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TITLE: U.S. PLUTONIUM DISPOSITION POLICY.....BOMBS FOR EVERYBODY FOREVER?

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U.S. Plutonium Disposition Policy....Bombs for Everybody Forever?

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Abstract

The U. S. policy on the disposition of weapons and commercial plutonium by geologic storage is examined and compared with destruction in reactors or accelerator-driven systems. The close coupling with Russian weapons plutonium is considered. Strong emphasis is placed on the preference by terrorists and rogue states for commercial plutonium over weapons plutonium for fast and simple nuclear weapons acquisition. U. S. policy faces now the issue of whether the plutonium is going to be with us essentially "forever" or whether several technical options for total destruction will be supported. Accelerator-driven transmutation technology is proposed as a safe, affordable, and complete solution to this problem.

This past February I found myself wearing a heavy ski jacket in the back of a cold conference hall in St. Petersburg, Russia beside a slightly bored Russian former nuclear weapons designer. We were there to discuss technology affecting the future of the two kinds of plutonium...weapons plutonium taken from nuclear weapons in stockpile reductions and the commercial plutonium being produced worldwide in commercial nuclear reactors. My Russian colleague was restless and presently he leaned over and whispered, "I don't understand the U. S. policy at all with regard to weapons plutonium. Why turn weapons plutonium into commercial plutonium when it's much easier to build nuclear weapons with commercial plutonium?" This was more interesting than the speaker's paper, so I nodded to him to proceed.

He said, "Three technologies must be mastered to make a nuclear weapon out of weapons plutonium. First, you have to master the compression technology...driving the plutonium into a highly compressed ball with conventional high explosive. Second, you must produce a burst of neutrons to start a rapidly growing chain reaction and that's not so easy. And third, you have to time the burst of neutrons just right or the neutrons will come too late or to early. If you fail at any of these three requirements, the bomb will be a dud." Everything he said had been first stated publicly in unclassified and published work[1] by Dr. Carson Mark, a leader in nuclear weapons design at Los Alamos in the 1960's. It had been recently repeated in the highly publicized study conducted by the U. S. National Academy of Sciences entitled, "Management and Disposition of Excess Plutonium[2]" and similar information has been communicated by Russian scientists[3]. So where was he headed?

He continued, "For nuclear weapons from commercial plutonium you need only the compression technology. Lots of neutrons are already present because the commercial plutonium contains isotopes which undergo spontaneous fission and produce neutrons all of the time. Because they are there already, one cannot control the timing of the injection of neutrons, so the explosive power is quite uncertain. It might be anywhere in the range from 2000 tons of TNT to 18,000 tons." Well", I thought, "2000 tons is about 1000 times larger than the Oklahoma City bomb which produced no radioactive fallout."

He went on, "Who cares whether the explosion is 2,000 or 18,000 tons when the damage is only about a factor of three different? Terrorists wouldn't and even a rogue nation's war planners wouldn't care much. So why does Washington keep pushing us to convert difficult-to-use weapons plutonium into easy-to-use commercial plutonium? Your policy is influenced too much by your weapons designers at Los Alamos and Livermore. With the advanced technology developed in the U. S. and Russia, sure, weapons plutonium is the best because the explosive power is highly dependable and therefore always the maximum, and you also can make all kinds of fancy bombs such as nuclear artillery shells and so forth. But suppose you don't have nuclear weapons and you want to get them quickly and easily and you have the choice of commercial or weapons plutonium." He made as if to hold weapons plutonium in the left hand and commercial plutonium in the right hand. "Your U. S. weapons designers believe a terrorist organization or rogue state will choose the weapons plutonium," nodding toward the left hand. "But the clever fellow who has to build a bomb for the boss fast and cheaply will choose the commercial plutonium every time."

The Russians wish partly for this reason to burn up all of the excess weapons and commercial plutonium as does most of the rest of the world. The Russians have developed new reactor technology to do this and the French, Japanese, and others also are working on this. My group at Los Alamos, working with modest internal funding is studying new means for destroying this material using accelerators, which make possible complete destruction by proliferation-resistant ultra-safe and affordable means. From this array of technologies could emerge practical means for total destruction of plutonium before the first plutonium anywhere in the world finds its way into geologic storage.

