U-ESR-G-00004

Spent Nuclear Fuel Alternative Technology Decision Analysis

by

C. B. Shedrow

Westinghouse Savannah River Company
Savannah River Site
Aiken, South Carolina 29808

DOE Contract No. **DE-AC09-96SR18500**

Document No. U-ESR-G-00004
Revision 0
June 26, 1998

Spent Nuclear Fuel Alternative Technology Decision Analysis (U)

"INFORMATION ONLY"

UNCLASSIFIED
DOES NOT CONTAIN UNCLASSIFIED
CONTROLLED NUCLEAR INFORMATION

ADC/Reviewing Official: E Ray Canatsea
Date: 6/25/98

ENGINEERING DOC. CONTROL - SRS
00342824

Westinghouse Savannah River Company
Savannah River Site
Aiken, SC 29808

SAFETY • RESPONSIBILITY • SECURITY
SRS
SAVANNAH RIVER SITE

THIS PAGE INTENTIONALLY LEFT BLANK

Spent Nuclear Fuel Alternative Technology Decision Analysis (U)

Prepared by: E. W. Zimmerman — 6/25/98
Date

E. W. Zimmerman
Principal Technical Advisor,
Systems Engineering
WSRC; Project, Engineering &
Construction Division

Concurrently Approved by: F. F. Cadek — 6/25/98
Date

F. F. Cadek
Manager, Systems Engineering
WSRC; Project, Engineering &
Construction Division

Approved by: M. W. Barlow — 6/26/98
Date

M. W. Barlow
Manager, SNF Alternate Technology
Programs
WSRC; Spent Fuel Storage Division

DOES NOT CONTAIN UCNI

CONCURRENT SIGNATURES OF TEAM MEMBERS

JR Chandler — 6/25/98
J. R. Chandler, Ph.D. — Date
Manager, Criticality Technology Services
Westinghouse Safety Management Solutions

N Dewes — 6/26/98
J. N. Dewes — Date
Manager, Regulatory Programs
WSRC; Spent Fuel Storage Division

William B. Epling — 6/25/98
W. B. Epling, Jr. — Date
Principle Technical Advisor,
Spent Fuel Storage Operations
WSRC; Spent Fuel Storage Division

Natraj Iyer — 6/26/98
N. C. Iyer, Ph.D. — Date
Manager, Materials Application & Corrosion Technology
WSRC; Savannah River Technology Center

Joseph F Krupa — 6/25/98
J. F. Krupa — Date
Principal Technical Advisor, Strategic Planning and Integration
WSRC; Site Integration & Program Development Division

A. R. Roof for N. L. Savin — 6/25/98
N. L. Savin — Date
Principal Engineer, Health Physics Technology
WSRC; Environment, Safety, Health & QA Division

DE Stewart — 6/25/98
D. E. Stewart — Date
Project Engineering Manager, Solid Waste and Facilities Decommissioning Divisions
BSRI; Project, Engineering & Construction Division

W F Swift — 6/25/98
W. F. Swift — Date
Manager, Alternative Technologies
WSRC; Spent Fuel Storage Division

R Stewart for D Wood — 6/26/98
D. C. Wood — Date
Deputy Manager, Spent Fuel Storage Engineering
WSRC; Spent Fuel Storage Division

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ACRONYMS

AHP	Analytic Hierarchy Process
BSRI	Bechtel Savannah River, Inc.
CFR	Code of Federal Regulations
CSRA	Central Savannah River Area
DDIS	(Mined Geologic Disposal System) Draft Disposability Interface Specification
DHEC	Department of Health & Environmental Control
DOE	Department of Energy
DU	Depleted Uranium
DWPF	Defense Waste Processing Facility
EBR	Experimental Breeder Reactor
EIS	Environmental Impact Statement
ES&H	Environmental, Safety, & Health
FRR	Foreign Research Reactor
HFIR	High Flux Isotope Reactor
HLW	High Level Waste
INEEL	Idaho National Engineering and Environmental Laboratory
LEU	Low Enriched Uranium
LLW	Low Level Waste
M&O	Management and Operations
MGDS	Mined Geologic Disposal System
MTRE	Materials and Test Reactor Equivalent
NESHAP	National Emission Standards for Hazardous Air Pollutants
NGO	Non-Government Organizations
NPDES	National Pollutant Discharge Elimination System
NRC	Nuclear Regulatory Commission
NWPA	Nuclear Waste Policy Act
O&M	Operations & Maintenance
OCRWM	Office of Civilian Radioactive Waste Management
OSHA	Occupational Safety and Health Administration
PA	Performance Assessment
PCD	Pre-conceptual Design
PDD	Presidential Decision Directive
PWF	Primary Waste Form
QA	Quality Assurance
ROD	Record of Decision
RRTT	Research Reactor (Spent Nuclear Fuel) Task Team
S&S	Safeguards & Security
SC	South Carolina
SNF	Spent Nuclear Fuel
SRS	Savannah River Site
TPC	Total Project Cost
TSF	Treatment and Storage Facility
WSMS	Westinghouse Safety Management Solutions
WSRC	Westinghouse Savannah River Company

EXECUTIVE SUMMARY

The Westinghouse Savannah River Company (WSRC) made a FY98 commitment to the Department of Energy (DOE) to recommend a technology for the disposal of aluminum-based spent nuclear fuel (SNF) at the Savannah River Site (SRS). The two technologies being considered, Direct Co-Disposal and Melt & Dilute, had been previously down-selected from a group of eleven potential SNF management technologies by the Research Reactor Spent Nuclear Fuel Task Team[1], chartered by the DOE's Office of Spent Fuel Management. To meet this commitment, WSRC organized the SNF Alternative Technology Program to further develop the Direct Co-Disposal and Melt & Dilute technologies and ultimately provide a WSRC recommendation to DOE on a preferred SNF alternative management technology.

The first step in developing a technology recommendation was to complete a technology risk assessment of the two proposed alternatives. The purpose of the risk assessment was to determine whether either of the alternatives posed any risks that would render that alternative unsuitable for further consideration. Although the risk assessment identified a number of potential risks for each alternative[2], none were deemed significant enough to eliminate either alternative. Consequently, the next phase of the process, a formal decision analysis, was undertaken with the formation of a diverse team of subject matter experts from WSRC, Bechtel Savannah River, Inc. (BSRI), and Westinghouse Safety Management Solutions (WSMS). Team members were chosen for their expertise in the functional areas of engineering, operations, criticality safety, environment, radiological and occupational safety and health, design, research and development, and strategic planning.

Utilizing a multi-objective decision making process known as the Analytic Hierarchy Process (AHP), the team conducted the evaluation through a series of fifteen interactive meetings. These meetings provided a forum to ensure that all team members had a common understanding of the alternatives being considered, and that they also had a common understanding of the decision objectives and criteria that were developed by the team for the decision analysis. The primary objectives selected by the team were:

1. Provide the highest assurance of disposal form performance in the repository (meeting disposal form performance requirements);
2. Provide the simplest (yet comprehensive), most reliable implementation of the process in a Treatment and Storage Facility (TSF) at SRS;
3. Have the lowest life cycle costs and schedule impacts;
4. Receive the highest level of public support;
5. Have the least effect on other programmatic issues;
6. Have the least impact on the environment, and on worker and public safety and health.

A total of twenty-one supporting decision criteria distributed among these primary objectives were selected by the team as offering some level of discrimination in judging each alternative's performance. Using commercially available software developed for AHP[a], the team organized the objectives, criteria, and alternatives into a four-level hierarchy structure model[b], evaluated the objectives and criteria for relative importance, and then assessed the relative performance of both alternatives against each of the decision criteria in the hierarchy. This data was then synthesized using the software to arrive at an overall alternative preference.

[a] The team used ECPro™ for Windows, a product of Expert Choice, Inc., Pittsburgh, PA 15213.
[b] See Figure 5 on page 19.

DOES NOT CONTAIN UCNI

Figure 1 below provides both a prioritized summary of the twenty-one decision criteria and a relative indication of alternative preference for each of those criteria.

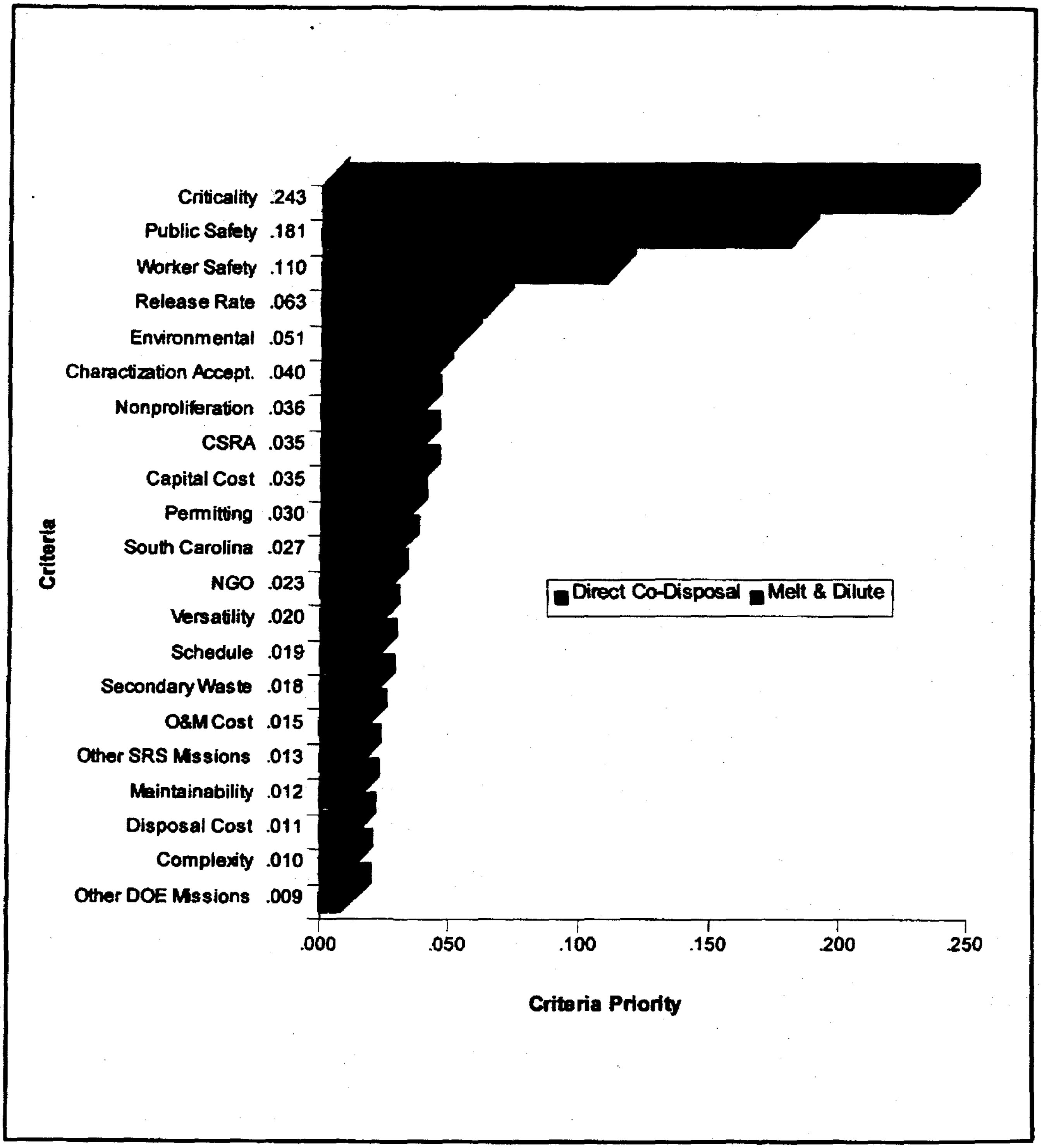

Figure 1. Global Priorities and Alternative Preferences for Decision Criteria

The results of the data synthesis indicated a preference for the Melt & Dilute alternative over Direct Co-Disposal by slightly more than 26%[c] as shown in Figure 2 below. Sensitivity analysis conducted using the software demonstrated that the overall alternative preference for Melt & Dilute was sensitive only to significant changes in objective priorities for disposal form performance and ES&H issues[d]. For the overall preference to switch from Melt & Dilute to Direct Co-Disposal (the "trade-off" point), either the disposal form performance objective priority had to decrease by approximately 65%, or the ES&H objective priority had to increase by approximately 68%. Since neither of these objective priority shifts is deemed likely to occur, the sensitivity analysis results were considered to be proof of the robustness of the overall preference for the Melt & Dilute alternative.

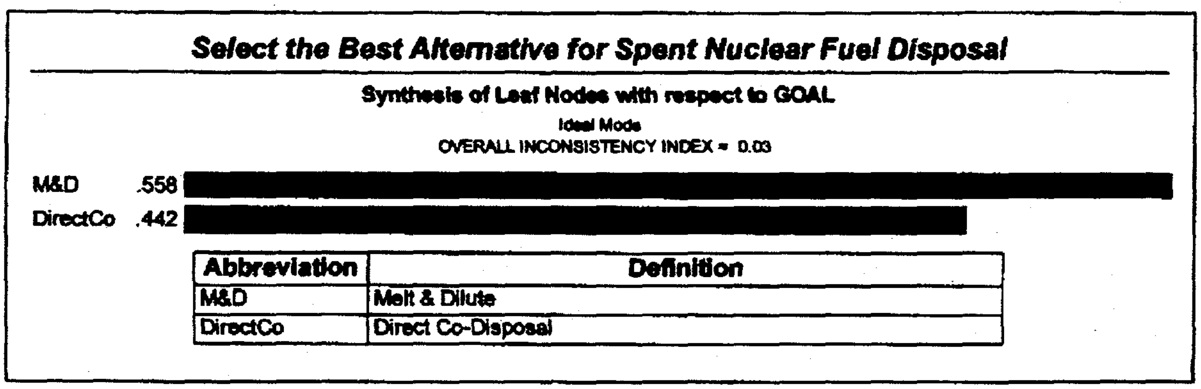

Figure 2. Synthesis Results

Based upon information gathered throughout the course of this study, the benefits of the preferred Melt & Dilute alternative, as determined by the team, are:

- Reduced disposal form volume which must be emplaced in a repository;

  Even though additional mass will be added to the disposal form during the melting process (in the form of aluminum and depleted uranium), the total volume required for the disposal forms will only be approximately one quarter of that required for Direct Co-Disposal. This reduced volume will not only result in significantly lower disposal costs (including transportation, surface storage at the repository, and final emplacement), but it will also result in lower risk to the public because of fewer canisters which must be transported from SRS to the repository. In addition, with fewer canisters required for the disposal of SNF, waste canister space is made available for other SRS missions, such as the disposal of ceramic stabilized plutonium.

- Results in a disposal form that is Low Enriched Uranium (LEU);

  Benefits derived from diluting the disposal form to LEU are a reduction in Safeguards & Security (S&S) requirements (and attendant costs) and elimination of nuclear nonproliferation concerns. The fact that the disposal form will be LEU makes it exempt from a number of 10 CFR 73[e] requirements. A disposal form that is LEU will also satisfy the intent of Presidential Decision Directive (PDD) 13[4] in that no weapons capable stockpiles of enriched uranium would be created, either at SRS or in the repository.

[c] The ratio of preference between Melt & Dilute and Direct Co-Disposal is (.558/.442) x 100% = 126.2%.

[d] Gradient sensitivity curves which show alternative preference "trade-offs" for each of the top level criteria are provided in Appendix E.

[e] Title 10 of the Code of Federal Regulations, Part 73[3].

- Provides a disposal form that is more stable with regard to criticality and short-term radionuclide release rates in the repository;

  The final disposal form produced by the Melt & Dilute alternative will have any required neutron absorber materials captured in the microstructure of the ingot. This feature will provide a disposal form that has much less criticality potential than one that could be created by simply adding discrete neutron absorber materials to the canister, such as with the Direct Co-Disposal alternative. The reduced surface area provided by the Melt & Dilute alternative will also result in lower short-term radionuclide releases in the repository.

- Accommodates the disposal of the most FRR SNF under one process.

  A separate process for the disposal of target materials in powdered form, referenced in Table 5.2-2 of the Research Reactor SNF Task Team Report[1], will not be required for the Melt & Dilute alternative.

Based upon the results of this study and assuming that the waste acceptance criteria (especially those concerning criticality) are not significantly changed, the team recommends to the DOE that the Melt & Dilute alternative be the primary technology for the disposal of aluminum-based DOE SNF. Because the waste acceptance requirements may change and Direct Co-Disposal is a viable alternative (and for many attributes, it is the preferred alternative), it is also recommended that the Direct Co-Disposal alternative be retained as a backup.

INTRODUCTION

INITIATION OF TASK

This fiscal year, WSRC committed to accelerate research in order to facilitate the recommendation of a preferred disposal technology alternative to the DOE for inclusion in an Environmental Impact Statement (EIS), and ultimately, for the selection of an alternative in a Record of Decision (ROD).

The decision analysis process used to develop this recommendation considered many variables and uncertainties, including repository requirements which are not yet finalized. This report documents the selection process, the recommendation, and justification for that recommendation.

BACKGROUND

The Record of Decision for the Environmental Impact Statement on the Proposed Nuclear Weapons Nonproliferation Policy Concerning Foreign Research Reactor (FRR) Spent Nuclear Fuel directed the DOE to implement alternative treatment and packaging technologies that could be utilized in place of conventional chemical processing to achieve safe and cost effective interim storage and ultimate disposal.

Due to the importance of demonstrating to national and local stakeholders a well conceived and viable path forward for this material, the Office of Spent Fuel Management chartered the Research Reactor Spent Nuclear Fuel Task Team (RRTT). The mission of the RRTT was to recommend a course of action, leading to a final technology selection with implementation by the year 2000, if possible, for the interim management and ultimate disposition of the foreign and domestic aluminum based research reactor SNF under DOE's jurisdiction.

The RRTT evaluated eleven potential SNF management technologies. The eleven technologies ranged from direct disposal and isotopic dilution to advanced treatments such as plasma arc treatment and glass material oxidation and dissolution. Each technology was examined and compared against the other technologies in the areas of Technical Performance and Implementation. To make a recommendation, the RRTT used a modified Kepner-Tregoe[5] evaluation using the criteria of:

- Confidence of Success;
- Life Cycle Cost;
- Technical Suitability;
- Timeliness to Operational Start.

The RRTT recommended that two technologies be developed in parallel. The two technologies are Direct Co-Disposal and an isotopic dilution alternative, Press & Dilute or Melt & Dilute. The RRTT also recommended that an advanced technology, Electrometallurgy, although not directly developed for aluminum research SNF nor funded by the SNF program, be considered as a secondary and diverse backup.

Based on the recommendations of the RRTT report[1], WSRC organized the SNF Alternative Technology Program to further develop the Direct Co-Disposal and Melt & Dilute technologies[f] and ultimately provide a WSRC recommendation to the DOE on a preferred SNF alternative management technology. This preferred technology recommendation will be considered by the DOE as input into the upcoming SRS SNF Management EIS.

TECHNOLOGY ALTERNATIVES

As noted above, only two technologies, Direct Co-Disposal and Melt & Dilute, were considered in this decision analysis. A brief description of each of these technologies is provided below.

Direct Co-Disposal (see Figure 3 on page 6[g])

In this technology, the SNF will be packaged intact in a canister which has a diameter of approximately seventeen inches and a length of approximately 120 inches. The canister of fuel will be vacuum dried and back-filled with helium. The fuel would be separated in the canister with a basket containing neutron absorber materials. Three to four baskets would be stacked within each canister. After the canister is back-filled and sealed, it will be temporarily stored at SRS in horizontal concrete storage modules.

Ultimately, the canisters will be shipped to a federal Mined Geologic Disposal System (MGDS) repository for final disposal. There each of the SNF canisters will be placed inside a larger waste package containing five Defense Waste Processing Facility (DWPF) High Level Waste (HLW) canisters before being emplaced in the repository.

The Direct Co-Disposal alternative will require a separate powder metallurgy process to accommodate the disposition of the foreign research reactor target oxide materials listed in Table 5.2-2 of the RRTT report[1]. These materials could be combined at 30 wt% with aluminum powder (or higher if necessary to make a good compact), compressed to make 3" OD X 24" slugs, cold welded, loaded into the standard canister, filled with inert gas, welded, leak checked, and finally, interim-stored prior to shipment to the repository.

