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COMPARISON OF SPENT NUCLEAR FUEL MANAGEMENT ALTERNATIVES

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C. L. Beebe, M. A. Caldwell
Lockheed Martin Idaho Technologies Company
Idaho Falls, Idaho USA

ABSTRACT

This paper reports the process and results of a trade study of spent nuclear fuel management alternatives. The purpose of the trade study was to provide: (1) a summary of various spent nuclear fuel (SNF) management alternatives, (2) an objective comparison of the various alternatives to facilitate the decision making process, and (3) documentation of trade study rational and the basis for decisions.

INTRODUCTION

During April 1992, the U.S. Department of Energy (DOE) chose to phase out reprocessing spent nuclear fuel (SNF) for uranium recovery and shifted its focus toward the management and disposition of radioactive fuels and wastes left over from reprocessing activities. The decision to discontinue reprocessing has left nearly 2700 metric tons of heavy metal (MTHM) of SNF in temporary storage throughout the DOE complex, with another 100 MTHM anticipated over the next 40 years from various Naval, U.S. Research, University, and foreign research reactors.

Although each site is responsible for managing their own SNF inventories and preparing it for final disposition, the National SNF Program was initiated to ensure an integrated approach is achieved for safe interim storage, treatment, and ultimate disposition of present and future DOE-owned SNF. This has become a highly complicated task due to the numerous interrelated elements within the DOE complex, including but are not limited to the following:

- More than 150 fuel types exist
- No single disposition plan can encompass all fuel types
- Storage facilities differ in acceptability for interim (40-60 years) storage; casks range in size, quantity, and certification for SNF transport
- Some interim and final disposition management strategies are pending National Environmental Protection Agency (NEPA) reviews
- SNF treatment and conditioning technologies vary and are not common to all SNF storage locations.

Data relative to the elements listed above has been generated by various sources throughout the complex, however, this data exists rather independently. The analysis of alternatives on a complex-wide level required that all information be pulled together to allow the impacts of different alternatives to be evaluated more efficiently. Spreadsheets were first used to capture and link the data. However, as work continued to integrate the elements and information, the set of equations and data soon became too cumbersome for spreadsheets to analyze. Consequently, a dynamic computer simulation model was designed to compare SNF management alternatives and create graphs, tables, and reports to display the impacts of various management strategies over time. This model, the Alternatives Comparison Tool (ACT), is currently being used to analyze the effects of implementing different strategies for managing SNF across the DOE complex.

ASSUMPTIONS

Three key documents currently constrain the management and disposition of DOE-owned SNF throughout the DOE complex:

1. The U.S. District Court's Opinion and Order of June 28, 1993, as amended by Judge Harold Ryan on December 22, 1993, regarding the management and storage of SNF and radioactive waste at the INEL.

2. The Record of Decision (ROD) for the *Programmatic Spent Nuclear Fuel Management and Idaho National Engineering Laboratory Environmental Restoration and Waste Management Programs Environmental Impact Statement* (EIS), dated June 1, 1995.[1]

3. The Settlement Agreement with the State of Idaho regarding the shipment of DOE-owned fuels to the INEL, dated October 16, 1995.[2]

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Current program assumptions and requirements, as mandated by the above documents, have been coded into the ACT model to facilitate the analysis of various SNF management options. The assumptions are listed below.

- Each load, unload, and decontamination bay of a facility will be able to process one cask at a time.
- The load, unload, and decontamination activities at a facility will be performed by three full-time equivalents (FTEs), with an overhead of nine engineers/managers.
- SRS is the only location that will perform processing. A possible exception will be EBR-II fuel at Argonne National Laboratory-West (ANL-W), wherein an electrorefining stabilization process for sodium-bonded fuel may result in uranium separation. At SRS, two types will be performed: fuel dissolution and uranium extraction; uranium extraction will occur via a blending and separation process. (This assumption is true only for the baseline scenario.)
- The Yucca Mountain Repository, or equivalent, is the only final disposal option for SNF.
- Treatment or conditioning, if needed, is determined by the technical experts and not optimized by ACT.
- MSRE fuels at the Oak Ridge National Laboratory (ORNL) will remain in their current location and have little, if any, impact on the rest of the system. (This assumption is true only for the baseline scenario.)
- Repository will be available for accepting DOE-owned SNF in 2025.

