Chapter II

Issues, Findings, and Executive Summary

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This chapter is comprised of three sections: issues and findings; a description of nuclear technology; and an executive summary. The first section presents selected issues and findings of the report under the following headings:

- The Problem—the desirability and accessibility of nuclear weapons; and
- The Control—possible control measures.

PROLIFERATION ISSUES AND FINDINGS

The Problem

Issue 1

Are More Countries Likely To Acquire Nuclear Weapons, and If So, Will This Proliferation Jeopardize U.S. and Global Interests?

Findings

The technical and economic barriers to proliferation are declining as accessibility to nuclear weapons material becomes more widespread. Consequently, the decision Whether or not to acquire a nuclear weapons capability has become increasingly a political one. The choice will turn on whether a nation views the possession of such a capability as being, on balance, in its national interest.

That balance will be affected by certain global trends. The diffusion of global power and the erosion of bipolar alliance systems and great power security guarantees tend to increase the incentives to proliferation. On the other hand, a number of states have long had the capability to acquire nuclear weapons but have been persuaded by a variety of political considerations to refrain. These disincentives may also be persuasive in the future to the growing number of countries which find nuclear weapons within their capability. With internationally derived incentives and disincentives broadly offsetting one another, the decision on acquiring a nuclear weapons capability will tend to hinge on the particular circumstances of each Nth country and the policy pursued by present nuclear weapons states, especially the United States.

Press reports indicate that at least two states (Israel and South Africa) are at the verge of acquiring or have already acquired nuclear weapons. Several other countries are close to a weapons capability and a few may choose to attain it over the next few years.

As for the consequences of proliferation, it can be argued that proliferation will have a stabilizing effect on international politics due to the deterrent value of nuclear weapons. The alternative, and more persuasive possibility, is that further proliferation will jeopardize regional and global stability, increase the

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likelihood of nuclear war (local or general), exacerbate the threat of nuclear armed non-state terrorism, and greatly complicate U.S. relations with new (potential or actual) nuclear weapons states. The extent to which proliferation has a disequilibrating effect on international politics also impacts directly on American foreign policy, which has had the maintenance of global stability as its overriding objective in recent years. From this perspective, the threat to American interests derives not so much from the mere number of Nth countries but from the probability that proliferation will tend to be greatest in regions with the highest potential for international conflict, e.g., the Middle East, Southern Africa, and East Asia. (See chapters 111 and IV.)

Issue 2

What Will Be the Proliferation Impact of the International Spread of Plutonium Recycle Facilities?

Findings

Reprocessing provides the strongest link between commercial nuclear power and proliferation. Possession of such a facility gives a nation access to weapons material (plutonium) by slow covert diversion which would be difficult for safeguards to detect. An overt seizure of the plant or associated plutonium stockpiles following abrogation of safeguards commitments could, if preceded by a clandestine weapons development program, result in the fabrication of nuclear explosives within days, Furthermore, such a plant reduces a nation's susceptibility to international restraints (sanctions) by enhancing fuel cycle independence. Finally, plutonium recycle is the most likely source for both black market fissile material and direct theft by terrorists,

Most nations expect to have their nuclear fuel reprocessed despite these obvious complications for the task of preventing further proliferation, and several (none of them Nth countries) are constructing large reprocessing plants. There have been increasing doubts as to the economic feasibility of reprocessing in the United States, but other countries perceive reprocessing as being attractive. Their more limited energy resources make the energy of plutonium more valuable, and possibly less-stringent regulatory requirements may make the facilities less expensive. In addition, if nuclear energy is to be a long-term option, reprocessing will eventually have to be an integral part of the fuel cycle, although uranium resources may be adequate to last until about the year 2000 even without reprocessing. Hence, nonproliferation strategies that involve a total renouncement of reprocessing will be difficult and probably expensive to implement.

Reprocessing in the United States and other weapons states is not a direct proliferation issue (except for terrorists). Other supplier states such as West Germany and Japan are also unlikely to use their commercial facilities to procure weapons material. The less advanced countries that might misuse facilities have been precluded from importing them by supplier agreements (except for Brazil and Pakistan who already have contracts and are resisting pressure to cancel them). The technology is uncomplicated enough for some Nth countries to develop on a commercial basis, but this endeavor would almost certainly be commercially uneconomical if other energy sources are available. A double standard approach to reprocessing would further strain relations between suppliers and importers. Multinationally controlled facilities may be necessary to alleviate this tension if reprocessing does become widespread in the supplier states (see chapters III, V, and X).

Issue 3

How Will U.S. Decisions on Domestic Plutonium Recycle Affect Efforts To Curb the International Spread of Reprocessing?

Findings

Decisions on the future of reprocessing and plutonium recycle in the United States must be made in the near future because of the imminence of operation of the large plant at

Barnwell, S.C. Nonproliferation will clearly be best served if no one reprocesses. Other nations, however, have a stronger interest in reprocessing (as described in Issue 2) and will be unsympathetic to efforts to convince them to refrain. If the United States alone refrains, the nonproliferation effort could actually be damaged because the resulting unavailability of fuel cycle services would induce more nations to build their own facilities. If the United States does not refrain, however, the credibility of its efforts to dissuade others will be diminished, There is general agreement that Nth country possession of reprocessing plants would be inconsistent with efforts to contain proliferation. The key factors shaping positions on this issue are:

- The effect of a double standard, where supplier states build their own reprocessing plants but deny exports to other nations: Importing states have expressed resentment over discriminatory export policies, and this policy would be certain to annoy some. It is significant, however, that few Nth countries will have enough reactors in this century to make an indigenous reprocessing plant more economical than having the service provided by a supplier state.
- The ability of the United States to persuade other nations to forgo reprocessing: A U.S. decision to refrain would have slight impact on other suppliers unless accompanied by costly political and economic pressure. Their commitment to reprocessing and to early deployment of breeder reactors (which require reprocessing) is much stronger than that of the United States. Importing states, however, are more likely to be impressed by such a gesture (see chapters III, VII, and X).

Issue 4

Would Deployment of Fast Breeder Reactors (LMFBRs) Be Compatible With a Policy To Curtail Proliferation?

Findings

The LMFBR is the highest priority energy development program in most nuclear supplier states. It was chosen because, of all the long-term options for essentially inexhaustible energy, it may well be most economic. It is also in a relatively advanced state of development, and thus the most likely to be available for widespread deployment by the end of the century.

Proliferation, however, was not a major consideration in the elevation of the LMFBR to its present priority. Certain characteristics of the LMFBR system as presently envisaged will conflict with efforts to control proliferation. These are:

- National possession of a full LMFBR cycle would eliminate all technical barriers to acquiring weapons material. It would also provide virtual immunity to an international embargo on fuel shipments because the LMFBR produces more than enough plutonium to refuel itself.
- Even a national LMFBR tied into an international fuel cycle (e.g., fuel leasing or multinational fuel centers) increases the opportunity for proliferation. Many nations could eliminate their dependence on the international or foreign fuel services by constructing indigenous fuel fabrication and reprocessing plants or by processing the fresh fuel or partially spent fuel within the reactor.
- Some of the plutonium produced by the LMFBR is of extremely high quality for weapons.
- The LMFBR requires reprocessing, which creates opportunities ‘for dive;sion of plutonium by nations or non-state adversaries.

An overall assessment of the desirability of the breeder must weigh its benefits as an energy source against its liabilities relative to proliferation, as well as other problems in comparison with alternative energy sources (see chapter VII, “Diversion From Commercial Power Systems”).

Issue 5

Do Uranium Enrichment Facilities Have a High Potential for Proliferation?

Findings

Any enrichment plant can theoretically be used for the production of weapons material while simultaneously providing immunity from international nuclear fuel embargoes, but only one type of enrichment plant—the centrifuge type—increases opportunities for proliferation on the same scale as reprocessing plants. Diffusion plants are economical only on a very large scale, so this enrichment route is out of the question for all but the largest and most highly developed countries.

The nozzle method is currently under development in South Africa and Germany. It promises to cost less than diffusion and be fundamentally simpler. It does demand highly precise manufacturing techniques, and its operation requires about twice as much power as a diffusion plant of the same capacity. This makes it commercially impractical for nations lacking low-cost power such as hydroelectricity, Despite its simplicity, it does not appear to be a good choice for a small facility dedicated to weapons material production.

By contrast, centrifuge plants may be sufficiently economical in small sizes for many nations to find them commercially attractive. These plants could only be developed by technically advanced nations, but could be purchased and operated by less advanced nations.

If sold to less advanced nations, centrifuge plants would be exceptionally vulnerable to clandestine diversion. Moreover, as with a reprocessing plant, a centrifuge facility could be seized and used to produce weapons material in a short time.

Advanced enrichment techniques could not be developed except by technically advanced countries. Barring an unforeseen breakthrough, commercial laser isotope separation (LIS) facilities will probably not be feasible for even advanced countries until the late 1980's or early 1990's, and then only if a number of very difficult problems are solved. The United States, U. S. S. R., and France, among others, are actively developing LIS technology. The proliferation potential for LIS and other advanced technologies stems from the high enrichment achieved per stage. Thus, it may be possible to produce weapons material in a very few steps. In addition, LIS facilities may be economical on a very small scale, making them attractive purchases for nations with small nuclear programs. The United States, by guaranteeing enrichment services at a low fee or at cost might slow down the spread of advanced enrichment technologies (see chapter VII, "Dedicated Facilities").

Issue 6

How Feasible Would it be to Use Commercial Nuclear Reactors as a Source of Weapons Material?

Findings

- The power reactors presently available for export (LWR and CANDU) do not involve material that could be used directly for nuclear explosives. A nation would also have to have a reprocessing or enrichment facility to use its nuclear system as a source of weapons material.

- Spent fuel from either reactor type does contain plutonium, which could be recovered in a small indigenously developed reprocessing plant. This opportunity can be decreased by fuel leasing or buy-back arrangements which prevent the long-term storage of spent fuel by Nth countries. This would restrict the availability of spent fuel to that in the reactor, the use of which would probably result in the loss of the reactor as a power source.

- Reactors and short-term spent-fuel storage facilities can be effectively safeguarded. Consequently, diversion from them would have to take the form of overt nationalization (i.e., seizure).

- The additional expertise a nation acquires in operating its own reactor would be useful should if decide to develop weapons.

Abandoning nuclear power would reduce, but not eliminate, the possibility of further weapons moliferation. Countries could still construct facilities dedicated to the production of weapons material or, alternatively, they might be able to purchase or steal either material or a finished weapon (see chapter VII).

Issue 7

Could a Nation Acquire Nuclear Weapons Without Diverting Fissile Material From Its Commercial Nuclear Power Facilities?

Findings

None of the countries which now have nuclear weapons diverted fissile material from their power facilities. They all built facilities specifically dedicated to the production or reprocessing of nuclear weapons material.

The only dedicated facility option open to a nation which is not technologically advanced is a small, natural uranium-fueled plutonium production reactor, producing about 10 kg of weapons-grade plutonium per year (enough for one or two explosives), and a small reprocessing plant. The total capital costs of these facilities would be several tens of millions of dollars. Such a facility might escape detection, especially if the nation were not considered to be among the five or six most likely Nth countries.

A technologically advanced nation would be able to build a dedicated facility to support a large weapons program, but it is unlikely that the existence of such a facility could be kept secret (see chapter VII, "Dedicated Facilities").

Issue 8

How Plausible is the Direct Acquisition of Fissile Material or Weapons by Purchase or Theft?

Findings

If plutonium becomes a commonly traded commodity, minimal intermittent black market transactions seem plausible, simply because the large amounts of material that could be circulating would be difficult to safeguard perfectly. Theft of existing weapons would be more probable if proliferation continues and security in the new nuclear states is lax. (See chapter VI.)

Issue 9

How Critical is Nuclear Power to Future Global Energy Requirements?

Findings

Projections of growth in global nuclear energy use have been repeatedly revised downwards in recent years. The lowest projections presently available are the most plausible. Nevertheless, many governments, especially in Europe and Japan, still feel that nuclear energy will be crucial to their well-being as global oil and gas reserves are depleted. Many developing countries are also counting heavily on nuclear energy. Coal, another major alternative to oil and gas, is abundant in some countries but fraught with environmental hazards. The economics of other resources (e.g., solar) are more speculative. Hence, nuclear power is likely to be a significant factor for at least the next few decades (see chapter X).

Issue 10

How Difficult Would It Be for a Nation To Construct a Nuclear Weapon?

Findings

Many nations are capable of designing and constructing nuclear explosives which could be confidently expected, even without nuclear testing, to have predictable and reliable yields up to 10 to 20 kilotons TNT equivalent (using UZSS, UZSS, or weapons-grade plutonium) or in the kiloton range (using reactor-grade plutonium).

A national effort to achieve the above objective would require a group of more than a dozen well-trained and very competent persons with experience in several fields of science and engineering. They would need a high explosive field-test facility and the support of a modest, already established, scientific, technical, and organizational infrastructure. If the program is properly executed, the objective might be attained approximately 2 years after the start of the program, at a cost of a few tens of millions of dollars. This estimate does not include the time and money to obtain the fissile material or to establish the infrastructure assumed above.

The success or failure of a national effort will depend more on the strengths and weaknesses of the particular people involved in the effort than on specifics of the technological base of the country (see chapter VI, "Nuclear Fission Explosive Weapons" for further details.)

Issue 11

Is a Non-State Adversary Group Likely To Turn to Nuclear Means of Extortion or Violence?

Findings

There is no evidence that any non-state group has ever made any attempt to acquire weapons material for use in a nuclear explosive. The incidents that have occurred to date involving nuclear material or facilities have mostly been low-level incidents of vandalism or sabotage. However, the present record of nuclear incidents was assembled in an era when nuclear reactors were relatively few. The expansion of nuclear power, the advent of plutonium recycle, and trends towards increased violence could lead non-state adversaries to attempt large-scale nuclear threats or violence.

Non-state adversary groups have not yet gone to the limits of their ability to cause harm by non-nuclear means. Historical analysis of adversary tactics suggests reasons for this restraint. However, non-state adversaries, particularly terrorists or revolutionaries, may not behave in the future as they have in the past. The psychological impact of the threat or use of nuclear weapons would be enormous, and an adversary group may decide to attempt to exploit this leverage.

