ATTACHMENT 3

U.S. Department of Energy
Office of Civilian Radioactive Waste Management

YUCCA MOUNTAIN PROJECT

Introduction and Background

Presented to:
DOE/NRC Technical Exchange Meeting on DOE Spent Nuclear Fuel

Presented by:
April V. Gil
Joe C. Price
Office of Repository Development
U.S. Department of Energy

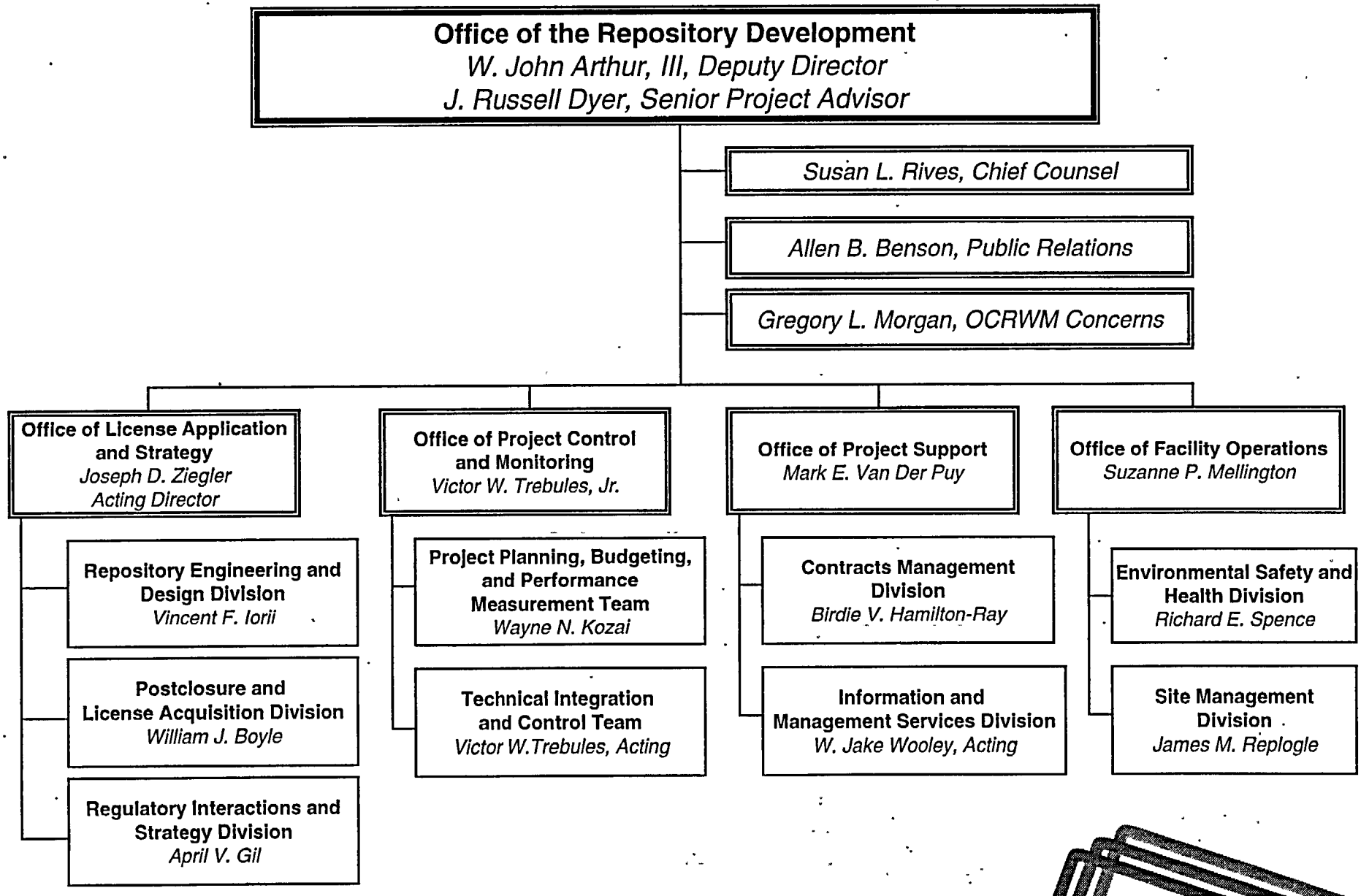
Mark Arenaz
Manager, National Spent Nuclear Fuel Program
U. S Department of Energy/Idaho

March 5-6, 2003
Rockville, Maryland

Outline

- Introductions and Background
- National Spent Nuclear Fuel Program
- Purpose of Technical Exchange
- Review of Agenda

OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT



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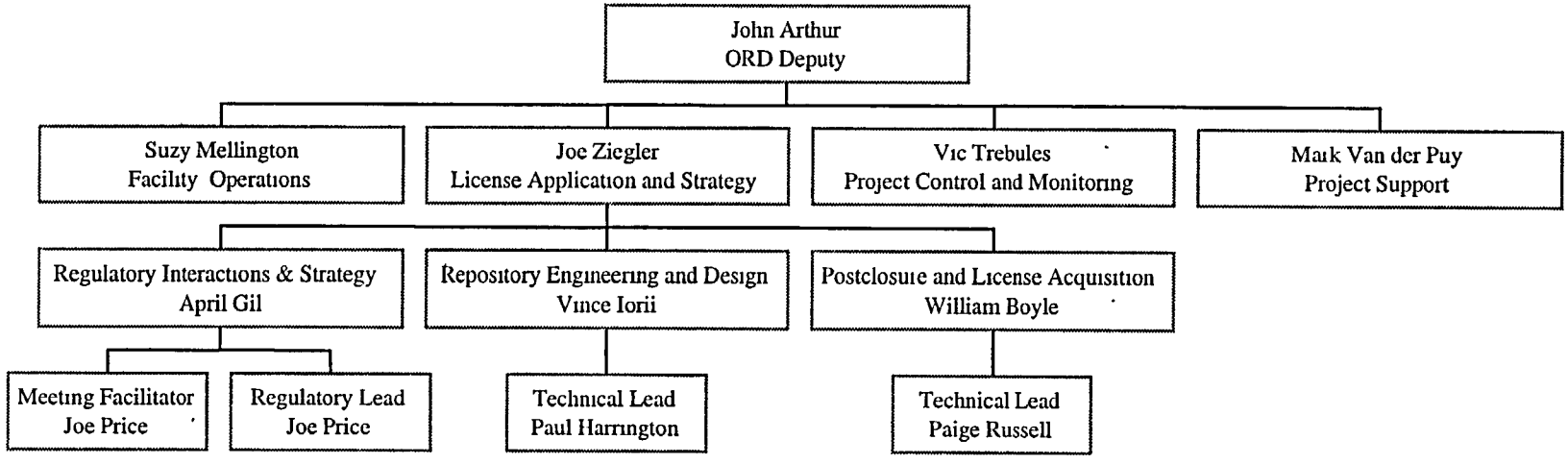
OFFICE OF REPOSITORY DEVELOPMENT