[f] Press and Dilute was not considered further because it did not offer the isotopic dilution capabilities of M&D without a cost benefit.

[g] Figure 6.5.2-1 from the Pre-conceptual Design Report[6] reprinted here for information only.

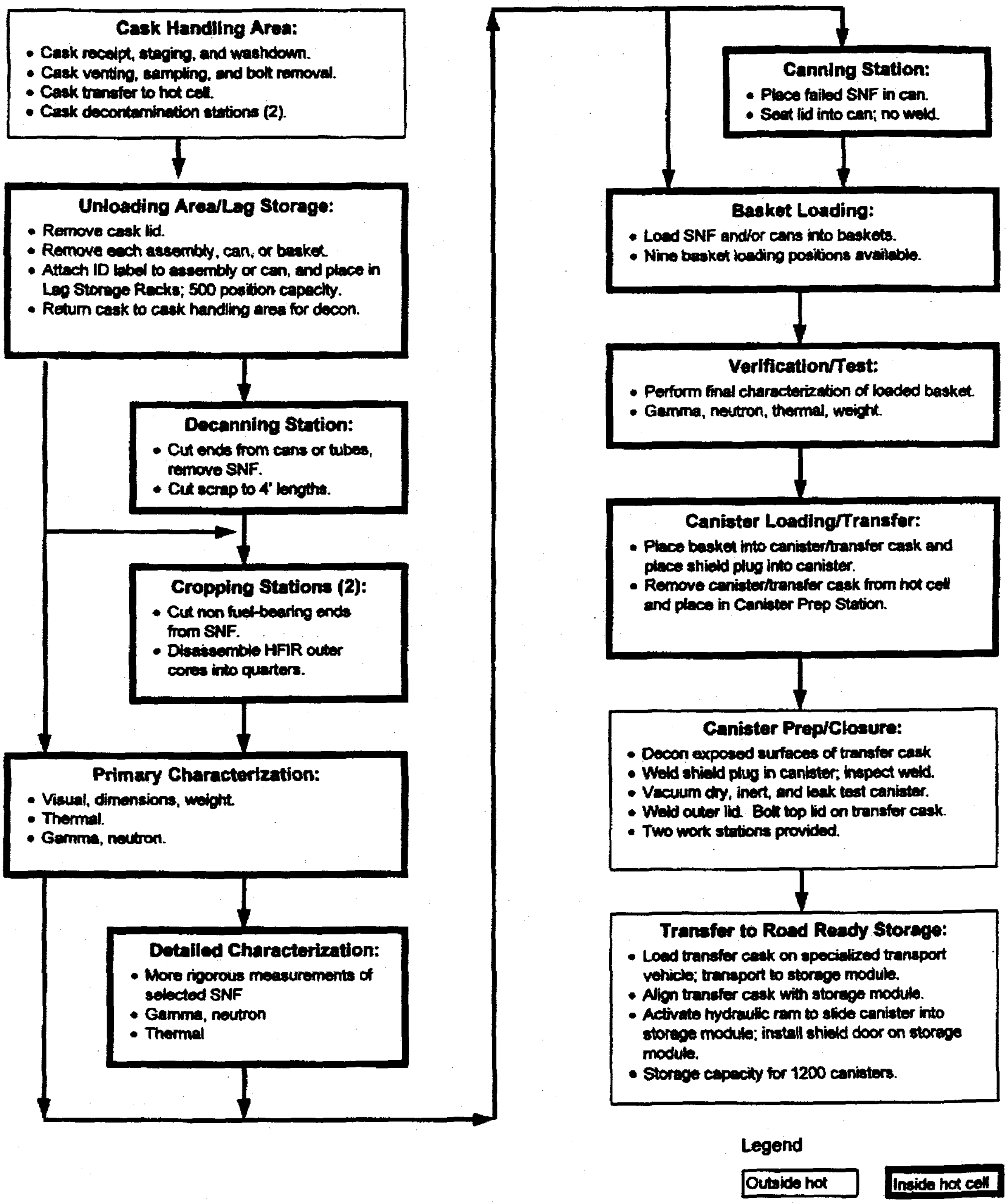

Figure 3. Facility Process Flow Diagram, Direct Co-Disposal

Melt & Dilute (see Figure 4 on page 8[h])

In this technology, the SNF will be melted in a furnace, and depleted uranium and aluminum (as needed to control the metallurgy and process temperature) will be added to the melt in order to reduce the ^{235}U enrichment to below 20%, the level required to be treated as low enriched uranium (LEU). If required, neutron absorber materials will also be added to the melt to minimize the potential for long-term criticality in the repository. The melt will be solidified and placed in a steel canister similar to that for the Direct Co-Disposal alternative. Several ingots may be stacked in each canister. The canister will then be back-filled with helium, sealed, and temporarily stored at SRS in horizontal concrete storage modules. Even though additional mass will be added to the disposal form during the melting process (in the form of aluminum and depleted uranium), the total volume required for the disposal forms will only be approximately one quarter of that required for Direct Co-Disposal.

Like the Direct Co-Disposal alternative, the canisters will ultimately be shipped to a federal MGDS repository for final disposal with DWPF canisters. The melting process will cause volatilization of some fission products. Those gases will be collected and processed onsite as either HLW or low level waste (LLW), with the exception of noble gases such as krypton which will be released to the facility stack.

Pre-conceptual design has been completed on both technologies.

[h] Figure 8.6.2-1 from the Pre-conceptual Design Report[8] reprinted here for information only.

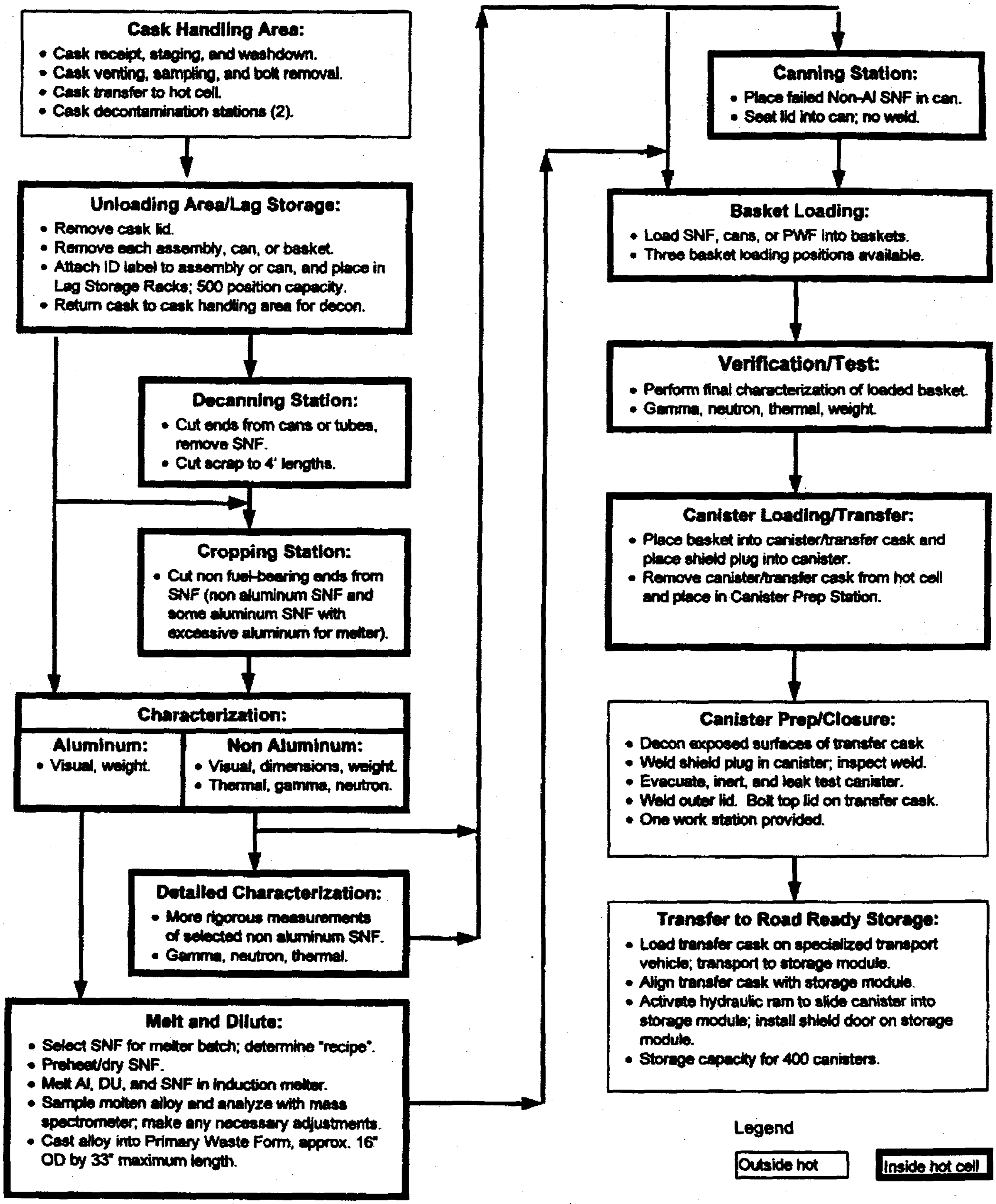

Figure 4. Facility Process Flow Diagram, Melt & Dilute

DISCUSSION

ANALYTIC HIERARCHY PROCESS

The Analytic Hierarchy Process (AHP), which forms the basis of the Expert Choice™ decision support software (ECPro™ for Windows) used in this study, enhances decision making by providing a logical, easy-to-use framework in which all elements of a decision can be defined, organized, and carefully evaluated. Designed to reflect the way people actually think, the AHP is a mathematical theory for measurement and decision making that was developed by Dr. Thomas L. Saaty more than twenty years ago. Today, the AHP is one of the world's most popular approaches to multi-objective decision making, and Expert Choice, Inc., has become one of the world's leading vendors of AHP-based decision software.

As Dr. Saaty notes in his book *Decision Making for Leaders*[7], "In solving problems by explicit logical analysis, three principles can be distinguished: the principle of constructing hierarchies, the principle of establishing priorities, and the principle of logical consistency. These natural principles of analytic thought underlie the AHP." He goes on to say "In utilizing these three principles, the AHP incorporates both the qualitative and the quantitative aspects of human thought: the qualitative to define the problem and its hierarchy, and the quantitative to express judgments and preferences concisely. The process itself is designed to integrate these two properties."

The AHP incorporates judgments and personal values in a logical way. It depends on imagination, experience, and knowledge to structure the hierarchy of a problem and on logic, intuition, and experience to provide judgments. The AHP provides a framework for connecting elements of one part of a problem with those of another to obtain the combined outcome. It is a process for identifying, understanding, and assessing the interactions of a system as a whole.

With the AHP, objectives, criteria, and alternatives are arranged in a hierarchical structure, or model, similar to a family tree. The factors affecting the decision are organized in gradual steps, from the general in the upper levels of the hierarchy to the specific in the lower levels. The purpose of the structure is to make it possible to judge the importance of the elements in a given level with respect to some or all of the elements in the adjacent level above. The process of building this structure not only helps to identify all the elements of a decision more accurately, but also helps to recognize the interrelationships between them.

Influence in this hierarchical structure is distributed downward. The top level, or goal, has the greatest importance (or priority) and thus has a value of one. This value is apportioned among the elements in the second level, and the values of each of these in turn is apportioned among those of the third level, and so-on to the lowest-level objectives/criteria. These objective/criterion priority values are derived by the ECPro™ program based upon pair-wise comparisons of the objectives at each of the model nodes[i].

Finally, pair-wise comparisons of the alternative solutions with respect to each of the lowest-level criteria provide alternative preference values. These preference values are then synthesized with the objective/criterion priority values by the program to derive an overall preference value for each of the alternative solutions being considered.

Among the benefits of AHP is the fact that it accommodates hard data, such as costs, as well as personal judgment and intuition. It also permits the derivation of relative, mathematically-based weights for objectives/criteria instead of simply assigning weights to variables as do some other decision analysis techniques. By reducing complex decisions to a series of simple comparisons and rankings and then

[i] The elements of a decision are represented by nodes. A node may represent an objective, a criterion, a subcriterion, an uncertainty (scenario), an alternative, (etc.). ECPro™ for Windows, User Manual[8], page 345.

synthesizing the results, the AHP not only helps in reaching the best decision, but also provides a clear rationale for that choice.

Another important feature of the AHP is that it provides a framework for group participation in decision making or problem solving. Ideas and judgments can be questioned and strengthened or weakened by evidence that other people present. And in fact, the conceptualization of any problem by the AHP requires the consideration of ideas, judgments, and facts accepted by others as essential aspects of the problem.

CREATION OF TEAM

Because of the need to consider multiple attributes, a diverse team of Savannah River Site (SRS) subject matter experts was assembled to participate in the technology selection process. Team members were chosen for their expertise in the functional areas of engineering, operations, criticality safety, environment, radiological and occupational safety and health, design, research and development, and strategic planning. The team members came from WSRC (and from four different divisions within WSRC), Bechtel Savannah River Inc. (BSRI), and Westinghouse Safety Management Solutions (WSMS).

The team completed the evaluation process through a series of fifteen interactive meetings. These meetings provided a forum to ensure that all team members had a common understanding of the alternatives being considered, and that they also had a common understanding of the decision objectives and criteria that were developed by the team for the decision analysis.

Biographical information for each of the team members is provided in Appendix A.

ASSUMPTIONS

The following general assumptions were used by the team in developing decision objectives and criteria, and in evaluating the performance of the two alternatives, Melt & Dilute and Direct Co-Disposal, against those criteria.

1. Both technologies (Direct Co-Disposal and Melt & Dilute) are viable and will produce waste forms that meet all anticipated Mined Geologic Disposal System Draft Disposability Interface Specification (DDIS)[9] requirements.

   This assumption is based upon one of the screening criteria used by the RRTT to eliminate from their further consideration waste forms that were not compatible with anticipated repository requirements. The Nuclear Regulatory Commission (NRC) has also concluded that "...based on current information, the staff believes that both the direct co-disposal and melt and dilute options would be acceptable concepts for disposal of aluminum-based research reactor SNF in the repository."[10]

2. Both technologies will meet all anticipated environmental, safety, and health requirements at SRS.

   This assumption is based upon one of the screening criteria used by the RRTT to eliminate technologies from further consideration in their study. The pre-conceptual design has also specified design requirements to ensure that environmental, safety, and health requirements are met.

3. All aluminum-clad SNF types and materials listed in Table 5.2-1 of the Research Reactor SNF Task Team Report[1] will be processed in the SRS canyons as recommended, and consequently, they were not considered in the technology decision analysis.

4. Target materials in powdered form to be received under FRR EIS (Canada, Belgium, Argentina, and Indonesia) listed in Table 5.2-2 of the Research Reactor SNF Task Team Report[1] will be processed in the new TSF at SRS and were therefore included in the technology decision analysis.

5. Data needs for repository characterization acceptance are identified in the OCRWM (Office of Civilian Radioactive Waste Management) Data Needs for DOE SNF[11] document.

6. DDIS Disposability Standard 2.1.1[9] requires compliance with the Nuclear Waste Policy Act (NWPA) 'legal' definition of SNF - namely, "fuel that has been withdrawn from a nuclear reactor following irradiation, the constituent elements of which have not been separated by reprocessing." For the purposes of this study, it is assumed that the Melt & Dilute disposal form meets the intent of this definition (i.e. - treating the SNF to reduce enrichment and achieve the desired metallurgy is not considered to be reprocessing.)

7. 10 CFR Part.60.111[12] requires retrievability of waste up to 50 years after emplacement operations begin. For the purposes of this study, it is assumed that this requirement applies only to the waste package and does extend to either the disposal form within the waste package or the SNF within the disposal form.

DECISION OBJECTIVES

The overall goal of the task team was to select the technology which will provide the best solution for preparing DOE-owned, aluminum-based SNF for interim storage, transportation, and disposal at a geologic repository. Using the first basic function of AHP, that of structuring complexity, the team identified a number of primary objectives which, if satisfied, would achieve this goal. While it would be highly unlikely that one alternative would be the best choice for all of the objectives, by using the AHP, it is possible to select an alternative which is most successful in meeting the aggregate of all objectives.

To this end, the team agreed that the best technology would be selected if it:

1. Provides the highest assurance of disposal form performance in the repository (meeting disposal form performance requirements);
2. Provides the simplest (yet comprehensive), most reliable implementation of the process in a TSF at SRS;
3. Has the lowest life cycle costs and schedule impacts;
4. Receives the highest level of public support;
5. Has the least effect on other programmatic issues;
6. Has the least impact on the environment, and on worker and public safety and health.

With these primary objectives in mind, the team then identified twenty-one supporting decision criteria against which the two alternatives could be evaluated. These elements were then organized into a hierarchy structure which formed the basis for the team's decision analysis model.

The team also agreed that all criteria selected for the decision analysis process should offer some level of discrimination between the two alternatives being considered. Consequently, even though a criterion might be important in its own right, any that were determined by the team to be equal with regard to the <u>selection</u> of a preferred alternative were not included in the study[j]. To do otherwise would have unnecessarily cluttered the decision analysis model with criteria which would not potentially contribute to the final selection of a preferred alternative.

[j] Examples of criteria which did not provide any discrimination between the two alternatives may be found in Appendix B.

In the final analysis, several criteria selected because they were initially believed to discriminate between the alternatives were later found to be non-contributors in the selection of an alternative. These criteria were not removed from the model, however, since they did not appreciably affect the final outcome of the preferred alternative selection process.

DECISION CRITERIA

To meet the primary decision objectives listed above, supporting decision criteria were developed in the following six general areas:

1. Disposal form performance in the repository;
2. Implementation of the process at a TSF at SRS;
3. Life cycle cost and schedule considerations;
4. Public support issues;
5. Programmatic issues;
6. Environmental, Safety, & Health issues.

The team's decision criteria under each of these six general areas are provided below. For each of the criteria considered and selected for inclusion in the decision analysis model, a 'Criterion Definition' is provided along with justification for its inclusion. In a like manner, Appendix B identifies criteria considered but not included in the decision analysis model along with discussion and justification for their exclusion.

'Criterion Definitions' were also developed for each of the six primary decision objectives to facilitate the generation of supporting decision criteria under each of the primary objectives.

1. Disposal Form Performance in the Repository

Decision Criterion Definition: *A relative measure of the difficulty in demonstrating conformance to all performance requirements specified in the Mined Geologic Disposal System Draft Disposability Interface Specification (MGDS DDIS)[9] or inferred by 10 CFR Part 60[12].*

Even though both alternatives are expected to meet all of the DDIS performance requirements (otherwise they would have been eliminated from further consideration), the degree of difficulty in attaining that required level of performance is expected to be different for each of the two alternatives. In reviewing the MGDS DDIS, the team only considered criteria in Section 4 (Draft Standards for Spent Nuclear Fuel in Disposable Canisters) which deals with characteristics of the SNF within the canister, and therefore might be impacted by the technology decision.

Although specific repository release rate limits have not been defined in 10 CFR 60 on an individual waste package basis, minimizing radionuclide releases from the SNF disposal form to the repository engineered barrier system is an important repository performance issue. Consequently, disposal form release rate was included as a criterion under this primary objective.

The following criteria were selected as being important in achieving the highest disposal form performance in the repository.

a.) Limits on Disposable Canister Criticality Potential (Disposability Standard 2.3.22)

Decision Criterion Definition: *A relative measure of the difficulty in maintaining $k_{eff} \leq 0.95$ for 10,000 years, including complete fuel degradation and fuel migration, assuming canister breach.*

This DDIS standard establishes limits on criticality potential by requiring canistered SNF to show a calculated $k_{eff} \leq 0.95$, after allowance for bias in calculation methods and uncertainty in the empirical data used to validate the method of calculation, assuming the following conditions:

- All canister basket structures have collapsed and degraded into component corrosion products;
- All supplemental neutron absorber materials, except hafnium, have degraded and are no longer part of the waste package;
- Assembly hardware has degraded and all fuel assemblies are touching in an optimum reactivity condition;
- SNF reactivity has increased to the peak levels in the early years after reactor discharge.