The entire subject of adversary actions involving massive threats or destruction has apparently just started to receive systematic study. When considering if non-state adversary groups will turn to massive extortion or violence, all routes to the same end--conventional explosives, other chemicals, nuclear and biological agents-should be considered. (See chapter V.)

Issue 12

How Difficult Would it be for a Non-State Adversary Group To Acquire Nuclear Material for a Nuclear Explosive Device?

Findings

It would be extremely difficult, verging on impossible, for a non-state adversary group to convert material diverted from LWR or CANDU fuel cycles to explosive's material, unless the spent fuel is commercially reprocessed to recover and recycle the plutonium.

In the LWR with plutonium recycle as presently planned, material suitable for nuclear explosives or easily convertible to weapons-useable material will be found at the reprocessing plant, in transit between the reprocessing plant and the fuel fabrication plant, and at the input area of the fuel fabrication plant. There are technologies and configurations (coprecipitation and collocation) under consideration that could eliminate most opportunities for the diversion of material easily converted to weapons material.

In the United States at present, the NRC is reportedly in the process of upgrading security at licensees handling plutonium or highly enriched uranium, requiring them to meet a threat of two or more insiders in collusion with several heavily armed attakers from the outside. Present safeguards and physical security may place undue reliance on one element of physical security-armed guards. It is not clear how well presently designed safeguards system can handle the problem of several insiders acting in collusion, or outsiders attacking with guile and deception rather than straightforward armed assault.

Some observers have also expressed doubts about the effectiveness of guard forces in handling diversion attempts, partly because of the questionable status of their exact legal powers. The subject of a Federal security force to protect plutonium and highly enriched uranium should be reopened, especially in view of the increased threat levels licensees are being required to meet.

Both ERDA and NRC have very promising safeguards programs in the development stage, but their ultimate effectiveness cannot be assessed at this time.

A vital point to note is that non-state adversaries are highly mobile, and capable of finding and attacking the weakest targets. No nation, however invulnerable its own facilities, can feel secure against non-state adversary nuclear threats and violence unless all facilities handling weapons-grade material worldwide are equally well protected. Physical security is generally left to the discretion of the individual nation, although supplier states are insisting on a minimum level as a condition for export. The International Atomic Energy Agency has no physical security enforcement powers, (see chapters V and VIII).

Issue 13

Could a Non-State Adversary Design and Construct Its Own Nuclear Explosive?

Findings

Given the weapons material and a fraction of a million dollars, a small group of people, none of whom have ever had access to the classified literature, could possibly design and build a crude nuclear explosive device. The group would have to include, at a minimum, a person capable of searching and understanding the technical literature in several fields, and a jack-of-all-trades technician. They would probably not be able to develop an accurate prediction of the yield of their device, and it could be a total failure because of either faulty design or faulty construction. If a member of the group is careless or incompetent, he might suffer serious or fatal injury. However, there is a clear possibility that a clever and competent group could design and construct a device which would produce a significant nuclear yield (see chapter VI “Nuclear Fission Explosive Weapons” for details).

Issue 14

What Are the Civil Liberties Implications of Safeguarding Nuclear Power, in Particular, Plutonium Recycle?

Findings

The civil liberties implications of safeguards turn on the scope of a security clearance program, the standards and procedures used in employee clearance, the scope and intrusiveness of domestic intelligence activities, and the nature of a recovery effort should a diversion occur.

There is disagreement among experts as to whether a safeguards program can be adequate for security without fundamentally infringing upon civil liberties. One position believes adequate safeguards will necessarily violate basic liberties for employees and political dissidents. A second position treats safeguards as an acceptable extension of existing clearance programs and blackmail threat responses in other fields of high security. A third position believes safeguards could be installed without doing serious damage to civil liberties, but only if a "least intrusive measures" approach is adopted and a zero-risk goal is rejected.

Although a safeguards system that would be extremely respectful of civil liberties can be designed, three potential dangers exist:

1. A gradual erosion of civil liberties as the safeguards system is "strengthened,"
2. A shunting aside of civil liberties during a recovery operation if weapons material were diverted and a convincing threat received; and
3. A public demand for Draconian safeguards in the future, even at the expense of civil liberties, if a diversion followed by a convincing threat or an actual act of destruction occurred.

Measures can be envisaged that would reduce the probability of the above three occurrences. Continued public monitoring of safeguards systems for civil liberties infractions, new technologies or configurations (e.g., coprecipitation or collocation), and response planning integrated at the local, State, regional, and Federal levels with authority clearly delineated could reduce the probability of civil liberties infractions in a strong safeguards system.

The Control

Issue 15

What is the Outlook for Control of Proliferation?

Findings

It is not too late to contain proliferation at a level which can be assimilated by the international political system. However, there are no single or all-purpose solutions; no short cuts, A viable nonproliferation policy will require the coordinated, planned use of a wide variety of measures: (a) political, economic, institutional, technological; (b) unilateral, bilateral, multilateral, international; and (c) executive and legislative.

Components of a nonproliferation policy would include: (a) Steps designed to tip the balance of political incentives and disincentives regarding the acquisition of weapons in favor of disincentives; (b) A comprehensive safeguards regime to prevent the diversion of nuclear material from civilian energy programs to weapons use; (c) Controls over exports, particularly with regard to enrichment and reprocessing capabilities, in conjunction with arrangements for the return of spent fuel to the supplier or any international repository; (d) A broad range of domestic and foreign policy supporting actions, including steps to upgrade physical security measures to prevent theft of nuclear materials, expansion of reactor-grade uranium production to obviate the need for reprocessing, and arms control negotiations; and (e) Steps to assure that other countries can meet their energy requirements without resorting to enrichment and / or reprocessing national facilities.

Moreover, because each Nth country is to some degree unique, policy must be tailored to fit particular national circumstances. This is especially true because of the potential for serious conflict between nonproliferation and other foreign policy objectives. The nature and severity of that conflict will vary from one Nth country to another, a fact which policy must take carefully into account, (Chapters 111 and IV.)

Issue 16

What Influence Can the United States Exert Upon Potential Weapons States?

Findings

In the long run two general rules apply: (a) Solutions to the proliferation problem will have to be found primarily, though not exclusively, through multilateral actions, and (b) The extent of U.S. influence will vary from country to country.

As American preeminence in the international market for nuclear fuel, facilities, and technology has been allowed to erode, the ability of the United States to unilaterally determine the ground rules of international nuclear cooperation has diminished. With the entrance of other suppliers into the market, importers have the option to turn to non-U.S. sources. If the United States were to remove itself from the global market entirely, other suppliers could quickly replace the withdrawn capacity. As a consequence American actions will tend to be most effective in a multilateral context—particularly in conjunction with other suppliers. The effectiveness of this approach has been demonstrated in the negotiations which led to the NPT, and more recently in the Suppliers' Conference.

There remains, however, significant scope for the unilateral assertion of U.S. influence—both in terms of positive inducements and negative sanctions. The recent successful U.S. effort inducing South Korea to abandon plans for purchasing a French reprocessing facility is an instance of the effective use of unilateral influence. Some of the more obvious levers available to Washington include:

- security guarantees;
- assistance to civilian nuclear energy programs;
- foreign economic aid (including U.S. influence in international lending institutions);
- military assistance programs;
- political pressures and diplomatic persuasion;
- mediation of international disputes with proliferation implications;
- controls on the export of sensitive nuclear technology;
- assistance concerning non-nuclear energy sources; and
- domestic policy initiatives (e.g., concerning reprocessing) which might enhance the credibility of U.S. efforts to persuade other countries to take similar steps.

The single most effective instrument of U.S. influence would be the capability to guarantee adequate low-enriched uranium exports to meet the needs of overseas users while, at the same time, providing for the collection and return of spent fuel.

An effective effort to assert U.S. influence will combine the carrot and the stick, with principal reliance on the former for the longer term. Such an effort wiIl also take into account the wide variation in leverage available to Washington when dealing with one Nth country or another. Thus U.S. influence with nations dependent upon American military or economic assistance (e.g., South Korea) is very substantial but where such dependence is lacking (e.g., Argentina) U.S. influence declines.

Issue 17

What Influence Can the United States Exert Upon Other Supplier States?

Findings

Efforts by the United States inducing other supplier states to pursue policies supportive of nonproliferation will generally be most effective if they are formulated in a multilateral context and emphasize positive inducements. Possible measures include:

- political-diplomatic persuasion (e.g., the Suppliers' Conference),
- tie-in agreements guaranteeing U.S. enrichment services at nondiscriminatory prices to reactor customers of other suppliers,
- joint-venture enrichment and/or reprocessing facilities,
- market sharing agreements,
- multinational enrichment and/or reprocessing facilities,
- international fuel storage repositories, and
- a multilateral study of alternatives to reprocessing.

The problem of reprocessing is extremely difficult for two reasons. First, other supplier states (such as Germany) have already made a basic national decision in favor of reprocessing and the breeder. They regard this policy as a vital element in their efforts to assure" adequate energy in the future. European breeder

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technology is the most advanced in the world. Second, other major suppliers are also America's principal allies and trading partners. The linkages of mutual interest and dependence are so extensive as to render most attempts to apply coercive pressures self-damaging. Consequently, U.S. efforts to obtain a global moratorium on reprocessing will encounter stiff European and Japanese resistance. The one area where agreement is demonstratively possible concerns control on exports of reprocessing facilities.

Issue 18

How Effective Are International Atomic Energy Agency Safeguards?

Findings

(a) Safeguards for reactors can be very effective. Nuclear material is contained in a relatively small number of discrete items, the fuel elements. Exact item accountability can be accomplished without great difficulty.

(b) Safeguards procedures for reprocessing plants, enrichment plants, and other fuel-cycle facilities which handle very large flows of nuclear material are in the experimental stage. It will be difficult to detect significant diversion of uranium or plutonium using nuclear material accountancy alone, even if the most advanced analytical techniques and accountancy methods are used. The task is further complicated by restrictions on IAEA inspection effort, inspector access, and the full use of IAEA surveillance devices.

(c) Containment and surveillance must play a key role in safeguards and must be regarded as more than supplementary to materials accountancy. Effective safeguards systems for enrichment and reprocessing plants will have to include the most advanced online monitoring and real-time accounting systems as well as highly reliable, instantaneously reporting, tamper-indicating surveillance equipment.

(d) A credible safeguards system provides a significant deterrent to diversion, by both increasing the chances of detection and establishing standards of legal behavior that buttress the position of political groups opposed to proliferation.

(e) No safeguards system can prevent an overt national seizure of a facility and its operation for weapons purposes.

Issue 19

Are Multinational Fuel-Cycle Facilities (MFCFS), on Balance, a Useful Approach for the Control of Proliferation?

Findings

The primary intent of MFCFS is to remove sensitive facilities (particularly enrichment and reprocessing) from national control. A part owner/operator of such a facility will find it much harder to tamper with equipment for purposes of diversion or to seize the plant outright even if on its own territory. It also offers economies of scale to nations with only a few reactors and improved security against nonstate adversary actions.

A great many political, economic, and institutional questions must be resolved before the concept can be considered viable. Member nations may not find acceptable sites in other members' territory. Another problem is the possibility that membership in a sensitive facility could provide sufficient access to the technology for members to recreate it indigenously. Thus MFCFS could spread the very problem they are intended to prevent.

Issue 20

Are Sanctions a Useful Instrument of Nonproliferation Policy Toward Nth Countries?

Findings

Provisions for modest sanctions (e.g., the cutoff of nuclear assistance) already are contained in U.S. and IAEA nuclear agreements with nonweapons states, and a variety of stronger sanctions can be postulated. To be most effective, sanctions should be applied jointly or multilaterally rather than unilaterally. Threats should be accompanied by inducements and rewards designed to relieve the pressures toward proliferation. A sophisticated approach will also combine automatic with more discretionary and flexible sanctions,

Depending upon the prospective proliferator, a significant degree of vulnerability to one or more of the available levers is likely to be present. In cases such as Taiwan, where the Nth country is dependent on the United States for security support as well as nuclear imports, the scope for the imposition of unilateral U.S. sanctions is substantial. In other cases, such as that of Brazil, resort to sanctions could probably prove futile. Sanctions could be more effective in all cases as an instrument to prevent proliferation than as a means to punish or "roll back" proliferation after it has occured. The most effective channel for imposition of unilateral sanctions will probably be the Suppliers' Conference. Because user states comprise a majority of IAEA membership, there are serious questions as to whether the agency could muster the political will to impose sanctions on a recipient—particularly if the circumstances surrounding the alleged violation are at all ambiguous.

Issue 21

Would an Arms-Reduction Agreement by Present Nuclear States Significantly Strengthen the International Norm Against Proliferation?

Findings

A meaningful multilateral arms reduction by the nuclear weapons states would demonstrate a commitment to the objective of nonproliferation and, in particular, to the Non-Proliferation Treaty, The extent of the impact of this demonstration is not clear, but the public stance of some of the non-weapons states indicates that it could be substantial. A corollary benefit might be a reduction in the prestige attached to nuclear weapons.

Issue 22

To What Extent Can Improvements in Technology Help Contain or Limit Further Proliferation?

Findings

There is no technological fix that can eliminate the problem of proliferation, but concepts under development could, if successful, make diversion from commercial facilities much more difficult or even close to impossible.

One of the most promising medium-term approaches is the nonproliferating reactor. This concept is a fundamental y new approach both to reactor design and to nonproliferation. By incorporating nonproliferation requirements into the design of the reactor, the diversion routes which are present in current and projected power reactor systems could be largely eliminated. This approach deserves a thorough assessment and open-minded comparison with other alternatives to determine if it should be funded at an expanded scale.

Less radical changes are alternate fuel cycles (thorium) and modifications to present fuel cycles (e.g., coprecipitation and tandem cycles). New approaches are also being developed in safeguards technology. Integrating safeguards systems into facility designs would considerably strengthen safeguards effectiveness. Greater R&D emphasis on nonnuclear energy sources, especially those most appropriate for developing countries, could reduce the dependence on nuclear power and postpone or even eliminate the eventual need to move to more sensitive systems (such as fast breeders).

Issue 23

Can the Non-Proliferation Treaty (NPT) Play a Useful Role in Containing Proliferation?

Findings

The NPT has important weaknesses. It lacks universal adherence and a party can, under some conditions, legally withdraw with only 3 months notice. Nonparties to the treaty include a number of the strongest candidates for the acquisition of nuclear weapons. Moreover, the sanctions provided for in the treaty are not particularly impressive and there is a serious question whether even they could be enforced in the event of a violation.

