WIPP AND PLUTONIUM DISPOSITION: FEASIBILITY AND SECURITY ISSUES

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Note: This paper was written and presented before the February 2014 radiological release at WIPP. It has been revised for clarity, but has not been updated to address the implications of the accident. Until DOE determines the root cause of the event and takes all necessary corrective actions, it is premature for UCS to recommend implementation of the WIPP option as described below. However, the relative life-cycle public health, safety and environmental risks must be key considerations in evaluating all plutonium disposition alternatives.

The Department of Energy (DOE) is constructing a mixed-oxide (MOX) fuel fabrication facility at the Savannah River Site (SRS) to convert at least 34 metric tons of surplus weapon-grade plutonium into fuel for light-water reactors, in accordance with the 2000 U.S.-Russian Plutonium Management and Disposition Agreement and the 2010 revised protocol. However, construction of the fuel fabrication facility has experienced significant cost overruns and schedule delays, and at present no utility has committed to purchasing and using the MOX fuel. In its Fiscal Year 2014 budget request, DOE stated that “Cost growth and fiscal pressure may make the project unaffordable, so the Administration is conducting an assessment of alternative plutonium disposition strategies and identifying options for FY 2014 and the outyears. As a result, NNSA will slow down the MOX project and other activities associated with the current plutonium disposition strategy during the assessment period.”[1]

Among potential alternatives is one that, in principle, could offer the simplest and cheapest way to dispose of U.S. excess plutonium: burial at the Waste Isolation Pilot Plant (WIPP) in New Mexico.

This disposition path has already been proven with 3.2 metric tons of plutonium residues from the former Rocky Flats Plant, and DOE plans to dispose of 0.585 metric tons of non-pit material at the Savannah River Site (SRS) considered unsuitable for MOX use through packaging and shipment to WIPP. [2] In addition, DOE is currently considering the option of disposing in WIPP up to an additional 6 metric tons of non-pit excess plutonium not covered under the U.S.-Russian agreement. [3]

The cost of the current approach for processing plutonium for WIPP disposal has been estimated to be about $100,000 per kilogram of plutonium—several times less than the projected cost of MOX fuel fabrication. [4] However, the current capacity for WIPP packaging at SRS is only 0.6 metric tons per year, so additional gloveboxes would need to be added to scale up to the necessary throughput of 1.3 metric tons a year as specified in the 2010 revised protocol.

Although an attractive option on the surface, there are several issues that would have to be addressed in order for DOE to emplace a large additional quantity of plutonium in WIPP. First,
there are legal constraints on the volume of waste that WIPP can accept. Second, WIPP is subject to environmental regulations that limit potential radioactive releases. Finally, disposal at WIPP must meet adequate security standards, consistent with the objectives of plutonium disposition.

**WIPP CAPACITY CONSTRAINTS**

The WIPP Land Withdrawal Act limits the volume of transuranic (TRU) waste in WIPP to 175,600 cubic meters. Depending on its level of radioactivity, TRU waste is classified as either contact-handled (CH) or remote-handled (RH). CH-TRU waste has a surface dose rate of less than 200 millirem per hour, whereas RH-TRU waste has a surface dose rate between 200 millirem and 100 rem per hour and is too radioactive to be directly handled by personnel. A separate 1988 agreement between DOE and the state of New Mexico restricts the total volume of RH-TRU waste to no more than 7,080 cubic meters.

In the 1996 Storage and Disposition of Weapons-Usable Fissile Materials Final Programmatic Environmental Impact Statement, DOE considered but eliminated from further evaluation the direct disposal of a nominal 50 metric tons of excess plutonium in WIPP, claiming that it would not have sufficient capacity for both the excess plutonium stockpile and DOE’s projected inventory of TRU waste. [5] The document further stated that this option “would likely require amendment” of the WIPP Land Withdrawal Act. However, DOE reached this conclusion before WIPP even became operational and before there was a firm estimate of the actual total quantity of TRU waste around the complex that would need disposal.

