factors, however. One is that special inspections must be carried out "in consultation" with the state, which as currently interpreted effectively precludes short-notice inspections such as those provided for in the Chemical Weapons Convention.[80] Without such consultation, many countries would consider that such inspections by the IAEA would violate their sovereignty. How-

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[78] IAEA Officials have said that the agency's extensive verification activities have led to a high level of confidence that South Africa's declared HEU inventory is essentially correct and complete. This contrasts to the situation in North Korea, where lack of cooperation has increased the IAEA's need for national intelligence information to reconstruct that country's nuclear history.

[79] Note that the term *special inspection* as used in INFCIRC/ 153 can refer to inspections requested either by the IAEA (e.g., to reconcile differences or ambiguities it discovers during the course of routine inspections), or by the state. This discussion refers to the former.

[80] Short-notice inspections might be useful to preclude the inspected state from quickly hiding evidence of violation of its safeguards agreements or international commitments. An analogy is the attempt of Iraq to hide its "calutron" uranium enrichment equipment from the UNSCOM/IAEA inspection team by driving them out the back of a facility when the team was at the gate. If the team had not arrived on short notice, the removed calutrons might never have been found.

ever, states could agree to reinterpret or waive their rights of consultation under this article to give the IAEA more timely access.

Another limitation is that requests for special inspections are taken very seriously, require weighty political consideration, and, depending on their outcome, have considerable implications for IAEA credibility. Since they have to be justified to the country and possibly also to the Board of Governors, coming up empty-handed too many times could erode confidence in the IAEA's ability to identify suspect activities. False alarms might also call into question the reliability or appropriateness of national sources of information, if such had been used, and could preclude the IAEA from calling for and conducting further special inspections. As such, special inspections within the current IAEA framework are no panacea and cannot be expected to become significantly more frequent (see box 3-9). Most likely they will con-

BOX 3-9: Different Types of Inspections

Within the context of strengthening IAEA safeguards, several different types of inspection have been discussed. They differ according to several factors: who can request them; how much notification time (if any) is afforded the inspected site; the legal authority (i.e., whether the state can refuse them); and which facilities are covered. The following represent four principal types of inspection (summarized in the accompanying table):

- **Technical visits.** Totally voluntary inspections on the part of the state to demonstrate openness or allow the IAEA to observe activities at sites that mayor may not be related to safeguarded facilities.
- **Regular safeguards inspections.** Can be carried out by the IAEA in either routine or ad hoc modes under safeguards agreements negotiated between the IAEA and the state.
  - *Routine* inspections are limited to material in declared facilities (under INFCIRC/153, for NPT states), to declared facilities irrespective of their material content (under INFCIRC/66, for safeguarded facilities in non-NPT states), and to key "strategic" measurement points for specified material-balance areas. Once a safeguards agreement has been implemented, the state has only very limited rights to refuse any given inspection, but may freely reject individual inspectors when first selected by the IAEA.
  - *Ad hoc* inspections verify initial declarations, establish baselines for the routine inspections that follow, and verify design Information. They must be agreed to in advance by the state, but they can be carried out as soon as a safeguards agreement is in force, even if negotiations to produce the specific legal documents authorizing inspections (the Subsidiary Arrangements and Facility Attachments) have not yet been completed. To a certain extent and with reasonable justification, they can encompass undeclared facilities.
- **Special inspections.** Authorized by INFCIRC/153 paragraphs 73 and 77 (for NPT non-nuclear weapon states) for the purpose of allowing the IAEA to verify or gather additional information needed to fulfill its safeguards responsibilities.[1] Special inspections can be requested by the Director General or by the Board of Governors, and can be aimed at declared or, with reasonable justification, undeclared facilities, but must be individually notified and, in practice, agreed to by the state before being carried out. If the state refuses, and the Board decides that the inspection is urgent to verify that no diversion is occurring, the dispute can ultimately be taken to the Security Council for resolution. The IAEA's first request for a special inspection at a nondeclared facility was presented to North Korea in early 1993 and was denied,

(continued)

[1]The United States, although not a non-nuclear-weapon state, has voluntarily offered to accept IAEA safeguards on a large number of selected civil nuclear facilities, and its safeguards agreement with the IAEA also contains language authorizing the IAEA to conduct special inspections. However, the United States is under no obligation to declare military nuclear facilities or permit inspections of them. Therefore, special inspections of the United States would be limited to resolving questions concerning only the nuclear material that was voluntarily put under safeguards, and they could not be used to investigate allegations of undeclared nuclear sites.

BOX 3-9 (Cont'd.): Different Types of Inspections

- **Challenge inspections.** The state would be notified, but would not be allowed to refuse. The IAEA has no right to conduct challenge inspections, They have been included in the Chemical Weapons Convention, however, which provides member states the opportunity to request challenge inspections at any locations or facilities in the territory of another member state. Requests for challenge inspections under the CWC maybe rejected by the Executive Council established by that treaty (somewhat analogous to the IAEA's Board of Governors) if it determines the request to be frivolous, abusive, or clearly beyond the scope of the Convention, However, once a challenge inspection has been approved by the Executive Council, the challenged state has no authority to refuse or delay it,

  CWC challenge inspections are based on the principle of "managed access, " in which the inspected state is required to provide some access to the inspected site but enters into negotiations—and ultimately has the last word—concerning the level of that access. However, the inspected state is obligated to demonstrate that those locations to which full access was not granted are not being used for prohibited activities. For more information on CWC challenge inspections, see box 3-5.
- **Surprise inspections.** Short-notice or unannounced inspections that would not recognize a state's right of refusal—so-called "anytime/anywhere" inspections, The first such inspections pertaining to weapons of mass destruction were directed at Iraq through U.N. Security Council Resolution 687 in February 1991, as part of the terms of the ceasefire ending the Persian Gulf War, These go well beyond the authority given by INFCIRC/153. In practice, they have proven difficult to carry out thereon a number of occasions, due to substantial Iraqi interference, but in other cases they were very successful in ferreting out equipment that Iraq was attempting to hide,

Characteristics of Different Types of Inspections

Inspection type	Characteristics	Model
Technical visit	▪ Volunteered by inspected state ▪ No formal safeguards role	No standard model
Regular inspection	▪ Routine or ad-hoc Routine inspections are agreed-to well in advance (with limited exceptions such as very short-notice inspections of aspects of centrifuge enrichment plants) ▪ Routine inspections look at declared facilities only ▪ Limited rights of refusal (e.g., can refuse individual inspectors)	INFCIRC/153
Special inspection	▪ Requested by IAEA Director General or Board of Governors ▪ Includes undeclared facilities (when justifiable) ▪ Consultation with state required ▪ Unresolved issues can be taken to U.N. Security Council	INFCIRC/153 paras, 73,77
Challenge inspection	▪ State is notified, but cannot refuse or delay ▪ Can be requested by any member state ▪ Includes undeclared facilities	CWC "managed access"
Surprise inspection	▪ Short-notice or unannounced ▪ No right of refusal • "Anytime/anywhere"	U.N. Security Council Resolution 687 (Iraq)

tinue to be invoked only in egregious circumstances, such as in North Korea.

Nevertheless, the authority to carry out special inspections, together with access to intelligence information, can constitute a powerful tool to detect clandestine activities. Given what has been discovered in Iraq and North Korea, it can be expected that special inspections, or even simply "technical visits," when combined with increased use of intelligence supplied by member states, may play a much greater role than they have in the past. Some precedent has also been set within the Chemical Weapons Convention regarding challenge inspections, using "managed access" to set the terms of those inspections (see box 3-5).[81] Once that Convention comes into force and some experience has been gained with its challenge inspections, the IAEA could seek to apply any lessons learned to its own inspection activities.

Though Iraq is indeed a special case, the success in implementing U.N. Security Council Resolution 687 depended on three factors, which are applicable to special inspections more generally:

- access to relevant information on suspect locations,
- the right to timely and unrestricted access to identified sites, and
- the assurance of predictable Security Council backing when support for implementation was necessary.

Although much of the information upon which special inspections or technical visits might be based will inevitably have to come from national intelligence sources, some could come from environmental sampling programs carried out by the IAEA itself. To persuade certain countries to allow or undertake environmental sampling programs on their territory, it might help if neighboring countries could be convinced to volunteer first. For instance, the United States might urge South Korea to allow for such sampling in an effort to persuade the North to follow suit. Of course, there is no guarantee that this would work, but such a tactic would further call into question the motives of the North if it refused to follow a South Korean lead.

In addition, special inspections will require advanced or new kinds of portable instruments for field inspectors (e.g., compact multichannel analyzers or environmental sampling kits) and additional training for inspectors to learn what they are looking for and how to react to unexpected information they might discover. Increased member state support along these lines in the form of voluntary contributions, equipment, and training would be beneficial.

Initiating Safeguards for States with Nuclear Infrastructures

When a state first comes under safeguards, for example upon acceding to the Non-Proliferation Treaty, it must declare to the IAEA all of its nuclear materials and the facilities where these materials are processed or stored. The IAEA has a responsibility to verify the completeness of this initial declaration. That is, it must ensure that the state is not hiding nuclear materials, particularly those capable of being used in weapons. This task is a challenging one whenever the state has a substantial nuclear infrastructure. According to IAEA Director General Hans Blix:

> There is an inherent difficulty in verifying the completeness of an original inventory in a country in which a substantial nuclear programme has been going on for a long time. It requires much effort both by the inspectorate and much openness and co-operation by the inspected party—extending beyond declared facilities and current records.[82]

Kazakhstan and Ukraine are in this category. Both states had nuclear facilities and nuclear materials while part of the Soviet Union, a nuclear-

[81] See U.S. Congress, Office of Technology Assessment, *The Chemical Weapons Convention: Effects on the U.S. Chemical Industry*, OTA-BP-ISC-106 (Washington, DC: U.S. Government Printing Office, August 1993).

[82] Hans Blix, Statement to the 36th Session of the General Conference of the IAEA, Sept. 21, 1992.

weapon state that was not required to put its facilities under safeguards. Now that these states are independent countries and parties to the NPT, all their nuclear materials and facilities must be safeguarded, and the IAEA must make sure that the initial declaration these states make is complete.

This task is particularly important if the state entering safeguards is suspected or known to have mounted a nuclear weapon program. Indeed, several such states have either come under or are about to come under full-scope IAEA safeguards, including Argentina, Brazil, South Africa, and North Korea. To help allay suspicions that a nuclear weapon program or capability might secretly continue after the state comes under safeguards, it is important to ensure that all nuclear materials that may have been produced in the past are fully accounted for, and that all activities that had been related to the weapon program have ceased.

OPTION: *IAEA verification of the termination of a nuclear weapon program.*

Several steps could be taken to help cement the nonproliferation commitments of states thought to have mounted nuclear weapon programs in the past. First, the United States and other NPT parties could reemphasize the original meaning of the NPT commitment not to manufacture nuclear weapons. From the Treaty negotiating record and from statements of William Foster, then-director of the U.S. Arms Control and Disarmament Agency, activities prohibited under this commitment include all related development, component fabrication, and testing activities specifically related to creating nuclear explosive devices.[83] Such a reaffirmation is especially important for former threshold states, since IAEA safeguards were originally set up to verify only one aspect of such activities—the nondiversion of nuclear material from declared peaceful purposes.

Since the discovery of the Iraqi weapon program, the world community has expected more of safeguards. The IAEA has accordingly placed much more emphasis on: 1) verifying the completeness of a state's initial inventory of nuclear materials, ensuring to the extent possible that it has not hidden a stockpile of weapon-capable materials, and 2) ensuring the absence of undeclared nuclear facilities, eliminating to the extent possible the concern that the state is preparing to secretly violate its NPT commitment.

It could be made clear by the United States, by the IAEA, or by the United Nations more broadly that former threshold states have a special obligation to declare any such prior activities and to provide assurances that they have ceased, as well as to accept full-scope safeguards. Such assurances could include demonstrating that scientific teams had been reassigned, that facilities had been dismantled or converted to non-weapon purposes, and that any prior manufactured components and materials had been destroyed. If agreed to by the states in question, technical visits could then be used to verify the completion of these steps (see box 3-10). Short-notice inspections could also be used to help guard against the possibility of a state's moving former bomb material or nuclear-related equipment in order to hide it from inspection, and thus enhance the confidence in determining initial inventories of previously unsafeguarded nuclear-weapon-usable material.[84] Such inventories are particularly important instates that are suspected of having gone very far down the path of developing nuclear weapons.

■ Procedural and Institutional Improvements to Safeguards

OPTION: *Make greater use of inspectors from nuclear-weapon states who have intimate knowledge of nuclear explosive technology*

[83] George Bunn and Roland Timerbaev, "Avoiding the 'Definition' Pitfall to a Comprehensive Test Ban," *Arms Control Today,* vol. 23, No. 4, May 1993, pp. 16-17.

[84] Leonard S. Spector, "Repentant Nuclear Proliferants," *Foreign Policy,* fall 1992. p. 35.

BOX 3-10: IAEA Nonroutine Inspections in North Korea and South Africa

Subsequent to the Persian Gulf War and IAEA activities under Security Council Resolution 687, the IAEA has gained vital experience in at least two other countries of serious proliferation concern. In North Korea, inspections in the months following that country's signing of its first safeguards agreement revealed anomalies that led to the request for special inspections at two sites suitable for containing nuclear waste associated with reprocessing activities. In South Africa, the need to verify inventories of HEU that had been associated with nuclear weapons resulted in the IAEA undertaking an unprecedented level of "nuclear archeology" to understand and reconstruct uranium production levels and nuclear weapon development activities dating back well over a decade. As in Iraq, the IAEA has faced unique challenges in these two states and, as a result, has shown its capability for assertive actions and thorough analysis. In both cases, a new emphasis has been placed on verifying with the highest confidence possible that initial declarations be not only correct, but also *complete.*

North Korea delayed signing its safeguards agreement with the IAEA from 1985 until 1992. Partly through analysis of plutonium and other isotopes obtained from swipes taken around product handling areas, the IAEA's initial ad hoc inspections revealed evidence of inconsistencies in North Korea's declarations, For instance, it became clear that waste the IAEA was allowed to sample was inconsistent with the limited reprocessing that North Korea had declared, and that there must have been at least one other reprocessing campaign. Information supplied by the United States and shared with the IAEA Board of Governors showed that the North Koreans had concealed two sites probably containing nuclear waste, This information provided clear evidence of attempted deception on the part of the North Koreans and buttressed radiochemical evidence that the IAEA's own efforts had obtained. When the IAEA made a request to conduct "special inspections" at these sites, North Korea refused and threatened to withdraw from the NPT. It did not carry out this threat, but—as of this writing—it has not yet permitted the IAEA to inspect these sites and is therefore not in compliance with its safeguards agreement,

The South African program presented quite a different set of challenges. Here, the state was cooperating fully, but admitted to having run enrichment campaigns for over a decade producing substantial quantities of HEU, some at very high enrichments. Given the foreseen transition of the South African government from minority to majority rule, extreme political sensitivity surrounded the question of whether some of the highly enriched uranium produced by South Africa might have been hidden from

As an institution, the IAEA is not required to have nuclear weapon expertise. Indeed, since its membership and its technical staff draw from nuclear and non-nuclear states alike, the IAEA and its staff must not be permitted to acquire weapon information, lest the agency promote proliferation in the process of helping fight it. Nevertheless, inspectors with nuclear weapon expertise may be in a better position to detect weapon activities. Assigning them to inspection teams could bolster confidence in an enhanced IAEA agenda that sought to take a more vigorous approach toward exposing covert nuclear weapon programs and undeclared nuclear sites.

Such a proposal would be difficult to implement beyond the level of informally assigning particular individuals to inspection teams. The IAEA makes no formal distinction between inspectors from weapon states and nonweapon states. Weapon-state inspectors will face difficulty in sharing suspicions with other IAEA personnel—including their counterparts from other weapon states—if doing so would force them to reveal nuclear weapon information that is classified by their national governments.

The IAEA has already begun to grapple with some of these issues following its inspections of Iraq after the Gulf War. Since these inspections

BOX 3-10 (Cont'd.): IAEA Nonroutine Inspections in North Korea and South Africa

the IAEA and the incoming government. The Board of Governors therefore passed a special resolution calling attention to the importance of verifying the "completeness" of South Africa's initial declaration: had it produced more material than it declared? To find out, the IAEA determined that past enrichment history dating back almost 15 years needed to be fully understood. Operating records were gathered to reconstruct this history.

Two problems were evident. First, given their focus on producing material for weapons, South Africa had failed to keep detailed records of certain operating parameters that would have been useful for calculating material balances, but were less relevant for production, such as the enrichment levels of the waste product or "tails." Second, frequent plant shutdowns, one as long as 2 years, had occurred as a result of a peculiar problem with the South African Helikon process. Once these shutdowns were properly taken into account and the complete set of operating records was verified as authentic, the IAEA was finally able to conclude that the inventory estimates provided by South Africa were probably correct.

Several lessons can be drawn from these experiences: **the** IAEA **does its job best when the inspected country cooperates; the more difficult the inspection task, the more cooperation is needed. Second, intelligence data can significantly enhance the IAEA's ability to unravel inconsistencies when it discovers them, though such data is not necessarily required nor always the final word in explaining the nature of such anomalies.** Third, while the IAEA has never been tasked to verify any non-nuclear research or development activities associated with nuclear weapons, evidence of such activity can indeed be sufficient for it to ask for more information regarding the nuclear *material* inventory—which the IAEA does have ultimate responsibility for verifying. The Director General has emphasized this point in the context of states such as South Africa, where the IAEA verified dismantlement of parts of the weapon complex not involving nuclear material. Such a precedent could have important implications for other states having prior or suspected connections to nuclear weapon programs, such as Argentina, Brazil, and North Korea, and if they were accede to the NPT as non-nuclear-weapon states, India, Israel, and Pakistan.

SOURCE: Office of Technology Assessment, 1995

were conducted under the authority of U.N. Security Council Resolution 687, rather than a typical IAEA safeguards agreement, the IAEA was free to accept assistance from, and to share inspection results with, whomever it pleased. However, special procedures had to be developed to limit the access of non-nuclear-weapon state personnel to sensitive Iraqi nuclear weapon design information. It will be harder to make such a distinction in the context of routine safeguards activities.

OPTION: *Increase transparency within the IAEA itself.*

Just as the IAEA requires access to facilities and information to achieve its safeguards objectives, so do those attempting to assess the adequacy of IAEA safeguards need detailed information about the functioning of the IAEA to determine how robust those safeguards objectives are and how well they are being implemented. To its credit, the IAEA has earned the reputation of being able to keep proliferation-sensitive and proprietary information closely held within its ranks. In fact, it is mandated to do so by Article VII(F) of the IAEA statute, which instructs the Director General and his staff to "not disclose any industrial secrets or other confidential information coming to their knowledge by reason of their official duties for the Agency."

Nevertheless, the practice of restricting the dissemination of information appears to extend into areas and types of information that might, in fact, offer benefits in increased public confidence in the safeguards system if they were to be made available. In contrast to "safeguards-confidential" information, which is generally not shared with member states or the Board of Governors, many reports by the IAEA Secretariat *are* distributed to the member states, but are not released to the public. For instance, the 1991-1995 *Safeguards Criteria* document, which contains a detailed and updated description of the safeguards and inspection activities that must be carried out at any given type of facility, is not publicly available.[85] Neither are the annual *Safeguards Implementation Reports* (SIRS) available. These safeguards reports present an overall assessment of how well the IAEA has met its safeguards goals for the year, including problems it has encountered with C/S and other equipment. **Distribution of SIRS is restricted despite the efforts made to protect the identities of any specific country or facility discussed in them.** There are many IAEA technical papers and analyses on safeguards whose distribution is not explicitly restricted, but that are not widely publicized.[86] However, there is a large body of public literature, available in various conference proceedings and journal articles, to which IAEA and outside researchers both contribute.

Public confidence in the IAEA's effectiveness is difficult to earn in a closed environment. Greater openness on the part of the IAEA itself might also allow outside experts to formulate more informed proposals for its improvement, an outcome which could ultimately strengthen the overall safeguards regime.

OPTION: *The United States could encourage IAEA member states to accept the IAEA's proposed assignments of inspectors to their territories, and to issue inspectors long-duration, multiple-entry visas.*

Under INFCIRC/153, states are allowed to reject the IAEA's assignment, or "designation," of inspectors to their country for any reason they choose. (This provision is not unique to the IAEA; the 1993 Chemical Weapons Convention, for example, also permits states to exclude particular inspectors from their territory.) Although restricting which inspectors may visit which countries generates inefficiencies, and can even lessen the credibility of IAEA inspections in certain areas, the United States and almost every other IAEA member-state government have exercised this right to exclude individual inspectors or classes of inspector at some time.[87] Some of the restrictions imposed by states include requiring that inspectors

[85] It is difficult to argue that withholding this document from the public makes it significantly harder to identify and take advantages of weaknesses in the safeguards system. Plant operators-who, if anyone, would be the ones to take advantage of such weaknesses-become intimately familiar with this documents' requirements during the routine course of safeguards inspections.

[86] For instance, there are extremely few entries in the 1990-92 IAEA catalogue of publications under the heading of safeguards. Although the safeguards budget comprises over a third of the IAEA budget; only two pages of the catalogue's 170 pages list safeguards publications, and the majority of these are at least 10 years old. (The catalog lists publications that are for sale by the IAEA and does not include materials distributed free of charge.) According to the IAEA, the intention of the sales publications is to "compile state-of-the-art knowledge from the international nuclear community for dissemination to Member States to help them enhance their own abilities to apply peaceful, nuclear techniques in medicine, industry, agriculture, etc." Given the prominence that IAEA safeguards have attained due to the IAEA's involvement in Iraq and North Korea since 1991, the IAEA has made a conscious effort "to give corresponding weight to our technical assistance efforts that remain at the heart of the bargain implicit in the 'Atoms for Peace' philosophy and of central importance for our developing Member States that are numerically in the majority." Quotations are from letter in response to Office of Technology Assessment questions from Jan Priest, Division of External Relations, IAEA, January 17, 1995, op. cit., footnote 34, p. 3.