Nevertheless, the NPT remains a key component of an effective nonproliferation policy. The fact that there have been no known violations of the treaty suggests that it acts as an important constraint upon Nth countries. It embodies a basic international consensus that proliferation poses a serious threat to global well-being and should be contained. It also provides an agreed framework of mutual rights and obligations constituting a fundamental bargain between supplier and user states. As such, it sets forth a standard by which to measure and perhaps influence the behavior of states. For example, the NPT may provide some of the impetus behind current efforts by the superpowers to negotiate a new arms control agreement.

Two additional features of the NPT give it particular significance. First, by allowing the IAEA to impose safeguards on their domestic nuclear programs, the nonweapon parties to the treaty relinquish a significant measure of their sovereignty. This establishes an important principle upon which to build stronger international arrangements for controlling proliferation. Second, in addition to providing a statement of principles and objectives, the NPT encompasses an institutional mechanism (IAEA) for their implementation. The NPT is more than a treaty: it is an ongoing program. (Chapters 111 and VIII "International Control of Proliferation.")

Issue 24

What Issues Require Priority Attention, i.e., What Developments Threaten to Foreclose Future Options?

Findings

The following subject areas require immediate consideration by policy makers and legislators if the course of proliferation is not to be determined by default.

- Domestic (U. S.) reprocessing.
- US. enrichment capacity.
- Upgrading of supplier (export) controls.
- Sanctions and inducements to be applied to Nth countries.
- Research and development priorities (LMFBR vs. other breeders and nonnuclear sources).

NUCLEAR TECHNOLOGY DESCRIPTION

Strong forces bind together the basic particles—protons and neutrons-that constitute the nucleus of the atom. Some of this binding energy is released when a neutron strikes a heavy nucleus and causes it to split, or fission, into two lighter elements plus more neutrons. The total mass of the products is slightly less than that of the original nucleus, This mass difference is converted into energy according to the relationship E=mc2. The neutrons may, in turn, initiate other fissions, (Neutrons that have been slowed down by a moderator such as water or graphite are more likely to cause fissions.) Thus, a *chain reaction* can begin. In a nuclear reactor, the chain reaction is *controlled* to be just self-sustaining, with one of the extra neutrons, on the average, initiating a new fission. In a nuclear explosive, the chain reaction is carried on by fast neutrons in a multiplicative and uncontrolled mode. These different conditions-sustaining or multiplicative-depend on a number of parameters, including the quantity, chemical form, concentration, and geometrical arrangement of the *fissile* material and the amount, properties, and arrangement of the nonfissile material which is present.

Most materials, even when in pure chemical element form, contain a mixture of *isotopes*-atoms of the same element that have different numbers of neutrons in their nuclei and hence different masses.] Only a relatively few isotopes are fissile, and, in fact, only one fissile isotope occurs in nature—uranium-235, or, as it is usually written, U^{235}. Two other fissile isotopes are important in any discussion of nuclear power—uranium-233 (U^{233}) and plutonium-239 (Pu^{239}). These isotopes do not occur in nature, but are bred when the *fertile* nuclei U^{238} and thorium-232 (Th^{232}) absorb neutrons to become U^{239} and Th^{233}, and then undergo two successive radioactive decays to Pu^{239} and U^{233}.

The power reactors in common use today use uranium as fuel; the fissile concentration is well below that necessary for a nuclear explosive. Specifically, it is impossible, not merely impractical, to use a light water reactor (LWR) or a Canadian CANDU reactor uranium fuel in a nuclear fission explosive without an expensive and technologically advanced enrichment facility. (See chapter VII for further discussion of this point.)

Uranium fuel goes through many operations both before and after its use in the reactor. These operations constitute the nuclear fuel cycle. Figure 11-1 shows the fuel cycle for the most common reactor, the light water reactor (LWR).

From the mine, the uranium ore is sent to a mill where uranium is recovered from the ore in the form of an oxide. The next step, after conversion of the oxide to uranium hexafluoride, is *enrichment*. At the enrichment plant, the concentration of U^{235} is increased from the naturally occuring value of 0.7 percent to about 3 percent. Most present-day enrichment plants use the gas *diffusion* process, but most new plants in the construction and planning stage will use the gas *centrifuge* method. After enrichment, the uranium goes to a fuel fabrication plant to be formed into fuel elements which will be combined into fuel assemblies and inserted into the reactor.

[1]Isotopes are specified by the total number of neutrons and protons they contain and a symbol indicating the chemical elements. For instance, the isotope with 92 protons and 143 neutrons is uranium - 235, or, as it is usually written, U^{235}.

After the fuel has been in the reactor for a time (typically several years), it contains too little uranium-235 and too many neutron-absorbing (and radioactive) fission products to be useful. The fuel is then removed and placed into pools of water for cooling. In an LWR, the *spent fuel* does not have to be reused, but it still has about 0.9 percent uranium-235, a higher concentration than occurs in nature, plus about 0.5 percent plutonium-239 which is bred from the abundant uranium-238. If it is deemed economical and desirable to recover the unused fissile material, the spent fuel will be sent to a *reprocessing plant*. There, the uranium and plutonium are chemically separated from waste products and (under present plans) from each other. The uranium may be reenriched while the plutonium is sent directly to a fuel fabrication plant, The plutonium is then mixed with uranium (both uranium and plutonium being in oxide form), to form *mixed oxide fuel.*

The fuel cycle for other reactors may differ in the necessity for, and nature of, the various stages in the light-water reactor fuel cycle just described, For example, the Canadian CANDU reactor uses natural uranium, and recovery of plutonium from its spent fuel is not at present economical. Hence, the CANDU fuel cycle excludes both the enrichment and reprocessing steps.

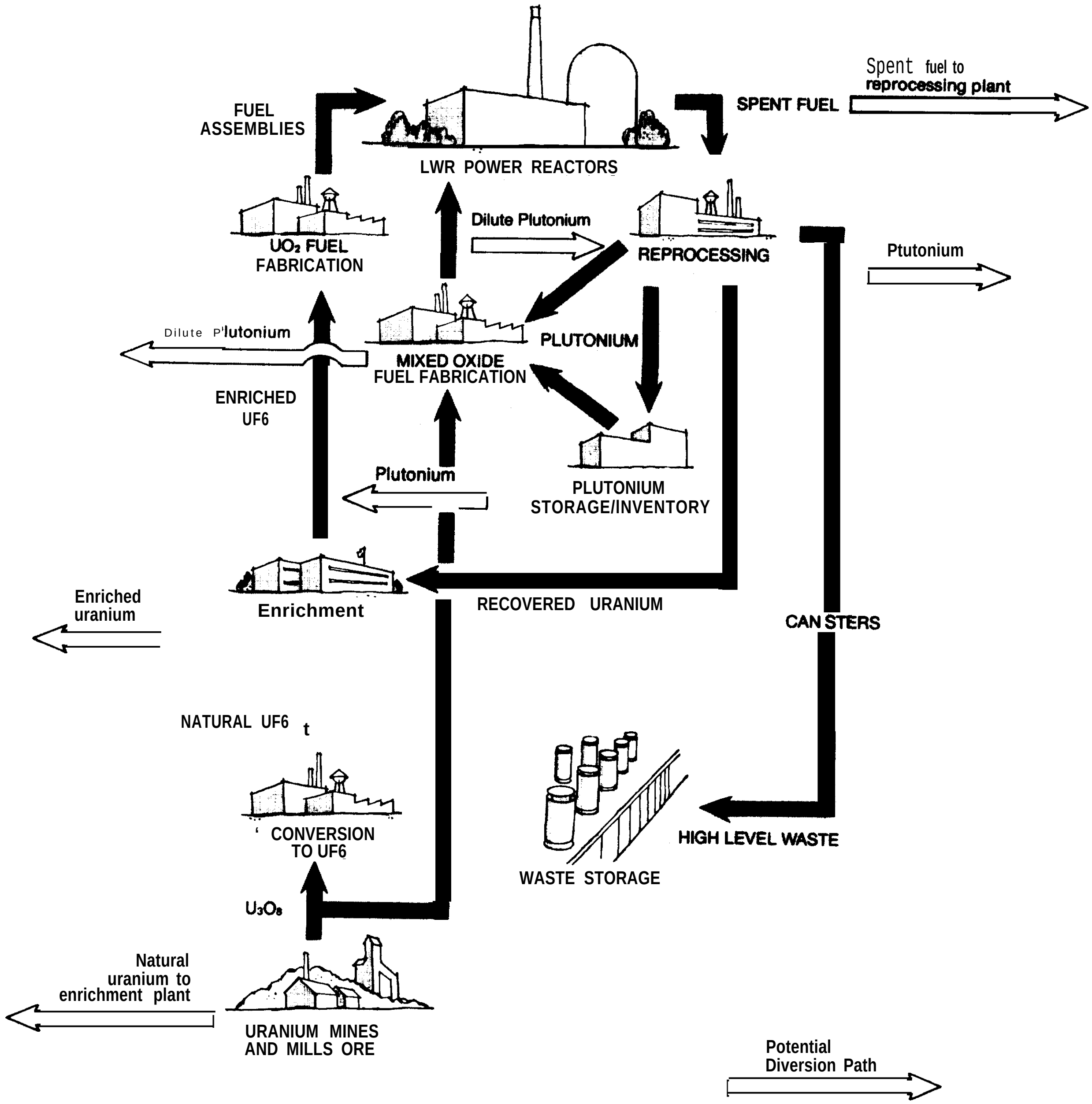
A future reactor concept is the breeder, a reactor that would create more new fissile fuel than it burns to produce power. Most development work has concentrated on the liquid metal fast breeder reactor, (LMFBR) which will yield enough plutonium to refuel itself and excess plutonium to contribute to the fueling of new reactors. The breeder fuel cycle would eliminate the enrichment step but absolutely requires the reprocessing step.

All the reactors mentioned so far use uranium as a fuel, with fissile uranium–235 to produce power and with fertile uranium–238 to breed another fissile isotope, plutonium–239. Another fuel cycle may be based on the element thorium, The isotope thorium–232 is fertile and breeds fissile uranium–233.

In most of the fuel cycle for commercial nuclear power reactors, the concentration of

Figure 11-1.

Light-Water Reactor Fuel Cycle



SOURCE: OTA

fissile fuel is low. By contrast, the concentration of fissile material in a nuclear weapon is quite high—typically pure plutonium, or uranium enriched to about 90 percent in the isotope uranium–235. (See chapter VI for a discussion of the minimum concentration of fissile material that can be used to construct a nuclear explosive of practical weight.) The object in designing a weapon is to initiate a chain reaction that will cause a large number of nuclei to fission in a very short period of time. This condition will be obtained only if a certain minimal amount of nuclear material called the critical mass is present. With less than this quantity, an explosion will never occur. No specific number can be assigned to the critical mass—it varies with a number of parameters, including, for example, the particular fissile isotope and its concentration and chemical form. A nuclear weapon initially contains one or more subcritical masses of fissile material. Detonation of the weapon requires a means of rapidly moving the subcritical mass or masses into a condition of supercriticality sufficient to produce a significant nuclear yield before it blows itself apart.

There are two basic methods of assembling the fissile material in a nuclear weapon. The first is to shoot two (or more) subcritical masses into each other. This is a *gun-type weapon.* The second is to surround a subcritical configuration of fissile material with high explosives and use them to compress the material into a supercritical mass. Such a device is called an *implosion weapon.*

Note that the highly concentrated fissile material required for weapons is exposed at only one portion of the nuclear fuel cycle described above-at the reprocessing and fuel fabrication plants and the transportation link between the two. These areas are thus the most vulnerable to the diversion of nuclear material from a power program to a weapons program. However, there are other possible crossovers between peaceful and destructive *uses* of nuclear energy that are not that direct and obvious as described in chapter VII.

EXECUTIVE SUMMARY

Incentives and Disincentives

As the technological and economic barriers to proliferation have diminished, the decision whether or not to acquire nuclear weapons has become principally political. It will hinge on a complex balance of incentives and disincentives which, though unique for each country, exhibit sufficient similarities to permit generalization.

General incentives that might lead a government to select the nuclear weapons option include the following:

1) Deterrence.—Several states on every list of potential new nuclear weapons states (Nth countries) have reason to fear direct attack or long-term deterioration of their security vis-a - vis neighbors or regional adversaries.

2) Increased International Status.—As a symbol of modernity and technological competence, nuclear weapons are often viewed as a source of status, prestige, and respect. Aside from its symbolic significance, a nuclear weapon capability will augment national military and political power in real terms,

3) Domestic Political Requirements.—Nuclear weapons may bolster a government's domestic political support for many of the same reasons they can enhance a nation's international reputation. The Indian detonation may have been motivated in large part by such considerations.

4) Increased Strategic Autonomy .—Even if it is already protected by an alliance, a nation may feel it has more options to pursue national objectives as a nuclear state than as a non-nuclear state. France is an example of this reasoning.

5) Strategic Hedge Against Military and Political Uncertainty.—Uncertainty about the reliability of allies and the intentions and capabilities of adversaries may make nuclear weapons attractive,

6) Possession of "A Weapon of Last Resort." —Nuclear weapons may be perceived

by a state such as Israel as offering an ultimate guarantee against extinction.

7) Leverage Over the Industrialized Countries.—Certain developing countries may conclude that acquiring nuclear weapons is a means of compelling the advanced nations to take more serious account of the interests of the less developed.

General disincentives that might discourage a state from acquiring nuclear weapons include the following:

1) Resource Diversion.—It is argued that a nuclear weapons program is not an optimal use of limited national resources, and that the loss of the opportunity to pursue economic or social programs outweighs the benefits of a nuclear weapons program.

2) Adverse Public Opinion.—In a number of countries (e.g., Japan) prevailing public opinion appears to oppose development of nuclear weapons,

3) Disruption of Established Security Guarantees.—Reliance on security guarantees constitutes one of the most important elements in many countries' strategy for coping with adversaries. If the acquisition of nuclear weapons jeopardizes that guarantee, the effect may be counterproductive in terms of national security.

4) Infeasibility of a Desired Nuclear Strategy.—The nation may be unable to attain the desired nuclear capability in an appropriate time frame, or because of a lack of resources.