National Spent Nuclear Fuel Program

- Primary technical interface between DOE Program (EM) and RW
- Manage and perform DOE Spent Nuclear Fuel (SNF) repository-related activities
- Development of standardized canister
- Qualify DOE SNF site Quality Assurance programs
- Integration of technology development needs

Yucca Mountain Project Waste Forms

Waste Forms

- Commercial SNF
- DOE SNF
- Naval reactor SNF
- DOE waste (i.e., high-level waste glass)

Issues

- Characterization - waste forms
- Criticality
- Waste package design
- Near field
- Performance

Purpose of Technical Exchange

- Provide background on DOE SNF
- Update NRC on DOE plans for inclusion of DOE SNF in the repository License Application
  - Describe DOE SNF generically as a waste form
  - Address plans to use the standard DOE canister
  - Discuss the preclosure safety, criticality, and performance assessment analyses performed in support of the licensing approach

Scope of Technical Exchange

- Limited to DOE SNF; excludes other waste forms such as immobilized plutonium, high-level waste, commercial mixed oxide, etc.
- Focus on conceptual level issues

Review of Agenda

- Overview of DOE SNF
- Handling and Disposal of DOE SNF
- Yucca Mountain Project Approach to Control of Criticality and Radionuclide Transport
- DOE SNF Source Term Development
- DOE SNF Canisters
- DOE SNF Approach for Postclosure Assessment (TSPA-LA)
- Criticality Analyses

U.S. Department of Energy
Office of Civilian Radioactive Waste Management

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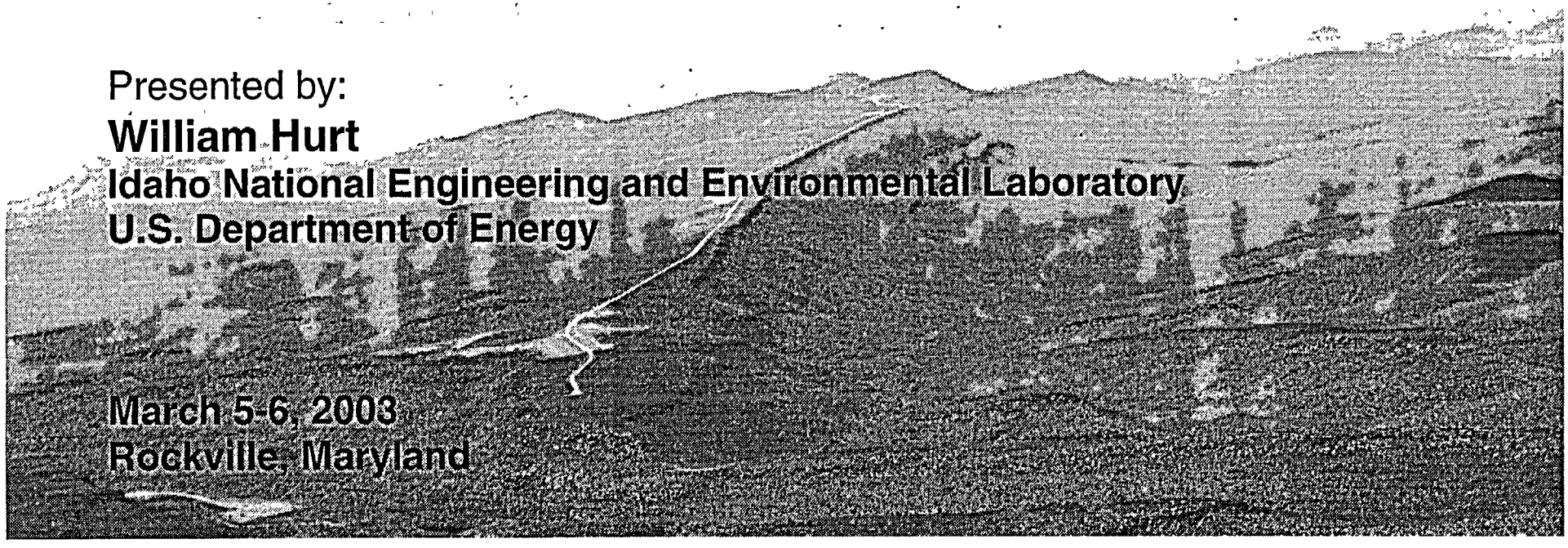
Overview of DOE Spent Nuclear Fuel

Presented to:
DOE/NRC Technical Exchange Meeting on DOE Spent Nuclear Fuel

Presented by:
William Hurt
Idaho National Engineering and Environmental Laboratory
U.S. Department of Energy



March 5-6, 2003
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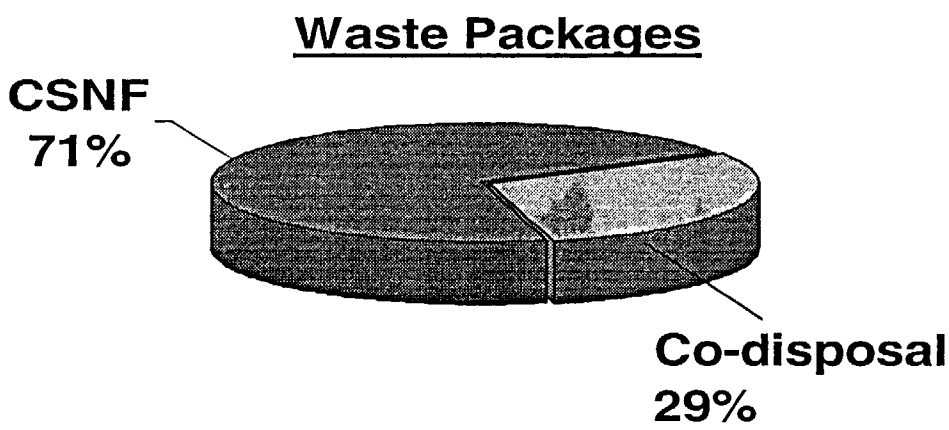
Outline

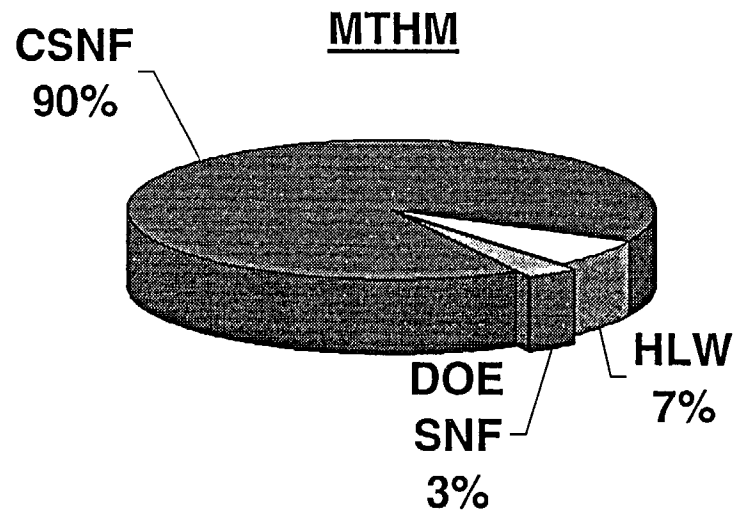
- Scope of DOE Spent Nuclear Fuel (SNF) for Discussions
- Comparisons of Repository Inventory
- DOE SNF Origins
- Characteristics of DOE SNF
- DOE SNF Information
- DOE SNF Canisters
- Summary