This criterion was included in the model because there is a significant difference between the two alternatives in the assurance of maintaining criticality control in the repository

b.) Repository Release Rate [10 CFR 60, §60.113(a)(1)(ii)(B)]

Decision Criterion Definition: *A relative measure of the quantity of radionuclides released from the disposal form into the repository environment (i.e., ground and air) as a function of time in the repository.*

This criterion was included in the model because it was expected there would be a difference between the two alternatives in the quantity of radionuclides available for release over time, and a difference in the ability to prevent the release of radionuclides. Although release limits are not specified in 10 CFR 60 at the waste package level to permit a direct assessment of each technology, clearly the alternative which minimizes radionuclide release rate is preferable.

2. Implementation of the Process at a SRS TSF

Decision Criterion Definition: *A relative measure of the difficulty in developing and implementing a process to create the disposal form.*

This primary objective was included in the decision model to address the various advantages and disadvantages in implementing either of the two alternative technology processes. Because of the fundamental differences between the Direct Co-Disposal and Melt & Dilute processes, the team expected that criteria under this objective dealing with such engineering issues as complexity, characterization acceptance, maintainability, etc., would be significant discriminators in the decision analysis process. Consequently, the following criteria were selected as being important in implementing the best process at a TSF at SRS.

a.) Complexity

Decision Criterion Definition: *A relative measure of the complexity of the process used to create the disposal form.*

This criterion was included in the model because there is a significant difference between facilities built to implement the two alternative technologies with respect to the number and complexity of process steps, technologies involved, technical maturity, handling techniques, etc. Process complexities are further magnified by the need to perform many operations under remote handling conditions, regardless of technology alternative.

In addition, a process which is less complex would also be expected to be more reliable, and hence would have a higher facility availability.

b.) Characterization Acceptance

Decision Criterion Definition: *A relative measure of the difficulty in obtaining acceptable characterization data for the final disposal form required by the repository, both technically and administratively.*

This criterion was included because the SNF data available from Appendix A of the fuel shipping contracts do not always meet the MGDS repository Quality Assurance (QA) requirements[13]. Some of the data currently required for the repository is suspect. (The data required for basin storage are acceptable.) Changes in requirements as well as certain process steps could either facilitate or increase the difficulty in getting repository-acceptable data for characterization of the SNF.

c.) Maintainability

Decision Criterion Definition: *A relative measure of the difficulty in performing routine and non-routine maintenance activities in a SNF TSF.*

This criterion was included in the model because the team expected there would be a significant difference between the two alternatives with regard to maintaining a TSF. Process equipment in a facility that had experienced high temperatures and contamination would be expected to be more difficult to maintain than equipment that had not.

d.) Secondary Waste Stream Impacts

Decision Criterion Definition: *A relative measure of the impacts to SRS resulting from quantities and types (LLW, HLW) of secondary wastes generated by a SNF TSF.*

This criterion was included in the model because the team expected there would be a significant difference in the quantity and complexity of the secondary waste streams generated by each of the alternatives.

e.) Permitting

Decision Criterion Definition: *A relative measure of the difficulty in obtaining the required permits (NESHAP, DHEC, NPDES, etc.) and DOE approval (or NRC license) to operate a SNF TSF.*

This criterion was included in the model because the team expected that, based upon differences between potential effluents from the two alternative processes, the degree of difficulty in permitting facilities for the two alternatives would be a discriminator.

f.) Versatility

Decision Criterion Definition: *A relative measure of the ability to accommodate changes in design assumptions or repository requirements.*

While it was assumed that both processes could be designed initially to accommodate all forms of aluminum-based SNF in the FRR scope[k], changes to that scope are inevitable, especially considering the current preliminary state of the repository requirements. This criterion was included in the model because it was determined that there was a difference between the two alternatives in accommodating these anticipated changes.

[k] See Assumptions 3 and 4 on Page 10.

3. Life Cycle Cost and Schedule Considerations

Decision Criterion Definition: *A relative measure of the importance in considering life-cycle cost and schedule impacts of the technology decision.*

This primary objective was selected because cost and schedule are important parameters in selecting an alternative, and there are differences between the two alternatives.

All cost estimates used for the decision analysis were derived from a cost study[14] generated for the Transfer & Storage Services Facility Pre-conceptual Design (PCD)[6]. The cost study included the additional costs associated with the powder metallurgy process required by the Direct Co-Disposal alternative to deal with the powdered fuel identified in Table 5.2-2 of the RRTT Report, even though that process was not included in the PCD.

The following criteria were selected as being important in achieving the lowest life cycle cost and minimizing schedule impacts.

a.) Capital Cost

Decision Criterion Definition: *Total Project Cost (TPC) for the design, construction, startup, and turnover to operations of a SNF TSF.*

This criterion was included in the model because capital costs require approval of Congress. If there is a significant difference in capital cost, it would be a strong discriminator.

b.) Operating & Maintenance (O&M) Cost

Decision Criterion Definition: *Life cycle costs associated with the operation and maintenance (including modifications) of a SNF TSF.*

This criterion was included in the model because operating and maintenance costs are an important component of life-cycle costs, and because the team determined there would be a difference between the O&M costs of facilities designed to implement the two alternative technologies.

c.) Disposal Cost

Decision Criterion Definition: *Life cycle costs associated with transportation of disposal forms to the repository, surface storage at the repository, and final emplacement of disposal forms in the repository.*

This criterion was included in the model because disposal costs are an important component in life-cycle cost analysis, and because of the difference in the number of waste canisters required for each alternative.

d.) Schedule

Decision Criterion Definition: *A relative measure of SNF TSF project schedule impacts at SRS, including costs for continued operation of basins.*

This criterion was included in the model because the team determined that there would be different schedule risks involved with the two alternatives. Any significant schedule delays will result in increased life-cycle costs due to both increased construction cost and the cost associated with extended wet basin storage of the SNF at SRS.

4. Public Support

Decision Criterion Definition: *A relative measure of the likelihood that the public will support DOE's proposed technology.*

This primary objective was selected since public support plays a major role in decision making. With public support, it becomes less costly, difficult, and time consuming to implement the selected technology.

The following criteria were chosen as being important in addressing public support issues because each group represented by a criterion may have a different opinion.

a.) Non-Government Organizations (NGO)

Decision Criterion Definition: *A relative measure of the likelihood that NGOs (outside the CSRA) will support DOE's proposed technology.*

This criterion was included in the model because NGOs have the power to significantly delay (and thus increase the cost of) projects with which they have strong objections.

b.) Central Savannah River Area (CSRA)

Decision Criterion Definition: *A relative measure of the likelihood that organizations and the public within the CSRA, including the Congressional delegation, will support DOE's proposed technology.*

This criterion was included in the model because successful implementation of a technology will require local and Congressional support. For the purpose of this decision analysis, the Congressional delegation is considered to be part of the CSRA.

c.) South Carolina (SC)

Decision Criterion Definition: *A relative measure of the expected acceptance of the technology decision by the SC State Government.*

This criterion was included in the model because the Governor of South Carolina has already challenged DOE in court on the issue of receiving FRR fuel into basin storage for indefinite periods of time. Support from the South Carolina statehouse would be contingent on its confidence that a technology could successfully produce a repository-acceptable waste form.

5. Programmatic Issues

Decision Criterion Definition: *A relative measure of the impact the technology decision may have on key programmatic issues.*

This primary objective was included in the model to capture the difference in impact each alternative will have on other programmatic issues considered important by DOE.

The following criteria were selected as being important in addressing programmatic issues.

a.) Other Missions at SRS

Decision Criterion Definition: *A relative measure of the impact a technology choice will have on other missions at SRS (e.g. - effect on plutonium stabilization may be a function of the number of canisters used by SNF).*

This criterion was included in the model to capture the effects a technology choice might have on other missions at SRS. For example, SNF and ceramic stabilized plutonium (can-in-a-canister) may compete for waste package space, and the amount of available space is very dependent upon the alternative technology selected.

b.) Nonproliferation

Decision Criterion Definition: *A relative measure of the disposal form's value for diversion to weapons production.*

This criterion was included in the model because Presidential Decision Directive (PDD) 13[4] indicates that the United States will "seek to eliminate where possible the accumulation of stockpiles of highly-enriched uranium or plutonium, and to ensure that where these materials already exist they are subject to the highest standards of safety, security and international accountability." Alternatives that leave HEU fuel intact are less desirable since they may be perceived as creating weapons-capable stockpiles of enriched uranium at SRS and the MGDS, contrary to the intent of PDD 13.

c.) Other DOE Missions

Decision Criterion Definition: *A relative measure of the impact a technology choice will have on determining the treatment requirements for other DOE SNF (i.e. - setting precedence).*

This criterion was included in the model because comments by National Spent Nuclear Fuel Program personnel indicate that they have a concern over the impact of this technology decision on the requirements for other DOE SNF, which may or may not be amenable to a dilution approach like Melt & Dilute.

6. Environmental, Safety, & Health (ES&H) Issues

Decision Criterion Definition: *A relative measure of the differences in impacts to the environment and on worker and public safety & health which are posed by the two alternatives.*

This primary objective was included in the model to influence the selection of the alternative which minimizes effects on the environment, and provides the higher degree of safety and health protection for the public and workers. Simply meeting the Environmental, Safety and Health requirements at SRS will be reflected in the cost elements of the technology decision. This primary objective addresses the impact (the effect) on the environment, etc. of the selected technology.

Consideration of ES&H impacts are for SRS and transportation to the repository only, and do not include impacts at the repository. Those impacts have already been addressed by the repository requirements.

The following criteria were selected as being important in addressing environmental, safety, and health issues:

a.) Worker Safety

Decision Criterion Definition: *A relative measure of differences in safety impacts (accumulated dose and OSHA) to the SRS worker which are posed by the two alternatives.*

This criterion was included in the model because although each alternative will, by definition, remain within applicable worker safety limits, the extent to which each alternative stays below these requirements may vary. Consequently, the alternative which provides and maintains the highest margin of worker safety would be preferred.

b.) Public Safety

Decision Criterion Definition: *A relative measure of differences in safety impacts (accumulated dose) to the public which are posed by the two alternatives.*

This criterion was included in the model because although each alternative will, by definition, remain within applicable public safety limits, the extent to which each alternative stays below these requirements may vary. Consequently, the alternative which provides and maintains the highest margin of public safety would be preferred.

c.) Environmental Impacts

Decision Criterion Definition: *A relative measure of the differences in impact to the environment (flora and fauna) caused by the amount and type of releases (radionuclide, chemical, etc.) from the process.*

This criterion was included in the model because although each alternative will, by definition, remain within applicable environmental release limits, the extent to which each alternative stays below these requirements may vary. Consequently, the alternative which provides and maintains the highest margin of environmental protection would be preferred.

CREATION OF DECISION MODEL

With the objectives and criteria necessary to reach a technology decision clearly established, they were then easily organized into a four-level hierarchy structure to create the AHP model shown below in Figure 5. In this model, the first level, the goal of the decision, is at the top, followed by two levels of objectives and criteria, and a fourth and final level of alternatives. As noted earlier in the discussion about AHP, the factors affecting the decision are organized in gradual steps from the general, in the upper levels of the hierarchy, to the specific in the lower levels. Again, the purpose of the structure is to make it possible to judge the importance of the elements in a given level with respect to some or all of the elements in the adjacent level above.

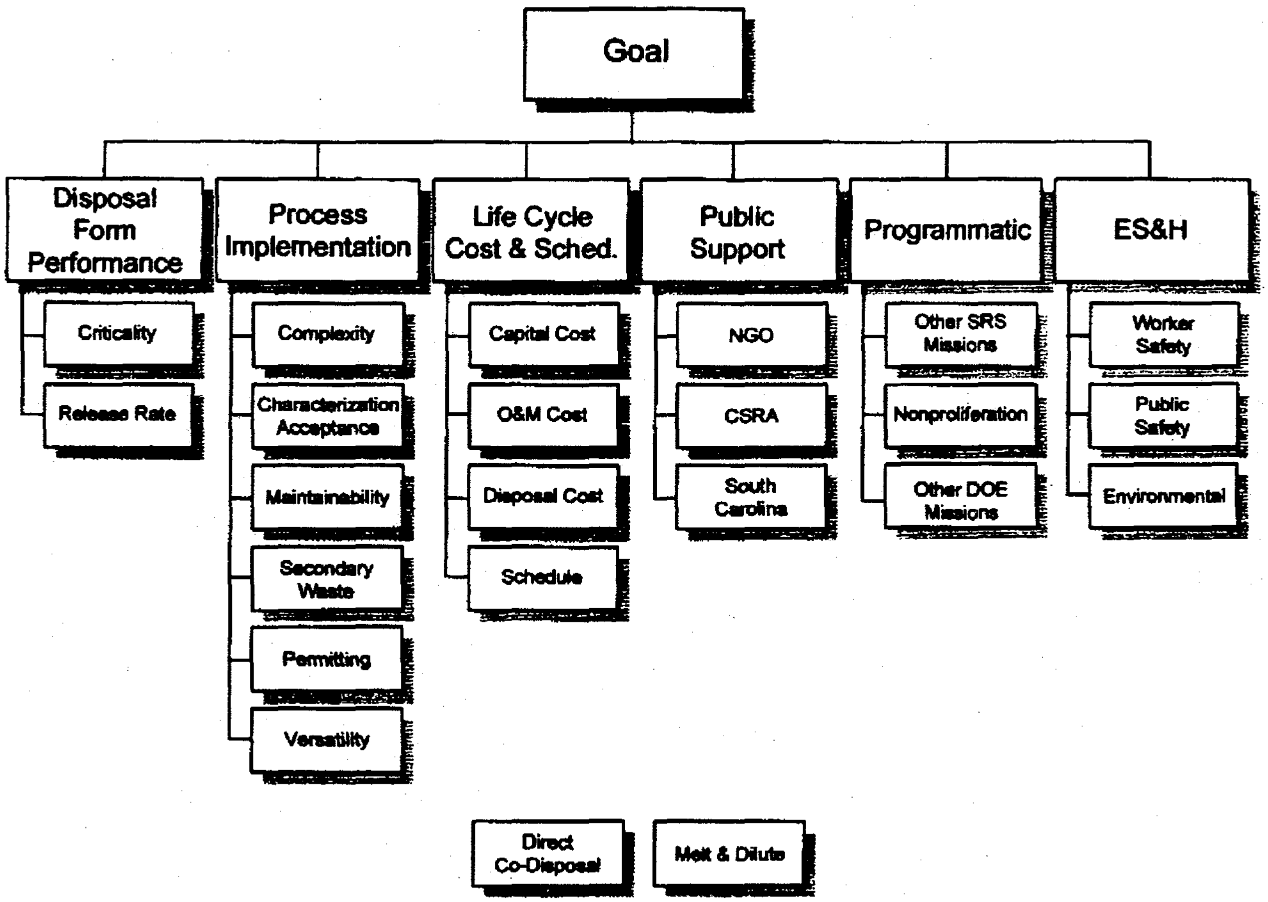

Figure 5. Decision Analysis Model

DETERMINATION OF CRITERIA IMPORTANCE

The next step in the AHP addressed by the team was the determination of criteria importance, or priorities. This process involved the use of pair-wise comparisons of objectives and criteria at each of the seven nodes of the model shown above in Figure 5.

Referring to the goal node as an example, the importance of disposal form performance was compared to the importance of process implementation, life cycle cost and schedule, public support, programmatic issues, and finally, ES&H issues. Next, the importance of process implementation was compared to the importance of life cycle cost and schedule, public support, programmatic considerations, and ES&H issues.

This process continued until all pair-wise comparisons at the goal node were completed. A partial example of the questionnaire used for evaluating the goal node is provided in Figure 6.

COMPARING RELATIVE IMPORTANCE OF OBJECTIVES WITH RESPECT TO GOAL

In selecting a preferred alternative, which is more important?

1. Providing the highest assurance of disposal form performance in the repository, or providing the simplest (yet comprehensive), most reliable implementation of the process in a TSS facility at SRS?

1 = Equal   3 = Moderate   5 = Strong   7 = Very Strong   9 = Extreme

DispForm	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Process

2. Providing the highest assurance of disposal form performance in the repository, or having the lowest life cycle costs and schedule impacts?

1 = Equal   3 = Moderate   5 = Strong   7 = Very Strong   9 = Extreme

DispForm	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	LifeCycl

3. Providing the highest assurance of disposal form performance in the repository, or receiving the highest level of public support?

1 = Equal   3 = Moderate   5 = Strong   7 = Very Strong   9 = Extreme

DispForm	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Public

4. Providing the highest assurance of disposal form performance in the repository, or having the least effect on programmatic issues?

1 = Equal   3 = Moderate   5 = Strong   7 = Very Strong   9 = Extreme

DispForm	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Program

5. Providing the highest assurance of disposal form performance in the repository, or having the least impact on the environment, and on worker and public safety and health?

1 = Equal   3 = Moderate   5 = Strong   7 = Very Strong   9 = Extreme

DispForm	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	ESH

6. Providing the simplest (yet comprehensive), most reliable implementation of the process in a TSS facility at SRS, or having the lowest life cycle costs and schedule impacts?

1 = Equal   3 = Moderate   5 = Strong   7 = Very Strong   9 = Extreme

Process	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	LifeCycl

7. Providing the simplest (yet comprehensive), most reliable implementation of the process in a TSS facility at SRS, or receiving the highest level of public support?

1 = Equal   3 = Moderate   5 = Strong   7 = Very Strong   9 = Extreme

Process	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Public

8. Providing the simplest (yet comprehensive), most reliable implementation of the process in a TSS facility at SRS, or having the least effect on programmatic issues?

1 = Equal   3 = Moderate   5 = Strong   7 = Very Strong   9 = Extreme

Process	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Program

Figure 6. Sample Questionnaire

Pair-wise comparisons were then completed for the remaining six nodes of the model. In each case, the evaluations were first performed individually by each team member, and the results were then averaged (to a geometric mean) by the ECPro™ program to provide an aggregate team determination of objective importance.

The results of the pair-wise comparisons for all seven model nodes are shown in Tables C-1 through C-7 in Appendix C. For each pair-wise comparison shown in the tables, the team judged Objective/Criterion A more important than Objective/Criterion B by the factor shown. Reasons for the determination of relative importance are provided in the discussion column of each table.

Summary of Criteria Priorities

After all objectives were evaluated for importance at each of the model nodes, the overall results were synthesized using the ECPro™ program. Table 1 below provides a prioritized summary of all objectives/criteria and their relative overall importance (global priority) in selecting the preferred alternative. Note that these data are arranged in the model hierarchy levels, and within those levels, are listed according to the priority of the individual criteria.

Table 1. Summary of Objective/Criterion Priorities (Global)

OBJECTIVES	CRITERIA		OBJECTIVES	CRITERIA
ES&H = .342			Public = .085	
	Public Safety = .181			CSRA = .035
	Worker Safety = .110			South Carolina = .027
	Environmental = .051			NGO = .023
Disposal Form = .306			Life Cycle = .080	
	Criticality = .243			Capital Cost = .035
	Release Rate = .063			Schedule = .019
Process = .130				O&M Cost = .015
	Charact. Accept. = .040			Disposal Cost = .011
	Permitting = .030		Program = .058	
	Versatility = .020			Nonproliferation = .036
	Secondary Waste = .018			Other SRS Missions = .013
	Maintainability = .012			Other DOE Missions = .009
	Complexity = .010			

Figure 7 on the next page provides a prioritized summary of the overall importance (or global priority) of all of the criteria. This list is significant in that performance of the alternatives (and hence the technology decision) was judged directly against these criteria. Note that criticality alone accounts for almost 25% of the importance in the decision, and that the first five criteria (criticality, public safety, worker safety, release rate, and environmental - all safety or environmental concerns) account for approximately 65% of the importance in the decision.