ANALYSIS METHODOLOGY

As outlined in the EIS ROD[1], regionalization-by-fuel-type (alternative 4a) is the selected alternative for managing DOE-owned SNF. Under this alternative, spent nuclear fuel management will occur at three sites: the Hanford Site, the INEL, and SRS. Under this decision, the fuel type distribution is as follows:

- Hanford fuel will remain at its present location with the exception of the sodium-bonded Fast Flux Test Facility (FFTF) fuel, which will be transported to the INEL for management;
- Aluminum clad fuel will be consolidated at the SRS; and
- Non-aluminum clad fuels (including the Naval SNF, but excluding the Fort St. Vrain SNF, which will be safely maintained at its present location) will be transferred to the INEL.

This trade study uses the 4a alternative as the baseline scenario for comparing SNF management alternatives. The parameters of the baseline are as follows:

- Constraints placed on the INEL by the Settlement Agreement with the State of Idaho are included in the baseline scenario.
- Approximately 40 casks are considered available, of which 5 are most often used. Availability is determined by the ability to obtain cask certification, compatibility of fuel-cask match (provided by the Transportation group of the National SNF Program), level of cask utilization, compatibility with facility loading and unloading, and compatibility with transportation routes.
- The priorities for moving fuel are based on the *Systems Analysis Priorities for SNF Transfer and/or Stabilization* study[3], completed by the National SNF Program in April 1995. The priorities for movement were determined based on the need for the fuel or facility where the fuel resides to achieve a safe stable condition. The ACT model was coded to allow the programmer to override, at the request of the user, established priorities when necessary to meet other court orders and agreements.
- SNF data comes from the *Integrated Spent Nuclear Fuel Database.*
- Consistent with the nonproliferation policy and the assumption of the SRS processing, the baseline scenario does not include processing for the recovery of high-enriched uranium (HEU). The option, however, has been considered for some of the alternatives identified in this study.

DOE-owned fuels were categorized by fuel type, and management alternatives were identified and evaluated for each fuel category. These processes are described in detail below.

FUEL CATEGORIES. More than forty years of nuclear reactor development and testing have spawned a plethora of fuel types, resulting in a legacy of stored SNF varieties. A primary effort has been the combining and grouping of these SNF types into larger groups having similar characteristics, such as cladding, fuel matrix, hazardous materials, and general condition. The almost 150 fuel types have been placed into the following 12 major fuel groups: Navy-like Fuel, ATR-type Fuel, Graphite Fuel, EBR-II type Fuel, Fermi Driver Fuel, TMI-2 Fuel, Commercial-like Fuel, Tory-like Fuel, FFTF-type Fuel, Metal-clad Carbide, MSRE (ORNL) Fuel, and N-Reactor Fuel. Since the primary focus was for safe and cost effective SNF management, group characteristics (e.g., SNF cladding, fuel matrix alloys, and hazardous materials) that provided for a common path forward to interim and long-term dry storage in modular facilities were selected as the basis for fuel groupings. Combined fuel types ranged from highly stable and robust navy fuels to badly disrupted Tory type to the sodium-bonded EBR-II type fuels. Although chemical processing and/or conditioning is an important alternative for many groups, only the sodium-bonded EBR-II group has a clear need for conditioning to resolve a potential Resource Conservation and Recovery Act (RCRA) issue, assumed to be removed prior to final disposal.

ALTERNATIVES IDENTIFICATION. The identification of alternatives for this evaluation has been extensive. More than 100 different fuel types reside in the DOE complex. These differing fuel types present a potential for an equal number of disposition paths, since no one process exists to manage all DOE-owned fuels through to final disposition. To simplify the analysis, the fuels were combined and grouped into the 12 major categories, as previously discussed.