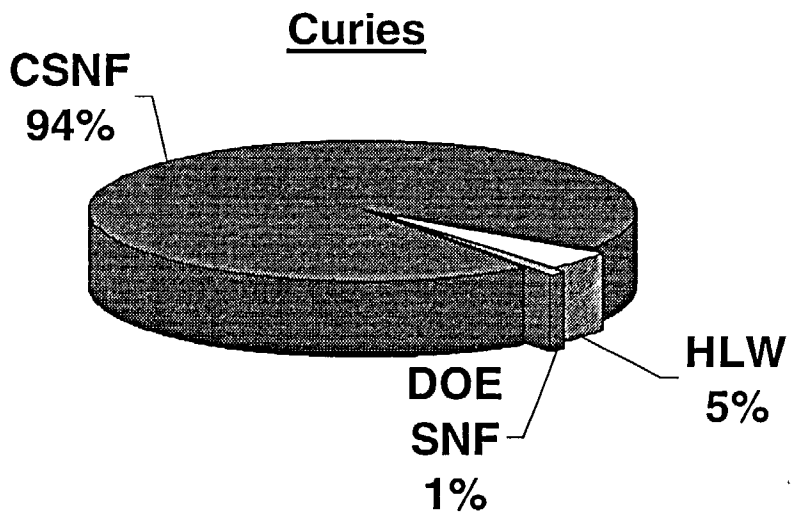
Scope of DOE Spent Nuclear Fuel for Discussions

- Scope of this discussion is limited to DOE-managed SNF destined for disposal
- Excludes:
  - Naval SNF
  - Commercial-like SNF with handling fixtures
  - Sodium-bonded SNF

Comparisons of Repository Inventory







DOE Spent Nuclear Fuel Origins

- Spent fuel generated from numerous reactors
  - Test, training, and research reactors
    - DOE, NRC licensed, universities, foreign
  - DOE production reactors
    - N reactor, single pass reactors, etc.
  - Development
    - Fort St. Vrain, Shippingport, Fermi, etc.
  - Commercial power reactor SNF
    - Three Mile Island, West Valley, Dry Rod Consolidation, etc.

Characteristics of DOE Spent Nuclear Fuel

- Fuel forms
  - Rod array, element, plate array, annulus, blocks, pins, debris in cans
- Fissile radionuclides
  - U-233, U-235, Pu-based fuels
- Fissile enrichments
  - Ranges from depleted uranium to 93 percent
- Cladding types
  - Aluminum, stainless steel, Zircalloy, Hastelloy, Inconel, Nichrome

Characteristics of DOE Spent Nuclear Fuel

(continued)

- Fuel compounds
  - Alloy, oxide, carbide, nitride, hydride, metal, silicide
- Matrices
  - Aluminum, graphite, ceramic, and stainless steel
- Condition
  - Intact, cropped, corroded, disassembled, post irradiation examination residuals
- Sizes
  - 0.06 to 29 in. wide
  - 4 to 177 in. long
- Burnups
  - From <1000 to >500,000 megawatt-days (MWd)/metric tons of heavy metal (MTHM)
  - 0.1 percent to >70 percent of original fissile