According to DOE’s 2012 draft Surplus Plutonium Disposition Supplemental Environmental Impact Statement (DSEIS), the available capacity of WIPP for excess plutonium, which would be considered CH-TRU waste, is approximately 19,700 cubic meters. This figure, however, underestimated the available volume because it was based on outdated and invalid information. First, this estimate assumes that WIPP will eventually receive the maximum authorized amount of RH-TRU waste. However, the actual inventory of RH-TRU waste is less than this amount, and the balance can be made up with more CH-TRU waste.

Second, the 2012 DSEIS estimate was based on the 2011 Annual Transuranic Waste Inventory Report. In the 2012 edition of the report, the total inventory of TRU waste destined for WIPP was reduced because the Pit Disassembly and Conversion Facility, which would have generated TRU waste, was cancelled. In the 2012 report, the total amount of TRU in WIPP was reported as 79,700 cubic meters, and the inventory of TRU that had yet to be disposed of was 71,500 cubic meters, for a total of about 151,000 cubic meters. This left 24,600 cubic meters of unsubscribed capacity. These numbers were revised slightly in the 2013 report, which indicate an excess capacity of 24,200 cubic meters. Contrary to DOE’s implication in the SEIS, this entire volume can be dedicated to disposal of excess plutonium.

How much plutonium can be disposed of within this volume? TRU waste disposed of in WIPP is commonly packed into 208-liter drums. The available volume of 24,200 cubic meters could accommodate about 116,350 drums. The amount of fissile material that can be loaded in an individual waste drum is limited to prevent any criticality accidents. The plutonium limit for 208-liter drums is 200 Pu-239 fissile gram equivalents (FGEs). To transport and dispose of plutonium-rich residues in WIPP, DOE has used a system known as a pipe overpack container (POC), which is
a 208-liter waste drum containing a “pipe overpack component” filled with plutonium blended with diluent materials to below 10 weight-percent. For excess plutonium disposition, DOE has assumed a loading of 175 Pu-239 FGEs per POC. Thus, the available volume could accommodate over 20 metric tons of excess weapon-grade plutonium packed in POCs.

However, DOE is currently considering a different packaging arrangement for transport and disposal utilizing “criticality control overpacks” (CCOs). These would allow an increase in the Pu-239 FGE per 208-liter waste drum and, being lighter than the POCs, would also allow more drums to be carried in a single shipment, reducing transport costs. DOE is assuming a limit of 380 Pu-239 FGEs per CCO. If the CCO approach is implemented, 116,350 drums could be loaded with over 44 metric tons of plutonium. The Nuclear Regulatory Commission (NRC), which licenses radioactive waste packages for transport, approved the CCO in 2013.

Thus it appears that if CCOs can be used, WIPP can accommodate, without amending the Land Withdrawal Act, the entire 34 metric tons of excess plutonium covered by the U.S.-Russian plutonium disposition agreement, as well as 10 of the 13 metric tons of additional plutonium DOE is currently evaluating in the SEIS. (Currently, DOE is only considering disposing of an additional 6 MT of this plutonium in WIPP, with most of the remainder going to MOX.)

ENVIROMENTAL REGULATIONS

WIPP must also comply with the Environmental Protection Agency regulations in 40 CFR 191 and 40 CFR Part 194. These requirements impose probability-based restrictions on the cumulative release of radionuclides from the repository over a 10,000-year period, and separately limit committed effective doses and groundwater contamination. Both natural processes and human intrusion scenarios must be considered in evaluating compliance with the regulatory limits.

Emplacing an additional 44 metric tons of excess weapon-grade plutonium in WIPP would increase the total amount of Pu-239 by approximately a factor of four and would double the total radionuclide activity. Because the plutonium concentration in groundwater is primarily solubility-limited and the risk of groundwater leakage from WIPP is considered to be very low in any event, this increase in the plutonium inventory should not significantly impact WIPP’s regulatory compliance with respect to natural processes.

