FACING REALITY

BEYOND the BOMB

Dismantling Nuclear Weapons and Disposing of their Radioactive Wastes

FACING REALITY reports are published under the auspices of the Council on the Department of Energy's Nuclear Weapons Complex of the Tides Foundation's Project for Participatory Democracy. A Management Committee oversees each publication.

BEYOND THE BOMB is the third in a series of Council publications, preceded by *FACING REALITY: The Future of the U.S. Nuclear Weapons Complex* and a companion *Citizens' Guide to the Future of the U.S. Nuclear Weapons Complex.*

Dismantlement of U.S. nuclear weapons and disposition of their radioactive wastes demand thorough discussion by both professionals and concerned citizens organizations. Resolution of current problems and issues is important both domestically and for the United States to take leadership among nations in containing global proliferation of nuclear weapons and their components. To exert effective leadership the United States must address its own nuclear arsenal problems with credibility, including public disclosure of its plans and actions.

This publication, based upon professional research and analysis, is intended for wide use by policy-makers and citizens groups concerned with the future of the U.S. Nuclear Weapons Complex.

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This report is based upon published government documents and the research efforts of many independent experts and organizations. Cooperating in producing the current report has been the Military Production Network, a national alliance of organizations working to address issues of nuclear weapons production and waste cleanup.

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OVERVIEW

by Peter Gray

Beyond the Cold War

It will be recorded as perhaps the largest and most dangerous endeavor in history. Across the United States and the former Soviet republics, vast factories were built and hundreds of billions of dollars were spent in order to pile up nuclear arsenals of inconceivable destructive power. With that exotic profusion of nuclear bombs and missiles came elaborate strategies and preparations for every imaginable contingency.

Except one—the end of the Cold War, along with the collapse of the Soviet Union and a series of dramatic arms reduction treaties. The United States and the former Soviet republics now host a combined arsenal estimated at about 50,000 nuclear warheads. Under expected arms reductions, more than 80 percent of these weapons will be retired and taken apart. Something must be done with the nuclear materials they contain.[1]

At best, the task of nuclear weapons dismantlement and materials disposition will require several decades and billions of dollars.[2] While some aspects of the process are more clear than others, no person or group yet has all the facts necessary for advocating exactly where, when, and how dismantlement and disposition should occur. Therefore this document does not offer a precise schedule for dismantlement or a definitive plan for disposition. Instead it draws from the available information in order to outline the challenges ahead, and it sets forth a set of explicit criteria to be used for choosing among disposition options.

The U.S. nuclear weapons complex was caught unprepared for dramatic arms reductions following the end of the Cold War and the collapse of the Soviet Union.

Disassembly of surplus weapons will leave large quantities of "fissile materials"—plutonium and highly enriched uranium (HEU)—the two key ingredients of nuclear bombs. Both materials pose hazards to human health and international security. Keeping these materials from contaminating the environment and from being used in future weapons poses a challenge closely connected to perhaps the greatest single threat to humanity—the continued spread (proliferation) of nuclear weapons.

Of the two key nuclear materials, plutonium is particularly dangerous. Capable of causing cancer if inhaled in quantities of one-millionth of an ounce, it is very risky to handle and it could be used as a weapon of radiological terror.[3]

Three to five kilograms of plutonium are sufficient to construct a nuclear weapon. Total U.S. and Russian military plutonium stockpiles contain about 250 metric tons of it—enough for up to 75,000 warheads.[4] Roughly half this inventory is in the United States. Plutonium is difficult to dispose of due to its relative ease of use in weapons, its severe biological hazards, and its 24,000 year radioactive decay half-life (the period required for half of a given quantity of plutonium-239 to be changed into a less radioactive element—uranium-235). Military plutonium cannot be made unusable for weapons by diluting it with other kinds of plutonium.

Energy Secretary O'Leary has taken aggressive steps toward increased openness and accountability, but large portions of the DOE bureaucracy are stubbornly resisting reform.

The other key material—highly enriched uranium—can be diluted with conventional uranium. With sufficient dilution, it is not a greater proliferation threat than that posed by widely available commercial reactor fuel, which is not directly usable as a primary weapon component. Because it is much less radioactive than plutonium, HEU poses less severe health and environmental hazards, but it too is radioactive, it has a decay half-life of more than 700 million years, and it is a toxic heavy metal.

In some ways HEU might be a more immediate threat to global security than is plutonium. While more HEU than plutonium is required to make a simple nuclear bomb, a reliable uranium bomb is easier to design. U.S. and former Soviet HEU stockpiles are about ten times larger than their inventories of military plutonium, and in the United States the sizes and conditions of HEU stockpiles are shrouded in excessive secrecy.

Department of Energy (DOE) Secretary Hazel O'Leary and some of her staff have taken aggressive steps toward an era of increased openness and accountability. While only a small fraction of DOE's secret documents have been released so far, numerous stories of irresponsibility, radiation experiments on unknowing human subjects, and other horrifying events have been revealed. This reform effort is an essential first step toward rectifying past abuses and starting on a better future path.

However, an influential coalition made up of military contractors and their Congressional allies resists policy changes that would adapt to the new political and strategic reality. Large portions of the vast DOE bureaucracy are stubbornly resisting reform in an effort to continue their programs as if the arms race had not ended.

For decades overly zealous secrecy has been standard operating procedure within the nuclear weapons production complex. For good reasons, citizens have developed a high level of distrust for nuclear weapons plant managers and their activities. Any dismantlement and disposition decisions—regardless of their technical merits—will face stiff opposition unless they are made with genuine public participation. Concerned citizens need to take advantage of opportunities to cooperate with new DOE leadership, while understanding that their knowledge and political pressure are still essential to formulating rational policy.

A Framework For Action

- **Release Information** – In the interest of international openness and public trust, data on the U.S. nuclear weapons stockpile and inventories of key nuclear materials should be declassified.
- **Dismantle And Store Warheads** – As quickly as possible without accident or contamination, warheads withdrawn from deployment should be dismantled and stored securely.
- **Process Materials for Disposition** – The key nuclear materials, particularly plutonium, must be put into forms that minimize environmental risk and are at least as difficult to extract for re-use in weapons as it would be to obtain them from other available sources.
- **Arrange For Intermediate Security and Storage** – Plutonium might be put into a form that minimizes the risks of contamination or re-use in as little as a few years, but the selection and development of a final disposal method might take much longer. Planning for an intermediate storage facility should begin soon.
- **Final Disposition** – Proposals for developing and locating long-term disposal facilities must be debated openly and honestly.

These steps must be carried out so that actions taken do not preclude valid options later. Methods and processes should be judged against the criteria described in more detail on the following pages: 1) Discouraging Proliferation, 2) Protecting Safety, Health, and Environment, 3) Timeliness, 4) Sound Economics, and 5) Openness and Accountability.

What Next? Dealing with the Garbage

Even officials who have access to classified information face failure if they attempt to proceed based upon that data alone. Additional scientific and economic research must be undertaken before the various materials processing and disposition options can be fairly compared. Interminable research contracts, however, should not be used as a device to maintain the status quo. Open review from outside the nuclear industry will be essential in order to distinguish dangerous pork-barrel options from cost-effective alternatives that promote security and environmental protection.