But work on the development of this new accelerator-driven technology has not been supported by the National Academy of Sciences recommendations,[4] and the U. S. policy has been rather neutral instead of supportive of such studies in other countries[5]. The U. S. Department of Energy is proposing the adoption of the U. S. National Academy of Sciences recommendations[2] which urge placement of plutonium of all types underground with or without partial burn-up. It is now in the final stages of information gathering prior to a decision to embark on the implementation of these options[6].

Questioning U. S. plutonium disposition policy

Before the U. S. and others adopt this strategy, it would be useful to question the arguments which have steered thus far the selection of underground storage. These arguments are restated as questions below.

Does reprocessing promote an international market in plutonium?

Perhaps the weakest technical element in total plutonium destruction using existing technology is the PUREX process for separating plutonium from spent nuclear fuel. This technology was developed in the post-war years and it or its derivatives are now widely deployed except in the U. S. It is presently not capable of dealing with the build-up of highly radioactive constituents of the waste produced in the course of complete plutonium destruction. One might develop the technique further to deal with its shortcomings, but it also has the problematic feature that it produces a pure stream of plutonium. The Swedes call this "naked" plutonium. The separation of this naked plutonium does not necessarily, or perhaps ever, match perfectly the feed into the plutonium-destroying systems. Therefore the excess must be stored. And perhaps to get a better balance between those who store and those who use plutonium, it could be sold thereby creating a plutonium market. As with any commodity market, it's not easy to prevent some of the commodity from being lost or stolen. The U. S. is correct on the point of avoiding a market and should push on to prevent the development of a market in plutonium.

The solution to destruction of plutonium without producing a market in plutonium is to perform separations which do not produce pure plutonium. From the beginning of our work on plutonium destruction at Los Alamos, the focus has been on separations which allow the destruction of plutonium *without* the production of naked plutonium[7]. Only the weakly radioactive zirconium fuel cladding and the uranium are removed so that the plutonium remains mixed with the most radioactive ingredients of the nuclear waste. The concentration of radioactivity of this product is about 100 times higher than in commercial spent fuel and this product can be fed directly into the transmuter. The Los Alamos process also only makes accessible as much plutonium as the system burning it can use, so no excess is accumulated. With highly contaminated plutonium and no excess, no market in plutonium can be developed. It is almost certainly feasible to develop means for destroying plutonium without promoting a market in plutonium.

Is plutonium safe in geologic storage?
The burial solution would work if the plutonium would stay put for the period of over 100,000 years required for it to decay away. If it were placed in the ground with sufficient care and expense, it might not move around much of its own accord, but that doesn't mean it will stay put. There are a lot of reasons for people to want to recover unique material from the repository. Prof. P. Peterson of the University of California Berkeley Nuclear Engineering Department has looked into the question of how a subnational group or rogue state might go about obtaining weapons material in the future[8]. They can always attempt to follow the present route of countries such as Iraq or North Korea of producing plutonium in a reactor or of producing ^{235}U by uranium enrichment. Added to these choices there will also be the option of mining of plutonium from one of the many repositories which will exist all over the world if the world adopts the U. S. policy. Dr. Peterson compared recovery of plutonium, from a repository with the other two routes and concluded that it was over ten times faster and over ten times less expensive to recover the plutonium from storage than to pursue either of the other two options. The International Atomic Energy Agency (IAEA) recognizes the danger of the stored plutonium also[9] and takes the position that geologic repositories must be guarded forever. It seems impossible to avoid guards for underground plutonium in the U. S. much less in other less stable countries.