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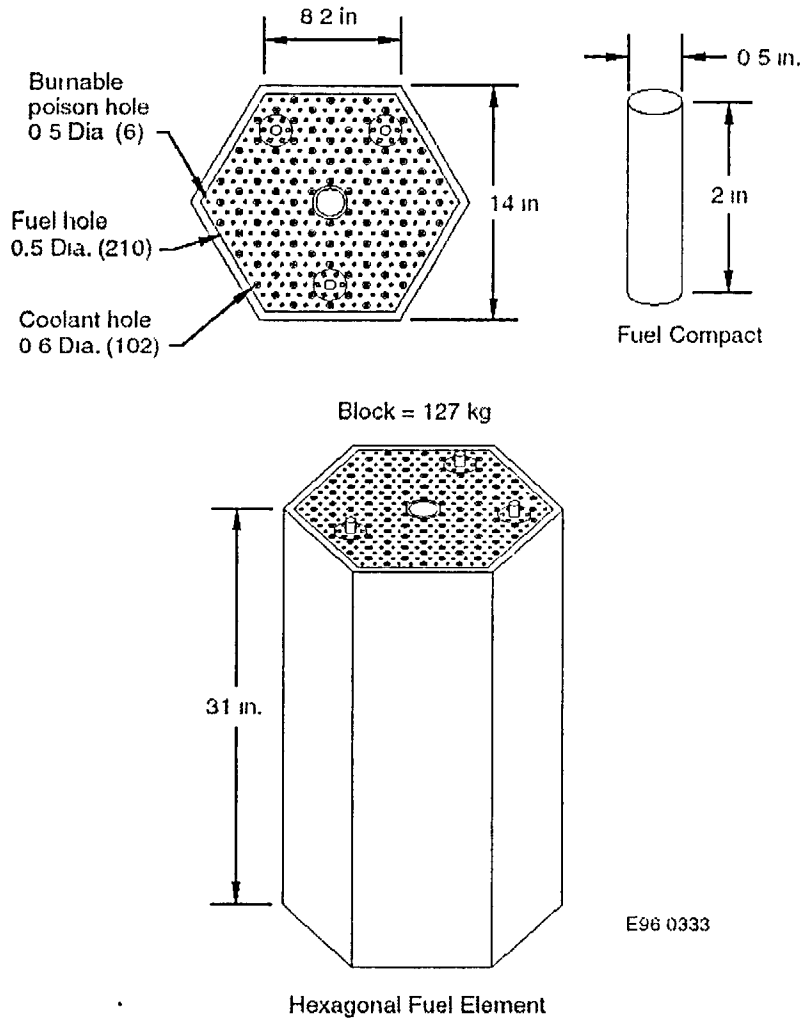
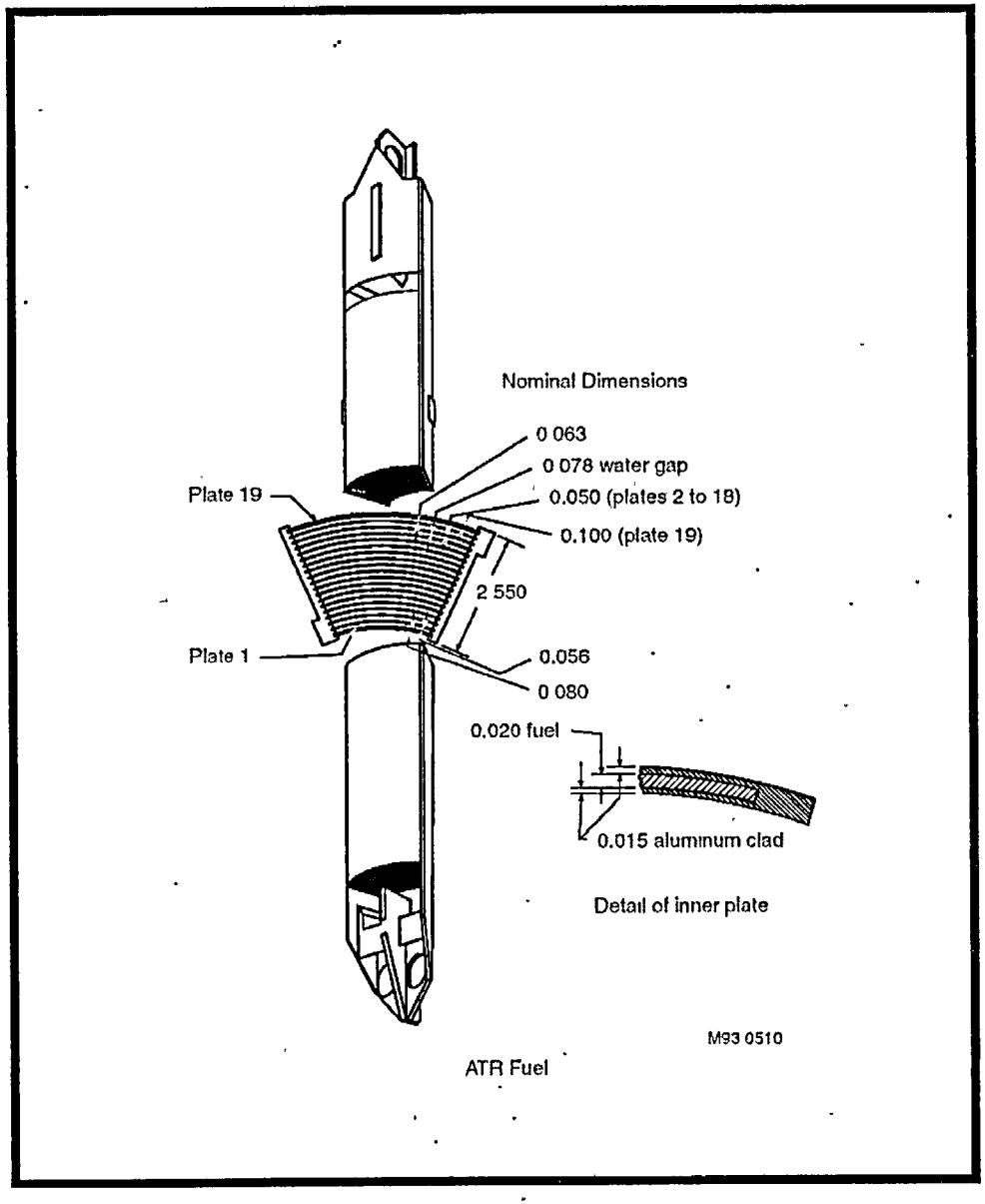
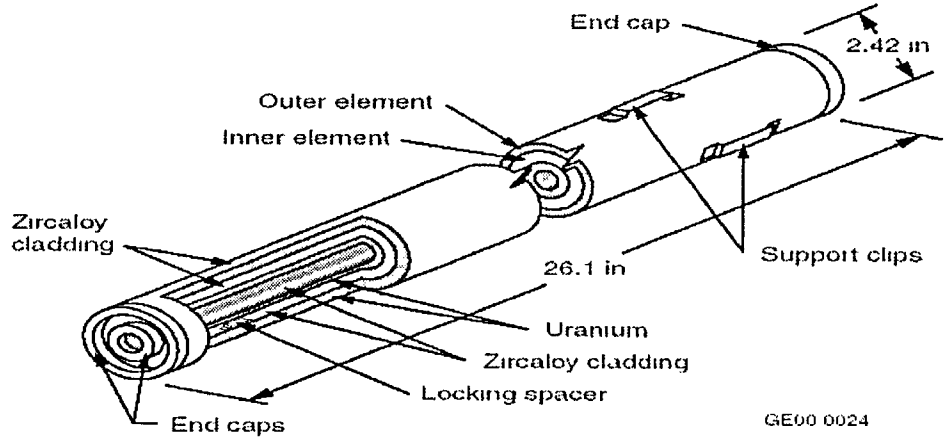
Fort St. Vrain Fuel



Advanced Test Reactor Fuel



N Reactor Fuel



DOE Spent Nuclear Fuel Information

- Fissile and fertile information exists for all DOE SNF
- Radionuclide inventory developed for all DOE SNF
- Cladding, fuel compound, fuel matrix, and dimensional information exists for nearly all DOE SNF
- Reactor operating and fuel fabrication information is available for newer reactors

Information Sources

- Material Control and Accountability (MC&A)
- Technical reports
- Safety analyses
- Post irradiation examinations
- Reactor directories
- Textbooks
- Reactor records
- Shipping records
- Storage records

Information Uses

- NRC storage safety analyses
  - Three Mile Island, Fort St. Vrain, and Idaho Spent Fuel Facility
- DOE safety analyses
- Transportation analyses
  - FRR, University, Three Mile Island-2
- Yucca Mountain Project repository analyses

National Spent Nuclear Fuel Program Spent Fuel Database

- A centralized single source of information for DOE SNF
  - Contains information for all DOE SNF in inventory and projections through 2035
  - Updated semiannually
  - Traceable; change control tracking is in place
  - Information is reconciled and consistency checks are performed
  - Information is reconciled with MC&A data

DOE Spent Nuclear Fuel Canisters

- Simplify handling
  - Reduces handling fixtures
  - Reduces number of handling activities
- Provides containment and contamination control
- Two types
  - Multi-Canister Overpacks (MCO)
  - Standardized Canisters

Multi-Canister Overpack

- Developed to move and store production reactor SNF
- N-stamped American Society of Mechanical Engineers (ASME) Section III
- Corrosion-resistant material (304SS)
- 24-in. diameter x 13 ft 9 in. long
- Designed for handling, storage, and transportation at Hanford
- Will be analyzed to demonstrate containment for preclosure events

Multi-Canister Overpack

External Length:

165 in.

Outside Diameter:

24 in.

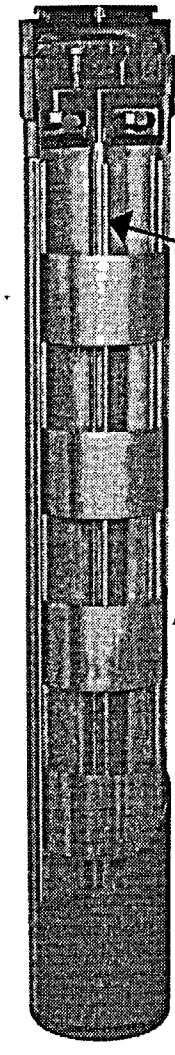
Wall Thickness:

½ in.