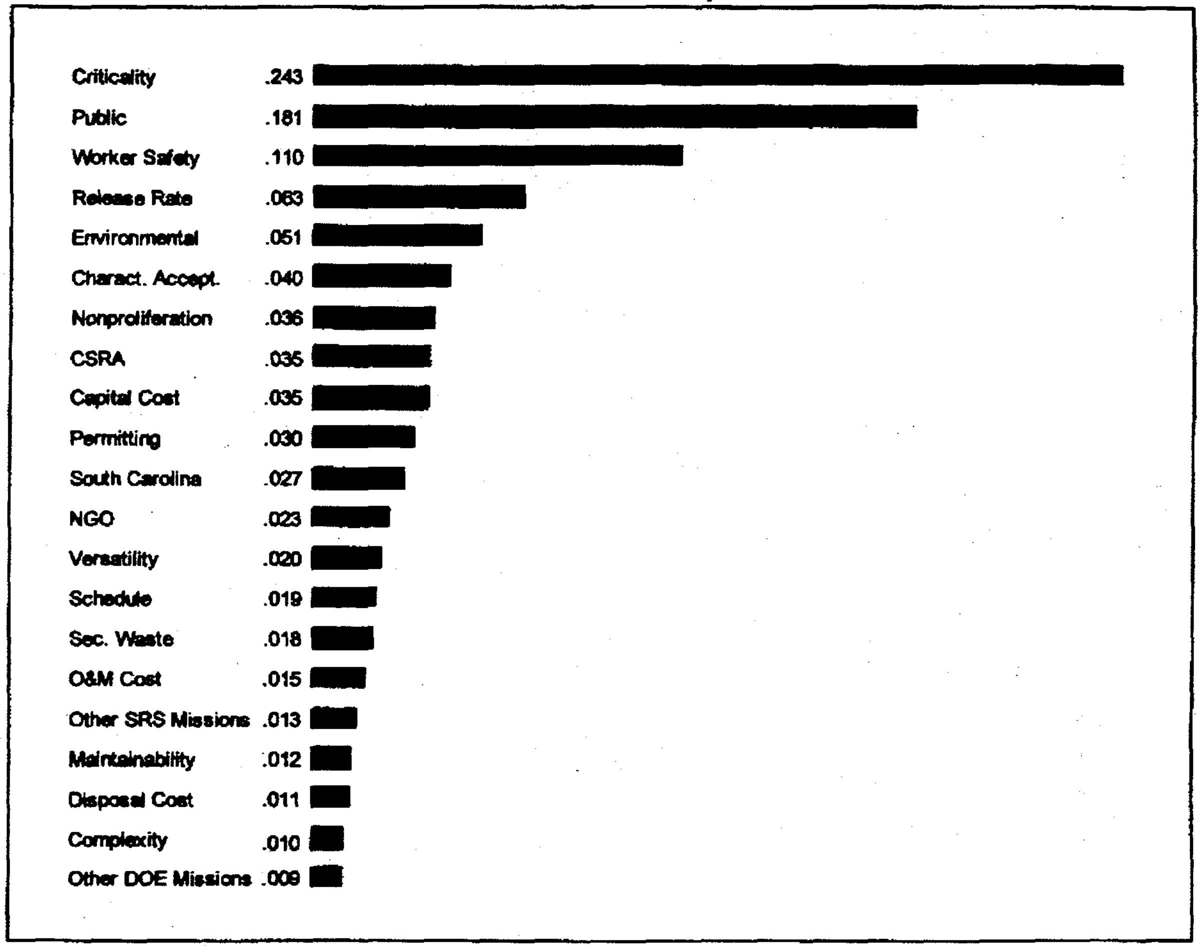

Figure 7. Global Priorities for Decision Criteria

DETERMINATION OF ALTERNATIVE PREFERENCE

After all criteria priorities were established, the team then focused on selecting a preferred alternative for each of the criteria using pair-wise comparisons. Again, comparisons were done individually by each team member, then combined in the team decision model using the ECPro™ program. For each pair-wise comparison shown in Table D-1 in Appendix D, the team selected either Direct Co-Disposal or Melt & Dilute as the preferred alternative by the factor shown. Reasons for the team's selections of alternative preferences are provided in the discussion column of that table.

A summary of the ECPro™ computations of alternative preferences for each of the twenty-one criterion is provided in Table 2 on the following page.

Table 2. Alternative Preferences for Decision Criteria

	Criteria							
Alternative	Criticality	Release Rate	Complex.	Charact. Accept.	Maintain.	Secondary Waste	Permitting	Versatility
Direct Co-Disposal	.162	.265	.704	.185	.787	.747	.705	.203
Melt & Dilute	.838	.735	.296	.815	.213	.253	.295	.797
Alternative	Capital Cost	O&M Cost	Disposal Cost	Schedule	NGO	CSRA	South Carolina	
Direct Co-Disposal	.485	.529	.251	.670	.637	.391	.426	
Melt & Dilute	.515	.471	.749	.330	.363	.609	.574	
Alternative	Other SRS Missions	Nonprolif.	Other DOE Missions	Worker Safety	Public Safety	Environ.		
Direct Co-Disposal	.259	.164	.645	.726	.514	.692		
Melt & Dilute	.741	.836	.355	.274	.486	.308		

RESULTS OF SYNTHESIS

With all criteria priorities and alternative preferences defined by the team, the data were then synthesized using the ECPro™ program to derive an overall alternative preference for the team model. The results shown below in Figure 6 indicate a preference for the Melt & Dilute alternative which is approximately 26% greater than that for the Direct Co-Disposal alternative (.558 vs. .442, respectively)[1].

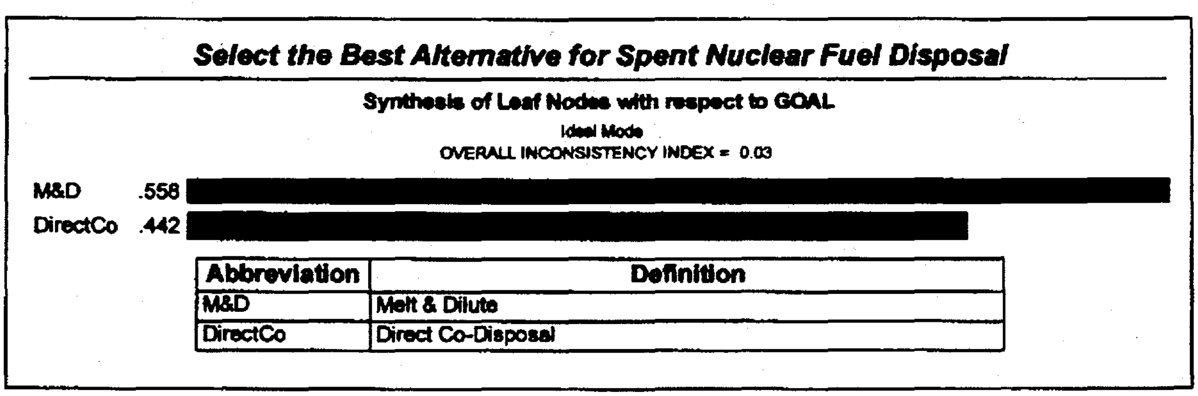

Figure 6. Synthesis Results

[1] Because AHP is based upon ratio scale numbers, the overall alternative preferences are also ratio scale numbers. Hence, the ratio of preference between Melt & Dilute and Direct Co-Disposal is (.558/.442) x 100% = 126.2%.

The ECPro™ program provides a performance sensitivity graphical output which may assist in assessing the basis for these results. Figure 9 below is the ECPro™ output for "Performance Sensitivity at Goal Node". For the Goal Node, this graph shows the relative priorities of each of the criteria, the alternative preferences for each of those criteria, and finally, the overall alternative preference at that specific node. Since the Goal Node is the highest level in the model, this particular graph provides a performance sensitivity analysis for the overall selection of a preferred alternative.

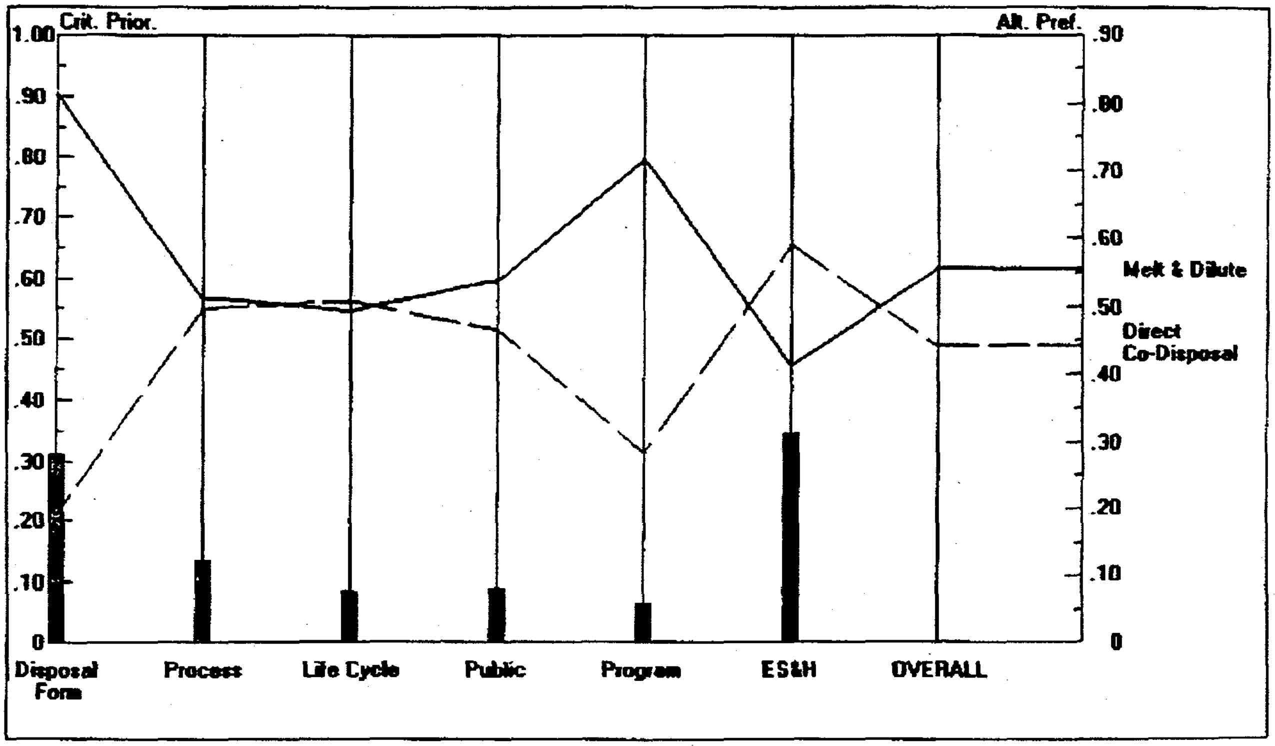

Figure 9. Performance Sensitivity at Goal Node

The height of each bar (Disposal Form, Process, Life Cycle, etc.) shows the relative priority of each of the criteria for the Goal Node as read from the axis at the left (labeled Crit. Prior.). The point where an alternative line (Melt & Dilute or Direct Co-Disposal) intersects a criteria vertical line, as read from the axis on the right (labeled Alt. Pref.), indicates the preference the alternative received for that criterion. And finally, the overall preference of each alternative at the Goal Node is defined by its intersection with the last vertical line to the right (labeled OVERALL).

Referring to the Disposal Form criterion as an example, the criterion priority is .306 as read from the left axis. The preferences for Melt & Dilute and Direct Co-Disposal for the Disposal Form criterion are .815 and .185, respectively, as read from the right axis. And finally, the overall alternative preferences at the Goal Node are .558 and .442 for Melt & Dilute and Direct Co-Disposal, respectively, as read from the right axis.

Alternative preference data calculated by the ECPro™ program for all of the Goal Node criteria are summarized in Table 3 on the next page.

Table 3. Alternative Preferences at Goal Node

	Criteria						
Alternative	**Disposal Form**	**Process**	**Life Cycle**	**Public**	**Program**	**ES&H**	**OVERALL**
Direct Co-Disposal	.185	.494	.507	.467	.277	.592	.442
Melt & Dilute	.815	.506	.493	.533	.723	.408	.558

These results show the team's evaluation that the Melt & Dilute alternative offers a significant advantage over Direct Co-Disposal in meeting disposal performance requirements (factor of ~4.4) and addressing programmatic issues (factor of ~2.6), and a slight advantage in achieving public support (factor of ~1.1). Direct Co-Disposal, on the other hand, offers a slight advantage in satisfying ES&H concerns (factor of ~1.5). The results also show that the two remaining criteria used in the study (process implementation and life cycle costs and schedule) are essentially non-contributors to the overall technology decision (factors of ~ 1.0 each).

These results are consistent with the global priorities of the five highest priority decision criteria (ref. Figure 7).

SENSITIVITY ANALYSIS

Sensitivity analysis is used to investigate the sensitivity of the alternative preferences to changes in the priorities of the criteria, or objectives. This analysis may be conducted at any of the model nodes. For example, sensitivity analysis conducted from the goal node will show the sensitivity of alternative preferences with respect to the criteria immediately below the goal, that is, how the overall preferences for the alternatives change as the priorities of the criteria are changed. In a similar fashion, when sensitivity analysis is performed from a criterion node immediately below the goal node, the sensitivity shows how the preferences for the alternatives in that node change as the priorities of the sub-criteria immediately below that criterion node are changed.

Of the five sensitivity analysis modes available in the ECPro™ program, only two, Performance Sensitivity and Gradient Sensitivity, will be discussed here. Both of these modes provide graphical views of priorities and alternatives in the analysis model and show how they relate. Each mode simply emphasizes different aspects of the model's priorities.

A Performance Sensitivity graph depicts the relative priorities of criteria, the alternative preferences for each of those criteria, and the overall alternative preference for that specific model node. An example of a Performance Sensitivity graph for the Goal Node was presented earlier in this report as Figure 9 on Page 24.

A Gradient Sensitivity graph depicts alternative preferences as a function of the priority assigned to the respective criteria. The important information to be gained from this graph is the point at which the alternative preference lines cross one-another, if ever. This is the 'trade-off' point where the preferred alternative with respect to the selected criterion changes. As an example, refer to the graph in Figure 10 on the following page titled "Gradient Sensitivity for Disposal Form with respect to Goal". This graph shows that for a Disposal Form criterion priority of .306, alternative preferences at the Goal Node for Melt & Dilute and Direct Co-Disposal will be .558 and .442, respectively. Furthermore, the overall alternative preference will switch from Melt & Dilute to Direct Co-Disposal only if the Disposal Form criterion priority is reduced below .107, a decrease of approximately 65%[m]. The fact that such a significant change in the Disposal Form criterion priority is required to reverse the alternative preference indicates the overall preference for Melt & Dilute is very insensitive to changes in the Disposal Form criterion priority.

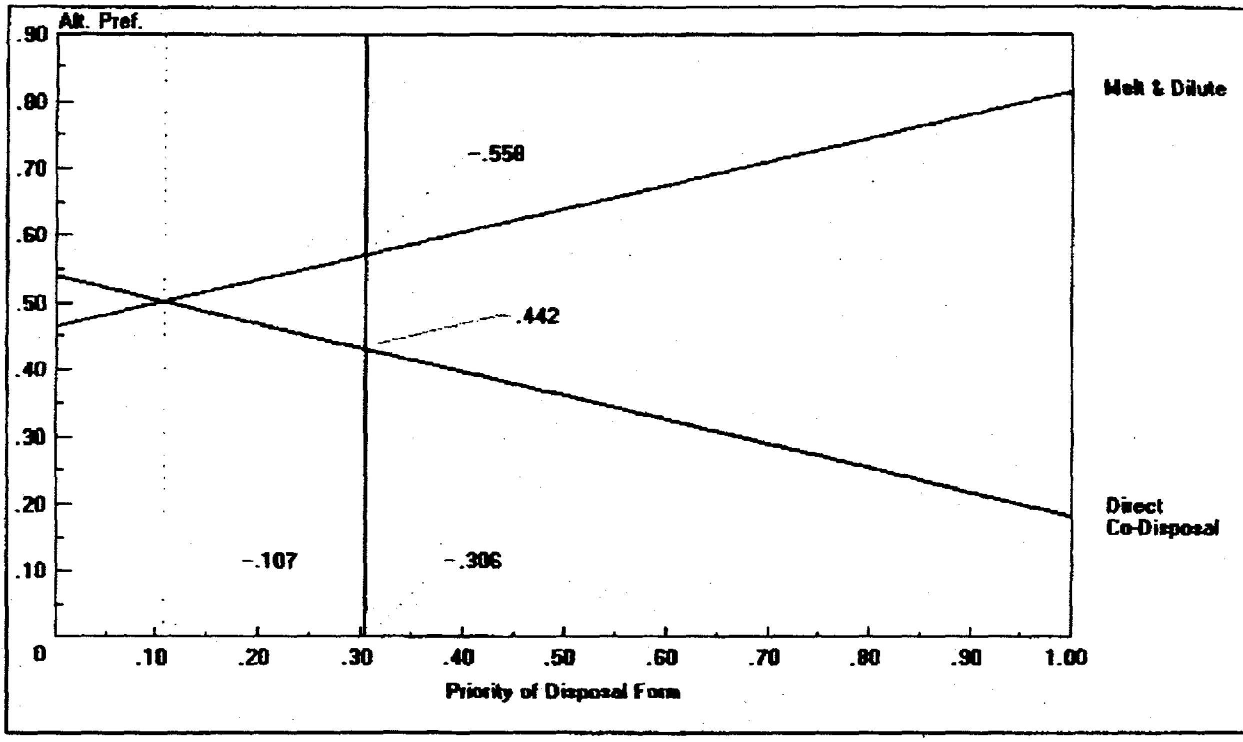

Figure 10. Gradient Sensitivity for Disposal Form with respect to Goal

Sensitivity analysis was conducted for the remaining five criteria of the Goal Node with the following results as shown in gradient sensitivity curves provided in Appendix E. For the sake of completeness, Figure 10 above is reproduced in Appendix E as Figure E-1.

- Process - Figure E-2 demonstrates that there is no alternative preference trade-off for this criterion, and that the Melt & Dilute alternative is always preferred.
- Life Cycle - Figure E-3 indicates that an alternative preference trade-off from Melt & Dilute to Direct Co-Disposal will occur if the priority of this criterion increases from .080 to .880, an order of magnitude change. However, since the likelihood of this change occurring is extremely remote, for all practical purposes the preference for Melt & Dilute is completely insensitive to any change in the priority of the Life Cycle criterion.
- Public - Figure E-4 shows that there is no alternative preference trade-off for this criterion, and that the Melt & Dilute alternative is always preferred.
- Program - Like Process and Public, there is no alternative preference trade-off for this criterion as shown in Figure E-5, and again, the Melt & Dilute alternative is always preferred.

[m] It is important to remember that as the criteria priority being evaluated is manipulated during this sensitivity analysis, the remaining criteria priorities of that node must change proportionately such that the sum of the criteria priorities at that node remain unchanged. For the goal node, the sum of the criteria priorities is 1.

- ES&H - Figure E-6 indicates that a trade-off from Melt & Dilute to Direct Co-Disposal will occur if the priority of this criterion increases from .342 to .575, an increase of approximately 68%. The fact that such a significant change in the criterion priority is required to reverse the alternative preference indicates the overall preference for Melt & Dilute is very insensitive to changes in the ES&H criterion priority as well.

The results of these Goal Node sensitivity analyses are summarized below in Table 4.

Table 4. Alternative Preference Sensitivity at Goal Node

Criterion	Nominal Criteria Priority	Criteria Priority @ Trade-Off	Change in Criteria Priority	Change in % of Original Priority
Disposal Form	.306	.107	-.199	-65%
Process	.130	N/A	N/A	N/A
Life Cycle	.080	.880	+.800	+1000%
Public	.085	N/A	N/A	N/A
Program	.058	N/A	N/A	N/A
ES&H	.342	.575	+.233	+68%

The ECPro™ program also provides the capability to conduct sensitivity analysis from the lowest-level criteria, not only with respect to the next higher level of criteria, but also with respect to the GOAL Node. In this way, one can verify that the overall alternative preference, in this case Melt & Dilute, is not affected by changes in priorities of any of the decision criteria. These analyses were conducted for all of the decision criteria and verified that the overall preference for the Melt & Dilute alternative was completely insensitive to any changes in criteria priorities. To demonstrate this fact, gradient sensitivity graphs for the Disposal Form and ES&H nodes (because they are the 'most sensitive' objectives/criteria) are also provided in Appendix E[n].

CONCLUSIONS

Of the two alternatives considered in this decision analysis study, the team preferred Melt & Dilute over Direct Co-Disposal by slightly over 26% (.558 vs. .442, respectively). This preference was based upon objectives and criteria selected and defined by team consensus during extensive discussions at numerous interactive meetings throughout the process. Furthermore, this preference was demonstrated by sensitivity analysis to be very insensitive to any changes in objective or criteria priorities.

Throughout the course of this study, the pros and cons of each alternative were weighed to derive a technology recommendation. It may be helpful, therefore, to summarize here the benefits of the preferred Melt & Dilute alternative as determined by the team.