[87] Fischer and Szazs, op. cit., footnote 2, pp. 63-64. For instance, it has been reported that in the 5 years preceding the 1981 Israeli bombing of Iraq's Osirak reactor, Iraq had allowed only Soviet and Hungarian nationals to carry out inspections on its territory. One inspector from France-the country that had sold the reactor to Iraq—had also been accepted, but had yet to conduct an inspection (see Roger Richter, testimony before the Senate Foreign Relations Committee hearing on Nuclear Nonproliferation, June 19, 1981).

come from NPT states or from states that themselves are under IAEA safeguards; or requiring that they speak the language of the inspected state.[88] The United States excludes inspectors from states that do not accept U.S. inspectors, and those from states that do not have diplomatic relations with the United States. Like practically all other states, it also reserves the right to refuse to issue visas to particular individuals that it deems ineligible to enter the country (e.g., that are suspected of being terrorists).

Since few states will give up control over the entry of foreign nationals to their territory, few states will be willing to waive completely their right to exclude proposed inspectors. The IAEA can, however, discourage countries from abusing this procedure, or from taking an unreasonably long time to respond to lists of inspectors proposed for their territory. For example, it could publicize such rejections and their justifications, if any; impose the highest allowed inspection frequencies in states that have a history of refusing the bulk of inspector designations; or perhaps even call for a certain number of special inspections at *declared* sites while the state deliberates on accepting inspector designations.

To reduce bureaucratic delays, and to help make inspections more timely, countries could agree to provide long-duration, multiple-entry visas to inspectors. Requiring IAEA inspectors to obtain visas for each inspection visit makes it impossible for them to conduct short-notice inspections even if a state has agreed to accept such inspections as a transparency measure.

Director General Blix proposed in 1988 that states waive their right to approve the designation of individual inspectors for their territory, and instead accept inspectors as approved by the IAEA Board of Governors. It is understood that such a waiver may be subject to reservations, and may be withdrawn at any time. The United States has accepted this proposal, and it provides IAEA inspectors designated for the United States with one-year, multiple-entry visas.[89] In waiving the right to approve individual inspector designations, the United States is presumably assuming that the IAEA will not designate inspectors that the United States finds unacceptable. Alternatively, the United States may be relying on its ability to withdraw this waiver if necessary. The Director General also offered a modified proposal in which states that did not respond within a certain time to the list of inspectors that the IAEA proposed for their territory would be considered to have approved the list in its entirety. Under previous practice, if a state did not respond, the list was considered to be rejected.

OPTION: *Exclude non-NPT states or NPT states with dubious nonproliferation credentials from membership on the IAEA Board of Governors.*

The IAEA grew out of the "Atoms for Peace" era and was established more than a decade before the NPT was signed. Despite its having been assigned the responsibility for conducting the principal verification activities of the NPT, the IAEA is an independent institution that maintains certain inherent contradictions with respect to its role in nonproliferation policies. One is its promotional role for nuclear energy and research, elements of which arguably make it easier for certain states to develop a nuclear weapon program. An alternate view, however, is that the IAEA's promotional activities enhance the nonproliferation regime since: 1) without them, fewer states may have been willing to participate in the safeguards regime at all, and 2) promotional and technical cooperation activities conducted under IAEA auspices can provide considerable insight—if the information is shared between the IAEA's technical cooperation and safeguards divisions—as to the breadth and depth of a state's nuclear technology,

[88] Fischer and Szasz, op. cit., footnote 2, pp. 63-64.

[89] Letter in response to Office of Technology Assessment questions, from Jan Priest, Division of External Relations, IAEA, Jan. 17, 1995. op. cit., footnote 34, p. 2

including technology acquired independently of the IAEA.

Another mismatch between the IAEA as originally created and the new responsibilities given it by the NPT is the IAEA's membership, and particularly that of its 35-member Board of Governors.[90] In recent years, the Board has included representatives from a number of states that, at the time, were not NPT members: Argentina and Brazil (which were thought to have had nuclear weapon ambitions), India and Pakistan (both widely believed capable of fielding nuclear weapons on short notice), Algeria (whose imported research reactor from China had caused concern), Ukraine, and Cuba. The Board of Governors has also included NPT member Libya, which was widely reported to have sought to purchase nuclear weapons from China. Another NPT party on the Board with a less-than-perfect nonproliferation record is Romania, which as recently as 1992 admitted violating the terms of its NPT commitments under one of its previous political regimes.

It has been suggested that the IAEA's credibility is weakened by having non-NPT or would-be proliferant nations on its Board of Governors sitting in judgment of potential proliferants.[91] In this view, the IAEA would better serve the NPT if its Board of Governors could be restricted to NPT members, if not to NPT members with robust nonproliferation credentials. Admittedly, it would be difficult or impossible for the IAEA as an institution to make such a determination. As was demonstrated by the United Nations in the 1970s, the inclusion of countries with strongly contrasting approaches to security can polarize an institution, bogging it down with political infighting.

On the other hand, the Board—unlike the U.N. Security Council—is not subject to vetoes, and a small number of non-NPT states would not be able to subvert the Board's actions even if they wanted to. Some IAEA officials argue that involving states such as India and Pakistan directly in IAEA affairs actually has positive effects for nonproliferation by helping draw them into the circle of responsible nations. IAEA officials also claim that representatives of such countries have often been helpful in Board decisions, commanding influence with G-77 (nonaligned) states and bringing to the IAEA valuable perspectives on nonproliferation norms. On decisions involving Iraq and North Korea, the Board, including its NPT nonmembers, was able to act quite decisively once information was presented to it.

In any case, the IAEA Statute stipulates that "The Agency is based on the principle of sovereign equality of all its members....," making it very difficult to establish new criteria for selection for the Board of Governors that would exclude some of the IAEA's member states. The Statute can be amended by a two-thirds vote of the Board of Governors followed by two-thirds ratification of the state parties, but states not accepting the amendment are not bound to remain within the IAEA. Restricting the Board of Governors could thus push certain states to withdraw their membership altogether, along with their political, financial, and technical contributions. Perhaps more importantly, it might alienate states who are unlikely to join the NPT but whose participation would be desirable in future, related arms-control activities such as a global comprehensive nuclear test ban or a cutoff in the production of fissionable materials for nuclear weapons. On balance, attempts at restructuring Board membership appear to be fraught with significant obstacles and limited tangible benefits.

[90]States serving on the IAEA Board of Governors for 1994-1995 are noted in appendix B.

[91]See, e.g., U.S. General Accounting Office, *Nuclear Nonproliferation and Safety*, op. cit., footnote 43, pp. 5, 22.

Beyond the Traditional NPT/IAEA Framework 4

The preceding chapters presented several options to bolster controls over nuclear weapon material production that can be implemented within the context of existing institutions and agreements. However, that discussion also noted that some issues simply cannot be addressed within the present regime. Put another way, even if safeguards worked perfectly in those states agreeing to them, there would still be issues of concern for nonproliferation. For example, although the Non-Proliferation Treaty is the world's most widely subscribed-to arms control agreement—with 178 members as of May 25, 1995 (see appendix B)—it does not have universal adherence. While only three holdouts—India, Pakistan, and Israel—are of any real proliferation concern, that concern is genuine, given that these states almost certainly possess nuclear weapons or the capability to make them on very short notice. Furthermore, while the Treaty prohibits the use of nuclear technology for weapon purposes, it also requires that states promote the transfer of peaceful applications of such technology. Under International Atomic Energy Agency full-scope safeguards agreements, NPT parties are also permitted to acquire and stockpile nuclear-weapon-usable material. Finally, even if the IAEA is able to detect violations of safeguards, it and the rest of the world community may be unable to compel compliance, especially within the time necessary to forestall serious consequences.

From the perspective of nuclear nonproliferation, the current regime to control nuclear weapon materials contains certain inherent contradictions and limitations. This chapter presents a number of distinct policy options that might be pursued to mitigate or eliminate some of these limitations.[1] The various options are not meant to comprise a mutually consistent package, nor does discussion by the Office of Technology Assessment necessarily imply its support or opposition to any of them.

AMENDING THE NON-PROLIFERATION TREATY

Despite the NPT's limitations, amending it is probably not a viable option for both procedural and political reasons. Procedurally, the amendment process specified by Article VIII of the NPT makes the Treaty extremely difficult to strengthen in any significant way. Each proposed amendment must be circulated by the Depository Governments (the United States, the United Kingdom, and Russia) to all NPT members, and at least one-third of the members (59 out of 177) must request a conference be convened to discuss the amendment. Before entering into force, the amendment must be approved and ratified by a majority of all parties to the Treaty (89 out of 177), including all the nuclear weapon states (now that all are parties to the NPT) as well as all NPT parties that are represented on the IAEA's Board of Governors at the time the amendment is circulated. Even then, an amendment only binds those states that approve it. Thus, it is possible through such amendments that different versions of the NPT could be in force at the same time. Moreover, some states not approving the amendment might use the opportunity to withdraw from the Treaty altogether.

Politically, the problems may be even worse. The NPT would never have been concluded if a number of compromises had not been struck. For example, non-nuclear-weapon states agree to forego nuclear weapons, and in return nuclear-weapon states agree to work toward nuclear disarmament. States agree to forego weapon applications of nuclear technology in return for access to its peaceful applications. Re-opening any of these debates—and possibly, re-opening any portion of the Treaty—could rend these compromises asunder. Not only might a proposed amendment fail to win widespread support, but a divisive debate could ensue that would seriously damage support for the rest of the Treaty as well. Many of these issues were raised at the Treaty's 25th anniversary review and extension conference in April and May 1995, but that conference only had the authority to decide on the Treaty's extension and was not empowered to amend it (see box 4-1).

In lieu of amending the NPT, other approaches might be considered that could be less contentious, easier to arrange, and ultimately just as effective politically, although perhaps not legally binding. Such alternatives could have included making statements in the final consensus document of the 1995 NPT extension conference, although in fact no such document was issued by the conference. They could also include adding protocols to the IAEA Statute; strengthening other institutions related to the nonproliferation regime, such as Nuclear Suppliers Group dual-use export controls; implementing G-7 policies on foreign aid and trade[2]; passing resolutions in the United Nations Security Council; or enacting new multilateral agreements such as a fissionable material production cutoff or a comprehensive test ban treaty. Negotiation of a complete alternative or successor to the NPT, however, would be a diffi-

[1] For a discussion of nonproliferation policy options in areas other than control of nuclear materials or IAEA activities, see U.S. Congress, Office of Technology Assessment, *Proliferation of Weapons of Mass Destruction: Assessing the Risks*, OTA-ISC-559 (Washington, DC: U.S. Government Printing Office, August 1993). Specific nonproliferation policies are also discussed in two other publications from this OTA assessment: U.S. Congress, Office of Technology Assessment, *Export Controls and Nonproliferation Policy*, OTA-ISS-596 (Washington, DC: U.S. Government Printing Office, May 1994) and U.S. Congress, Office of Technology Assessment, *Proliferation and the Former Soviet Union*, OTA-ISC-605 (Washington, DC: U.S. Government Printing Office, September 1994).

[2] The G-7 countries are the major industrial economies of the world: Canada, France, Germany, Italy, Japan, the United Kingdom, and the United States.

BOX 4-1: The 1995 NPT Extension and Review Conference

Unlike other major arms control treaties, the Non-Proliferation Treaty did not have unlimited duration. At the time the Treaty was drafted in the late 1960s, it was not clear how successful the Treaty would be at simultaneously arresting the spread of nuclear weapons among nonweapon states, reversing the nuclear arms race among the weapon states, and fostering the spread of peaceful nuclear technology. Its negotiators did not want to assume that it would be desirable to maintain the situation that evolved under the NPT indefinitely. Therefore, Article X, paragraph 2 of the NPT states that:

> Twenty-five years after the entry into force of the Treaty, a conference shall be convened to decide whether the Treaty shall continue in force indefinitely, or shall be extended for an additional period or periods. This decision shall be taken by a majority of the Parties to the Treaty.

The conference specified in Article X, held in New York in April and May 1995, resulted in the indefinite extension of the NPT by consensus. This decision does not require ratification by the NPT parties, which in ratifying the original Treaty (including Article X) have already agreed to delegate to the extension conference the power to extend the Treaty. However, **the** extension conference **was not empowered to make any changes to the Treaty's text.** Revisiting any of the provisions of the NPT would require amending the Treaty, a complicated procedure that most experts believe to be virtually impossible in practice. (See discussion on "Amending the Non-Proliferation Treaty" in the main text.)

The United States and many other NPT parties strongly supported indefinite extension of the NPT, arguing that it is in every nation's interest to prevent the spread of nuclear weapons, and that the NPT represents the only international arms control agreement binding all the nuclear weapon states to make progress toward nuclear disarmament. However, these sentiments are by no means unanimous. Other nations came into the extension conference opposed to indefinite extension, at least in the absence of significant additional measures toward nuclear disarmament by the nuclear weapon states. In fact, some argued that the Non-Proliferation Treaty should be superseded by a "Nuclear Weapons Convention" that would ban nuclear weapons entirely, just as the Chemical and Biological Weapons Conventions ban all parties from maintaining those types of weapon. In addition, some states also argued that the industrialized NPT parties have not complied with their obligation to "participate in the fullest possible exchange of equipment, materials, and scientific and technological information for the peaceful uses of atomic energy. "

Factors that were raised during the extension conference, many of which are beyond the scope of this study, include:

- the pace of superpower nuclear arms reductions, and progress toward a global comprehensive test-ban treaty[1] or fissionable material cutoff;
- U.S. or other nuclear-weapon state pledges of "no first-use" of nuclear weapons or other security guarantees made to non-nuclear-weapon states;
- the West's position on targeting NPT members such as Iran with export controls on nuclear-unique and nuclear-related technologies;
- progress in removing former Soviet nuclear weapons from Belarus, Ukraine, and Kazakhstan—all now non-nuclear-weapon state parties to the NPT—to Russia;
- the behavior of North Korea in resolving its conflicts with the NPT and IAEA over safeguards inspections and once-threatened Treaty withdrawal;

(continued)

[1]Although nuclear test bans by themselves cannot prevent proliferation of fission weapons and are therefore not essential *technical* ingredients to preventing proliferation, they have played an important political role in the proliferation debate, especially over the NPT extension in 1995, See U.S. Congress, Office of Technology Assessment, Technologies *Underlying Weapons of Mass Destruction,* OTA-BP-ISC-115 (Washington, DC: U.S. Government Printing Office, Decemeber 1993).

BOX 4-1 (Cont'd.): The 1995 NPT Extension and Review Conference

- the perceived effectiveness of the IAEA and the U.N. Special Commission for Iraq (UNSCOM) in enforcing the nonproliferation regime; and
- improved international relations, reducing the need for a nuclear deterrent.

The alternatives to indefinite extension, as specified in Article X, are extension "for an additional period or periods. " Extension for a fixed period would have terminated the NPT at the conclusion of that period, since the Treaty makes no provision for a future extension conference to extend the Treaty once its initial extension period has expired. By explicitly differentiating extension for additional *periods* (plural) from extension for an additional *period* (singular), the Treaty text does imply that the 1995 conference is empowered to do something other than either extend the Treaty for a single term or extend it indefinitely. One possibility in between those cases would have been to extend the Treaty for an indefinite series of fixed periods, each concluded by a conference that would determine whether the Treaty would continue through the following period.[2] This option was the principal alternative to the indefinite extension that was eventually adopted, but it was not supported by very many of the parties attending the conference.

Only a simple majority of the parties to the Treaty was needed to decide on the Treaty's extension. However, a close vote would have been undesirable since it would indicate that a substantial fraction of the Treaty's membership was opposed to extension on whatever terms had been adopted, undermining support for the Treaty. Therefore, it was important to the United States and other supporters of indefinite extension that the conference reach its final result by consensus. This consensus was made possible by creatively wording the extension resolution to read that "a majority exists among States party to the Treaty for its indefinite extension. "[3] In this way, even countries that would not have voted for indefinite extension could agree that a majority for indefinite extension existed, avoiding a recorded vote that would have been divisive to the nonproliferation regime.

[2]George Bunn, "Extending the Nonproliferation Treaty: Legal Questions Faced by the parties in 1995, " American Society Of International Law, Issue Papers on World Conferences, No. 2, October 1994.

[3]Draft extension resolution proposed by the NPT Conference President, "Extension of the Treaty on the Non-Proliferation of Nuclear Weapons, " NPT/CONF. 1995/L 6, 9 May 1995.

cult and contentious affair that would have to contend with all the political difficulties that make NPT amendment so difficult.

REINTERPRETING THE NON-PROLIFERATION TREATY

International law differs from domestic law in that under normal circumstances, there is no supranational governmental structure that can provide and enforce authoritative interpretations of a treaty's provisions. U.N.-affiliated agencies such as the IAEA can ask the International Court of Justice in the Hague for advisory opinions on treaty interpretation, but these have no binding authority.[3] The U.N. Security Council has the power to issue and enforce resolutions that are binding upon all U.N. member states, but it can do so only when acting to "maintain or restore international peace and security" under Chapter VII of the U.N. Charter. Otherwise, the Security Council does not have any binding authority to interpret treaties, although even a nonbinding resolution may carry significant weight. **In effect, therefore, a treaty**

[3]Many treaties—not including the NPT—specify that disputes between parties over treaty provisions are to be referred to the International Court of Justice.

means what its members agree that it means, providing at least the possibility that the members might collectively agree on a new interpretation of a treaty without formally amending it.

In practice, however, NPT reinterpretation may not be much easier to accomplish than a formal amendment. Should some member states disagree with the consensus arrived at by the others, those states may decide they are not bound by the reinterpretation. In case of dispute, treaty interpretation is based upon the treaty's negotiating record, upon presentations made to various legislatures when their consent to the treaty's ratification was sought, and upon the record the parties have accumulated in implementing the treaty—none of which will be very amenable to reinterpretation after the fact.[4]

Treaty reinterpretation may be contentious within governments as well as between them. In countries such as the United States and Russia that have legislatures that are independent of their executive branches, those legislatures may object to reinterpretations that are inconsistent with the record that was submitted by the executive branch when legislative consent to treaty ratification was granted.

However, if the Non-Proliferation Treaty were to be reinterpreted, an alternate reading of Article III could require the application of tighter safeguards to non-nuclear-weapon states, as suggested in the following two options.[5]

OPTION: *Combine INFCIRC/153 safeguards required of all non-nuclear-weapon NPT members with INFCIRC/66 safeguards that can provide greater coverage of selected plants, equipment, and facilities.*

OPTION: *Apply safeguards to materials other than fissionable or fissile materials that nevertheless have relevance for nuclear weapons, such as tritium, lithium-6, and beryllium.*

Article 111.1 of the NPT requires non-nuclear-weapon states to accept IAEA safeguards over "all source or special fissionable material [e.g., highly enriched uranium, plutonium, or the materials from which these materials are produced] in all peaceful nuclear activities" within its territory. No provision explicitly requires safeguards to be placed on facilities independent of the nuclear materials they may contain, nor over any other type of material relevant to nuclear weapon manufacture. Consequently, the IAEA's INFCIRC/153 safeguards, developed to implement the safeguards mandated by the NPT, center on nuclear materials. For any specific facility, INFCIRC/153 safeguards are not as stringent as the INFCIRC/66 safeguards that predated the NPT, which can cover plant and equipment independent of any nuclear materials they may contain, and can also encompass materials such as tritium, lithium-6, and beryllium that have relevance to nuclear weapons but are not considered "special nuclear materials."

An alternate interpretation of Article 111 of the NPT would place greater weight on the requirement that safeguards be applied "... for the exclusive purpose of verification of the fulfillment of [a non-nuclear-member state's] obligations . . . to preventing diversion of nuclear energy from peaceful uses to nuclear weapons ..." In this view, IAEA safeguards exist to prevent the manufacture of nuclear weapons, and they can justifiably cover a broader scope than just the nuclear materials that might be diverted to those weapons. **However, IAEA safeguards under the NPT have until**

[4] Treaty interpretation is addressed in the Vienna convention on the Law of Treaties, which is in force and reflects customary practice accepted by the United States, even though the United States has not ratified it. See discussion in footnote 19, p. 7 of George Bunn, "Extending the Non-Proliferation Treaty: Legal Questions Faced by the Parties in 1995," American Society of International Law, Issue Papers on World Conferences, No. 2, October 1994.

5 See, e.g., Leonard Weiss, "The NPT: Strengths and Gaps," published paper distributed by the Senate Governmental Affairs Committee, NOV. 18, 1994, p. 14.

now not been taken to be this encompassing, and it would be difficult to gain international consensus behind this new interpretation. Moreover, implementing such an interpretation would require renegotiation of every safeguards agreement between the IAEA and a non-nuclear-weapon NPT party.

PROBLEM NPT STATES

"Problem NPT states" are those states that are members of the NPT but have obstructed the implementation of safeguards**,** have shown clear signs of insincerity in fulfilling their nonproliferation commitments, or have pursued the development or acquisition of delivery vehicles for weapons of mass destruction. North Korea is a prime example. **The NPT, along with the IAEA as its verification instrument, is fundamentally limited in its ability to deal effectively with such states.** First, safeguards can only detect—and not prevent (except by deterring)—the diversion of nuclear materials to weapon use. In addition, safeguards cannot *prevent* NPT states from building clandestine facilities outside of safeguards (although doing so would be a violation of the safeguards agreement), nor do they *prohibit* any of the following activities:

- developing technologies related to non-nuclear components of nuclear weapons,[6]
- building reprocessing and enrichment facilities (thus providing a potential cover for weapon-related material-production capability),
- stockpiling direct-use weapon material (e.g., material containing plutonium or highly enriched uranium) from such facilities, and
- withdrawing from the treaty if the state determines it is in its vital interest to do so, while retaining facilities and materials that were acquired while under the treaty.