However, human intrusion may be a different story. Adding a large number of additional TRU waste drums with higher actinide density could increase the probability and/or consequences of a deliberate human intrusion event. Performance assessment results for WIPP human intrusion events generally find the resulting level of groundwater contamination to be around a factor of 10 lower than the regulatory limit, so excess plutonium disposal probably would not threaten compliance; however, this needs to be evaluated in detail. [6] The potential for increased risk could possibly be offset by stabilizing the plutonium in a leach-resistant matrix before emplacing it in WIPP; this also needs to be evaluated in detail. Although this could increase the cost of the option, it would likely remain far cheaper than the MOX option.
WIPP DISPOSAL, THE SPENT FUEL STANDARD AND ATTRACTIVENESS LEVELS

Even if it is legally and technically possible to dispose of an additional 47 metric tons of excess weapons plutonium in WIPP, would it be a desirable course of action from a security perspective?

There are four distinct security aspects that need to be considered. The first is compliance with DOE graded safeguards policy. The second is compliance with the “spent fuel standard” that DOE developed for the plutonium disposition program based on a recommendation of the National Academy of Sciences. The third aspect is compliance with commitments in the PMDA. And the fourth is the degree to which WIPP disposal can afford a means for the IAEA to verify the irreversibility of the plutonium disposition end state, assuming that the three parties—the United States, Russia and the IAEA—eventually reach agreement on a monitoring regime. Unfortunately, the relevant standards in each of these areas are different and it is not always clear that they are consistent with each other.

DOE safeguards policy

DOE standards dictate that domestic safeguards be terminated on materials containing “special nuclear materials” (SNM)—including plutonium—prior to their transfer to WIPP. WIPP is a “property protection area” with security standards even below those required for sites possessing a Category IV quantity of SNM (e.g. 1 gram for plutonium-239). Termination of safeguards on SNM, according to DOE guidance, generally requires the material to meet Attractiveness Level E criteria (see Figure 1). [7] According to current guidance, a solid item containing plutonium would be considered Attractiveness Level E either if it contained less than 0.1 to 1 percent plutonium by weight, depending on the chemical nature of the matrix, or if it was “highly irradiated”¹ (see Figure 2). However, DOE allows termination of safeguards on Attractiveness Level D material if a security analysis shows that addition of the material to the waste storage area would not significantly increase the risk of theft, diversion or sabotage of a Category II quantity of material, which is 16 kilograms of plutonium for Level D. [8]

¹ Prior to issuance of the most recent DOE guidance, “highly irradiated” was defined as exceeding 100 rem/hr at one meter. In the current guidance, no dose rate limit is specified. Instead, “highly irradiated” is determined by whether or not an adversary could likely complete all necessary tasks to acquire a target quantity of SNM (e.g. theft, transport, processing) before being incapacitated. The old dose rate standard would probably not meet this criterion for many threat scenarios.
### Figure 1: DOE Graded Safeguards Table

<table>
<thead>
<tr>
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<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>WEAPONS</td>
<td>A</td>
<td>All N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>PURE PRODUCTS</td>
<td>B</td>
<td>≥2 ≥0.4&lt;2 ≥0.2&lt;0.4 &lt;0.2 ≥5 ≥1&lt;5 ≥0.4&lt;1 &lt;0.4 N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>HIGH-GRADE MATERIALS</td>
<td>C</td>
<td>≥6 ≥2&lt;6 ≥0.4&lt;2 &lt;0.4 ≥20 ≥6&lt;20 ≥2&lt;6 &lt;2 N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>LOW-GRADE MATERIALS</td>
<td>D</td>
<td>N/A ≥16 ≥3&lt;16 &lt;3 N/A ≥50 ≥8&lt;50 &lt;8 N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>ALL OTHER MATERIALS</td>
<td>E</td>
<td>N/A N/A Reportable Quantities N/A N/A Reportable Quantities</td>
<td>Reportable Quantities</td>
</tr>
</tbody>
</table>

1. The lower limit for Category IV is equal to reportable quantities in DOE O474.2.
2. The total quantity of U-233 = (Contained U-233 + Contained U-235). The category is determined by using the Pu/U-233 side of this table.
3. In this Technical Standard "highly irradiated" is defined in the definitions.