5) Adverse International Reactions.—Anticipation of censure from the international community (including the superpowers) would constitute a significant disincentive.

6) Adverse Reactions by Adversaries.—Proliferation may stimulate an adversary to take a variety of measures, including the acquisition of a countervailing nuclear force.

7) Advocacy of Neutralist Aims.-Countries like Sweden and Switzerland eschew a nuclear weapons capability, in part because it would be perceived as degrading their arms control and neutralist positions.

A review of the existing nuclear weapons states suggests that the desire to maintain or enhance the nation's security and international influence were the primary incentives behind their original weapons programs. Economic disincentives, even for less developed nations such as China and India, were not compelling, Similarly, for Nth countries, security and political influence are the dominant incentives. Thus far, however, these have been offset by disincentives, notably concern about adversary responses, the economic costs of diverting resources to weapons development, and possible alienation of the superpowers with a resulting loss of nuclear and economic development assistance.

The Non-State Adversary

Subnational groups might be as interested as nations in obtaining nuclear weapons. Potential nuclear non-state adversaries span a wide spectrum, from the isolated lunatic, to the criminal, to the organized revolutionary group. The actions they might conceivably undertake range from hoaxes to the construction and detonation of a crude nuclear explosive device. Strictly speaking, token acts of violence do not constitute nuclear adversary actions, although it is useful to study such occurrences for indications of trends towards more serious acts.

Concern about the potential nuclear non-state adversary has continued to grow since the late 1960's, although incidents involving nuclear material or facilities that have occurred so far have been mostly low level acts of vandalism or sabotage. There is no evidence that any non-state group has attempted to acquire weapons material for use in a nuclear explosive.

However, the lack of serious malevolent nuclear actions is not a cause for complacency about the future. The expansion of nuclear power, the advent of plutonium recycle, and trends towards increased violence could lead non-state adversaries to attempt large-scale nuclear threats or violence.

Terrorist groups might decide to use nuclear means to cause widespread damage or kill large numbers of people, but so far terrorists have not even gone to the limit of their non-nuclear capability to destroy and kill. On the basis of the historical record and the theory of terrorism, it is not clear that causing massive casualties is attractive to terrorists; indeed it could even be regarded as counterproductive. Therefore, some experts have argued that mass murder will probably not be contemplated by terrorist groups capable of making elementary political judgments.

Several factors could cause terrorists to break the previous patterns. A desperate insurgent group might decide to strike one catastrophic blow, Nihilist groups may emerge, whose goals would be well served by pure massive destruction. On the other hand, the primary attraction for terrorists to go nuclear may not be to cause mass casualties. Almost any nuclear action by terrorists would cause great alarm, attract widespread attention, and possibly win concessions.

Whether organized crime should be counted among likely nuclear non-state adversaries remains a matter of debate, centering around its interest in doing so rather than its capability to undertake nuclear actions. The acquisition of a nuclear capability of its own, however, would mean that organized crime had decided to defy the nation in which its normal and highly profitable activities take place. It is easier to imagine organized crime playing a middleman role in a nuclear materials black market. Some observers have argued that organized crime would steer clear even of supplying nuclear material for nuclear weapons, because this activity might evoke a level of response that would jeopardize all their activities.

Some perpetrators of nuclear hoaxes have manifested desires of becoming nuclear non-state adversaries, but none have demonstrated the required capabilities. If hoaxers did have access to nuclear material, it is not clear that they would escalate from hoax to action.

Psychotics have probably been responsible for many of the low-level nuclear incidents and hoaxes that have occurred so far. Psychotics have also been the perpetrators of many known schemes of mass murder. Thus, in terms of intention alone, some psychotics are potential nuclear non-state adversaries. In terms of capability they probably rank lowest of all the categories of potential non-state adversaries. However, there are some brilliant psychotics who have technical knowledge and skill. If such an individual had the will to cause mass destruction and had access to nuclear material, he would constitute a formidable adversary.

Whether any of the current potential non-state adversaries will decide to go nuclear cannot be answered at this time. There is a vast area of uncertainty between what can be done and what will be done. This area could be reduced if analysts had a better understanding of how potential adversaries themselves perceive the usefulness of nuclear actions. Moreover, in the case of terrorists, there is at present no clear understanding of how they could exploit a nuclear action or threat to effect an irreversible political gain of magnitude comparable to the action or threat.

The nuclear non-state adversary might not arise from those groups currently identified as potential nuclear adversaries. International terrorists are a new entity that emerged in the past decade. It is difficult to say what new entities may emerge in the coming decade. It is disquieting to realize that most new terrorist groups have not been detected prior to their first terrorist act.

Among current adversaries, new tactics may be invented to effectively exploit the leverage that a nuclear capability would give. If an individual or a group did successfully carry out a scheme of nuclear extortion or violence, other individuals or groups would probably try to imitate their act.

Moreover, the growth of a transnational terrorist network over the past several years means that no nation, however invulnerable its own nuclear facilities, can regard itself as invulnerable to nuclear non-state adversary action.

Civil Liberties Implication of Safeguards

Whether a safeguards program to protect special nuclear material in a plutonium industry would jeopardize civil liberties has been a growing topic in the plutonium recycle debate. The concern is not only to protect rights of privacy, free expression, and fair procedure for employees of a plutonium recycle industry, but also to ensure that residents of nearby communities, political critics, and society at large are not subjected to unacceptable levels of surveillance in order to prevent diversion attempts, or to even more harsh and intrusive techniques if recovery of diverted material had to be undertaken. Judgments on what safeguards measures would be reasonably required and what their civil liberties implications would be is, in the first instance, a matter of public policy for elected officials and the public, and only later an issue that might produce judgments of constitutionality or interpretive modifications from the courts.

Concern over the civil liberties implications of plutonium recycle first arose when projections of the size of the industry were much higher than they are now. It now appears that only about 20,000 employees will be required to have clearances for work in the fuel cycle. Transportation of pure plutonium could possibly be eliminated by arrangements such as collocation or coprocessing. Both lowered growth and potential technological innovations affect perceptions of civil liberties problems.

It is generally accepted that protecting plutonium facilities from diversion efforts would represent a genuine security need, that there is no way to structure an adequate safeguards program that would not actually or potentially have some civil liberties impact, and that there is no way for society to eliminate all the motivations under which terrorists or deranged persons might try to divert plutonium for their purposes. As a result, safeguard measures of the kind used in other high-security contexts would have to be applied here.

Such safeguards fall into four categories: employee screening, material protection, threat analysis, and recovery measures. In each, there are possible techniques ranging from those raising minimal threats to civil liberties to those that, if used, would raise far more serious questions,

The debates over what safeguards would be needed and how these would affect civil liberties has produced three main positions:

Position One maintains that a plutonium economy would require such extensive security safeguards and have such high impact on civil liberties that basic freedoms would be jeopardized. It assumes that Congress and the public would insist upon a rigorous, virtually zero-risk program, especially if actual incidents heightened concern. Furthermore, preventive intelligence programs would inevitably be expanded to cover anti-nuclear groups and protest movements and lead to a rise in surveillance, databanks, and infiltration of dissenters, not just terrorists. Finally, should there be a successful diversion and blackmail threat, sweeping incursions of personal and press freedoms would take place. To avoid creating risks of such dangers, and because it is believed there are alternative ways of conserving and securing energy that do not raise comparable threats to civil liberties, advocates of this position call for a rejection of plutonium recycle in the United States on civil liberties grounds.

Position Two maintains that safeguards can be adopted that would be both effective for security purposes and acceptable in terms of civil liberties, just as other high-security activities are now safeguarded. Believing that plutonium is a necessary and safe energy source, the notion is rejected that threats from a handful of terrorists or deranged persons should force this nation to forgo plutonium recycle. Because persons working in this industry would do so voluntarily, there would be nothing improper in using techniques such as personnel clearances or on-the-job surveillance. Diversion and bomb threats should be treated with the same professional skills that would be used for other terrorists threats, whether with chemical, biological, or nuclear material or in hostage situations. Preventive intelligence activities would be put under clear legislative guidelines and supervisory checks. Position Two concludes that plutonium recycle should be allowed to proceed and that continually improved safeguards systems should be developed as the industry grows.

Position Three would also go ahead with plutonium recycle but only if the philosophy of a safeguards program were that some small risks of diversion would be accepted in order to avoid major risks to civil liberties. They would limit safeguards measures to those meeting specific criteria of effectiveness, limitation, and capacity for control against abuse. A least intrusive measure standard would be followed. This position would require such standards to be developed in public proceedings, written into legislation, monitored by independent review, and regularly audited.

These sets of assumptions and judgments could be significantly affected by alterations in a plutonium system or in safeguards options. Transportation risks might be reduced if the policy of collocating reprocessing and fuel fabrication plants were adopted. Coprecipitation of plutonium and uranium at the reprocessing plant would also eliminate the transport of pure plutonium. Such measures, coupled with the use of hardened facilities, could reduce the pressures to use intrusive preventive intelligence measures.

However, some observers believe that the fundamental civil liberties problems would still remain, especially in a recovery operation.

These three approaches on civil liberties not only rest on sociopolitical judgments about liberty and security but also mirror the main positions on plutonium recycle in terms of safety and economy. Thus, the civil liberties aspect is one portion—though a very important part-of the total judgment about plutonium recycle. If plutonium recycle does go forward, a most important task will be the close and steady monitoring of the safeguards program to keep it consistent with United States civil liberties.

Nuclear Weapons

Assuming that a nation or a non-national group had the will to design and construct a nuclear weapon, would it also have the ability? This chapter examines the manpower, time, money, and equipment necessary to design and construct the explosive, assuming that enough fissile material had been obtained by one of the routes discussed in chapter VII.

These requirements depend upon the complexity of the nuclear weapon. An assessment of the minimal program necessary to produce a nuclear weapon is of special relevance to nuclear proliferation. This chapter will examine only relatively small weapons development programs and thus will consider only low technology designs, i.e., equivalent to 1945 U.S. technology.

A minimal *national* program is an effort to produce, *without nuclear testing,* a first weapon which is very *confidently* expected to have a *substantial nuclear yield,* This program will call for a group of more than a dozen well-trained and competent persons with experience in several fields of science and engineering. They would need a high explosive field test facility and the support of a modest, already established, scientific, technical, and organizational infrastructure.

If these requirements are met and the program is properly executed the objective might be attained approximately 2 years after the start of the program, at a cost of a few tens of millions of dollars. This estimate does not include the time and money to obtain the fissile material or to establish the infrastructure assumed above.

Some details of the effort would depend on which of the two general types of weapons—gun or implosion—were built. Contrary to common belief, the construction of a gun-assembly weapon presents difficulties roughly equivalent to those of an implosion weapon.

The success or failure of producing a militarily effective nuclear explosive, via the effort described above, is far more dependent on the competence of the people involved than on the technological problems themselves. In trying to evaluate the potential of a specific nuclear weapons development program a detailed knowledge of the strengths and weaknesses of the personnel is more valuable than details of the technological base of the country. However, some general statements can be made about what it is possible to achieve with the national effort described above.

The material for a nuclear weapon might be plutonium, or uranium with a high concentration of either one of two uranium isotopes—U^{233} or U^{235}. Using either form of uranium or weapons-grade plutonium it is possible to design low-technology devices that would reliably produce explosive yields up to the equivalent of 10 or 20 kilotons of TNT. With reactor grade plutonium it is possible to design low-technology devices with probable yields 3 to 10 times lower than those mentioned above (depending on the design), but yields in the kiloton range could be accomplished.

Militarily useful weapons with reliable nuclear yields in the kiloton range can therefore be constructed using low technology and reactor-grade plutonium.

The national program just described is at the upper end of a range of minimal efforts to construct a nuclear fission explosive. At the low end, a small group of people (possibly terrorists or criminals), none of whom have ever had access to classified literature, could possibly design and build a crude nuclear explosive device. They would not necessarily require a great deal of technological equipment or have to undertake any experiments. The group would have to include, at a minimum, a person capable of searching and understanding the technical literature in several fields, and a jack-of-all-trades technician. Again, it is assumed that sufficient quantities of fissile material have been provided.

The actual construction of even a crude nuclear explosive would be at least as difficult as the design itself. In contrast to the national effort, the small group of people described above would probably not be able to develop an accurate prediction of the yield of their device. It could be a total failure, because of either faulty design or faulty construction. A great deal depends on the capability of the group; if it is deficient, not only might the device itself be a total failure, but a member of the group might suffer serious or fatal injury.

However, there is a clear possibility that a clever and competent group could design and construct a device which would give a significant nuclear yield.

Sources of Nuclear Material

A nation that wants nuclear weapons must develop an appropriate source of fissile material. The amount of material needed for an explosive is about 5 to 10 kg of plutonium or uranium-233 or 15 to 30 kg of highly enriched uranium, that is, uranium that contains about 90 percent or more of the isotope uranium-235. Uranium enriched to as low as 20 percent could be used in nuclear weapons, but much more material would be required. The exact quantity of uranium depends on its form and on the type of weapon—implosion or gun assembly.

Fissile material might be obtained by one of three general routes. Most attention has recently been focused on diversion of material from a civilian nuclear power program. A nation might evade safeguards on a nuclear facility or use an unsafeguarded facility, possibly after the abrogation of safeguards agreements.

The second route is the construction of facilities specifically designed to produce nuclear weapons material. Examples of such dedicated facilities are a small reactor to produce plutonium or an enrichment plant to yield highly enriched uranium. A third route is the purchase or theft of fissile material or even a complete weapon. Each of these routes is subject to constraints, and will be evaluated differently by different nations or groups depending on their resources, capabilities, political situations, and intentions.

DIVERSION FROM COMMERCIAL NUCLEAR POWER SYSTEMS

Although a nation could remove the fissile material needed for nuclear weapons from its commercial power systems, no present nuclear weapons state has followed this path. The difficulty of such diversion depends on the type of reactor system and the safeguards applied to the system. The reactor type determines the necessity for and nature of various fuel-cycle facilities. These facilities might include enrichment, fuel fabrication, and reprocessing plants to separate plutonium and uranium from spent fuel. The opportunities for diversion from all such facilities will be assessed here as a function of the reactor system.

The two classes of nuclear power reactors available on the world market today are light water reactors (LWRS) developed by the United States and Canadian heavy water reactors (CAN DUS). Others which could be deployed in the near future are the high temperature gas-cooled reactor (HTGR) and the advanced gas cooled reactor (AGR). Most development effort is being focused on the liquid metal fast breeder reactor (LMFBR), but commercialization is not expected for at least 10 years.