Through the pursuit of such activities, a state could position itself to manufacture nuclear weapons on relatively short notice. Therefore, the United States has judged that countries such as Iran, Iraq, and Libya should be discouraged from acquiring civil nuclear technology of any kind, whether or not full-scope safeguards are in place.[7] This position does not necessarily imply a lack of confidence in safeguards themselves, but rather in the commitment of these states to remain under them. **Even a perfect safeguards system—one that was certain to detect whether a state were pursuing a nuclear weapon program—cannot stop a country that wants nuclear weapons more than it fears disclosure.**

As a result, a former Department of Defense official offered the skeptical viewpoint that:

> ...[reprocessing and enrichment activities] bring nations so close to having a bomb—within days or weeks—that no amount of inspections provide enough warning to prevent it. To assure such warning we must limit the activities of inspected nations to those that are clearly 'safe,' that is, so distant from bomb making that inspections would afford years of warning.... We should use this occasion [North Korea's threat-

[6]Although technically not a safeguards violation, non-nuclear development that was weapon-related would probably violate the NPT's prohibition against "manufacture" of nuclear weapons. See footnote 9, and the related chapter text, for discussion of this point.

[7]Except in the case of a clear-cut safeguards violation or some other objective test, the IAEA is forbidden by its Statute from discriminating against member states. It therefore cannot withhold nuclear technology from—or refuse to apply safeguards in—certain NPT parties thought by some to be "problems." A policy that drew such distinctions among NPT states could appear to conflict with those provisions of the NPT that require the "fullest possible exchange" in the peaceful uses of nuclear technology. (See the section later in this chapter on implementing general embargoes of nuclear technology to problem NPT states.) Iraq is a special case, given that U.N. Security Council resolutions 687 and 707 prohibit Iraq from conducting nuclear activities "of any kind" (except for use of radioactive isotopes for medical, agricultural, or industrial purposes). These constraints go far beyond the NPT.

> ened withdrawal from the NPT] to dispel our long-time fantasy that we can take assurances from secretive, militant nations like North Korea and safeguard dangerous activities merely by inspecting them.[8]

For clear historical reasons, the NPT does not prohibit these so-called dangerous activities. They were part of the bargain to induce states with nuclear power or research programs to accept inspections and other infringements on their sovereignty by the IAEA; **if they had been banned, there never would have been a Non-Proliferation Treaty. The NPT** does, however, require states to refrain from "manufacturing" nuclear weapons, which, under the so-called Foster interpretation, has come to mean engaging in any of the activities directly associated with developing, testing, or producing nuclear *or non-nuclear* components for nuclear weapons.[9] Since nuclear weapons ultimately require nuclear materials, any evidence of research or production efforts relating to nuclear weapons—including their non-nuclear components— would indicate the strong possibility that preparations are being made to produce, divert, or otherwise acquire nuclear materials for weapon purposes. Therefore, the IAEA's current position is that even though nuclear safeguards agreements with states deal specifically with nuclear materials, any evidence of a nuclear weapon program—even non-nuclear aspects of one— would trigger requests for additional information or special inspections to verify the absence of undeclared activities or materials, or of any preparations for such diversions.

Such a scenario is not without precedent. In South Africa, both the admission by the government of having actually assembled six nuclear devices, as well as information obtained from technical visits to various types of facilities, led to a very thorough and aggressive program of inspections by the IAEA. Nevertheless, these inspections were only made possible by the cooperation of the South African government and its desire to dispel any remaining doubts about the reversal of its weapon program. They were also facilitated by South Africa allowing outside nuclear weapon experts to accompany an IAEA inspection team.

To deal with problem NPT states, therefore, the IAEA can encourage such cooperation and insist that nuclear weapon experts be allowed to join inspection teams (if they are not already incorporated among the inspectorate), whether for technical visits, or routine, ad hoc, or special inspections. If such cooperation is not forthcoming, the IAEA could also make maximum use of the provision for special inspections under the rationale that "completeness" of the inventory or of all declared activities cannot otherwise be assured.

OPTION: *Support placing additional constraints on the ability of states to withdraw from the NPT on 90 days' notice.*

Article X of the NPT states that:

> Each Party shall in exercising its national sovereignty have the right to withdraw from the Treaty if it decides that *extraordinary events,* related to the subject matter of this Treaty, *have jeopardized the supreme interests of its country.* It shall give notice of such withdrawal to all other Parties to the Treaty and to the United Nations Security Council three months in advance. Such notice shall include a statement of the extraordinary events it regards as having jeopardized its supreme interests. [emphasis added]

Such withdrawal clauses have now become common in arms control treaties. Although the NPT does not specify what would constitute "extraordinary events" or "supreme interests," it is clear that withdrawal is a very serious matter that would not be taken lightly by the Security Coun-

[8] Henry Sokolski, U.S. Defense Department deputy for nonproliferation from 1989 until February 1993, "Non-Proliferation Fantasy: NPT Will Not Quell N. Korean Nuclear Ambitions," *Defense News,* vol. 8, No. 14, April 12-18, 1993, p. 20.

[9] See discussion in George Bunn and Roland Timerbaev, "Avoiding the 'Definition' Pitfall to a Comprehensive Test Ban," *Arms Control Today, vol. 23, No. 4,* May 1993, pp. 16-17.

cil. (The first country ever to have begun the formal process of withdrawal from the NPT was North Korea in 1993.[10])

One option for dealing with this contingency is to clarify-perhaps via resolution of the U.N. Security Council—what it would take to constitute legitimate grounds for treaty withdrawal: for example, a clear, newly emerging nuclear threat from another country, imminent risk of invasion by an overpowering military force, or some other direct threat such as threatened or actual use of other weapons of mass destruction. On the other hand, clarifying reasons for withdrawal in this reamer might make it easier for parties to leave the Treaty. It could also damage the nonproliferation regime by implicitly assuming that the actual possession of nuclear weapons might be needed to deter aggression, and by diminishing the role of other responses, such as looking to the international community for support or becoming allied to an established nuclear weapon state. Moreover, states may be reluctant to take actions or set precedents that may limit their own freedom of action with respect to other treaties, even if they support the objective of making it more difficult to leave the NPT. One international legal expert, for example, suggests that the United States chose not to seek a U.N. Security Council resolution challenging North Korea's announced decision to withdraw from the NPT because it did not want to limit its own freedom of action in the future.

This option could also encompass the formulation of policies for determining ownership and setting forth the ultimate fate of the withdrawing country's safeguarded nuclear material. One option—admittedly unlikely to be enacted and difficult to enforce—would be for the withdrawing state to forfeit any such materials immediately to an international body for safekeeping. The U.N. Security Council could goon record with a resolution declaring (well in advance of any particular case) that if a state withdrew from the NPT without surrendering all the weapon-usable nuclear materials it possessed—and possibly any additional nuclear materials and facilities that had originally been provided by NPT states—then that state would be considered a threat to international peace and security. Although such a resolution would not prevent withdrawal, it could clarify that any state that amassed a stockpile of nuclear weapon material under the cover of safeguards, only to renounce its obligations and claim possession of that material, could open itself up to the possibility that the Security Council would authorize coercive means-perhaps including military force—to remove that state's weapon potential.

Such an approach could encounter difficulties, however, in its execution or its acceptance to states already party to the NPT. The United Nations would have to decide what measures it would consider appropriate to enforce such a take-back policy. Seizing material produced with little or no foreign assistance would certainly meet with considerable opposition. The use of military force would quite possibly be required. Thus, such a policy might have to be limited to fuel and other nuclear materials produced or obtained with the help of direct assistance from other NPT states—and possibly only to fuel supplied after the Security Council resolution had been made. The Nuclear Suppliers Group (NSG) might be a useful forum from which to stipulate such a condition of supply, further bolstering its recent decision to require full-scope safeguards as a condition of any significant new supply of dual-use nuclear technologies.

OPTION: *Attempt to implement general embargoes of nuclear technology for problem NPT states.*

Members of the Nuclear Suppliers Group have agreed to withhold nuclear technology not only from states that are *not* subject to full-scope IAEA safeguards agreements, but also from those states that *are* but whose commitment to comply with them is considered questionable. In addition, the guidelines adopted by the NSG in April 1992 ex-

[10] North Korea suspended its withdrawal just before the 90-day period ended.

plicitly state that a country's eligibility to import certain dual-use items (i.e., those having both weapon applications and legitimate civil uses) from an NSG member depends on factors such as the recipient country's statements and behaviors regarding its nonproliferation commitments.

However, withholding assistance from NPT parties poses a number of dilemmas. For instance, which criteria should be used to determine the nations to be embargoed, or even to determine what might constitute a given country's "legitimate" nuclear fuel-cycle requirements? So far, the United States has been most interested in isolating Iran, but has had little success in convincing its European allies to join in an embargo of general high-technology trade. (In part, this difficulty is because Iran has thus far apparently abided by its IAEA safeguards agreements.) In the case of Iran, government officials had made alarming statements (later contradicted) indicating their desire to develop nuclear weapons.

Many observers argue that this approach violates not only the spirit but the letter of the NPT, since Article IV, section 2 states that:

> All the Parties to the Treaty undertake to facilitate, and have the right to participate in, the fullest possible exchange of equipment, materials, and scientific and technological information for the peaceful uses of nuclear energy. Parties to the Treaty in a position to do so shall also co-operate in contributing . . . to the further development of the applications of nuclear energy for peaceful purposes, especially in the territories of the non-nuclear-weapon States Party to the Treaty, with due consideration for the needs of the developing areas of the world.

In response, the United States argues that section 1 of Article IV, while acknowledging the "inalienable right" of NPT parties to pursue nuclear energy for peaceful purposes, explicitly makes such activity contingent upon its being conducted "in conformity with Articles I and II," which ban the development of nuclear weapons by non-nuclear-weapon states. Analysts also note that there should be some latitude for "consideration for the needs" of countries seeking nuclear assistance. For example, oil-rich states might be seen as having lesser needs for nuclear power, and states that have not even built or operated nuclear power reactors might be legitimately denied technology for developing enrichment or spent-fuel reprocessing capabilities. Since the Nuclear Suppliers Group puts restrictions on dual-use export controls, for instance, that go well beyond what is required by the NPT (which does not address export controls on dual-use items), it would appear that it (or a subset of its members) could certainly apply these kinds of considerations as well.

OPTION: *Argue for an expanded United Nations Special Commission (UNSCOM) mandate to include exposing, and possibly even rendering harmless, any clandestine nuclear facilities in any non-nuclear-weapon NPT states worldwide, not just Iraq.*

In the aftermath of the Gulf War, the U.N. Security Council created a Special Commission and gave it extraordinary powers to ensure the "destruction, removal, or rendering harmless" of Iraq's weapons of mass destruction and its capability to produce more.[11] In the case of Iraq's nuclear weapon program, the U.N. Special Commission shares these powers with the IAEA.

UNSCOM is unique; only in Iraq, a militarily defeated power, has the world community exercised the ability to reverse forcibly the development of weapons of mass destruction. Some have argued that since the heads of state of the nations comprising the U.N. Security Council have declared the proliferation of weapons of mass destruction to be a "threat to international peace and security," the Security Council should take similar measures against other proliferant states, or at least against those states that have committed not to develop nuclear weapons but do so anyway.

One way to *expose* nuclear weapon facilities in such countries might be through the creation of a special organization like UNSCOM, under the

[11] U.N. Security Council Resolution 687, S/RES/687 (1991), Apr. 8, 1991.

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Destruction of an Iraqi nuclear facility at direction of the United Nations Security Council.

direction of the U.N. Security Council, to receive and evaluate national intelligence information on possible clandestine nuclear programs. This organization, with explicit *prior* U.N. backing, would then direct the IAEA to conduct special inspections, possibly assisting in the inspections.

This new agency would deal with cases wherein intelligence information strongly indicated the presence of a clandestine nuclear fuel-cycle facility, and the matter were serious, sensitive, and urgent enough to demand rapid and vigorous action. The advantage of such an organization would lie not in replacing the function of the IAEA, but in pre-establishing the Security Council's interest in ensuring the investigation of clandestine nuclear facilities in states that have foresworn them. Establishing such an organization and granting it the needed authority might be extremely hard, however, since it would require U.N. Security Council action and would be subject to a veto. Implementing missions to render any such discovered facilities harmless would be even more difficult, and would almost certainly require explicit Security Council action on a case-by-case basis. It is extremely unlikely that the Security Council would (or even could) delegate to this new organization the authority to force a state to accept an inspection or destroy a facility.

Since the IAEA already can request special inspections of locations that it has reason to believe would reveal violations of a state's safeguards agreement, this approach is not necessary to obtain the authority to ask for access to such facilities. Where it would go beyond existing IAEA authority would be in short-circuiting the safeguards process—which is primarily focused on declared facilities anyway—and in demonstrating prior Security Council backing for inspections. That is, under the present situation, before the IAEA can report a matter to the Security Council, it has to: 1) find an anomaly through routine safeguards activities or through other information made available to it, 2) bring the problem to the attention of the government involved, 3) attempt to resolve the problem, and 4) request a special inspection if the matter cannot be resolved. There are no preordained timelines within which special inspections must be completed. Establishing a U.N. organization to deal directly with possible clandestine activities in NPT states would allow this procedure to be streamlined in egregious cases, thus possibly saving many months or more of time that might otherwise be required by the standard escalating sequences of IAEA procedures.

This option might be opposed from two different directions: because it goes too far, or because it does not go far enough. In the first camp, some would object that the IAEA already has the authority to conduct special inspections, and the creation of a new organization for the same mission invites duplication, if not confusion. At the least, relations between this organization and the IAEA would have to be managed very carefully.

Those who argue that this proposal does not go far enough, on the other hand, might prefer to see the United Nations establish a body that would replace the IAEA—rather than work with it—for this mission. They might, for instance, believe that with its dual mission of safeguarding nuclear facilities and promoting nuclear power, the IAEA is not able to confront possible nuclear proliferation as vigorously as would anew United Nations organization. However, this argument faces serious difficulties. First, replacing the IAEA's authority to conduct special inspections would probably have a detrimental effect on the rest of the IAEA's safeguards activities, and it might entail the costly duplication of existing IAEA functions.

Second, since it is doubtful that the Security Council would delegate the authority to force a state to accept an inspection or destroy a facility, having a standing UNSCOM-like organization may not help much. Should the Security Council decide to take such action in the future, it could reconstitute such an organization.

Finally, and most significantly, **if the desire to substitute a U.N. organization for the IAEA is motivated by doubts that the IAEA would be willing to take forceful action against one of its own members, much the same doubts could also surround any new U.N.-related organization.** It might be added that in the case of North Korea, it was the IAEA that uncovered discrepancies in the North Korean declaration, confronted the North Koreans with its findings, and pressed for special inspections. When the matter was referred to the U.N. Security Council, the Council declined to take enforcement action. The United Nations and the IAEA are each governed by their respective memberships, which are largely the same. In the current international system, states may be quite reluctant to encourage the Security Council to exercise its full powers, fearing that these powers may someday be turned against themselves.

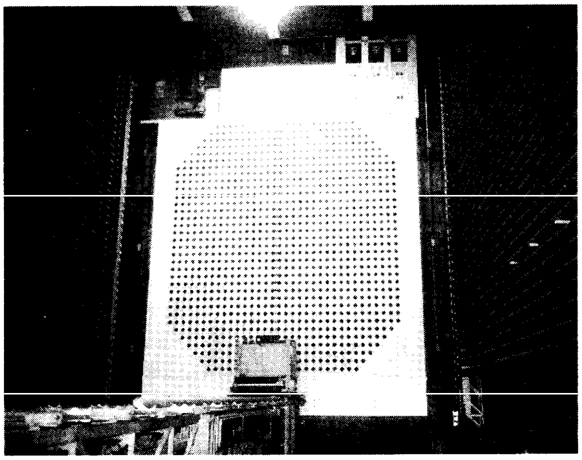
NON-NPT "THRESHOLD" STATES

OPTION: *Bring threshold nuclear states at least party into the nonproliferation regime by capping their production of weapon materials.*

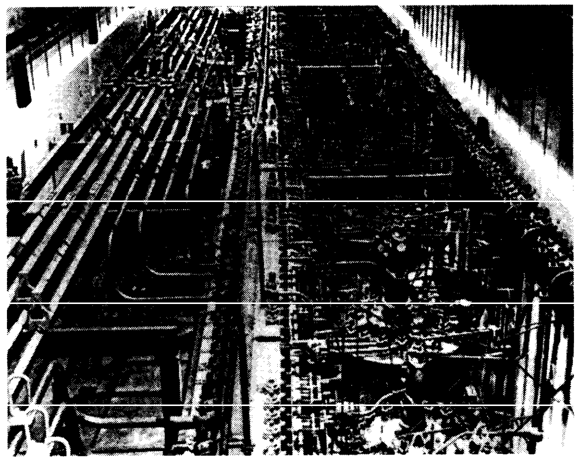
"Threshold states" are those, most notably India, Israel, and Pakistan, that are widely believed to have a nuclear weapon capability or the ability to deploy nuclear weapons on short notice, but have never officially acknowledged it. Although it is unlikely that these states would be willing to accept full-scope (INFCIRC/153-like) safeguards under present circumstances, they might be willing to participate in greatly increased safeguards coverage by joining a proposed universal (or nearly so) international convention to ban the production of fissile materials for nuclear weapons or outside safeguards. Such a convention, as supported by the Clinton Administration, would allow threshold states that may already have an overt or latent nuclear weapon capability to place all their current and future nuclear material production facilities under safeguards without having to declare or acknowledge past material production or weapon development activities. **The essential difference between this arrangement and full-scope safeguards is that a verified fissionable cutoff would only look forward; it would not seek to verify the absolute size or whereabouts of current stockpiles of nuclear material and would not address the issue of weapon possession or past development.** It would be full-scope only with regards to facilities and *future* production of materials, all of which would have to be declared, safeguarded, and constrained to peaceful applications. It would therefore offer at least the benefit of assuring others that no participating country was producing any *additional* materials that could be used in a weapon program. It would also include identical provisions for the nuclear-weapon states, thereby avoiding the discriminatory aspect of the NPT.

Such a convention would have no effect on the non-nuclear-weapon states party to the NPT, which are already forbidden from producing nuclear materials for use in weapons or outside safeguards. It would, however, place additional constraints upon the NPT nuclear-weapon states, which are now free to produce nuclear weapon materials without limit and are not even required to place their peaceful nuclear programs under safeguards. In so doing, it would be consistent with the nuclear disarmament provisions of Article VI of the NPT.

A fissile-material production cutoff would not, however, impose any significantly new burdens on the United States, since the United States announced in June 1992 that it would not produce any more highly enriched uranium or plutonium. Existing stockpiles of nuclear material were assumed to suffice for whatever might be done with the U.S. nuclear arsenal. Where this convention would affect the United States is in its verification provisions. The U.S. government has not yet



U.S. DEPARTMENT OF ENERGY



U.S. DEPARTMENT OF ENERGY

Former U.S. nuclear material production facilities would probably become subject to international monitoring—possibly by the International Atomic Energy Agency—if a convention banning the production of nuclear materials for weapons were to come into force. ***Left:*** *the N-reactor, a former plutonium production reactor at the Hanford site in Washington state.* ***Right:*** *the interior of a plutonium reprocessing facility at the Savannah River facility in South Carolina.*

agreed either on what provisions the United States would wish to see applied to other nations in order to have confidence that they were complying with the cutoff, or on what provisions the United States could live with if applied to U.S. facilities.

Such a convention also for the first time would place limits on any non-NPT states that chose to join it. The inducement for countries such as Israel, India, and Pakistan to do so would involve self-interest in advancing regional peace processes, as well as obtaining concessions from the nuclear-weapon states by accepting binding constraints on their own programs.

If such a convention could be implemented, it could go a long way toward capping a nuclear arms race in South Asia and contributing to the Middle East peace process. However, even though the convention itself would be silent as to any existing stockpiles of nuclear weapons or weapon materials among the threshold states, it **might harm the nonproliferation regime because it may be viewed as legitimizing the existing nuclear capabilities of the threshold states.** Any verification regime for the convention, for example, would have to exempt (implicitly or explicitly) existing stockpiles of weapon materials, since past production would not be covered. Such an exemption might be construed as lending legitimacy to the excluded stocks.

A cutoff convention would also lock in perceived nuclear disparities among both threshold and acknowledged nuclear weapon states, without providing a clear recipe for further confidence-building measures or disarmament. It also would tacitly legitimize the production of *safeguarded* weapon-usable material, regardless of a country's fuel-cycle needs. (In this, though, it is no more permissive than the NPT, which also allows such production.) Indeed, some critics of a cutoff convention fear that in lining up international support for the convention, the United States would promise other states freedom to pursue activities that are not explicitly prohibited by the convention (e.g., producing weapon-capable materials under safeguards). In so doing, they argue, the United States would have the effect of creating an "entitlement" for states to conduct activities that the United States would otherwise oppose.

Cutoff proponents, in turn, counter that the United States does not *have* to promise its negotiating partners that it would support their decision to conduct such activities. The United States could make clear that it opposed such activities even while acknowledging that it was not yet able to get international consensus on banning them.

OPTION: *Allow a one-time-only extension of the "nuclear club" while universalizing the NPZ 12*

The concept of a one-time extension of the declared nuclear states would involve setting up a time period in which *de facto* nuclear powers would be encouraged to declare their nuclear weapon status one way or the other, followed by the U.N. Security Council issuing a *binding resolution* that any *future* acquisition of weapons of mass destruction by any state (whether or not a member of the NPT) would constitute a threat to international peace and security that the Security Council would be required to halt.[13] The deadline for self-declaration of nuclear status would allow states such as Israel, India, and Pakistan a chance to establish themselves as nuclear-weapon states, if they chose to do so, and thus avoid coming under the provisions of this declaration. Once declared as nuclear-weapon states, they would have no political reason to stay outside a suitably broadened NPT, which could then become universal. At the cost of expanding the nuclear club, therefore, a universal (albeit still two-tiered) NPT might be created that would be stronger than one having several significant holdout states. Without these holdouts, there would be great pressure on the remaining states still outside the NPT to join, making the NPT truly universal. If enforced by the Security Council, such a treaty would probably be more effective than the existing NPT at preventing still further proliferation. There would be the problem, however, of verifying that a claimant actually had a nuclear weapon. Otherwise, a state could, in effect, reserve itself a slot in the nuclear club in advance.