The United States is in a position to lead the world toward fulfillment of the nuclear disarmament provisions of the Non-Proliferation Treaty.

Some steps should be taken immediately. For arms reduction agreements to be lasting and meaningful, dismantlement must be conducted as openly as possible, with international monitoring, and warhead components should be processed in ways that prevent easy reassembly. Such steps are necessary to foster an environment of trust and to lay the foundation for ultimately disposing of materials from retired warheads.

We propose five criteria for making plutonium disposition decisions. These criteria also apply to other aspects of the U.S. dismantlement program, including disposition of HEU:

1. **Be Consistent With Nonproliferation Goals** – A global nuclear holocaust appears less likely than in the past, but the risk of regional arms races, inadvertent or intentional nuclear war, and terrorism remains. U.S. leadership is essential. Our internal policies must be consistent with those we are asking other nations to adopt. Other countries are unlikely to comply with international monitoring if the United States does not accept similar measures. U.S. policy must be designed to provide the least possible direct or indirect encouragement to potential proliferators.

   The United States is in a position to lead the world toward fulfillment of the nuclear disarmament provisions of the Non-Proliferation Treaty, signed by the United States in 1968.[5] It should help reduce the demand for nuclear weapons as well as strengthening the barriers to obtaining key nuclear materials.

   Surplus plutonium and HEU should be put into non-weapons-usable forms as quickly as possible in compliance with environmental, health, and safety laws. In practice this means that both materials must be diluted or contaminated to the point at which their extraction is at least as difficult as obtaining them from commercially available uranium or from spent reactor fuel.

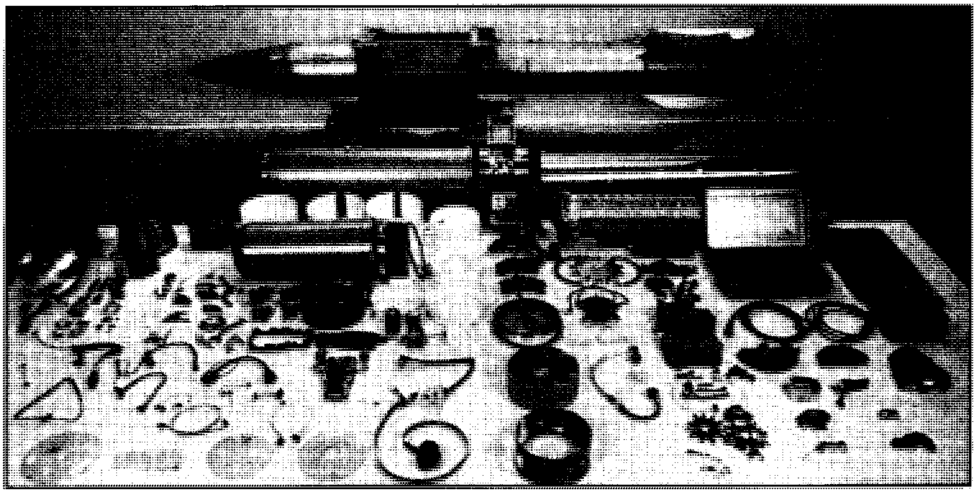
In addition to seeking a ban on military production of these materials, the United States should discourage their civilian uses. At a minimum, the significant dismantlement and disposition activities of all countries must be subject to international accounting and verification. U.S. resistance to such oversight will discourage cooperation by other nations, in particular the former Soviet republics.

2. **Protect Human Health, Safety, and the Environment** Because the key nuclear weapons materials are hazardous and very long-lived, their handling and processing practices must not jeopardize workers, future generations, or the environment. Nuclear materials from retired weapons should be isolated in the most stable forms feasible, consistent with non-proliferation.

   To control hazards to workers and citizens, surplus warhead materials should be put through the minimum of processing and transportation steps, consistent with safe, permanent disposal. Because of the quantities of radioactive waste that it would generate, the "reprocessing" of spent reactor fuel in order to re-use plutonium should be rejected.

3. **Act Soon** – An otherwise ideal technology that requires decades of research and development before it can be used might arrive too late to help prevent proliferation and environmental damage. The uncertain future of the nuclear-armed former Soviet republics, and the potential for black-market sales of nuclear warheads or materials demand that secure and verified procedures be established quickly. Plutonium disposal, however, should not be rushed to the point of creating future health risks or environmental damage.

Dangerous nuclear materials from retired weapons should be isolated in the most stable forms feasible, consistent with non-proliferation efforts.



U.S. Department of Energy

A "B-61" nuclear bomb in several stages of disassembly.

4. **Control Economic Costs** – When options are identified that satisfy the above criteria, their costs should be analyzed and compared. For example, the purported benefits of any proposal requiring expensive facilities such as new reactors should be examined carefully. Reliable estimates of short and long term costs, hazards, and benefits should be used for comparison (see page 8).
5. **Be Open With Our Citizens** – Viable U.S. plans for dismantlement and disposition cannot be formulated without accurate information on nuclear safety, material inventories, and proliferation risks. Further, they cannot be implemented without public support and understanding. Continued secrecy about nuclear weapons and materials stockpile data blocks progress toward global accounting of these items.

   A welcome step to dispel secrecy has come with the Clinton administration's "openness in government" initiative. Consistent with that policy, in late 1993 DOE Secretary O'Leary began declassifying portions of a set of documents dating back to the 1940s. While it is valuable to set straight the historical record, of equal importance will be a commitment by DOE to make future decisions with genuine public participation, and holding government officials and private contractors accountable for their actions.

Our five criteria make it possible to quickly eliminate several proposed plutonium disposition methods.

These standards should be applied immediately to the problems of verified warhead dismantlement and storage at the Pantex site in Texas—where warheads are initially disassembled and plutonium components are stored—and at Oak Ridge, Tennessee—the site of secondary disassembly and HEU storage.

Disposing of Hopeless Proposals

While the five criteria listed above are difficult to meet simultaneously, they make it possible to quickly eliminate the following methods currently being proposed for long-term disposition of plutonium.

- **Transmutation** – Theoretically, plutonium could be changed into non-weapons-usable materials in a linear accelerator or a special type of nuclear reactor by irradiating it with high-energy neutrons. This method fails on economic and environmental grounds, and in terms of time requirements. It would require extensive research, costly new facilities, and a long lead time before processing could begin. It would also generate additional highly radioactive waste.

- **Burning Plutonium in New Reactors** – Several nuclear reactor designs have been proposed that could, in theory, "burn" some proportion of the plutonium with which they are fueled, generating electricity in the process. This option, however, fails to meet any of the first four criteria. Plutonium fuel is unlikely to become economical for at least another century, and any plutonium fuel cycle poses unavoidable proliferation risks and waste disposal problems, while offering benefits that are debatable at best. Every new reactor option would require the investment of tens of billions of dollars and at least 10-20 years development and construction time before processing could begin.