While manmade nuclear explosions have become a matter of major international concern, it is now clear that nuclear explosions can occur in other ways than through the careful design by humans. In a paper recently published[10] we show that it is possible for plutonium emplaced as safely subcritical configurations to reassemble under natural means into supercritical arrangements. Accidental nuclear critical configurations above ground have the feature that they all possess strong negative reactivity feedback so that they turn themselves off naturally with minor consequences. However, we show that for plutonium underground either positive or negative reactivity feedback is possible and that the positive feedback means that energy release from supercriticality leads to even higher supercriticality such that significant explosive energy release is possible. The energy release is further enhanced underground by the confinement and maintenance of the supercriticality by the surrounding rock, which of course cannot happen above ground. The energy release from these configurations are calculated to be in the tens to hundreds of tons of high explosive equivalent.

Our study of these explosions only involved highly enriched uranium and weapons plutonium. However Pigford[11,12] and Choi have studied the criticality issues for emplacement underground of commercial spent fuel and spent mixed-oxide fuel. These investigators determined that both waste types can reach criticality with positive (explosive driving) feedback even without separation of the plutonium from the waste cladding, the uranium or the fission product. They further showed that the presently configured containers for commercial waste emplacement in Yucca Mountain would become critical if filled with water and would show positive feedback if the consequences of the energy release were to move the waste outward from its original configuration so that it mixes with the surrounding backfill. Therefore, it presently appears that criticality with positive feedback is possible spontaneously for perhaps all of the fissile waste under consideration for repository storage.

Is accidental or purposeful repository intrusion inconsequential?
Of course, natural processes are not the only ones that could lead to critical configurations. The repository studies supported by the U. S. Department of Energy acknowledge the possibility of accidental intrusion into the repository as for example in drilling for water or minerals, although these studies had not recognized the possibility of criticality with positive feedback. The IAEA study and the Peterson study make the case that there are strong reasons to reenter and recover the plutonium from the repository for those wishing to obtain nuclear weapons capability. The repositories may be the richest lode available for other non-fissile materials of possible future interest. For example, all of the elements in the waste have isotopic concentrations different from those that occur naturally and have potential value for that reason. Mining a repository purposefully is therefore almost a certainty, and if the mining is not done with great care, critical configurations could be created accidentally. Finally it is not out of the question that repository explosions might be deliberately induced for malevolent reasons. If the possibility for spontaneous criticality could be reduced to an acceptably low value (and how would that be decided?), the possibility of purposeful and accidental, reconfiguration to criticality remains.

Is conversion to the "spent fuel standard" worthwhile?
For the many years while plutonium was stored in large inventories of nuclear weapons, the safety of weapons plutonium was not questioned. Since relative peace has brought major stockpile reductions, the disposition of the excess weapons plutonium, particularly Russian plutonium, has become an issue of major focus. There is good reason to want to get Russian weapons plutonium under control as quickly as possible. In response to this concern, the U. S. Academy of Sciences conducted a study entitled Management and Disposition of Excess Weapons Plutonium[2] to evaluate possible options. The recommendations included (1) declarations of weapons plutonium in the U. S. and Russia, (2) Safeguarded storage of this material, and (3) final disposition including storage underground or partial burn-up in reactors before storage underground. After settling on underground storage, the issue of burning before storage underground was addressed by the NAS in a separate study with a report entitled, Management and Disposition of Excess Weapons Plutonium....Reactor-Related Options[13].

Both reports were strongly influenced by the concept of the "spent fuel standard." The plutonium in the commercial spent fuel, as we have already seen, is a mixture of isotopes which has some disadvantages for making sophisticated nuclear weapons. In addition, the commercial spent fuel is in the form of spent fuel assemblies. The presence of the fission product radioactivity in the assemblies with the plutonium is felt to be another considerable deterrent to attempts to remove the plutonium for possible weapons use. Since there is so much more commercial plutonium than weapons plutonium, the transformation of weapons plutonium to commercial plutonium by burning in a reactor gets rid of the weapons plutonium but increases the amount of commercial plutonium by only about 10 %. Therefore conversion of weapons plutonium to commercial plutonium by partial burning is seen to be worthwhile.

