Rebaselining of the Plutonium Residue Elimination Project at Rocky Flats Environmental Technology Site

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ABSTRACT

Systems Engineering and Value Engineering principles were put into practice in rebaselining the Pu Residue Stabilization and Elimination Project at the Rocky Flats Environmental Technology Site. Tradeoff studies were conducted as to how to best rebaseline the system under the new Safeguards Termination Limits (STLs) issued by the Department of Energy. Through the use of a computerized database, the means by which Stakeholder values and other high-level requirements have been included in the tradeoff studies were documented.

INTRODUCTION

With the Department of Energy (DOE) formally adopting a Systems Engineering approach to managing large projects, the use of Systems Engineering principles will become more common in the DOE complex.

The Pu residue stabilization program at the Rocky Flats Environmental Technology Site (RFETS) came into being as the result of the Defense Nuclear Facilities Safety Board's (DNFSB's) Recommendation 94-1 to the Secretary of Energy that Pu scrap and other residues, now stored in drums at Rocky Flats and at other sites, shall be put into a safe form as quickly as possible (DNFSB, 1994). This was a result of safety concerns with respect to the current chemical form and packaging configurations in which they are stored. The ultimate goal is to place the Pu in packages that will be accepted by the DOE's Waste Isolation Pilot Plant (WIPP), or in packages that are safe for long-term storage (> 20 years) at Rocky Flats or another DOE site. There is also an interim safe-storage commitment that RFETS has made to the DNFSB that all unstable scrap forms will be stabilized by May 2002.

The requirements to certify the packages for WIPP are documented in the WIPP Waste Acceptance Criteria (DOE/WIPP, 1996) which is commonly called the WIPP-WAC. The standard for long-term storage packages is stated in the DOE Standard 3013-96 and thus long-term storage packages are called "3013" packages (DOE, 1996a). The document that delineates how Pu shall be stored ("stabilized") for periods not exceeding 20 years is called the Interim Safe Storage Criteria (ISSC) (Curtis, 1996).

The original (baseline) program has proceeded through Title I and Title II Design stages (DOE, 1995a). New equipment to perform the operations has already arrived on site. The great majority of the Pu was destined for WIPP and was to be packaged in a form that would meet the WIPP-WAC.

The rebaselining was necessitated by the issuance of Safeguards Termination Limits (STL's) (McCallum, 1996). They can be stated *for our purposes* as a maximum allowed percentage of Pu in five different chemical forms that may go to WIPP, ranging from 0.2% for salts to 5% for vitrified glass. If the current baseline were pursued, roughly 40% of the waste that would be destined for WIPP would not meet the STLs. Meeting the STLs requires either the removal of plutonium from the scrap and concentration into a form suitable for a 3013 container, dilution with a filler material before shipping to WIPP, or changing the chemical form so as to allow a higher percentage of Pu in WIPP-destined waste (Figure 1).

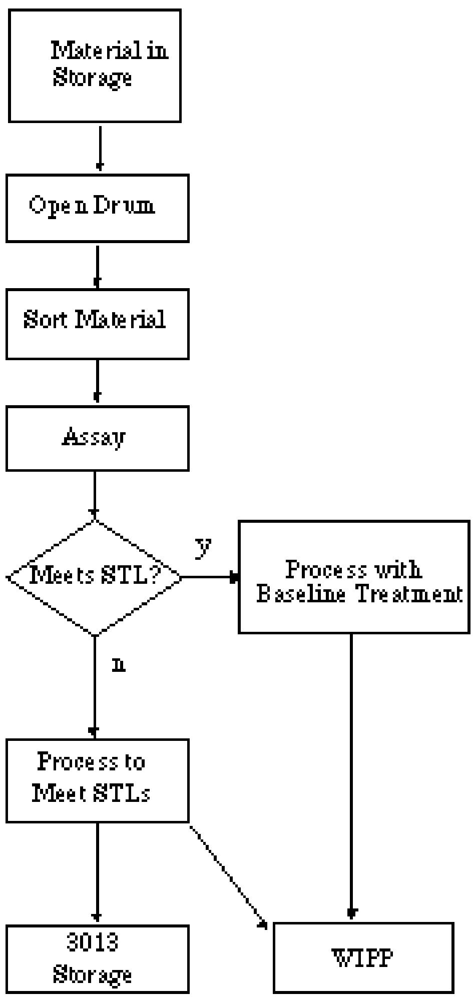

Figure 1. The process that will be used for the Pu scrap stabilization function in light of the Safeguards Termination Limits.

