Chapter VIII

Control of Proliferation

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The first seven sections of this report described the nations or groups that might want to make weapons and how they might go about it. The materials required for such an enterprise are common, and will become more so as nuclear technology spreads. Many means of control have been developed or proposed to prevent this material from being used for military purposes. There are four general levels on which these efforts can be based. The first is to detect if a diversion has in fact taken place, through the use of safeguards measures. In the United States, the term safeguards generally encompasses physical security, since the threat (non-state adversaries) is the same for both types of protection. On the international level, safeguards and physical security are quite distinct. International safeguards are measures designed to detect and deter diversion and misuse of fissile material by governments authorized to hold such material, while physical security is designed to foil theft, sabotage, and external attacks by unauthorized groups and individuals. From a political and institutional standpoint the two problems are quite different. Supplier and recipient governments have a common interest in physical security, but by definition, national diversion does not involve such a community of interest. Safeguards assume a potentially adverse relationship between inspectors and users of nuclear material. Consequently, safeguards involve the imposition of external controls on the user state by a supplier state or regional or international agency. Primary responsibility for the application of international safeguards has been assumed by the International Atomic Energy Agency (IAEA). Euratom, an agency of the European Community, has regional safeguards responsibilities which are being coordinated with the IAEA. Neither of these agencies has the power to provide or require physical protection, or to pursue and recover stolen material. Nor do they have the authority to detect clandestine weapons facilities or purchase/theft activities. The functions they do perform are described below. Other functions can be performed by intelligence agencies (such as the CIA) as alluded to in the sections on these routes.

In our own government from 1946 to 1974, the important branches were the Atomic Energy Commission (AEC), the Department of State, and the Congressional Joint Committee on Atomic Energy. Two years ago the AEC was split into the Energy Research and Development Administration (ERDA) and the Nuclear Regulatory Commission (NRC). The NRC is responsible for safety rules, security safeguards, and accounting safeguards throughout this country.

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The second level is to respond to a detected diversion in such a manner as to force its reversal and deter others from like actions. Neither the IAEA or Euratom have any significant authority in this area, nor has any other international institution. If sanctions are to be applied it must be done by arrangements among nations, as discussed below.

Third, nuclear systems and facilities can be limited to those that minimize opportunities for diversion. This requires cooperation among all suppliers of nuclear equipment. It consists of restricting the export of sensitive facilities (enrichment and reprocessing plants), except possibly for those operated under multinational control. The development of reactors and facilities that are inherently less vulnerable can be emphasized. Suppliers' conferences have been useful in attaining some of these ends. Multinational fuel-cycle facilities may be a promising approach for others. There appears to be very little emphasis yet on low vulnerability systems in any country and no international move to implement them.

The final level is to set a climate in which nations will not want to proliferate. This means decreasing incentives and enhancing disincentives as discussed in chapter IV. It also means weaving a network of treaties, promises, and commitments that is hard to break becuase of the moral, financial, and public appearance factors that act on modern nations. The Non-Proliferation Treaty (NPT) has been a cornerstone in this effort, binding its parties to accept IAEA safeguards on all their nuclear material and on all exports (even to nonparties).

International cooperation is the thread that binds all these objectives. None is perfect or even very effective by itself. Together the total may be greater than the sum of the parts, but only if there is a continual effort to strengthen each element. If successfully and flagrantly breached, the entire system could rapidly collapse.

The first part of this chapter describes the controls the United States places on its domestic nuclear program to protect against theft or diversion of nuclear material. The IAEA procedures for the detection of diversion of nuclear material are also discussed. The second part of this chapter analyzes the institutions and other arrangements designed to control proliferation. Appendices VIII and 1X of volume II provide further detail on safeguards and on the international institutions respectively.

SAFEGUARDS TECHNOLOGY

U.S. Domestic Safeguards

In the United States, safeguards have been defined as "all measures designed to detect, deter, prevent, or respond to the unauthorized possession or use of significant quantities of nuclear materials through theft or diversion; and sabotage of nuclear-facilities. "[1]

[1] WASH-1.l 327, P. V-61 (August 1974) Draft (GESMO).

The three subsystems of the U.S. safeguards system are physical protection, material control, and material accounting. These subsystems are discussed in detail in appendix VIII of volume II.

The primary safeguard measures the United States uses to prevent or detect diversion are the physical protection and material control systems. The goal of the physical protection subsystem is to prevent access by force, stealth, or the use of false identity to nuclear material in a facility or shipment. This subsystem should prevent unauthorized removal of nuclear material and prevent sabotage. The physical protection subsystem overlaps the material control subsystem, which is designed to detect any unauthorized or suspicious activity involving nuclear material.

Examples of elements of a physical security system include armed guards, barriers, alarms, locks, portal monitors for detection of smuggled nuclear material, a central command and communication station, search procedures, and liaison with local and State police. Material control encompasses a set of procedures for access to and transfer of nuclear materials. The aim of these procedures is to prevent any two insiders, acting in collusion, from diverting nuclear material from the facility. The effectiveness of these procedures depends on the interpretation of regulations by NRC and the facility operator, and on continued surveillance and testing to ensure that the procedures are in fact being followed.

Material accounting for nuclear material is similar to accounting systems for other valuable materials, involving complete records of movement of the material and the taking of physical inventories. At present, the primary job of the material accounting subsystem is to determine, after some period of time, that the other two subsystems have been effective, or to provide information as to where. and how they may have failed. Highly automated, semicontinuous measurement systems designed to provide prompt information that nuclear material may be missing are under development. (See "Advanced Material Accounting Systems " in this chapter.)

A history of U.S. safeguards from 1946 to the present is given in appendix VIII of volume II. Until recently, safeguards have not been a matter of high priority to government or the public. Several years ago, safeguards began to attract widespread interest and increased funds were provided. However, a sudden injection of interest and money cannot quickly make up for years of complacency.

In the United States there are three major nuclear programs and three agencies having safeguard responsibilities. The three programs are: military, nuclear power, and nuclear research. The Department of Defense provides safeguards for the nuclear weapons in its possession. The Energy Research and Development Administration (ERDA) operates production facilities for the nuclear military programs and conducts research on nuclear power and other nuclear applications. The Nuclear Regulatory Commission (NRC) is responsible for applying safeguards to both privately owned nuclear facilities and a few ERDA-owned facilities.

NRC Safeguards

This discussion focuses on NRC safeguards. The NRC safeguards can be considered in four classes. The first three are of present concern; the fourth allows time for further study. These problems are:

1. Protection of power reactors against sabotage;
2. Protection of shipments of privately owned weapons-grade material;
3. Protection of existing production facilities that possess and process weapons-grade material against theft or sabotage; and
4. Protection of future fuel facilities that would process large quantities of plutonium-containing fuel or other concentrated weapons-grade material.

The key facilities to be guarded in a domestic nuclear power program are (1) those which a non-state adversary might sabotage, or (2) those from which it might steal or embezzle nuclear material that can be used in a nuclear weapon with little or no processing.

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Protection of Power Reactors Against Sabotage.—The reactor itself must be safeguarded against sabotage, but not, at present, against theft of weapons-grade material. U.S. reactors (with the one exception of the Fort St. Vrain HTGR) do not presently contain onsite material useable in nuclear explosive weapons, except for the plutonium contained in spent-fuel elements. (See discussion in chapter VII of the usefulness of spent fuel to the non-state adversary.)

The subject of reactor sabotage was judged peripheral to the topic of this study—nuclear weapons proliferation. Thus, this report has not assessed safeguards at U.S. reactors.

Shipments of Privately Owned Weapons-Grade Material.—Presently, NRC and ERDA require physical protection for shipments of strategically significant amounts of special nuclear material, i.e., more than 5 kilograms (kg) of highly enriched uranium, or 2 kg of plutonium or U^{233}. Until recently, both ERDA and privately owned materials were transported by private transport companies which met the then-existing security requirements. In 1976, ERDA decided to provide its own transportation system for its nuclear materials, including highly enriched uranium fuels for naval reactors and research reactors and plutonium fuels for the test breeder program. In consequence, all ERDA shipments of significant amounts of nuclear materials between its facilities, private contractors licensed by NRC, and ERDA and private facilities, are now protected by the ERDA system, while the relatively few shipments of privately owned materials are subject to NRC regulations.

ERDA and NRC transportation safeguards are described in appendix VIII of volume II. The important differences between the two systems are: (a) ERDA transport convoys maintain continuous communication with the ERDA control center in Albuquerque over a nationwide dedicated communications network (SECOM). SECOM cannot be used by NRC shipments; (b) ERDA shipments are made in specially designed tractor trailers providing protection to the drivers, resistance to penetration, and wheel locks. The transport vehicle is accompanied by escort vehicles, with which it is in constant communication. NRC requirements are less stringent.

There appear to be no serious legal, economic, or institutional reasons for NRC shippers not to employ the ERDA communications and control system. This, coupled with the use of tractor trailers (similar in performance to ERDA's) and the requirement of an accompanying escort vehicle would significantly upgrade NRC transportation security.

Protection of Existing Facilities That Possess Weapons-Grade Material.—The NRC has licensed 15 privately owned facilities (listed in volume II, appendix VIII) to process strategic quantities of highly enriched uranium or plutonium.

There is at present a controversy over whether or not safeguards at these facilities are adequate. The controversy centers on what level of threat the safeguards should meet: i.e., the debate is about the phzysicul *security* systems.

In the spring of 1976, a joint NRC-ERDA task force investigated the safeguards systems at these facilities. The threat-levels defined for the review consisted of:

- an internal threat of one employee occupying any position, or
- an external threat comprised of three well -armed (legally obtainable weapons), well-trained individuals, including the possibilities of inside knowledge or assistance of one insider.[2]

Nearly half of the licensees were found unable to meet this total threat level and were ordered by NRC to upgrade their physical security. A number of critics, notably the National Resources Defense Council (NRDC), have claimed that the above threat level is far too low. NRDC quotes a memorandum from Carl Builder, then Director of NRC's Division of Safeguards, expressing concern that some current licensees could not meet the lowest threat being considered for the safeguards supplement of the *Generic Environmental Statement on Mixed-Oxide Fuels* (GESMO), which was, like the threat level postulated above, three outsiders and one insider, NRDC further

[2]NUREG-0095/ERDA 77-34: Joint ERDA-NRC Task Force on Safeguards (U) Final Report, July 1976, [Unclassified Version].

refers to several studies done for NRC which spoke of maximum credible threats or credible threats in the range of 12 to 15 or 6 to 8 persons, with 2 or 3 insiders.

The National Resources Defense Council petitioned NRC to dispatch Federal marshals as an emergency procedure to ensure security at the facilities. This petition was denied by the NRC commissioners. On January 21, 1977, the commissioners stated their intention to conduct a public rulemaking "to consider upgraded interimsafeguards requirements and proposed longer term upgrading actions. "

In late February 1977, NRC decided that security at these facilities should be upgraded to meet a threat of two or more insiders acting in collusion with an outside group of several adversaries armed with automatic rifles, recoilless rifles, and high explosives. Guard forces were ordered increased and required to be armed with semiautomatic rifles. Full-field background investigations were required for licensed employees who might effectively conspire to steal or divert weapons material.

This report has not assessed NRC safeguards at the facilities in question, but several general observations can be made. Of all of the attributes of the potential adversary, numbers has received the most attention. This may be because the number of possible assailants is the easiest attribute to deal with in designing a security system. The estimated number of attackers is also often considered to directly determine the required number of guards. Guards are an expensive component of security systems, Guards at Government facilities must be paid for by Government; at licensed facilities by private industry. A requirement to maintain a large guard force could shut down some facilities not able to pay the costs and remain profitable.

Appendix III of volume II summarizes a number of studies of threat size and describes the data bases of the studies.

Current research at the RAND Corporation is investigating a number of (non-nuclear) adversary actions which have been selected as analagous to potential nuclear theft or sabotage, This work shows that groups of 3 to 6 are common, that larger groups do appear, and that a group size of 12 does appear to be somewhat of an upper boundary, although there are a few cases in modern industrialized societies in which larger groups have been involved. More importantly, the RAND researchers argue that one must be extremely cautious in interpreting historical data regarding the number of attackers. The number of attackers taking part in a mission are, for the most part, what the perpetrators perceived to be necessary to accomplish the mission, and in most cases what turned out to be sufficient. In other words, the adversaries came with as many as they needed to do the job, and no more. The fact that most came with a handful of persons, 3 to 6, does not represent an upper limit on their capacity to mobilize people. The upper limit would appear to be higher.