The conversion of weapons plutonium to the spent fuel standard of commercial plutonium by partial burning would be an exercise of rather little value. As we have already seen, the commercial plutonium is more valuable to those we wish not to have plutonium than weapons plutonium. The value of the radioactivity as a deterrent decreases with time such that in about one to two hundred years the chemical separation of plutonium from the waste could be accomplished without the radioactivity being a significant barrier. Whatever advantage from the presently proposed policy of conversion to the spent fuel standard would be temporary and mainly passes the resolution of the problem to future generations. They would have the responsibility for destruction following the probably dangerous task of recovery.

Is the value of weapons plutonium always negative?
Of course the main objective of this U. S. policy might not be U. S. weapons plutonium but Russian weapons plutonium. The Russians understand that weapons plutonium has significant positive value and expect to receive some considerable societal benefit from the destruction of this material. The U. S. argues that weapons plutonium has negative value, citing the energy value of the plutonium which is no different than for any fissile material. In the U. S. this case is valid because we currently have no technology available to extract much of the energy efficiently. However Russia has developed an advanced lead-cooled naval reactor[14] which it plans to move into the commercial sector which can burn the plutonium with significant advantage. In addition the Russians understand that the primary value of the weapons plutonium is not in the fission energy produced from burning but in the neutrons it produces. Much of the reason weapons plutonium is valued for sophisticated weapons is that it is an exceedingly rich source of neutrons. Since the key to nuclear energy is sustaining a chain reaction, the burning of weapons plutonium enhances the reactor neutron economy allowing the chain to continue to operate while performing other useful functions such as destroying nuclear waste by transmutation using these neutrons. Studies at Los Alamos show that the economics of transmutation of commercial nuclear waste is very significantly enhanced by the burning of weapons plutonium and highly enriched uranium concurrently[15].

Why is plutonium more dangerous outside rather than inside of nuclear weapons?
The sudden urgency of dealing with the Russian plutonium, now that it is coming out of the nuclear weapons, seems strange when the same urgency was not in evidence while the plutonium was in the weapons. While the apparent dissolution of controls in some aspects of Russian society in recent years might give reason for concern for plutonium in general, there should be just as much basis for concern now about the availability of weapons plutonium while in weapons as there is after removal from weapons.

The National Academy of Sciences therefore has skewed or biased their recommendations[2,4,13] by basing them on the following highly questionable assumptions:
1. Weapons plutonium can be placed in geologic storage in less time than it takes to develop new technology to completely destroy the plutonium.
2. The weapons plutonium and other plutonium is safe in geologic storage.
3. Weapons plutonium has negative value.
4. Weapons plutonium deserves priority attention because it is more weapons-useful than commercial plutonium by rogue states or subnational groups.
5. Russian plutonium in nuclear weapons is safe but outside of the weapons it is unsafe.
6. Destruction by transmutation of both weapons and commercial plutonium will be too costly.

Technologies for complete destruction of plutonium
Although there are several promising technologies which have been proposed for complete destruction of plutonium, none have been demonstrated yet because the plutonium problem was not prominent until U. S. and Russian stockpile reductions created an excess of plutonium and the problems of repository storage of commercial plutonium became apparent. Several approaches are briefly described below.

Sodium-cooled fast-spectrum reactors:
This technology has received billions of dollars of support worldwide because of its capability to breed plutonium. By operating them differently it is possible also to burn plutonium, and this technology is perhaps the most prominent candidate technology now. However these systems are criticized for criticality safety reasons and for their use of the sodium coolant which burns actively in oxygen, nitrogen, and even with concrete. Perhaps the main criticism of them is that their deployment for plutonium destruction opens the door to future use as breeders of plutonium and therefore for proliferation of nuclear weapons. For this reason development of this technology was halted last year in the U. S. and the U. S. government is putting pressure on other nations to halt this technology development as well. Since only 15 % or so of the plutonium in a single fuel load can be destroyed, these systems require removal of plutonium and recycling of this plutonium back into the reactor. The separations necessary for recycling this plutonium repeatedly to complete burnup has not been demonstrated and the National Academy of Sciences believes that the relationship of burn-up to inventory is such that a practical burn-up plan might take over 200 years to complete[4]. There is much to be debated about this technology, but the fact that it has not yet reached acceptance after more than 25 years of development speaks to a considerable degree for itself.