MAIN BODY

In conducting the tradeoff studies we followed the guidance of DOE Office of Facilities Management, who has the responsibility of implementing DOE Order 430.1, Life Cycle Assets Management (DOE, 1995b). Alternative architectures were developed specifically for the tradeoff study. They were known in sufficient detail that the relative worth of each could be judged reliably and accurately.

According to DOE guidance (DOE, 1996b), a Mission Analysis is required before beginning the tradeoff studies to determine the top-level source of requirements and constraints.

A Mission Analysis was performed. This study, described in Figure 2, identified the current situation (initial state) , desired outcome (final state), and established the high-level requirements and constraints. The mission statement is contained within the box that represents the system. The inputs to the system are on the left and the principle outputs on the right. Constraints on the system are immediately above the box, whereas drivers such as stakeholder views, DNFSB recommendations and DOE Guidance are above and to the side.

While DOE Orders and Federal, state and local laws provide constraints to the system, the drivers for determining the technical path are in the stakeholder values, along with the need to adhere as closely as possible to the Site’s Ten Year Plan (RFETS, 1996a) goals and the DNSFB recommendations.

Stakeholder and DNFSB Values

The preeminent document expressing the stakeholder values is the Rocky Flats Cleanup Agreement (RFCA) (RFETS, 1996b). This document mostly addresses the eventual site-wide cleanup baseline, but in some sections there is discussion of values that impact the Pu residue elimination program.

The “Vision” accompanying the RFCA states the following: “The highest priority at Rocky Flats is to reduce the risks posed by plutonium, other special nuclear materials and transuranic wastes. These materials will be collected, consolidated, and safely stored in a retrievable and monitored manner in the fewest number of buildings for removal to off-site locations at the earliest possible date.” It is clear therefore that adhering to the schedule for nuclear material stabilization and safe storage must be considered first among stakeholder values.

This view is shared by the DNFSB, who stated in their Recommendation 94-1 that “The Board is especially concerned about the following situations: . . . Many of the containers of plutonium metal also contain plastic and, in some at the Rocky Flats Plant, the plastic is believed to be in intimate contact with the plutonium. It is well known that plutonium in contact with plastic can cause formation of hydrogen gas and pyrophoric plutonium compounds leading to a high probability of plutonium fires . . . The Board recommends that preparations be expedited to repackage the plutonium metal that is in contact with, or in proximity to, plastic or to eliminate the associated existing hazard in any other way that is feasible and reliable . . . “

Performance Indices

The processing alternatives are measured for their relative suitability by eleven performance indices which have been derived from Stakeholder Values and DNFSB Recommendations. Of these eleven, six are tied to reducing the risk of schedule slippage. In each of the eleven indices, a metric is evaluated and the alternatives are then ranked relative to one another by their score on the metric. As an example, suppose there are three alternatives and they score 2, 7, and 6 on a given metric. These scores are translated into a rank of 1, 3 and 2, respectively for this index. To find an overall winner, the ranks in each of the eleven indices are added together, giving