The Melt & Dilute alternative will:

- Reduce disposal form volume which must be emplaced in a repository;

  Even though additional mass will be added to the disposal form during the melting process (in the form of aluminum and depleted uranium), the total volume required for the disposal forms will only be approximately

[n] Refer to Appendix E, Figures E7 through E11.

one quarter of that required for Direct Co-Disposal. This reduced volume will not only result in significantly lower disposal costs (including transportation, surface storage at the repository, and final emplacement), but it will also result in lower risk to the public because of fewer canisters which must be transported from SRS to the repository. In addition, with fewer canisters required for the disposal of SNF, waste canister space is made available for other SRS missions, such as the disposal of ceramic stabilized plutonium.

- Result in a disposal form that is LEU;

  Benefits derived from diluting the disposal form to LEU are a reduction in S&S requirements (and attendant costs) and elimination of nonproliferation concerns. The fact that the disposal form will be LEU makes it exempt from a number of 10 CFR 73 requirements. A disposal form that is LEU will also satisfy the intent of PDD 13 in that no weapons capable stockpiles of enriched uranium would be created, either at SRS or in the repository.

- Provide a disposal form that is more stable with regard to criticality and short-term radionuclide release rates in the repository;

  The final disposal form produced by the Melt & Dilute alternative will have any required neutron absorber materials captured in the microstructure of the ingot. This will provide a disposal form that has much less criticality potential than one that could be created by simply adding discrete neutron absorber materials to the canister, such as with the Direct Co-Disposal alternative. The reduced surface area provided by the Melt & Dilute alternative will also result in lower short-term radionuclide releases in the repository.

- Accommodate the disposal of the most FRR SNF under one process.

  A separate process for the disposal of target materials in powdered form, referenced in Table 5.2-2 of the Research Reactor SNF Task Team Report, will not be required for the Melt & Dilute alternative.

Based upon the results of this study and assuming that the waste acceptance criteria (especially those concerning criticality) are not significantly changed, the team recommends to the DOE that the Melt & Dilute alternative be the primary technology for the disposal of aluminum-based DOE SNF. Because the waste acceptance requirements may change and Direct Co-Disposal is a viable alternative (and for many attributes, it is the preferred alternative), it is also recommended that the Direct Co-Disposal alternative be retained as a backup.

REFERENCES

1. John C. Devine, Jr., et. al. *Technical Strategy for the Treatment, Packaging, and Disposal of Aluminum-Based Spent Nuclear Fuel - A Report of the Research Reactor Spent Nuclear Fuel Task Team.* Prepared for the Department of Energy, Office of Spent Fuel Management (1996).

2. Valerie F. Perella & Edgar W. Zimmerman. *Spent Nuclear Fuel Alternative Technology Risk Assessment.* SRS Document Y-TRA-G-00001, Rev. 0, Savannah River Site, Aiken, SC 29808 (1998).

3. The Code of Federal Regulations, Title 10, Part 73. *Physical Protection of Plants and Materials.*

4. The White House, Office of the Press Secretary. *Fact Sheet, Nonproliferation And Export Control Policy* [Presidential Decision Directive (PDD) 13], September 27, 1993.

5. Charles H. Kepner & Benjamin B. Tregoe. *The New Rational Manager.* McGraw-Hill, Princeton, NJ (1981).

6. Grant A. Cook, et. al. *Savannah River Site Spent Nuclear Fuel Transfer and Storage Services Pre-conceptual Design.* SRS Document G-CDP-G—00002, Rev. Draft B, Savannah River Site, Aiken, SC 29808 (1997).

7. Dr. Thomas L. Saaty. *Decision Making for Leaders.* RWS Publications, Pittsburgh, PA 15213 (1995).

8. Faith Giglio. *ECpro for Windows, Decision Support Software User Manual.* Expert Choice, Inc., Pittsburgh, PA 15213 (1995).

9. Mark S. Abashian. *Mined Geologic Disposal System Draft Disposability Interface Specification.* USDOE Report B00000000-01717-4600-00108, Rev. 00, TRW Environmental Safety Systems Inc., Las Vegas, NV 89134 (1998).

10. Malcolm R. Knapp, Acting Director, Office of Nuclear Material Safety and Safeguards, U.S. NRC. *Subject: Review of the Aluminum-Based Research Reactor Spent Nuclear Fuel Disposition Program.* Letter to John E. Anderson, Acting Assistant Manager for Material and Facility Stabilization, Savannah River Operations Office, U.S. DOE, Aiken, SC 29802 (June 5, 1998).

11. Scott Vance. *OCRWM Data Needs for DOE Spent Nuclear Fuel.* USDOE Report A00000000-01717-2200-0090, Rev. 02, TRW Environmental Safety Systems Inc., Vienna, VA 22180 (1998).

12. The Code of Federal Regulations, Title 10, Part 60. *Disposal of High-Level Radioactive Wastes in Geologic Repositories.*

13. *Quality Assurance Requirements and Description for the Civilian Radioactive Waste Management Program.* U.S. DOE Document DOE/RW-0333P.

14. Joseph F. Krupa. *Savannah River Site Aluminum-Clad Spent Nuclear Fuel Alternative Cost Study Rev 1(U).* USDOE Report WSRC-TR-97-299, Savannah River Site, Aiken, SC 29808 (1997). RP

15. Robert L. Sindelar, et. al. *Alternative Aluminum Spent Nuclear Fuel Treatment Technology Development Status Report.* USDOE Report WSRC-TR-97-00345, Savannah River Site, Aiken, SC 29808 (1997).

16. The Code of Federal Regulations, Title 49, Part 173. *Shippers - General Requirements for Shipments and Packagings.*

17. David C. Losey. *Decay Heat Characterization of SRS Research Reactor Fuels.* SRS Document WSRC-TR-98-00116, Rev. 0 (Ref. WSMS-CRT-97-0016, Rev. 0), Westinghouse Safety Management Solutions, Aiken, SC 29803 (1998).

18. Si Young Lee & Robert L. Sindelar. *Thermal Analysis of Repository Codisposal Waste Packages Containing Aluminum Spent Nuclear Fuel (U).* SRS Document WSRC-TR-98-00158, Rev. 0, Savannah River Site, Aiken, SC 29808 (1998)

19. ANSI N14.5-1997. *Radioactive Materials - Leakage Tests on Packages for Shipment.* American National Standards Institute, New York, NY 10036 (1997).

20. F. Feizollahi and D. Shropshire. *Waste Management Facilities Cost Information Estimating Data for Spent Nuclear Fuel.* EGG-WM-10708, EG&G Idaho, Idaho Falls, ID 83403 (1993).

21. F. Feizollahi and D. Shropshire. *Waste Management Facilities Cost Information Report for Spent Nuclear Fuel.* EGG-WM-10670, EG&G Idaho, Idaho Falls, ID 83403 (1993).

22. Bill Hurt. *DOE SNF Safeguards & Security Issues.* Slide presentation at DOE National Spent Nuclear Fuel Program mid-year review meeting, Washington, D.C. (April 16, 1998).

23. John A. McClure, et. al. *Evaluation of Codisposal Viability for Aluminum-Clad DOE-Owned Spent Fuel: Phase II Degraded Codisposal Waste Package Internal Criticality.* USDOE Report BBA000000-01717-5705-00017, Rev. 01, TRW Environmental Safety Systems Inc., Las Vegas, NV 89134 (1998).

24. Mark W. Barlow. *Use of Poisons in Road Ready Package, Review and Assessment of Documents.* cc:Mail attachment, (April 27, 1998).

25. Milton Levenson. *Research Reactor Aluminum Spent Fuel, Treatment Options for Disposal.* National Research Council Report ISBN 0-309-06049-4, National Academy Press, Washington, DC 20055 (1998).

APPENDIXES

Appendix A: CURRICULA VITAE
Appendix B: CRITERIA CONSIDERED BUT NOT INCLUDED IN MODEL
Appendix C: EVALUATIONS FOR CRITERIA IMPORTANCE
Appendix D: EVALUATIONS FOR PREFERRED ALTERNATIVES
Appendix E: SENSITIVITY GRAPHS

Appendix A

CURRICULA VITAE

TABLE OF CONTENTS

INTRODUCTION

This appendix contains biographical information on each of the team members responsible for selecting a preferred technology alternative in this decision analysis process.

John R. Chandler, Ph.D.

John Chandler holds B.S. and Ph.D. degrees in Physics from North Carolina State University. He has nineteen years experience at Savannah River Site in a variety of engineering and physics positions, including nine years as a group manager. Five years experience is nuclear safety, criticality safety, and radiological engineering. Projects include handling and storage of fresh and spent reactor fuel, various waste processing and storage facilities, laboratory research and development activities, and project design and development activities. Positions have involved development of nuclear safety methodology, nuclear safety analyses, safety basis documentation, and radiological engineering activities. He is experienced in application of DOE orders, ANSI standards, and Codes of Federal Regulations pertaining to nuclear and criticality safety, radiological engineering, and authorization basis documentation.

John N. Dewes, P.E.

Mr. Dewes holds a B.S. degree in Nuclear Engineering from Purdue University. Prior to joining WSRC, John worked for The Detroit Edison Company as a Shift Technical Advisor at the Fermi 2 Nuclear Power Plant, was certified as a Senior Reactor Operator, and was also appointed a Loaned Employee to the Institute of Nuclear Power Operations in the Training and Accreditation Division in Atlanta.

Since coming to WSRC, John has held positions of increasing responsibility in the Reactor Engineering and Reactor Quality Departments. Assignments include Lead Engineer, Systems Analysis, Manager, Cooling Water Systems, Manager, Quality Engineering, and Manager, Regulatory Programs. In his current position, Mr. Dewes is responsible for Environmental Compliance, Safety Analysis, and Criticality Safety for the Spent Fuel Storage Division. He is experienced in application of DOE Orders, Codes of Federal Regulations pertaining to environmental, nuclear safety, and criticality safety, and authorization basis documents.

John is an active member of the American Nuclear Society, currently serving on the Environmental Sciences Division Executive Committee, and is a past Chair of the Savannah River Local Section, as well as being Chairman of the Special Committee on Electronic Communications. John also serves as an accredited representative of ANS to the United Nations Commission for Sustainable Development.

W. B. Epling Jr.

Mr. Epling received his B.S. in Mechanical Engineering from Virginia Polytechnic Institute. He has twenty years experience at the Savannah River Site primarily associated with nuclear reactor operations. Mr. Epling has also held engineering assignments in facility operations and reactor components support. He has also held assignments as a certified operations shift manager and reactor area maintenance manager. Mr. Epling has twelve years of experience managing an organization responsible for all aspects of reactor fuel handling in four facilities. Activities in these facilities included fresh core assembly, core loading, irradiated core unloading, and disassembly of material for processing. Most recently Mr. Epling served as facility manager for the spent fuel receipt and storage basins. Currently, Mr. Epling serves as technical advisor to the Spent Fuel Storage Operations Department.

Natraj C. Iyer, Ph.D.

Natraj Iyer received his B.S in Metallurgy from the Indian Institute of Technology; M.S. and Ph.D. in Materials Engineering from Drexel University and MBA from the University of South Carolina. He has nineteen year experience in the area of materials technology with focus on materials processing and environmental degradation. His early experience, approximately 11 years at the Westinghouse Science & Technology Center, was in the area of materials processing including powder metallurgy and rapid solidification. He was a recognized expert in the field of electrical contact materials and the processing of hyperconductors and superconductors. Since joining SRS in 1990, his experience has been in materials application and corrosion technology for nuclear and environmental management systems. As manager of the Materials Application and Corrosion Technology group at SRTC, he has been very active, within the DOE complex, in the technologies for safe management, storage and disposition of SNF for the past 6 years. He is also responsible for the coordination and management of all the SNF technology activities at SRTC. He has also been active in activities related to the environmental degradation of high level waste tanks, DWPF materials of construction and in the materials technologies for new tritium production systems. He has published over 50 papers in journals and/or conference proceedings and over 12 U.S. patents. He is active in a number of technical societies including the ASM International, NACE, ASTM. He also serves on a number of DOE and University committees/panels.

Joseph F. Krupa

M.E. Ch. E. University of Idaho
M.Sc. in Chemistry, University of California Berkeley – (AEC fellowship in Nuclear Science and Engineering
B.Sc. in Chemistry, U.S. Air Force Academy, CO

Mr. Krupa has over 24 years experience in the nuclear field. He started his career performing radiochemical analyses as a Nuclear Research Officer in the U.S. Air Force. He then spent ten years at the Idaho Chemical Processing Plant performing studies of actinide removal from spent fuel waste using bidentate phosphorous ligands. He was the lead for a NRC funded experimental program to evaluate post-accident (nuclear) radio-iodine sampling and measurement equipment.

He developed Flourinel Dissolution Process reagent addition computer programs for which he was awarded George Westinghouse bronze award in 1985. He was a key player in the successful modification and implementation of the Fluorinel Process for Naval Fuel dissolution including developing analytical methods for process control, modeling of process dissolution criticality permitting deletion of a major system, operating the Fluorinel Dissolution Pilot Plant and acting as a startup engineer for the Fluorinel Dissolution hot startup.

From 1987-1992 he was a Nuclear Engineer for the Department of Energy's Savannah River Operations Office. During his tenure he acted as DOE Nuclear Materials Manager; coordinated and reviewed technical planning studies on nuclear materials disposition, transportation and capital asset management; and participated in task forces on capital asset management, reconfiguration siting, and plutonium discard limits.

Mr. Krupa has, as a Principal Technical Advisor for Westinghouse Savannah River Company, published two studies of Al-clad spent fuel options to support Department of Energy Environmental Impact Statement Records of Decision. The latest study also provides cost and schedule information for a study of the non-proliferation impacts of spent fuel reprocessing. He has co-authored studies of life-cycle costs for spent fuel disposition with criticality prevention, SRS spent fuel storage, SRS plutonium discard limit implementation, SRS nuclear materials disposition and complex-wide nuclear material disposition issues.

He is active in the American Chemical Society (28 years) and American Nuclear Society, and has served as the Chairman of the American Chemical Society's Savannah River Local Section.

Nicholas L. Savin

Mr. Savin received a B.S. degree in Physics and Mathematics from York College of the City University of New York, and a M.S. degree in Nuclear Engineering from Polytechnic Institute of New York. He has 25 years experience working as a Nuclear Engineer, 4 years with Burns and Roe, and the last 21 years with Westinghouse. During that time, he was responsible for performing the radiological design for both PWR and BWR commercial nuclear power plants, and for DOE facilities processing uranium, plutonium, tritium, and low level and high level radioactive waste. He was also responsible for the reactor physics calculations and reactor core reload designs for numerous nuclear power plants serviced by Westinghouse. In addition, he was also responsible for performing the nuclear criticality analysis in support of Westinghouse new and spent fuel rack bid proposals.

David E. Stewart

Mr. Stewart has 34 years experience in the nuclear field. He started his career with six years in the Naval Nuclear Submarine Force. He then spent nineteen years with Bechtel Power Corporation in commercial nuclear power plant design, construction , startup and project management. He has nine years experience at Savannah River Site as design engineering manager for numerous treatment, storage and disposal facilities for hazardous and mixed waste. He is currently responsible, as project engineering manager, for design engineering for both Solid Waste and Facility Decommissioning Divisions. He is a registered professional engineer in Alabama and Mississippi and is a member of the National Society of Professional Engineers. He holds an A.S. in Mathematics from York College, a B.S. in Nuclear Facilities Management from Troy State and an MBA from Mississippi College.

William F. Swift

Mr. Swift received his B.S. in Chemical Engineering from the University of Notre Dame. He has 18 years experience at Savannah River Site primarily associated with nuclear production reactor engineering. Mr. Swift has held engineering assignments in day to day operations, reactor components support, long range planning and capital project development. He has also held engineering management assignments in systems engineering, as the engineering representative to the joint test group and for development of capital projects. Mr. Swift has also held positions as manager of solid waste engineering support and as manager of the site geotechnical groundwater modeling group. In his current assignment, Mr. Swift is responsible for supporting development of alternative technologies for disposition of spent nuclear fuel and development of a project to implement the chosen technology.

Daniel C. Wood

Mr. Wood has been involved with various programs at the Savannah River Site for over sixteen years after graduating with honors with a B.S. in Mechanical Engineering from Clemson University. Mr. Wood's various assignments at Savannah River have included analysis, oversight, and management in the areas of Accident Analyses, Testing, Maintenance, Quality Assurance, Operational Readiness Reviews, and Technical Surveillance of Reactor Operations. Mr. Wood has also managed engineering efforts within the High Level Waste Program and Spent Fuel Storage Program, and provided engineering services support site-wide.

Appendix B
CRITERIA CONSIDERED BUT NOT INCLUDED IN MODEL

TABLE OF CONTENTS

INTRODUCTION

This appendix contains information on objectives or criteria which were considered by the team in developing the decision model, but for reasons described below, were not included in the final model. To facilitate a comparison with criteria that were selected for the model, the following discussions are arranged in the same order as the included criteria in the body of this report.

DECISION CRITERIA EVALUATION

1. Disposal Form Performance in the Repository

Disposability Standards referenced in the following discussions are from the MGDS DDIS[9]. The team did not consider DDIS criteria which defined physical or external design requirements for the disposable canister itself since the same disposable canister external design will be used for both alternatives.

a.) Minimum Cooling Time Since Reactor Discharge (Disposability Standard 2.1.2)

SNF that is discharged from a reactor and allowed to cool for less than five years before delivery to the MGDS repository will not be accepted for emplacement. This criterion restricts MGDS acceptance of these wastes to ensure that internal waste-package temperature and total thermal outputs from waste packages remain within acceptable limits.

This criterion was not included in the model because it was not considered to be a factor in selecting a technology (i.e. - regardless of which technology is selected, if the SNF has not been allowed to cool for at least five years, it will not be accepted for emplacement at the MGDS repository). Most of the fuel will be received at SRS by 2010-2011. Since the earliest the repository will be opened is about 2015, and SRS DOE spent fuel will probably follow INEEL fuel, it is unlikely that any of the bulk of the fuel will have less than eight years of cooling. Fuels received after the repository opens can be held until the minimum cooling criteria is met. This should not be a serious problem because little fuel is scheduled to be shipped to SRS post 2015 (maximum of 150 MTRE and 12 HFIR cores/year).

b.) Provision That SNF Be a Solid (Disposability Standard 2.1.3)

This criterion requires that waste, to be accepted by the MGDS, must be in a solid form at temperatures ranging from 25°C to 400°C and a pressure of 1 to 5 atm (surface to peak repository conditions and internal waste package environment) to ensure pre-closure operational safety and post-closure repository performance.

This criterion was not included in the model because all of the DOE SNF will be in a solid form, and both alternatives result in a solid disposal form. Foreign Research Reactor target materials will be consolidated for direct disposal either through powder metallurgy or other appropriate means.

c.) Limits on Free Liquids in Canistered SNF (Disposability Standard 2.1.22)

Free liquids are not acceptable because they provide a potential mechanism for transport of radionuclides from the repository to the environment, and because they may make any release from a pre-closure accident more difficult to contain. In addition, they may enhance internal pressurization of waste packages, provide a degradation mechanism for both SNF and the waste package, and also accelerate hydrogen gas generation. Consequently, disposable canisters are not permitted to contain free liquids in an amount that could compromise the ability of the waste package to meet pre-closure safety or post-closure performance requirements. The determination of a quantifiable acceptance limit for this criterion is the subject of a future study planned by the MGDS M&O Contractor.

This criterion was not included in the model because both alternative disposal forms will be vacuum dried to minimize the likelihood of free liquids. In addition, SRS interim storage criteria limit the amount of water present to levels that would ensure essentially no liquid present at the time fuel is transferred to the MGDS.

d.) **Maximum Allowable Quantity of Particulates (Disposability Standard 2.1.23)**

Particulates provide a potential airborne pathway for contaminant release during repository operations and are subject to high radionuclide dissolution rates over time when exposed to water. Particulates generated as a product of uranium metal degradation may also be chemically reactive or pyrophoric. To ensure pre-closure safety and post-closure performance, this criterion requires the consolidation of particulates by incorporation into an encapsulating matrix. The determination of a quantifiable acceptance limit for this criterion is the subject of a future study planned by the MGDS M&O Contractor.