Light Water Reactors

Nuclear fuel convertible to weapons-grade material could be diverted from any point in the LWR fuel cycle, but the difficulty of conversion (chemical or isotopic separation), and hence the usefulness of the material to the diverter varies markedly from point to point. The most attractive points are those where plutonium appears in separated form: in the reprocessing plant; in transport to a mixed-oxide fuel fabrication plant; and at the input area of the fuel fabrication plant. These steps are necessary to the LWR fuel cycle only if plutonium, in the spent fuel is to be recycled back into the reactor. Plutonium recycle is not essential to the operation of LWRS, but may be undertaken to reduce the demand for uranium and the need for enrichment.

If spent fuel is not reprocessed, the LWR fuel cycle includes only the steps through spent fuel storage. This is known as a once-through or throwaway cycle. Theft of spent fuel, followed by subsequent extraction of the plutonium, is only barely credible for a highly organized, well-financed, and technically competent non-state adversary group with a secure base of operations. This action would expose the group to radiation hazards, and to a significant possibility of discovery because of the time required for chemical processing. Isotopic enrichment of fresh fuel to weapons material is not credible for a non-state adversary.

In the LWR cycle without commercial reprocessing, the national diverter would have to divert spent fuel for reprocessing or fresh fuel for enrichment. A small reprocessing plant capable of separating enough plutonium for several explosives per year is within the capability of many countries even if an economical commercial plant is not (see section on “Dedicated Facilities”). Removal of the spent fuel could probably not be done covertly, however, since effective safeguarding of LWRS and their spent fuel pools appears feasible with relatively straightforward improvements in IAEA techniques and procedures. If a nation did decide to divert spent fuel openly, it would have to choose between maintaining normal power output from the reactor and producing so-called weapons-grade plutonium. When operated normally, a 1000 MW(e) LWR discharges about 240 kg of plutonium in 31,000 kg of spent fuel annually. Because this plutonium contains about 25 percent of the isotope Pu^{240} it is not ideal for weapons, although reliable weapons can be made using such material. The nation that wanted weapons-grade plutonium (with 7 percent or less Pu^{240}) would have to operate the reactor differently, sacrificing around one-half the power and producing about one-quarter as much plutonium per kg of fuel. This mode of operation approximately triples fueling requirements.

The front end of the once-through cycle contains only natural- and low-enriched uranium. Enrichment to a considerably higher fraction of U^{235} would be necessary for weapons. This would be expensive and difficult for most nations, which lack commercial enrichment facilities. Nations possessing a commercial facility (especially a centrifuge plant) could covertly dedicate a portion of it to weapons grade enrichment, use the same technology to construct another facility for weapons grade production, or abrogate safeguards and overtly convert some or all of the plant to the production of highly enriched uranium. Covert diversion from a centrifuge enrichment plant would be difficult to detect with safeguards alone, judging by present constraints on safeguards procedures (see chapter VIII "Safeguards Technology"). Overt conversion of a commercial centrifuge plant could quickly yield large amounts of highly enriched uranium.

In a LWR fuel cycle that includes plutonium recycling, the material at the output of the reprocessing plant, the first stages of the mixed-oxide fuel fabrication plant, and the transportation link between the two plants, is vulnerable to both the national and non-state diverter. As presently envisaged, this material is pure plutonium oxide ($Pu0_2$) which can be used directly in a nuclear explosive. Once plutonium oxide is mixed with uranium oxide at the fuel fabrication plant, the material becomes significantly less attractive to the non-state diverter, because of both the time-consuming chemistry required to separate the plutonium and the logistics of diverting a large mass of material.

For the national diverter, a reprocessing plant provides immediate access to weapons material. A large reprocessing plant will be extremely difficult to safeguard effectively against covert diversion by the national diverter. Enough plutonium for several explosives per year could be extracted from the process stream within the error limits of material accountancy. Furthermore, however effective international safeguards may become in their job of detecting covert diversion, they cannot prevent a nation from seizing its own reprocessing plant. Once the political decision is made to seize the plant or its plutonium stockpile the nation can have a reliable explosives in a matter of days to weeks, even using reactor-grade plutonium.

The CANDU

Separated fissile material is not exposed anywhere in the CANDU fuel cycle because no reprocessing occurs. The diversion points in the CANDU cycle are the reactor itself and the spent fuel storage pool. As in the case of the LWR, nonstate theft of spent fuel followed by reprocessing is only barely credible. National diversion and subsequent reprocessing of CANDU spent fuel, however, is technically possible for many nations.

Whether a nation wishes to remove material openly or secretly, it will find the CANDU more vulnerable to diversion than the LWR without plutonium recycle. The CANDU is refueled continuously without having to be shut down, and the fuel bundles are small. Thus, fuel bundles need only be pushed through the reactor faster than normal to obtain weapons-grade plutonium.

International Atomic Energy Agency safeguards systems for CANDU reactors and storage pools (possibly involving resident inspectors) can probably be designed and implemented so that significant diversion of spent fuel bundles will be extremely unlikely to remain undetected. Thus, diversion from the CANDU is also likely to be overt.

A nation that decides to divert openly from a CANDU reactor may be less vulnerable than the operator of a LWR to such sanctions as withholding of fuel services. The CANDU uses natural uranium and does not need enrichment. However, it does rely upon a supply of heavy water, which might be subject to an embargo.

The LMFBR

The diversion-prone points in the LMFBR cycle are qualitatively the same as those in the LWR cycle with plutonium recycle, but its plutonium is more abundant and concentrated. Moreover, weapons-grade plutonium is produced in one portion of the LMFBR. An additional advantage to the national proliferator is that the breeder gives it an independent supply of fuel, making it less vulnerable to sanctions. Another breeder reactor concept—the gas cooled fast reactor (GCFR)—may be even more attractive to the nation that wants nuclear weapons because it breeds slightly more plutonium than the LMFBR.

Thorium Fuel Cycle

Power reactor fuel cycles starting with thorium as the natural resource have received much less attention than the uranium/plutonium fuel cycles discussed above, In this fuel cycle the thorium produces a fissile isotope, uranium-233. Except for the HTGR, light water breeder reactor (LWBR), and the molten salt breeder reactor (M SBR), thorium/uranium fuel cycles have involved only paper studies. Yet thorium cycles offer a number of potential advantages, such as the possibility of more efficient use of resources through thermal breeders or near breeders. Thorium fuel cycles also present barriers to diversion. The fresh fuel can be rendered unuseable for weapons by denaturing, that is, by mixing uranium-233 with the non-fissile isotope uranium-238. In addition, separated U233 is dangerous to handle because of the penetrating gamma radiation emitted by one of the decay products of U^{232}, an unavoidable impurity in U^{233}.

Comparison of Reactor Systems

The relative value of these opportunities for diversion depend on the intention and capability of the diverter. Four general categories of proliferators can be envisioned:

1. Nations desiring a major weapons force;
2. Nations satisfied with a small and not necessarily sophisticated nuclear capability;
3. Nations wishing the option of rapid development of nuclear weapons in the future; and
4. Non-state adversaries limited to a few crude devices.

The factors that these diverters would consider include:

1. The production rate and quality of fissile material;
2. Ability to withstand international embargoes and sanctions;
3. Impact of diversion on the fuel cycle;
4. Cost of the facilities;
5. Ease of conversion of diverted material to weapons material; and
6. Opportunities for covert diversion.

Figure II-2 ranks the various systems in terms of their resistance to each of these proliferators.

Research Reactors and Critical Assemblies

A substantial diversion or theft potential exists outside the commercial power industry, because of (a) the large number of research reactors throughout the world that are either fueled with highly enriched uranium or produce significant amounts of plutonium, and (b) the critical assemblies in several countries that use plutonium. (Critical assemblies are experimental facilities that run at zero power,) Critical assembly plutonium is essentially uncontaminated by fission products and is of high quality for use in weapons.

Alternate Fuel Cycles

Present commercial and near-commercial fuel cycles have been conceived and developed with essentially no thought given to their implications for proliferation or to the difficulties of safeguarding them. However, ERDA has recently set up a study in the Office of Nuclear Energy Assessments, Division of Nuclear Research and Applications, to investigate and evaluate alternate fuel cycles. The criteria for evaluation of alternate cycles are: (a) potential for preventing proliferation; (b) safeguard potential; (c) technical feasibility; (d) economics and resource utilization; (e) commercial feasibility; and (f) introduction date. In evaluating the potential for preventing proliferation, the study will emphasize deterrence to diversion or theft of nuclear material for the purpose of making an explosive weapon. Both domestic and foreign applications will be considered.

The schedule calls for a final report in October 1978, with a developed set of proliferation criteria and an assessment of selected alternate fuel cycles. Supplemental funds of $4 million

Figure II-2.

Reactor Systems Resistance to Proliferation

(Note that a high rank means the system is least susceptible to diversion.)

Reactor System	Availability	1. Major Force	2a.	2b. Major (un	Option	Non-State Adversaries
Light Water Reactor (enrichment)	Present	5	6	7	1	"1
Light Water Reactor (spent fuel)	Present	4	3	1	4	4
Light Water Reactor (reprocessing)	Present	6	5	8	5	6
CANDU	Present	8	7	2	2	2
High Temperature Gas Reactor	Near Term	7	4	6	6	7
Advanced Gas Reactor	Near Term	3	2	3	3	3
Liquid Metal Fast Breeder Reactor	R&D (advanced)	9	9*	9	9	9
Gas Cooled Fast Reactor	R&D	10	10'	10	10	10
Light Water Breeder Reactor	R&O	1	1	4	7	8
Molten Salt Breeder Reactor	R&D) (present inactive)	2	8*	5	8	5

"May not be an option for cost or technological reasons.

SOURCE: OTA

for FY 77 have been requested from Congress by ERDA, and the program has been budgeted at $7 million for FY 78.

In order for the results of this program to be most useful, the alternates that are selected for study should be balanced between relatively short-term payoff technical modifications of existing cycles and radically new approaches, specifically including continuation of study on the nonproliferating- reactor concept discussed below.

Nonproliferating Reactors

One of the most intriguing concepts being studied by ERDA is funded at $250,000 for FY 77 by the Division of International Security Affairs (ISA). This is the concept of nonproliferating reactors through strict design requirements, this approach seeks to eliminate the diversion paths available in current and projected reactor systems and their associated fuel cycles. Several key design criteria are: (a) the system shall contain only a small amount of fissile material at any given time after start-up; (b) there shall be no access to the fuel during the lifetime of the reactor; (c) any diversion of fuel will cause the reactor to shut down; (d) the reactor shall be refuelled by the addition of fertile (i.e., nonfissile) material only; (e) the reactor shall not operate as a breeder, but as a sustainer producing only enough fissile material to keep itself running. Conceptual studies of three reactor systems have been funded by this program. This program is the first attempt to design reactors with nonproliferation as a specific design criterion. As such, it deserves continued funding at an expanded scale, a wide hearing, a thorough assessment, and an open-minded comparison with other alternatives. There are apparently no plans by ISA to continue funding this program in FY 78. If this promising new approach is to receive further attention it apparently must do so under aegis of the Alternate Fuel Cycle Program, described above.

DEDICATED FACILITIES

All nations which now possess nuclear weapons have obtained the fissile material from facilities specifically dedicated to the production or separation of this material, Thus, a commercial nuclear power program is not a prerequisite for a nuclear weapons program. The main advantage of a dedicated facility is that it provides a reliable, possibly secret and/or legal source of weapons material. As safeguards are improved and extended over all imported nuclear facilities, and as greater restraints are placed on the sale of enrichment and reprocessing plants, nations embarking on a nuclear weapons program may be constrained to follow this route.

Construction of a dedicated facility (which is, of course, not safeguarded) constitutes a violation of the Non-Proliferation Treaty (NPT) by parties to that treaty. Nations that are not party, however, can quite legally build and operate weapons facilities, even while importing safeguarded nuclear material or technology from NPT nations,

A nation which decides to build a dedicated facility has two basic options:

1. Construct a plutonium production reactor plus a reprocessing plant to separate the plutonium from the spent fuel.
   A variant on this option is to feed a dedicated reprocessing plant with spent fuel from an already existing research or power reactor. (This is the route India took with the unsafeguarded Cirrus research reactor.)
2. Construct an enrichment plant to produce weapons-grade uranium from natural or low-enriched uranium.

The choice between these options depends upon a number of factors peculiar to each country, including its technological base, production schedule, the existence of any civilian nuclear facilities, and the number of weapons

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wanted. These factors, especially the technological base, will also affect the time, personnel, and cost required for construction of dedicated facilities.

Dedicated facilities are smaller and can be simpler in design than corresponding commercial facilities. The technology for reactors and reprocessing plants is not classified, with several detailed plans of such plants available to the public. These facts make construction of certain dedicated facilities within reach of many nations. In particular:

1. The construction of a reactor producing about 10 kg of plutonium per year and a small reprocessing plant is within the capabilities of many developing nations. The total capital cost would be several tens of millions of dollars, and about 5 years would be required to construct the facilities and produce and separate the first 10 kg of plutonium. The reactor would be fueled by natural uranium, moderated by graphite, and cooled by air. Very pure Pu^{239} would be produced.
2. Crude, imperfectly shielded, but technically feasible reprocessing plants based on the techniques of solvent extraction or ion exchange can be built for a quick emergency response program at a cost of one to several million dollars. The nation would have to have access to spent fuel from a reactor to feed into such a plant. Such a facility would not be suitable for a sustained weapons program.
3. A low-cost, low-detection-risk option for a nation already possessing a commercial centrifuge facility may be to build a small "add-on" centrifuge facility, either on or off the site, for the production of highly enriched uranium.
4. A reactor producing about 100 kg of plutonium per year and fueled by natural uranium would be a suitable dedicated facility for an open weapons program in an at least moderately advanced nation.
5. There are no enrichment techniques presently suitable for dedicated facilities in any but technically advanced nations. (An exception might be an "add-on" to a purchased commercial centrifuge facility, as discussed in #3, above.) Laser isotope separation (LIS) is unlikely to be feasible for use as a dedicated facility (barring an unforseen break-through) before the late 1980's or early 1990's and then probably only for technically advanced nations.