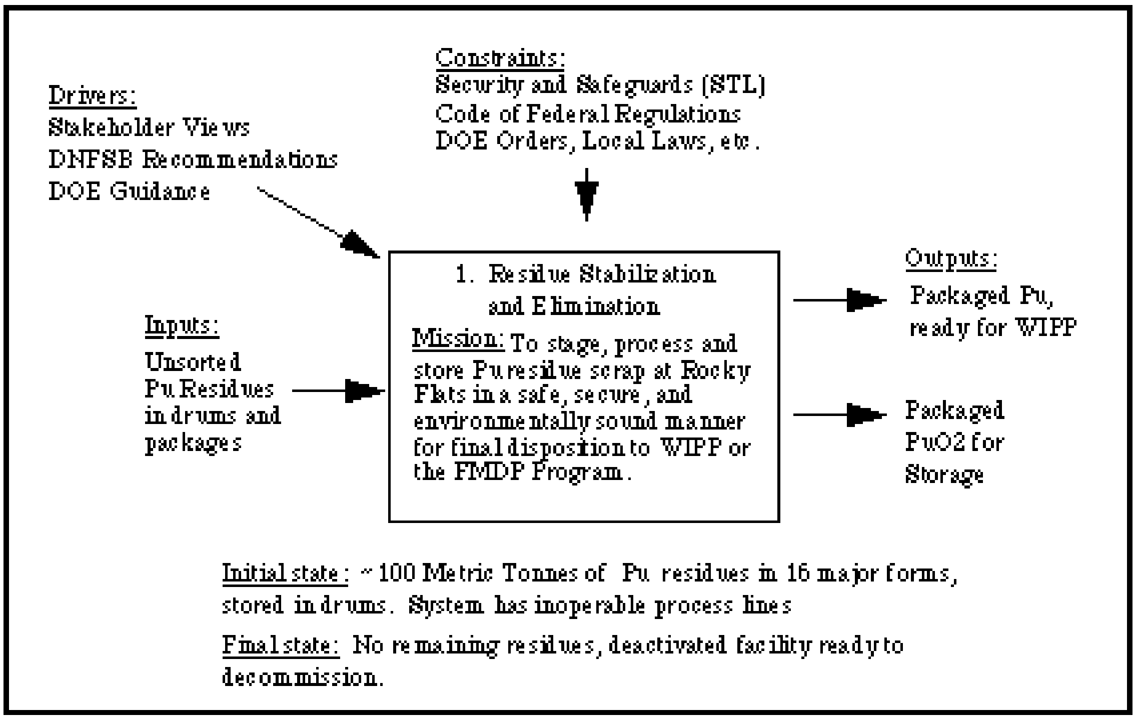

Figure 2. Diagrammatic Representation of the Mission Analysis Results

an overall score. In the case of a tie or no clear winner, a more careful cost analysis is required before a recommendation can be made. The eleven performance indices are listed below.

1. Waste minimization: The total number of TRU and low-level waste drums generated (primary and secondary) is determined for each processing option from the flow sheets. This is the metric: the fewer the number of drums, the better.

2. Schedule. A tentative schedule is determined for each processing alternative, which includes delay to implement the reconfiguration of installed hardware and operator training. All alternatives are assumed to meet the major milestones, which is to have all residues stabilized by May 2002. Certain residues, such as pyrochemical salts, sand, slag and crucible and combustibles have intermediate milestones in the 3-4 year range because the DNFSB considers them to be a higher risk. Because of the assumed risk that the unremediated Pu residues pose due to their unstable nature, the sooner the residues are repackaged the better. Therefore the metric is taken as the date for the start-of-operations. The earlier the starting date the better.

3. Process Level-of-Demonstration. The flow sheet is examined. For each sub-process on the flow sheet, the metric is found as follows. If sub-process is: (1) previously run at RFETS on plutonium-bearing materials (2) previously run at other DOE or defense site on plutonium-bearing materials (3) demonstrated on full scale at RFETS or other DOE site on plutonium-bearing materials (4) demonstrated on laboratory scale on plutonium-bearing materials (5) demonstrated on full scale at RFETS or other DOE site on surrogate materials (6) demonstrated on laboratory scale at RFETS or other DOE site on surrogate materials (7) demonstrated in industry (8) is conceptual only. Obviously, the higher the number, the less the level-of-demonstration. At this point, the overall metric for a process is taken as the worst of all its sub-processes. For instance, if a process has ten sub-processes and nine have a rating of (1), and one sub-process is rated as a (7), the overall rating for the process is (7).