This criterion was not included in the model because the decision analysis assumes particulate materials like Sterling Forest Oxide will be reprocessed in H Canyon[a], and Foreign Research Reactor target oxides will be converted to a solid, either in the Melt & Dilute process or via powder metallurgy for Direct Co-Disposal[b].

e.) **Limits on Pyrophoric Materials (Disposability Standard 2.1.24)**

Wastes expected to be pyrophoric under conditions ranging from 25°C to 400°C and a pressure of 1 to 5 atm (surface to peak repository conditions and internal waste package environment) are excluded from the MGDS due to possible compromise of surface facility or repository pre-closure safety or repository long-term performance. The determination of a quantifiable acceptance limit for this criterion is the subject of a future study planned by the MGDS M&O Contractor.

This criterion was not included in the model because uranium metal fuels are assumed to be reprocessed in F Canyon, e.g. EBR-II blanket materials. Aluminum-based fuels to be treated at SRS do not include metallic uranium but are alloys, and alloys of aluminum-uranium are not pyrophoric in the expected particle size range for treatment[c].

f.) **Limits on Combustible, Explosive, or Chemically Reactive Waste Forms (Disposability Standard 2.1.25)**

Pre-closure safety concerns prohibit MGDS acceptance of disposable canisters containing compounds in concentrations that could be considered to be combustible, explosive per 49 CFR 173.50[16], or chemically reactive under conditions ranging from 25°C to 400°C and a pressure of 1 to 5 atm (surface to peak repository conditions and internal waste package environment). The determination of a quantifiable acceptance limit for this criterion is the subject of a future study planned by the MGDS M&O Contractor.

This criterion was not included in the model because no fuels to be received by SRS are considered combustible, explosive or chemically reactive as defined by the DDIS.

[a] See Assumption 3 on page 8 of report.

[b] See Assumption 4 on page 8 of report.

[c] See Ref. 15, §4.4.6

g.) Weight of Disposable DOE-Owned SNF Canisters (Standard 2.2.21.3)

Canisters of DOE-owned SNF that will not be unloaded prior to emplacement must be of a weight to ensure that waste packages loaded with these canisters do not exceed total weight limits. To meet this criterion, canisters are limited to a maximum weight of 2750 pounds (1247 kg).

The weight limit value for this criterion is still being evaluated. However, this criterion was not included in the model because a typical package will be designed to be below the finalized maximum weight.

h.) Limits on Radionuclide Inventories in Canistered SNF (Disposability Standard 2.3.20)

This criterion, subdivided into sub-criteria, sets upper limits per assembly on radionuclides that are problematic for pre-closure safety and post-closure performance. This criterion also establishes limits on parent radioisotopes that can lead to unacceptable levels of daughter products at any time during the life of the repository. The acceptance limits provided are considered preliminary until additional Performance Assessment (PA) analyses are performed, and the repository PA is accepted by the NRC as part of the repository licensing process.

This criterion was not included in the model because the inventories to be disposed of are the same in both cases. They are also significantly lower than the inventories in commercial spent nuclear fuel, so they should not be problematic.

i.) Limits on Organic Materials in Canistered SNF (Disposability Standard 2.3.23)

This criterion limits the amount of organic material permitted in disposable canisters accepted into the repository due to long-term repository performance issues (corrosion acceleration, formation of soluble species with radionuclides, adverse affect on hydrogen ion concentrations, etc.) and regulatory requirements (no hazardous waste). Waste package and performance assessment studies are planned by the M&O Contractor to quantify limits for both trace levels of acceptable organics and acceptable levels of individual organic species.

This criterion was not included in the model because organic material is not expected to be associated with any fuel to be received at SRS.

j.) Limits on Total Thermal Output for Disposable Canisters (Disposability Standard 2.4.20)

Thermal limits on canisters ensure that waste packages loaded with these canisters will not exceed the corresponding limits of the entire waste package or limits for the combined effect of emplaced waste packages on the repository. This criterion imposes a maximum thermal output limit of 1500 watts for single-element disposable canisters that can be accepted into the MGDS.

Based upon the following data extracted from a SNF decay heat characterization study[17], the conclusion was drawn that there is little difference between the two types of assemblies, except that the Melt & Dilute alternative will place more assemblies into a canister.

Decay Time (Years)	Co-Disposal Assembly Bounding (Watts)	Co-Disposal Assembly Nominal (Watts)	Melt-Dilute Assembly Bounding (Watts)	Melt-Dilute Assembly Nominal (Watts)	DWPF Canister Design Basis* (Watts)
1	109	47	100	43	635
2	48	21	41	18	594
3	27	12	21	10	568
6	12	5	8	4	520
10	9	4	6	3	472

* The decay heat for the DWPF design basis canister is based upon the time of canister production, assuming 5 year old sludge and 15 year old precipitate.

The Savannah River Technology Center estimate of ~330 canisters for Melt & Dilute assumes ~85 assemblies/canister. Direct Co-Disposal will have about one-fourth as many assemblies/canister. To remain below the 1500 watt limit imposed by the DDIS, each of the ~85 Melt & Dilute assemblies/canister must, on average, produce less than ~18 watts/assembly. From the data above, this corresponds to about two years decay time for a nominal assembly, and approximately four years decay time for the bounding assembly. Since there is also a minimum decay time limit of five years for acceptance at the repository[d], the decay heat issue is truly a non-discriminator, and consequently it was not included in the model.

k.) Limits on Disposable Multi-Element Canister Thermal Design (Disposability Standard 2.4.21)

Multi-element disposable canisters must not exceed prescribed peak temperature limits for the SNF cladding in order to meet requirements for the repository engineered barrier system and to ensure the integrity of the SNF cladding and other waste package materials. This criterion establishes peak temperature limits for SNF cladding in wastes in disposable canisters of 350°C, and it must be shown to be achievable over 1000 years. Canister surface temperatures are assumed to reach a maximum of 200°C the 51st year after the canister leaves the waste-custodian site.

Calculations in a thermal analysis study conducted for the SNF program at SRS[18] show that peak cladding temperatures in the repository will be well below 350°C for both alternatives. Therefore, compliance with this cladding temperature limit is not a discriminator, and consequently, this criterion was not included in the model.

l.) Provision for Canister Internal Pressure (Disposability Standard 2.4.23)

Sealed disposable canisters must not be over-pressurized in order to be safely handled in the MGDS surface facility. This criterion specifies a disposable canister design pressure of 50 psig and also establishes canister internal pressure limits. The criterion also requires that the sealed disposable canister shall neither contain nor generate free gases other than air, inert cover gas, and radiogenic gases.

This criterion was not included in the model because, as noted previously, large quantities of liquids are not expected in the final disposal form of either alternative since both processes will be designed to remove water. No gases other than radiogenic gases will be generated since no other kinds of

[d] See discussion regarding DDIS 2.1.2 on page B-2 of this Appendix.

reactions will be occurring in the canister. There will be no liquid water from which to generate gases of any kind.

m.) Limits on Disposable Canister Leak Rates (Disposability Standard 2.4.24)

Verification of containment envelope integrity is required before sealed disposable canisters are accepted at the MGDS. This criterion defines the canister leak-rate limits and tolerances, and requires leak testing per ANSI N14.5[19] at the time of closure or anytime any leaks are suspected.

This criterion was not included in the model because there was no perceived differentiation between the two alternatives. Canister leak rates for the relatively short time period between treatment at the TSF and final emplacement at the repository are not impacted by the technology selected for producing the disposal form.

n.) Waste Form Degradation

This criterion was not included in the model because both waste form are essentially aluminum metal. Both will degrade in similar geologic time frames, neither of which will compromise the integrity of the MGDS.

2. Implementation of the Process at a SRS TSF

The team did not identify any additional criteria that were not included in the model.

3. Life Cycle Cost and Schedule Considerations

a.) Decontamination & Decommissioning (D & D) Cost

This criterion was not included in the model because it did not offer any significant discrimination between the two alternatives. As noted in the PCD Cost Study[14], D & D costs for Direct Co-Disposal and Melt & Dilute facilities are estimated at $18.9M and $19.9M respectively. These estimates are based upon facility footprints and a D & D cost of $450/Sq.ft. (FY92$) from the EG&G studies (Shropshire & Feizollahi[20,21]) escalated to FY98$.

b.) Safeguards & Security (S&S) Cost for Non-Self-Protecting SNF

Incremental domestic S&S costs above repository baselines attributable to non-self-protecting DOE SNF have been estimated to be $100M. This includes transportation S&S, repository surface facility physical security, and annual operating costs[22]. Based upon total quantities of non-self-protecting SNF to be emplaced in the repository, the aluminum-based SNF 'share' of this incremental cost should be less than $30M. Since this incremental cost is within the existing TPC contingency for both alternatives, this criterion was not included in the model even though the additional cost would only apply to a portion of the SNF treated via the Direct Co-Disposal alternative.

4. Public Support

a.) Public Support in Nevada

Public acceptance in Nevada was considered but not included in the model because it was not deemed to be a discriminator. Impact on the repository of the fission product difference between the two DOE SNF disposal technology alternatives is not significant relative to the impact of commercial SNF. Acceptance (support) assumes that public concerns regarding such things as nonproliferation, reprocessing, and environmental releases are satisfied, and these concerns are included in the model.

5. Programmatic Issues

The team did not identify any additional criteria that were not included in the model.

6. Environmental, Safety, & Health Issues

The team did not identify any additional criteria that were not included in the model.

Appendix C
EVALUATIONS FOR CRITERIA IMPORTANCE

LIST OF TABLES

INTRODUCTION

This appendix contains the results of the team's pair-wise comparisons of objective and criterion importance for all seven nodes of the decision analysis model. For each pair-wise comparison shown below in Tables C-1 through C-7, the team judged Objective/Criterion A more important than Objective/Criterion B by the factor shown. Reasons for the determination of relative importance are provided in the discussion column of each table.

Table C-1. Evaluation at Goal Node

Objective A	Objective B	Factor	Discussion:
Disposal Form	Process	4.4	The project objective is to get the aluminum-based spent nuclear fuel into the repository. Therefore, the disposal form performance was very important. The primary concern is to minimize the difficulty in meeting all of the disposal form performance requirements. A higher degree of difficulty in developing and implementing the process would be accepted to attain this.
Disposal Form	Life Cycle	3.6	The primary concern is to minimize the difficulty in meeting all of the disposal form performance requirements. A higher cost and schedule slippage would be accepted to attain this.
Disposal Form	Public	3.4	The primary concern is to minimize the difficulty in meeting all of the disposal form performance requirements. Public support, while important, is a secondary concern.
Disposal Form	Program	4.1	The primary concern is to minimize the difficulty in meeting all of the disposal form performance requirements. The importance of programmatic issues which may be impacted by the technology decision is secondary.
ES&H	Disposal Form	1.6	The primary concern is to minimize the impact on the environment and to maximize protection of the worker and public health and safety. In fact, the setting of disposal performance requirements for certain characteristics is to do just that. Since the repository is a subsurface facility designed specifically to minimize impact on public health, the ES&H criterion is given slightly more importance.
Process	Life Cycle	2.3	The cost, although important, is essentially the same for each alternative. Therefore, selecting a process that more easily resolved engineering issues would be preferred.
Process	Public	1.8	Public support, although important, would be a secondary concern when compared to the desire to implement a process that more readily resolves engineering issues.
Process	Program	2.8	Programmatic concerns, although important, would be secondary when compared to the desire to implement a process that more readily resolves engineering issues.
ES&H	Process	3.6	The primary concern is to minimize the impact on the environment and to maximize protection of the worker and public health and safety. The process, although important, would be compromised before ES&H.

DOES NOT CONTAIN UCNI

Table C-1. Evaluation at Goal Node (cont.)

Objective A	Objective B	Factor	Discussion:
Public	Life Cycle	1.1	For this study, it was determined by the team that public support is slightly more important than the Life Cycle cost or schedule.
Life Cycle	Program	1.8	In today's world of shrinking budgets, Life Cycle costs are an important factor in choosing an alternative. Programmatic concerns, although important, would be secondary.
ES&H	Life Cycle	3.6	The primary concern is to minimize the impact on the environment and to maximize protection of the worker and public health and safety. The cost, although important, would be compromised before ES&H.
Public	Program	1.6	Public opinion is important in making this decision. Programmatic concerns are less important in this decision.
ES&H	Public	3.5	The primary concern is to minimize the impact on the environment and to maximize protection of the worker and public health and safety. Public opinion, although important, would be a secondary concern.
ES&H	Program	4.2	The primary concern is to minimize the impact on the environment and to maximize protection of the worker and public health and safety. Programmatic concerns, although important, would be secondary.

Table C-2. Evaluation at Disposal Form Node

Criterion A	Criterion B	Factor	Discussion:
Criticality	Release Rate	3.9	Criticality was judged more important based on its environmental, safety, and health impact. The release rate in the repository was judged to have less of an environmental, safety, and health impact based on the very long time frames considered and on the minimal impact on the repository Performance Assessment.

Table C-3. Evaluation at Process Node

Criterion A	Criterion B	Factor	Discussion:
Charact. Acceptance	Complexity	3.1	The importance of characterizing the SNF was judged by the team to be more important than developing and implementing a process which is less complex. A process which is more complex but yields a higher degree of certainty in waste characterization is preferred.
Maintainability	Complexity	1.8	Maintainability is related to complexity. However, given the option to make the process easier to maintain but more complex, maintainability is more important.

Table C-3. Evaluation at Process Node (cont.)

Criterion A	Criterion B	Factor	Discussion:
Secondary Waste	Complexity	2.2	The generation of secondary waste streams could have adverse financial, environmental, and health and safety impacts. Process simplicity would be sacrificed to minimize secondary waste generation.
Permitting	Complexity	2.3	Permits will be required in order to operate the facility. Simplicity of the process is a desired attribute, but is not a requirement. Thus the permit criterion is more important.
Versatility	Complexity	2.1	The ability of the process to accept changes in scope are deemed more important than process complexity.
Charact. Acceptance	Maintainability	3.2	Waste characterization is a requirement for repository acceptance of the waste form. A process, which may necessitate more maintenance , but yields a higher degree of certainty in waste characterization, is preferred.
Charact. Acceptance	Secondary Waste	2.8	Waste characterization is a requirement for repository acceptance of the waste form. A process, which may produce more secondary waste, but yields a higher degree of certainty in waste characterization, is preferred.
Charact. Acceptance	Permitting	1.3	Both characterization and permits will be required to complete SNF disposal. Thus they are nearly equal in importance.
Charact. Acceptance	Versatility	2.5	Waste characterization is a requirement for repository acceptance of the waste form. A process which is less versatile, but yields a higher degree of certainty in waste characterization, is preferred.
Secondary Waste	Maintainability	2.1	The generation of secondary waste streams could have adverse financial, environmental, and health and safety impacts. Process maintainability would be sacrificed to minimize secondary waste generation.
Permitting	Maintainability	2.3	Permits will be required in order to operate the facility. Thus ease of obtaining permits is preferred over ease of maintenance.
Versatility	Maintainability	2.0	Process versatility is preferred over maintainability.
Permitting	Secondary Waste	1.6	Permits will be required in order to operate the facility. Although secondary waste has an affect on permitting, there is some margin to adjust this.
Versatility	Secondary Waste	1.6	The generation of slightly more secondary waste would be accepted for a more versatile process.
Permitting	Versatility	2.3	Permits will be required in order to operate the facility. Thus permitting is more important than process versatility.

Table C-4. Evaluation at Life Cycle Node

Criterion A	Criterion B	Factor	Discussion:
Capital Cost	O&M Cost	2.7	If the capital cost is too high, facility construction will not be funded, and the O&M cost would then be irrelevant.
Capital Cost	Disposal Cost	3.2	If the capital cost is too high, facility construction will not be funded, and the disposal cost would then be irrelevant.
Capital Cost	Schedule	1.5	If the capital cost is too high, facility construction will not be funded, and any schedule impacts would then be irrelevant.
O&M Cost	Disposal Cost	1.6	O&M costs are viewed as slightly more important than disposal costs. O&M costs are more near term. They also could have a bigger impact on the life cycle costs if the repository schedule is delayed.
Schedule	O&M Cost	1.2	Project schedule and O&M costs were evaluated to have essentially the same impact with schedule being slightly more important.
Schedule	Disposal Cost	1.5	Project schedule was judged to be slightly more important than out-year disposal costs. The DOE has committed to make the fuel road-ready as soon as possible.

Table C-5. Evaluation at Public Node

Criterion A	Criterion B	Factor	Discussion:
CSRA	NGO	1.4	It is judged that public support from within the CSRA will be more important to this decision.
South Carolina	NGO	1.2	It is judged that the SC position would be more important than the position of those outside SC for this decision.
CSRA	South Carolina	1.4	It is judged that public support from within the CSRA will be more important to this decision.

Table C-6. Evaluation at Program Node

Criterion A	Criterion B	Factor	Discussion:
Non-proliferation	Other SRS Missions	3.4	From a safety and a policy point of view, nonproliferation is considered more important than the impact the selected alternative would have on other SRS missions.
Other SRS Missions	Other DOE Missions	1.7	The impact the chosen alternative would have on other SRS missions is judged more important than the effect of setting precedence for the disposal of other DOE SNF.
Non-proliferation	Other DOE Missions	3.3	From a safety and a policy point of view, nonproliferation is considered more important than the impact the effect of setting precedence for the disposal of other DOE SNF.

Table C-7. Evaluation at ES&H Node

Criterion A	Criterion B	Factor	Discussion:
Public Safety	Worker Safety	2.1	The protection of the public is the primary concern. The worker has accepted a certain level of risk associated with the job.
Worker	Environmental	2.8	The safety of the worker takes precedence over environmental impacts.
Public Safety	Environmental	2.8	The safety of the public takes precedence over environmental impacts.

Appendix D
EVALUATIONS FOR PREFERRED ALTERNATIVE

LIST OF TABLES

INTRODUCTION

This appendix contains the results of the team's pair-wise comparisons of alternative preferences for all twenty-one of the decision criteria. For each criterion shown below in Table D-1, the team selected either Direct Co-Disposal or Melt & Dilute as the preferred alternative by the factor shown. Reasons for the team's selections of alternative preferences are provided in the discussion column of the table.

Table D-1. Evaluations for Preferred Alternative at Each Decision Criterion

Criterion	Preferred Alternative	Factor	Discussion:
Criticality	Melt & Dilute	5.2	Melt & Dilute has the capability to combine neutron absorber materials with the SNF into a homogenous LEU mixture. Thus it provides a greater assurance that criticality will not occur in the repository, even after the waste form has degraded. Long term non-criticality in the repository for the Direct Co-Disposal form is less assured because the form contains HEU and relies on the physical placement of neutron absorber materials within the disposal form's canister for criticality control. In addition, the recommended neutron absorber[23], gadolinium phosphate ($GdPO_4$) or one of its derivatives, is not commercially available. The uncertainty surrounding both the availability of $GdPO_4$ and the development of a process to produce an engineered neutron absorber from that compound[24] will have a much more significant impact on the Direct Co-Disposal alternative. The NRC concluded that the criticality analyses for the Direct Co-Disposal option have many conservative assumptions, but some aspects of the calculations still need to be addressed to eliminate potential non-conservatism. The NRC further concluded the criticality of the Melt & Dilute waste form is less of a concern than for Direct Co-Disopsal, but still needs to be addressed in order to determine whether neutron absorber material needs to be incorporated in the melt.[10]
Release Rate	Melt & Dilute	2.8	The Melt & Dilute final form has less surface area, so short term radionuclide release rates should be lower. However, long term differences in radionuclide release rates should not be significant since both disposal forms will essentially be composed of the same materials.
Complexity	Direct Co-Disposal	2.4	The Direct Co-Disposal process is relatively straight forward except for the complexity of proven powdered metallurgy technology required for disposal of FRR target materials identified in Table 5.2-2 of the RRTT Report (~ 4% of SNF will be powder). In this process, the SNF is characterized, cropped, and placed into disposable canisters fabricated of steel with neutron absorber inserts as required. The SNF is then vacuum dried and stored temporarily until the repository is available. The Melt & Dilute process, on the other hand, is more complex. It involves high temperature melting of the SNF and mixing it with depleted uranium and/or aluminum, as required, to achieve both the desired wt% of ^{235}U (generally 20% or less) and the alloy composition of 13.2 wt% uranium in aluminum before the mixture is either poured or solidified in the furnace crucible. The ingot is then placed into a disposable steel (Cont. on Page D-3)

DOES NOT CONTAIN UCNI

Table D-1. Evaluations for Preferred Alternative at Each Decision Criterion (cont.)