In brief, many nations might be able to build a dedicated facility to produce fissile material for a weapons program, For example, about 40 nations already possess one or more research or power reactors and thus have experience with nuclear programs. (See appendix V of volume II.)

It is unlikely that a dedicated facility to support a large weapons program (about 10 explosives per year) could remain undetected. However, a dedicated facility to support a small weapons program (one or two explosives per year) could present a detection problem for intelligence agencies, especially if the nation were not among the five or six Nth countries most likely to be under intensive surveillance.

PURCHASE AND THEFT

A third potential route to proliferation is by the direct acquisition of weapons or fissile material from another country. A nation or group could purchase these items from an illegal black market, covertly buy or trade them from a friendly nation in what is termed a gray market, or steal another nation's weapons. Any of these methods bypasses the need for the expensive and demanding technologies entailed by the commercial power and dedicated facilities routes. If this type of transaction emerges, the scope of proliferation could be extended to technologically limited nations and non-state adversaries who would otherwise have found the task difficult and risky. The pace of proliferation could be further accelerated by the relative ease of obtaining weapons, a general sense that the nonproliferation regime was crumbling, and a specific concern that one's enemies might be covertly arming.

Nuclear black market commodities might be fissile material, weapons designs, or weapons. Of these, the most likely to drive a black market is the fissile fuel plutonium: If plutonium is extensively recycled numerous opportunities would exist to divert this substance. Only a very small fraction of the plutonium need be taken from a full plutonium fuel cycle to produce material for many bombs per year. An alternative source might be material intended for research purposes and military weapons.

The most probable customers for material used directly in a nuclear weapon are less developed nations or countries faced with an emergency that foreclosed other routes to nuclear weapons. This material might also interest terrorists or criminals bent on extortion. The suppliers might be employees of a reprocessing plant who gradually withdraw amounts below safeguards detection limits, or criminals or non-state adversaries who stage armed attacks on plutonium shipments or stockpiles. The size of a nuclear black market would be small compared to that of the illegal drug market, but profits could still be large enough to make emergence of such a market credible. Establishment of contact between diverse suppliers and buyers for isolated transactions would be difficult. Once initiated, however, this contact could be the nucleus for a sustained market, especially if supply and demand are high.

In a gray market, transactions are technically legal but are kept secret because of anticipated negative responses, including sanctions and preemptive attacks. In order for the transaction to be legal, the buyer will always be a government. The nation might be interested in such commodities as weapons, fissile material, or technical assistance, although weapons would probably be supplied only under extreme national emergencies. The country might more commonly receive nuclear technical assistance,

One potential supplier would be another nation motivated by the need to obtain a vital resource such as oil or by the desire to curry favor with a key nation. Another supplier conceivably could be a corporation that is subjected to pressure to assist a nation in which it has considerable investments or sales expectations. Most corporations, however, will have high resistance to such pressure in matters as serious as nuclear weapons proliferation. A third supplier could be an appropriately trained individual, peddling himself as a scientific mercenary.

The gray market involves more natural partners (national allies) than the black market, and it may be more easily established although less widely spread. Participants in both markets must take high risks and thus must have strong motivations. Both markets may be detected by enhanced intelligence activities, and once located, could be halted only by the cooperative efforts of many nations. The black market in plutonium might be largely eliminated by a ban on reprocessing. An adverse feature of this ban, or any other measure that decreases employment in the nuclear industry, is its tendency to create a potential supply of scientific mercenaries.

Theft is the most direct route to nuclear weapons. A detailed assessment of military security was not made for this report, but some observations can be made. Weapons are protected internally against unauthorized use in the United States, but might be rebuilt to bypass these mechanisms. The psychological value of a successful theft would be considerable even if the weapons were actually unuseable. Security for weapons is considerably more stringent than for commercial facilities, but even so, the need for upgrading is recognized by the Department of Defense. A well-trained Commando raid of about 8 to 20 attackers using an imaginative plan and assisted by insiders could be difficult to resist without rapid reinforcement. Intelligence activities could make an important contribution by providing warning of such an attack. Massive attacks that are essentially acts of war would be even more likely to succeed, but would be easy to track, Strong political or military responses would be required to assure return or destruction of the weapons. Physical security used by other weapons states seem to present about the same obstacles to theft as those of the United States, but new nuclear states may be more vulnerable.

Control of Proliferation

Attempts to acquire nuclear weapons by any of the three routes just discussed are subject to four general levels of control effort. The first is detection of the attempt, either by safeguards which watch for diversion from commercial nuclear material flows, or by intelligence activities which can spot dedicated facilities or illegal nuclear transactions. The second level is the response to the detection of such activity in order to force its reversal and deter others from like actions, Sanctions administered by other nations are one method of response. The third level is the restriction of nuclear systems to those that present the lowest risks for proliferation. Supplier agreements can coordinate a ban on sales of enrichment and reprocessing plants and emphasize the development of new systems. The final level is creation of an international climate, through treaties and commitments, wherein nations will not want to proliferate or will find it difficult to do so for political reasons. Each of these levels has produced institutions and arrangements to perform the needed functions. Many of the components would benefit from strengthening, but together they present an effective, though not insurmountable, barrier to proliferation,

The first part of this chapter will survey the safeguards technology to detect diversion, The second part will discuss the various institutions and arrangements that assist in the levels of proliferation control.

SAFEGUARDS

The objective of domestic safeguards in the United States is to detect, deter, prevent, and respond to theft or sabotage by a non-state adversary. The objective of international safeguards such as those applied by the International Atomic Energy Agency (IAEA) is to detect diversion of nuclear material by a nation from its own nuclear facilities. In addition, international safeguards should assist the national safeguards system in detecting nonstate diversion.

United States Domestic Safeguards

The three basic elements of the U.S. system are physical protection, material control, and material accountancy. Physical protection elements are those that prevent unauthorized outsiders from entering a facility or seizing control of a transport vehicle, and prevent nuclear material from leaving by an unauthorized route. Examples are armed guards, barriers, and portal monitors. Material control measures consist of procedures for access to and transfer of special nuclear material. They are aimed at preventing any two insiders acting in collusion from removing nuclear material from the facility. Materials accounting for nuclear material is similar to accounting systems for other valuable materials, involving complete records of the movement of material and the taking of periodic physical inventories. The physical protection and material control systems are the primary safeguards measures in the United States.

Safeguards were not given high priority by the public or the Government until recently. Several years ago, safeguards began to attract widespread interest and increased funds were provided, but, a sudden surge of interest and money cannot quickly compensate for years of complacency.

The United States has three major nuclear programs, and three agencies (ERDA, NRC and the Department of Defense) with safeguards responsibility for these programs.

Because NRC has primary responsibility for commercial nuclear facilities, it has been the focus of this report. The NRC safeguards tasks can be considered in four classes; the first three are of present concern but the fourth allows time for further study.

1. Protection of Shipments of Privately Owned Strategic Nuclear Material.—The Nuclear Regulatory Commission requirements on shipments of strategically significant amounts of special nuclear material (i.e., 5 kg or more of highly enriched U^{235} or 2 kg or more of plutonium or U^{233}) are currently less stringent than those recently adopted by

ERDA for shipment of its own material. One critical element of effective safeguards is secure communication during transportation. ERDA has such a system (SECOM), but its use is at present restricted to transport of ERDA material. There appear to be no serious legal, economic, or institutional reasons why shippers of privately owned nuclear material cannot employ the ERDA communications and control system. Transportation security for NRC licensees would be further upgraded by the use of specially designed, penetration resistant tractor-trailers similar in performance to ERDA's and accompanied by escort vehicles.

2. Protection of Production Facilities That Possess Strategic Special Nuclear Materials.—NRC sets requirements to protect those privately owned facilities licensed for possession of strategic quantities of plutonium or highly enriched uranium. NRC also inspects the facilities to ensure licensee compliance to its regulations. Controversy over whether or not safeguards are presently adequate at these facilities centers around what level of threat safeguards should meet. Although this report has not assessed safeguards at specific facilities, it can make some observations about the methods of assessment now being used.

In current assessments, more attention has been given to the size of a potential non-state adversary group than to any other single attribute. Although some historical data on size of threats are useful as a guide, an estimate of the numbers of attackers is inescapably a matter of judgment. A study in progress at the RAND Corporation suggests a range of anywhere from 7 or 8 to about 15 attackers as a prudent estimate, without speaking in terms of a maximum threat. NRC has reportedly ordered its licensees to upgrade physical security to meet a threat of two or more insiders acting in collusion with several heavily armed attackers from the outside.

In addition to numbers, other important parameters to consider are armament, tactics, and the characteristics of the facility itself. Present safeguards and physical security may place undue reliance on one element of physical security-armed guards, It is not clear how well presently designed safeguard systems can handle the problem of several insiders acting in collusion, or outsiders attacking with guile and deception rather than straightforward armed assault.

Moreover, guards at nuclear facilities presently have only civilian arrest powers, which are quite limited and vary from state to state. Serious consideration should be given to ways to clarify the power of the guards. The question of using a Federal security force to protect nuclear material needs reopening, particularly in light of the increased threat levels licensees are being required to meet.

It should also be recognized that there could be an alternative to reliance on onsite guards for standoff of an armed attack, A crucial question, which deserves serious review, is the extent to which safeguards systems can be designed to sufficiently *delay* attacking adversaries so that the burden of engagement and arrest falls on off site response forces rather than onsite guards.

3. Protection of Power Reactors Against Sabotage.—The question of reactor sabotage was judged peripheral to the main focus of this study: the proliferation of nuclear weapons. This report has therefore not assessed the adequacy of U.S. domestic security at power reactors.

4. Protection of Future Facilities That Would Process Plutonium-Containing Fuel or Other Concentrated Weapons Material.—It is not clear whether NRC will decide to license plutonium processing facilities, or if so, when. The only such plant which could start operations within the next few years is the Allied-General Nuclear Services spent-fuel reprocessing plant 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.

Several safeguard concepts have been put forth in recent years to meet the problems posed by large-scale concentrated weapons material in processing and fabrication facilities. These are listed and briefly assessed below :

a. *Massive Spiking*

Massive spiking is the addition of lethal amounts of radioactive material to fresh fuel as a barrier to theft. Studies indicate that this technique is not cost effective compared to massive containment and stringent physical security for domestic safeguards use. Massive spiking would not be useful at all in restraint of national proliferation.

b. *Light Spiking*

Spiking of highly enriched uranium with low levels of radioactive material should be given further study.

c. *Denaturing of Plutonium*

The concept of denatured plutonium—plutonium which, because of its isotopic composition, is not suitable for explosives—is fallacious. (See chapter VI "Nuclear Fission Explosive Weapons".)

d. *Storage and Transport* of *Plutonium in Dilute Mixed-Oxide Form*

If plutonium dioxide were always mixed with a large quantity of uranium oxide, when stored and transported, its usefulness to the non-state adversary would be considerably reduced. A group would have to steal large amounts of mixed-oxide material and undertake time-consuming chemistry to separate the plutonium. However, the dilute mixed-oxide form would constitute much less of a barrier against national diversion.

e. *Collocation* of *Reprocessing* and *Fuel Fabrication Plants*

The collocation of reprocessing plants and mixed-oxide fuel fabrication plants would eliminate the transport of pure plutonium oxide. The advantages and disadvantages of this safeguard measure have not yet been assessed in any systematic way. However, if coprecipitation is employed at the reprocessing plant so that its output is dilute plutonium oxide in uranium oxide, co-location would probably not offer significant additional safeguard advantages.

f. *Advanced Materials Accounting System*

No substantial economical improvement in the sensitivity of materials accountancy can be expected unless real-time material control can be implemented. Two such systems are being developed: DYMAC at Los Alamos Scientific Laboratory and RETIMAC by NRC at Lawrence Livermore Laboratory. Considerable development work and in-plant demonstration is required before the effectiveness and costs of real-time material control can be reliably assessed. However, even once developed, such systems could not do the entire safeguards job, Physical security, containment, and surveillance will still play crucial roles in both domestic and international systems.

g. *Integrated Safeguard Systems*

The most effective safeguard systems would be those in which the various elements are integrated with one another and into the design of new facilities. Such systems demand not only development of hardware and computerized control but, also, development of methodologies to assess their effectiveness against both outside attack and embezzlement by insiders. The input to this assessment must be reliable data on the individual elements of the system. It is therefore important to continue experimental programs to provide information on the penetration resistance of barriers, the reliability of alarms, and the efficacy and safety of techniques such as foams and reactive sensors that delay and confuse the adversary.

IAEA Safeguards

The objectives of the IAEA safeguard systems is to detect national diversion.

Materials accountancy is considered to be the safeguards measure of fundamental importance by the IAEA. Containment and surveillance are regarded as important complementary measures.

The materials accountancy system is based on records and physical inventories made by the facility operator and subsequently verified by the IAEA inspector. Containment is the use of physical barriers to restrict and control access to or movement of nuclear material. Surveillance means instrumental or human observation to detect access to or movement of nuclear material. It is generally accepted that there are unavoidable limitations on material accountancy due to measurement errors: containment and surveillance will therefore have to be assigned much greater importance in the design of safeguards.

The role of IAEA in the issue of physical security is an advisory one. Physical security systems are the prerogative of the individual nation. As part of an effort to upgrade physical security worldwide, ERDA physical-security review teams visited a large number of countries in 1975-76. The result of the visits are classified by ERDA because of the classified nature of physical security measures in foreign states: ERDA further stated that laws, regulations and factors peculiar to each nation made it difficult to draw even general observations about the visits.

IAEA Safeguarding of Power Reactors.—It is difficult to evaluate the present effectiveness of IAEA safeguards on power reactors because information about critical IAEA procedures and policies is either not available outside the Agency or is classified by the IAEA as "Safeguards Confidential." Some of this information may become available in the Director General's proposed Special Safeguards Implementation Report to the Board of Governors. The report is expected in September 1977, after several delays totaling over a year.

On the basis of the available information, it appears credible that IAEA will develop and implement improved equipment and techniques to make undetected diversion from light water reactors or their spent fuel storage pools very unlikely. Safeguarding onload reactors, such as the CANDU which is refuelled without being shut down, is substantially more difficult.

A great deal of research is being done on surveillance and containment to safeguard CANDU reactors, but not enough information is available at present for a reliable assessment. The IAEA may decide to request the right to station resident inspectors at these reactors. Such a move would greatly increase IAEA costs and workload.