Maximum Weight with Fuel:
20,220 lbs

Material:

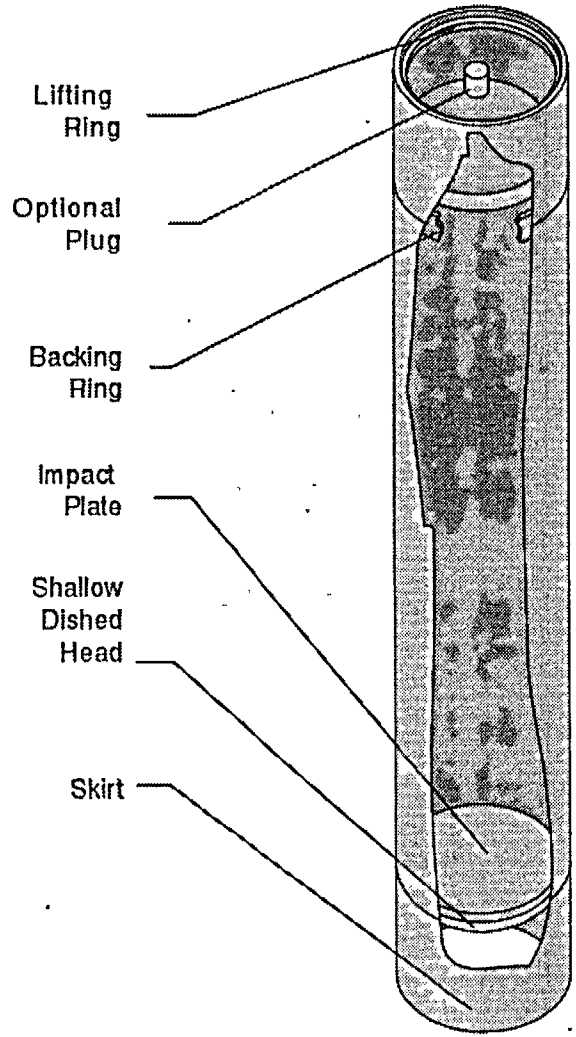
Canister Body SS 304L



Standardized Canister

- Developed to simplify handling during interim storage, transportation, and disposal
- Designed to ASME Section III with N stamp
- Corrosion-resistant material (316SS)
- Multiple sizes
  - 18 in. diameter (10 and 15 ft long)
  - 24 in. diameter (10 and 15 ft long)
- Designed to demonstrate containment for preclosure events

Standard DOE Spent Nuclear Fuel Canister



Nominal Outside Diameters:
18 in. and 24 in.

Wall Thickness:
3/8 in. for 18 in. canister
1/2 in. for 24 in. canister

Maximum Weight with Fuel:
5,000 to 10,000 lbs.

External Lengths:
Short Canister: 118.11 in.
Long Canister: 179.92 in.

Material:
Canister Body: SS316 L

GT00 0119

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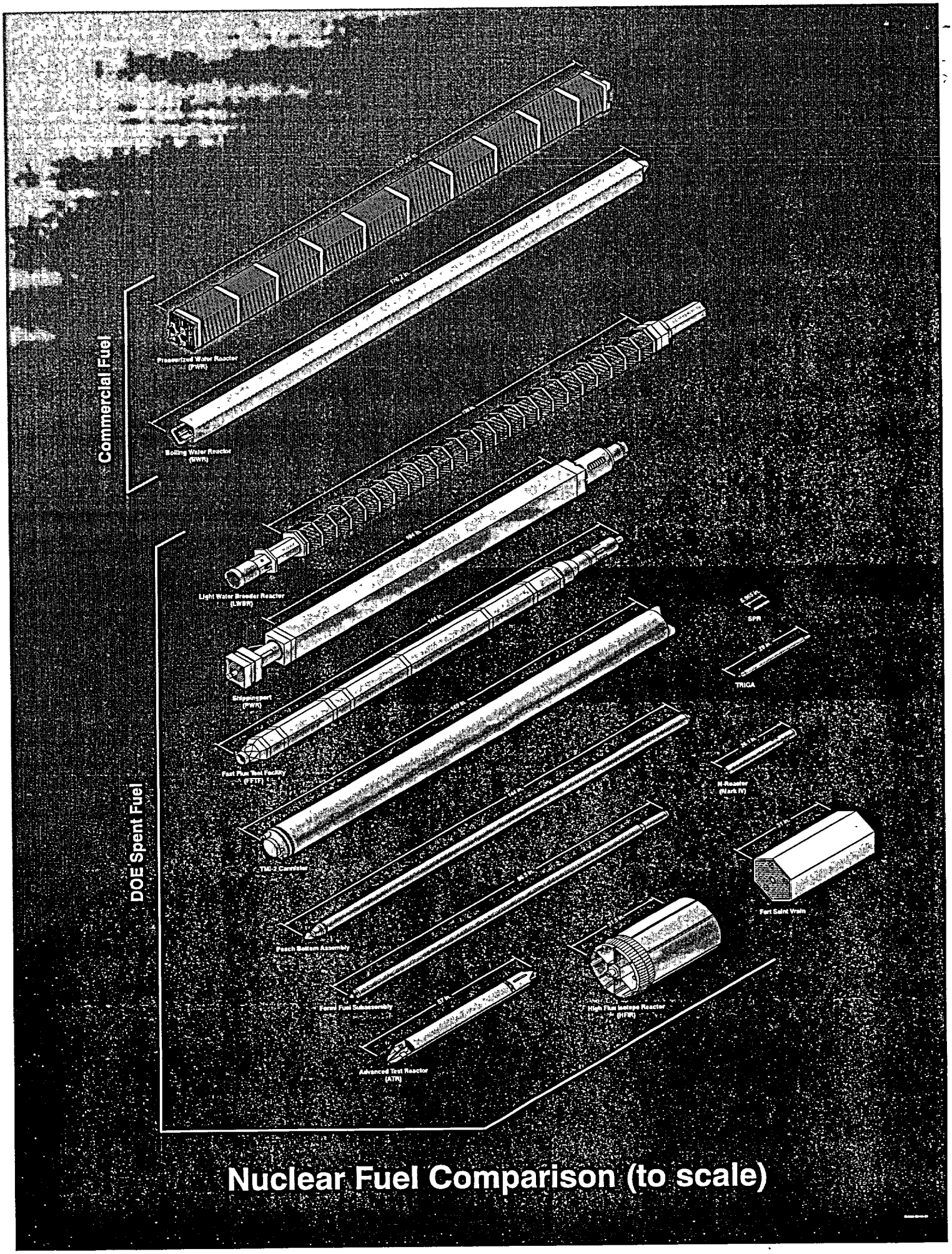
Summary

- DOE SNF is a small fraction of the repository inventory
- Diverse inventory of DOE SNF
- For the initial License Application submittal, DOE SNF is analyzed in ASME designed canisters



Nuclear Fuel Comparison (to scale)

U.S. Department of Energy
Office of Civilian Radioactive Waste Management

YUCCA MOUNTAIN PROJECT

Handling and Disposal of DOE Spent Nuclear Fuel

Presented to:
DOE/NRC Technical Exchange Meeting on DOE Spent Nuclear Fuel

Presented by:
Paul Harrington
Office of Repository Development
U.S. Department of Energy

March 5-6, 2003
Rockville, Maryland

Outline

- Regulatory and Interface Documents
- Waste Form
- Repository Surface Facilities
- Waste Packages
- Subsurface Disposal
- Summary