Criterion	Preferred Alternative	Factor	Discussion:
Complexity (Cont.)			canister for temporary storage (similar to that for the Direct Co-Disposal alternative). The Melt & Dilute alternative will also generate off-gas waste streams that must be collected and processed. "However, all of the technologies needed to make this system function successfully have been used in other applications, and it should be a relatively straightforward exercise to bring them together for aluminum spent fuel treatment."[a]
Characterization Acceptance	Melt & Dilute	4.4	Characterization under the Direct Co-Disposal alternative requires acceptance and validation of existing fuel data and operating history (Appendix A type). The reliability of some Appendix A data is questionable. Pretreatment characterization for the Melt & Dilute alternative is required primarily to determine the ^{235}U content of the SNF. Post-treatment characterization of Al-SNF forms produced under each disposal alternative is considered to be similar to meet repository requirements. However, the scope for the Melt & Dilute alternative should be lower due to the uniformity of the waste form produced and the reduction in number of canisters required[b].
Maintainability	Direct Co-Disposal	3.7	Equipment that experiences high temperatures and contamination, such as the furnaces and off-gas confinement systems required for the Melt-Dilute alternative, would be expected to be more difficult to maintain than equipment that does not, like the additional characterization equipment required for the Direct Co-Disposal alternative.
Secondary Waste	Direct Co-Disposal	3.0	Direct Co-Disposal would be expected to generate only LLW, while Melt & Dilute would be expected to produce solid HLW from the capture of volatile fission products such as cesium.
Permitting	Direct Co-Disposal	2.4	Direct Co-Disposal, with its simpler process and fewer effluents (both radiological and non-radiological), would have an advantage over the Melt & Dilute alternative in securing the permits and/or licenses required to operate a TSF at SRS.
Versatility	Melt & Dilute	3.9	Melt & Dilute would be expected to handle changes which might be required to deal with additional types and forms of SNF without major process modifications. The Melt & Dilute alternative could also easily adapt to disposal form enrichment limitations which might be imposed by the repository in the future. The Direct Co-Disposal alternative, on the other hand, might require significant process modifications to accommodate these changes, and in the case of enrichment limitations, may not be able to meet those limitations, if imposed.

[a] See Ref. 25, Page 51.
[b] See Ref. 15, §1.4

Table D-1. Evaluations for Preferred Alternative at Each Decision Criterion (cont.)

Criterion	Preferred Alternative	Factor	Discussion:
Capital Cost	Melt & Dilute	1.1	This preference is based upon actual PCD estimate data of $215.6M for Melt & Dilute and $229.2M for Direct Co-Disposal. The estimate for Direct Co-Disposal includes the cost of powder metallurgy required by that alternative for the powdered SNF identified in Table 5.2-2 of the RRTT Report. Overall capital costs for both alternatives are about the same because higher equipment costs for Melt & Dilute are essentially offset by the increased cost of additional interim storage racks required by the Direct Co-Disposal alternative.
O&M Cost	Direct Co-Disposal	1.1	This preference is based upon actual PCD estimate data of $855.3M for Direct Co-Disposal and $960.3M for Melt & Dilute. These PCD O&M cost estimates were based upon staffing levels of 375 persons for Direct Co-Disposal and 447 persons for Melt & Dilute.
Disposal Cost	Melt & Dilute	3.0	This preference is based upon actual PCD estimate data of $71.4M for Melt & Dilute and $212.6M for Direct Co-Disposal. Melt & Dilute offers a significant volume reduction of the SNF with a corresponding reduction in the number of disposable canisters which must be temporarily stored at SRS and eventually emplaced in the repository (approximately 337 canisters for Melt & Dilute versus 1400 canisters for Direct Co-Disposal).
Schedule	Direct Co-Disposal	2.0	Both alternatives currently have the same schedule for construction and startup. However, schedule risk for Direct Co-Disposal should be lower since it involves a simpler process than Melt & Dilute.
NGO	Direct Co-Disposal	1.8	Direct Co-Disposal, with its simpler process and fewer effluents, would be expected to gain higher support from NGOs. Two possible exceptions to that support may be due to 1.) the perception that Direct Co-Disposal would pose more of a proliferation threat than the Melt & Dilute alternative, and 2.) Melt & Dilute will have fewer overland shipments to the repository, with lower risk and lower visibility to the public.
CSRA	Melt & Dilute	1.6	If all other aspects of the two alternatives were considered equal, the CSRA would likely support the alternative which has the greatest economic impact on the region in terms of jobs. That being the case, Melt & Dilute would probably be preferred to Direct Co-Disposal.
South Carolina	Melt & Dilute	1.3	Melt & Dilute will result in more jobs for South Carolina and will be less of a proliferation threat. However, Direct Co-Disposal will have less impact on the environment in South Carolina.
Other SRS Missions	Melt & Dilute	2.9	Based upon current estimates for the number of disposable canisters required for each of the alternatives, Melt & Dilute would offer an advantage over Direct Co-Disposal in freeing waste canister space for use by other SRS missions.

Table D-1. Evaluations for Preferred Alternative at Each Decision Criterion (cont.)

Criterion	Preferred Alternative	Factor	Discussion:
Nonproliferation	Melt & Dilute	5.1	Proliferation concerns for both interim and geologic storage are addressed by Melt & Dilute since it will be diluted to LEU. Direct Co-Disposal, since it leaves the HEU fuel intact, may be perceived as creating weapons-capable stockpiles of enriched uranium both at SRS and the MGDS, contrary to the intent of PDD 13.
Other DOE Missions	Direct Co-Disposal	1.8	Disposing of SNF via the Direct Co-Disposal alternative will not set a precedent for other DOE fuel, while volume and enrichment reduction, both benefits of the Melt & Dilute alternative, might.
Worker Safety	Direct Co-Disposal	2.7	Direct Co-Disposal, with its simpler process and fewer effluents, would have an advantage over the Melt & Dilute alternative for worker safety, both OSHA and radiological. For the purposes of this decision analysis, the draft EIS accumulated dose estimates of 38 man-rem/yr for Direct Co-Disposal and 50 man-rem/yr for Melt & Dilute were considered.
Public Safety	Direct Co-Disposal	1.1	Direct Co-Disposal, with fewer effluents, would have an advantage over the Melt & Dilute alternative for one aspect of public safety. However, the increased risk to the public during transportation of the disposable canisters from SRS to the repository (a function of the number of canisters to be transported) would favor the Melt & Dilute alternative.
Environmental	Direct Co-Disposal	2.2	Direct Co-Disposal, with fewer effluents, would have an advantage over the Melt & Dilute alternative with regard to environmental impacts. However, Melt & Dilute will be essentially stacking only noble gases since Cs will be filtered out of the facility stack gases.