Lead-cooled fast-spectrum reactors:
The Russians have developed a different version[14] of the fast reactors which employ the much safer lead-bismuth as the coolant. The reactor was developed for use in Russian submarines where high power from a small system was desirable and submarines powered with it have held the world submarine speed record for many years. The reactor is reported to have eighty reactor-years of successful operation which substantially exceeds that of the sodium reactors. It was developed primarily to resolve the flammability problem of the sodium coolant but it avoided the fast reactor void coefficient issue as well. Furthermore the passive solidification of the lead-bismuth if it leaks from the reactor is an additional significant safety advantage for confining the system radioactivity in normal or accident conditions. This reactor was developed in military secrecy, but a Russian private company has been organized to commercialize it. Its design allows the complete burn-up of plutonium and the minor actinides provided proposed new non-aqueous separations techniques are proven to be practical. It is not suitable for destroying the long-lived fission product, so an accelerator-driven system might be added to the infrastructure to accomplish this. The most effective start-up fuel is weapons plutonium or the highly enriched uranium recovered from weapons reductions. Russia has a technology unavailable in the U. S. or elsewhere which can use their excess weapons material to great advantage. Russia therefore has practical options for destruction of excess materials which are unavailable in the U. S. The impact of the relative inactivity in the development of advanced nuclear technology over the past two decades in the U. S. is beginning to show.

Mixed-oxide burning in commercial light water reactors:
Existing commercial light water reactors can be employed to burn weapons plutonium as an alternative fuel consisting of plutonium mixed with uranium called mixed oxide fuel (MOX). After one cycle the plutonium can be recycled once more for a further reduction. However, after that cycle existing fuel reprocessing systems cannot cope with the high radioactivity of the remaining plutonium and its higher actinide products. Complete burn-up therefore is not possible although burn-up to the "spent fuel standard" is possible. Therefore the only reactor capability that the U. S. has can only do a job partially which should be done to completeness or not at all. The fact that *something* can be done perhaps accounts partly for the current support in the U. S. for this MOX approach. Since the U. S. has no MOX fuel fabrication plants, it is considering transporting the 50-100 tons of

weapons plutonium to Europe for fabrication into fresh MOX fuel. The U. S. government still will have to pay for converting the weapons plutonium to a form more readily useful by terrorists and rogue states than the original weapons plutonium. The MOX option offers nothing for the elimination of commercial plutonium.

High-temperature gas-cooled reactors with accelerator assistance:
General Atomics has pursued the development of high-temperature gas cooled reactors (HTGRs) for commercial production of nuclear power. The Corporation has proposed to burn weapons plutonium to completeness without fuel reprocessing by burning the fuel first in their existing reactor design until the reactor can no longer maintain criticality and then to move the fuel to an accelerator-driven system which continues the burn-down to a much higher degree in a subcritical assembly[16]. Both systems sell electric power to pay the costs of this operation. The resulting 5 % remnant of plutonium and higher actinide mixture is not useful for nuclear weapons owing to its poor isotopic content and its high specific decay heat. The same system also could be used to destroy commercial plutonium. The Corporation believes that the weapons plutonium has a positive value in this mode; the economic situation is less clear for commercial plutonium owing to the complications of the additional reprocessing required. The design of the components of this system is mature following many years of research and development, but this type of reactor has not been shown to be competitive with light water reactors in the production of commercial nuclear power.

Accelerator-driven transmutation technology:
All reactors operate as critical systems with criticality being a considerable constraint on system function and fuel usage. The use of accelerators as intense neutron sources to allow reactor-like systems to operate as subcritical systems has been considered for many years. The advantages are safer operation as subcritical systems, operation over a wider dynamic range of fuel burn-up, a superior neutron economy owing to the supplemental neutrons supplied by the accelerator, and the absence of neutron losses in control rods[17]. The safe subcritical operation also makes possible operation with a liquid fuel which allows continuous refueling and removal of fission products. The liquid fuel improves the neutron economy further and avoids the cost and infrastructure for fuel fabrication and refabrication. The reactor-like system with its on-line separations capability allows one to feed fissile material into the system continually and to remove fission product alone continuously. Therefore total fissile material burn-up is possible. If these systems were deployed as thermal rather than fast spectrum systems, the burn-up per year would be a large fraction of the fuel inventory. An examination of the logistics of plutonium destruction shows that such a system could destroy both commercial and weapons plutonium in a period of about sixty years[4] instead of the 200 required for a fast spectrum system.