4. Process Simplicity. The flow-sheet is examined and a set of sub-indices (a)-(g) are evaluated. The metric for "simple process" is then the sum of these 7 indices. The sub-index (a) is found as: what is the minimum number of major process steps for this process? The sub-index (b) is found as how many of these steps are chemical process steps? Next, the most complicated piece of equipment from a maintenance and reliability viewpoint is examined. If this is a simple piece of equipment, the index (c) is given a value of 1, if moderately complex, 2; and if very complex, 3. Next, the most carefully-controlled process stream is evaluated as to its difficulty of control-requirements. If its process parameters are not stringently controlled, the sub-index (d) is given a value of 1. If there are some process control complications, a value of 2 is awarded. If the control is complex, a value of 3 is assigned. Sub-index (e) is determined in a similar way, except in reference to the safeguards and accountability requirements. The sub-index (f) is then determined in the same way with respect to certification for ISSC and WIPP. The last sub-index, (g), is found based on the amount of negotiation required with WIPP, DNFSB, or the State of Colorado. Its value also ranges from 1 to 3, depending on complexity.

5. Flexibility. There is no "flexibility" metric per-se. Rather the processing options are simply ranked with respect to one another, based on relative flexibility. The processes are evaluated with respect to whether they are likely to treat other RFETS residues or waste streams and whether the process is insensitive to feed variability. This metric measures the robustness of the technology selection to variability of initial conditions or technology upsets.

6. Worker radiation exposure. The metric is the number of bag-in[a] and bag-out operations, as determined from the flow sheet. These operations are the major point of radiation exposure per Activity Control Envelope studies.

7. Risk to worker/public. Three sub-indices (a)-(c) are evaluated and the metric is determined as the sum of these three indices. The sub-index (a) is whether or not the process generates dispersible fines at any point. The score is 1 if it does, 0 otherwise. Sub-index (b) is found by relative rank of transportation risk. The processes are ranked against one another based upon the total number of shipments of primary waste and Pu oxide or metal shipments. The sub-index (c) is determined by a judgment of how safe the process is from an industrial viewpoint. A very safe process is given a 1, moderately safe a 2 and less safe a 3. Involved in this evaluation is whether the process uses or generates flammable, combustible, shock-sensitive, or pyrophoric materials; and whether it involves hazardous equipment or toxic chemicals. This metric measures risk to worker/public not including the risk to public due to schedule delays (see #2 above).

8. Implementability. The process is evaluated and is scored as a 1, 2, or a 3 with 1 being the most easily implemented, 3 being the most difficult. The judgment is made considering all implementability factors not included in the other metrics. Of all the processes evaluated, none were judged to be impossible to implement. However, a score of 3 was given to those processes where the likelihood of schedule slippage due to implementation difficulties was judged to be significant.

[a] A bag-in or bag-out operation is a process by which radioactive materials are placed into or removed from a glove box while maintaining confinement of radioactive particulates with a plastic bag which can be taped closed and cut off.

9. Authorization Basis (DOE, 1992): The ease of obtaining an Authorization Basis (AB) for the process is judged by (1) whether the safety analysis would be included within existing Safety Analysis Reports (SAR's) for the buildings we intend to use and (2) there are potential Unresolved Safety Questions (USQ's). The likelihood of a difficult-to-address USQ is also evaluated. The processes are then simply ranked against one another to find the metric. This metric is a measure of the likelihood of schedule slippage due to troubles obtaining an authorization basis.

10. Stakeholder Acceptability. This metric refers to estimated level of opposition from local citizens, local elected officials, and the Citizen's Advisory Board (CAB). The metric is given a value of 1 if no opposition is expected, through 4 if a large amount of opposition is expected. Processes that have generated opposition in the past have usually involved incineration of contaminated wastes or permanent on-site storage of waste. It is also anticipated that processes that involve large quantities of liquid radioactive waste which must be stored even temporarily on-site may invoke opposition.

11. Life-cycle costs. The processing alternatives are ranked relative to one another based on projected cost. In this analysis, the costs factors considered are:

A. Capital and operation costs are derived from the baseline costs as follows: * The baseline value for total capital and operating cost (for the feed under consideration) is determined from existing budgetary data. * If additional (fewer) operators are needed for the process alternative under consideration, they are accounted for at + (-) $150K per operator-year. * If glovebox removal and replacement is required, that cost is computed as number of gloveboxes replaced times a fixed cost per glovebox. The cost per glovebox depends on if there is radioactive contamination. For a contaminated (non-contaminated) glovebox, the cost is $1.5M ($0.5M) to stripout and $2M ($1.5M) to install.