### Figure 2: Additional Attractiveness Level E Criteria for SNM

<table>
<thead>
<tr>
<th>Description/Form</th>
<th>Maximum SNM concentration* (wt%) for MC&amp;A and physical protection termination</th>
<th>Maximum SNM concentration* (wt%) for only physical protection equivalent to Category IV</th>
</tr>
</thead>
<tbody>
<tr>
<td>SNM solutions and oxides: nitrate, caustic or chloride solutions, contaminated/impure oxides, metal fines and turnings, glove box sweepings</td>
<td>0.1</td>
<td>N/A</td>
</tr>
<tr>
<td>SNM amenable to dissolution and subsequent separation: pyrochemical salts, chloride melt, hydroxide cake, floor sweepings, alumina, condensates reduction residues, sand, slag, and crucible, magnesium oxide crucibles spent fuel and spent fuel residues</td>
<td>0.1</td>
<td>0.2</td>
</tr>
<tr>
<td>SNM in organic matrices or requiring mechanical separation disassembly and subsequent multiple recovery operations: HEPA filters, organic solutions, oils and sludges, graphite or carbon scrap, surface contaminated plastics, metal components, combustible rubber</td>
<td>0.2</td>
<td>1.0</td>
</tr>
<tr>
<td>SNM bound in matrix of solid, sintered, or agglomerated refractory materials: SNM embedded in glass or plastic, high-fired incinerator ash, spent resins, salt sludges, raffinates, and sulfides</td>
<td>0.5</td>
<td>2.0</td>
</tr>
<tr>
<td>SNM microencapsulated in refractory compounds or in solid-dilution: vitrified, bituminized, cemented, or polymer-encapsulated materials, SNM alloyed with refractory elements (tungsten, platinum, chromium, stainless steel); ceramic/glass salvage</td>
<td>1.0</td>
<td>5.0</td>
</tr>
</tbody>
</table>

*SNM weight percent is based on element weight for plutonium and isotope weight for U-235 and U-233.
The spent fuel standard

Distinct from termination of safeguards, DOE also has a general policy to convert excess plutonium into a form that meets the “spent fuel standard” prior to disposal. As defined by the National Academy of Sciences in 1994, excess plutonium should be rendered “roughly as inaccessible for weapons use as the much larger and growing stock of plutonium in civilian spent fuel.” The National Academy emphasized that the spent fuel standard referred to intrinsic properties of items, and not extrinsic ones like security and institutional controls.

The chief material properties relevant to the comparative inaccessibility of disposition forms and civilian spent fuel are the mass and bulk of the item, the plutonium dilution, and the “self-protection”—that is, the intensity of external radiation from the fission products in spent fuel, primarily cesium-137. Isotopic composition of the plutonium was considered a much less important characteristic, given that changing the isotopic composition from weapons-grade to reactor-grade would have no effect on the ability of either the U.S. or Russia to utilize the material in their warheads, nor render the plutonium less attractive to terrorists seeking a crude nuclear device. Consequently, the National Academy judged that both spent light-water reactor MOX fuel and plutonium homogeneously immobilized in high-level waste canisters met the spent fuel standard. The presence of a substantial radiation barrier stands out as one of the defining characteristics of the spent fuel standard in the 1994 report. The National Academy considered it essential to preclude processing of the plutonium disposition forms in an unshielded glovebox operation that would be relatively cheap and difficult to detect. The prevailing view at that time was summed up in a statement from a 1998 report by DOE contractor Kaiser-Hill: “it has been clearly shown that no material form containing plutonium is truly ‘proliferation-proof’; experienced plutonium chemist [sic] have demonstrated they can recover plutonium from any form with the only issue being time and resources necessary to accomplish the end objective.” [9] This statement is also true for plutonium mixed with highly radioactive fission products; however, the National Academy gave significant weight to the differences between a reprocessing facility needed to separate plutonium from self-protecting spent fuel and a chemical processing facility that could be used to separate plutonium from a material that was not highly radioactive.