Although the historical data are useful as a guide, an estimate of the number of attackers is inescapably a matter of judgment. Without speaking in terms of a maximum threat, the RAND studies suggest a range of anywhere from 7 or 8 to about 15 as a *prudent* estimate,

Again, although it is judgmental, military men and law enforcement officials argue that more than this number might be counterproductive. It is no coincidence that after 5,000 years of military history, the smallest operational unit of almost all armies is a squad composed of 9 to 13 men, Although an attacking force could be composed of several squads, it should be recognized that to assemble even 10 or 12 attackers would stretch to the limit the capacity of most known violent political extremist groups in this country. Moreover, although no one has attempted to determine precisely how many persons must be in conspiracy to commit a serious crime before it is no longer a secret, the probability of discovery must increase rapidly in the higher ranges. The fear of leaks appears to be a principal consideration and constraint in assembling the personnel for a task-force crime.

The number of attackers is not the only parameter to consider in determining the adequacy of physical security. Another factor to consider is armament. Here the potential adversaries seem to have the edge. Civilian guard forces are armed with pistols, shotguns, and in some cases, semiautomatic rifles. (The recent NRC upgrading calls for guards armed with semiautomatic rifles. Guards at ERDA facilities may be armed with automatic weapons and at some facilities may also have armored cars.) NRC officials concede that attackers may be armed with automatic weapons, hand grenades, and possibly even antitank weapons.

Another, and a most important parameter, is tactics. Armed robbers seldom assault their target. They employ stealth, deception, diversion, and other techniques to gain access. Often they are inside or close upon the guards before displaying arms and revealing their intentions. Deception often proves to be successful where assault would probably fail.

A fourth set of parameters involves the size and location of the facilities themselves, and the amount, form, and location of the nuclear material they possess. The number of guards, indeed the adequacy of the physical security system as a whole, is a judgment that can only be made by an examination of each specific site. The approach to be taken should be to design an entire physical security system to protect a specific facility against all conceivable actions—burglary, armed robbery, embezzlement, sabotage, armed assault, standoff attacks—rather than to pick a number of attackers and let an equation determine the number of guards. Once this is done, a team composed of physical security experts and nuclear technology experts should jointly assess the system probing for weaknesses and trying to design successful attacks on the system (i.e., black-hatting evaluation should take place).

This is the approach being taken by ERDA and NRC in their safeguards research programs, discussed in more detail in the section on "Domestic Safeguards Research and Development" later in this chapter. The safeguards system concepts now being developed aim to integrate safeguards and physical security into the design of new facilities, and hold the promise of making them more easily defensible against both outside attack and inside embezzlement. The point to emphasize here is that physical security can and should eventually be upgraded in more basic, varied, and imaginative ways than by simply increasing the numbers of guards and the power of their armament.

For example, it should be recognized that there could be an alternative to relying on onsite guard forces to overcome armed adversary attack. A crucial question, which deserves serious review, is the extent to which safeguard systems can be designed to delay attacking adversaries sufficiently so that the burden of engagement and arrest falls on offsite response forces instead of on onsite guards.

The preceding discussion on numbers of attackers and guards leads to another issue involving guards at nuclear facilities. At present, unless they are deputized by a Government agency, guards at nuclear facilities have only limited civilian-arrest powers. Moreover, the powers of such guards, particularly with respect to the use of deadly force and permissible behavior in hot pursuit, vary from State to State (some licensees have facilities in more than one State). Guards who overstep State laws, even to protect special nuclear material, can face lawsuits, Although unauthorized possession of special nuclear material is a Federal crime (Sec. 42 U.S.C. 2271 (b) and 2272), it is not clear if this crime, by itself, is a dangerous felony. The use of deadly force is justified only to prevent a dangerous felony.

The entire subject of the powers and status of guard forces at privately owned nuclear facilities should be reexamined. The subject of a Federal security force to protect weapons material should be reopened, particularly in view of the increased threat levels licensees are being required to meet.

In addition, there are indications that safeguard threats to private nuclear facilities are coming to be regarded as threats to national security, without being explicitly defined as such. Should sabotage of a nuclear power reactor or detonation of a nuclear explosive by terrorists be regarded as having national security significance? Would sabotage of a large dam or of a liquid-natural-gas tanker, which would cause comparable damage, be a threat to national security? So far, these questions have not been explicitly considered.

One measure that apparently hinges on the question of national security significance is the requirement of clearances for employees of nuclear facilities. NRC and ERDA have maintained in the past that only a few key employees of private nuclear facilities would (or should) be cleared. The purpose of this clearance would be to provide added assurance that managers and guards would not engage in conspiracies to steal nuclear material or sabotage nuclear facilities. The legal basis for such a clearance requirement is an amendment to an appropriation bill (Public Law 93-377), which authorized the Atomic Energy Commission (AEC) to require clearance for licensee personnel if deemed necessary for national security. In light of this wording, NRC seems to have implicitly decided that safeguarding nuclear facilities is essential to national security: that is, it seems possible that the enabling statute which authorizes security clearance for national security reasons might not provide the authorization necessary to clear nuclear employees who may not be involved in national security.

By the year 2000, according to the Draft Societal Impact Chapter of GESMO, the number of people employed in mixed-oxide fuel cycle facilities and requiring security clearances would be in the range of 13,000 to 20,000. In addition, NRC has recently announced a proposed rule to require that 6,000 employees of 63 nuclear reactors be cleared. This program is aimed at protecting against reactor sabotage. This represents a substantially larger number of employees than those "few hundred" thought to be affected when the appropriation bill mentioned above authorized the AEC to implement a clearance program for private licensees.

The question of national security significance needs to be clarified. Moreover, if protection of nuclear facilities against domestic threats is defined as necessary for national security, the policy of using private guard forces becomes extremely questionable.

Protection of Future Fuel-Cycle Facilities. —The preceding discussion of physical security at nuclear facilities has highlighted certain tasks that must precede effective evaluation and implementation of safeguards. These tasks include the determination of a reasonable estimate of the size of a potential attacking force, the inclusion of other attacker attributes in the design of physical security systems for a specific facility, the clarification and standardization of guard powers, and the decision on whether theft from, or sabotage of, a nuclear facility constitutes a threat to national security.

These tasks are important for both existing and future facilities if plutonium reprocessing goes forward.

It is not clear at this time if or when NRC will license plutonium processing facilities. The only such plant which could start operations within the next few years is the Allied-General spent-fuel reprocessing plant, which has been built at Barnwell, S.C. Other facilities to produce plutonium oxide or to fabricate plutonium for breeder reactors exist only on paper and are 5 to 10 years from completion. In the meantime, the ERDA safeguards R&D program is working to develop substantially improved safeguard techniques to meet the problems posed by large-scale plutonium processing and fabrication facilities. Several techniques are discussed below under the heading "Domestic Safeguards Research and Development."

Domestic Safeguards Research and Development

Both NRC and ERDA have safeguards R&D programs. ERDA has the responsibility for developing safeguards for the new energy systems it develops, and also to ensure that the safeguards for its military and research programs will meet future safeguard goals. On the other hand, the Energy Reorganization Act of 1974 assigned NRC the responsibility for confirmatory research. This has been interpreted so far to mean that ERDA would support the bulk of hardware research, technology development, and demonstration and testing of safeguards systems in actual facilities, while NRC has put emphasis on systems studies, on the development of analytical techniques, and on programs to help it to (1) define safeguard requirements for the facilities that it regulates, and (2) assess not only compliance of these licensees but also the effectiveness of its role in protecting and advancing the interests of the U.S. public.

The most important subjects for study, which both NRC and ERDA are emphasizing, are the methods of assessing and evaluating safeguard systems and subsystems, and of how to make cost-benefit analyses. Both tasks, especially the latter, are very difficult when the threats are hypothetical, the systems remain untested because there have been no significant incidents so far, and the consequences range from zero to catastrophic.

Appendix VIII of volume II describes the principal elements of U.S. domestic safeguards research. The following section discusses and, to the extent possible at this time, evaluates several specific technical safeguards concepts of particular prominence.

Massive Spiking

Massive spiking is the addition of lethal amounts of radioactive material to fresh reactor fuel. The purpose of massive spiking is to protect fresh fuel containing highly enriched uranium or plutonium against theft by nonstate adversaries. The idea has a long history and several studies have recently been done, the most complete of which was a part of the 1975 NRC Special Safeguards Study. It considered several possible methods to achieve massive spiking, and also the possible attachments of intensely radioactive cobalt-60 rods to fresh-fuel assemblies.

The NRC study concluded that massive spiking of fresh fuel would not constitute an insuperable obstacle to an adversary who was competent (1) to separate plutonium from uranium in mixed-oxide form, and (2) to design and fabricate an effective terrorist nuclear explosive.

On the other hand, such spiking would increase the cost of fuel fabrication and transportation by a large factor, expose nuclear facility employees to increased radiation, and substantially increase the risk to the public due to accidents or acts of sabotage.

Attaching cobalt-60 sources to fresh fuel in shipment would place one more obstacle in the way of the diverter, but not an insurmountable one. It would increase transportation costs but more importantly create problems both in loading and unloading and in the risk of accidental exposure.

Massive spiking is not cost-effective when compared to massive containment and stringent physical security for domestic safeguards use. It would not be useful at all in restraint of national proliferation.

Light Spiking

Light spiking is the addition of low levels of radioactive material to fissile material to afford easy detection. This concept was also investigated in the NRC Special Safeguards Study. All three fissile isotopes—U^{235}, U^{233}, and plutonium-are naturally radioactive. The important question is how difficult it would be for an adversary to shield significant amounts of any of these isotopes and pass radiation monitors without being detected.

The NRC study concluded that: (1) gram amounts of highly enriched uranium in easily carried shielded containers can probably be removed without detection; (2) portal monitors equipped with both gamma-ray and neutron detectors should detect attempts to remove as little as one to several grams of plutonium in portable shielded containers; (3) existing portal monitors should effectively detect small quantities of U^{233} because of the highly penetrating (2.6 MeV) gamma-rays associated with unavoidable trace impurities of U^{232}.

The study recommended that the subject of low-level spiking for highly enriched uranium be investigated further, and that an experimental program be undertaken to design and test gamma-ray and neutron portal monitors for plutonium of various isotopic compositions.

Evidently, no further studies or experiments were conducted by NRC or ERDA. It would therefore be useful if: (1) ERDA institutes a design, test, and evaluation program for portal monitors in actual production facility environments (radiation backgrounds directly affect monitor sensitivity), and (2) NRC or ERDA initiate a study to assess costs and benefits which might derive from low-level spiking of highly enriched uranium. It should be noted that the large amounts of highly enriched uranium in military and naval programs are presently the most attractive targets for an adversary who wants material to use in a nuclear explosive.

Spiking is unlikely to be used except for domestic safeguards, but the subject of radiation monitors for surveillance of nuclear facilities is of considerable interest to the IAEA.

Denaturing of Plutonium

The concept of denaturing Pu^{239} with Pu^{240} or some other isotope of plutonium also has a long history. It has long been believed that a high content of Pu^{240}, because of its **high** spontaneous fission rate, renders plutonium unsuitable for use in a nuclear weapon. This is not true. A high content of Pu^{240} is a complication. Given a free choice, a designer would prefer low Pu^{240} material, but all plutonium isotopes can be used directly in nuclear explosives. (See chapter VI.)

Storage and Transport of Plutonium in Dilute Mixed-Oxide Form

Plutonium oxide stored and transported in a mixture containing large amounts of uranium oxide (i.e., dilute mixed-oxide form) would present a significant (but not insurmountable) obstacle to the non-state adversary. This technique would be a much less-effective deterrent against national proliferation than against the non-state adversary. The dilute mixed-oxide material might be produced in the following ways:

(a) Plutonium would not be separated at all from uranium at the reprocessing plant (coprecipitation)

(b) Plutonium would be incompletely separated from uranium at the reprocessing plant (partial coprecipitation)

In alternate (a), the concentration of plutonium in uranium would be approximately 1 percent. The machinery for separating plutonium and uranium would not exist, so plutonium could never appear in concentrated form in the fuel cycle. However, the increased costs of both a larger nitrate-to-oxide conversion facility, and a larger plutonium-uranium mixed-oxide fuel fabrication facility, plus the necessity for over-enriching additional uranium, could more than outweigh savings in the solvent extraction process and in eliminating conversion of recovered uranium to UF_6. If so, this option would not be economically attractive compared to (b) with more stringent safeguards. ERDA plans to consider option (a), at least in the preliminary stages of its Alternate Fuel Cycle Study. (See chapter VII "Diversion From Commercial Power Systems.")

Alternate (b) appears to provide significant improvement in safeguards without undue economic penalties. In effect, it moves one processing step from the fuel-fabrication plant to the reprocessing plant.