The main problem with this proposal is that it would require an amendment of the NPT, which is crafted to make amendments virtually impossible (see discussion earlier in this chapter). Moreover, the admission of three more powers into the nuclear club might weaken international resolve against proliferation if no untoward consequences were to result for them. Other disadvantages of this would be that it would force the hand of Israel, India, and Pakistan, which already face serious security dilemmas. Each of these states has its own reasons for keeping the status of its nuclear program secret, and these reasons are probably tied primarily to regional security concerns. Such a one-time extension approach also fails to explain how regional or international security would be enhanced by threshold countries declaring their nuclear weapon capabilities openly, rather than harboring them implicitly. The decision to announce a nuclear weapon program publicly would be a provocative political act that might stimulate a response. In addition, neighbors of the new nuclear states, who would now confront a newly overt (if not new) nuclear threat, may in return withdraw from the Non-Proliferation Treaty on the grounds that it does not address their security needs. They may even conclude that they need at least to explore a nuclear weapon option.

Possibly, states making such declarations could then begin to work toward transparency (in an attempt to limit possibly destabilizing worst-case analysis by their adversaries) and toward arms control measures, such as were pursued by the United States and the former Soviet Union/Russia since the 1960s. But given the track record of superpower transparency and arms reductions, it could be years, if not decades, before tangible benefits could be derived from such an approach.

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[12] See David Kay, "The IAEA—How Can It Be Strengthened?", paper presented at the conference *Nuclear Proliferation in the 1990s: Challenges and Opportunities,* Woodrow Wilson Center, Washington, DC, Dec. 1-2, 1992 (footnote 23 of Kay's paper).

[13] The heads of the Security Council members, meeting in January 1992 at U.N. Headquarters in New York, declared in a statement that proliferation of weapons of mass destruction "constitutes a threat to international peace and security." However, this statement did not have the force of a binding Security Council resolution.

It might also be difficult to convince other states that the Security Council was serious about this extension of the nuclear club being indeed "one-time," never to be repeated if world circumstances were to change drastically.

IMPROVEMENTS IN THE INTERNATIONAL NUCLEAR FUEL CYCLE

OPTION: *Work to achieve a worldwide cutoff-either voluntary or negotiated with verification provisions—on production of all weapon-usable materials (highly enriched uranium and separated plutonium).*[14]

One of the most serious weaknesses of the current regime of controls over nuclear materials is that states are permitted to produce and stockpile weapon-usable materials—highly enriched uranium or separated plutonium—as long as they are placed under safeguards. After amassing a stockpile, a state would be free to withdraw from NPT and use its materials in weapons. One way to close this loophole is to eliminate the production of highly enriched uranium or separated plutonium entirely. Such a policy goes beyond the fissionable material cutoff described earlier, which permits the continued production of these materials under safeguards for nonweapon purposes.

■ Highly Enriched Uranium

Highly enriched uranium (HEU) has little use in the civil sector. Although a number of research reactors were originally designed to use HEU, the RERTR (Reduced Enrichment for Research and Test Reactor) program has developed high-density, low-enriched uranium (LEU) fuels that can be substituted for HEU fuel in a number of reactor types. Many such reactors have been converted. (See discussion below on the RERTR program.) Some reactors, however, have yet to be converted, and suitable fuels for others do not yet exist.

For example, Germany is considering construction of a new HEU-fueled research reactor to produce intense beams of neutrons for materials studies. (The United States has just cancelled its plans for a similar reactor.) Conversion of this reactor to run on LEU fuel would introduce cost, performance, and schedule penalties that the project's supporters view to be unacceptable. Another civil use for HEU is for the initial fuel loading for breeder reactors, which are reactors designed to produce plutonium fuel. Under such a cutoff proposal, such reactors would not be allowed, so HEU would not be needed to develop them. (See discussion of banning plutonium, immediately below.)

Cutting off the production of HEU is more problematic for military purposes, since naval nuclear reactors run on HEU. Nuclear-weapon powers with surplus stocks of HEU may be able to draw on those stocks to fuel their nuclear-powered naval vessels for many years; otherwise, states would need to consider conversion to LEU (if possible) or abandonment of those vessels.

Monitoring a ban on the production of HEU is complicated by the fact that many enrichment technologies can be rather easily converted from LEU production to HEU production. Therefore, special means might have to be found to assure those participating in a fissionable production ban that LEU production facilities were not being converted in this way. Such means of verification might have to be more intrusive than the Hexapartite safeguards agreement already in place for centrifuge facilities (which allows only limited access to the cascade area), and might have to extend to all enrichment technologies. In many cases, these means would have to involve very short-notice inspections, such as provided for under the Hexapartite agreement. Such short notice is possible in Europe and Japan, because the IAEA has resident inspectors either in-country or able to travel there

[14] A brief but useful summary of the history and ramifications of various fissile cutoff proposals is contained in the National Resources Defense Council report "Non-Proliferation and Arms Control: Issues and Options for the Clinton Administration," January 1993, pp. 20-22.

without lengthy border-crossing procedures. This approach may not be so easily extended to enrichment facilities elsewhere in the world, were they to be established there.

Plutonium

Eliminating the production of separated plutonium would terminate exploration and exploitation of one fuel cycle that had been envisaged since the dawn of nuclear power: the recovery of plutonium from spent reactor fuel and the exploitation of that plutonium in either the current generation or a future generation of reactors (see box 4-2). Because of its adverse implications for proliferation, the United States actively tried to discourage the use of plutonium in civil reactor programs overseas under the Carter Administration in the late 1970s. In 1984, the United States terminated the Clinch River breeder reactor program in Tennessee, and as of this writing the United States no longer operates any experimental or prototype breeder reactors.[15] However, several countries around the world still use, or say they intend to use, plutonium-based fuel cycles.

Banning the separation of plutonium would eventually foreclose the exploitation (and even the study) of the breeder reaction option. For many nuclear power proponents, such a step is unthinkable. It would be strenuously opposed, for example, by Russia, Japan, France, and possibly India, Kazakhstan, and the United Kingdom, as well as by some nuclear power proponents in the United States, which would see such a move as putting the most attractive feature of nuclear power forever out of reach. Russia has more practical reasons to oppose a ban on plutonium production: the three plutonium production reactors remaining in operation in Russia are producing steam heat and electricity for nearby towns, and are the only source of employment for skilled nuclear scientists and engineers in the area.[16] At present, the spent fuel from these production reactors must be reprocessed within about two years to avoid corrosion and radioactive leakage into the spent fuel pond. At least as of now, Japan still plans to make extensive use of plutonium, having broken ground in 1994 for its large reprocessing facility at Rokkasho-mura, now envisioned to attain full operation in the middle of the next decade.

Even so, interest in breeder reactors is declining around the world, making it easier to consider banning the use of plutonium than it would have been 10 years ago (see box 4-3). A ban on the production of weapon-usable materials would be supported by those who are unwilling to allow nations to stockpile such materials under safeguards, by those who do not believe that safeguards on plutonium handling plants are adequate to ensure that plutonium is not diverted, and by those who believe that shipping significant amounts of plutonium between nuclear facilities poses unacceptable safety and security risks even if diversions

[15]For discussion of the advanced liquid metal reactor, an advanced reactor capable of being configured as a breeder, see U.S. Congress, Office of Technology Assessment, *Technical Options for the Advanced Liquid Metal Reactor*, OTA-BP-ENV-126 (Washington, DC: U.S. Government Printing Office, May 1994). The reactor was terminated by Congress and the Clinton Administration in 1994.

[16]These reactors also have characteristics that give them inherent needs for reprocessing, despite the fact that the resulting plutonium, with less than 1,000 MW-days/ton burnup, is necessarily of excellent weapon grade. The reactors at Tomsk, like those at Hanford, cycle through roughly 1,200 ton of natural uranium fuel per year (as opposed to 35 tons of low-enriched uranium/year for a light-water reactor); storage facilities at the reactor are adequate for only 6 to 12 months of spent fuel (which cannot be stored for longer than two years in any case; see main text). While options for conversion to coal- or gas-fired generators are being studied, there is no infrastructure to bring in these fuels, and most such options appear to run up against budgets on the order of at least a billion dollars. Laurin Dodd, Pacific Northwest Laboratory, presentation at NRDC/FAS meeting, Washington, DC, Dec. 16-17, 1993. U.S. Vice President Gore and Russian Premier Chernomyrdin agreed in December 1993 to shut down these reactors by the year 2000 while taking steps to provide alternative energy supplies, with U.S. assistance.

BOX 4-2: The Allure of the Plutonium Fuel Cycle

Nuclear reactors today generate their energy from the uranium-235 form of uranium, which comprises only 0.7 percent of natural uranium, The remaining portion of natural uranium, almost entirely the uranium-238 form, does not directly produce energy in civil reactors. Some small fraction of this uranium-238 is, however, converted to plutonium—which can generate energy-during the course of reactor operation, such that by the time a load of fuel in one type of civil reactor requires replacement, some 25 percent of the energy being produced by that fuel is actually generated by the plutonium that has previously been created within it.

Plutonium and unused uranium can be recovered from spent reactor fuel in a procedure called chemical reprocessing, with the plutonium subsequently being used in one of two ways: in present-generation "light-water" nuclear reactors in the form of "mixed-oxide" (MOX) fuel, or in next-generation "breeder" reactors. MOX, which has been used in a number of reactors around the world, typically consists of a few percent plutonium oxide mixed with natural or depleted uranium oxide and formed into fuel rods, (Depleted uranium is the byproduct of producing enriched uranium. It has a smaller fraction of uranium-235 than natural uranium has.) Although MOX eliminates the need to enrich uranium, the extraordinary expense of processing plutonium into MOX makes MOX fuel more expensive than enriched uranium fuel with the same energy content, In fact, processing costs are so high that MOX would be more expensive than uranium even if the plutonium used to make it were free. (Even if uneconomic in terms of fuel costs, reprocessing might still be done for waste management purposes. It separates the most intensely radioactive, shorter-lived reactor byproducts from less radioactive, although longer-lived, components of the spent fuel,)

In a breeder reactor, a "blanket" containing natural uranium surrounds the reactor core, which is fueled initially either with highly enriched uranium or plutonium. Uranium-238 in the blanket turns to plutonium when irradiated, and a breeder reactor can generate more plutonium than it consumes. In so doing, it can extend uranium reserves by as much as a factor of 1,000, compared with what would be available if low-enriched uranium fuel were stored as waste after being used in a nuclear reactor.[1] When the availability of uranium was thought to be the limiting factor to the spread of nuclear power, it was assumed that the nuclear fuel cycle would eventually be based on the generation, recovery, and re-use of plutonium. However, for both economic and nonproliferation reasons, plutonium reprocessing has lost much of its initial allure, and interest in breeder reactors has similarly declined (see box 4-3).

[1] A factor of 100 comes from the relative abundance of uranium-238 compared with uranium-235; another factor of 10 represents the additional low-grade uranium resources that might make sense to recover if the uranium-238 content were to be exploited to make plutonium, but that would not be economic to mine if only the uranium-235 were used. See National Academy of Sciences, *Management and Disposition of Excess Weapons Plutonium* (Washington, DC: National Academy Press, 1994), p. 53, (footnote 29 of the Academy report).

were certain to be detected. In this view, foregoing the civil use of plutonium would be the lesser of two evils.[17]

Policies governing the production or use of new plutonium will influence, if not determine, the methods chosen to dispose of existing stock-

[17] As an alternative to recycling, while retaining some of the energy value of the plutonium, there has been some interest in a fuel cycle called "DUPIC" or Direct Use of Spent Power Reactor Fuel in Candu reactors. This approach envisions using spent LEU fuel directly in Candu natural-uranium reactors. Canada has been pushing this as a long-term approach, and there is the possibility that countries such as South Korea might be interested in the future. The 0.9 percent Pu contained in the spent LWR fuel going in is reduced to 0.2 percent Pu. The advantages of such an approach are that it gets rid of much Pu, and what Pu is left has a smaller proportion than does the original spent fuel of the Pu-239 isotope that is desirable for weapons. One disadvantage is that radioactive fuel must be loaded into the Candu. More seriously, by institutionalizing the processing of spent fuel into new fuel to obtain additional energy, such a fuel cycle might still awaken interest in chemical reprocessing of full-circle spent fuel and the development of a plutonium fuel cycle.

BOX 4-3: The Declining Interest in Breeder Reactors

Breeder technology—which poses proliferation concerns since it requires separating and recycling plutonium—is no longer being vigorously pursued outside of Russia, India, and Japan. France's 1,200-MW Superphénix fast-breeder reactor (FBR) has been shut down for extended periods. It was connected to the French electrical grid for two days in December 1994, reaching 20 percent power, but has not operated since then. Despite the investment of more than DM4 billion (more than $2.5 billion) between 1974 and 1991, Germany's controversial 300-MW FBR at Kalkar had never opened. In March 1991, German officials declared that the project had no hope of being licensed and was being abandoned.[1] In August 1992, Britain confirmed its decision to shut down by 1994 the Dounreay 250-MWt (megawatts of thermal power) Prototype Fast Reactor in Scotland on the grounds that commercial deployment of fast reactors in the United Kingdom would not be required for 30 to 40 years. The United Kingdom is also pulling out of a joint European project in fast reactors.

Breeder programs are making better headway in Japan, although they still face obstacles. Japan's Monju prototype FBR, with a generating capacity of 280 MWe (megawatts of electrical power), reached criticality in April 1994, a year and a half later than had been originally planned, using the plutonium shipped back from France at the end of 1992. Completion of Japan's larger scale demonstration fast-breeder reactor, which in 1991 was scheduled for the year 2000, has been delayed by at least a decade until 2010. Startup of the large commercial reprocessing plant at Rokkasho-mura has likewise slipped to about 2005, and a second proposed reprocessing plant has also been delayed.[2]

Only in India, Russia, and possibly Kazakhstan does there appear to be a strong ambition in the near term to pursue plutonium-based or plutonium-breeding fuel cycles. In the latter two countries, much of this ambition is driven by a desire to derive energy, if not economic benefit, from the scores of tonnes of plutonium that are expected to be obtained from dismantled warheads. It is also part of an ambitious overall plan Russia has put forth in an attempt to double its nuclear-generating capacity by 2010, including building 20 new reactors to produce an additional 20 GWe (gigawatts electrical power) of generating capacity.[3] The initial stage of the plan calls for constructing a 630-MWe FBR reactor at Sosnovy Bor, to be followed by three FBRs.[4] There is already a 600-MWt breeder reactor (BN-600) in operation at Beloyarsk. Kazakhstan has plans to build a second 350-MWt FBR at Aqtau (formerly Shevchenko), where it already had a BN-350 (350 MWt; 60 MWe) reactor inherited from the U.S.S.R. However, given the economic situation in these two countries, such optimistic plans for expansion may be unrealistic,

In India, the new, unsafeguarded breeder reactor and reprocessing facilities at Kalpakkam emphasize that country's continuing interest in the plutonium cycle.

Finally, in the United States, breeder reactors seemed to have reached a dead end with the termination of the Clinch River breeder reactor at an early stage of construction in 1984. Recently, there has been a small revival of interest in the nuclear industry and some national laboratories in developing the so-called ALMR—the advanced liquid metal reactor (formerly called the integral fast reactor) —which would be collocated with reprocessing and plutonium fuel fabrication facilities. There would be minimal access to plutonium-bearing fuel, whether fresh or spent, and the collocation of the elements of the fuel cycle would add significantly to proliferation resistance. In 1994, however, the U.S. administration recommended terminating work in this area as well. Despite some efforts in Congress to restore minimal levels of funding to pursue this option, the program was killed. Even if demonstrated to be feasible, which would necessitate the investment of several billion dollars, the prospects for market acceptance of such a reactor within the next decade or two are highly questionable.

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[1] *Arms Control Reporter,* 1992, p. 602. B.234.

[2] The latest Long-Term Nuclear Energy Development and Utilization Program, published in November 1994 by Japan's Atomic Energy Commission, states that the Rokkasho reprocessing plant "Is scheduled to be commissioned shortly after the year 2000" (p. 50 of unofficial English translation by the Atomic Energy Commission), but press sources indicate that the plant "won't begin operating until 2004 or so. " See, e.g., N. Usui and A. MacLachlan, "Japan AEC Looking at Delay in Startup of Reprocessing Plants, " *Nuclear Fuel,* Feb. 14, 1994, pp. 10-11.

[3] Russia also has a small (11-MWt) breeder at Dimitrovgrad and a 800-MW breeder 10 percent complete at Yuzhnouval'skaya, whose construction has been suspended.

[4] *Arms Control Reporter, 1992, p. 602. B.236.*

piles of separated plutonium, including that recovered from dismantled nuclear weapons. Some who advocate that surplus weapon plutonium be "burned" in nuclear reactors-either as mixed-oxide fuel in existing light-water reactors, or more directly in future breeders—do so in large part to maintain interest in plutonium fuel cycles.[18] Conversely, it will be difficult to pursue options for burning weapon plutonium in nuclear reactors—even in government reactors not connected with civil power production—in an environment where separation of plutonium for use in civil nuclear reactors is banned.

A variation on the option to ban the production of weapon-usable nuclear materials would be a ban on separating and stockpiling excess plutonium—any plutonium that would not be used immediately to fuel a nuclear reactor. Since the rate at which plutonium is being loaded into Japanese nuclear reactors has not kept up with the rate at which Japan now plans to import plutonium separated from the spent fuel that it had earlier shipped to European reprocessing plants, tons of separated plutonium will begin to be stockpiled on Japanese territory. Even if Japan does not give up the plutonium option, some observers have urged it to delay its own reprocessing, and to stop accepting shipments of separated plutonium from Europe, until its plans to consume plutonium catch up to its ability to produce it.

OPTION: *Reinvigorate the Reduced Enrichment for Research and Test Reactors program, combined with an expanded U.S. take-back policy for U.S.-supplied HEU reactor fuel.*

Research reactors are proliferation risks in two ways: all of them are capable of producing plutonium, and in addition, many are fueled with highly enriched uranium. The quantities both of fuel and of potential plutonium produced are roughly proportional to the power of the reactor, and the proliferation risks are small for reactors below about 10 MW thermal power (MWt). These would normally be fueled by considerably less than a "significant quantity" (SQ) of HEU and could produce only similar fractions of an SQ of plutonium per year, even if optimized for maximum production. The risks become more significant, however, for reactors of 30 to 50 MWt power levels. The issue of plutonium production is related to the effectiveness of safeguards (see box 4-4). The discussion here addresses the HEU aspect, which can be affected by unilateral actions on the part of the small number of suppliers of this specialized fuel (the United States being one of the largest).

In the United States, Argonne National Laboratory has been addressing the issue of finding alternative (LEU) fuels for such reactors for over a decade, though its funding was scaled back

[18] For extensive discussion of options for destroying weapon-grade plutonium in the United States and the Soviet Union, see U.S. Congress, Office of Technology Assessment, *Dismantling the Bomb and Managing the Nuclear Materials, OTA-O-572* (Washington, DC: U.S. Government Printing Office, September 1993) and Committee on International Security and Arms Control, National Academy of Sciences, *Management and Disposition of Excess Weapons Pluutonium* (Washington, DC: National Academy Press, 1994). A major recommendation of the latter study is that disposition of weapon plutonium be treated as an independent issue and not be subsumed under decisions concerning the future of nuclear power and the adoption or rejection of plutonium fuel cycles. The report urges that separated plutonium from weapons rapidly be put into a form where it would take at least as much effort to recover the plutonium as it would to reprocess plutonium from the much larger stocks of spent fuel already existing worldwide. The report also concludes that once weapon plutonium has been converted to such a form— for example by mixing it with radioactive waste to create "artificial spent fuel," or by converting it to mixed-oxide fuel and partially burning it in a light-water reactor—there is little point to proceeding to eliminate it entirely before addressing those stocks of spent fuel as well.

BOX 4-4: IAEA Safeguards on Research Reactors

At present, safeguards requirements do not provide for full-time camera surveillance of nuclear material at small research reactors. This leads to the theoretical possibility of diverting reactor fuel and clandestinely reprocessing it to obtain small amounts of plutonium. Iraq, for instance, reprocessed several fuel rods from its IRT-5000 reactor before the Persian Gulf war in lab-facilities ("hot cells") it was known to have, separating just over 2 g of plutonium. On that scale, this action—if done for civil, experimental purposes---did not need to be reported to the IAEA, and did not technically constitute a safeguards violation. However, Iraq also clandestinely irradiated its own, undeclared uranium fuel in this reactor, separating 3 additional grams of plutonium. The undeclared production and separation of plutonium violated Iraq's safeguards agreement.[1] Nevertheless, small research reactors produce plutonium so slowly that reprocessing their fuel to obtain material for a weapon would be impractical.[2] If extra precautions are desired, however, camera surveillance at such reactors would help detect diversion of significant quantities.[3]

The main difficulties in attaining safeguards inspection goals at research reactors and critical assemblies (RRCAs) tend to involve verifying both the irradiated fuel and the fact that there was no diversion of 1 SQ or more of direct-use material if such material was produced through unrecorded irradiation. For example, inspection goals are sometimes not attained at RRCAs because of a lack of a full set of containment and surveillance or other safeguards measures for confirming the absence of unrecorded irradiation of nuclear material. (Containment and surveillance measures are difficult to apply, or draw conclusions from, because material and equipment in the reactor vault is frequently moved even during normal operation.) Certain reactor design aspects can also make it difficult to access for verification purposes the irradiated fuel located in the reactor core.

[1]Programme for promoting Nuclear Non-proliferation, *Newsbrief,* No. 15, Autumn 1991, p. 10, citing IAEA Press releases and other sources.