In addition to the baseline scenario described above, this study considered the possibility of processing certain fuel categories. This resulted in a range of 3-10 alternative paths for each fuel type. A generic schematic of the various potential paths is shown in Figure 1. Specific schematics were developed and evaluated for each of the 12 fuel groupings.

ALTERNATIVES EVALUATION. The primary objective of this trade study was to compare various alternatives by evaluating potential management paths for each fuel category, as shown above, against an established set of decision criteria.

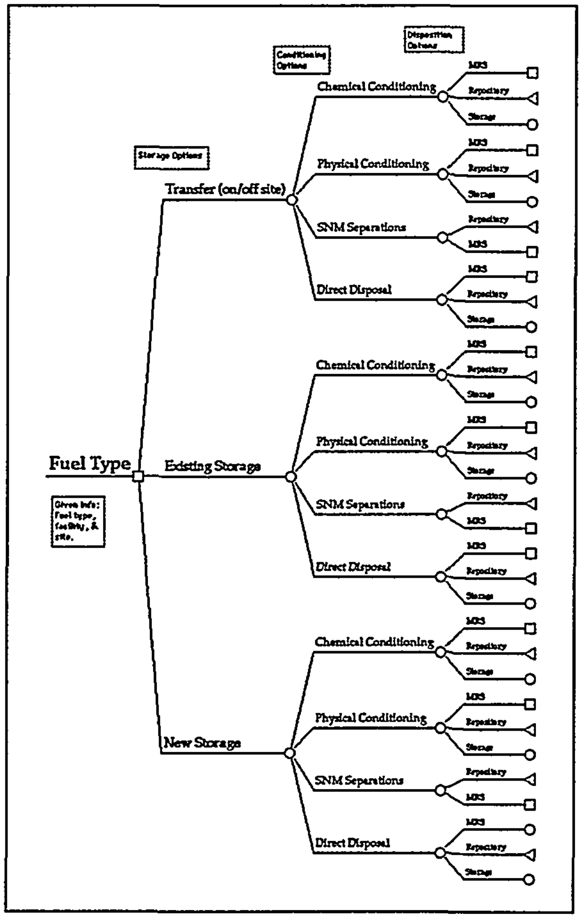

Figure 1. Generic Decision Tree

Using the Alternatives Comparison Tool (ACT), alternative paths were analyzed in terms of transportation costs and schedules, facility costs and schedules, processing costs and schedules, final fuel form volumes, number of shipments, quantities being shipped, etc. The evaluation was conducted by maintaining 11 of the 12 fuel categories consistent with the baseline and analyzing the remaining fuel category according to its various alternative paths. The lowest cost and volume options were then saved for further analysis. This process continued for all 12 of the fuel types. The best options will be optimized as a whole in follow-on studies. The sections below describe the ACT model and outline the decision criteria used in the evaluation.

Alternatives Comparison Tool (ACT)—ACT is a priority-driven, resource-limited model developed to evaluate various alternative paths DOE-owned SNF may follow to final disposition. In explanation, the fuel shipments for a given scenario are entered into a database and a priority is assigned[3]. The flexibility to override priorities when necessary has been programmed into the model to force shipments and resources needed to meet other commitments. Resources simulated in the model include: shipping facilities, receiving facilities, casks, and conditioning processes (canning, etc.). Since any resource has a finite capacity, the combinations of resources required for moving fuel and the priority assigned to that fuel determine the transportation schedule. A detailed description of the logic used to configure ACT appears in *Transmittal of Model Documentation*, GEM-45-95, June 1, 1995.[4]

ACT utilizes data from several databases to simulate the complex interactions of inter-site transfers. These databases include the *Integrated Spent Nuclear Fuel Database*, the cask (transportation) database, and the facilities database. The ideal scenario is for a fuel to be placed in stable interim storage pending repository disposal. Where some type of stabilization (e.g., canning, drying, treatment, etc.) is required prior to repository disposal, ACT evaluates the cost and schedule for a particular path. Data regarding fuels, facilities, transportation, conditioning, and costs are assembled into electronic data files from which the model draws to compare the alternatives on a fuel type basis. Results from the model are displayed in terms of cost, schedule, SNF inventories, and volumes of SNF being transported or stored.