Repository Requirements and Interfaces

- 10 CFR Part 63
- Comprehensive Memorandum of Agreement-internal to DOE
- Waste Acceptance System Requirements Document (WASRD)
- Interface Control Document
- Compliance plans

Waste Acceptance System Requirements Document

- WASRD Rev. 3
  - Based on 10 CFR Part 60
- WASRD Rev. 4
  - Based on 10 CFR Part 63
  - Current version
- WASRD Rev. 5
  - Under development
  - Shifts DOE Spent Nuclear Fuel (SNF) transportation responsibility to RW; other changes

Interface Control Document

- Established to control important parameters that are not actual acceptance criteria but affect interfaces - information contained in previous versions of WASRD
- Jointly establishes design envelope for interfacing systems
  - Cask dimensions and weights
  - Standard canister dimensions
- Facility accommodation of DOE SNF
  - Minimize lift height

Waste Form

- Some DOE SNF will be canistered throughout transportation, surface facility handling, and subsurface disposal process
  - Canisterization simplifies repository handling
  - Canisters are credited in preclosure safety analyses
  - Used in cases of fuel degradation or other reasons
  - Examples include N Reactor fuel and Three Mile Island core debris
- Some DOE SNF will be transported, handled, and disposed as bare fuel assemblies
  - Intact SNF of commercial origin currently managed by DOE, which can be handled as other commercial SNF

Waste Form

- Remaining DOE SNF currently slated for canisterization, but under reassessment
  - Robust canisterization simplifies repository handling and analyses, but requires investment at shipping sites
  - Canisterization being revisited from DOE-wide perspective
  - Potential for some DOE SNF currently expected to be canisterized to be shipped as bare fuel assemblies
  - Repository preclosure design and analyses assume robust canisters, but may be modified pending completion of assessments
  - Repository postclosure analyses use surrogate fuel information and are unaffected by canisterization

Repository Surface Facilities

- Dry cell for waste transfer
- Transfer of waste from transportation casks
  - Cranes for large or small canisters
  - Fuel handling machines for bare fuel assemblies
- Placement of waste into disposal containers
  - Generally directly into disposal containers
  - Small amount of surge capacity in dry cell
  - Remediation building and aging pad generally for commercial SNF assemblies
- Waste package welding, non-destructive examination, stress mitigation
- Transfer to subsurface facility

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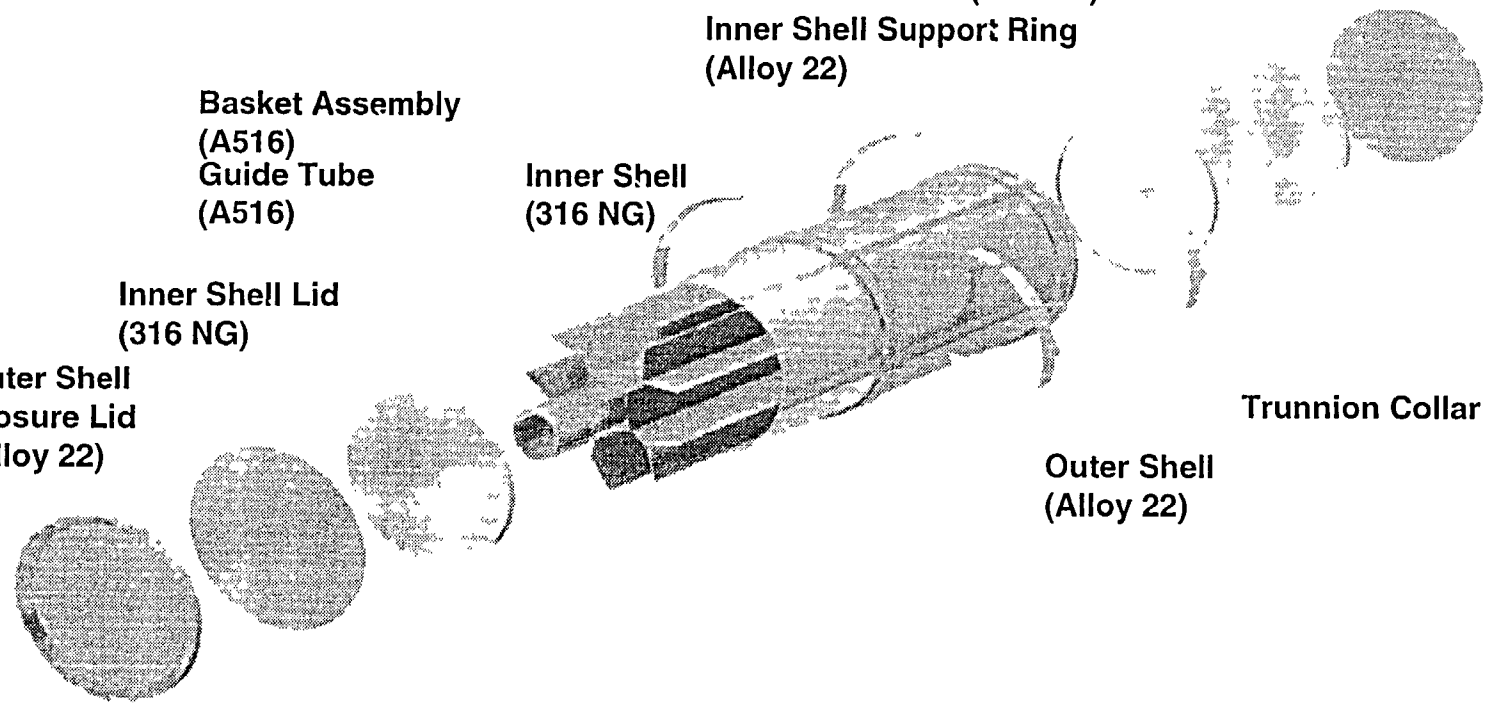
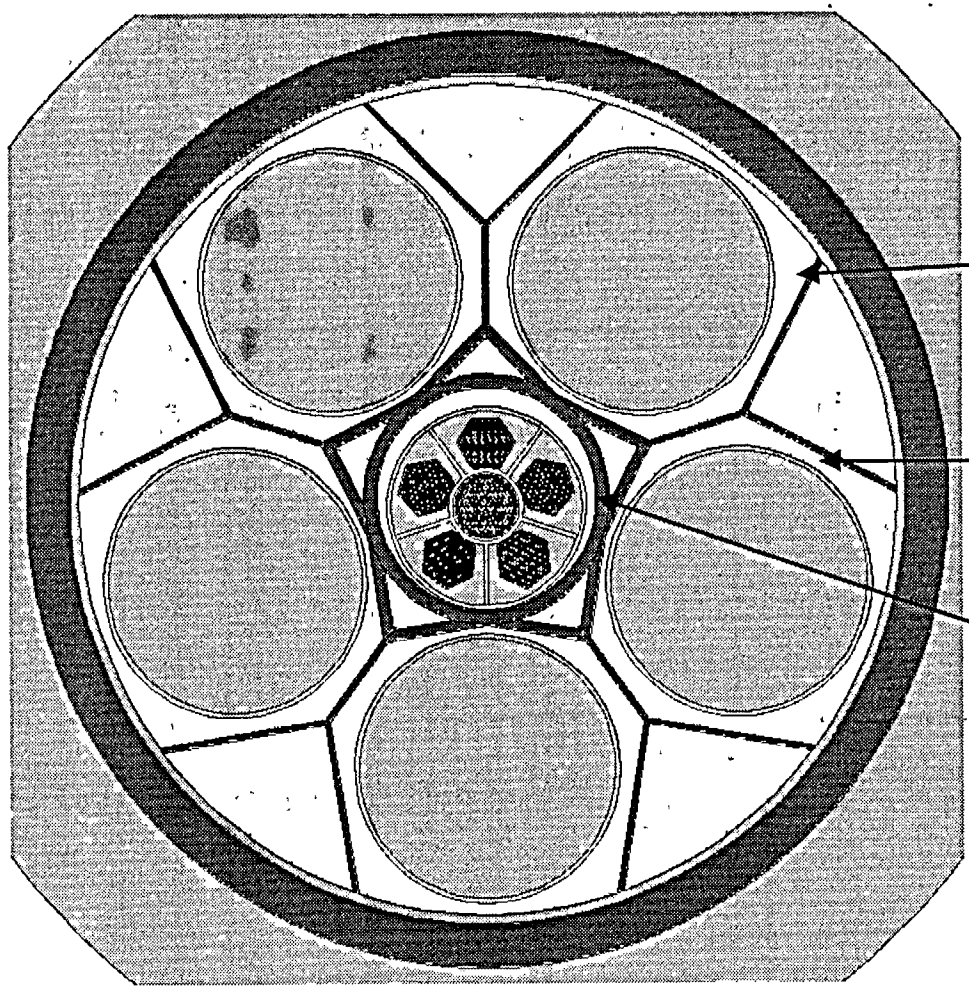
Waste Package Co-Disposal of DOE Spent Nuclear Fuel with High-Level Waste