The major contribution of scheme (b) is elimination of transport of concentrated plutonium. A potential non-state embezzler or national diverter could still tinker with the separation system at the reprocessing plant to produce pure plutonium. Materials accounting in a large plant could not provide timely detection of the removal of 10 kg of pure plutonium, thus the physical security and material control subsystems (or the containment and surveillance systems in the case of IAEA safeguards) would be crucial.

As far **as** this report has determined, the only study of the deterrent effect of diluting plutonium with uranium was done as part of the NRC Special Safeguards Study. The study investigated the effort required by a non-state adversary group to separate plutonium from uranium. It concluded that an ion-exchange operation, operated in a 10 kg batch mode with 5-percent-plutonium content, would require $5,000 in chemical costs alone. The time per batch was not explicitly stated, but analysis of what is presented suggests 40 to 80 hours processing time per batch, or 30 to 60 days of round-the-clock operation to obtain 10 kg of plutonium. The process as described is clearly not a laboratory operation; it is a small pilot-plant operation, and as such requires the supervision of someone with *practical* experience in chemical engineering or larger-than-laboratory scale chemistry. The time required for the operation, during which the adversaries are immobile, significantly enhances their chances of being discovered.

It is not clear whether any additional work on this subject has been done. It would be valuable to have a clearer idea of the actual time-delay granted by this technique. Although a month or two may be too long, at least several weeks sounds extremely plausible. It would also be useful to examine what new search and recovery techniques could take advantage of the fact that the adversaries would be carrying on a pilot-plant scale chemical operation.

The following proposal for collocating reprocessing and fuel fabrication facilities is closely related (in its potential effect on safeguards) to the above proposal for diluting plutonium oxide with large amounts of uranium oxide,

Collocation of Reprocessing Plant and Fuel Fabrication Plant

If reprocessing plants were sited adjacent to fuel fabrication plants, the transportation of plutonium in concentrated form would be eliminated. However, although the NRC Nuclear Energy Site Survey-1975 (NUREG-001) concluded that ". . . . collocation might have a beneficial effect on safeguards effectiveness; however transportation safeguards considerations do not preclude dispersed siting," all the advantages and disadvantages of collocation have not yet been assessed in any systematic way. This question cannot be separated from the previous question—that of complete or partial coprecipitation of plutonium oxide and uranium oxide at the reprocessing plant. If some form of coprecipitation is used, then the added advantage of collocation would seem to be small.

Advanced Material Accounting Systems

There are unavoidable limitations on material accountancy because of statistical measurement errors. These errors will translate into an inability to detect diversion of significant quantities of weapons material in future large commercial facilities unless the sensitivity of material accountancy can be significantly improved.

No substantial and economical improvement in the sensitivity of materials accountancy can be expected unless real-time material control can be achieved. Two such systems are being developed: DYMAC at Los Alamos Scientific Laboratories (LASL) and RETIMAC by NRC. (See appendix VIII of volume II for a description of these systems.) These two R&D programs have the same goal: to provide continuous or nearly continuous measurements of all materials being stored, transferred, or processed.

The LASL safeguards group is developing instrumentation and online computer systems for DYMAC. This system is being implemented at LASL in three phases. In phase 1, the present LASL plutonium processing facility is being used as a test bed for component development and operator training, Phase II is the design and installation of a DYMAC system for the new plutonium processing facility (TA-55) presently under construction at LASL. This is a small facility with a typical throughput of tens of kilograms per month of plutonium. It does not handle spent fuel. Installation of DYMAC/TA-55 is scheduled for June 1978. Phase III is a program to evaluate the performance of DYMAC at the TA-55 facility.

Operation of DYMAC/TA-55 in the new LASL plutonium processing facility is intended to investigate:

- the reliability and operational feasibility of online nondestructive analysis instrumentation in a production environment,
- the timeliness and sensitivity to missing nuclear material that can be achieved,
- the accuracy and efficiency of data collection that can be achieved,

- the operation of common data base management, and
- the capability for production control, quality assurance, and financial management.

Another task is to design on paper and evaluate the cost effectiveness of such systems for future commercial facilities. The most useful of these studies has been done by LASL and Sandia as part of a project to develop an integrated safeguards system for a mixed-oxide fuel fabrication facility. The report gave estimates of costs and sensitivities for the real-time measurement and analysis system.

LASL and Sandia based their designs on a mixed uranium-plutonium oxide fuel fabrication plant planned by Westinghouse for construction at Anderson, S.C. (Throughput 8000 kg/year of plutonium.) They contacted Westinghouse for assistance in defining plant parameters and providing cost estimates. Although this is a paper study, plant data are realistic and the online measurement and computer systems are conventional or state-of-the-art.

The report states that capital safeguards costs for this system are less than 5 percent of the total plant cost and the total safeguards staff (excluding guards) is about 8 percent of the total staff of 300. At a false-alarm rate of 0.1 percent, a single theft of the order of 0.1 to ().2 kg of plutonium could be detected with a 50 percent probability. With a 16 percent false-alarm rate, a dribble theft of approximately 1 kg over 1 month could be detected with an 85 percent probability of detection. These results should be compared with present NRC requirements for a fuel fabrication facility which are: a 50 percent probability of detection of removal of 0.5 percent of throughput with a material balance every 2 months and a false-alarm rate of 2.5 percent. For the case above, this corresponds to a 50-50 chance of diverting 7 kg of plutonium in 2 months, without being detected by the materials accounting system. (Note that this does *not* mean a 50-50 chance of diverting 42 kg of plutonium per year.)

Although considerable development work and in-plant demonstration is required before the effectiveness and costs of real-time material control can be reliably assessed, the studies indicate that improvements made using DYMAC will be greater for fuel fabrication facilities than for spent-fuel reprocessing plants. DYMAC is batch-oriented, as is the operation of a fuel fabrication plant, whereas a reprocessing plant is a continuous operation.

The R&D Office of the NRC has been supporting work at Lawrence Livermre Laboratory (LLL) on systems studies of material control and accounting techniques, which include automated online measurements systems for nuclear production facilities (RETIMAC). These are purely software studies, and are not advanced enough to give sensitivities or costs.

One thing that is clear is that even real-time, online materials accountancy systems cannot do the entire safeguards job. Physical security, containment, and surveillance will still have crucial roles to play in any effective safeguards system.

Research on Physical Security Systems

Work on physical security systems for new facilities is being performed by Sandia Laboratories under contract to ERDA, The approach is to design for specific nuclear facilities, either existing ones such as the Allied General reprocessing facility, or specific engineered designs such as the Westinghouse fuel fabrication plant proposed for construction at Anderson, S.C.

On the assumption that credible threat characteristics may change in the future, the researchers postulate a spectrum of internal and external threats, and various combinations of the two. Combinations of barriers, alarms, and guards are chosen to provide multiple impediments to an intruder, or to authorized insiders attempting to perform unauthorized acts. A spectrum of divisionary scenarios, including emergency situations, are considered. The physical protection design is coordinated with the Los Alamos design of fully automated online nuclear material measurement and control of all nuclear materials in the facility. Capital and operating costs for a given system configuration are determined with assistance from the designers of the particular facility. (Compare with the preceding section on "Materials Accountancy,")

Sandia and Brookhaven have developed computer-based models to assess the comparative effectiveness of alternative combinations of safeguards elements to protect nuclear materials against postulated overt attacks on the facility with or without the aid of one or two insiders. Sandia is also in the process of developing models for assessing the safeguards systems against covert diversion attempts by a trusted employee or by several employees in collusion. This is based on the National Bureau of Standards analytical method called "Diversion Path Analysis. " The overt-attack model is presently in use. The covert-diversion model is still in the early developmental stage. The assessment experts emphasize that their analytical tools give qualitative rather than quantitative assessments of effectiveness.

ERDA safeguards system designers believe that the strategy and performance of both adversary and defender personnel are very difficult to predict in any satisfactory manner. Hence, special attention is paid to physical barriers and devices which will delay the adversary, whatever his skill and dedication, without requiring heroic behavior by the on-site guard force. Another aim is to design a safeguards system that will be adaptable to changing design threats with economically acceptable modifications in plant equipment or changes in the size of the guard force.

The most effective safeguards system will be one in which the various safeguard elements are balanced against each other and are integrated into the design of the facility. At this time, it appears to be at least as important to develop a methodology for evaluating the effectiveness of a safeguards system as it does to work on the development of equipment and computerized controls. In order for safeguards assessments to give useful results, reliable input data on the individual elements of the safeguards system is necessary. It is also important, therefore, to continue the experimental program to provide better information on the penetration resistance of barriers, reliability of alarms, and efficacy and safety of techniques, such as foams and reactive sensors that delay and confuse the adversary.

The object of designing a safeguards system to delay attacking adversaries has been described by de Montmollin and Walton:

> "The effect on the design against forcible theft is heavy reliance on passive barriers, the restriction of material accessibility, and protected defensive positions for guards. It is not necessary for the safeguards system to capture or kill adversaries; it is only necessary that control of the material be maintained. The system should be designed to withstand a protracted siege, and the sequence of actions necessary for an adversary to gain ultimate control of the materials should be attacked at many points. Delay should be exploited, and the uncertainty of success as perceived by the adversary should be enhanced wherever possible. Increased delay of the adversaries will correspondingly increase their probability of failure. Given sufficient delay, police support will be ultimately decisive; first, by sealing off the general area to maintain contact as adversaries attempt to break out, and eventually to overcome them. The mission of the safeguards systems must be to provide decisive delay rather than to overcome adversaries in a direct, armed confrontation."[3]

Interaction of U.S. Research and IAEA Requirements and Research

The ERDA safeguards systems development, and complementary NRC work on developing methodologies for safeguards systems assessments, hold forth a good deal of promise for both U.S. and international safeguards. ERDA is aiming for a 1980–82 demonstration of a integrated safeguards system for IAEA safeguards. A discussion of IAEA research programs, and US. and foreign research related to IAEA needs is given in appendix VIII of volume II.

Long-Term Safeguards Effectiveness

A subject which is of concern to some in NRC and ERDA, and which is receiving some preliminary attention, is the question of how

[3] J.M. de Montmollin and R.B. Walton, *The Design Of* Integrated *Safeguards System for Nuclear Facilities,* Nuclear Materials Management Vol V, No. III, p 317 (Fall 1976).

safeguards effectiveness can be maintained during long periods of quiet. The safeguards system, as described early in this chapter, is designed to deter, detect, prevent, and respond. A safeguards system will effectively deter only if it is perceived as being able to very effectively detect, prevent, and respond. Functions must be exercised to remain effective, and if the object is to never give the safeguards system, and the people who run it, real exercise, then sufficiently challenging substitutes must be designed to maintain the quality of the safeguards system and attract good people to run it.

Physical Security Outside the United States

Primary responsibility for the application of international safeguards has been assumed by the International Atomic Energy Agency (IAEA). Euratom, an agency of the European community, has regional safeguards responsibilities which are being coordinated with IAEA. Neither of these agencies has the power to provide or require physical protection, or to pursue and recover stolen material; nor do they have the authority to detect clandestine weapons facilities or purchase/theft activities. As stressed in the introduction, international safeguards are aimed at detection of diversion by a nation from its own facilities. Physical security of the facilities is the responsibility of the nation.

IAEA does advise on physical security, and has published a discussion of physical security procedures in an IAEA manual, INFCIRC/225. In a brief discussion in the IAEA Bulletin of possible future IAEA actions on physical security, IAEA envisages its role as advising, organizing training courses and conferences, and acting as a clearinghouse for information.

The United States has also tried to encourage greater physical security on nuclear facilities worldwide, as it recognizes that nuclear material obtained in one nation may well be used in another nation, In a Presidential message dated May 1975, it is stated that the United States has adopted a policy of no longer issuing licenses for the export or retransfer of more than 5 kg of highly enriched uranium, or 2 kg of plutonium or U^{233}*, unless the government of the recipient country "has an established system of physical security measures acceptable to the United States." This report is unaware of any detailed standards of acceptability beyond a statement that they should be "comparable to those imposed domestically. "

To implement this policy, physical-security review teams were dispatched by ERDA to 18 countries in 1975–76. Visits to an additional 21 nations were planned for 1976, ERDA stated that by the end of 1976, "the United States will have made reviews of the physical-security measures of all major recipients of strategic quantities of U.S. nuclear materials and intends to cover all nations with whom it has Agreements for Cooperation, as well as other nations that might receive trigger quantities through the U.S.–IAEA Agreement. " This report has not assessed physical security in other countries, nor has it been able to assess the ERDA review of foreign physical security, because ERDA has classified its review citing the following reasons: ". . states continue to keep their specific physical-security measures classified and/or under proprietary restrictions. The results of the US. visits are therefore classified, at the request of the nations involved, and the United States cannot divulge results of the review. Furthermore, the laws and regulations of the various recipient nations as well as the factors peculiar to each recipient nation make it difficult to present even general observations." (Some additional material is presented in volume 11, appendix VIII.)