Results from ACT allow different SNF management scenarios to be compared and contrasted. The types of possible scenarios are almost endless; different types and numbers of casks can be used for transportation; different facilities can be used for receipt of fuels; and different priorities can be used for shipping schedules. By varying specific parameters, DOE decisionmakers can anticipate the parameter's effects on the transportation and storage of SNF.

Further work on determining the priorities for fuel transfers is in progress[5]. Near-term priorities were determined by examining the site plans and schedules, generally covering five to ten years. Long-term priorities were set using a combination of fuel and facility vulnerability. Work is also continuing on refining established priorities and will include other factors, such as O&M cost savings for early or late closure of facilities, commitments to various Stakeholders, and shipping facility SNF storage capacity.

Decision Criteria—To present a meaningful comparison of alternatives, it is imperative that trade study results are provided using the parameters that are most likely to determine the path of a particular fuel. Not only should the alternatives be compared using discriminating criteria, but the identified parameters need to be quantifiable and accurately measure the relative differences between a given set of alternatives. ACT reports results in several different ways and by different parameters. These parameters, shown in Table 1, have been grouped for reporting purposes in terms of cost and fuel volumes over time.

Table 1. Decision Criteria

CRITERIA	DEFINITION
Transportation Costs	This includes the planning necessary for fuel transport, actual loading and unloading, initial campaign costs, safety analyses, cask rentals, cask maintenance and a cost per mile of shipment.
Processing Costs	This includes the cost of performing processing.
Facility Projects Costs	This includes the design, construction, and start-up of new facilities.
Facility O&M Costs	This includes the day to day costs of maintaining the facility and keeping it operational.
Stabilization (Conditioning) Costs	This includes the cost to perform the work to can the fuel.
Transportation Time	This is the duration from the time the fuel is loaded for shipment to the time the fuel is received at its destination.
Processing Time	This is the duration that it takes to perform processing.
Facility Project Time	This is the time that it takes to design, construct, and start-up a facility.
Stabilization (Conditioning) Time	The time it takes to perform canning.
SNF Volume	This is the quantity of fuel that will be destined for the repository after any conditioning or processing.
HLW Volume	This is the quantity of waste that will be destined for the repository as a result of any processing.
LLW Volume	This is the quantity of waste that will be destined for the repository as a result of any processing.
Facility Capacity	This is the combination of the capacity of the facility and the percent utilization of that capacity.
Cask Capacity	This is the combination of the capacity of the cask and the amount of fuel that may be stored or transported in the cask.

TRADE STUDY RESULTS

Results for all alternatives considered in this trade study are currently being finalized for inclusion in a report to the DOE Office of Spent Nuclear Fuel Management. As such, only a brief summary of selected options is available at this time.

To date, a total of ten management alternatives for TMI-II, Metal-clad Carbide, and FERMI fuel types have been evaluated against the baseline scenario. A comparison of the lowest-cost and lowest-volume options for each of these three fuel categories appears in Figure 2.