- Co-disposal (1 SNF and 5 High-Level Waste (HLW)) and Multi-Canister Overpack (2 SNF and 2 HLW) waste packages are same general designs as for rest of waste stream
- Current limits on emplacement inventory, coupled with radionuclide equivalency of HLW, results in last one-third of the SNF canisters having no HLW available for co-disposal
- Disposal of SNF without HLW has minimal effect on repository performance

Co-Disposal Waste Package



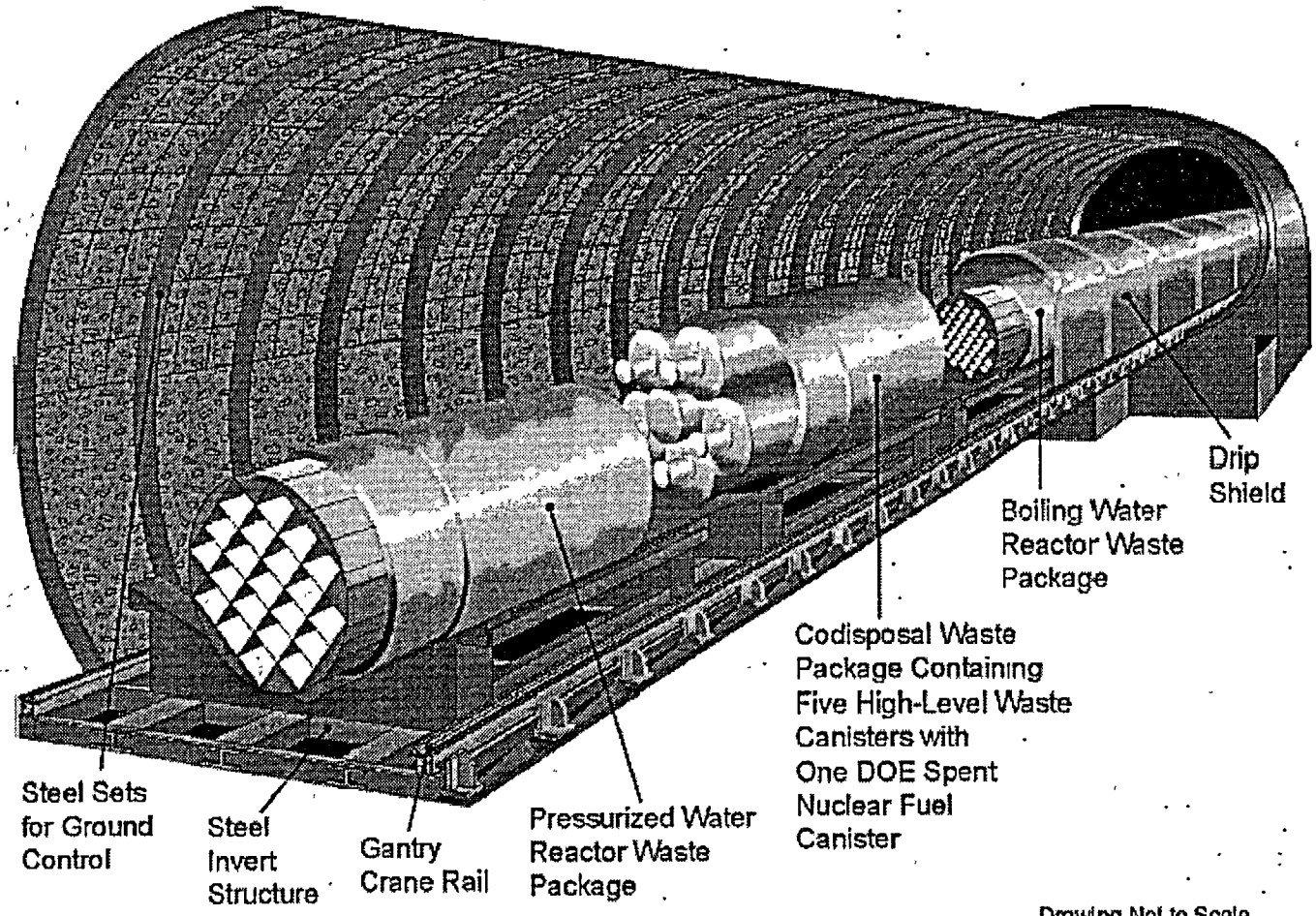
Co-Disposal Waste Package Section



Subsurface Disposal

- Co-disposal waste packages are approximately one-third of the total number of waste packages
- Handling and emplacement are the same as for commercial SNF and other waste packages
- DOE co-disposal waste packages are interspersed with commercial SNF waste packages
- Lower temperatures of co-disposal waste packages are used to lower average temperatures of groups of waste packages, but other means may be used to control temperatures

Waste Package Emplacement



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Summary

- Current DOE baseline assumes most DOE SNF is in standard canisters or multi-canister overpacks
- Current preclosure safety analysis allocates some performance to robust canister
- Results of current assessments may modify degree of use of standard canister
- Preclosure safety analyses would be modified as necessary based upon results of evaluations-prevention and mitigation functions may transfer to facility