[2]Reactors containing mostly uranium-238 in their fuel (natural uranium or a few percent enriched LEU) produce plutonium at low burnups at a rate of roughly 1 g per MWt per day, such that a 30-MWt reactor would produce just over 8 kg of Pu per year if it were operated 75 percent of the time. Reactors running on HEU are able to produce smaller amounts in uranium-238 targets placed in and around their core; in practice only 0.5 to 0.65 g of plutonium per MWt per day is produced, due to neutron losses in control rods and out of the reactor, and absorption by fission products such as xenon-1 35. See Marvin M. Miller, MIT, "The Potential for Upgrading Safeguards Procedures at Research Reactors Fueled with Highly Enriched Uranium: Part 11," report prepared for the U.S. Arms Control and Disarmament Agency, July 1984.

[3]Statement of Hans Mayer, IAEA spokesperson, September 16-20, 1991 at the regular session of the IAEA General Conference in Vienna, as cited in the *Arms Control Reporter,* 1991, p. 602. B.200.

significantly in the 1990s.[19] Such fuels have been developed for a number of reactor types and have been substituted into many U.S. and foreign reactors.[20] In 1992, the Schumer amendment to the Energy Policy Act (Public Law 102-486) prohibited the export of directly weapon-usable HEU reactor fuel from the United States unless the United States was developing suitable alternate

[19]Some believe that the suspension of the RERTR program may have been a political decision to delay the conversion of foreign research reactors so as to avoid the pressure that would inevitably then be placed on the U.S. Department of Energy to convert its own HEU-fueled research reactors.

[20]As of 1990, the IAEA was safeguarding 42 research reactors or critical assemblies handling more than 1 SQ each of nuclear material, of which 37 handled more than 1 SQ of direct-use material outside the reactor core.

fuels, and no HEU exports were made in 1993 or 1994.[21]

The RERTR program has made significant progress in the past at finding alternate fuels. Continued funding would permit it to see its goals through to the implementation stage for additional types of reactors. Cooperative work with other countries—particularly Russia—can further reduce the use of HEU in research reactors through the development of alternative fuels for reactors that were not originally fueled with U.S.-origin HEU.

HEU Fuel Take-Back Policy

Since the 1950s, the United States has supplied HEU fuel for a number of foreign research reactors, and since about 1960 it has had a policy to take back spent HEU fuel of U.S. origin.[22] During the Carter Administration, the United States instituted a policy to develop the alternative LEU fuels mentioned above while taking back HEU fuels from reactors converted to the new fuels.

The take-back policy was suspended in 1988 because of the need to conduct an environmental review, given the lack of any permanent repository for storage of radioactive used fuel in the United States. Under pressure from the State Department and the IAEA, however, the U.S. Department of Energy (DOE) agreed on July 13, 1993 to prepare an environmental impact statement, as required by the National Environmental Policy Act, for resuming shipments of HEU fuel elements to DOE's facility at Savannah River, South Carolina. The environmental impact statement assesses the environmental consequences of taking back the fuel and compares them to those of alternate policies.

Of the some 22,700 fuel elements slated for return to the United States, 409 presented an immediate problem because they were stored at reactors that needed to discharge spent fuel but had no remaining onsite storage capacity. If these elements could not be returned to the United States, those reactors would be forced either to shut down or to have the fuel elements reprocessed in conflict with U.S. policy. After completing an environmental assessment in April 1994, DOE concluded that the return of these elements was urgently needed, and that it posed no significant environmental impact. The federal government then began accepting the fuel at Savannah River.

South Carolina challenged the return of this fuel in court and obtained an injunction preventing DOE from accepting it. However, DOE won a reversal of the injunction on appeal,[23] and it has received some 100 of the fuel elements at Savannah River pending resolution of the court challenge. Should the federal government prevail, the remainder of the 409 elements will be returned to the United States. Return of the full 22,700 fuel elements awaits completion of the environmental review process specified in the National Environmental Policy Act.

To further the goals of the RERTR program, the United States can continue its development of alternate fuels, and it can continue efforts to encourage foreign reactor operators—including operators of reactors not originally fueled with U.S.-supplied HEU—to convert to them. More-

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[21]The amendment (now section 903 of the law) prohibits export of U.S.-origin HEU fuel to foreign research reactors unless three conditions are met: 1) there is no alternative [LEU] fuel or target that can be used in that reactor; 2) the proposed recipient of the uranium has provided assurances that whenever an alternative [LEU] fuel or target can be used in that reactor, it will use that alternative in lieu of HEU; and 3) the U.S. government is actively developing an alternative nuclear reactor fuel or target that can be used in that reactor.

[22]According to a report prepared by the Nuclear Regulatory Commission, the United States has exported a total of 25,875 kg of HEU, of which 8,394 kg have been returned, leaving 17,489 kg of HEU in 51 countries that could be returned. (As cited in Michael Knapik, "DOE Drafting Policy on Taking Back HEU Fuel from Non-U.S. Reactors," *Nuclear Fuel*, Apr. 12, 1993, p. 14.) This breaks down into the following (in kilograms): 13,677 in EURATOM, 1,184 in Canada, and 1.973 in Japan. Other countries include Argentina, 58; Australia, 146; Austria, 39; Brazil, 9; Chile, 12; Columbia, 3; Iran, 6; Israel, 34; Jamaica, 1; Mexico, 12; Norway, 4; Pakistan, 16; Philippines, 3; Romania, 39; Slovenia, 5; South Africa, 10; South Korea, 25; Sweden, 127; Switzerland, 82; Taiwan, 10; Thailand, 5; and Turkey, 8. (Due to roundoff errors, individual entries may not add to totals.)

[23]Department of Energy press release, "Court Blocks Shipment of Foreign Spent Fuel," DOE News, September 13, 1994.

over, U.S. nonproliferation objectives will be harmed if the inability to take back spent HEU fuel forces foreign reactor operators to reprocess U. S.-origin fuel.

In a case that is not part of the RERTR program but also involved the shipment of highly enriched uranium to the United States, the Department of Energy successfully brought some 600 kg of HEU originating in Kazakhstan to its facility in Oak Ridge, Tennessee. This transfer, known as Project Sapphire, was undertaken to eliminate the possibility that the material might end up in unauthorized hands. Although it was conducted under cover of secrecy, state and local officials received classified briefings in advance. No court challenges were brought.

OPTION: *Undertake studies to look seriously at the feasibility and desirability of internationalizing various aspects of the nuclear fuel cycle.*

A "mild" form of internationalization would be to place stockpiles of separated plutonium under international control or management at perhaps one or a small number of agreed sites. The IAEA Statute envisions such a role for the IAEA, with Article XX.A.5 authorizing the IAEA to require the deposit of surplus plutonium to prevent stockpiling. Such an international plutonium storage system has been under study within the IAEA, at varying levels of attention, since at least the late 1970s.[24] More recently, the IAEA revisited the idea and held a series of meetings beginning in 1992 and 1993 in Vienna. In 1995, the United States placed highly enriched uranium and plutonium declared excess to its weapon program under IAEA safeguards (see discussion in chapter 3 of the United States' "voluntary offer" to accept safeguards.) However, this arrangement is strictly a bilateral one. It does not involve international ownership or control.

Difficulties in implementing international storage include issues of ownership of the contributed material, the conditions under which a state would be able to access and utilize plutonium that it had contributed, and fears by some that creating such a system would legitimize the production of plutonium. A more fundamental problem would be gaining the participation of states that had rejected the NPT and would not likely place their own plutonium under international control.

A more far-reaching change to the existing nuclear regime than any option so far discussed would be to revisit some of the major assumptions underlying the current regime, such as the assumption that nuclear weapon-usable materials should be permitted to remain under the control of individual states. One mechanism for keeping weapon-usable nuclear materials out of national control is to ban their production, as discussed above. However, since individual nations or (in the case of enrichment consortia) groups of nations would retain uranium enrichment capability under such an approach, they would inherently retain the capability to produce weapon-usable material by converting from LEU to HEU production. A stronger mechanism for ensuring that countries do not develop nuclear weapon-usable materials would be to place those portions of the nuclear fuel cycle that are of greatest proliferation concern under direct international control. With the Acheson-Lilienthal report and the Baruch plan, such an approach was discussed at the beginning of the nuclear era; the events of the 1990s have created fresh interest in the idea.

Instituting an international nuclear material control regime would involve the internationalization of enrichment, reprocessing, and, possibly, fuel fabrication facilities. Such a regime would be based on the assumption that existing safeguards on such facilities will not be sufficient to meet nonproliferation goals, but that banning these facilities entirely is neither desirable nor politically achievable. As such, an international control regime would involve drastic changes to the way the uranium and plutonium markets now operate, affecting the ownership and

[24] David A.V. Fischer and Paul Szasz, *Safeguarding the Atom: A Critical Appraisal* (London: SIPRI, Taylor and Francis, 1985), pp. 115-116.

operation of many billions of dollars worth of existing facilities. Dramatic changes would be required to the international legal regime, along with extensive treaty negotiations.

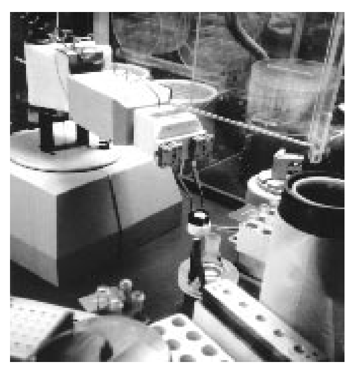
It would be very difficult to create such a regime. Non-nuclear-weapon states would likely object strongly to a regime that reinforced the discriminatory aspects of the NPT by denying them the ability to operate nuclear fuel-cycle facilities by themselves, while permitting the nuclear weapon states to do so in their military programs. Given the magnitude of the changes such a policy would require, it would likely be possible only with sustained effort over many years, if at all. More detailed analysis of this issue is beyond the scope of this report.

Appendix A: Safeguarding Reprocessing Facilities

A

This appendix focuses on the issue of safeguards at reprocessing plants, a type of bulk-handling facility of particular interest because it produces large quantities of plutonium that can be used to make nuclear weapons. Although there is only one currently operating reprocessing facility under INFCIRC/153-type safeguards (Japan's Tokai plant), there are several large plants in operation or to be built in the future.[1] The other large plant that will be under INFCIRC/153 safeguards is the Rokkasho-mura plant in Japan, which is expected to begin full operation in about 2005 (see table A-1).[2]

The ability of safeguards to assure the nondiversion of "significant quantities" of plutonium from large reprocessing plants has been the subject of considerable attention and controversy for many years. The major technology holders have been studying these issues under the auspices of the LASCAR (Large Scale Reprocessing) forum since the late 1980s and have completed a major study.[3] This appendix will describe the basic safeguards ap-



[1]Those in operation, however, are in nuclear weapon states—France, the United Kingdom, and Russia—that are not required to place their nuclear facilities under IAEA safeguards. Parts of the several reprocessing plants in France and the United Kingdom are safeguarded under the voluntary offer these states have made to place certain facilities under IAEA safeguards. However, these safeguards do not extend to the entire plant.

[2]N. Usui and A. MacLachlan, "Japan AEC Looking at Delay in Startup of Reprocessing Plants," *Nuclear Fuel*, Feb. 14, 1994, pp. 10-11.

[3]The only publicly available document from LASCAR is the booklet *Report of the LASCAR Forum: Large Scale Reprocessing Plant Safeguards,* STI/PUB/922 (Vienna, Austria: IAEA, July 1992).

TABLE A-1: Civil Reprocessing Facilities

Location	Plant name	Capacity[a]	Operational status	Safeguards status
NPT nuclear-weapon states (NWS):				
France (Cap de la Hague)	Cogema UP2[b], UP3	800 t HM (LWR fuel)/yr each; 1,600 t HM/yr total	In operation; UP2 since 196& UP3 since 1990	Limited IAEA safeguards through nuclear-weapon-state voluntary offer LASCAR involvement with UP3
France (Marcoule)	Cogema UP1	400 t HM (metal fuel)/yr[d]	1958- 2000?	(EURATOM only)[c]
France (Marcoule)	CEA APM	6 t HM (FBR fuel)/yr	1988- present	(EURATOM only)
Russia (Chelyabinsk-40)	Mayak	600 t HM (LWR fuel)/yr	1978- present	No
United Kingdom (Sellafield)	Windscale B205	1,500 t HM (magnox)/yr	1964-201 O?	(EURATOM only)
United Kingdom (Sellafield)	Thermal Oxide Reprocessing Plant (THORP)	1200 t HM (LWR fuel)/yr	In commissioning	EURATOM; limited IAEA safeguards under United Kingdom voluntary offer to the IAEA LASCAR involvement
United Kingdom (Thurso)	Fast Reactor Fuel Reprocessing Plant; (Dounreay)	7 t HM (FBR fuel)/yr[d]	In operation; (1958 - 1995?)	Limited IAEA safeguards for period (1980-1982) through United Kingdom voluntary offer; training and R&D
USA (West Valley)	Nuclear Fuel Services (NFS)	300 t HM (LWR fuel) / yr	1966-1972 (retired)	Training and R&D
NPT non-nuclear-weapon states (NNWS) with potential for large reprocessing capability:				
Germany (Karlsruhe)	Wiederauf-Arbeitungs Anlage Karlsruhe (WAK)	35 t HM (LWR fuel)/yr	1971-1991	IAEA NPT safeguards; EURATOM
Germany (Wackersdorf)	Wiederauf-Arbeitungs Anlage Wackersdorf (WAW)	500 t HM (LWR fuel)/yr	Canceled	Planning, R&D; LASCAR involvement
Japan (Tokai-mura)	Tokai Reprocessing Plant	90 t HM (LWR/ATR fuel)/yr	In operation (startup 1981)	IAEA NPT safeguards
Japan (Rokkasho-mura)	Rokkasho Reprocessing Plant	800 t HM (LWR fuel)/yr	Under construction (startup 2005?)	IAEA NPT safeguards; LASCAR involvement

TABLE A-1 (Cont'd.): Civil Reprocessing Facilities

Location	Plant name	Capacity	Operational status	Safeguards status
Japan (Tokai-mura)	Chemical Process Facility	Fast reactor R&D reprocessing plant[d]	1982-1987	IAEA NPT safeguards
Japan (Tokai-mura)	Recycle Engineering Technology Facility (RETF)	24 t HM (LMR fuel)/yr	Under license review	IAEA NPT safeguards
NPT non-nuclear-weapon states with small to medium scale reprocessing capability:				
Belgium (Mel)	Eurochemic	30-60 t HM (LWR and MTR fuel)/yr	1966-1974	IAEA safeguards applied after plant shut down; EURATOM
Italy (Saluggia)	EUREX	20 t HM (LWR fuel)/yr	Shut down	IAEA NPT safeguards; EURATOM
Italy (Rotondella)	ITREC	4 t HM (Th fuel)/yr	Shut down	IAEA NPT safeguards (EURATOM)
Italy (Ispra)	Petra	Experimental; TRU waste R&D	Awaiting commissioning	IAEA NPT safeguards (EURATOM)
NPT (or otherwise safeguarded) states of past or current proliferation concern:				
Argentina (near Buenos Aires)	Ezeiza	[5 t HM/yr]	Suspended 1990	Partly
Brazil (Resende)		[3 t HM/yr]	Suspended 1980s	Yes
DPRK (Yongbyon)	Radiochemical Laboratory	Confidential [pilot scale?]	Confidential [1992?]	Nominally IAEA NPT safeguards, but now in violation
Iraq (Tuwaitha)	No name given	Confidential [lab scale]	1989-1991 (destroyed)	Violation
South Africa (Pelindaba)		[Pilot scale]	[1987 - ?]	IAEA NPT safeguards
Non-NPT states:				
India (Tarapur)	PREFRE	100 t HM (Candu fuel)/yr	In operation (commissioned 1982)	IAEA safeguards only when safeguarded fuel is reprocessed
India (Trombay)	B. A.R.C.	30 t HM/yr	1966 - 1974; [and 1983- present?]	No
India (Kalpakkam)		[100-200 t HM/yr?]	Planned startup 1993/1994?	No
Israel	Dimona	[50 -100 t HM/yr]?	1966? - present?	No

(continued)

TABLE A-1 (Cont'd.): Civil Reprocessing Facilities

Location	Plant name	Capacity	Operational status	Safeguards status
Pakistan (Chasma)		Planned 100 t HM/yr	Construction may have ended 1978	No (but IAEA safeguards had been planned)
Pakistan (Rawalpindi)	New Labs	[5 t/ HM yr?]	Believed not to be operating	No

[a] Capacity in tons per day is generally about 1/200 times the capacity given in tons per year. Items in [brackets] or with question marks represent estimates or substantial uncertainty, respectively.

[b] UP2 operated at 400 t HM/yr capacity until 1990; its upgrade, UP2-800," began operating in 1992. The latter, along with UP3, will be involved with limited IAEA safeguards.

[c] All *civilian* nuclear material in European Community member states (even in France and Britain) is safeguarded by EURATOM under EC Regulation 3227/76. However, because they are nuclear weapon states, France and Britain are not obligated to place their facilities under IAEA safeguards.

[d] Because FBR fuel contains relatively large fractions of plutonium, a given reprocessing capacity (in terms of spent FBR fuel) translates to a plutonium throughput up to 15 times higher than would result from reprocessing the same amount of typical light-water reactor spent fuel.

KEY: CEA = Commissariat a' l'E'nergie Atomique; Cogema = Compagnie Ge'ne'rale des Matie'res Nucle'aires; FBR = fast breeder reactor (liquid metal reactor); HM = heavy metal; LASCAR = IAEA forum on large-scale reprocessing; LWR = light-water reactor; magnox = type of reactor; MTR = materials test reactor; TRU = transuranic

SOURCE: Adapted from Thomas Shea et al., "Safeguarding Reprocessing Plants: Principles, Past Experience, Current Practice and Future Trends," *Journal of Nuclear Materials Management,* July 1993, p. 20; David Albright, Frans Berkhout, and William Walker, *World Inventory of Plutonium and High/y Enriched Uranium, 7992* (Oxford, United Kingdom: Oxford University Press/SIPRl, 1993), p. 90; Leonard S. Spector and Jacqueline R. Smith, *NuclearAmbitiorts: The Spread of Abe/ear Weapons, 7989-7990*(Boulder, CO: Westview Press, 1990); and James E. Lovett, "Nuclear Materials Safeguards for Reprocessing," International Atomic Energy Agency Report STR-151/152, December 1987, pp. 25-36.

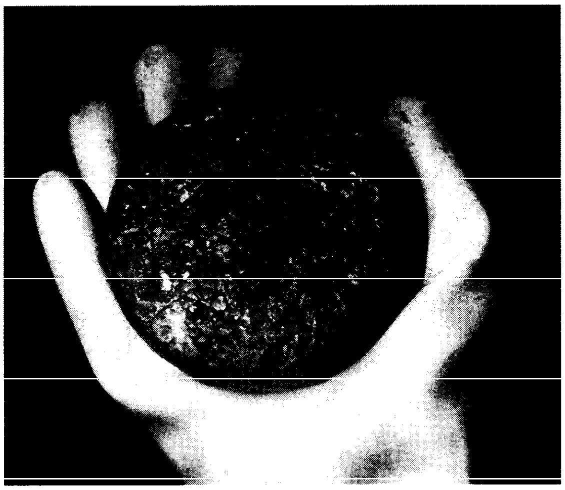
preach and attempt to evaluate the current understanding of the safeguardability of reprocessing plants.[4]

In general, nuclear safeguards are concerned with monitoring items or amounts of material held in material balance areas (MBAs). MBAs are separate parts of a facility within whose boundaries reliable inventories of nuclear materials can be established, and material flows in or out can be monitored. Flows are measured at predetermined locations known as "key measurement points," and samples may be taken from various tanks, containers, and storage areas. Bulk-handling facilities may be divided into several MBAs: sometimes the first will encompass a receipt and storage area (for spent fuel, plutonium, or uranium) and, for reprocessing plants, the head-end fuel shearing and dissolution area, where spent fuel rods are chopped up and dissolved; the second comprises the process area; and the third, a product storage area (see figure A-1).[5] Until recently, the thinking in the safeguards community was that increasing the number of MBA's would increase effectiveness. However, it is now realized that multiple MBA's require extensive reporting of inventory changes and separate material balance reports, increasing the work of operators, state authorities, and IAEA staff. The current approach is to move toward increasing the amount of data in the process available to the IAEA, enabling localization down to small process cells, through process monitoring and near-real-time accountancy (NRTA), but without the burden of additional MBAs.

[4] Additional information on safeguards of reprocessing plants is presented in Burton Judson, "Needs and Obstacles in International Safeguards of Large Nuclear Fuel Reprocessing Plants," contractor report to OTA, December 1993, NTIS No. PB95-199170.

[5] Frans Berkhout and William Walker, "Safeguards at Nuclear Bulk Handling Facilities," in J.B. Poole and R. Guthrie (eds.), *Verification Report 1992* (London, U. K.: VERTIC, 1992), pp. 199-209.

DEPARTMENT OF ENERGY



Plutonium metal from the U.S. weapon program. In civil reactors, plutonium is practically always used in oxide, rather than metallic, form.