- **Underground Explosions** – Many plutonium components could be placed in an underground cavity surrounding a nuclear bomb that when exploded would vaporize the plutonium and supposedly leave it mixed with glassified rock. However, such a method would violate several criteria.[6] It would undermine nonproliferation efforts by threatening prospects for a global Comprehensive Test Ban Treaty, and it would leave vast quantities of plutonium in uncontrolled underground waste dumps.

- **Space Launch** – Plutonium could be permanently eliminated if it were launched into space and sent into the sun (or in any direction at Earth's escape velocity). However, any foreseeable space launch technology would have an unacceptably high catastrophic failure rate. To dispose of most U.S. military plutonium, NASA has estimated a present day cost for launch alone of at least 30 billion dollars.[7] Space disposal would require several hundred space flights, and proven technologies have serious accidents in about four percent to five percent of launches.

- **Sub-Seabed Disposal** – Individual plutonium "pits" from weapons might be encased in heavy bronze or stainless steel containers and dropped into deep sea trenches, where they would plunge tens of meters into the sediment, possibly preventing environmental contamination and human access long enough for the plutonium to decay. There are concerns, however, about possible future retrieval and re-use, however, and many experts are concerned that any exception to the global treaty banning ocean disposal of radioactive waste could undermine the entire accord. The potential for recovering plutonium in weapons-usable form might pose an irreversible proliferation risk.

Comparing The Costs

A November 1993 RAND National Defense Research Institute study, funded by the Department of Defense analyzes processing and disposition options for plutonium and HEU.[8] The report's authors are blunt in their assessment of plutonium's value:

> *"We found that military plutonium is a liability rather than an asset."*

Under generous assumptions, the RAND analysis predicts that plutonium fuel will not be economical for at least 50-100 years, and advises against storing plutonium in reactor- or weapon-usable forms. The report also says

> *"Countries...should be encouraged to phase out their plutonium and [uranium] enrichment activities or at least not to expand or build more."*

While the RAND economic findings for plutonium disposition are summarized in the table below, the report's authors note,

> *"The key policy factor should still be the proliferation risk in each option, not economics."*

Option	**Cost for 100 metric tons**
Mix with waste	$100 million
Store for 20 years*	$380 million
Once-through MOX** (WPPSS-type reactor)	$560 million
Once-through MOX** (ALMR-type reactor)	$1.8 billion
Space launch (optimistic estimate)	$5 billion
Space launch (NASA estimate)	$30 billion

*Similar storage costs are expected whether the plutonium is eventually mixed with existing spent fuel or converted to spent fuel using a reactor.

**Reactor options using mixed-oxide fuel are discussed on pages 14 through 16.

RAND's report notes that if plutonium were recycled through reactors in order to transform higher proportions of it into radioactive waste, reprocessing costs would significantly increase the MOX (mixed-oxide fuel) option costs listed above.

WARHEAD DISMANTLEMENT AND MATERIALS DISPOSITION

ENVIRONMENT, SAFETY, HEALTH

by Arjun Makhijani

Some scientists and policy-makers have viewed plutonium as an instrument to save humankind. It could be used in nuclear weapons to "bring the world into a pattern in which the peace of the world and our civilization can be saved," according to Henry Stimson, Secretary of War during World War II. It would provide a "magical" endless energy source for everything from airplanes to heated Scuba diving suits.[9]

The reality has been quite different. As a fuel, plutonium has proven too hazardous and costly. After the Cold War, plutonium is more of a security and proliferation threat than a source of strength.

There are about 400 metric tons of military and civilian separated plutonium in the world today–most of it in U.S. and former Soviet stockpiles.

Basic Science

There are several isotopes of plutonium, and samples from nuclear weapons generally contains a mixture of them. They are:

Plutonium-239 – this predominant isotope emits alpha radiation which is not very penetrating (it cannot pass through a sheet of paper), but is highly damaging if lodged inside the body.

Plutonium-240 – this form emits neutrons that penetrate containers and increase the radiation dose to workers.

Plutonium-241 – is present in small quantities and decays radioactively into another radioactive element—americium-241—which emits penetrating gamma radiation. Plutonium components of nuclear weapons become more dangerous for workers to handle as the americium accumulates with age.

Plutonium, a synthetic element, is created by nuclear reactors. Spent reactor fuel contains a mixture of uranium, plutonium, and highly radioactive "fission products." In order for the plutonium to be used in weapons, it must first be separated from spent fuel through a chemical or electrochemical process. That is why civilian spent fuel does not pose a proliferation danger as long as the plutonium in it is not separated.

There are about 400 metric tons of separated plutonium (not including a much larger quantity still embedded in spent nuclear reactor fuel) in the world today—most of it in U.S. and former Soviet military stockpiles.[10] Plutonium-239 has a half-life of about 24,000 years, while the second most common component, Pu-240, takes 6,500 years to decay by half. After 50,000 years, roughly 20 percent of the today's plutonium inventory will still exist.

Nuclear Poison

Research using animals, combined with limited data on human exposure, has established that extremely small quantities of plutonium induce cancer, especially if inhaled as a fine powder. With virtual certainty, one-millionth of an ounce of inhaled plutonium oxide dust will cause lung cancer in humans. Soluble forms of plutonium can remain in bone and in soft tissues such as liver, kidneys, and ovaries, increasing the risk of cancer in these organs. A few micrograms of internal plutonium appreciably increase the risk of cancer.

Plutonium's dim economic prospects and its human health, environmental, and proliferation hazards imply that it should be treated as a dangerous waste, not as a valuable resource.

Plutonium storage poses several dangers. First, in its pure metallic form (as used in weapons), plutonium is dangerous to handle and process due to its tendency to ignite if exposed to air. Fire is especially dangerous because it converts plutonium into small airborne particles of plutonium oxide that can be inhaled.

Second, warhead components will necessarily stay in storage sites for years or decades. Plutonium-241 gradually decays into gamma-emitting americium-241, so that prolonged storage increases the risks faced by workers. Finally, storing plutonium for prolonged periods can pose nuclear proliferation risks due to the potential for theft or diversion.

Production and Processing Hazards

Plutonium production for weapons at DOE's Hanford, Washington and Savannah River, South Carolina sites has left two of the most extensive waste and contamination legacies in the United States. Plutonium metallurgy at the Rocky Flats plant has also created serious contamination problems and two major fires—in 1957 and 1969—the health effects of which are still being debated.

The high cost of producing the plutonium in nuclear weapons does not imply that it has any economic value. In fact, it would cost more to process existing plutonium for use in reactors than to simply buy uranium fuel. The ample known reserves of inexpensive uranium make plutonium's economic prospects very dim for at least another century. Its human health, environmental, and proliferation hazards are additional reasons for a firm decision to treat plutonium as a dangerous waste.