IAEA Safeguarding of Enrichment and Reprocessing Plants.—To date, IAEA has not safeguarded any type of enrichment plant (including pilot plant), nor has it undertaken the routine application of safeguards on a long-term basis to any commercial reprocessing plant.

As now proposed, IAEA inspection procedures for enrichment plants (especially centrifuge plants) leave open a path for a nation to obtain highly enriched uranium for weapons. The nation might convert one section of its centrifuge plant to a high enrichment loop. Detection of this loop would be difficult: the IAEA inspector is currently denied access to the cascade area (that is, the area where the actual enrichment takes place), and is not allowed to monitor any new equipment that goes in and out of this area. Reconfiguration of the plant would have to be deduced from measurements of other inputs and outputs to the cascade area. Furthermore, materials accounting is currently not accurate enough for a Iarge plant to assure the inspector that a significant diversion has not taken place. Despite objections that permitting IAEA inspectors inside the cascade area will expose commercial secrets, doing so would greatly enhance the effectiveness and credibility of IAEA inspection.

Present material accounting systems (both U.S. and IAEA) for use in large commercial reprocessing plants are not sensitive enough to reliably detect diversion of the order of tens of kilograms of plutonium. More importantly, detection may occur weeks or months after the diversion. The IAEA requires materials accountancy to be supplemented by containment and surveillance measures. Advanced containment and surveillance systems are currently in the conceptual design stage. The aim is to develop systems that will be effective and reliable, indicate attempts to tamper, and eventually be able to report in real time to both a central inspector station and IAEA headquarters in Vienna. Such systems are essential to the credibility of IAEA safeguards on reprocessing plants.

The IAEA 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 system should be able to improve as the size of facilities under safeguards increases. It is not, however, 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 truly credible safeguards against covert diversion for these types of plants.

INTERNATIONAL INSTITUTIONS, AGREEMENTS, AND SANCTIONS

Safeguards on nuclear facilities can be only as strong as the agencies that apply them, and only as effective as the responses that enforce them. The entire climate for international safeguards is governed largely by the institutions and agreements that are described below.

International Atomic Energy Agency and Euratom

The International Atomic Energy Agency (IAEA) operates a safeguards inspection system required for all nuclear material of non-nuclear weapons states party to the Non-Proliferation Treaty (NPT), and on all exports by members to nonmembers. These safeguards are aimed at detecting whether a nation has diverted nuclear material from its own facilities, so an adversary attitude toward the nations is assumed. The IAEA has no power to enforce physical protection, recover diverted material, or detect dedicated facilities or illegal transactions.

IAEA response to possible evidence of a national diversion is limited. The evidence initiates a sequence of reports and efforts to resolve the discrepancy. If these fail, the matter is referred to the Board of Governors, who must weigh the evidence and such factors as the effectiveness of the Agency's procedures and inspectors, the quantity and quality of missing material, and political factors within the state in order to decide whether a nation has indeed removed some nuclear material. If the Board decides this is the case it sends a report to its members and to the UN, but it has essentially no other recourse.

This noncompliance path has not yet been tested. If governments perceive the risks of detection to be low, however, they may be enticed to try to divert. Some of these attempts would be detected, even in an enrichment or reprocessing plant. Once a state is caught in an attempted diversion, it may apply political pressure or attempt to stall the Agency's efforts to reconcile the problem. The Agency's response to the first attempt will be especially crucial and must be strongly supported by its member states.

Besides the limited response to violations, IAEA safeguards face other problems: they are somewhat restricted by proprietary interests of many nations; they are hampered by failure of facility designs to integrate the application of safeguards; they are dependent upon inspector quality and morale. On the other hand, the very acceptance by nations of Agency inspectors in their nuclear facilities represents a considerable concession, The IAEA safeguarding efforts are certainly not perfunctory and they are making a credible effort to prepare for the expanded work load ahead.

Eurakmn is the multinational agency of the European Economic Community that performs the safeguards functions for its member states. The Euratom safeguards system is less formally structured than the IAEA system, and Euratom's inspection access rights are stronger and still exercised by its inspectors. Euratom and the IAEA have been moving to coordinate their inspections, but important differences remain to be resolved,

Sanctions

Sanctions can be used either to deter or reverse a nation's efforts to obtain nuclear weapons. To be effective, sanctions must enjoy firm and widespread support within the international community, especially by the nuclear suppliers. Sanctions lose their credibility if they are not applied or are successfully flouted. Sanctions could include the termination of nuclear assistance or trade, a cessation of economic assistance, a general trade embargo, or termination of military support or security guarantees. Because these measures will impact differently on different countries, they must be applied on a selective basis. The history of sanctions in other cases is not encouraging but, given a strong international norm against proliferation, the threat can be made credible. Sanctions will be an important element in proliferation constraint, but their deterrent effect can be overcome by sufficient incentives such as a threat to national survival. The defusing of proliferation pressures therefore remains a critical concern, no matter how severe the sanctions.

The Suppliers' Conference and Multinational Facilities

In 1974, after extended negotiations, 10 nuclear exporting nations announced agreement on export procedures designed to coordinate fulfillment of supplier obligations under the NPT. The designated procedures and the so-called "Trigger List" of sensitive exports represented the first major agreement on uniform regulation of nuclear exports by actual and potential nuclear suppliers. It established the principle that nuclear supplier nations should regulate the international market for nuclear materials and equipment in the interest of nonproliferation.

In response to the Indian nuclear detonation a second series of supplier negotiations began. On January 27, 1976, the seven participating nations exchanged letters endorsing a uniform code for conducting international nuclear sales. The provisions strengthened the 1974 agreement with regard to the Trigger List equipment, retransfer of exports, and physical security requirements for the protection of exported materials and facilities. The new agreement indicated the importance that nuclear supplier states attach to strengthening the international barriers against proliferation. The Conference also served to elevate the issues of nonproliferation and nuclear exports to the highest political levels within participating governments. Subsequent to the agreement, there has been a notable strengthening of the nonproliferation posture of Canada, West Germany, and even France. Previous agreements to export reprocessing facilities to Pakistan and Brazil have been cast into doubt.

There is a danger that the success of the Suppliers' Conference could lead user states to view it as a cartel designed to preserve the continued preeminence of the supplier states in the international nuclear market. The result could be a weakening of the sense of bargain which makes the NPT acceptable to many non-nuclear states.

Multinational Fuel Cycle Facilities (MFCF) have been proposed as a way to supply reprocessing services without having the plants under national control. This would greatly reduce opportunities for diversion by any one nation. However, MFCFS might weaken the arguments against reprocessing in general and disseminate the technology to do it. Nevertheless, MFCFS do show promise as a means of forestalling national reprocessing. A number of economic and political issues must be resolved first. The IAEA is presently conducting a study addressed at many of these. Another application of the MFCF concept would be for spent-fuel storage, which would be much easier to implement than reprocessing. It would also make a clear contribution to nonproliferation while not foreclosing eventual multinational reprocessing.

The Non-Proliferation Treaty (NPT)

A major factor constraining nations from nuclear weapons development has been the NPT. The Treaty was designed to prevent the diversion of nuclear material in commercial power systems to weapons purposes by the imposition of safeguards, and to gain a formal commitment by the nonweapons 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. Over 100 nations have ratified the NPT, but some of the key countries have not. The greater restrictions on nonweapons states compared to weapons states has caused some discontent, as has the lack of progress towards nuclear disarmament. The NPT prevents only its ratifiers from developing weapons, and parties can, under extraordinary circumstances, withdraw on only 3 months notice and quite legally produce their own. Nevertheless, it is a significant deterrent in that most members would find it politically difficult to resign, and it has helped create a climate that makes proliferation an act outside the pale of international propriety.

Comparison of Routes to Nuclear Materials

The two previous sections have described three routes to obtain fissionable nuclear material suitable for weapons, and the restraints on those routes. The route that would be selected by a particular nation or non-state adversary will depend on various characteristics of the country concerned.

1) Technological Capability: If its ability is high, a nation can consider any route. A low capability limits the proliferator to a purchase or theft.

2) Availability of Nuclear Facilities: The ability of a proliferator to divert nuclear material depends on the type of facility it owns or can readily acquire.

3) Urgency of Need: If the proliferator must have the weapons on a short time-scale, it may have to openly abrogate safeguards on its own nuclear facilities or obtain weapons by purchase or theft.

4) Critical Resources: If a nation has large quantities of uranium, it would be less vulnerable to sanctions if caught diverting and less liable to be detected if it constructs a dedicated facility.

5) Political Relationships: Acceptance of safeguards or vulnerability to sanctions will, at least, force a nation to travel a route with the least chance of detection. On the other hand, alliance with a more advanced nation may provide the nation with technology or resources for a dedicated facility.

6) Perceptions of Controls: If a nation perceives safeguards to be effective, it will be less likely to attempt diversion.

The interaction of all these factors will determine the optimal pathway each nation or subnational group would use to obtain nuclear weapons. This interaction will be strongly influenced by the particular objectives a nuclear weapons program is designed to serve. In chapter VI, four such objectives were identified,

a) Nations desiring a major weapons force.

b) Nations satisfied with a smaller, perhaps less sophisticated force.

c) Nations wishing the option of rapid development of nuclear weapons in the future.

d) Non-state adversaries limited to a few crude devices.

A major weapons program can be defined as one that produces at least 10 high-quality weapons per year. Only a country with a relatively extensive technological base can realistically consider such a program. Such a nation would not select a route as unreliable or intermittent as an illegal nuclear market. It could pursue either of the other two routes, but would probably be unable to keep its intentions secret for long. The diversion of sufficient quantities of nuclear material from a commercial nuclear power program would necessitate open abrogation of safeguards, unless the nation already had an un - safeguarded facility. Sanctions such as nuclear embargoes might effectively hamper a nation from continuing along this route unless it had its own uranium reserves and a natural uranium or fast breeder reactor. Construction of a plutonium production reactor dedicated to production of weapons material might have more appeal, in that it would be legal for a nation that is not a party to the NPT, and its production capabilities could be kept secret even if the existence of the facility itself could not be.

The nation that wants a small number of unsophisticated weapons might procure the material from any of the three routes, If it needed the weapons quickly it might purchase the required goods on a black or gray market, if available, or might consider overt diversion from a reprocessing or enrichment plant. If its needs are not urgent, a country might be able to obtain the nuclear materials secretly. If it owned a reprocessing plant it might be able to covertly divert sufficient material. The country might, however, be unwilling to risk detection if it perceived the safeguards to be effective. In that case it could construct a plutonium production reactor, especially if uranium were available. The reactor would be on such a small scale that it could easily escape detection. A final alternative for a country that possessed a centrifuge enrichment plant would be to rework a portion of it into a high enrichment loop or to build a small "add on" to the existing plant.

The nation wishing only an option for future nuclear weapons development might require commercial nuclear power reactors with eventual diversion in mind. A reprocessing plant would be essential for it to extract the weapons material from spent reactor fuel. If it could not obtain such a facility, it might build one of it own to hold in reserve. A small reprocessing plant for weapons is far easier to design and build than a commercial plant.

The non-state adversary can obtain nuclear material either by black market transactions or by armed attack on shipments or stockpiles of plutonium in commercial power program. The non-state adversary would probably not be able to use material from other points in the fuel cycle because construction of the facilities required to convert such material to weapons grade most likely would be beyond the group's capabilities.

This brief analysis shows that all three routes are plausible under some conditions. The least predictable is purchase/theft. If such a route comes into existence, it could satisfy three of the four categories of proliferators. It might also serve the major force nation wanting a few bombs in hand to forestall the preemptive attack that might occur if its intentions became known before its program was complete. Hence, a high priority must be given to controlling this type of transaction. Diversion from commercial power systems can be largely controlled if Nth countries do not have their own reprocessing or enrichment plants. A reprocessing plant in particular provides instant access to weapons material for any nation willing to abrogate its safeguards agreement and many opportunities for covert diversion by those that are not. The dedicated facility route is the least subject to control. Many nations are capable of this route because of ready access to sufficiently detailed plants and the availability of the modest resource requirements. One of its few disadvantages is its high cost which is not offset by power production. More attention should be directed to possible means of detecting those nations embarked upon a dedicated facility route.

International Nuclear Industry

Control of nuclear weapons proliferation depends to a large extent on the nature and scope of the future international nuclear industry. Key factors to understand are the real and perceived need for nuclear energy in general, and for proliferation-prone facilities (such as breeders or reprocessing plants) in particular. Also important are the motivations of and relationship between the nuclear suppliers, as these will determine the efficacy of any attempts to control proliferation.

Nuclear power has been widely expected to replace oil and gas as a major energy source to meet the growing consumption of most nations, especially as production of these fossil fuels decline and their prices rise. Expectations for nuclear energy were boosted by the oil price increases in 1973, but have fallen sharply since then; costs for nuclear plants and fuels have risen as demand has fallen, and opposition to them has grown in many countries.

Nuclear energy is mainly suited to the production of electricity, the form of energy with the highest growth rate. Although electricity may be inappropriate for many applications, such as low temperature heat, the very high growth rate worldwide results from strong social and economic forces that will not be quickly and easily reversed. Some nuclear powerplants can be replaced by coal plants. World coal resources are many times that of oil, but the costs of extracting, transporting, and using vastly increased quantities of coal in an environmentally acceptable manner may be very high.

The perceived need for nuclear power varies from country to country and depends on many factors. Nuclear power is chiefly appropriate for a nation having a large and growing electricity demand and no cheap alternatives, including conservation. A number of industrialized nations fit this description. Less developed countries (LDCS) may want nuclear power to diversify their energy sources or to provide for a future when there may be no alternative. However, the LDCS may also find that their financial resources are too limited, their electric grids too small, and their technical infrastructure too immature to support such a large and complex power source. The disadvantages may be great enough so that LDCS should be encouraged to find alternatives (such as imported coal), especially those LDCS that are considered high proliferation risks,

In the face of such variable factors governing the need for nuclear power, projections of its growth are very uncertain. The most recent official estimate is one that ERDA produced in 1976, by modifying downward a projection by the IAEA and the Office of Economic Cooperation and Development (OECD). The results are as follows:

World Nuclear Capacity (1000 MW)

Year	1975	1980	1985	1990	2000
Us.- ----	39	67	145	250	510
Other Nations---	29	100	230	425	1030
Total	68	167	375	675	1540

These figures are considerably lower than previous projections, and many observers expect this trend to continue. Actual installed capacity could be substantially lower. Those LDCS with a heavy commitment to nuclear power are Brazil, Argentina, Mexico, India, Iran, Taiwan, and Korea. Several others expect to be heavily dependent by 2000.