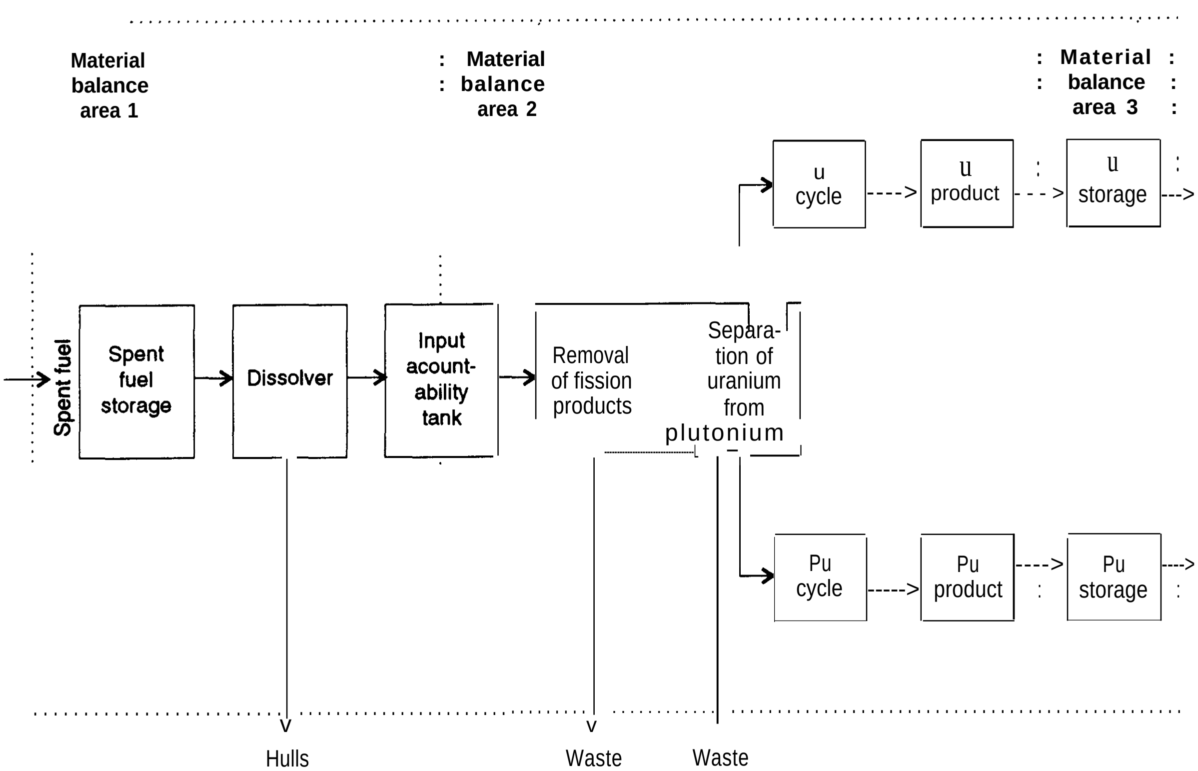
As with other types of facilities, the basic safeguards approach for reprocessing plants is material accountancy, supplemented by containment and surveillance (C/S) techniques. C/S is used primarily to keep track of items that have already been measured in the input and product storage areas, and particularly for items in transit from the input storage area to the head end of the process area. C/S is also intended to provide assurance that plant operations conform to declarations given to the IAEA—that there are no undeclared reprocessing campaigns or attempts to bypass key measurement points available to the IAEA. At the head end, fuel assemblies are chopped into small pieces and dissolved in nitric acid, transforming them from discrete into bulk form. At this point, verification requirements become less amenable to C/S measures.. The C/S equipment currently in routine use consists almost entirely of seals and camera or video surveillance.

The "process area" consists of everything between the head end and the point at which the separate plutonium (and uranium) product streams are converted into solid form and transferred once again into discrete containers and stored.[6] **Because the plutonium in the process area of reprocessing plants is dissolved in solution—and because large plants process so much of it over the course of a year—accurate material-accountancy measurements to assure that none has been diverted pose significant challenges.** Further, much of the process involves highly radioactive streams, which change chemical composition and concentration many times and must be handled remotely behind thick radiation shielding. While a multitude of process variables are controlled and monitored by computers, access to the actual materials for measurement purposes is quite limited.

To address these challenges, the IAEA and operators of reprocessing plants have taken several approaches. First, they have worked to improve the accuracy associated with each of the various measurement techniques used in applying material accountancy. Second, they have examined the use of near-real-time accountancy techniques, in which material inventories within various stages of processing, as well as flows in and out of these stages, are monitored daily or weekly. (See box A-l.) NRTA methods improve the *timeliness* of diversion detection over conventional materials accountancy methods, since NRTA inventories are monitored more frequently. NRTA can also improve detection *sensitivity* by applying statistical tests to the much larger data sets that are generated. Third, the IAEA and plant operators have sought to acquire a much more thorough understanding of safeguards-relevant design information for such plants by early reporting of design information, and by verification of plant designs during construction. Finally, and most important, there is increasing reliance on detailed process monitoring by the IAEA to obtain real-time data on inter-vessel transfers. This monitoring will

[61] In some plants, however, including Rokkasho the reprocessing plant's output, in the form of plutonium nitrate solution, is piped directly to a separate conversion plant for metal-oxide fuel production, rather than converted to plutonium oxide powder and stored.

FIGURE A-1: Material Balance Areas for a Plutonium Reprocessing Plant



SOURCE: Modified from figure in S.J. Johnson and A. B. MN. Islam, "The Current IAEA Approach to Implementation of Safeguards in Reprocessing Plants," *Proceedings of the Fourth International Conference on Facility Operations-Safeguards Interface,* Albuquerque, NM, Sept. 29-Oct, 4, 1991 (La Grange Park, IL: American Nuclear Society, 1992).

help assure that the plant is being operated according to the operator's declarations and also provides input data for NRTA.

Understanding design information complements the primary safeguards approach of material accountancy in much the same way as do C/S techniques. An anomalous inventory measurement or large amount of material unaccounted for (MUF) could indicate the possibility of diversion, but it would rarely be definitive. If material is to be diverted from the plant, it must be removed by some physical means in a plausible way. Verification of plant design information plays an important role in giving added assurance against the existence of unmonitored diversion paths. It is also necessary to ensure, for example, that what is purported to be drawn from a particular tank was indeed drawn from that tank and no other. For this purpose, data from process monitoring is vital.

At each point in a reprocessing plant, diversion of useful material would require overcoming significant obstacles. At vulnerable points where items are routinely moved around (e.g., at the head end and product areas), cameras and other monitoring techniques watch for the possibility of diversion. This is especially important before the spent fuel rods are chopped up, and after plutonium output streams are converted into plutonium oxide powder, sealed into cans, and placed in storage using automated material-handling equipment. Additional measures are taken to ensure that areas such as the plutonium stores are heavily

BOX A-1: New Approaches to Material Accountancy for Reprocessing Plants[1]

Through the mid-1980s, one of the criteria for successful application of reprocessing-plant safeguards involved meeting the so-called Accountancy Verification Goal (AVG). The AVG was set at either 8 kg plutonium or 3,3 percent of annual plutonium throughput, whichever was larger.[2] For small plants processing up to 30 t light-water reactor spent fuel per year, 3,3 percent of throughput does not exceed 8 kg and the difference between the AVG and the 8 kg significant quantity (SQ) is irrelevant. (Of all reprocessing plants that had been fully safeguarded up to that point, only the Tokai facility, at 90 t/yr, had exceeded this level.[3] In addition, the safeguards approach required the IAEA to apply various tests of statistical significance to material unaccounted-for (MUF) values and to operator/inspector differences—the differences between values of various quantities (material inventories, etc.) as reported by the plant operator and as independently verified by the IAEA.[4] Discrepancies that were deemed significant by these tests required investigation. **Nevertheless, the criteria for statistical significance were often difficult to satisfy because the needed measurement-error-variance data either were incomplete or were not of sufficient quality to lend confidence to the conclusions.** Without valid measurement uncertainty data, the whole question of detection probability becomes meaningless. Therefore, the practical result of not having good uncertainty data was that inspectors rarely had firm grounds on which to challenge operator declarations.[5] More recently, the IAEA has been estimating operator measurement errors by comparing IAEA measurements with operator measurements of identical samples over time.

In large commercial reprocessing facilities, the uncertainty associated with the verification of material-unaccounted-for, or σ (MUF), can easily exceed 8 kg (1 SQ) at a year-end physical inventory. Thus, 3.3 σ (the size of a diversion that would be detected with 95 percent confidence at a 5 percent false positive rate; see box 3-2 of the main text) can be much larger than 1 SQ. Therefore, even facilities meeting their AVG might nevertheless have lost well over one SQ to diversion in the course of a year without being detected by material balance evaluations, Recognizing this, and in an attempt to achieve timely detection, facility operators and safeguards agencies have sought chiefly to improve upon traditional materials accountancy. At the same time, the IAEA has phased out use of the AVG, and the revised Safeguards Criteria introduced in 1991 make no reference to the concept,

Even though the AVG is no longer in use, *conventional* material accountancy methods alone appear unable to verify the absence of diversion or loss of material from large reprocessing plants to within annual uncertainty levels of 1 SQ of plutonium. At least four techniques to improve upon conventional material accountancy have been described, The running book inventory (RBI) and cumulative flux method techniques are similar and are only appropriate to plants operating in steady

(continued)

[1]This box draws significantly from Frans Berkhout and William Walker, "Safeguards at Nuclear Bulk-Handling Facilities, " in *Verification Report* 1992 (London, UK: VERTIC, 1992), pp. 199-209.

[2]J.E. Lovett, "Nuclear Materials Safeguards for Reprocessing," International Atomic Energy Agency Report STR-151/152, December 1987, p. 138. This threshold is based on an overall measurement uncertainty (one standard deviation) of 1 percent of throughput times the factor of 3.3 by which a diversion must exceed measurement uncertainty in order to be detected with a 95 percent detection likelihood at a 5 percent false alarm rate. See box 3-2 in the main text,

[3]India's PREFRE facility, at 100 t/yr, also exceeded this level, but it was only safeguarded during three campaigns between 1982 and 1985, when safeguarded fuel was present. Voluntary offers from the United Kingdom and France for safeguarding certain aspects of their own large reprocessing facilities came later, and in any case were usually limited in scope, such as being applied only to spent fuel storage and product areas. As nuclear weapon states, the United Kingdom and France are not required to put any of their nuclear facilities under safeguards.

[4]Lovett, op. cit., footnote 2, p. 138.

[5]Ibid., pp. 140, 173.

BOX A-1 (Cont'd.): New Approaches to Material Accountancy for Reprocessing Plants

state, and for which the in-process inventory is small. Neither is acceptable to the IAEA for large plants. (These approaches have little value during periods of startup, shutdown, or other process upsets.) Book inventories for a given plant are calculated simply by subtracting the plutonium outputs from inputs (each measured), with no attempt at measuring any portion of the actual in-process inventory. Diversion is assumed not to have taken place if these inventories fall within predetermined limits (smaller than an SQ). An approach using RBI was being applied at the UP2(400) plant at La Hague. At that facility, the amount of material being processed at any one time was normally quite small, passing through the plant in two days to a week.

In contrast, adjusted running book inventory (ARBI) and near-real-time accountancy (NRTA) involve in addition the direct measurement of *in-process* inventories, so that data are available with which to apply various statistical tests to MUF figures (and their explanations in terms of measurement uncertainties). ARBI is distinguished from NRTA in its reference to past data on process variables in an MBA. ARBI and NRTA are particularly necessary when wide variations in process inventories are expected, as in the process areas at THORP in the United Kingdom and Rokkasho-mura in Japan, both of which are designed with large buffer tanks that allow such wide fluctuations in process inventories. At THORP, for example, process inventories may approach 0.6 tonnes of plutonium. Since at any time, more than 80 percent of this inventory may reside in the buffer and accountability tanks, it is amenable to direct measurement.

The basic principle of NRTA is that the in-process inventory of plutonium is frequently monitored (perhaps daily or weekly) using a combination of direct measurements from in-process instruments, off-line analyses, and indirect measurements using computer simulations of the chemical process areas.[6] Most tanks and many process vessels are amenable to measurement or estimation of actual inventory or of minimum operating inventories. One obvious advantage is that the throughput over a short interval is significantly smaller than that over an entire year, so that the effects of some of the overall measurement uncertainties are proportionally reduced. Another is that many more measurements are taken, permitting the use of various statistical tests on the additional data and effectively increasing the detection timeliness over that of monthly interim inventories.

The in-process inventory measurement is evaluated by looking for unexplained *trends* in the derived MUF values. However, to calibrate the NRTA system, a baseline must first be established by obtaining a sequence of MUF values over a substantial length of time under conditions where it can be assured that no diversion is taking place. Under such conditions, all deviations observed in MUF values must be due to measurement error and to unreported plant losses such as hold-up (the retention of small amounts of plutonium in pipes and at the bottom of tanks). During subsequent operation of the plant, MUF values can be compared with this baseline, which represents the systematic errors in the measurement system, Use of this baseline data effectively reduces the magnitude of σ (MUF), improving the sensitivity of detection. The development of a baseline is begun as part of the design information verification activities during cold and hot plant commissioning.

(continued)

[6] For instance, direct measurement is not feasible in certain types of process equipment, such as Contractors and evaporators, which might account for 10 percent of the total in-process inventory.

BOX A-1 (Cont'd.): New Approaches to Material Accountancy for Reprocessing Plants

The statistical treatment of sequential MUF data has become highly sophisticated and the relevant literature huge,[7] although research has been narrowing the alternative tests down to a few.[8] Statistics derived from the sequences of data are tested against the hypothesis that a diversion has taken place.[9] The detection sensitivity of different tests varies with the diversion scenario (a test known as Page's test allows parameters to be adjusted to improve the sensitivity for one type of diversion over another), and no single test is most sensitive to detecting all types of protracted and abrupt diversions.

One saving feature, however, is that:

> ...detectionof the gross falsifications necessary to conceal an assumed abrupt diversion can be separated from the problem of the detection of a series of small falsifications which might conceal an assumed protracted diversion. In the former case, verification must be timely but need not be highly accurate [since the diversion is so large]; while in the latter case, it must be highly accurate but need not be timely [since the diversion takes place over sufficient time that it will be detected before a significant amount is lost]. There are no verifications which must be both.[10]

So far, NRTA has been investigated primarily at relatively small plants, such as Japan's Tokai reprocessing plant, with a throughput of 90 tonnes heavy metal per year. However, it is also being explored at the large British THORP reprocessing facility. In addition to periodic recalibration of measurement systems, it requires a "clean" set of data free from diversion or corruption, including freedom from an operator's intentionally widening MUF values by adding and subtracting material randomly during the calibration period. IAEA's plans for addressing this latter problem include scrutinizing any sequence of MUF values that is large-not only when compared to the expected Target Values, but also to those generated by similar plants operating in other countries. " However, the total number of such plants is very small, most of their designs unique, and the amount of experience in interpreting such comparisons virtually nonexistent. **Thus, there may be considerable uncertainty in the ultimate performance of NRTA methods at large plants for some time.**

(continued)

[7] An overview is given in Lovett, op. cit., pp. 111-135, and references 181-188 and 202-203 therein. Other representative articles are R. Beedgen and R. Seifert, "Statistical Methods for Verification of Measurement Models, " and Barry J. Jones, "Near Real Time Materials Accountancy Using SITMUF and a Joint Page's Test: Comparison with MUF and CUMUF Tests," both in *ESARDA Bulletin, No,* 15, November 1988, pp. 5-8 and 20-26; and M. Delange, "The Cumulated Flux Verification Approach ," in *Proc. Third International Conference on Facility Operations-Safeguards Interface,* San Diego, CA, Nov. 29-Dee. 4, 1987 (La Grange Park, IL: American Nuclear Society, 1988), pp. 222-229.

[8] Two such tests are known as Neyman-Pearson with test statistic CUMUF, and Page's test. The mathematics of Page's test are complex, but the concept is not. Rather than examining the absolute magnitude of CUMUF (the cumulative value of the MUF summed over the various material balance periods), it examines the *slope* of a line describing the CUMUF data. At any point, the test asks whether the most recent point is consistent with past data, in such a way that recent data is given more weight than older data. Lovett, op. cit., p. 132. In other words, a sequence of cumulative MUF values in the absence of real loss would be expected to "random walk" away from a zero value at a rate proportional to the square root of the number of MUF values used in the sum, but no faster than this. By mathematically adjusting the CUMUF data to eliminate the effect of this expected wandering away from zero, one would expect a best-fit line in the absence of loss to have zero adjusted slope. The actual slope is then compared and tested for statistical significance using Page's test. See also R. Beedgen and R. Siefert, "Statistical Methods for Verification of Measurement Models," *ESARDA Bulletin, No. 15,* November 1988, pp. 5-8.

[9] Another statistical test, know as the Kalman filter, is a technique for obtaining a "best estimate" from a sequence of MUF data of the amount of loss that has taken place per period. However, it is not useful from a safeguards perspective, because it fails to indicate whether MUF data require further investigation. That is, it does not indicate whether the "best estimate" loss is significantly different from zero, given uncertainties in measurement.

[10] IAEA, TASTEX, *Tokai Advanced Safeguards Technology Exercise,* Technical Report Series No. 123 (Vienna, Austria: IAEA, 1982), p. 111.

[11] Target values represent the expected current performance—in terms of achievable uncertainty limits—of various measurement techniques. See P. De Bievre, "Random Uncertainties in Sampling and Element Assay of Nuclear Materials Target Values 1988, " *ESARDA Bulletin, No. 13,* October 1987, pp. 8-16.

BOX A-1 (Cont'd.): New Approaches to Material Accountancy for Reprocessing Plants

The ultimate detection sensitivity of NRTA for *abrupt* diversion has not been precisely defined, and indeed cannot be except in terms of a specific reprocessing plant and its specific measurement procedures. There has been some speculation among safeguards experts that an 8 kg abrupt diversion detection goal may be achievable, even in the larger (800 t/yr) plants, but at least one study (albeit one about a decade old) claimed a limit no better than about 17 kg plutonium, and 24 kg for protracted diversion.[12] Another estimated that while NRTA might be able to lower detection thresholds by as much as an order of magnitude from conventional material accountancy, such levels still amounted to uncertainties of 15 to 30 kg of plutonium.[13]

In any case, a considerable body of statistical data—more than 50,000 paired sets of data of IAEA and operator measurements from a variety of types of bulk-handling facilities—are already being accumulated and analyzed by the IAEA. The variation of this data about its own mean provides a statistically valid estimate of the total random error in its underlying measurement data, and the difference between its mean value (over some period) and zero is a useful estimate of the net total of all uncorrected measurement biases. Statistically, much can be done with such data to evaluate the *qualify* of measurement systems themselves, which is critical both for evaluating and improving overall material accountancy. Some statisticians object to such a global approach, arguing in favor of a systematic measurement-by-measurement analysis (allowing traditional error propagation studies). However, given the amount of data that NRTA methods are expected to produce, an approach based on analyzing historical data appears to hold some promise.

[12] D. Gupta et al., "Investigations on Detection Sensitivity of the NRTA Method for Different Size Reprocessing Facilities," Kernforschungszentrum Karlsruhe, KfK 4017, December 1985, as cited in Lovett, op. cit., pp. 200, 203. The test for protracted diversion is based on Page's test.

[13] R. Avenhaus et al., 'Comparison of Test Procedures for Near-Real-Time-Accountancy," 6th ESARDA Symposium, Venice, May 14-18, 1984.

guarded and can only be entered by those possessing the right keys and codes.[7] Diversion at points early in the process area, after the spent fuel is dissolved in hot nitric acid but before the fission products are removed, would be difficult because of the intense radioactivity and low plutonium concentration of the solution. At this stage in the process, for instance, there might be only 2 g plutonium per liter of solution, requiring thousands of liters to be bled off to divert 1 significant quantity (SQ) of plutonium.[8]

The latter scenario would require the solution to be transported through additional pipes, valves, or other means to a shielded location outside the material balance area and to be clandestinely replaced with alike quantity of plutonium-depleted solution. It would also require that material accountancy methods fail to detect the missing plutonium. Early submission of plant design information to the IAEA and its subsequent verification during the construction of large plants is thus a key element in helping to rule out such

[7] Berkhout and Walker, op. cit., footnote 5, p. 7. These measures guard against theft, but not diversion commited by the plant operator.

[8] Plutonium concentrations increase as the process streams proceed through the plant. For example, to remove 8 kg of plutonium would require diverting about 4,000 liters of solution from the dissolver, about 800 liters from the last extraction cycle, or 30 to 40 liters from the concentrated evaporator liquor. J.E. Lovett, "Nuclear Materials Safeguards for Reprocessing," International Atomic Energy Agency Report STR-151/152 (December 1987), p. 161.

diversion scenarios. The better a plant design is understood, the more confidence the IAEA would have in ruling out undeclared diversion paths. This aspect of "safeguardability," in fact, is being taken very seriously in the design and construction of new plants.

Tests to be carried out during cold commissioning (i.e., with the use of unirradiated reactor fuel in lieu of actual spent fuel) and hot commissioning (i.e., with actual spent fuel, which is intensely radioactive) will also confirm the physical verification of plant systems and establish baselines for comparing future observations. However, given the complexity of large reprocessing plants, involving multiple buildings, underground pipes, many large storage tanks, and inaccessibility of various radioactive process areas once operating, IAEA experts and others admit that such verification can never completely rule out the possibility of hidden design features. The IAEA nevertheless claims that by carefully examining the operation of the plant, including the flows and material balances, during commissioning tests and *over extended periods of time in near-equilibrium conditions*, it is able to further verify the plant design parameters, making diversions from the process area more likely to be detected.

The intense radioactivity of the spent fuel being reprocessed mandates that radiation shielding be placed around process operations areas in a reprocessing plant. This shielding facilitates increased use of C/S techniques. However, containment of the process area is not absolute, since lines must carry the spent fuel and other chemicals into the process area and carry the plutonium product and various wastes out. Numerous steam, vacuum, and instrumentation lines also penetrate the shielding. (In general, though, both the intense radiation and the corrosive nitric acid environment inside the shielded process area dictate that nothing be placed inside the shielding if it is feasible to leave it outside.) The total number of shielding penetrations in a large reprocessing plant is in excess of 1,000, including buried pipes to adjacent process buildings and to waste storage tanks. Design verification is essential to ensure that pipes suitable for plutonium transfer are identified and controlled.[9]

Once a plant is operating, the experience of the inspectors in understanding the plant operating history becomes increasingly important in interpreting measurement results. For this reason, it is very important to include some inspectors with industrial reprocessing experience. Safeguards experts point out that when various statistical tests are applied to a sequence of process control data and to measurements taken at various points in the plant, and these measurements are combined with a thorough understanding of the plant's designed operating conditions, sensitivity to diversion detection improves over the case in which only annual material balance measurements are used. **Nevertheless, no single statistical test is best suited to detecting all types of abrupt and protracted diversion scenarios, and there is little practical experience in directly applying these tests to large plants.[10]** Furthermore, there remains considerable disagreement over the extent to which more sophisticated statistical tests will be able to improve the uncertainties over simpler methods. The ultimate constraint is measurement uncertainty, rather than statistical analysis methodology.[11] Experience to be gained by EURATOM in safeguarding the large THORP reprocessing plant (in the United Kingdom) will be useful in assessing these advanced data analysis techniques. Furthermore, the problem is more difficult both for older plants, whose measurement

[9]Ibid., p. 213.