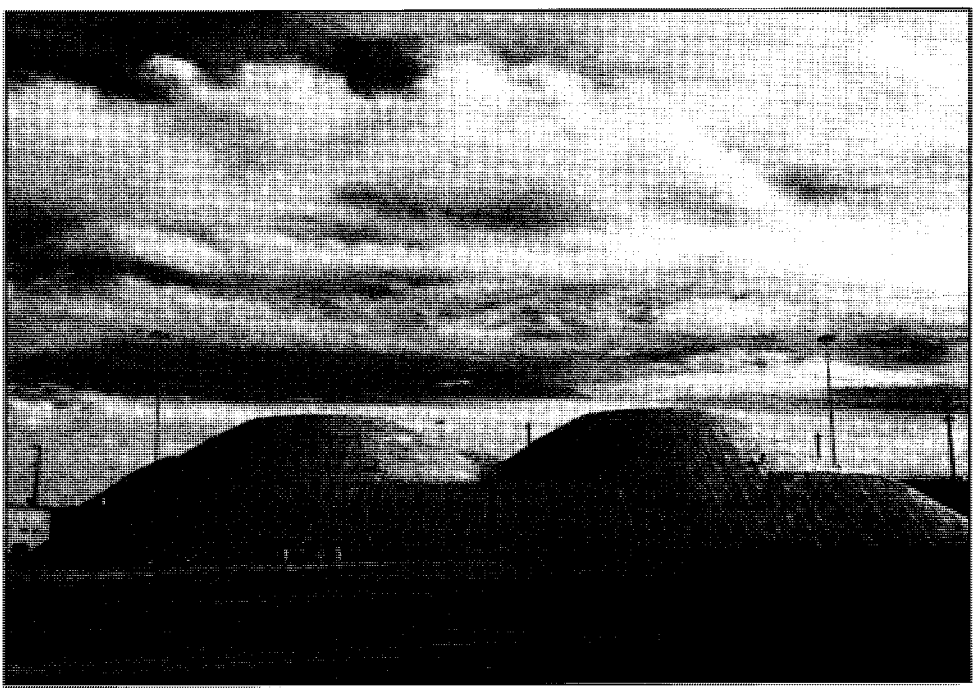
PLUTONIUM STORAGE TODAY: A Test Case for DOE

by Beverly Gattis

Changed international conditions demand extensive reform in the U.S. government's assumptions and methods of dealing with nuclear weapons. The U.S. Department of Energy must develop new procedures reflecting the need for openness and public responsibility. The government must learn to work effectively at the local level in order to be capable of responding to international imperatives. The opportunity for lasting mutual arsenal reductions is now testing DOE's capacities and intentions.

The opportunity for mutual arsenal reductions is testing DOE's capacities and intentions.

With many of DOE's facilities in dubious condition, and some capabilities completely missing except on a laboratory scale, the demands of dismantlement and storage are falling on a limited and ill-prepared complex. DOE's approach to the challenging combination of world change and shifting national security priorities has been troubling. The problems stem less from the fact that old facilities are being used, which is inevitable for now, than from how DOE is proceeding in this new era.



The Pantex nuclear weapons assembly/disassembly plant near Amarillo, Texas.

Safety Problems

An October 1993 report from the U.S. General Accounting Office (GAO) notes a variety of safety and operational problems at Pantex, DOE's dismantlement facility located near Amarillo, Texas.[11] The study says:

> *"Safety analysis reports are important because they establish a basis to determine that a facility can operate safely and to conclude that operating the facility does not pose an unacceptable risk to public health and safety. ...Pantex currently has completed fewer than 50 percent of the required safety analysis reports."*

. . . .

A GAO official has said, "Pantex is probably one of the worst, in terms of occupational safety and health of any of the facilities."

According to the New York Times,

> *"Victor S. Rezendes, a manager at [GAO] who has supervised the audits of many nuclear weapons plants, said, 'Pantex is probably one of the worst, in terms of occupational safety and health of any of the facilities.'"*

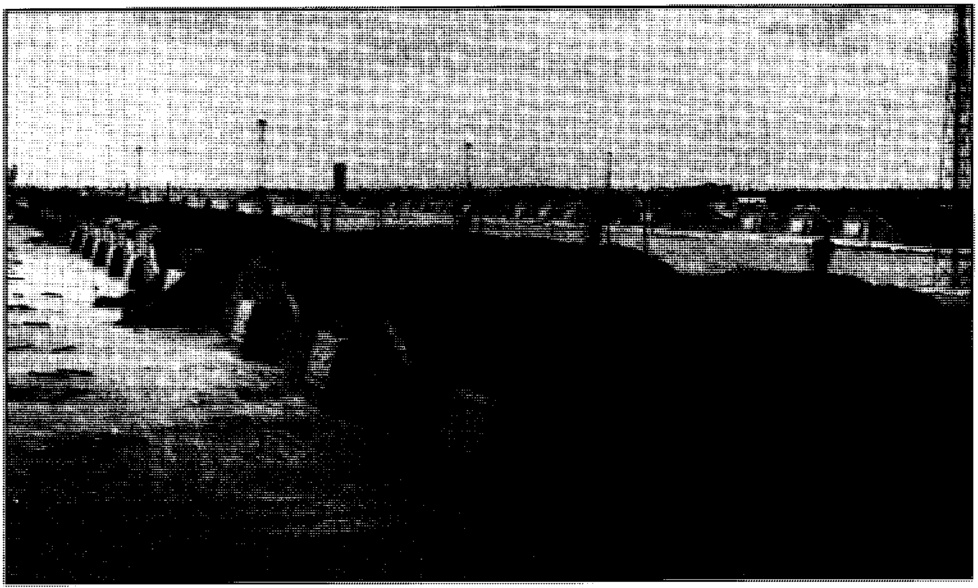
Citizens living near the plant understand the value and necessity of dismantlement, but they still ask, "How can this work be done safely?" The answers have been unsatisfactory and piecemeal.

Storage Capacity

Plutonium cores, or "pits", from dismantled warheads are being stored in World War II-vintage munitions bunkers at the Pantex facility. Since storage space at Pantex is limited under current operating procedures, in April 1992 DOE began an Environmental Assessment proposing operational changes and the use of additional bunkers to store all the pits generated by dismantlement.

Drafts of the Environmental Assessment have been controversial in their fundamental approach, have contained errors, and have failed to objectively evaluate the storage capabilities in the current weapons complex which could help fulfill urgent near-term needs. The first draft claimed that the bunkers would be needed for only 6-10 years of storage (which was unrealistic-ally short), but the second draft set no time limits—suggesting that the bunkers would be used until long-term decisions are implemented.

If the storage method for plutonium from dismantled warheads is troubling, the paucity of information about how hundreds of tons of highly enriched uranium (HEU) are to be stored is appalling. DOE has refused to reveal even which buildings at the Y-12 facility in Oak Ridge, Tennessee are used for this material, much less the conditions under which it is stored. Not until December 1993 did DOE announce an Environmental Assessment to address HEU storage.



U.S. Department of Energy

Plutonium "pit" storage bunkers at the Pantex site.

Crucial Choices

It is one thing to have to depend on current facilities of questionable safety, but quite another to gloss over problems or refuse to take a comprehensive public look at the demands arsenal reductions are putting on the entire complex. Storage areas, already crowded with materials and residues from past production, now must accommodate materials from dismantlement as well.