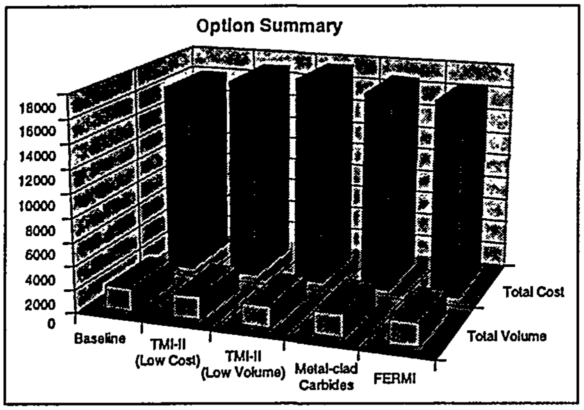

Figure 2. Summary of Selected Options

As stated above, the baseline scenario is the EIS ROD[1] Regionalization-by-Fuel-Type (Alternative 4a) option, as modified by the Settlement Agreement with the State of Idaho[2]. Under the TMI-II low cost option, fuel remains in existing storage facilities until 2025, when it will be transferred to a geologic repository. The TMI-II low volume option stores the fuel in dual purpose canisters (DPCs) pending approval for final disposition. The Metal-clad carbide option also stores the fuel in DPCs pending approval for final disposition and represents both the low cost and low volume alternative. The low cost/low volume option for FERMI fuels stores fuels in DPCs until 2025, when it will be transferred to a geologic repository.

COSTS. Evaluation results at this point in time do not provide significant cost savings over the baseline scenario, shown here in millions of dollars. It is anticipated, however, that as evaluation results are completed and preferred management alternatives are optimized significant cost savings will be realized, particularly in characterization costs associated with SNF processing options.

VOLUMES. Although costs are important, the limited repository space allocated to the DOE demands that SNF volumes destined for the repository be kept to a minimum. Figure 3 is an enlargement of the SNF volumes displayed in Figure 2. As shown, the TMI-II low-volume option reduces the amount of SNF destined for the repository by approximately $130m^3$. Note, however, that this option does not consider final disposition in a repository. As such, the displayed volume may increase as the quantity is prepared for repository emplacement.

It is anticipated that final evaluation results and optimization of preferred alternatives, including the option to process for HEU recovery, will offer significant reduction in SNF volumes and potentially decrease the demand on the DOE's limited allocation of repository space.

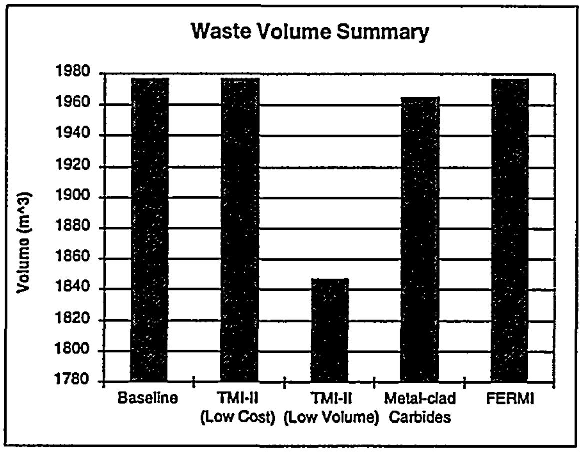

Figure 3. Summary of Waste Volumes for Selected Options

CONCLUSIONS AND RECOMMENDATIONS

Results at this point are insufficient to draw firm conclusions and/or make defensible recommendations regarding SNF management alternatives. Recommendation will be made upon completion of alternative evaluation efforts and presented in the *Trade Study of Spent Nuclear Fuel Management Alternatives* report to DOE in August 1996.

REFERENCES

1. *Record of Decision for the "Programmatic Spent Nuclear Fuel Management and Idaho National Engineering Laboratory Environmental Restoration and Waste Management Programs Environmental Impact Statement."* Washington D.C.: U.S. Department of Energy, June 1, 1995.

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3. C. L. Bendixsen, Letter Bndx-05-95 to G. E. McDannel, *Systems Analysis Priorities for SNF Transfer and/or Stabilization*, April 28, 1995.

4. *Transmittal of Model Documentation.* INEL Letter GEM-45-95, June 1, 1995.

5. C. L. Bendixsen, Letter Bndx-09-95 to Bill Jackson, Doug Turner, and John Womack, *Systems Analysis Priorities for SNF Transfer and/or Stabilization*, August 18, 1995.