In 2000, the National Academy undertook a review of the spent fuel standard concept in part to address the concerns of critics who argued that DOE’s preferred immobilization alternative, “can-in-canister” immobilization, did not meet the spent fuel standard. Under this approach, the plutonium would be incorporated into a non-radioactive ceramic matrix and placed in cans, which would then be placed in a larger canister filled with radioactive waste. Critics argued that it would be possible for thieves to rapidly disassemble the waste canisters with cutting tools or explosives to obtain the plutonium-rich, portable and non-self-protecting cans inside. [10]

In its review, the National Academy judged that the most important barriers to subnational groups or to proliferant states were the low concentration of plutonium in an item, the difficulty of partly separating plutonium from bulk materials (e.g. the “canisters” in the can-in-canister option) on site, the technical difficulty of dissolution and separation once the cans were acquired, and the quantity of material needed. In contrast to the 1994 study, this assessment by the National Academy only rated the radiation hazard as moderately important since the external radiation doses, even from relatively young spent fuel assemblies, would not be immediately disabling and might not be sufficient to deter suicidal adversaries. Using these criteria, the NAS concluded that research and
testing were needed to determine whether the can-in-canister approach met the spent fuel standard. This issue was left unresolved when the United States cancelled its immobilization program in 2002.

DOE safeguards and the spent fuel standard
The relationship between the spent fuel standard and the attractiveness levels that determine DOE graded safeguards was never clearly defined. This lack of consistency is compounded by the problem that it is not straightforward even to determine under what conditions a spent fuel assembly can be considered “highly irradiated” and hence Attractiveness Level E. But if the spent fuel standard concept is to be consistent with the graded safeguards approach, it should be flexible enough to allow tradeoffs between different attributes of a plutonium disposition form. For example, greater dilution, or other measures that could increase the time and resources needed for plutonium recovery, could compensate for a smaller or non-existent radiation barrier.

For example, in 1998, the Rocky Flats Environmental Technology Site wanted to quickly get rid of about 3 MT of excess plutonium in the form of pyrochemical salts, incinerator ash and other residues by shipping it to WIPP. Despite being called “residues,” much of this material was rich in plutonium and fairly easy to process. In order to send the material to WIPP, Rocky Flats would have to convert the material to Attractiveness Level D items and conduct a vulnerability assessment to obtain approval to terminate safeguards. Also, in accordance with DOE policy on excess plutonium disposition, the material would have to be converted to a form meeting the spent fuel standard.

Even if technically feasible, adding a radiation barrier was not compatible with WIPP disposal. Sending highly irradiated items to WIPP was not an option because of the strict limits on the amount of RH-waste and its dose rate. Moreover, fission products from high-level waste could not have been used because WIPP was forbidden by law from accepting high-level waste.

Instead, Kaiser-Hill, the Rocky Flats contractor, argued that an alternative disposal arrangement would justify termination of safeguards and provide a level of inaccessibility comparable to that of plutonium immobilized with high-level waste. [11] It proposed combining residues or blending them down with “virgin material” to below 10 percent plutonium by weight (the attractiveness level D threshold) and packaging the material in pipe overpack containers with 200 FGEs or less of plutonium. Each POC would be placed inside a 208-liter drum.

Kaiser-Hill argued that this arrangement would render the material unattractive as a target for diversion or theft not because of the existence of a high radiation field, but because of the large number of drums that would have to be taken to acquire the same amount of plutonium (28 kilograms) as one high-level waste canister containing immobilized plutonium. It stated in its variance request that “to acquire a comparable quantity of material … will require that 127 to 160 drums weighing a total of 19,000 to 40,000 kg and having a volume of 26,400 to 33,300 liters, would have to be taken. The logistics for successfully acquiring and handling this quantity of material to recover the plutonium are recognized as low risk.”

Kaiser-Hill’s variance request did not credit any special properties of the “virgin” material that it used as a diluent for the plutonium residues. However, other sources report that this material,
originally called “stardust,” a mixture of cementing, gelling, thickening and foaming agents, was developed to “change the physical and chemical characteristics of the residues and make it more difficult and more complex to recover, concentrate and purify the plutonium.” [12] Stardust was blended with higher concentration, Attractiveness Level C residues to achieve an effective reduction to Level D, and then safeguards were terminated based on a security assessment. Presumably, simply blending higher concentration residues with a diluent without special chemical properties to reduce the plutonium concentration of the mixture to below 10 weight-percent was insufficient to warrant a Level D designation.

Stardust, now referred to as “termination of safeguards” material, is also being used at the Savannah River Site to package non-pit plutonium materials for disposal at WIPP as TRU waste, reconfirming DOE’s judgment that this disposal method does not significantly increase the risk of diversion or theft.