In the past the study of these systems was always limited by the absence of satisfactory accelerator technology. However advances over the years made it clear by 1990 that the required accelerators could be built, and accelerator-driven transmutation technology (ADTT) has been under study at Los Alamos since that time. Interest has grown in this technology the world over with a large international meeting[18], "The Second International Conference on Accelerator-Driven Transmutation Technology" planned for June 1996 in Kalmar, Sweden. Studies also are underway in France, Europe, Japan and Russia. The viability of a large accelerator in an industrial context was given a large boost by the U. S. Department of Energy's endorsement of the construction of a 1.3 billion volt 100 milliamp proton accelerator producing 130 megawatts of steady state beam power to produce tritium for the U. S. nuclear weapons stockpile. The accelerator beam will produce neutrons which will be absorbed into the helium 3 isotope to convert it to tritium (hydrogen 3). This tritium-producing accelerator is larger than the largest accelerators contemplated for transmutation technology.

At Los Alamos three versions of this technology are being studied. The first called Accelerator-Based Conversion (ABC) is aimed at the total burn-up of weapons plutonium. It is expected to have capability for burn-up not only of the high-quality plutonium which is returned from weapons stockpile reductions, but it should also readily destroy the plutonium remnant which was left as the 1-10 % contamination of the waste from the plutonium production process. This system would have its primary application in Russia and the U. S. where the excess and waste weapons plutonium exists.

The second system called Accelerator-Transmutation of Waste (ATW) is aimed at the destruction of commercial plutonium, the minor actinides, and the long-lived fission products. The system therefore would provide the means for destruction of the world's commercial plutonium and would transmute away the long-lived high-level waste produced from commercial nuclear power plants. One ATW facility operating at the same fission power level as a typical commercial power reactor would destroy the waste from four commercial power reactors. Since there are about 400 commercial power reactors in the world today, the destruction of just the waste from them would require 100 ATW systems. Obviously this would be impossibly expensive unless the fission heat from the destruction of the waste could be converted to electric power and sold to pay the construction and operating costs for the destruction of the waste. If all of these costs could be paid by electric power sales, the destruction of the waste would cost nothing. Society probably is willing to pay a modest surcharge for the disposition of these wastes, but will not accept a waste solution requiring a major increase in the nuclear electric power cost.

Destruction by fission of the plutonium and the minor actinides is less costly than the fission products because the neutrons provided by the accelerator for destruction by fission are supplemented significantly by the neutrons produced in the fission process. It appears that the destruction of the plutonium and minor actinides can be made economically practical by this means. However for the fission products, one neutron is required to transmute each atom of fission product. Therefore transmutation of the fission products is considerably more expensive in terms of requirements on the accelerator unless some other supplemental source of neutrons can be identified. Weapons plutonium and highly enriched uranium are good materials for weapons mainly because they are good sources of the neutrons necessary to drive the exponentially growing chain reaction in a nuclear explosive. If these weapons materials were used to supplement the neutron economy in fission product burning, the destruction of the long-lived fission products would be much more nearly economically practical. The destruction of all long-lived constituents of the waste is therefore made more viable by the feeding of some of the weapons plutonium or highly enriched uranium into the ATW system.

If this waste destruction can be done well enough, concerns for these wastes which must now extend for perhaps millions of years are transformed to a 300-year period. While this is still a long time, transmutation allows a fundamental reformulation of the waste handling problem. Without transmutation, containers cannot be built which outlive the radioactivity of the waste. Therefore the waste must be placed underground in media with geologic structures capable of confining the waste after the integrity of the waste container disappears. The scientific problem is to find the best geologic site if political conditions permit, and to characterize and engineer that site exhaustively so that emplacement of the waste may be done in the best possible way. Having by these actions made this site the best and only site available in the nation, all of the Nation's high level waste would then be placed there. Therefore the natural result of following the best scientific procedure available to select and develop the very best site creates the political problem that all of what many believe to be the Nation's worst waste is imposed on the single community which is host to this best site.