Important decisions are necessary, but it is difficult to make informed choices or judicious compromises when DOE obscures the big picture by breaking it into disjointed pieces. Comprehensive, coordinated, publicly accessible planning needs to be done by DOE to address how to "temporarily" store materials—possibly for decades—until long term decisions are made, funded by Congress, and implemented.

Citizens are frustrated and worried. They remember the mismanagement, contamination, and health and safety hazards spawned by secrecy, closed decisionmaking, and a drive to "get the job done." They see the same thing happening again, this time in the name of dismantlement. Although the work is important and DOE's neighbors are willing to see it through, they refuse to endure unnecessary risk. Dismantlement must mark a new beginning in how the United States conducts its nuclear weapons work—not only for the sake of world peace, but for the sake of its own citizens and the democratic principles upon which they rely.

EXISTING REACTORS:
Can They Dispose Of Plutonium?

by Peter Gray

The need to somehow cope with about 100 metric tons of surplus U.S. military plutonium has inspired a host of proposals for "burning" it in nuclear reactors.

"MOX"

Using existing reactors in a "once-through mixed oxide (MOX)" fuel cycle has been advanced most prominently. In this scheme, plutonium metal would be converted to an oxide form, mixed with uranium oxide, and made into fuel pellets. The MOX fuel would then be used once in civilian reactors of appropriate design. Although a relatively small fraction of the plutonium would be consumed, and energy recovery would be modest, there could be some potential advantages: 1) no reprocessing would be required; 2) known technology and existing facilities might be used; and 3) the remaining plutonium would be contaminated with isotopes that would make it less attractive for recovery and reuse in weapons.

. . . .

For economic, physical security, proliferation, and liability reasons, electric utility companies have shown little interest in plutonium fuel.

However, a recent RAND study points out that if enough MOX-fueled reactors were constructed to process U.S. military plutonium within 5-10 years, the reactors would be operational for another 20-30 years, and "would provide an added demand for the plutonium being separated by reprocessing. ...it seems inadvisable to enter into a situation that is much more likely to generate proliferation risk than economic benefits."[12]

In any case, reactors now operating in the United States are not currently licensed for this option. Either many decades or numerous reactors would be needed to process surplus military plutonium. For economic, physical security, proliferation, and liability reasons, electric utility companies have shown little interest in the idea.[13]

MOX For The Russians?

While details of Russian plutonium processing are beyond the scope of this document, some independent analysts have proposed a MOX option for taking Russian plutonium out of readily weapons-usable form and converting it into spent fuel.[14] This is a worthy goal, but a number of technical, political, and safety questions have not been fully explored.

However, the specter of more than 100 metric tons of plutonium in weapons-usable form stored in politically unstable

Russia has cropped up recently as a rationale for the "Isaiah Project" in the United States. The project would supposedly set an example for the processing of Russian plutonium.[15]

The Isaiah scheme proposes to complete two unfinished reactors in the Washington (State) Public Power Supply System (WPPSS), operate a MOX fuel fabrication plant at DOE's Hanford site, process surplus U.S. military plutonium, and sell electricity. The two reactors—assuming they could be financed, successfully completed, and were qualified for operating licenses from the Nuclear Regulatory Commission—would require perhaps 40 years to put all surplus U.S. weapons plutonium into spent fuel form.

Many questions have been raised about the Isaiah Project and about its backers' assumptions that plutonium is an asset, that plutonium-fueled reactors can be profitable, and that this method offers advantages over other processes such as vitrification. In addition to those problems, this option fails the environmental criterion and leaves proliferation concerns unsatisfied.

NEW REACTORS: Not Part of the Cure

by Peter Gray and Jill Lancelot

Congress is preparing to pour about two billion dollars—just for preliminary research and development—into a scheme for using surplus plutonium in nuclear reactors. The Advanced Liquid Metal Reactor (ALMR) is a repackaged version of the liquid metal "plutonium-breeder" reactor idea heavily promoted during the 1960s and 1970s as the solution to a supposed imminent crisis of uranium supply. Independent analyses concluded in the 1970s that breeder reactors would not become competitive for about a century—even if U.S. nuclear energy capacity expanded to more than six times its current level. Economic prospects for breeders were dismal then. Twenty years later they are much worse.[16]

Reactor enthusiasts have used deceptive relabeling to imply that "burning up" plutonium from weapons would alleviate the waste disposal burden.

Selling Trojan Pork

Reactor enthusiasts have used deceptive relabeling to imply that "burning up" plutonium from weapons would alleviate the waste disposal burden. Under the rubric of ridding the world of dangerous plutonium, nuclear reactor proponents have lobbied for a backdoor subsidy of new generations of power plants. They say their schemes would pay for themselves—or even generate profits through electricity sales—but this assertion contradicts numerous economic analyses. Any one of these programs would cost taxpayers tens of billions of dollars.[17]

In the late 1970s the United States postponed developing plutonium-fueled nuclear power, primarily on economic grounds. Since then the price of uranium has fallen dramatically and the experiences of countries that did try the plutonium route have confirmed the wisdom of the U.S. decision. Not only would a new generation of plutonium-fueled reactors be very costly, but proven plutonium extraction technologies are dangerous and increase the volume of chemical and radioactive waste. For several centuries after disposal, most of spent fuel's radioactivity will come from "fission products" such as strontium-90 and cesium-137. In the longer term, isotopes such as technetium-99 and iodine-129 will be more hazardous than plutonium compounds because of their greater solubility.[18]

Plutonium "reprocessing" technologies are dangerous and would increase the volume of chemical and radioactive waste.

Finally, if it builds such reactors, the U.S. will tacitly encourage traffic in weapons-usable plutonium, with serious proliferation risks.[19] The Advanced Liquid Metal Reactor is now advertised as a plutonium consumer, but relatively minor modifications could turn it into a producer of weapons-grade plutonium. Although reactor enthusiasts claim that U.S. plants would operate in a "proliferation-resistant" mode, the nuclear weapons Non-Proliferation Treaty obligates the United States to make "civilian" nuclear technology available to more than 150 other treaty signatories.

Unfulfillable Promises

In order to significantly reduce total plutonium inventories, a large complex of reactors would rely on plutonium extraction and recycling. This "reprocessing" poses an unsolvable problem. For the plutonium fuel cycle to be economical, reprocessing would need to somehow become less hazardous and difficult than it has been so far. But such an "advance" would tear down one of the chief obstacles to nuclear weapons proliferation—the high cost of extracting plutonium from plentiful spent fuel.

For all the reasons cited above, before the country opts to subsidize new reactor development the involved parties, including concerned citizens, must have available all information pertinent to the issues at hand, and should participate in open and complete discussion and debate.