Possession of a nuclear reactor alone, especially if it is safeguarded, does not greatly facilitate the acquisition of nuclear materials for a national weapons program (see chapter VI). Other elements in the nuclear fuel cycle impinge more heavily on proliferation control: the availability of uranium supplies affects the need for reprocessing plants and the breeder reactor; the capacity for enriching uranium will influence such measures as guaranteed fuel supplies; the dissemination of enrichment and reprocessing facilities gives their operators the means to produce weapons materials and also reduces their vulnerability to international sanctions. The supply and demand for all those items must be well understood.

Uranium reserves as presently estimated should not constrain the nuclear power growth projected above until about 2000. At about that time, it may become impossible to guarantee a lifetime supply for new reactors unless a new source of fuel has been determined. This could come from breeder reactors or from new technology that permits the extraction of low grade ores not now counted as economically recoverable. If growth in the demand for nuclear power is substantially lower than presently anticipated or if, as some expect, uranium resources are much larger than projected by the IAEA, there will be no constraint until well into the next century,

More enrichment capacity may be needed by the late 1980's, but there appears to be no inherent difficulty in supplying this. The timing of the need for spent fuel reprocessing is much less clear. Plants are now being built in the United States, Europe, and Japan, but capacity is far below need if all fuel is to be reprocessed, Unlike enrichment, reprocessing is not a vital part of the LWR fuel cycle. Justification for reprocessing as a means to extend fuel supplies may evaporate if nuclear growth slows or if uranium reserves prove adequate. The plants could be indigenously developed by many countries if desired, however. Consequently, export bans on reprocessing plants would be less effective than those on enrichment facilities.

The U.S. share of the total reactor export market has dropped sharply in recent years, as other suppliers have emerged and as U.S. policy has both restricted certain exports and engendered doubts as to the reliability of American commitments. The competition among the nuclear suppliers is quite keen, especially as many of them need a foreign market to fill their excess manufacturing capacity. If the United States unilaterally withdrew from the market, the other suppliers are capable of quickly filling the void.

The suppliers of reactors and enrichment services are as follows:

Reactors	*Enrichment*
U.S.A.	U.S.A.
Canada	U.S.S.R.
West Germany	France
United Kingdom[a]	United Kingdom
France	Netherlands[b]
Sweden[a]	Japan (proposed)
Italy[a]	South Africa (proposed)
Japan[a]	
U.S.S.R.	Brazil (proposed)

[a]Not expected to be major exporter.
[b]Location of URENCO trilateral facility.

If the United States, as expected, continues to export reactors and associated equipment as well as engineering, construction, and enrichment services, the export value will total about $2 billion per year until 1990, with possible variations depending on the policies of other supplier and importing nations.

Policy Implications

Perspectives

The growing debate over policy concerning proliferation hinges in large part on differing perceptions of the problem. There are three basic issues in dispute.

1) Is reliance on nuclear power to meet national and global energy needs unavoidable, or can adequate alternative sources of energy be developed?

2) Must the spread of nuclear power inevitably result in the proliferation of nuclear weapons, or can that potential linkage be broken?

3) Does proliferation really constitute a serious problem from the perspective of U.S. interests? Based on different answers to these questions, three major overviews or perceptions of the proliferation problem can be identified.

The first perspective rests on the basic assumption that reliance on nuclear energy is unavoidable and proliferation may be inevitable, but the latter need not pose a serious threat to vital U.S. interests. There is a corollary view that proliferation will occur only slowly, if at all. *In* either case, exaggerated fears concerning proliferation should not be allowed to jeopardize real U.S. interests, which involve the development of nuclear power as an energy source and the restoring of American preeminence in the global market for nuclear facilities, fuel services, and technology. This would require the United States, infer *alia,* to initiate commercial reprocessing, and to expand its enrichment capacity to service overseas customers and encourage rather than constrain nuclear exports. Moreover, if the United States seeks to exert effective leverage in support of nonproliferation objectives, it must do so from a position of predominance in international nuclear commerce.

The second perspective begins by accepting the proposition that there is an indissoluble link between the spread of civilian nuclear energy and proliferation. Where the previous perspective adjudges the need for nuclear energy as overriding and imperative, this perspective disagrees and assigns primary importance to containing proliferation—which is seen as posing a lethal threat to U.S. and global security. Since proliferation can only be stopped if the growth of the nuclear industry is curtailed, the primary task of policy is to reemphasize the use of nuclear power as an energy source and to develop alternatives. The alternatives would consist of developing coal as a transitional fuel, and long-term reliance on such renewable and environmentally benign energy sources as solar, wind, and organic conversion supplemented by conservation and recycling.

The third perspective assumes that the potential linkage between civilian nuclear energy and proliferation can be broken, i.e., it is possible to obtain the benefits of the commercial atom without entering into a Faustian bargain involving the spread of nuclear arms. This will require policies designed to:

(1) Promote an international political climate in which the incentive to "go nuclear" is minimized.

(2) Improve national and international institutions and procedures through which nuclear facilities and materials can be effectively safeguarded against national and subnational diversion.

(3) Strengthen national and international controls over the availability of weapons-grade nuclear material and the technology and facilities required to produce it.

(4) Develop and apply sanctions designed to reverse any proliferation which does occur and to deter other would-be proliferators.

(5) Develop reactors and facilities which, due to their technological characteristics, are inherently less susceptible to use for weapons-related purposes.

Pursuant to these objectives, a wide range of policies have been proposed or actually implemented (enumerated below). While some of the following policies will be congenial to advocates of all three major perspectives, this inventory is associated primarily with proponents of the third perspective, because the premise that nuclear energy and weapons can be decoupled opens the way for a detailed consideration of policies to achieve that result.

To be successful, policies must affect either the motivation of a Nth country contemplating the nuclear weapons option or the availability of materials and technology required. The former class of policies will be designated demand policies and the latter supply policies.

Demand Policies

One group of demand policies are those designed to weaken the incentives toward proliferation by non-weapon states. These include efforts to:

(1) Strengthen the security of Nth countries by means of a declaration by the nuclear weapon states foreswearing the use of such weapons against any non-nuclear state, security guarantees, alliances, deployment of U.S. troops and military facilities overseas, military assistance, and the overseas deployment of U.S. nuclear weapons and delivery systems.

(2) Reduce the prestige associated with a nuclear weapons capability by superpower arms control agreements; by dampening the rhetoric of the strategic balance and the accompanying impression that the United States views nuclear weapons as the sine qua *non* of its own security; and by attempts to increase the salience of conventional armaments and nonmilitary instruments of power.

(3) Resolve international disputes in which one of the protagonists might conclude that a favorable outcome could be achieved with the acquisition of nuclear weapons.

Attempts to implement these proposals will encounter a number of difficulties, the most serious being that they may conflict with other important U.S. foreign policy objectives, including attempts to scale down American military and security involvements overseas,

Other demand policies seek to strengthen the disincentives that confront Nth countries contemplating the nuclear weapons option. These include efforts to:

(1) Maintain the high technical and economic costs of acquiring nuclear weapons by subjecting all transfers of sensitive nuclear technology, materials, and facilities to strict controls.

(2) Increase the political costs by reinforcing the existing international norm against proliferation,

(3) Provide the external conditions (e.g., economic assistance) that would tend to strengthen the hand of those domestic political forces within Nth countries opposed to the nuclear weapons option.

(4) Develop sanctions designed to raise the costs (economic, political, or security) of any decision to acquire nuclear weapons. Examples include a cutoff of nuclear materials and assistance, a curtailment of bilateral economic and military assistance, a U. N.–imposed trade embargo, and even the threat of military force.

A variety of difficulties will confront any effort to implement these policies—the most serious being a nationalistic reaction on the part of the target states. This will be particularly true in the case of sanctions imposed by one or both of the superpowers. Under the circumstances, accusations of imperialism, neocolonialism, and great power hegemony will be unavoidable. These considerations suggest the limitations of unilaterally imposed disincentives and sanctions. Sanctions will generally make their most effective contribution to a nonproliferation strategy if they are applied in the context of a collaborative effort. The effectiveness of even multilateral disincentives and sanctions is not assured. For the majority of nations possessing limited economic and technological capabilities and lacking an indigenous uranium supply, strong multilateral measures will probably suffice to foreclose the nuclear option for the foreseeable future. On the other hand there are nations, like Argentina, which possess or soon will possess the requisite capabilities and indigenous uranium sources. If Argentina decides to produce nuclear weapons, the international community can raise the cost but probably cannot prevent it short of a resort to military coercion.

Supply Policies

There are several major categories of supply policies. The first involves controls over exports of nuclear materials, technology, and facilities. The major provisions agreed to at the Suppliers Conference have already been outlined. A number of steps might be taken to strengthen that agreement, including a requirement that importers accept full fuel cycle safeguards (or NPT membership) and that a combination of automatic and presumptive predetermined graded sanctions be imposed in the event a recipient state violates or abrogates the terms of an export agreement. Related steps might involve the creation of an international exporters' cartel with guaranteed market shares, so as to prevent export competition at the expense of safeguards, and the imposition of particularly stringent controls over exports to high risk areas (e.g., the Middle East).

Export controls are difficult to implement successfully. Not only must the natural rivalry of exporters be dampened, but importers must be persuaded that the terms are fair and the burden acceptable. If not, they may evade controls by constructing national nuclear facilities—the worst possible outcome from a nonproliferation perspective. In areas prone to conflict and instability even extraordinary safeguards and other precautions may prove ineffective.

A second major category of supply policies encompasses efforts to control the spread of reprocessing plants. It is generally agreed that diffusion of national reprocessing facilities will significantly increase opportunities for proliferation, but there are two schools of thought concerning what policies should be adopted to deal with the situation. The first, a "containment" view, rests on the assumption that the growth of a global reprocessing industry is virtually inevitable and can only be contained and managed. Specifically, reprocessing plants can be confined to the present supplier countries and multinational fuel cycle centers. A strategy designed to achieve this outcome might include some of the following elements: (1) Steps to reestablish the United States as a reliable international supplier of low-enriched reactor fuel and spent fuel services; (2) An agreement by all suppliers to refrain trom the export of both plutonium and reprocessing facilities and technology; (3) Establishment of an international spent fuel regime under existing IAEA statutory authority. If the containment approach is judged inadequate, the logical alternative is to eliminate reprocessing entirely. Proponents of this approach are generally convinced that the spread of reprocessing / recycle is not inevitable, and that its proliferation-related costs outweigh any energy benefits. A policy to implement this approach would comprise the same elements as for containment, with two exceptions. (I) Plans for domestic civilian reprocessing would be suspended until the exhaustion of commercially useable uranium reserves, and (2) Alternate fuel cycles, alternate reactor types, and technologies for extracting the energy in spent fuel without separating plutonium would be explored on a high priority basis.

Both these approaches will have to overcome major obstacles with regard to waste disposal and political resistance on the part of U.S. public opinion (e.g., with regard to the expense of the program). An attempt to institute a global moratorium on reprocessing will encounter strong objections from European supplier nations and Japan which are already committed to reprocessing.

Enrichment controls constitute a third type of supply policy. Like reprocessing, enrichment technology and facilities provide a means of acquiring bomb-grade material. Unlike reprocessing, maintenance of an adequate enrichment capacity cannot be avoided if the civilian nuclear energy industry is to meet the rising demand for electrical power. The proliferation potential in an expansion of enrichment capacity can be dealt with in two ways: by supplier controls over exports of technology and facilities, and by confining enrichment plants to the existing supplier states or multinational centers.

A fourth set of supplier policies concerns efforts to strengthen the nonproliferation regime. This would involve policies designed to make a commitment to nonproliferation more attractive to non-nuclear weapon states on the one hand, and steps to strengthen the control aspects of the regime on the other, In the former category are the following initiatives: (1) Negotiate a comprehensive test ban and a new strategic arms control agreement by the superpowers; (2) Accord preferential treatment to NPT signatories (e.g., concerning enrichment services); (3) Expand the participation of non-nuclear states in decisions regarding peaceful nuclear activities within an international framework. Policies in the latter, or control, category include: (1) Link nuclear exports and economic aid to adherence to the NPT by the recipient state; (2) Strengthen IAEA safeguards (e.g., by extending the application of existing safeguards to prevent intelligence efforts and capabilities with regard to proliferation; and (3) Encourage the creation of nuclear-free zones in appropriate regions.

Other major types of supply policies include: (1) Global and regional arrangements, including multinational fuel cycle centers and schemes for the internationalization of various stages of the fuel cycle; (2) Assistance to other countries in the development of non-nuclear energy sources; (3) Technological measures including efforts to develop a non-proliferating reactor; and (4) Measures to neutralize the non-state adversary threat, including efforts to upgrade physical security measures in the United States and abroad.

Policy Implementation

A taxonomy of available policies has been presented. The next logical step is to order those policies in terms of either their priority or the logical time sequence in which they might be addressed. In a simple three-stage time sequence, the criteria for distinguishing between the categories might be urgency, time required for implementation, and feasibility (in terms of technical difficulty, economic and political cost, and whether the desired initiative can be taken unilaterally by the United States or whether it requires collateral actions by other governments).

A preliminary effort to categorize major policy areas in terms of these criteria produced the following ranking (in terms of priority):

Stage I

- Export controls
- Enrichment
- Strengthen national intelligence capabilities
- Forego plutonium recycle

Stage II

- Contain plutonium recycle
- Weaken incentives
- Strengthen disincentives
- Neutralize non-state adversaries
- Assistance regarding non-nuclear energy sources
- Strengthen the nonproliferation regime
- Sanctions
- International spent-fuel storage regime

Stage III

- Global and regional arrangements

Existing bilateral and international agreements impose constraints upon policy.

Nevertheless, the choice, both at general and specific levels of policy, remains open to a significant degree. However, projected growth rates in the global nuclear industry, trends in international politics, and imminent technological innovations threaten to foreclose major options. It will constitute a major failure of our public institutions if the choice is made by default-a mindless product of the course of events. When the stakes are so high, it is imperative that the choice be conscious and informed.

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