IAEA Safeguards

The Statute of IAEA states that the objective of Agency safeguards is to assure, so far as it is able, that the nuclear assistance provided by it, or at its request, or under its supervision or control, is not used in such a way as to further any military purpose. As a result, IAEA safeguards differ in one vital respect from those of U.S. domestic safeguards. Domestic

*These respective amounts of highly enriched uranium, plutonium, and U^{233} are sometimes called "trigger quantities" because they are the amounts that will set safeguards into effect.

safeguards are concerned with the non-state adversary. International safeguards (i.e., IAEA and Euratom safeguards) focus on the detection of national diversion.

The word safeguards is generally understood to be a collective term comprising those measures designed to guard against the diversion of nuclear material from uses permitted by law or treaty, and to give timely indication of possible diversion or credible assurance that no diversion has occurred. The difference in objectives between U.S. domestic safeguards and international safeguards is reflected in the different measures encompassed in the word "safeguards." As discussed in the preceding section, U.S. domestic safeguards include physical security, material control, and material accounting. For IAEA, the use of materials accountancy is considered to be the safeguards measure of fundamental importance, with containment and surveillance at present considered only as complementary measures. The following definitions for these three measures have been derived from the IAEA Safeguards Technical Manual.

Material Accountancy .—Those safeguard measures which provide the essential knowledge on the identity, composition, quantity, and location of nuclear material. The basic source of data for the Agency's accountancy system is the facility operator's measurement system, records, and reports, and the State's system of accountancy for, and control of, all nuclear material subject to safeguards. For each material-balance area within a State, the facility operator must record, and the State report, the initial inventories of nuclear material and subsequent inventory changes to IAEA. Periodically, the operator's book inventory is compared with a physical inventory taken by the operator and independently verified by an Agency inspector.

Containment.—A safeguards measure which uses physical barriers to restrict or control access to, or movement of, nuclear material. Examples include process tanks and piping, transport casks, building walls, and fences.

Plant operators use containment primarily to provide physical protection of nuclear material, for reasons of health, safety, and/or operational necessity. If safeguards requirements are included in the earliest planning phases, containment can significantly enhance the effectiveness of safeguards. Failure to do so may result in an inherently unsafeguardable nuclear facility.

Surveillance.—A safeguards measure which uses instrument or human observation to detect access to, or confirm movement of, nuclear material.

Surveillance devices and instruments are used 1) during the absence of an inspector to indicate that access to or movement of nuclear material has not compromised the integrity of prior measurements made by the IAEA, and 2) to provide the inspector with a continuity of knowledge of specific inventories and material flows at key points in the fuel cycle. Surveillance devices include cameras, television, seals, and radiation monitors.

The Evolving Role of Containment and Surveillance in IAEA Safeguards

Nuclear material accountancy has continued to be the safeguards measure of fundamental importance in the implementation of IAEA safeguards procedures. The role of containment and surveillance, however, has evolved at a relatively rapid pace within the last few years and is now assuming greater significance. It is now generally accepted that there are unavoidable limitations on material accountancy because of measurement errors. For nuclear facilities with very large throughputs, cumulative measurement errors on nuclear material will introduce uncertainties in the material balance which exceed by several times the IAEA's own limits on significant quantities of diverted plutonium or uranium which it must detect. The dictum "what one cannot measure one must watch" underscores the urgent necessity for fully operational, reliable, tamper-resistant surveillance equipment.

In addition, renewed emphasis is being placed on the NPT objective of timely detection. Material accountancy, with its dependence on independent verification of physical inventories and material flows, is confronted, as above, with an exceedingly difficult problem. For manpower as well as economic reasons connected with facility downtime, physical inventories may be limited to one per year in some facilities, and possibly not more frequently than four per year in the largest facilities. Under the IAEA's own requirements for timely detection, the deterent value of a material balance may be seriously degraded. New surveillance equipment which is just now being designed may be able to meet many of the Agency's requirements for timeliness and holds forth the promise of eventually being able to provide IAEA headquarters in Vienna with real-time surveillance.

Initially, self-monitoring surveillance devices will require frequent communication between the facility operator and/or the host government and IAEA headquarters in Vienna. Within a period of 3 to 5 years, however, certain of the Agency's surveillance devices may be able to provide encrypted real-time status reports, first to IAEA regional safeguards offices and finally to the Vienna headquarters. This capability will place exceptionally stringent requirements on the long-term reliability of equipment and on the necessity for a very low false-alarm rate. The consequences of even a small number of false alarms would be so counterproductive that it seems probable that, like the space program, IAEA's equipment will be designed to meet a zero defects requirement and will be correspondingly expensive.

There have been substantial increases in money and manpower, both in the United States and within the IAEA, to develop surveillance equipment. In order to implement the increases in funding which Congress authorized under the Gifts-in-Kind Program to strengthen IAEA safeguards, ERDA has established an International Safeguards Project Office at Brookhaven National Laboratory. The draft program plan for Technical Assistance to IAEA Safeguards, Task E, Assistance for Containment and Surveillance, includes 22 separate projects. For FY 77, approximately $990,000 has been allocated to fund these projects. Funding by the United States, which is scheduled to continue over a period of 5 years, the increased support within the IAEA for surveillance equipment, and the greater willingness on the part of the nuclear suppliers to support improved measures for physical security and safeguards research in general, all should provide the Agency with reliable and effective surveillance equipment within the next few years.

Effectiveness of IAEA Safeguards for Power Reactors

On December 21, 1975, the IAEA had 43 nuclear power stations under safeguards, 10 of which were onload* refueled reactors of the CANDU or Magnox type. Most of the remainder were light water reactors (LWRS). (See annex L to appendix IX of volume II.) The Agency has fully developed model Facility Attachments and Safeguards Implementation Procedures (SIPS) for both classes of power reactors, including an analysis of potential diversion paths and possible means of countering diversion strategies. Evaluating the effectiveness of the Agency's safeguards on power reactors is rendered difficult because information about critical IAEA procedures and policies are either not available outside the Agency or are classified by the Agency as Safeguards Confidential. For example, no information is available on the Agency's site-specific diversion analyses, the allocation of its inspection effort, the reliability and performance of its surveillance and nondestructive analysis (NDA) equipment (much of which is in the early stages of development), the effectiveness of the different State Systems of Accounting and Control and, in a few instances, the inclusion of special conditions in the Safeguards Agreements with those states that restrict the nationality of acceptable inspectors or the normal use of safeguards equipment and procedures. It is hoped that in at least some of these areas the Director General's proposed Special Safeguards Implementation Report to the Board of Governors will remedy these shortcomings. This report is believed due in September 1977, after several delays totalling over a year in extent.

*I.e., reactors that are refueled without being shut down. See chapter VII "Diversion from Commercial Power Systems," and appendix V of volume II.

Of all the types of nuclear facilities on which the IAEA must apply safeguards, the light-water power reactor (LWR) presents the fewest problems. Safeguards on these facilities are based on an item accountability of fuel elements, a procedure which in principle is free of measurement error. Light-water reactor fuel is relatively large in size and involves a relatively small number of fuel elements in either the core or storage pond. The reactor is usually refueled only once a year; the remainder of the time the reactor vessel is closed and may be sealed by the Agency. The fresh fuel, containing low-enriched uranium, is expensive to fabricate, and tight fuel specifications at the fabrication plant mean that the amount and enrichment of the uranium in the fuel is known within the narrowest limit of any point in the fuel cycle. The intense radioactivity of the spent fuel severely limits the diversion possibilities. Even under INFCIRC/153 (the document issued in 1971 to govern NPT safeguards arrangements), the Agency is permitted adequate inspection effort for effective safeguards for this type of facility. Finally, secure surveillance equipment (such as cameras) is available, although a fair amount of development and testing remains to be done in order to assemble a fully reliable system. Nondestructive analysis techniques required to minimize the threats of fuel substitution have been demonstrated, but have not been routinely applied.

The Agency has the knowledge both in principle and in practice to provide effective safeguards on LWRS and implementation is proceeding.

The safeguarding of ordoad refueled reactors, such as the CANDU, is substantially more difficult. Nuclear fuel for such reactors is small in size, while the number of fuel elements in the core and in either the fresh or spent-fuel storage is very large. The onload refueling feature and the possible use of unsafeguarded natural uranium in the fuel greatly expand both possible diversion scenarios and the IAEA's task of devising and implementing effective countermeasures. Since 1968, the IAEA, Canada, and the United States have been engaged in joint R&D programs specifically directed at surveillance and containment problems of CANDU reactors. More recently, the Canadians significantly increased the level of effort of their R&D programs.

Sufficient information is not available at this point to evaluate the effectiveness of the new surveillance instrumentation in combination with the traditional review of the power stations records and reports. If the IAEA concludes at the end of its testing that credible and effective safeguards procedures for onload reactors cannot be achieved, it may request, and the States probably will grant it, the right to station inspectors at such facilities on a continuous basis. Such a move would greatly increase IAEA costs and workload.

IAEA Safeguards for Enrichment Plants

(Comparison of Domestic and International Safeguarding Problems)

To date, the IAEA has not safeguarded any type of enrichment facility, including pilot plants. However, it may have to undertake such a task in the near future as a result of its recent agreements with both Euratom and Japan. The proposed safeguards procedures for enrichment plants, contained in the IAEA Safeguards Technical Manual, are currently being revised and have not yet been officially released or published. Enrichment plants are not specifically covered in either of the two IAEA books of regulations (INFCIRC/66/Rev.2 or INFCIRC/153), except for one provision in the latter which states that a small plant producing uranium enriched to less than 5 percent in U^{235} need not be subject to continuous inspection.

In view of this lack of experience, and the preliminary nature of plans for safeguarding enrichment plants, only a very limited assessment of IAEA safeguard procedures can be made at this time. However, a few general statements about the difficulties in safeguarding enrichment plants and a few crucial points can be made.

An enrichment plant is the only nuclear facility besides a reprocessing plant that is capable of generating separated weapons material. However, a significant difference exists in that a reprocessing plant is designed to routinely handle material suitable for use in weapons (i.e., separated plutonium) either directly or after a simple chemical step. A commercial enrichment plant normally produces only 3 percent to 4 percent enriched uranium, which is impossible to use in nuclear-fission weapons without further enrichment. Therefore, the output of an enrichment plant is of use to the non-state adversary only if a criminal black market in low-enriched uranium develops. Portions of an enrichment plant can be reconfigured to produce highly enriched uranium. This is a credible scheme for a national diverter, but a scenario in which management and workers of a US. enrichment plant conspire to produce highly enriched uranium is not credible. Moreover, such a proceeding could not be kept secret from NRC inspectors who have the right of unlimited and unannounced access.

The case is different for IAEA inspection of enrichment plants. At present, IAEA inspectors are not permitted access to the cascade area of an enrichment plant (i.e., the portion of the enrichment plant where the actual enrichment takes place). Inspection techniques that are presently proposed for enrichment plants treat the cascade area as a black box with a number of inputs (e.g., people, uranium feed, and new equipment) and a number of outputs (e.g., people, low-enriched uranium, and old equipment). If a reconfiguration of a portion of the plant to produce a small highly enriched uranium loop occurred, IAEA would have to deduce its existence from input and output measurements. In the first place, materials accountancy in a large plant is not accurate enough to provide assurance that a significant diversion has not taken place. More important, new equipment is an undeclared path; IAEA is not permitted to monitor new equipment going into the plant. This path could be a route for clandestine feed for a small highly enriched uranium production loop.

For input-output monitoring to be effective, *all* streams need to be monitored. Physical inventory and surveillance methods need to complement continuous input-output monitoring. Other complementary inspection techniques would include enrichment monitoring (particularly checking tails enrichment) and the use of the isotope ratio technique to check the ratio of U^{235} and U^{234} in the product and tails.

These inspection techniques are still in the developmental stage and have not been applied in an integrated way to an enrichment plant.

Allowing inspectors access to the cascade area upon demand would greatly enhance the effectiveness and credibility of the inspection. Inspection accessibility to the cascade area would certainly not *ensure* that the plumbing changes required for a highly enriched uranium loop would be detected in the maze of cascade area piping. However, it would most likely act as a significant deterrent to any country wishing to conduct a covert operation. In addition, undeclared feed, product, or tails takeoff would also have a higher probability of detection.

There are two reasons given for restricting inspector access. The first, and probably the reason preceived as the most important, is that of protecting commercial secrets. The second is to prevent the dissemination of enrichment plant technology via the inspectors, i.e., to make nuclear proliferation less likely. This reason creates an interesting situation where, in the name of nonproliferation, inspectors are denied access to an area to which, in the cause of nonproliferation, they should have access.