PLUTONIUM VITRIFICATION

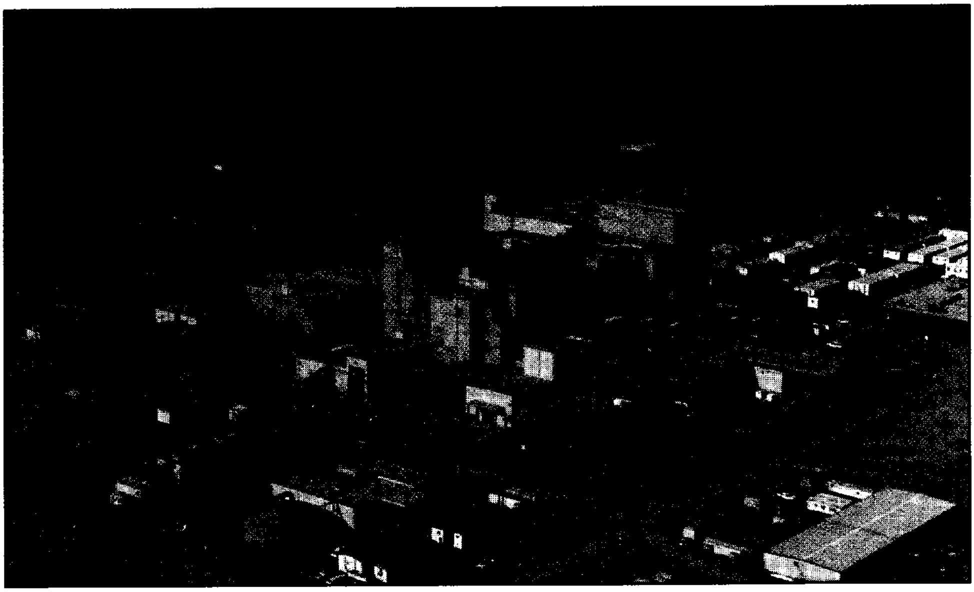
by Brian Costner and Arjun Makhijani

The most practical plutonium processing option currently proposed is called "vitrification." In this process a plutonium compound would be mixed with a special type of sand, melted, and poured into stainless steel containers, where it would cool into a glassy form. Vitrification could make plutonium difficult to use in nuclear weapons while controlling the biological and physical hazards associated with long-term storage and disposal.[20]

In principle, the two plants now being built could vitrify surplus military plutonium along with other radioactive wastes.

Plant Construction Underway

Vitrified waste would require specific temperature and moisture conditions in order to endure long enough for most of the plutonium to decay, but it would be relatively stable and difficult to "mine" in any attempt to reuse the plutonium. Raw materials for making glass are plentiful, and the technology is well developed. In principle the two vitrification plants now being built for processing highly radioactive waste—at the Savannah River Site, South Carolina and West Valley, New York—could vitrify surplus military plutonium along with other radioactive wastes. Disposing of 10,000 warheads worth of plutonium at either plant might require up to 15 years, depending upon the amount of plutonium per weapon and the concentration of plutonium in the glass.

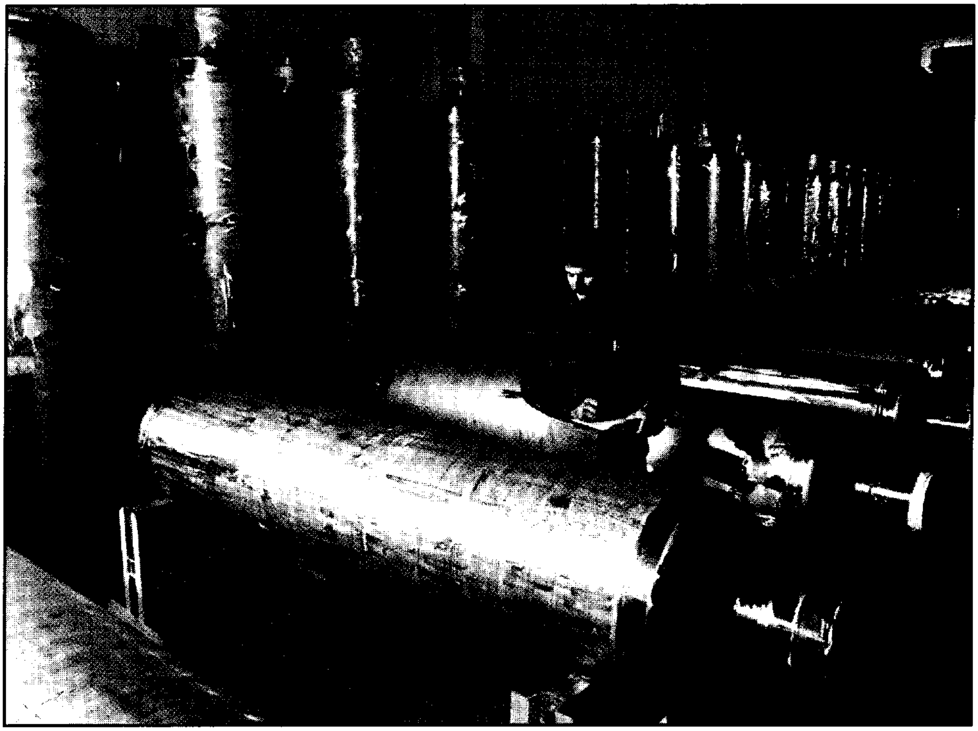


U.S. Department of Energy

The $2 billion radioactive waste vitrification plant near Aiken, South Carolina.

Vitrification Alternatives

Two methods of vitrifying plutonium have been considered. The first would mix plutonium with high-level radioactive waste—such as that from reprocessing activities used to produce the plutonium in the first place—before being fed into a glass melter. The advantage of this method is that radiation emitted by the fission products would increase the hazards and costs of recovering plutonium from the glass. However, the highly radioactive short-lived fission products would increase processing costs and hazards, and within 200-300 years they will lose most of their radioactivity. Vitrifying intensely radioactive waste poses other risks, including the heat generated by decay—a problem if the glass is exposed later to water.



Stainless steel cannisters for vitrified radioactive waste at the Savannah River Site.

Because of complications in processing radioactive wastes in the U.S. nuclear weapons complex, the opening of a completed vitrification plant at Savannah River has faced repeated delays, and work has been postponed on a similar plant at the Hanford site in Washington state. In view of this and of the reduced cost of new vitrification technology, it would probably be better to construct a new vitrification plant specifically for plutonium, whether it is mixed with fission products or not.

The second method could reduce proliferation risks more quickly and cheaply. Plutonium could be converted to an oxide or nitrate form and vitrified by itself in a "stirred glass melter" that would cost about ten million dollars to construct and would require minimal radiation shielding. However, the relative ease with which the plutonium could be recovered from the glass might add to the security costs of storing the final product. If plutonium were diluted sufficiently in the glass, extracting it later might still be about as costly as separation from spent fuel. The nonproliferation criterion would then be met.

Processing plutonium without mixing it with other radioactive waste might allow faster and cheaper vitrification.

A preliminary review of vitrification by the Westinghouse Savannah River Company for the National Academy of Sciences concluded that existing facilities might be adapted to begin vitrifying plutonium early in the next decade. Depending on the option chosen, the review's authors predict that 50 metric tons of plutonium could be vitrified in as little as one to eight years. Total costs to ready the plutonium glass for storage could range from about 100 to 600 million dollars.[21]

These estimates should be viewed as tentative—more research is necessary to evaluate the time and money requirements for vitrifying surplus plutonium. Some technical studies of long-term plutonium storage and disposal indicate safety margins lasting several centuries. However, there is little certainty about safety over the tens of thousands of years during which plutonium will be hazardous.