Science might help resolve this political problem by changing the characteristics of the waste so that it is not necessary to place all of this waste at one site. If the long-lived high-level waste could be transmuted such that the period of concern is much shorter, then containers can be readily made which will outlast the radioactivity of the waste. Since the containers are able to prevent the dispersion of the waste, one does not have to rely on geologic features for this purpose. Therefore there no longer is a single best site and the criteria for storage of the waste can be greatly relaxed. No state would have a technical problem identifying a site for its relatively innocuous waste remnant after transmutation. The storage of the remnant waste would become a state problem rather than a federal problem. The role of the federal government would be to help develop the technology and the licensing and regulatory aspects for adherence by the states. In such a situation the challenge of waste handling is greatly reduced and the politics of waste disposition are radically changed and improved. Transmutation also removes the issue of weapons material recovery or of underground criticality.

The third component of the ADTT project, Accelerator-Driven Energy Production (ADEP), is the production of nuclear energy from thorium using the accelerator without the production of weapons material and with concurrent destruction of the long-lived high-level waste. The energy available from thorium is virtually unlimited, there is no output stream of long-lived high-level waste, and operation as a subcritical system prevents nuclear runaway. These three features are also the primary advantages of fusion programs. We believe that this technology could be made available in 12-15 years and that the present technical maturity and likelihood of technical success far exceeds that of fusion.

Up to the present this ADTT project has been supported only with internal discretionary funds of the Los Alamos National Laboratory. With this limited funding, it is impossible to conduct demonstration experiments at a scale justified by the present design maturity.

Opposition to transmutation

If Los Alamos accelerator-driven transmutation technology offers such promise, why has it been difficult to obtain funding to develop and demonstrate this technology? The technical opposition to the accelerator-driven technology is weak, but the political opposition is diverse and formidable. Remarkably, geologic storage is almost everybody's solution to the waste problem except those who must live near the waste and some environmentalists. The various groups which support it are the following:

Repository storage development scientists

The Yucca Mountain repository storage facility has been funded until recently at the several hundred million dollar per year level. There is therefore a very strong built-in repository storage lobby within professional organizations, etc. which has a loud voice compared to the advocates of the new transmutation technology.

Electric utilities

Some of those in the electric utility business see geologic storage as an immediate and viable solution to the disposition of the waste accumulating at their power plants. Furthermore they want it to be the only solution so that the Nation can get on with that solution immediately. Transmutation, which might provide a much better solution than simple storage, gets in the way of what they perceive to be near-term geologic storage. Others in this community concerned about the long-term political and technical problems of geologic storage are more supportive.

Reactor venders

During the long hiatus in new reactor deployment in the U. S. , the reactor vendors have had a difficult time but have managed to design improved reactors. The accelerator-driven transmuters promise to be even safer and offer a benign waste stream which the new reactors cannot match. The prospect of availability of these transmutation systems not far into the future would not be good for the possibility of sales of the new reactors which rely on geologic storage. Of course this community is pleased with mixed oxide burning of weapons plutonium to convert it to the spent fuel standard. This group does not necessarily reject transmutation entirely, but would prefer it to be pushed far enough in the future that its effects would not influence the current decision process on commercial waste disposition

The thoughtful anti-nuclear community

This small but influential group which is prominently represented in the National Academy of Sciences studies is perhaps legitimately unhappy with the present status of nuclear technology, believes that nuclear technology has had its opportunity to provide solutions to the world's energy problems, and feels that other technologies deserve a better shot before nuclear gets a chance to try again. They recognize that we can't just walk away from the present nuclear problems and will listen to sound scientific arguments. They are generally unsupportive to the development of new nuclear technology wishing not to recognize that sometimes it is necessary to fight fire with fire and that there probably is no alternative to the development of new nuclear technology to solve current nuclear waste problems.