IAEA Safeguards for Reprocessing Plants—Comparison With Domestic Safeguards

The eventual effective safeguarding of a large reprocessing plant presents the greatest technological uncertainty of all safeguarding problems facing the IAEA, because of the complexity of the operation, the inaccessibility of large sections of the plant due to high radiation levels and difficult analytical problems.

Although the IAEA has somewhat more experience safeguarding reprocessing plants than enrichment plants, it has not undertaken the routine application of safeguards to any commercial reprocessing plant on a long-term basis. It has conducted safeguard experiments and exercises at the Nuclear Fuel Services Plant, West Valley, N.Y. (plutonium throughput of 300 kg/year), and at the

Eurochemic plant in Mel, Belgium (plutonium throughput 500 kg/year). Operation of both these facilities has been suspended indefinitely. Currently, IAEA has experimental safeguard projects at the two Italian pilot plants at Sallugia and Itrex (plutonium throughput 64 kg/year). The proposed Safeguards Technical Manual procedures for spent-fuel reprocessing have been drafted but have not yet been published. The safeguarding of reprocessing plants is treated in a very general way in INFCIRC/66/Rev. 2. INFCIRC/153, paragraph 80(b) states that for any facility involving more than 5 kg of plutonium, the Agency may expend at least 1.5 man years of inspection effort. This insures almost continuous inspection, even for very small reprocessing plants.

Table 6 in appendix V of volume II lists existing and planned reprocessing facilities worldwide. It can be seen that there is only one commercial facility in operation, and that most of the facilities to be subject to IAEA safeguards in the next 5 years or so have design capacities of no more than 2,500 kg of plutonium throughput per year. However, the Allied General (AGNS) plant at Barnwell, S. C., has a design capacity of 15,000 kg of plutonium throughput per year, and cost studies indicate that plants of this size or larger are the most economical. Therefore, this discussion will be referenced to a plant with plutonium throughput of 15,000 kg per year.

NRC requirements call for a 50 percent chance of detection by the materials accountancy system of a diversion of 1 percent of the throughput, with a materials balance taken every 6 months. This means that a diverter would run a 50 percent chance of being caught by the materials accountancy system if he diverted 75 kg of plutonium in 6 months from the reference plant. One might argue that 50 percent is too high a risk for the diverter; in that case he could content himself with 10 kg in 6 months with only a 5 percent chance of detection by the materials accountancy system. (The numbers are slightly different for the IAEA.)

For the IAEA, the expected accuracy of material balance is lower; the allowable false-alarm rate, although not yet set, may be lower; and the frequency of inventory is higher. These differences will not qualitatively change the conclusion of this analysis. Looking at the situation from the operator's point of view, he can be 95 percent confident of detecting a diversion of over 120 kg from the reference plant within a 6 month period. That is, if the materials accountancy system does not call a theft, all the operator can say is that he is 95 percent certain that a theft, if it did occur, was less than 120 kg.

Moreover, as one industry reviewer noted: "The conclusions regarding the probability of 'calling' a discrepancy fail to take cognizance of efforts to resolve the discrepancy prior to 'calling.' Since the 'calling' would undoubtedly entail added cost and inconvenience to the operator, there would be significant effort to resolve the discrepancy with the possibility of introducing an unsuspected bias. "

The above discussion reveals that the detection of diversion from a large reprocessing plant by the present materials accounting systems is not very sensitive to quantities of the order of tens of kilograms, nor, more important, is the detection timely. That is, detection would occur weeks or months after the diversion.

Both NRC and IAEA therefore require a variety of surveillance and containment systems. These, coupled with physical security systems and personnel (for domestic safeguards) and resident IAEA inspectors (for IAEA safeguards), would make diversion (a) more difficult, and (b) enhance the probability of timely detection. The development, installation, and prosecution of such systems is one of the most important safeguarding tasks to be accomplished.

An important distinction should be made between the non-state diverter and the national diverter.

Although a better understanding of the likely behavior of the white-collar embezzler-adversary and advances in the state-of-the-art in evaluating safeguards systems against covert insider actions are necessary, a national safeguards and physical security system can probably be designed which, if competently implemented, would make it very difficult for a non-national diverter to covertly remove kilogram quantities of plutonium from a reprocessing plant. For example, portal monitors are presently capable of detecting gram quantities of plutonium through a moderate amount of shielding.

The safeguarding problem is more difficult in the case of the national diverter. Although resident inspectors may be able to independently verify materials balances to the accuracies discussed above through promising techniques such as isotopic correlation, diversion from the process stream undetected by the materials accounting system of the order of tens of kilograms per year would still be possible. It would be very difficult for IAEA inspectors, who have no physical security function, to detect covert removal of this material by a nation from its own reprocessing plant. In effect, the inspectors would have to rely on a prompt-reporting, tamper-indicating leak-proof perimeter containment and surveillance system. Such systems have yet to be demonstrated, but are in the early conceptual design stage.

Future of Safeguards on Enrichment and Reprocessing Plants

In contrast to IAEA's limited experience in safeguarding enrichment and reprocessing plants, Euratom has had some experience in safeguarding small enrichment facilities. After many delays, the IAEA-Euratom Safeguards Agreement is now expected to come into force within the next few months. The staffs of the two organizations have worked together for many years in anticipation of this event, but differences in safeguards approaches and the IAEA requirement to *independently* verify that diversion has not taken place will present many problems. For example, it seems certain that IAEA inspectors will be denied access to the Almelo centrifuge cascade during their inspections.

The potential diversion scenarios directly related to measurement errors in the throughput of large plants will place a heavy burden on the use of surveillance and containment as supplementary safeguard measures. In general, the United States has taken the major role in the development of unattended, tamper-resistant surveillance devices for both enrichment and reprocessing plants. Unfortunately, integrated systems tests have not been undertaken in either case.

A major U.S.-IAEA effort to test installed safeguards surveillance equipment at a reprocessing plant (General Electric Company's Midwest Fuel Recovery Plant in Morris, 111.) was frustrated by a G.E. decision not to place the facility into operation. In the absence of a suitable U.S. enrichment facility, strong but unsuccessful efforts were made to persuade Urenco management to test U.S. enrichment plant surveillance equipment at Almelo. The United States is now considering a comprehensive perimeter safeguards system test at the Centrifuge Test Facility at Oak Ridge, Term.

IAEA and Euratom will not be immediately confronted with the safeguarding of very large enrichment or reprocessing plants. Given adequate manpower and technical and financial support, the safeguards systems should be able to evolve and improve as the size of facilities under safeguards increases. It is not possible to conclude at this time that this effort will be successful. There are a number of unresolved technical and political problems, any one of which might preclude credible safeguards against covert national diversion for these types of plants.

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International Atomic Energy Agency

The IAEA was formed under the auspices of the United Nations in 1957 to promote atomic energy for the benefit of mankind without contributing to any military purposes. Its safeguards functions arose from the latter constraint, The agency is authorized to establish and administer safeguards on fissionable and other materials, services, equipment, facilities, and information, but only with the consent of the safeguarded nation.

The statute establishing the agency granted explicitly limited powers. No authority to recover diverted material or to conduct intelligence activities was included, and the agency's role in combatting non-state adversaries by physical security is advisory only, Thus police powers were not conferred upon the IAEA, and none have been granted since.

Initially, safeguarding activities concerned only research and test reactors of less than 100 MW thermal. Procedures were outlined in Information Circular 26 (INFCIRC/26), approved in 1961. This document is reproduced in annex D to appendix IX of volume II. It is interesting chiefly because of its role in setting the pattern for subsequent activities. In particular, the Agency's interest was to develop a facility-specific safeguards system that would evolve with experience and technological developments. Two items later caused difficulty: only first generation fissile material was safeguarded (i.e., plutonium produced in a safeguarded reactor was not covered), and the safeguards agreements had an explicitly limited duration. Both these weaknesses offered a legal route for the acquisition of safeguarded fissile material.

The next major step occurred in 1964, as the emergence of large power reactors became imminent. IN FCIRC/66 was approved to describe the necessary safeguards system. It was later revised to include enrichment and reprocessing plants. INFCIRC/66 is still in effect for nations which have not ratified the NPT. The concepts embodied in INFCIRC/26 are apparent in its successor. The general intent is still to safeguard specific facilities. The desirability of safeguarding derived special nuclear material is recognized, but not to the degree of the original statute which allowed, ". . . access at all times to all places and data. . .“ The concern of some states over the intrusions safeguards might inflict on normal operations was addressed by a number of clauses restricting activities. Protection of commercial secrets is explicitly handled, but in a manner that has since been a source of concern in evaluating the effectiveness of the Agency. The inclusion of features which would enhance safeguards as a facility design parameter was not required, an omission which has substantially increased the difficulty of effectively applying safeguards. Most U.S. bilateral safeguards agreements have been transferred to the IAEA under these procedures. The IAEA had agreements with 20 states as of December 31, 1975, for this type of safeguarding arrangement. These are shown in annex F to appendix IX of volume II.

The NPT caused a major shift in the Agency's operation when it came into force in 1970. The salient feature is the shift from facility-specific arrangements to a full-fuel cycle system based on the flow of material at certain strategic points. Article III of the NPT (the safeguards article) is reproduced in appendix IX of volume II. In essence, it requires the non-nuclear weapons states to accept IAEA safeguards in verifying that no diversion had taken place. These safeguards were to be applied to all special fissionable material under control of the member state or transferred to another nonweapons state. Article III further stipulated that these safeguards were to be applied in a manner that would not interfere with the economic operation of the subject facilities. The NPT considerably strengthened the role of the IAEA by assigning it the responsibility for implementing NPT safeguards, and mandating acceptance of these safeguards on all nuclear activities by the non-nuclear weapons states. Another significant feature was the ban on the development of any nuclear explosive, thus removing the PNE loophole described in chapter VI

"Peaceful Nuclear Explosive s," This strengthening, however, came at the cost of losing unlimited access for inspection.

INFCIRC/153 was issued in 1971 to govern the NPT safeguards arrangements. The key sections of this document are reproduced in annex I of appendix IX of volume II. The emphasis is on the timely detection of material diversion, and the chief reliance is placed on material accountability with containment and surveillance as supplements. The material accountability is to be provided by the state with verification by IAEA inspectors. This verification is to be done by independent measurements and observations. The section on design information was considerably expanded over that in INFCIRC/66. In order for the Agency to determine the system needed for monitoring the material flow, it is required that sufficient information be presented. This involves the establishment of material balance areas, and timing and procedures for taking physical inventories. This section leads to the important observation that IAEA can refuse to safeguard a facility if it feels it cannot do so effectively. Since an NPT member cannot legally have an unsafeguarded activity, this gives the Agency considerable leverage. There is still a strong emphasis on minimizing the safeguards intrusion, which led to the material balance area concept. The inspectors' limited access however, is compensated for in part by the new requirements of accounting and the redundancy that is inherent in the safeguards of the full fuel cycle.

The present membership of 110 nations is shown in figure VIII-1. The Department of Safeguards and Inspections (DSI) is one of five major departments reporting to the Director General as shown in figure VIII-2. DSI has been the fastest growing department for 10 years, and its total manpower is scheduled to increase from 138 in 1976 to 161 in 1977. Budget information is presented in figure VIII-3. At present, DSI accounts for 18.6 percent of the total IAEA budget. The 34 industrialized states bear 95 percent of the safeguards cost.