[10]*Abrupt* or *protracted* refers to the rate at which plutonium is surreptitiously removed from the plant. Use of multiple tests could be one way to test for different types of diversion, but doing so can artificially increase and complicate the calculation of the false alarm rate.

[11]See, e.g., Marvin Miller, "Are IAEA Safeguards on Plutonium Bulk-Handling Facilities Effective?" *Nuclear Control Institute*, August 1990, p. 5.

systems may not be as reliable or as comprehensive as would be needed to thoroughly understand plant operation, and for larger plants, whose large throughput increases the size of measurement uncertainties. (Fortunately, there are very few large reprocessing plants outside nuclear weapon states.)

In addition to the need for accurate and precise material-accountancy measurements, the IAEA also requires accurate estimates of measurement *uncertainties* in order to carry out its safeguards functions. If uncertainties were overestimated, the utility of measurements for detecting actual losses would decline, while if the uncertainties were underestimated, excessive numbers of false alarms would be generated. There have been extensive efforts over the years to make scientifically defensible estimates of measurement uncertainties based on actual plant operating experience. Nevertheless, most of these so-called collaborative analysis programs have involved measurements on well-behaved, well-characterized materials (e.g., product materials) that have not been irradiated. Furthermore, samples taken for analysis by such programs are often given special attention by the best available analysts, which may not be the case for safeguards during routine plant operations.[12]

The Working Group on Techniques and Standards for Destructive Analysis of the European Safeguards Research and Development Association (ESARDA) has issued lists of “target values” that laboratories should be able to achieve on a routine basis—or that in some cases “must be met in the near future if the large material throughput of the new reprocessing plants under construction is to be adequately safeguarded.”[13] Some of these are given in table A-2.

Based on a simple numerical argument using these uncertainties—and barring acquisition of additional measurements and use of more sophisticated statistical analysis—many analysts have concluded that measurements are incapable of reliably detecting diversions of one or even several significant quantities of safeguarded material from large reprocessing plants.[14] The reasons for this are twofold. First, random and systematic measurement uncertainties (relative standard deviations) for many of the techniques used to verify material inventories in bulk-handling facilities are at best on the order of a few tenths of a percent, and some are as large as a few percent or more. At large plants, this fraction of annual plutonium throughput is considerably larger than 1 SQ. For example, table A-3 shows that a large reprocessing plant with a nominal measurement uncertainty of 1 percent and an annual capacity of 800 tons of spent fuel per year will have an uncertainty in plutonium throughput of 64 kg. Under conventional material accountancy calculcations, a diversion would have to be 3.3 times this amount—211 kg, or 26 SQ—before there would be a 95 percent probability of detecting it, assuming that false alarm rates were to be kept under 5 percent. Even improving measurement precision by a factor of five in this example would lower the corresponding diversion threshold to 5 SQ.

[12]Ralph Gutmacher, “Measurement Uncertainty Estimates for Reprocessing Facilities,” Los Alamos National Laboratory Report LA-11839-MS (ISPO-315), October 1990, pp. 1-2.

[13]See P. De Bievre et al., “Random Uncertainties in Sampling and Element Assay of Nuclear Materials. Target Values 1988,” ESARDA Bulletin, No. 13, October 1987, pp. 8-16.

[14]See, e.g., Miller, op cit., footnote 11.

TABLE A-2: Principal Sources of Plutonium Measurement Errors in Reprocessing Plants

Sampling/measurement point	Instrument or method	Measurement	Goal for onsite lab (percent relative)	Overall target values (percent relative)	
				Random	*Systematic*
Head end/separation stage					
Input tank solution	HKEDG	Plutonium concentration	=< 1	0.6	0.3
Buffer/feed tanks	IDMS	Plutonium concentration	=< 0.2	0.2- 0.4	0.1 -0.2
Scrub and waste tanks	Pu(VI) spectro.	Plutonium concentration	=< 25		
MOX conversion					
MOX canisters	NDA in plant	Plutonium concentration; total plutonium	1		
MOX canning	KEDG	Plutonium concentration	=<0.2		
Product area					
Plutonium oxide powder	T/C	Plutonium concentration		0.15	0.15
	HLNC	Total plutonium		1.0	0.5

KEY: HKEDG = hybrid k-edge densitometer; IDMS = isotope-dilution mass spectrometry; Pu(VI) spectro. = spectrophotometry; NDA = nondestructive assay (e.g., can include HKEDG, KEDG, and HLNC); KEDG = k-edge densitometer; T/C = titration/coulometry; HLNC = high-level neutron coincidence assay.

SOURCE: Adapted from Thomas Shea et al., "Safeguarding Reprocessing Plants: Principles, Past Experience, Current Practice and Future Trends," *Journal of Nuclear Materials Management,* July 1993, pp. 22,25.

Second, actual IAEA experience in safeguarding large plants is minimal, so that it is not known how well routine measurements will compare with their predicted performance.[15] Thus, while one analysis of the THORP facility, for example, concluded that the uncertainty inclosing the annual plutonium balance following a plant washout should be about+ 6.7 kg (1 σ) and that the uncertainty in determining in-process inventory should be about+ 2 kg, it further noted that these precisions are design targets and may not necessarily be achieved.[16]

[15] The six reprocessing facilities under IAEA safeguards at the end of 1992 were the DPRK's "radiochemical laboratory" (where reprocessing activities have since been suspended, but where North Korean unwillingness to allow the IAEA to determine the extent of previous reprocessing operations constitutes a violation of safeguards obligations); WAK in Germany (being decommissioned); PREFRE in India (where only stores of recovered PuO_2 are safeguarded, not the chemical parts of the plant); EUREX and ITREC-Trisaia in Italy (now shutdown); and Tokaimura in Japan. IAEA Annual Report for 1992, p. 161. None of these qualifies as a "large" reprocessing plant. (See table A-1.)

[16] R.D. Marsh et al., "Effective Safeguards in a Commercial Reprocessing Plant," in Proceedings of the Third International Conference on Facility Operations--Safeguards Interface, San Diego, CA, Nov. 29-Dee. 4,1987 (La Grange Park, IL: American Nuclear Society, 1988), p. 46. Note that to achieve a 95 percent detection probability with 5 percent false alarm rate requires a diversion of 3.3 σ, which in this case would be almost 3 SQ. (See Box 3-4 in the main text, chapter 3.)

TABLE A-3: Annual Plutonium-Throughput Uncertainties in Reprocessing Plants[a]

Nominal measurement uncertainty	Small reprocessing plant[b] (30 t HM/yr[c])		Medium reprocessing plant[d] (100 t HM/yr)		Large reprocessing plant[e] (800 t HM/yr)	
	Monthly	Yearly	Monthly	Yearly	Monthly	Year/y
0.2 %	0.04	0.48	0.13	1.6	1.1	12.8
1.0%.	0.2	2.4	0.67	8.0	5.3	64

[a] Uncertainties given in kilograms of plutonium, assuming 0.8 percent plutonium by weight in spent fuel (nominal average of commercial spent fuel from a mixture of 80 percent light-water reactors and 20 percent heavy-water "CANDU" reactors). Plutonium concentrations can range from under 0.1 percent in very low burnup fuel to about 1 percent in high burnup spent fuel from commercial LWRs.

[b] Similar in size to reprocessing facilities at Karlsruhe (Germany), Mol (Belgium), Saluggia (Italy), and Trombay (India). (See table A-1 for safeguards and operational status.)

[c] t HM/yr = tonnes of heavy metal (spent fuel) processed by the Plant per year

[d] Similar in size to reprocessing facilities at Dimona (Israel), Tarapur (India), Tokai-mura (Japan), and one that had been planned in the late 1970s at Chasma (Pakistan).

[e] Similar in size to reprocessing facilities at Cap de la Hague (France), Chelyabinsk-40 (Russia), Rokkasho-mura (Japan), THORP (United Kingdom), and one that had been planned for Wackersdorf (Germany).

Note that if these represent one standard deviation uncertainties in MUF determinations, then the amount of diverted plutonium that could be detected with a 95 percent detection probability and a 5 percent false alarm rate-the nominal safeguards goal—is 3.3 times the amount given in the table Diversions of one times the amount could also be detected, but with only about 26 percent probability if the 5 percent false alarm probability is to be maintained. See E.A. Hakkila et al., *Materials Management in an Internationally Safeguarded Fuels Reprocessing Plant,* vol. 1. Los Alamos Scientific Laboratory, Report LA-8042, April 1980, p. 8.

SOURCE: Office of Technology Assessment, 1995.

DIFFICULTIES AND LIMITATIONS IN IMPLEMENTING SAFEGUARDS

Experts within the IAEA claim that none of the problems associated with safeguarding reprocessing plants has precluded inspection goals from being attained, yet they concede that "improvements are needed to improve the technical credibility of the safeguards applied, or to lower the costs of safeguards implementation without adversely affecting safeguards effectiveness."[17] Many critics feel that the "inspection goals" being referred to in such statements are not as credible as they should be in providing strong assurances against diversion of significant quantities of material. 18 On the overall feasibility of safeguarding large plants, opinions range from strong skepticism to bold confidence. In the words of one of the more skeptical experts,

> In existing large facilities of this capacity and complexity, amounts of fissile materials that are single-weapon significant can be lost in the maze for months, and some in operations will know how to take advantage of this for diversion. Without the best in data and statistics, the problem is impossible. With the best in statistics the problem has not yet been resolved. Even those who operate a large reprocessing facility with the best of intentions will not know where significant amounts of materials reside all the time and will not be able to detect small continu-

[17] Thomas Shea et al., "Safeguarding Reprocessing Plants: Principles, Past Experience, Current Practice and Future Trends," *Journal of Nuclear Materials Management,* July 1993

[18] Inspection goals refer to the ability of inspectors to meet "safeguards criteria" for a given type of plant. These criteria consist of a detailed list of specific actions that must be carried out, including the records to verify, items to identify, count, or check for integrity (within various agreed levels of confidence), C/S measures to evaluate, measurements to take, and so forth. The procedures to meet these criteria are negotiated and set forth by the IAEA and the state as part of the Facility Attachment for each given plant.

ing diversion by persons familiar with the plant.[19]

IAEA officials knowledgeable on the subject claim that such plants are indeed "safeguardable." In making such a claim, they refer to a number of statistical methods, such as near-real-time accountancy, that will be used to reduce overall uncertainties. Nevertheless, they also note the following current limitations of safeguards at reprocessing plants:[20]

- Biases in solution measurements, meaning readings that are either consistently above or consistently below their true value, persist at levels 10 times greater than the expected "target values" for these measurements (i.e., at greater than 1 percent). Such inaccuracies are widely agreed to be one of the principal sources of error in closing material balances in reprocessing plants.
- Determining the plutonium content of spent fuel shipped to a reprocessing plant—to be compared with the plutonium content recovered via reprocessing—is problematic. The plutonium content of the fuel as it leaves the reactor is calculated, not measured; moreover, these calculations are inaccurate, particularly for boiling water reactors. In addition, batches of fuel with different plutonium content and from different types of reactors are often mixed during head-end operations at a reprocessing plant. Thus, improvements are required in the analysis of differences between plutonium content as declared by the shipper and as measured by the recipient (so-called shipper-receiver differences, or SRDs).[21]
- Sample preparations at the facility, shipping of samples to the IAEA Safeguards Analytical Laboratory, and sample analysis and evaluation can take up to three months.
- In some cases, it is not possible to assure that samples taken for the IAEA are not altered prior to shipment to the agency's laboratory. This uncertainty can undermine confidence in the safeguards regime for a reprocessing plant.
- Continuing verification of design information for operating plants (as recommended by the IAEA Board of Governors) will require significant effort and may interfere with plant schedules. Limitations caused by radiation once a plant begins operating will inhibit the ability of inspectors to conduct physical verification.

The plants examined by LASCAR are designed to process spent fuel in quantities about four times larger than those of plants built in the 1970s[22] and involve plutonium throughput, in-process inventory, and storage capacity 10 to 50 times the levels encountered in existing plants *under IAEA safeguards*.[23] Experts acknowledge that a considerable effort will be required to translate the LASCAR recommendations into specific working

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[19]John M. Googin, senior staff consultant, Oak Ridge National Laboratory, private communication, September 1993.

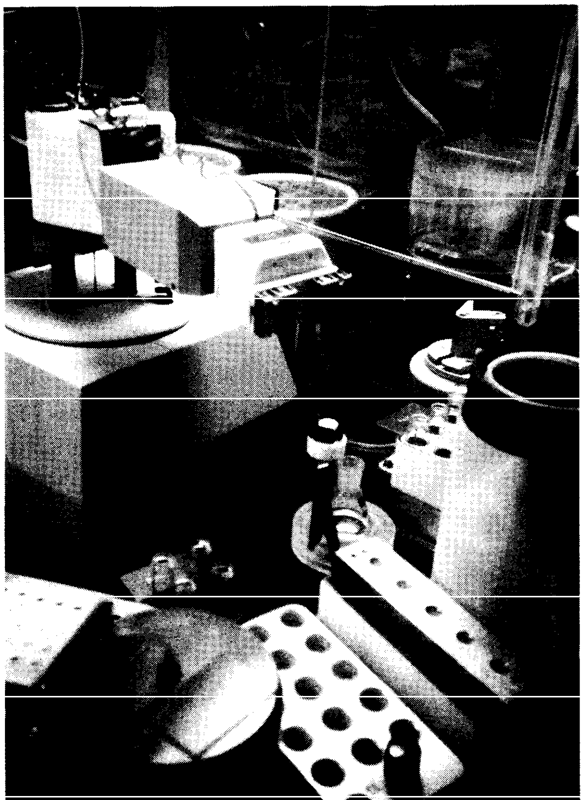
[20]See, e.g., Shea et al., op. cit., footnote 17, pp. 24-26.

[21]An alternate view is that the problem of determining plutonium content of spent fuel assemblies is not important if there is proper item accountancy of the assemblies, together with continuity of knowledge over the assemblies until their dissolution. In other words, if all the spent fuel—and hence all the plutonium it contains—ends up in the reprocessing plant, it does not matter how well the plutonium content is known before its first measurement in the reprocessing plant's front end. However, although maintaining item accountancy of the spent fuel would suffice to assure lack of diversion before the material enters the head end of the plant, an accurate, independent estimate of the plutonium content in the spent fuel would provide an additional check against diversion before the fuel's plutonium content had been measured. It would also provide an independent measurement to complement the assay made once the plutonium is in solution.

[22]LASCAR report, op. cit., footnote 3, p. 1.

[23]EURATOM has some experience in safeguarding large British and French reprocessing plants, but their experience and specific approach are independent and not shared with the IAEA.

GERALD EPSTEIN



Robotic analysis of plutonium-containing samples at the IAEA's Safeguards Analytical Laboratory near Vienna. Use of onsite laboratories at reprocessing plants can eliminate delays due to packaging and shipping samples to Vienna for analysis.

arrangements at new reprocessing facilities. Problems associated in particular with safeguarding such large reprocessing facilities are the following:[24]

- Even if target values for measurement uncertainty are achieved, technologies to account for the total amount of plutonium processed by such a plant are insufficient for the anticipated needs, since the 0.1 percent uncertainty target for annual throughput may be greater than 1 SQ of plutonium. (Box A-2 describes various measurement techniques associated with reprocessing plants, and table A-3 translates various percentage measurement uncertainties into uncertainties in plutonium throughput for different size plants.)
- Monitoring of process operations will be required in real-time, an arrangement more intrusive and requiring more frequent inspector inquiries than at present, unless some sort of remote monitoring is employed.
- Costs for implementing safeguards at these new reprocessing plants will be substantial, requiring additional resources for staff, equipment, and operations, and straining the limits of IAEA verification capabilities. For example, roughly 45 inspectors will be needed to implement safeguards at each of the THORP and Rokkasho facilities (see box A-3 on inspection efforts), while the current IAEA inspectorate has only about 200 inspectors and inspection assistants on which to draw. This issue remains unresolved.
- New plants may employ new types of equipment (e.g., continuous dissolvers, centrifugal contractors and continuous evaporators), requiring new inspection procedures. Specialized verification systems will tax the IAEA's ability to ensure reliable safeguards implementation unless aided by support from member states through programs with the cooperation of the plants' operators.

Within the LASCAR forum and elsewhere, however, much work has been done during the last five years to address these problems. There are several methods being implemented or considered for larger reprocessing plants:

- Expanded use of unattended verification arrangements, telecommunications, and resident inspector deployment as possible efficiency measures. (Resident inspectors will substantially reduce the inspector staffing requirements, but will require "attractive arrangements" to bring inspectors to live in remote areas.)

[24] Shea et al., op. cit., footnote 17, pp. 24-26.

BOX A-2: Measurements Associated with Reprocessing Plants

Measurement Categories *(WHAT is measured):*

- *Input and output solutions and solids:* concentration; isotopic composition; volume, density, or weight
- */n-process inventory:* as above, for solutions
- *Wastes:* leached hulls (short lengths of fuel-rod cladding after the fuel itself has been dissolved away); other wastes, such as centrifuge sludge (the undissolved solids removed by a centrifuge from the spent-fuel dissolver solution)

Measurement techniques *(HOW measurements are made):*[1]

- *Alpha spectrometry and isotope-dilution alpha spectrometry.* Measures radioactive alpha particles emitted by plutonium; measures the total plutonium in dissolver solutions, if the plutonium isotopic composition is known from other measurements.
- *Calorimetry.* Measures heat generated by radioactive decay; primarily used for plutonium oxide product material, when plutonium isotopic concentration and americium-241 content are known from other measurements,
- *Chemical titration.* Measures electrical properties of a solution containing a compound that undergoes a chemical reaction (e. g., changes valence states) while precisely measured amounts of another chemical are added; used to measure uranium and plutonium concentrations in dissolver solutions and product material; relative accuracies of 0.05 percent to 0.1 percent can be achieved at, for example, IAEA's Safeguards Analytical Laboratory at Siebersdorf.
- *Gamma-ray spectrometry* Measures the energy of gamma rays produced by a specific type of radioactive decay (e.g., with resolutions of ±600 eV at 94 to 104 keV energy levels, which are relevant to plutonium isotopes); used to measure the concentration and isotopic composition of plutonium in product solutions or in solid form.
- K-edge *absorption densitometry.* Measures the absorption of x-rays generated by cobalt-57 and selenium-75 sources whose energies are close to the point at which plutonium absorbs x-rays most strongly (e.g., around 110 to 120 keV); used for plutonium concentrations in product solutions, input solutions, and process solutions (in-line measurements); machines cost around $300,000-$400,000 and are to be installed in the field at Tokai and Rokkasho.
- *Manometers and vibrating-tube densimeters.* Measures mass and density properties of liquids; used for measuring the densities of solutions containing nuclear materials and for calibrating tank volumes. Electromanometers are used for on-line measurements.
- *Neutron techniques.* Can be either passive and active; measure neutron emissions from various materials, such as uranium, fluorine, and chlorine, to determine their content in samples.
- *Spectrophotometry* Determines the plutonium concentration of a solution by measuring light transmitted through it at a wavelength which is absorbed by plutonium. This technique is widely used for process control and material accountancy at all stages of the process, but less frequently used for safeguards purposes.
- *Uranium gravimetry.* Used to measure mass of uranium in product.

(continued)

[1]See e.g., Ralph Gutmacher, "Measurement Uncertainty Estimates for Reprocessing Facilities, " Los Alamos National Laboratory Report IA-1 1839-MS (ISPO-315), October 1990, pp. 14; and G. Robert Keepin, "State-of-the-Art Technology for Measurement and Verification of Nuclear Materials," in Kosta Tsipis et al. (eds.), *Arms Control Verification: The Technologies that Make it Possible* (Washington, DC: Pergamon-Brassey's, 1986), pp. 323-337.

BOX A-2 (Cont'd.): Measurements Associated with Reprocessing Plants

DEPARTMENT OF ENERGY

Mass spectrometer at the IAEA's Safeguards Analytical Laboratory

- *Mass spectrometry and isotope dilution mass spectrometry.* Measures the mass of ionized particles passed through a magnetic field; widely used for determining uranium and plutonium concentrations, and especially for isotopic composition (e.g., of samples containing isotopes ranging from uranium-233 to plutonium-242); current machines at the IAEA's Siebersdorf Laboratory can characterize microgram samples routinely; machines appropriate for clean-room facilities can characterize micron-sized particles containing only on the order of picograms (10-12 grams) of material.[2] Cost can be around $1 million for each device.
- *X-ray fluorescence.* Measures well-characterized emissions from various elements (ranging from sodium to the highest elements on the periodic chart) when they are stimulated by x-rays; has microgram detection limits and gives rough estimate of amounts of each element present (but not individual isotopes); primarily used as online instrumentation for process solutions for accurate determination of plutonium/uranium ratio; often used in combination with K-edge measurement to determine plutonium/uranium ratio in low concentration solutions, for example, in plutonium dissolver solution.

[2] David L. Donohue, head of the Isotope Analysis Unit, IAEA Safeguards Analytical Laboratory, Siebersdorf, Austria, Private Communication, Oct. 20, 1993.

- The use of onsite laboratories to eliminate delays in sample analysis, ensure integrity of the samples once taken, and achieve verification measurements of the main nuclear materials streams with accuracies on the order of 0.1 percent.
- Extensive use of NRTA methods for estimating in-process inventory on a timely basis.
- Greater use of data provided by the operator, appropriately authenticated, where it would be impractical for the IAEA to implement completely independent measurement or surveillance systems.