Vitrification at least deserves serious consideration in the debate over how to dispose of surplus plutonium. If early studies are on target, vitrification might offer a relatively inexpensive and quick way to put large quantities of plutonium into a form compatible with eventual permanent storage or disposal.

THE U.S. IN THE WORLD: The Proliferation Connection

VERIFICATION IS CRUCIAL

by Tom Zamora Collina

As the United States dismantles 75 percent of its nuclear arsenal during the next decade, it will set an important example for other nations—in particular, the former Soviet republics.

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Ideally, all weapons-usable fissile material in all countries should be accounted for in a United Nations registry.

Warhead dismantlement is now proceeding without any inspection arrangements. The United States and Russia have agreed to retire thousands of warheads under the Intermediate-range Nuclear Forces, START I, and START II treaties, but neither country is required to dismantle its warheads, much less open the process to international monitoring. Without reciprocal inspections, the United States will have little control over how Russia and the other former Soviet republics handle more than 30,000 nuclear warheads and the hundreds of metric tons of key nuclear materials they contain.

Verification Steps

To achieve effective and verified warhead dismantlement and materials disposition in the former Soviet Union and lay the foundation for deeper cuts in nuclear arsenals, the Clinton Administration should immediately pursue the following steps along with the former Soviet republics:

- Exchange data on total numbers of warheads, and on total amounts of fissile materials within and outside of nuclear weapons
- Exchange serial numbers and storage locations of all nuclear warheads and bombs
- Install and document tamper-resistant tags on all nuclear weapons
- Institute random inspection of weapon storage sites and track all movements of warheads or components in and out of dismantlement facilities
- Establish openness procedures for all steps in the dismantlement process, from transportation through storage and final disposition
- Institute international safeguards over all civil and excess military stocks of fissile materials, and over plants capable of producing them

President Clinton took a significant step in this direction in September 1993 at the United Nations when he announced that he would submit U.S. fissile material that was no longer needed for weapons to inspection by the International Atomic Energy Agency.

Ideally, all weapons-usable fissile material in all countries should be accounted for in a United Nations registry. Only when these materials are disposed of or diluted so that they are not readily adaptable for weapons should they be reclassified as non-weapons-usable. Verified dismantlement is an essential step toward reducing the long-term threat of nuclear war.

The Future Of Nonproliferation

The nuclear Non-Proliferation Treaty (NPT) expresses its signatories' desire

> *"to achieve the discontinuance of all test explosions of nuclear weapons for all time..." and "to facilitate the cessation of the manufacture of nuclear weapons, the liquidation of all... existing stockpiles, and the elimination from national arsenals of nuclear weapons and the means of their delivery...."*

In its entirety, Article VI of the NPT states:

> *"Each of the Parties to the Treaty undertakes to pursue negotiations in good faith on effective measures relating to cessation of the nuclear arms race at an early date and to nuclear disarmament, and on a treaty on general and complete disarmament under strict and effective international control."*

Many developing countries are displeased with the nuclear powers' failure to reach these stated goals, and the lifespan of the NPT after 1995 is in question.

The declining U.S.-Soviet balance of nuclear terror could degenerate into an unstable multipolar "nuclear-armed crowd," or it could be replaced by a cooperative international security system with a greatly reduced role for nuclear weapons.

Intentionally or by default, the world will make this choice, and U.S. leadership (or lack of it) will be pivotal. The United States' decisions on dismantling its Cold War arsenal will be key to demonstrating whether or not the country is willing to live up to its treaty obligations.

MOVING TOWARD VIRTUAL ABOLITION

by Christopher Paine

The United States has an historic opportunity to lead the way toward a fair, effective nuclear weapons nonproliferation system. Rational decisions on nuclear weapons dismantlement and disposition can benefit the U.S. economy, environment, and national security.[22]

Simply extending the Non-Proliferation Treaty will not be enough to discourage the further spread of nuclear weapons.

During the 1960s, the United States was central to formulating what is known as the "nonproliferation regime." First signed in 1968, then entered into force in 1970, the Treaty on the Non-Proliferation of Nuclear Weapons (NPT) is central to this regime. Less than five pages long, the treaty codifies restrictions on the transfer and use of materials, technology, and equipment to non-nuclear-armed countries. The treaty also commits the five "declared" nuclear-armed nations to nuclear disarmament.

The NPT faces growing challenges at the very time the treaty is up for extension. Many non-nuclear weapons states find the nonproliferation status quo increasingly intolerable. The regime has allowed the five declared nuclear powers—the United States, Soviet Union (now Russia), Britain, France, and China—to continue developing, testing, and manufacturing nuclear weapons. Meanwhile it seeks to prevent other nations from acquiring the Bomb.

Access to civilian nuclear technology motivated developing countries to join this discriminatory regime. However, the incentive eroded as nuclear power became less attractive economically. Meanwhile, several nations continue to develop "plutonium economies," a perfect cover for moving to within hours or days of obtaining nuclear weapons—legally, under the NPT.

Faltering U.S. Leadership?

Unfortunately, the United States has yet to advance a coherent program for verifying the elimination of tens of thousands of former Soviet warheads or for tracking hundreds of tons of nuclear materials that will be extracted from them. In the past, Pentagon and DOE officials often favored intrusive verification schemes precisely because they appeared unobtainable. After four decades of lecturing the Russians and the world on the importance of openness and reliable verification, it is embarrassing that the United States resists nuclear data exchanges, material accounting and tracking, and on-site inspections—at the moment in history when such measures could be implemented globally.

Uncertainty about the huge former Soviet arsenal is truly alarming. U.S. policy, though, has reflected an aversion to allowing the same level of international oversight that the United States would demand of other countries. Officials who recently insisted on the most stringent verification measures now suggest that relatively simple dismantlement and disposition verification is "not needed" because Russia is friendly and "democratic."[23] To say the least, this begs the question of what might happen if a less hospitable regime takes over. The results of the Russian elections in December 1993 suggest that the United States should do everything it can to permanently reduce Cold War arsenals and to help prevent the social and economic devastation that would result from a renewed arms race.

The United States has yet to advance a coherent program for verifying dismantlement of tens of thousands of former Soviet warheads.

Similarly, the United States has nothing to lose and everything to gain by taking a strong stance against production of and commerce in all weapons-usable fissile materials, including "civilian" plutonium. Although the United States has stopped making separated plutonium and has led the world in recognizing that plutonium-fueled reactors are uneconomical, the government continues to fund more breeder reactor research and has proven unwilling to oppose international commerce in civilian plutonium.

The United States cannot pursue even a limited plutonium reactor research program without implicitly approving of the large-scale operations planned in Russia, Europe, and Japan. A modest plutonium breeder reactor economy, equivalent to one tenth of U.S. nuclear power capacity, would require a plutonium inventory equivalent to between 10,000 and 25,000 bombs. Due to unavoidable measurement errors, diversion of several bombs worth of plutonium per year from even a small reprocessing plant cannot be detected.