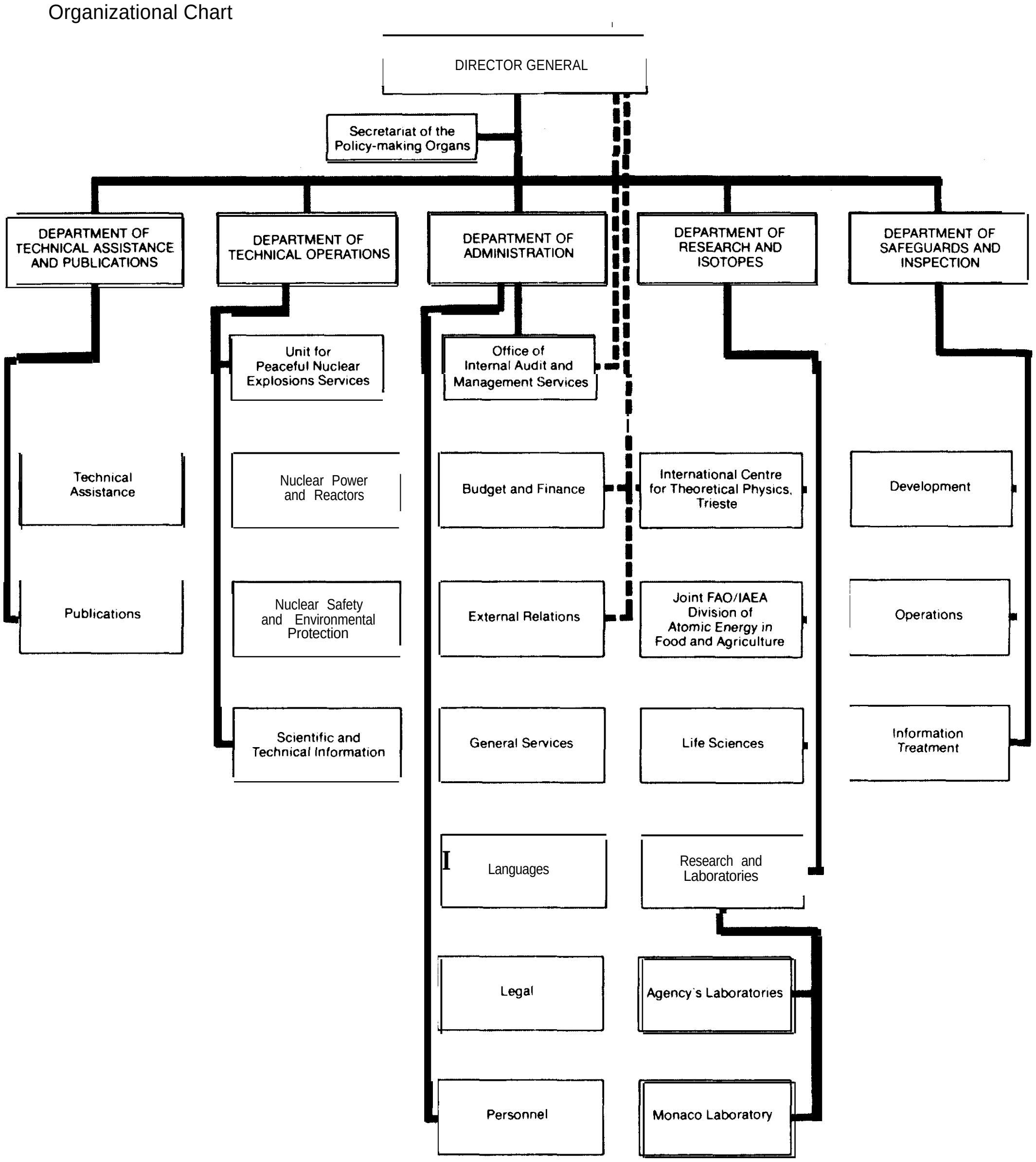
A key factor in the effectiveness of the IAEA's safeguards is the quality of the inspectors. Political pressure can be brought to bear on the hiring and retention of inspectors, and long-term contracts are not available to encourage career decisions. Even the best inspectors must grapple with morale problems when away from home for long periods, and face difficult and sometimes dangerous working conditions. Every effort must be made to ensure a high level of professional competence by providing equitable salaries, promotion opportunities, training programs, and a general understanding that the inspector role is a critical element and a matter of vital importance to the peace and security of the world.

A Safeguards Technical Manual (STM) is now being prepared to form the basis of the procedures and techniques of the safeguards system. Two parts have now been released (as described in appendix IX of volume II) and offer insight into the expectations and intentions of the Agency. Potential diverters and the means to diversion are candidly defined. The function of safeguards to these threats is then developed. The technical requirements of the system are described in the safeguards section above.

Each safeguarded facility will be the subject of a Safeguards Implementation Practices (SIP) document. These will be classified confidential because they are facility specific and contain the Agency analysis of the diversion possibilities and the means to detect them. One of the more important functions of SIPS is formalizing the Agency's analysis of the limitations currently experienced in its safeguarding activities, and identifying improvements which should be made. Both these documents reveal an understanding of the necessary adversary nature of international safeguards.

Noncompliance can take many forms, ranging from simple inadequacies of accounting to outright diversion, encompassing large unexplained losses, and denial of access to critical strategic points. The response would begin with an inspectors' report within DSI. This would be followed by a report from the Chief of the Regional Section to the Inspector General and Director General stating that the inspectors had been unable to verify that a diversion had not taken place. The Inspector

Figure VIII-1.
Organizational Chart



SOURCE=IAEA

General and Director General would be faced with a necessity to evaluate both the quantitative and qualitative information. Many technical as well as subjective factors would have to be weighed. These would include the effectiveness of the state system of accounting, previous history, the magnitude of the suspected diversion, throughput of the facility, the precision and accuracy of the measurements by both the facility operator and the IAEA, the availability and reliability of the containment and surveillance devices, the magnitude of the inspection effort, the performance of inspectors themselves, and, perhaps, questions of a political nature.

If still unresolved, the matter would be brought to the attention of the Board of Governors. Both the Agency and the Board are required to afford the state every reasonable opportunity to provide whatever necessary

Figure Vlll -2

IAEA Member Nations
June 22, 1976

Afghanistan
Albania*
Algeria*
Argentina*
Australia
Austria
Bangladesh*
Belgium
Bolivia
Brazil*
Bulgaria
Burma*
Belorussian Soviet
Socialist Republic*
Cambodia (Khmer Republic)
Cameroon
Canada
Chile*
Colombia
Costa Rica
Cuba*
Cyprus
Czechoslovak Socialist
Republic
Denmark
Dominican Republic
Ecuador
Egypt, Arab Republic of
El Salvador
Ethiopia
Finland
France*
Gabon
German Democratic
Republic
Germany, Federal
Republic of
Ghana
Greece
Guatemala
Haiti
Holy See (Vatican City)
Hungary
Iceland
India'
Indonesia
Iran
[rag
Ireland
Israel*
Italy
Ivory Coast
Jamaica
Japan
Jordan
Kenya
Korea, Democratic
People's Republic of*
Korea, Republic of
Kuwait
Lebanon
Liberia
Libyan Arab Republic
Liechtenstein*
Luxembourg
Madagascar
Malaysia
Mali
Mauritius
Mexico
Monaco*
Mongolia
Morocco
Netherlands
New Zealand
Niger*
Nigeria
Norway
Pakistan'
Panama
Paraguay
Peru
Philippines
Poland
Portugal*
Qatar*
Romania
Saudi Arabia*
Senegal
Sierra Leone
Singapore
South Africa*
Spain'
Sri Lanka
Sudan
Sweden
Switzerland
Syrian Arab Republic
Thailand
Tunisia
Turkey
Uganda*
Ukranian Soviet
Socialist Republic"
Union of Soviet
Sociatist Republics
United Arab Emirates*
United Kingdom of
Great Britian and
Northern Ireland
United Republic of
Tanzania*
United States of America
Uruguary
Venezuela
Vietnam
Y@slavia
Zaire, Republic of
Zambia*

"Member nations that are not party to NPT.
In addition, Taiwan is party to NPT but is not an IAEA member

SOURCE: IAEA

Figure VIII -3.

Safeguards Costs in Relation to Total Agency Expenditure Under the Agency's Budget 1971-76

Year	Safeguards (us $ 000)	Total Budget (us $ 000)	Safeguards Costs in percent of Regular Budget
1971	1636	14010	11 .l°/o
1972	2035	16532	12.3°/0
1973	2564	19881	12.9%
1974	3441	25064	13.7%
1975	4802	29675	16.2%
1976	6443	34702	18.60/0

See Working Papers Appendix IX.

reassurance is required. If the Board of Governors is unable to resolve a question of nondiversion brought to its attention by the Director General, it is instructed by statute to report the noncompliance to all members, to the Security Council, and to the General Assembly of the United Nations. Under statute, the Board may also "direct curtailment or suspension of assistance being provided by the Agency or by a member and call for the return of materials and equipment made available to the recipient member or group of members." As a final act, the Agency may suspend the membership of the state or states from the exercise of the privileges and rights of the membership. There has not yet been occasion to exercise or test the interpretation of these powers, none of which are likely, in themselves, to give pause to Nth countries. If, however, the phrase "or by a member" is interpreted to include the supplier states, the return of this material and equipment at the "demand" of the supplier states should considerably strengthen the Agency's position. The immensely more difficult problem of the actual application of sanctions would have to be the responsibility of the individual member states and more particularly of the supplier states acting individually or in concert. As has already been noted, the Agency cannot prevent diversion nor does it have the power to recover diverted material. It has no police powers.

In general, the Board of Governors operates by consensus. Votes are taken only when a state feels that its vital interests are at stake. Decisions of the Board as well as the action of the General Conference have been unique in their absence of the political discord which has characterized the deliberations of many other international organizations. In spite of this record, it is difficult to predict what the actions of the Board of Governors would be if it were confronted with a report from the Director General stating that he could not verify that there had been no diversion of nuclear material in a specific state. Although it should not be the case, the response of the Board to such an announcement might be conditioned by the identity of the state and whether or not it was a member of the Board.

Under some conditions of political pressures, the Board might find a majority vote on noncompliance very difficult to obtain, Nevertheless, the response to a proven case of diversion is so crucial to both the future effectiveness of safeguards and the willingness of would-be proliferators to test them that a majority of members of the agency are likely to insist that the Board take the actions authorized by statute. The truly difficult decisions will come when the evidence of diversion is somewhat ambiguous.

There are several political and institutional factors which may be expected to have a marked impact on the IAEA's ability to effectively carry out its safeguards responsibilities over the next few years. In the safeguards area the question of the attitude of member states is probably the most crucial factor. In spite of increased recognition of the need for effective and credible safeguards, there remains an urgent need to enlarge the perceptions of industrial and developing states to the dangers which proliferation presents to all. A cooperative attitude by most member states will establish a pattern of behavior difficult for other nations to flout. This in turn will strengthen the effectiveness of the technical safeguards and provide reasonable assurance that the diversion of nuclear materials for weapons purposes can be detected. Failing this, and confronted with inadequate funding and overriding concerns for either national sovereignty or the protection of industrial secrets, the success of the Agency's safeguards activities will be placed in serious doubt.

The most pressing near-term problem of an Institutional nature, directly affecting the operations of the Agency as a whole and its safeguards efforts in particular, is the matter of the retirement or imminent contract expiration of many key management people at the highest Agency levels. The Director General is 66 years old. If he is to be succeeded in an orderly manner, the nomination must be submitted to the Board of Governors in June 1977. Many of the members of the Director General's immediate staff are his contemporaries and are also approaching mandatory retirement. Of immediate concern is the fact that the contract covering the services of Dr. Rometsch, the Inspector General, must be renegotiated or a replacement recruited by September 1977. The Agency has recently circulated a request for nominations for the position of Director, Division of Operations, Department of Safeguards and Inspections. As a result of the proposed reorganization of DSI, Directors will have to be nominated for the new Division of Operations and the Division of Information. Finally, the Head of the Section for Methods and Techniques, Division of Development, is also approaching mandatory retirement and a replacement for this position will be required. The staffing of these positions will have a marked and long-range effect on the Agency, as well as on the performance and morale of DSI.

The reorganization of DSI (noted above) was planned to meet the major increase in safeguards activities resulting from the implementation of the IAEA-Euratom and Japanese Safeguards Agreements, and application of Agency Safeguards under the United States and United Kingdom offers. This substantial increase in the operational activities of DSI will place new and exacting demands on the Department and on the management of the two operations divisions. At the level of Inspector General there will be an even greater need for strong leadership and effective, imaginative management to meet this challenge.

It is too early to evaluate the impact of the very large increases the U.S. Congress has authorized to strengthen and support IAEA safeguards. In FY 1975, approximately $200,000 was made available in gifts-in-kind through the Foreign Assistance Act, In FY 1977 a total of approximately $1.6 million will be available through the Foreign Assistance Act of 1977 for similar gifts-in-kind. It was the recommendation of President Ford that approximately $5 million should be made available to the IAEA over the next 5 years. The effective use of this money will require a careful and realistic assessment of the Agency's needs.

If the United States does not actively strive to broaden this type of support among all of the nuclear supplier states and the Soviet Union, there is danger that the United States will find itself carrying a disproportionately large part of the burden. The report of a German decision to contribute approximately $300,000 in similar support for IAEA is heartening and should be encouraged.

The IAEA can also be assisted in political and technical ways as well as economic. Political support can be indicated by full backing in arguments, such as the present dispute with Euratom over the IAEA's oversight role, or by manifestations of faith in the Agency's ability to competently fulfill its functions. Technical assistance has been provided for many years by the United States and other nations. This has consisted of instrumentation and security hardware development, safeguards application, training of inspectors, and assistance in data management systems development.