However, recall that disposing of 44 metric tons of excess plutonium in WIPP would require increasing the amount of plutonium sent to WIPP by a factor of four. Without being privy to the security assessments that have enabled DOE to terminate safeguards on these materials, one cannot infer that the amount of plutonium sent to WIPP in this manner could be increased by this amount without significantly increasing the risk of terrorist access. For instance, Kaiser-Hill did take credit in its variance proposal for the difficulty adversaries would have in identifying which TRU waste drums contained immobilized residues with relatively high plutonium content. This advantage would diminish as the number of such drums increased.

But there are other options that could be used in addition to simple blending with termination-of-safeguards materials to further reduce accessibility, if desired. For instance, instead of diluting plutonium to below 10 weight-percent and loading the mixture into pipe overpack components, which take up only a small fraction of the volume within a waste drum, plutonium could be diluted with a cement grout to well below 1 weight-percent without requiring additional drums. This would enable termination of safeguards based on dilution alone, since the safeguards termination limit for plutonium encapsulated in cement is 1 weight-percent. Alternatively, the plutonium to be disposed of in WIPP could be embedded in glass or ceramic, although this would likely increase the cost of disposal.

**GEOLOGIC BARRIERS VERSUS INTRINSIC BARRIERS**

Inherent in the concept of the spent fuel standard is the underlying assumption that once converted to a disposition form, excess plutonium would be treated similarly to existing stockpiles of spent fuel and high-level waste—it would be placed in interim storage pending development of a geologic repository like Yucca Mountain where such materials could be buried. However, if one option could lead to faster or more certain burial than others, this assumption would no longer be valid, because that option could take credit for a geologic barrier to accessibility. And the geologic barrier is a formidable one with respect to both sub-national and national threats.

Sub-national groups would either have to covertly drill into a repository and remove a large volume of material undetected or would have to overtly seize a repository to gain control of its access portals for a considerable length of time, provided it had not yet been sealed.
A detailed adversary task analysis would be required to determine the degree to which the geologic barrier provided by WIPP could compensate for the lack of a radiation barrier when compared to spent fuel sitting in interim storage for a hundred years or more, a possibility that now appears more likely in the wake of the cancellation of the Yucca Mountain Project. However, it is clear that the National Academy believed the geologic barrier, as well as institutional barriers, would be necessary for the long-term security of disposition waste forms as radiation barriers declined with time. If substitution of a geologic barrier for a radiation barrier would provide adequate security in the long term, then logically it would also provide adequate security today. The prospect of near-term geologic disposal of excess plutonium, even without an intrinsic radiation barrier, should be a huge plus for the WIPP option.

For national threats, in contrast, some would argue that a geologic barrier can provide no real protection, as a nation could easily excavate the site and recover the material. This is the specter of the “plutonium mine.” The counter-argument is that such activities would be easily detectable with minimally invasive safeguards in place, such as acoustic monitors and satellite surveillance. In fact, it would be easier for the IAEA to safeguard a known geologic disposal site than one or multiple interim surface sites storing large stocks of aging spent fuel, not to mention to detect clandestine plutonium production activities which could occur anywhere.

CONCLUSION
The disposal of excess weapons plutonium in WIPP has been proven and may be an affordable option for disposing of the 34 metric tons of plutonium covered by the U.S-Russian disposition agreement, as well as a large fraction of the remaining inventory of U.S. excess plutonium. Burying excess plutonium in a mined repository in the near-term is attractive in comparison to disposing of plutonium in forms like spent fuel or vitrified high-level waste that will remain in above-ground interim storage for many decades or even centuries before a repository that is capable of accepting them becomes operational.

Issues that remain to be addressed include selection of the appropriate disposal scheme for the excess plutonium inventory in WIPP; development of the infrastructure needed to package and ship the plutonium; resolution of domestic political obstacles (e.g. Congressional support for MOX and potential local opposition to increasing the amount of plutonium disposed of in WIPP); and negotiation of a revised protocol with Russia. However, given the potentially enormous cost savings of the WIPP option, the benefits would be well worth the necessary effort.
REFERENCES