Appendix E
SENSITIVITY GRAPHS

LIST OF FIGURES

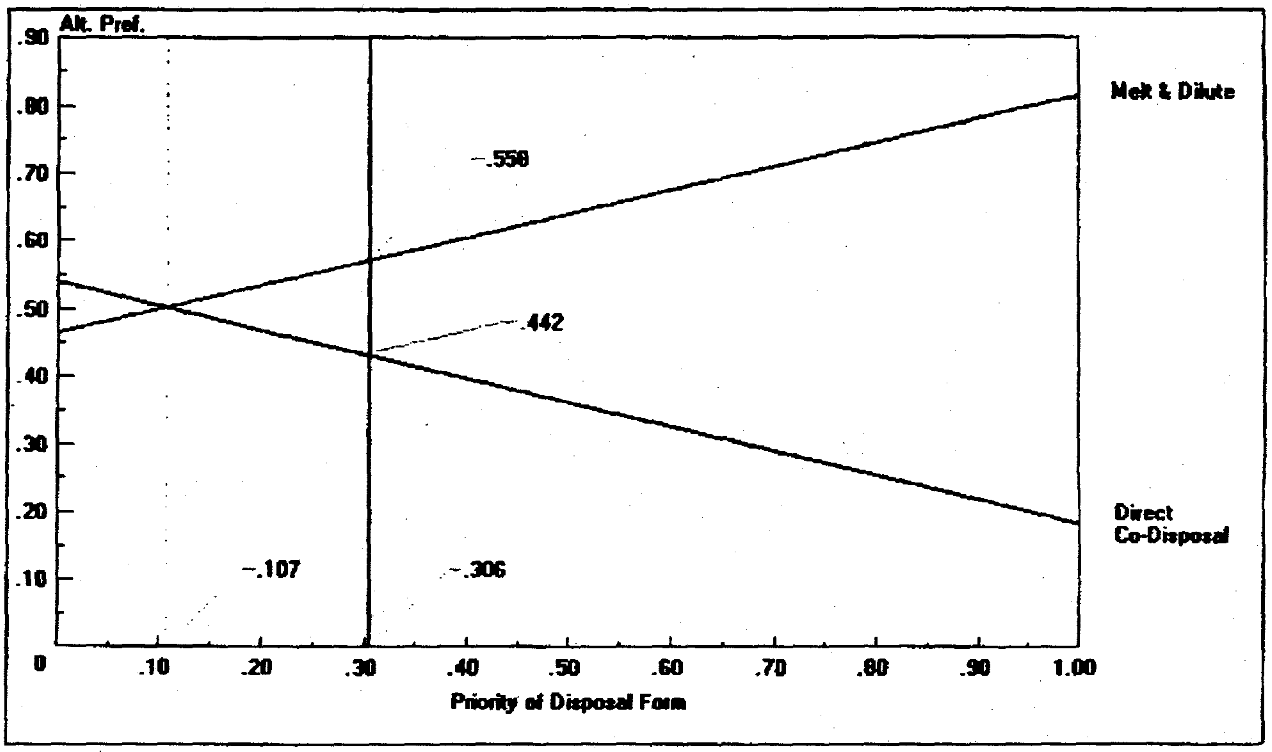

Figure E-1. Gradient Sensitivity for Disposal Form with respect to Goal

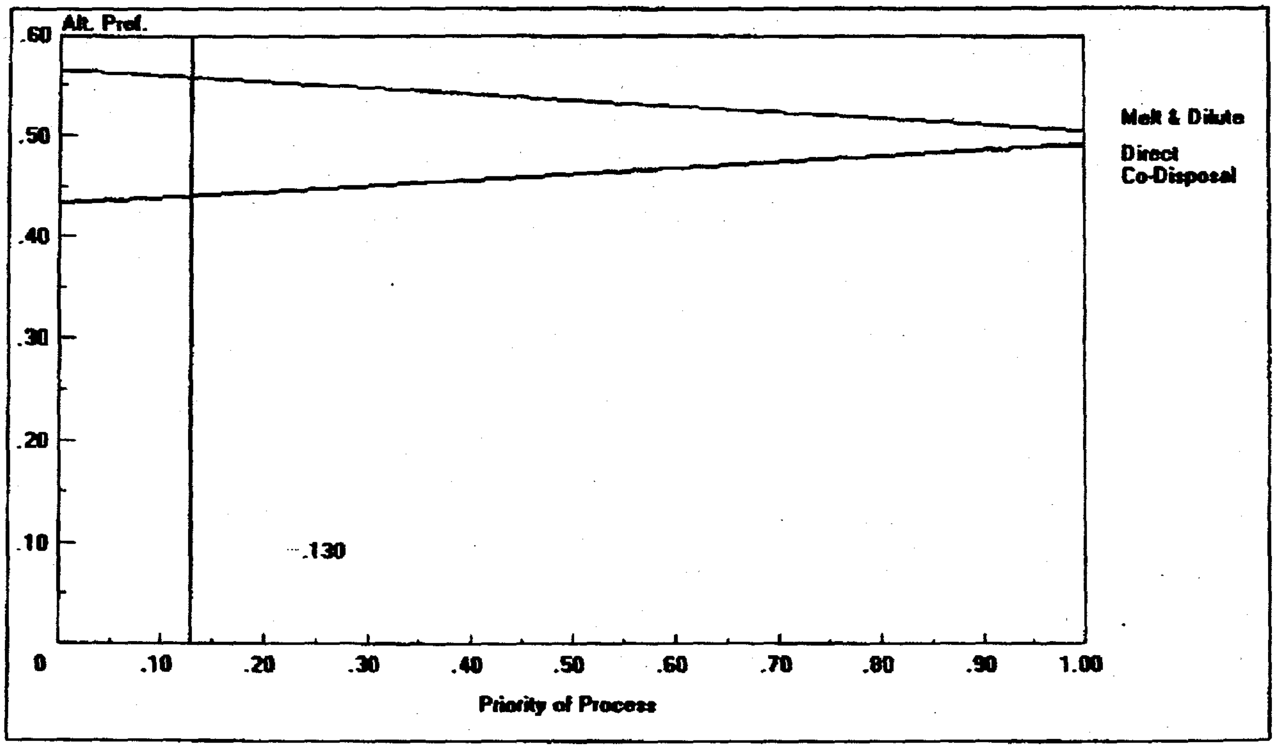

Figure E-2. Gradient Sensitivity for Process with respect to Goal

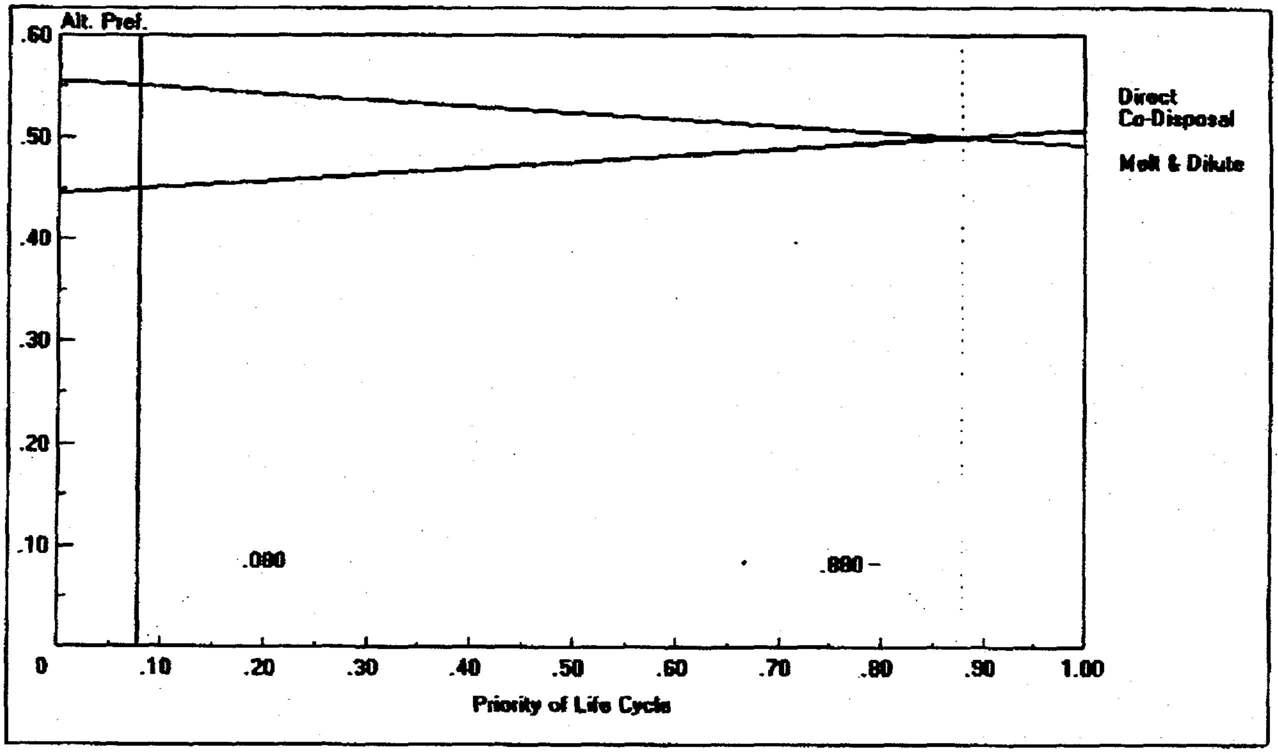

Figure E-3. Gradient Sensitivity for Life Cycle with respect to Goal

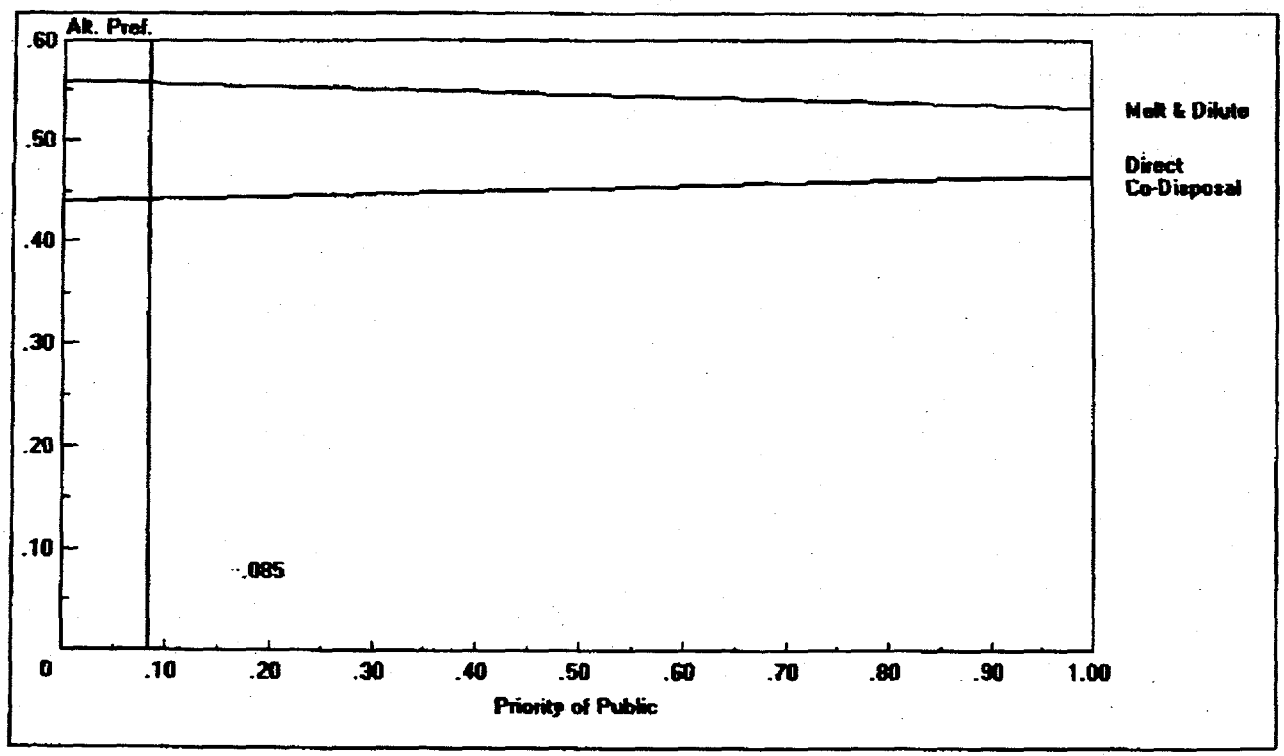

Figure E-4. Gradient Sensitivity for Public with respect to Goal

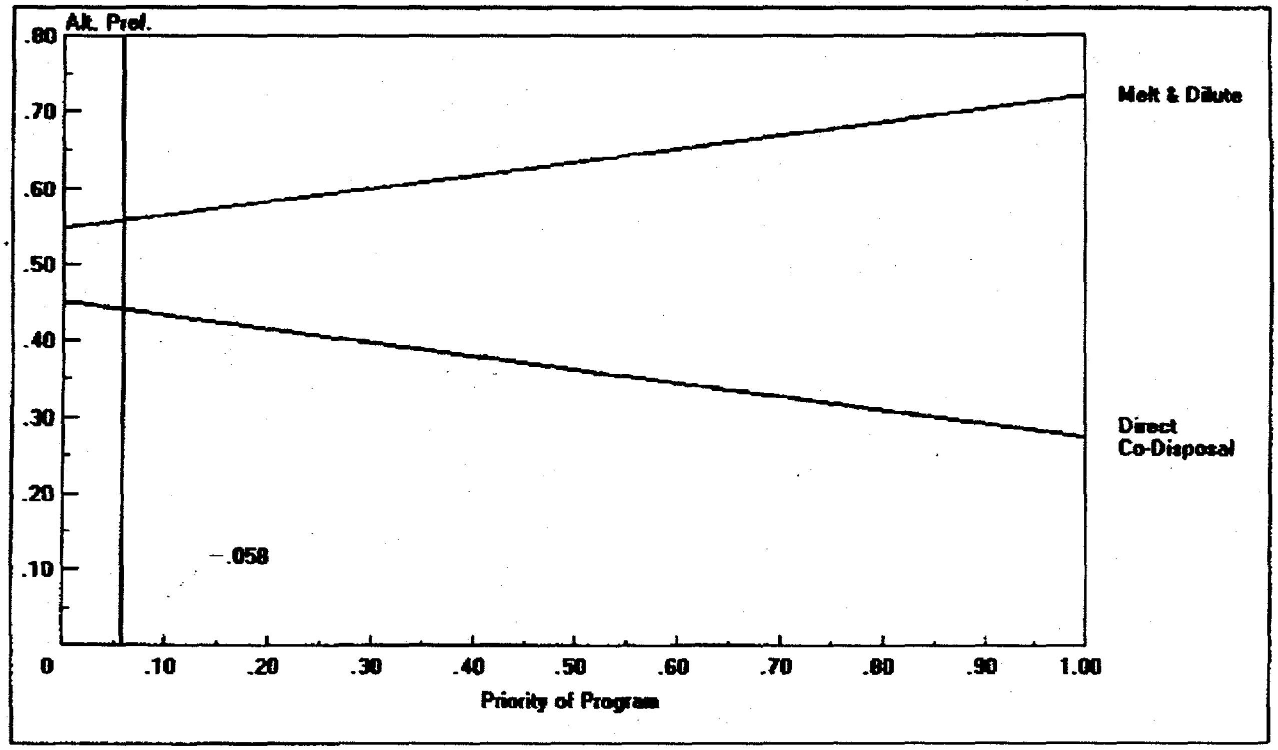

Figure E-5. Gradient Sensitivity for Program with respect to Goal

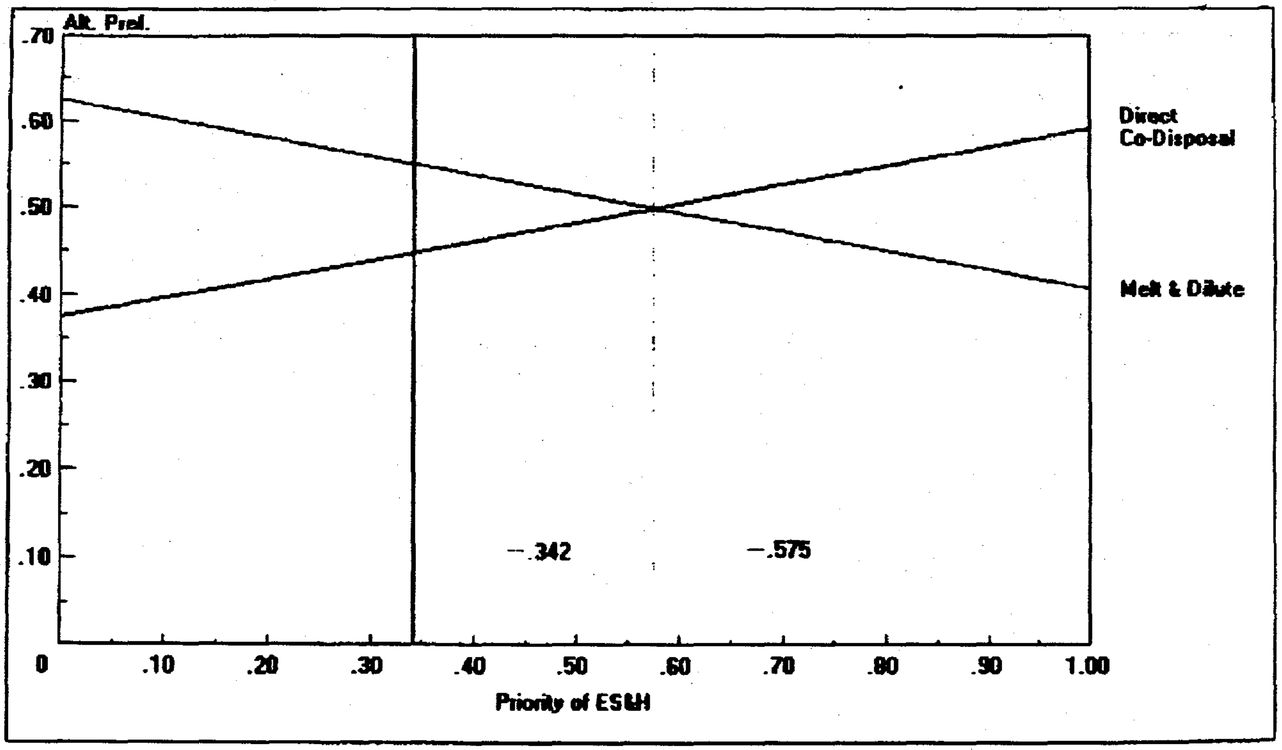

Figure E-6. Gradient Sensitivity for ES&H with respect to Goal

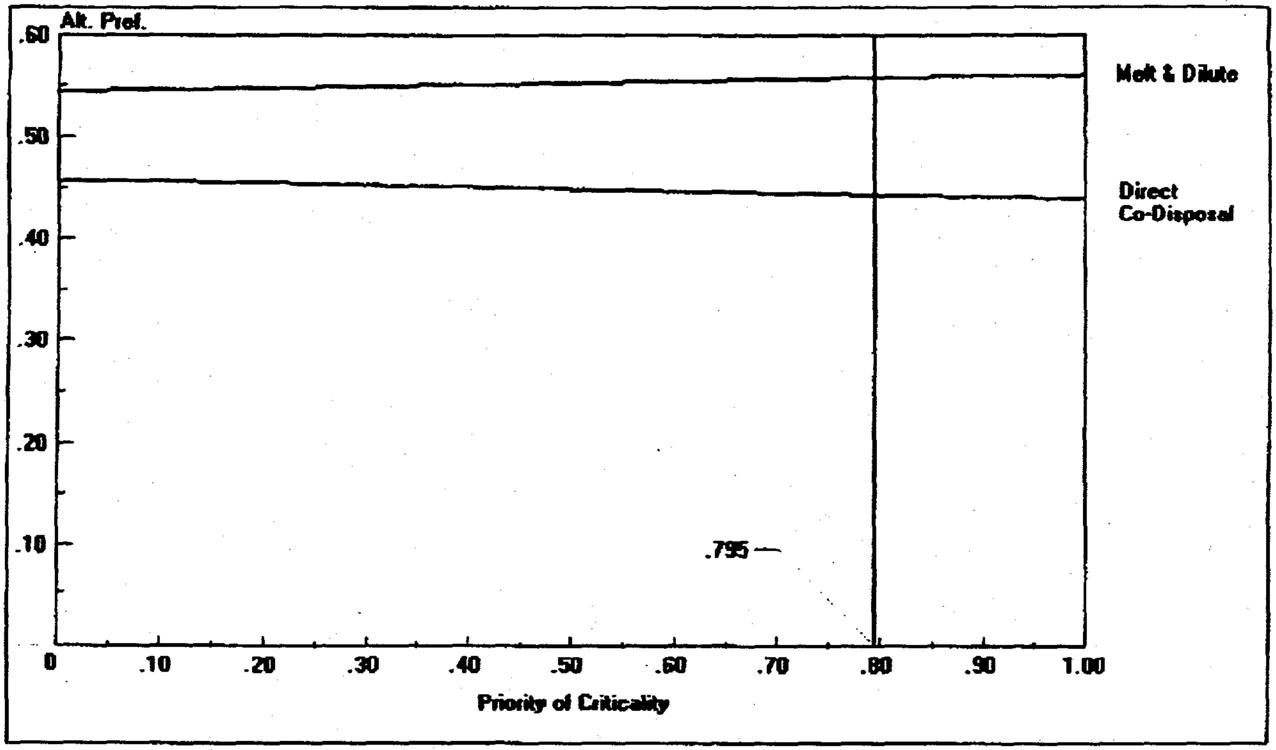

Figure E-7. Gradient Sensitivity for Criticality with respect to Goal

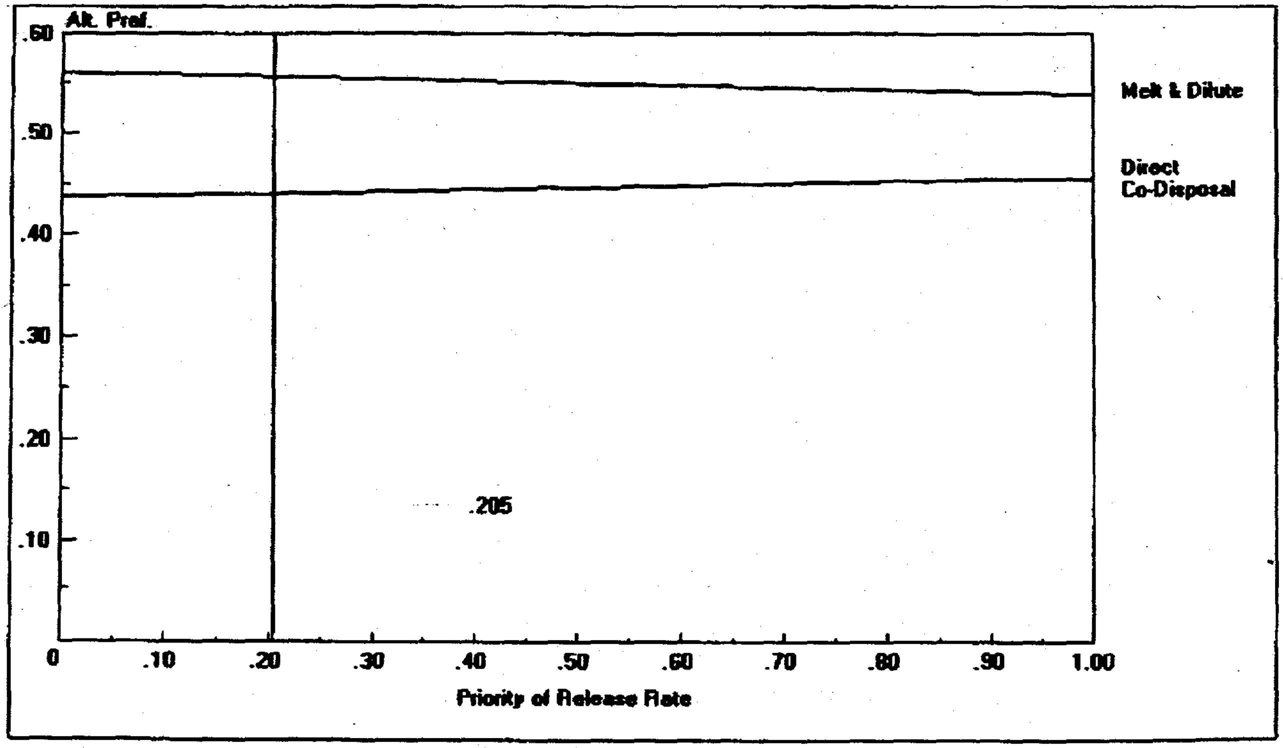

Figure E-8. Gradient Sensitivity for Release Rate with respect to Goal

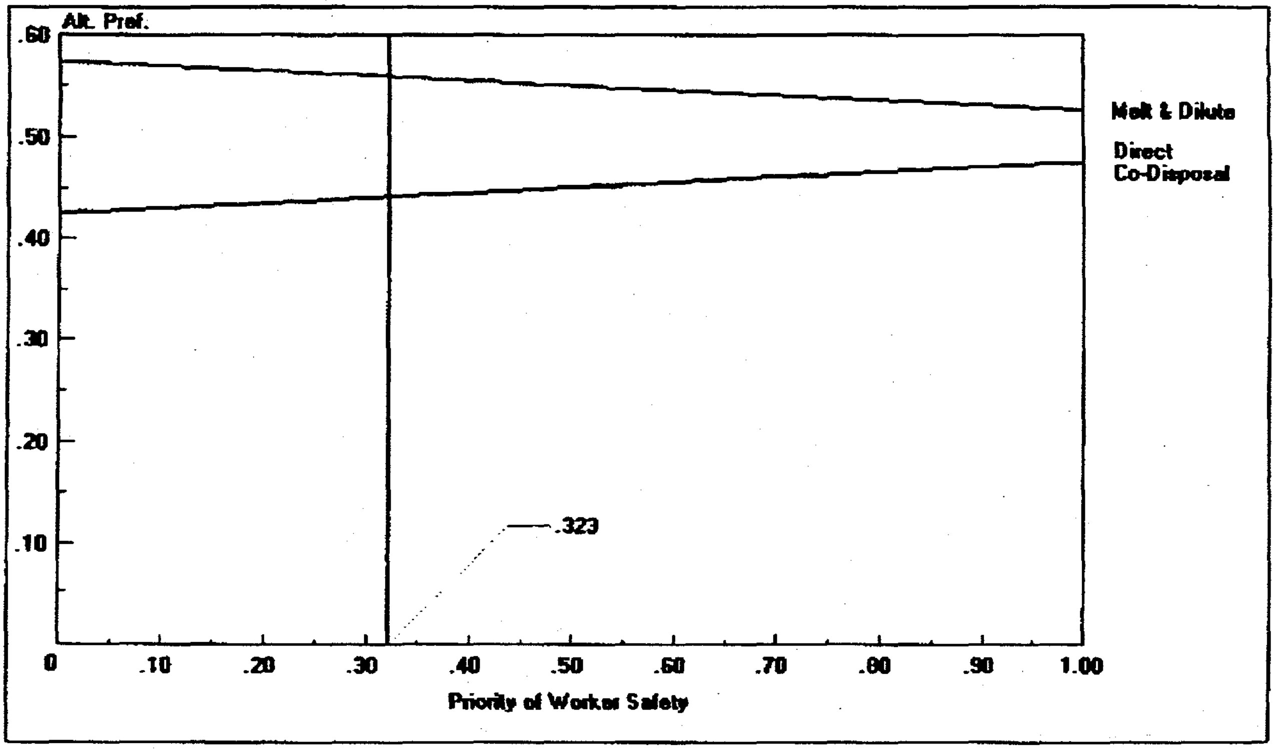

Figure E-9. Gradient Sensitivity for Worker Safety with respect to Goal

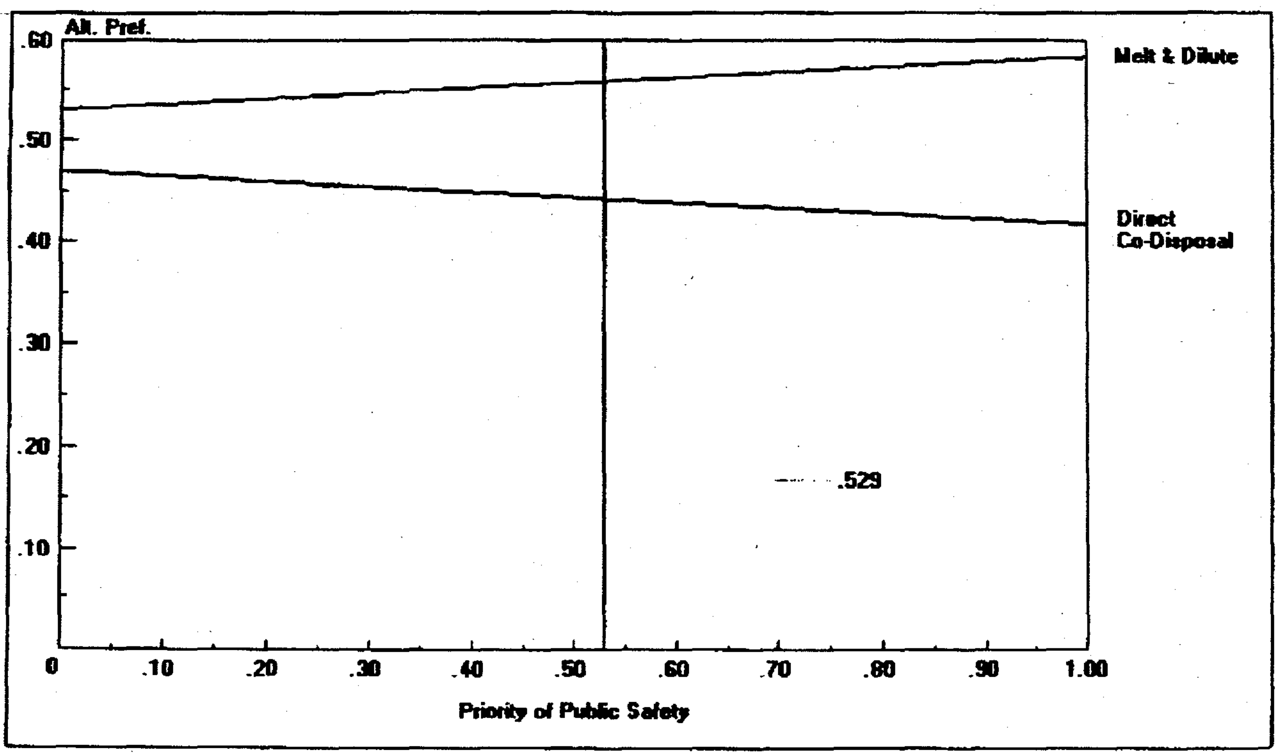

Figure E-10. Gradient Sensitivity for Public Safety with respect to Goal

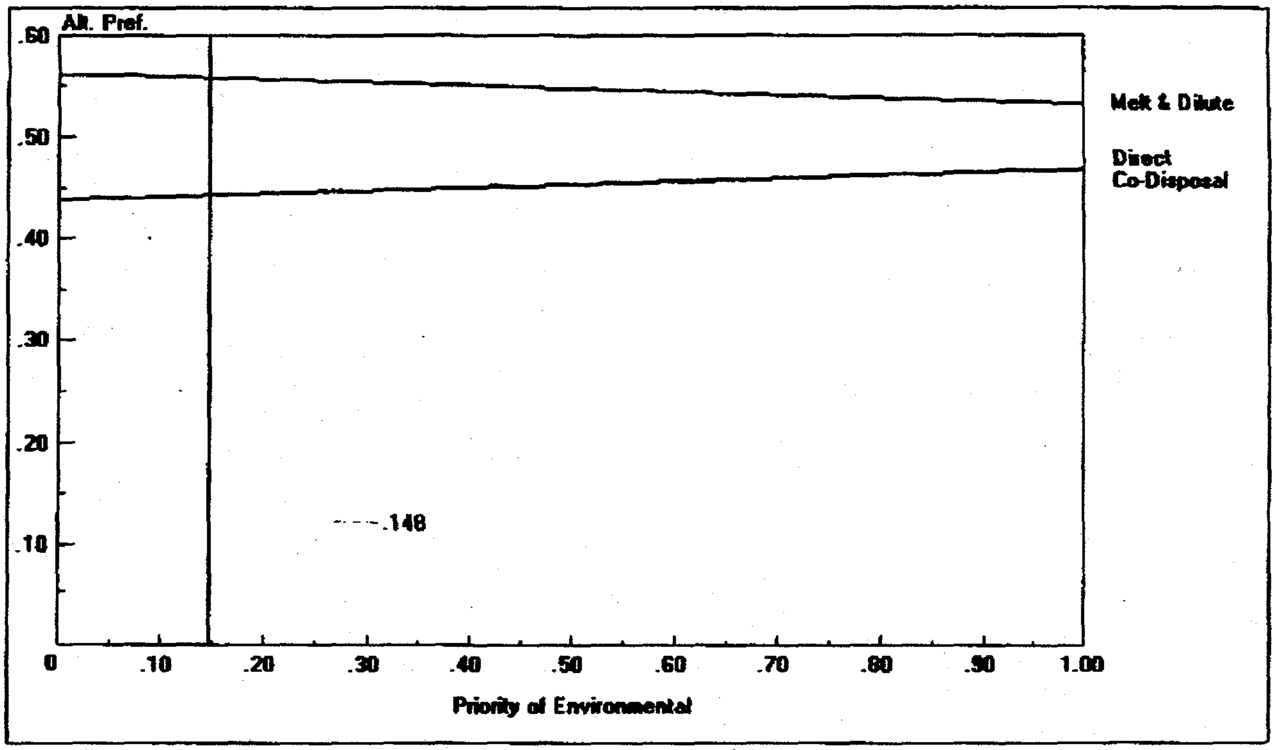

Figure E-11. Gradient Sensitivity for Environmental with respect to Goal