Euratom

The European Atomic Energy Community, created by the Treaty of Rome in 1957 along with the European Economic Community, was the first multinational safeguards system. The original members, *Belgium,* West Germany, France, Italy, Luxembourg, and The Netherlands were later joined by the United Kingdom, Denmark, and Ireland. All Euratom nations except France have since then ratified the NPT.

Euratom inspection rights are broader than those of the IAEA, and are in fact exercised by the inspectors. This includes ". . access to all places and data and all persons who by reason of their occupation deal with material, equipment, or installations subject to the safeguards. . ." The Commission may also require that all fissile material not immediately needed be stored by the Commission. Commercial sensitivity does not restrict the Euratom inspectors. The safeguards approach is similar to that of IAEA in that verification of material accountancy is the key element. In general, reports are required monthly to indicate both inventory changes and the final inventory.

Euratom at present has about 60 inspectors for 400 safeguarded facilities. It is Euratorn practice that the inspectors specialize in certain types of installations and are responsible for these installations wherever they may be found within the European community. The inspector proposes the inspection methods to be used for specific facilities, examines the records and reports of the facility, reviews the differences between the operator's declarations and his findings, and makes the first recommendation on the admissibility of losses and wastes reported by the facility operator. The final decision on this latter matter is made at the level of the Directorate. Responses available are stronger than the IAEA's, including temporary administration of the facility and sanctions by member states.

The non-nuclear weapons states are fulfilling their NPT responsibilities by an agreement between Euratom and IAEA which incorporates the essentials of INFCIRC/153. Euratom will continue its own inspections which will be verified by IAEA. Several significant differences remain to be resolved and the agreement is not yet in force, although considerable cooperation does already exist. One complication introduced by Euratom is the perception of it by other nations as essentially a self-inspection operation, since it is small and cohesive.

The Role of Sanctions in Nonproliferation Strategy

Sanctions already play a role in the nonproliferation regime. Article XII of the IAEA Statute provides that, in the event of a violation of safeguards, the Board of Governors is empowered to suspend nuclear assistance provided the offending country by the Agency or a member state. The Board may also require the return of materials or equipment previously provided and suspend any noncomplying member from continued participation in the Agency. Similarly, under bilateral American Agreements for Cooperation, noncompliance gives Washington the right ". . .to suspend or terminate this Agreement and to require the return of any materials, equipment, and devices. " The Symington Amendment to the Foreign Assistance Act provides for a cutoff of American economic or military assistance to any state exporting or importing unsafeguarded reprocessing or enrichment capabilities.

The purpose of sanctions is three-fold: to dissuade potential proliferators, to prevent the erosion of safeguards effectiveness which would follow a successful violation, and to reinforce international political norms against proliferation.

Sanctions might be triggered by a variety of events, including violations of safeguards agreements; violations of bilateral Agreements for Cooperation; sudden withdrawal from the NPT; nuclear gray marketing; and movement, though not in violation of any legal obligation, towards a nuclear weapon capability. However, the specific context within which these events occur could influence the feasibility and/or desirability of invoking sanctions. Under some conditions (e.g., where other foreign policy interests are involved) there may be compelling reasons not to threaten or apply sanctions. Consequently, any sanctions strategy should permit some degree of flexibility.

This can be accomplished by a strategy of combining two postures: one threatening automatic imposition of sanctions where a clear violation of a legal obligation is involved; a second designed to create a strong presumption that sanctions might be imposed even following more ambiguous violations. Failure to respond strongly following violation of a legal obligation would have serious adverse effects upon nonproliferation efforts. In this case, the risks of inaction are likely to outweigh those of action. On the other hand, the presumptive sanctions posture acknowledges that in some cases the costs and risks of taking action may be too high and that flexibility may be desirable.

The historical record concerning the threat or imposition of sanctions is not one to insure confidence. Major targets of international economic sanctions have included Mussolini's Italy, China, Cuba, and Rhodesia. In none of these instances did sanctions achieve the desired results. Canada's recent termination of nuclear assistance to India did not greatly slow India's nuclear program. But to extrapolate from past ineffectiveness into the future may be inappropriate. Instead, detailed assessment of the degree of existing leverage over specific Nth countries is needed. Within the framework of automatic and presumptive sanctions, a broad set of levers might be utilized. These include manipulation of nuclear assistance, economic and military assistance, U.S. influence over the lending policies of international financial institutions, trade, investment, and security guarantees. Ultimately it may include the threat and/or use of military force.

Different Nth countries are more vulnerable to some sanctions than to others; deterrent impact varies from case to case. At the same time, nearly all prospective near-term proliferators would be vulnerable to one or more of these levers. Recent American pressure upon South Korea to forgo acquisition of a reprocessing plant illustrates that sanctions can be effective, at least in a situation where the target state is highly vulnerable. Whether the threat of sanctions will be as effective under less optimal conditions (e.g., Pakistan and Brazil) remains to be seen.

Multinational Fuel Cycle Facilities

Multinational control of enrichment and reprocessing facilities has been proposed in order to reduce the opportunities for diversion by proliferators. In addition to the obviously greater difficulty one member would have in diverting strategic nuclear materials from a multinational facility as compared to diverting from a plant under his sole control, multinational fuel cycle facilities (MFCF) would have other advantages. They would generally be bigger than plants serving a single nation and therefore offer economies of scale. Fewer large plants are also cheaper to safeguard and protect. The expertise of an advanced member nation could benefit the operability of the plant, while participation by the less advanced nations will serve to mollify their sense of discrimination under the NPT.

Opposing these are several notable disadvantages. The primary one is that MFCFS threaten to spread the very disease they are designed to control, both by weakening the arguments against all reprocessing and by disseminating the technology so that nations could later build their own facilities. In addition, multinational reprocessing plants would still make plutonium accessible. This would necessitate possibly discriminatory burdens of heavy safeguarding of mixed-oxide fuels sent to potential Nth countries, or fuel-cycle schemes which send only enriched uranium to them and reserve the mixed oxide for existing weapons states.

Several important issues will have to be resolved before the concept will become practical. The details of the control of each facility will have to be spelled out in some detail before nations will feel secure in forgoing their option to build domestic plants. Too much control by individual members, however, will interfere with commercial operation when it conflicts with national objectives. Accessing the technology will have to be controlled, possibly by members renouncing the right to build their own facilities. The IAEA role in technical assistance and safeguarding will also have to be resolved.

Multinational fuel cycle facilities have precedents for both enrichment and reprocessing plants. Two enrichment plants and one reprocessing plant have been built in Europe by different groups of governments and private companies. The primary motivation was economic, and the partners were mostly advanced countries which are not generally considered prime proliferation threats. Nevertheless, the examples demonstrate that the concept is feasible at least under some conditions.

Alternatives to MFCFS are national facilities and abstinence, at least on the part of the target nations. A concensus appears to be developing among supplier nations that national control is undesirable. Abstinence can only be secured by guaranteeing substitutes for the services these facilities would have provided. This appears relatively straightforward for enrichment. A clear commitment by the United States to construct the necessary enrichment capacity could eliminate the need for other national facilities. Reprocessing is more difficult, as present or planned capacity cannot handle the spent fuel being produced. The spent fuel is simply being stored, and therefore demand for some sort of disposal is growing. In addition, as the technology of reprocessing is simpler than that of enrichment many nations could bypass export bans by building their own facilities. Some means of relieving potential proliferators of their spent fuel is therefore both necessary and desirable. This could be done by storing the spent fuel in nuclear weapons countries or in MFCFS designed only for fuel storage. The latter approach would have the advantage of beginning the MFCF concept for reprocessing without a full commitment to it, and the relative simplicity of the approach would ensure a greater chance of success.

The IAEA is presently conducting a major study of MFCFS. The first report on institutional and legal aspects has been issued, and others are expected in 1977. Preliminary indications are that the concept will be found beneficial in most respects.

The main impetus behind the concept is concern over proliferation. Even if the economics and fuel-cycle convenience prove useful, however, MFCFS will be contributors, not barriers, to proliferation unless access to the technology, and therefore to the plutonium, is controlled. Hence, implementation must be approached with caution. Spent-fuel storage facilities are one way to jointly test the concept and relieve the pressure for reprocessing.

The Suppliers' Conference

The First Suppliers' Agreement

On August 22, 1974, Australia, Denmark, Canada, the Federal Republic of Germany, Finland, The Netherlands, Norway, the Soviet Union, the United Kingdom, and the United States filed identical memoranda with the Director General of the International Atomic Energy Agency concerning "procedures in relation to exports of (a) source or special fissionable material, and (b) equipment and material designed or prepared for the processing, use, or production of special fissionable material. " As stated by all these states, except the Federal Republic of Germany and The Netherlands which had at the time not yet ratified the Non-Proliferation Treaty, these memoranda were intended to coordinate the fulfillment of "commitments under Article III paragraph 2 of the Treaty on the Non-Proliferation of Nuclear Weapons not to provide such items to any non-nuclear-weapon state for peaceful purposes, unless the source or special fissionable material is subject to safeguards under an agreement with the International Atomic Energy Agency." The documents relating to this agreement were distributed by the IAEA in INFCIRC/209, a copy of which is provided as annex S to appendix IX of volume II.

The agreed procedures and so-called Trigger List was the result of several years of negotiation, and represented the first major agreement on uniform regulation of nuclear exports by actual and potential nuclear suppliers. It had great significance for several reasons. It was an attempt to strictly and uniformly enforce the obligations of Article III, paragraph 2, of the Non-Proliferation Treaty. It was intended to reduce the likelihood that states would be tempted to cut corners on safeguard requirements, because of competition in the sale of nuclear equipment and fuel-cycle services. In addition, and very important in the light of subsequent events, it established the principle that nuclear supplier nations should consult and agree among themselves on procedures to regulate the international market for nuclear materials and equipment in the interest of nonproliferation. Notably absent from the list of actual participants or potential suppliers, as from the list of parties to the NPT, were France, India, and the People's Republic of China. By 1974, however, French policy had changed to one of respect for the agreed-upon Trigger List, and in all other matters related to nuclear exports began to act as if she were a party to the NPT.

The 1976 Agreement

Within a year of the delivery of these memoranda a second series of supplier negotiations were underway, This round, convened largely at the initiative of the United States, was a response to 1) the Indian nuclear test of May 1974, 2) mounting evidence that the pricing actions of the Organization of Oil Exporting Countries were stimulating Third World and other non-nuclear states to initiate or accelerate their nuclear power programs, and 3) recent contracts or continuing negotiations on the part of France and West Germany for the supply of enrichment or reprocessing facilities to Third World states. The initial participants in these discussions, conducted in London under the veil of official secrecy, were Canada, the Federal Republic of Germany, France, Japan, the Soviet Union, the United Kingdom, and the United States.

Two major issues were discussed in the series of meetings which led to a new agreement in late 1975. The first was if, and under what conditions, technology and equipment for enrichment and reprocessing, the most sensitive parts of the nuclear fuel cycle from a weapons proliferation perspective, should be transferred to non-nuclear states. The United States, with support from several other participants, was reported to argue in favor of both a prohibition on such transfer and a commitment to reprocessing in multinational facilities. France had already signed contracts to sell small reprocessing plants to Pakistan and South Korea, and West Germany had agreed to sell technology and facilities for the full fuel cycle to Brazil. They successfully resisted the prohibition proposed by others. The second issue was whether transfers should be made to states unwilling to submit all nonmilitary nuclear facilities to IAEA safeguards, or whether total industry safeguards should become a condition of sales.

On January 27, 1976, the seven participants in the negotiations exchanged letters endorsing a uniform code for conducting international nuclear sales. The major provisions of the agreement require that before nuclear materials, equipment, or technology are transferred the recipient state must:

1. pledge not to use the transferred materials, equipment, or technology in the manufacture of nuclear explosives;
2. accept, with no provision for termination, international safeguards on all transferred materials and facilities employing transferred equipment or technology, including any facility that replicates or otherwise employs transferred technology;
3. provide adequate physical security for transferred nuclear facilities and materials to prevent theft and sabotage;
4. agree not to retransfer the materials, equipment, or technology to third countries unless they too accept the constraints on use, replication, security, and transfer, and unless the original supplier nation concurs in the transactions;
5. employ "restraint" regarding the possible export of "sensitive" items (relating to fuel enrichment, spent fuel reprocessing, and heavy water production); and
6. encourage the concept of multilateral regional facilities for reprocessing and enrichment.

There is of course a problem in trying to impose such constraints on the diffusion of technology. Technical advances made by the recipient country may alter the initial technology to the point where it can reasonably be claimed to be different technology. Such ambiguities are handled by specifying an arbitrary time period—reported to be 20 years—within which all related technology will be unambiguously considered as transferred technology and after which differing interpretations may be possible. The basic obligation, however, is not limited in time. A copy of the U.S. Arms Control and Disarmament Agency news release of February 23, 1976, a discussion of these provisions is found in appendix volume II.