The reactionary anti-nuclear community

This group does all it can to eliminate nuclear technology by the placement of obstacles in the path of any solution to the nuclear waste problem. Some of this community at first hearing like transmutation technology because it competes with other waste technology and to some degree confuses the issues by raising another option. They are however afraid of the benefits accruing to nuclear technology if this means of waste disposition and energy generation were to be successful.

So backing for repository storage is strong indeed and transmutation is generally viewed as obstructive to getting on immediately with repository storage. However within most of the above communities there is growing concern about both the technical and political viability of the geologic storage solution. The dangers which have been identified in the past year of the commercial plutonium stored in them, of the easy accessibility to this plutonium, of the simplicity in the use of this plutonium in nuclear weapons, and the possibility of spontaneous or induced underground explosions of the fissile material were unwelcome indeed. Undoubtedly work will go on for some time to try to make repository storage of fissile material safe. However plutonium will always be recoverable if it was possible to bury it, so the nuclear weapons problem never goes away. French law requires the expenditure of as much on waste burning as is spent on geologic storage. Why not spend in the U. S. half of that now being spent on underground storage to demonstrate the means for total destruction of the material? We believe that this technology could be available in 12-15 years which is the earliest time that any high-level waste is scheduled to be placed in repository storage anywhere in the world. If we continue with present policy, fifty years from now when all of the waste has been placed underground, scientists still will be trying to convince the public that the waste has been safely stored "forever." If transmutation technology development were pursued now with success, scientists instead would be able to tell the public that the waste is gone forever.

Therefore it seems that those who would bury plutonium are just passing off a dangerous problem to our children to avoid the option of developing the technology for complete destruction of plutonium. With the repository we preserve the material for 100,000 years for national or subnational groups to build nuclear weapons, and leave open the danger to the population and to the environment from spontaneous, accidentally, or purposeful eruptions from permanent storage of fissile material underground. It should be remembered also that plutonium 239 which is the key isotope of weapons plutonium decays into the other key weapon ingredient uranium 235, which lasts for 800 million years.

Solving the plutonium problem using transmutation

If the National Academy of Science's leadership has not always provided sound recommendations, what course of action should be followed instead? The following are recommended:

1. Implement to the degree possible the Academy's call for declarations, accounting, and safe storage of excess weapons plutonium
2. Continue the U. S. policy discouraging a plutonium economy, the implementation of MOX burning of plutonium, and the continued use of PUREX-based processing which produces a naked plutonium stream.
3. Recognize that transforming weapons plutonium to the spent fuel standard makes the plutonium more dangerous and only puts the ultimate solution off on future generations.
4. Announce as the U. S. national goal the destruction of plutonium of any kind and of all other material useful for nuclear weapons construction.
5. Support demonstrations in the U. S. of means for destroying weapons plutonium, commercial plutonium, and other higher actinide if the technology reduces the production of weapons material and improves on the safety and proliferation vulnerability of present deployed nuclear technology.
6. If repository storage is necessary, reserve it for fission products and the more innocuous remnants of the nuclear waste stream, and devise means for interim weapons plutonium storage for the 30-50 year period required to destroy it using newly developed technology.
7. Encourage the development of means for generating nuclear energy which do not produce weapons material in the first place.

This plutonium concern does not exist only for the U. S. at Yucca Mountain. The U. S. is advocating the emplacement of spent reactor fuel underground for the 30 or so other nations which operate commercial nuclear power reactors. Since the IAEA recognizes that safeguarding repositories forever is not practical, this policy clearly leaves the plutonium problem out of control. The views expressed by the Russian nuclear weapons designer should be heeded. Present society and future generations the world over deserve the opportunity not to be saddled with a disposition means which makes possible nuclear weapons for everyone forever.

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6. The receipt of public input on the report, "Storage and Disposition of Weapons-Usable Fissile Materials Draft Programmatic Environmental Impact Statement" was completed on May 7, 1996. The document may be obtained from U. S Department of Energy, Office of Fissile Materials Disposition, P. O. Box 23786, Washington, DC 20026-3786

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