The Nonproliferation Treaty: Next Steps

A conference in April 1995—to consider extension of the NPT beyond its first 25 years—will be a key nonproliferation event. However, simply extending the treaty will not be enough to discourage the further spread of nuclear weapons. Several developing countries are unlikely to accept indefinite treaty extension, given the current division of the world into nuclear-armed and non-nuclear-weapon states.

If the United States takes nonproliferation seriously, it should undertake a series of additional initiatives. These initiatives would be viewed by non-nuclear-armed countries as a good faith effort to fulfill Article VI of the NPT, making extension and universal adoption of the treaty more likely, meaningful, and enforceable:

The United States should pursue a "No-First-Use" agreement among the nuclear-armed powers, and take all nuclear forces off day-to-day alert.

- Negotiate a Comprehensive Test Ban on all nuclear explosions by 1995
- Release nuclear material inventory data
- Announce a policy to cap and then reduce inventories of highly-enriched uranium and separated plutonium, and seek a global treaty banning production, transfer, and use of key nuclear weapons materials
- Pursue a "No-First-Use" agreement among the nuclear powers, and take all nuclear forces off day-to-day alert in order to make the agreement credible
- Conduct nuclear warhead dismantlement, component storage, and crucial materials disposition using verification procedures that will give other nations confidence that retired nuclear weapons have been eliminated and that their key materials are securely and permanently removed from weapons use
- Help create a fair global system for short-notice inspections, international sanctions, and other measures to detect activities that violate nonproliferation treaties and agreements, and improve controls on the transfer of equipment and technology crucial to nuclear weapons
- Take the lead in creating a "virtual abolition" strategy of reducing nuclear arsenals to small, securely stored, internationally monitored stockpiles that could be re-attached to their delivery systems in the event of a serious international security threat that justifies redeployment

CONCLUSION & RECOMMENDATIONS

by Peter Gray

Last Battle Of The Cold War

The world appears safe from the imminent threat of massive nuclear war, although some dangerous hair-trigger systems and policies have yet to be eliminated. Arms reduction treaties and other prospects for cooperation between former Cold War enemies are cause for great hope. However, Russian political instability and the potential resurgence of a belligerent government demand that dealing with the legacy of the nuclear arms race be a top U.S. priority.

The end of the Cold War has eliminated neither the grossly oversized superpower nuclear arsenals nor the hundreds of tons of extremely dangerous materials they contain. The alarming reality of more than 30,000 nuclear warheads or their components scattered across several unstable former Soviet republics has not been adequately addressed by international agreements or by U.S. policy.

Nuclear stockpiles are more secure in the United States, and appear to pose little immediate proliferation threat. Effective long term reduction of global nuclear weapons risks, however, depends upon positive U.S. action, both cooperative and unilateral.

Elements Of Disposition Policy

Although the details of final plutonium and highly enriched uranium disposition are unresolved, the United States should take many steps now:

- Involve U.S. citizens in an open decision-making process for deciding how to dispose of nuclear weapons materials
- Declassify the total numbers of nuclear weapons and quantities of fissile materials
- Promote international monitoring of U.S. nuclear arsenals, materials stockpiles, and production facilities
- Recognize that plutonium poses health, safety, and security threats while there is no prospect in the foreseeable future that it will be an economical energy resource—therefore it should be treated as a waste
- Dismantle surplus warheads as quickly as is safely feasible
- Destroy or damage the plutonium components of surplus weapons and dilute HEU into non weapons-usable forms
- Adopt and disclose rational criteria for selecting plutonium disposition methods, consistent with optimal nonproliferation planning

ENDNOTES

1. U.S. Congress, Office of Technology Assessment, *Dismantling the Bomb and Managing the Nuclear Materials*, OTA-O-572 (Washington, DC: U.S. Government Printing Office, September 1993).
2. General Accounting Office, *Nuclear Weapons: Safety, Technical, and Manpower Issues Slow DOE's Disassembly Efforts,* GAO/RCED-94-9 (Washington, DC: U.S. Government Printing Office, October 1993).
3. International Physicians for the Prevention of Nuclear War and Institute for Energy and Environmental Research, *Plutonium: Deadly Gold of the Nuclear Age*, (New York, NY, 1992).
4. Albright, Berkhout, Walker, *World Inventory of Plutonium and Highly Enriched Uranium 1992*, (Oxford University Press, 1993).
5. Peter Gray, *Briefing Book on the Nonproliferation of Nuclear Weapons*, (Council for a Livable World Education Fund, Washington, DC, January 1994).
6. NASA's estimate was $200,000 (1982 dollars) per kilogram of plutonium—on the order of 100 times the likely cost of geologic disposal. The U.S. will need to dispose of about 100,000 kilograms, and one 1982 dollar is equivalent to about 1.5 1993 dollars.
7. Chow and Solomon, *Limiting the Spread of Weapon-Usable Fissile Materials*, (RAND, National Defense Research Institute, Santa Monica, CA, November 1993).
8. *Plutonium: Deadly Gold of the Nuclear Age*, p 137. Several hundred explosions might be required, each at a cost of at least 50 million dollars.
9. *Plutonium: Deadly Gold of the Nuclear Age*, p 3.
10. *World Inventory of Plutonium and Highly Enriched Uranium 1992.*
11. *Nuclear Weapons: Safety, Technical, and Manpower Issues Slow DOE's Disassembly Efforts.*
12. *Limiting the Spread of Weapon-Usable Fissile Materials,* p 73.
13. Plutonium-fueled reactors have been rejected by private investors, and the only recent interest shown by electric utilities is a promise by one company to contribute a token two-million dollars to research.
14. O'Very, Paine, Reicher, *Controlling the Atom in the 21st Century*, Westview Press, 1993.
15. Science Applications International Corporation, et al, "The Isaiah Project: Unsolicited Proposal for Plutonium Disposal," September 1993.
16. For a summary, see Feiveson, von Hippel, and Williams, "Fission Power: An Evolutionary Strategy," (*Science*, January 26, 1979).
17. Frank von Hippel, (Testimony before the Subcommittee on Energy and Power of the Committee on Energy and Commerce, June 9, 1993).
18. Ibid.
19. David Albright, (Testimony before the Subcommittee on Energy and Power of the Committee on Energy and Commerce, June 9, 1993).
20. Arjun Makhijani, "Plutonium in Glass: A Preliminary Examination of the Issues Concerning Vitrification of Plutonium from Dismantled Nuclear Weapons," (Institute for Energy and Environmental Research, October 1992).
21. J.M. McKibben, et. al., "Vitrification of Excess Plutonium" (WSRC-RP-93-755, May 1993, Predecisional Draft).
22. *Controlling the Atom in the 21st Century.*
23. E.g., August 4, 1992 Congressional testimony of Dr. Robert Barker, former Assistant to the Secretary of Defense for Atomic Energy: "A concern about Russian nuclear weapons security should not result in a mandate for Russian inspection of U.S. facilities. An automatic requirement for reciprocity is, frankly, old-think."

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