B. Waste certification costs. The cost per can varies as to which category the can falls into. Category A includes sealed cans with homogeneous fill and cost $2197 per can to certify. Category B includes vented cans or cans with a strong pedigree (obviating the need for individual can inspection) and cost $2443 per can to certify. Category C includes cementous fill or cans with a weak pedigree and cost $7062 per can to certify.

C. Costs for 3013 canisters produced are taken as $4500 per canister.

D. TRU Transportation and disposal costs are $7100 per drum (to the DOE). These costs are not incurred by RFETS.

E. The number of secondary drums of waste is considered in the calculation. Based on studies of RFETS processing, this number is taken as 0.15 drums of secondary waste per kg of material input to the process (including packaging) for dry, non-dusty processes. For dusty or wet processes, this number doubles.

F. Decontamination & decommissioning costs are taken as fixed for one process relative to another. Therefore they are ignored in this comparison.

An Example: ER Salts

Among the 16 major feed streams for the process is the Electrorefining (ER) salt stream, which is roughly 10 metric tons (MT) out of a total of 100 MT of scrap to be remediated at the site. The evaluation for this particular type of scrap feed stream addresses all options, considerations, and constraints contained in the rebaselining guidance issued by the local DOE field office (Dalton, 1996). The following were the architecture options for ER salts. (1) pyro-oxidation/distillation (2) salt scrub/pyro-oxidation/ship to Savannah River Site (3) pyro-oxidation/aqueous dissolution (4) pyro-oxidation/blend with U_3O_8 (5) blend with U_3O_8 (6) salt scrub/pyro-oxidation/blend with U_3O_8 (UO_3)

The recommendation was to implement pyro-oxidation and install distillation furnaces in parallel for all ER salts (97% exceed STLs). The main advantages enjoyed by this method were: (1) the process minimizes drums to WIPP - hundreds of drums versus thousands of drums for UO_3 blending options and (2) uses proven technology (3) U_3O_8 on site at RFETS is F-listed according to RCRA (US Congress, 1992) and may contain unburned uranium - this requires a permitted roasting step, which complicates the overall process.

The results of the cost analysis are shown in Table 1. The analysis includes vault storage, development, and WIPP shipment and disposal. Rebaselining ER salts to meet STLs costs RFETS an additional $8.5M, but the net change in cost to DOE is a savings of $5.0M resulting from the fewer drums to WIPP.

Table 1. RFETS and DOE Costs for Remediation of ER Salt

ER Salts	Baseline	New	Δ
RFETS Costs	39.5	48.0	8.5
DOE Costs	84.3	79.3	(5.0)

Computerized Database

With definition and analysis of the system becoming more important, a computer-aided systems engineering tool is critical for supporting and documenting the work. Throughout the rebaselining effort, the Systems Engineering tool CORE was used for that purpose.[b]

[b] Vitech Corp. 2070 Chain Bridge Road, Suite 105, Vienna, VA 22182, Phone: (703) 883-2270, or http://www.vtcorp.com/

The systems description document (SDD) is a living document that maintains the baseline for the system. It contains a description of the functions, the requirements, inputs, outputs, constraints, tradeoff studies, critical issues, assumptions, risks and decisions. As the results of tradeoff studies are known and architecture specified, the SDD contains architecture descriptions, specifications and testing and verification procedures. Both the bases and the results of the tradeoff studies are kept within this database.

CONCLUSIONS

Tadeoff studies based on DOE/FM good practice guides have helped us to reach rebaselining decisions that should be of maximum benefit to stakeholders. Such studies will become more common in the future at RFETS because they are best for the Site and the Department of Energy.

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AUTHOR BIOGRAPHIES

Dr. T. P. Burns was awarded Ph.D. in Chemistry from U. Nebraska Chemistry Department in August, 1986. He then joined Los Alamos National Laboratory as a postdoctoral fellow in the Medical Radioisotopes Research Program. He moved to the LANL's Rocky Flats office in April, 1990. He has worked in the area of mixed waste since then.

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