These measures will certainly improve safeguards capabilities over current practice. **However, the application of safeguards to such large-scale plants is unproven, at least pending more experience from safeguards application at UP-3 in France and THORP in the United Kingdom.**

BOX A-3: Routine Inspection Effort at Reprocessing Plants

For medium-size and large reprocessing plants, the "maximum routine inspection effort" (MRIE) ceilings are the following:

Medium reprocessing plant[1]

For spent fuel containing 0.8 percent plutonium, the nominal plutonium throughput would be 800 kg/yr, and the MRIE for such a plant as specified in INFCIRC/153 (see box 3-4 of main text) would be 30 times the square root of 800, or about 850 person-days-of-inspection (PDI)/yr. Since one PDI allows one inspector access to the plant for up to 8 hours, this would translate into continuous presence of a single inspector for about 280 days, If such a plant were operated for 250 days/yr, this level of effort would provide for a single inspector 24 hours/day during operation plus about another 100 person-days per year for additional activities.[2]

Large reprocessing plant[3]

For spent fuel containing 0.8 percent plutonium, the nominal plutonium throughput would be 6,400 kg/yr, and the MRIE = 30 times the square root of 6,400 = 2400 PDI/y. This would set the ceiling at 2 inspectors working around the clock, 365 days/yr, plus 210 PDI/yr of additional inspections. Note that providing this level of inspection would require assigning 10 inspectors to the facility, since a full-time workload for a single inspector is 40 hrs/week for 48 weeks per year, or 240 PDI per year per inspector,

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[1]Throughput of 100 t HM/yr---enough to reprocess spent fuel from about 3 commercial LWRs.

[2]Thomas Shea et al., "Safeguarding Reprocessing Plants: Principles, Past Experience, Current Practice and Future Trends," *Journal of Nuclear Materials Management,* July 1993, p. 21,

[3]Throughput of 800 t HM/yr---enough to reprocess spent fuel from about 25 commercial LWRs.

Appendix B: Parties to the NPT, the IAEA, and Safeguards Agreements

B

Country	Date of joining the NPT	Date of joining the IAEA	Safeguards agreement	Nuclear activities
Afghanistan	2/4/70	1957	FS: 2/20/78	
Albania	9/1 2/90	1957	FS: 3/25/88	
Algeria	1/1 2/95	1963#	Partial	Yes
Andorra				
Angola				
Antigua and Barbuda	6/1 7/85		FS: 2/1/90"	
Argentina	2/1 0/95	1957#	FS: 3/4/94	Yes
Armenia	7/15/93	1993	FS: 5/5/94	Yes
Australia	1/23/73	1957#	FS: 7/10/74	Yes
Austria	6/27/69	1957	FS: 7/23/72	Yes
Azerbaijan	9/22/92			
Bahamas, The	8/1 1/76			
Bahrain	11/3/88			
Bangladesh	8/31/79	1972	FS: 6/1 1/82	Yes
Barbados	2/21/80			
Belarus	7/22/93	1957	FS: 9/12/94**	
Belgium	5/2/75	1958	FS: 2/21/77	Yes
Belize	8/9/85		FS: 8/13/92'	
Benin	10/31/72			
Bhutan	5/23/85		FS: 10/24/89	
Bolivia	5/26/70	1963	FS: 2/6/95	
Bosnia and Herzegovina	8/15/94			
Botswana	4/28/69			
Brazil		1957#	FS: 3/4/94	
Brunei	3/26/85		FS: 11/4/87	
Bulgaria	9/5/69	1957	FS: 2/29/72	Yes
Burkina Faso	3/3/70			
Burundi	3/1 9/71			
Cambodia	6/2/72	1958		
Cameroon	1/8/69	1964	FS: 5/21/92'	
Canada	1/8/69	1957#	FS: 2/21/72	Yes
Cape Verde	10/24/79			
Central African Republic	10/25/70			

Country	Date of joining the NPT	Date of joining the IAEA	Safeguards agreement	Nuclear activities
Chad	3/10/71			
Chile	5/25/95	1960	Partial	Yes
China	3/9/92	1984#	VO: 9/18/89	Yes
Colombia	4/8/86	1960#	FS: 12/22/82	Yes
Comoros				
Congo	10/23/78			
Costa Rica	3/3/70	1965	FS: 11/22/79	
Cote d'lvoire	3/6/73	1963	FS: 9/8/83	
Croatia	6129/92	1992	FS: 1/19/95	
Cuba		1957#	Partial	Yes
Cyprus	2/1 0/70	1965	FS: 1/26/73	
Czech Republic	1/1/93	1993	FS: 3/3/72[9]	Yes
Denmark	1/3/69	1957	FS: 2/21/7710	Yes
Dijibouti				
Dominica	8/10/84		FS: 9/12/94**	
Dominican Republic	7/24/71	1957	FS: 10/1 1/73	
Ecuador	3/7/69	1958	FS: 3/10/75	
Egypt	2/26/81 [1]	1957#	FS: 6/30/82	Yes
El Salvador	7/11/72	1957	FS: 4122175	
Equatorial Guinea	11/1/84		FS: 6/13/86"	
Eritrea	3/16/95			
Estonia	1/7/92	1992	FS: 2/24/9**	
Ethiopia	2/5/70	1957#	FS: 1212/77	
Fiji	7/14/72		FS: 3122/73	
Finland	2/5/69	1958#	FS: 2/9/72	Yes
France	8/3/92	1957#	VO: 9/12/81	Yes

NOTES ON NPT MEMBERSHIP

NPT membership and accession/succession/ratification dates are as given in U.S. Arms Control and Disarmament Agency, *Fact Sheet: Signatories and Parties to the Treaty on the Nonproliferation of Nuclear Weapons,* 2/1 4/95, with a correction for Tanzania and the addition of states that joined the NPT after 2/14/95, according to information from the U.S. State Department, Dates given are the earliest dates on which a country deposited its instrument of ratification or accession—whether in Washington, London, or Moscow. In the case of a country that was a dependent territory which became a party through succession, the date given is the date on which the country gave notice that it would continue to be bound by the terms of the Treaty.

NOTES ON IAEA MEMBERSHIP

IAEA membership as listed in the inside back cover of the *IAEA Bulletin,* the quarterly journal of the International Atomic Energy Agency, vol. 36, No. 4, 1994, Vienna,

#Member of IAEA Board of Governors, 1994-1995.

NOTES ON SAFEGUARDS AGREEMENTS

"FS" denotes states that have full-scope (NPT) safeguards agreements covering all nuclear material on their territories, as modeled after INFCIRC/153. Unless otherwise indicated, the date shown is the date that the agreement entered into force. In some cases, the date is the date of a full-scope safeguards agreement that has since been superseded by another such agreement. Data on the status of full-scope safeguards agreements was provided by the International Atomic Energy Agency and is current as of 3/1/95.

"Partial" denotes states that have one or more safeguards agreements in force over individual facilities only. Such agreements, which do not cover the state's entire fuel cycle, are modeled after INFCIRC/66.

"VO" denotes nuclear-weapon states that have made voluntary offers to the IAEA to place some of their civil nuclear facilities under safeguards, as of the date given.

*Safeguards agreement has been signed but has not yet entered into force.

**Safeguards agreement has been approved by the IAEA Board of Governors following signature but has not yet entered into force.

NOTES ON NUCLEAR ACTIVITIES

"Yes" indicates that the state has at least one power reactor or research reactor in operation or under construction, or has fissile material, as indicated in "Affiliations and Nuclear Activities of 172 NPT Parties," *Arms Control Today, vol.* 25, No. 2, March 1995, pp. 33-34, That table provides data on non-nuclear members of the NPT as of 3/1/95. Data on other states (states that have joined the NPT since March 1, states that are not NPT members, and nuclear-weapon NPT states) provided by the Office of Technology Assessment,

Country	Date of joining the NPT	Date of joining the IAEA	Safeguards agreement	Nuclear activities
Gabon	2/19/74	1964	FS: 12/3/79*	
Gambia, The	5/1 2/75		FS: 8/8/78	
Georgia	3/7/94			
Germany, Federal Republic of	5/2/75[1,2]	1957#	FS: 2/21/77	Yes
Ghana	5/4/70	1960#	FS: 2/17/75	
Greece	3/11/70	1957	FS: 12/17/81[11]	Yes
Grenada	9/2/75			
Guatemala	9/22/70	1957	FS: 2/1/82	
Guinea	4129/85			
Guinea-Bissau	8/20176			
Guyana	1 0119/93			
Haiti	6/2/70	1957	FS: 1/6/75*	
Holy See	2/25/71[1]	1957	FS: 8/1/72	
Honduras	5/16/73		FS: 4/18/75	
Hungary, Republic of	5/27/69	1957	FS: 3/30/72	Yes
Iceland	7/18/69	1957	FS: 10/16/74	
India		1957#	Partial	Yes
Indonesia	7/12/791	1957#	FS: 7/14/80	Yes
Iran	2/2/70	1958	FS: 5/15/74	Yes
Iraq	10/29/69	1959	FS: 2129172	Yes[15]
Ireland	*7/1/68*	1970#	FS: 2/21/77	
Israel		1957	Partial	Yes
Italy	5/2/75[1]	1957	FS: 2/21/77	Yes
Jamaica	315/70	1965	FS: 11/6/78	Yes
Japan	6/8/76[1]	1957#	FS: 12/2/77	Yes
Jordan	2/11/70	1966	FS: 2/21/78	
Kazakhstan	2/14/94	1994	FS: 7/26/94'	Yes
Kenya	6/1 1/70	1965		
Kiribati	4/1 8/85		FS: 12/29/90	
Korea, Democratic People's Republic of	12/12/85		FS: 4/10/92	Yes
Korea, Republic of	4/23175	1957	FS: 11/14/75	Yes
Kuwait	11/1 7/89	1964		
Kyrgyzstan	7/5/94			
Laos	2/20/70		FS: 11/22/91'	
Latvia	1/31/92	19918	FS: 12/21/93	Yes
Lebanon	7/15/70	1961 #	FS: 3/5/73	
Lesotho	5/20/70		FS: 6/12/73	
Liberia	3/5/70	1962		
Libya	5/26175	1963	FS: 7/8/80	Yes
Liechtenstein	4/20/78[1]	1968	FS: 10/4/79	
Lithuania	9/23/91	1991	FS: 10/15/92	Yes
Luxembourg	5/2/75	1958	FS: 2/21/77	
Macedonia	4/12/95	1994		
Madagascar	10/8/70	1965	FS: 6/14/73	
Malawi	2/18/86		FS: 8/3/92	
Malaysia	3/5/70	1969	FS: 2/29/72	Yes
Maldives	4/7/70		FS: 1O/2/77	
Mali	2/10/70	1961		
Malta	2/6/70		FS: 11/13/90	
Marshall Islands	1/30/95	1994		
Mauritania	10/23/93			
Mauritius	4/8/69	1974	FS: 1/31/73	
Mexico	1/21/69[1]	1958#	FS: 9/14/73	Yes
Micronesia	4/1 4/95			

Country	Date of joining the NPT	Date of joining the IAEA	Safeguards agreement	Nuclear activities
Moldava	1 0/1 1/94			
Monaco	3/J 3/95	1957		
Mongolia	5/1 4/69	1973	FS: 9/5/72	
Morocco	11/27/70	1957#	FS: 2/18/75	Yes
Mozambique	9/4/90			
Myanmar (Burma)	12/2/92	1957		
Namibia	10/2/92	1983		
Nauru	6/7/82		FS: 4/13/84	
Nepal	1 /5/70		FS: 6/22/72	
Netherlands	5/2/75[3]	1957	FS: 2/21/77	Yes
New Zealand	9/1 0/69	1957	FS: 2/29/72	
Nicaragua	3/6/73	1977	FS: 12/29/76	
Niger	10/9/92	1969		
Nigeria	9/27/68	1964	FS: 2/29/88	
Norway	2/5/69	1957	FS: 3/1/72	Yes
Oman				
Pakistan		1957#	Partial	Yes
Palau	4/1 4/95			
Panama	1/1 3/77	1966	FS: 12/22/88*	
Papua New Guinea	1/1 3/82		FS: 10/13/83	
Paraguay	214170	1957	FS: 3/20/79	
Peru	3/3/70	1957	FS: 8/1/79	Yes
Philippines	10/5/72	1958#	FS: 10/16/74	Yes
Poland	6/1 2/69	1957#	FS: 10/11/72	Yes
Portugal	1 2/1 5/77	1957	FS: 7/1/86[12]	Yes
Qatar	4/3/89	1976		
Romania	2/4/70	1957	FS: 10/27/72	Yes
Russia	3/5/704	1957#	VO: 6/1 0/85	Yes
Rwanda	5/20/75			
St. Kitts and Nevis	3/22/93		FS: 9/1 2/94	
St. Lucia	12/28/79		FS: 2/2/90	
St. Vincent and the Grenadines	11/6/84		FS: 1/8/92	
San Marino	8/1 0/70		FS: 2/23/77**	
Sao Tome and Principe	7/20/83			
Saudi Arabia	10/3/88	1962		
Senegal	1 2/1 7/70	1960	FS: 1/14/80	
Seychelles	3/12/85			
Sierra Leone	2/26/75	1967	FS: 11/10/77*	
Singapore	3/1 0/76	1967	FS: 10/18/77	
Slovakia	1/1/93	1993#	FS: 3/3/72[9]	Yes
Slovenia	4/7/92	1992	FS: 12/23/73[13]	
Solomon Islands	6/17/81		FS: 6/17/93	
Somalia	3/5/70			
South Africa	7/1 0/91	1957	FS: 9/16/91	Yes
Spain	11/5/87	1957#	FS: 4/5/89	Yes
Sri Lanka	3/5/79	1957	FS: 8/6/84	
Sudan	1 0/31/73	1958	FS: 1/7/77	
Suriname	6/30/76		FS: 2/2/79	
Swaziland	12/1 1/69		FS: 7/28/75	
Sweden	1/9/70	1957	FS: 4/14/75	Yes
Switzerland	3/9/77[1]	1957#	FS: 9/6/78	Yes
Syrian Arab Republic	9/24/69	1963	FS: 5/18/92	Yes
Taiwan[7]	[1/27/70]			Yes
Tajikistan	1/1 7/95			
Tanzania	6/7/91	1976	FS: 8/26/92*	

Country	Date of joining the NPT	Date of joining the IAEA	Safeguards agreement	Nuclear activities
Thailand	12/2/72	1957#	FS: 5/16/74	Yes
Togo	2/26/70		FS: 11/29/90’	
Tonga	7/7/71		FS: 11/18/93	
Trinidad and Tobago	10/30/86		FS: 11/4/92	
Tunisia	2/26/70	1957#	FS: 3/13/90	
Turkey	4/1 7/80[1]	1957#	FS: 9/1/81	Yes
Turkmenistan	9/29/94			
Tuvalu	1/1 9/79		FS: 3/15/91	
Uganda	10/20/82	1967		
Ukraine	12/5/94	1957#	FS: 1/1 3/95	Yes
United Arab Emirates		1976		
United Kingdom[5]	11/27/68	1957#	VO: 8/14/78	Yes
United States	3/5/70	1957#	VO: 12/9/80	Yes
Uruguay	8/31/70	1963#	FS: 9/17/76	
Uzbekistan	5/2/92	1994	FS: 2/21/94”	
Vanuatu				
Venezuela	9/25/75	1957	FS: 3/1 1/82	Yes
Vietnam	6/1 4/82	1957	FS: 2/23/90	Yes
Western Samoa	3/1 7/75		FS: 1/22/79	
Yemen	6/1/79[6]	1991		
Yugoslavia	[3/4/70]	1957	FS: 12/28/73[14]	
Zaire	8/4/70	1961	FS: 11/9/72	Yes
Zambia	5/1 5/91	1969	FS: 9/22/94	
Zimbabwe	9/26/91	1986		

TOTAL: 178 NPT parties (not including Taiwan—see note 7-or Yugoslavia, which has dissolved)
122 IAEA members (including Yugoslavia but not Latvia—see note 8)

[1] With statement.

[2] The former German Democratic Republic, which united with the Federal Republic of Germany on 10/3/90, had signed the NPT on 7/1/68 and deposited its instrument of ratification on 10/31/69.

[3] Extended to Netherlands Antilles and Aruba.

[4] Russia has given notice that it would continue to exercise the rights and fulfill the obligations of the former Soviet Union under the NPT.

[5] Extended to Aguilla and territories under the territorial sovereignty of the United Kingdom.

[6] The Republic of Yemen resulted from the union of the Yemen Arab Republic and the People’s Democratic Republic of Yemen. The table indicates the date of signature and ratification by the People’s Democratic Republic of Yemen, the first of these two states to become a party to the NPT. The Yemen Arab Republic signed the NPT on 9/23/68 and deposited its instrument of ratification on 5/1 4/86.

[7] On 1/27/70, an instrument of ratification of the NPT was deposited in the name of the Republic of China. Effective 1/1/79, the United States recognized the People’s Republic of China as the sole legal government of China. The authorities on Taiwan state that they will continue to abide by the provisions of the Treaty and the United States regards them as bound by the obligations imposed by the Treaty. The IAEA applies safeguards to the nuclear facilities in Taiwan on a nongovernmental basis.

[8] Latvia’s membership in the IAEA has been approved by the IAEA’s General Conference and will take effect once the required legal instruments have been deposited.

[9] The full-scope safeguards agreement concluded with Czecholovia on 3/3/72 continues to be applied to the Czech Republic and to Slovakia.

[10] The full-scope safeguards agreement with Denmark, in force since 3/1/72, has been replaced by the agreement of 4/5/73 between the non-nuclear-weapon states of EURATOM, EURATOM, and the IAEA.

[11] The full-scope safeguards agreement with Greece, provisionally in force since 3/1/72, has been superseded by the agreement of 4/5/73 between the non-nuclear-weapon states of EURATOM, EURATOM, and the IAEA, which Greece acceded to on 12/17/81.

[12] The full-scope safeguards agreement with Portugal, in force since 6/14/79, has been superseded by the agreement of 4/5/73 between the non-nuclear-weapon states of EURATOM, EURATOM, and the IAEA, which Portugal acceded to on 7/1/86.

[13] When Slovenia became an independent state, it succeeded to the safeguards agreement between the IAEA and Yugoslavia. A new safeguards agreement concluded with Slovenia was approved by the IAEA’s Board of Governors on 6/8/94 but has not yet entered into force.

[14] The safeguards agreement between the IAEA and Yugoslavia continues to be applied in Serbia and Montenegro.

[15] Iraq’s reactors are no longer operational.

Appendix C: Abbreviations and Glossary

C

ABACC Argentine-Brazilian Agency for Accounting and Control of Nuclear Materials

ALMR Advanced Liquid Metal Reactor, a relatively recent concept for a self-contained breeder reactor, designed so that reprocessing and fuel fabrication facilities are collocated with the reactor, and there is minimal access to the fuel at all stages of the cycle

CANDU Canadian Deuterium-Uranium reactor, a type of nuclear reactor fueled by natural uranium and moderated by heavy water

C/S Containment and Surveillance

DA Destructive Assay

Detection probability levels, as defined by the IAEA The IAEA's safeguards criteria specify the detection probability with which various types of measurements on various types of materials are to be made. For these purposes, low detection probability is defined as 10 percent, medium detection probability is defined as 50 percent, and high detection probability is defined as 90 percent.

Direct-use material Nuclear material that can be used for the manufacture of nuclear explosives components without transmutation (i.e., changing isotopes to different isotopes) or further enrichment (i.e., increasing the concentration of some isotopes at the expense of others). Examples are highly enriched uranium, plutonium with less than 80 percent plutonium-238, and uranium-233. Note that chemical compounds or mixtures of direct-use materials (e.g., MOX, see below) are also direct-use materials, as is the plutonium contained in spent fuel. *Unirradiated* direct-use material (e.g., fresh highly enriched uranium or separated plutonium) would require less processing time and effort to make into a weapon than *irradiated* direct-use material such as spent fuel, which would need to be reprocessed before it could be used in a weapon.

EURATOM European Atomic Energy Community

FBR Fast Breeder Reactor (most common type is the liquid-metal fast breeder reactor, or LMFBR)

HEU	Highly Enriched Uranium (20 percent or more in uranium-235)
IAEA	International Atomic Energy Agency
IIV	Interim Inventory Verification (e.g., monthly for facilities holding substantial quantities of separated plutonium).
Indirect-use material	All nuclear material except direct-use material. Natural uranium or low-enriched uranium, an indirect-use material, must be enriched (into highly enriched uranium) or transmuted (into plutonium) before it can be used in nuclear weapons. See *direct-use material.*
INFCIRC	Information Circular; type of official document published by the IAEA
LASCAR	Large-Scale Reprocessing (a forum advisory to the IAEA)
LEU	Low-Enriched Uranium (< 20 percent in U-235)
LWR	Light-Water Reactor
MBA	Material Balance Area
MC&A	Material Control and Accountancy
MOX	Mixed Oxide Fuel (usually contains natural or depleted uranium and plutonium oxides)
MUF	Material Unaccounted For
NDA	Non-destructive Assay
NRTA	Near-Real-Time Accountancy
PIV	Physical Inventory Verification (e.g., yearly)
PUREX	Plutonium-Uranium Redox Extraction, the most common chemical process by which spent fuel is reprocessed
RSD	Relative Standard Deviation
SAGSI	Standing Advisory Group on Safeguards Implementation
SIR	Safeguards Implementation Report (the annual report by the IAEA to its Board of Governors on its safeguard activities for the past year)
SQ	Significant Quantity (8 kg of plutonium or uranium-233 or 25 kg of uranium-235 contained in a uranium product enriched to 20 percent or more in uranium-235)
SRD	Shipper-Receiver Difference
SSAC	State's System of Accountancy and Control
Strata	Subsets of measured items or batches that are chosen to be statistically homogeneous, for instance, having similar nuclear material content and measured using the same procedures

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