Evaluation of the 1976 Agreement

It is important to recognize what this suppliers' agreement does and does not do. It does not ban transfers to nonparties of the NPT or to states that refuse to place all nuclear facilities under IAEA safeguards.[4] It also does not ban the export of reprocessing and enrichment facilities and equipment, but it attempts to render such exports benign through the imposition of safeguards and government pledges.

It requires IAEA safeguards be applied, and a no-explosives-use pledge be associated both to facilities that are actually exported and to facilities the recipient may build based on the same technology. This is a significant strengthening of the provisions previously applied to Trigger-List equipment. The retransfer provision not only precludes states acquiring technology with fewer constraints by retransfer, but also gives the exporter a veto over what countries may receive retransfers. In this way any countries thought to be particularly high risk, can be prevented from obtaining help via an intermediary. The provisions also explicitly recognize the importance of physical security protection of nuclear materials and facilities, and will strengthen the IAEA role as advisor on physical security matters to interested states.

Beyond the agreement's provisions themselves, its very existence and the process of negotiation that produced it have some significant implications. The most important benefit is perhaps the strengthening of the international norm prescribing the acquisition of nuclear weapons by non-nuclear states. The importance that nuclear supplier states attach to the prevention of proliferation is indicated and symbolized by their agreement on uniform standards. Agreement is made despite the rather considerable opportunities and incentives for each state to compete for sales in a rather tight and lucrative export market by demanding less stringent anti-proliferation requirements than other vendors. In addition, the process of negotiation and the publicity associated with it were instrumental in causing the issues of nuclear proliferation and nuclear exports to be raised to the highest political levels within the governments of all participants. Considerable pressure could therefore be brought to bear on France and West Germany to adopt a policy more closely in line with other major exporters.

While producing only partial (although still quite significant) changes before major agreement was achieved in January 1976, subsequent statements by both governments indicate continued movement closer to the American position and away from insistence of their right to export sensitive facilities. Progress is evidenced by a French decision to avoid any future export agreements involving reprocessing technology and facilities. President Giscard has also announced the formation of a cabinet-level committee to coordinate and supervise French nuclear exports. President Ford announced a toughening of U.S. export criteria in line with the London agreements, calling for a 3-year moratorium on the export of reprocessing and enrichment technologies. In the meantime, Canada has gone further than other suppliers by declaring that its nuclear exports would be confined to countries that have ratified the NPT or that accept full fuel-cycle safeguards. Finally, the existence of the supply negotiations aided the application of American pressure on South Korea and Pakistan to abandon their plans to build reprocessing plants, and increased the political cost for other states that might be contemplating acquiring reprocessing facilities. As of this writing (May 1977), the French-Pakistan deal may be canceled and implementation of the West German-Brazilian agreement is in some doubt.

On the negative side is the fact that the negotiations have involved only actual and potential nuclear suppliers. Having conducted the negotiations in official secrecy and totally outside the IAEA context, the parties have left themselves open to several criticisms by potential purchasing states. The first is that the suppliers are in violation of their obligations under Article IV, paragraph 2 of the NPT "to facilitate. . . the fullest possible exchange of equipment, materials and scientific and technological information for the peaceful uses of nuclear energy," and to "cooperate in contributing. . . .to the further development of the application of nuclear energy for peaceful

[4] Ratification of the NPT or acceptance of international safeguards on all nuclear facilities has now been adopted unilaterally by Canada as a condition for the supply of reactors or uranium. Canada has also called on other suppliers to adopt comparable conditions of export.

purposes, especially in the territories of non-nuclear-weapons states party to the Treaty, with due consideration for the needs of the developing areas of the World.” The second possible criticism is that through the suppliers’ agreement a group of industrialized states have formed a nuclear cartel and are conspiring to promote the continued dependency of developing countries prevented from acquiring industrial capability, the importance of which for building modern industrial economies is demonstrated by the suppliers’ own pursuit of such capability.

If such interpretations gain favor among potential recipients states, the suppliers’ agreement could contribute to a weakening of the sense of bargain on which the acceptability of the NPT to many non-nuclear states rests. It could also weaken the American argument in international forums that cartelization is an inappropriate mechanism for organizing commodity markets. In addition, it could become a symbolic issue of contention in the context of North-South negotiations over the distribution of the world’s resources, wealth, technological capabilities, and power.

Current and Future Issues

As of November 1976, Belgium, Czechoslovakia, East Germany, Italy, The Netherlands, Poland, Sweden, and Switzerland were reported to have adopted the suppliers’ guidelines and joined the suppliers’ discussions. This raises the number of participants to 15 and omits only Argentina, India, and South Africa of those states potentially able to enter the nuclear equipment or services export market in the foreseeable future. By adding three members of the Soviet bloc in addition to Russia, the suppliers’ conference has become a joint East-West enterprise-a fact of considerable political significance. There is still no indication that the IAEA will become involved, even to the extent of serving as a communications medium to other states as it did in the case of the 1974 Trigger List agreement, Possible items for future agendas **of** the suppliers’ group include reopening the question of reprocessing and enrichment exports, establishing uniform nonproliferation provisions in Agreements for Cooperation and contracts leading to the supply of enrichment or reprocessing services, and multinational fuel reprocessing or spent-fuel storage facilities.

The Non-Proliferation Treaty (NPT)

The NPT evolved from the concern over the increasing access to nuclear material from commercial powerplants that emerged in the late 1960’s. The intent was to restrict this access by safeguards and gain a formal commitment by the non-weapons states to remain weaponless. These considerable intrusions into national sovereignty were obtained by guaranteeing access to peaceful nuclear technology and obligating the weapons states to pursue disarmament. The treaty, which went into effect in 1970, is reproduced in appendix IX of volume II.

The status of nations relative to the NPT is noted in figure VIII-2. The great number of signers is encouraging, but included in the almost 50 nonsignatories are Argentina, Brazil, Chile, Peoples Republic of China, France, India, Israel, North Korea, Pakistan, Portugal, Saudia Arabia, South Africa, Spain, and North Vietnam. That lack of participation is a serious weakness of the NPT. The membership could be expanded if participation were made more attractive, possibly by offering members preferential treatment in the export of nuclear technology or security assurances.

The asymmetry between the nuclear and non-nuclear states has caused some discomfort. The non-nuclear states surrendered considerably more sovereignty than did the weapons states, in that the major obligation of the latter was only to pursue negotiations towards arms control. Most states are apparently willing to accept the separate status accorded the present nuclear weapons states, provided that their access to imports is not impaired and that the arms control negotiations are conducted in good faith. Of particular interest are the views of the non-nucIear, nonaligned states of Africa, Asia, and Latin America. These nations have been opposed to the imposition of stricter new controls and limitations on their nuclear imports in light of the nuclear powers' refusal to accept such constraints and controls for themselves as regarding nonweapon aspects of nuclear energy.[5] In their viewpoint, controls regarding the peaceful utilization of nuclear energy should be applied equitably to both nuclear and nonnuclear energy.

The major concern of these nations, however, was focused upon the large political issues rather than upon technical matters. Led by Mexico, Nigeria, Romania, and Yugoslavia, a number of specific demands for action by the superpowers were presented:

- an end to underground nuclear tests;
- a substantial reduction in nuclear arsenals;
- a pledge not to use or threaten to use nuclear weapons against non-nuclear parties to the Treaty;
- concrete measures of substantial aid to the developing countries in the peaceful uses of nuclear energy;
- creation of a special international regime for conducting peaceful nuclear explosions; and
- an undertaking to respect all nuclear-free zones.[6]

Some movement towards meeting these demands will have to be visible for these nations to feel that the NPT is a partnership and not just a constraint on them. The bitter reaction of the nonweapons states during the 1975 NPT Review Conference and the threat of Yugoslavia to withdraw from the Treaty because, in its view, the United States and the Soviet Union in particular had not fulfilled their solemn obligations under Article 6, are clear evidence that the non-nuclear weapons states do not take lightly their understanding of the balance of obligations undertaken by all parties to the NPT.

The NPT by itself clearly does not solve the proliferation problem. As noted above, some of the key countries have not signed the treaty, and hence, are not legally bound from developing their own weapons. Further, any member can, upon justification of extraordinary circumstances, withdraw with only 3 months notice. Members can also legally make all preparations except final assembly of weapons. Hence, a fully armed nuclear state can spring forth, leaving a rather surprised world little time to formulate a response.

Despite these weaknesses, the NPT was a momentous achievement and remains a significant deterrent. There are strong reasons why a nation could find it very difficult to abrogate the NPT, even though it is technically easy to do so. Few nations can afford to flaunt international public opinion so flagrantly, especially if their justification is not convincing. This would be construed as reneging on a commitment to nonproliferation, as well as a violation of an international consensus, and could provoke a strong international response. Nor would most nations take lightly the possible unraveling of the fabric of nonproliferation,

The NPT is useful, at least in the short-term, in slowing down or deterring proliferation, but it should not be viewed as an end in itself. It has been observed that even if the NPT were suitably strengthened and extended by the accession of states not now party to it, it would not be a perpetual assurance that nuclear wars would be prevented.[7] That lack of assurance is attributable to the dynamic nature of competing interests, goals, and objectives. The fate and effectiveness of the NPT will depend upon the actions undertaken by the nuclear weapons parties to fulfill their obligations to the non-nuclear parties, as well as upon the preference or benefits the non-nuclear parties to the treaty accrue as compared to the treatment received by non-nuclear states not party to the treaty. In the long term it is important to recognize that the NPT is merely a part, although a central part, of a more extensive strategy aimed at inhibiting proliferation.[8]

[5] William Epstein, "Retrospective on the NPT Review Conference: Proposals for the Future," Congressional Record, p. S. 19558 (Nov. 10, 1975).

[6] Ibid.

[7] John Maddox, "Prospects for Nuclear Proliferation," *Adelphi* Papers, No. 113, p. 1 (London: The Institute for Strategic Studies, 1975).

[8] Ibid., p. 2.

Conclusion and Prognosis

The basic purpose of the control mechanisms discussed above is to supplement eroding technological barriers to proliferation with institutional and political constraints. These include the Non-Proliferation Treaty, IAEA safeguards, Euratom safeguards, the Suppliers' Conference, various bilateral and other export controls, and unilateral or multilateral sanctions. The achievements to date have been considerable. Thev include:

(1) an improved but still inadequate comprehension of the nature of the problem and the requirements for a solution;

(2) the creation of a broadly endorsed international norm against further proliferation;

(3) the bridging of the East-West gap in international politics with regard to this issue;

(4) the voluntary relinquishment by non-nuclear weapons states of certain sovereign prerogatives in the interest of nonproliferation (e.g., forswearing the right to obtain nuclear weapons, permission for international civil servants to inspect national nuclear facilities, acceptance of controls and restrictions on nuclear imports);

(5) the creation of at least rudimentary institutions for a coordinated international approach to the problem;

(6) the establishment of national governmental machinery to implement bilateral agreements;

(7) identification and utilization of a variety of policy instruments designed to contain proliferation (e.g., security guarantees, international safeguards, nuclear-free zones, etc.);

(8) the elevation of proliferation to near the top of supplier/state agendas and to the attention of the highest level of governmental authority; and

(9) the agreement on a broad *quid pro quo* between nuclear weapons states and non weapons states involving the reciprocal obligations delineated in the NPT.

Although still inadequate, these achievements can provide the basis for the development of a truly effective nonproliferation regime. Whether that promise will be actualized depends largely on two master variables: technological change and political will,

Assuming that the pace and configuration of technological advance (e.g., new enrichment techniques or fast breeder reactors) can be managed or accommodated and that the political will is present, what does the future agenda regarding nonproliferation look like? In broad terms the task will be to:

(1) achieve a clearer understanding of the issue in all its complexity, particularly the linkage between its technological and nontechnological dimensions;

(2) identify priorities for action in terms of importance, urgency, feasibility, and time required for implementation;

(3) reinforce the international norm against proliferation;

(4) strengthen the IAEA by improving its capabilities (e.g., budget) and expanding its responsibilities (e.g., regarding international fuel repositories);

(5) improve international safeguards and export controls by expanding their scope, standardizing their requirements, etc.;

(6) develop institutional innovations (e.g., multinational fuel-cycle facilities);

(7) redefine or clarify the bargain between nuclear weapons states and non-nuclear weapons states underlying the NPT to place the nonproliferation regime on a firmer international political foundation (i.e., bridge the gap between industrialized and less developed countries on this issue);

(8) develop comprehensive sanctions along with an enforcement capability in support of the nonproliferation regime; and

(9) improve coordination between bilateral and multilateral nonproliferation controls.