OCCURENCE

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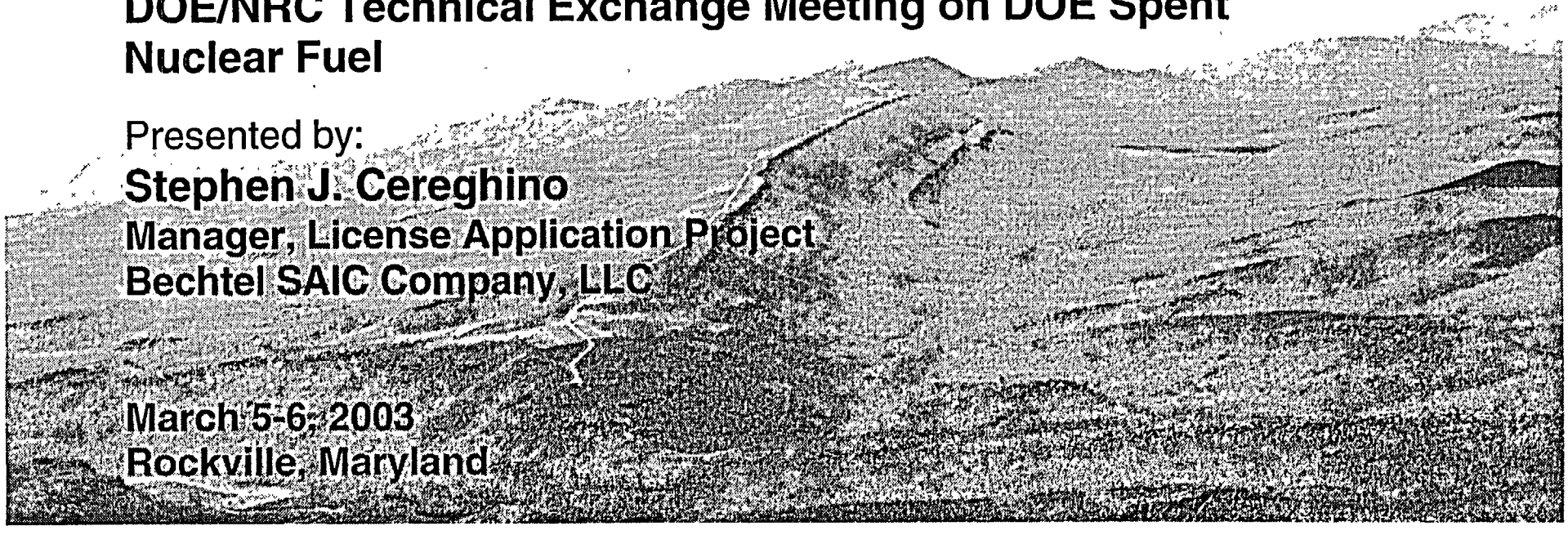
U.S. Department of Energy
Office of Civilian Radioactive Waste Management

Yucca Mountain Project Approach to Control of Criticality and Radionuclide Transport

Presented to:
DOE/NRC Technical Exchange Meeting on DOE Spent Nuclear Fuel



Presented by:
Stephen J. Cereghino
Manager, License Application Project
Bechtel SAIC Company, LLC

March 5-6, 2003
Rockville, Maryland

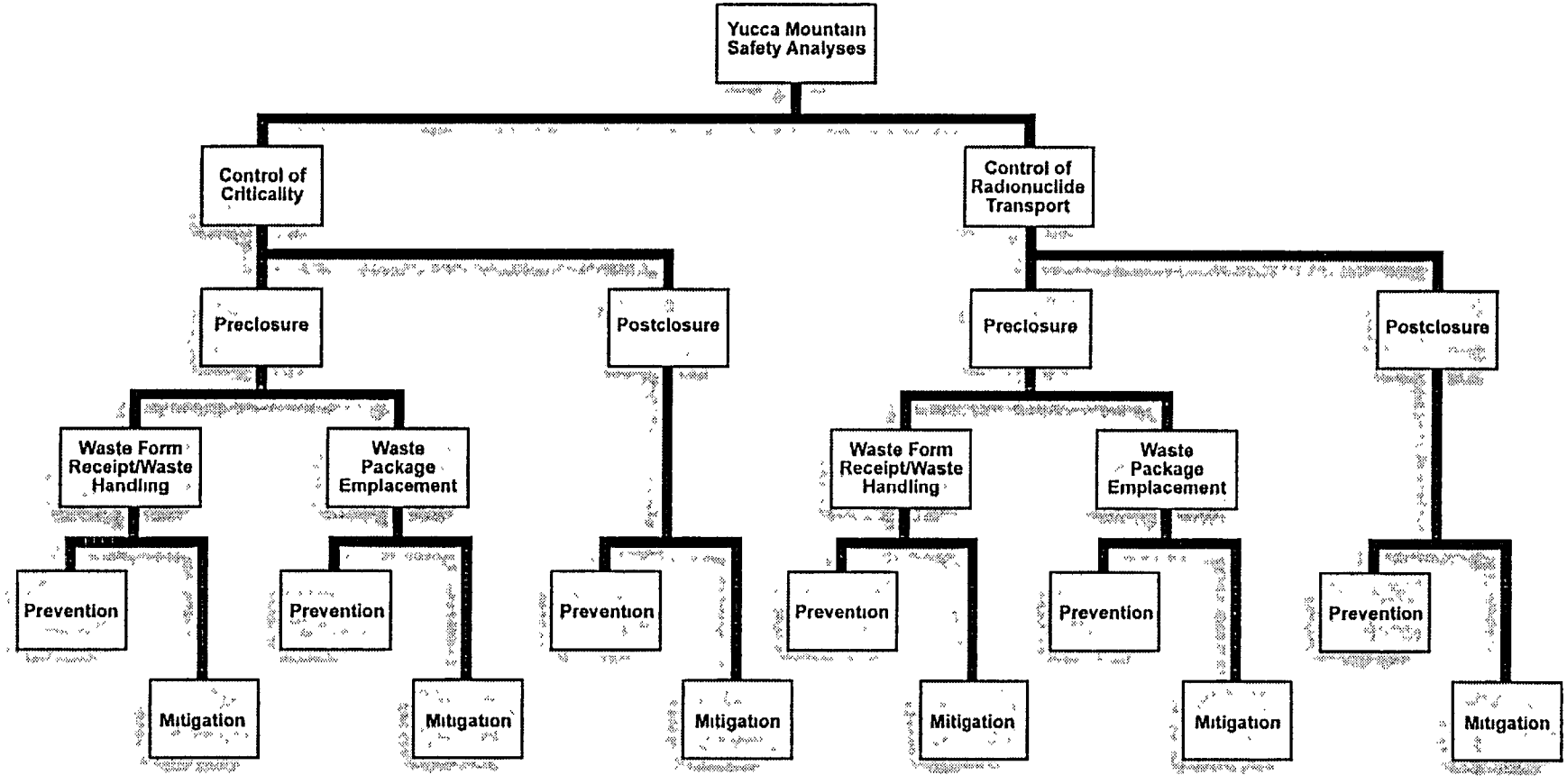
Outline

- Design and Safety Analysis Principles
- General Approach to Control of Criticality and Radionuclide Transport
- Specific Approach for DOE Spent Nuclear Fuel (SNF)
- Confidence Building Evaluations
- Summary

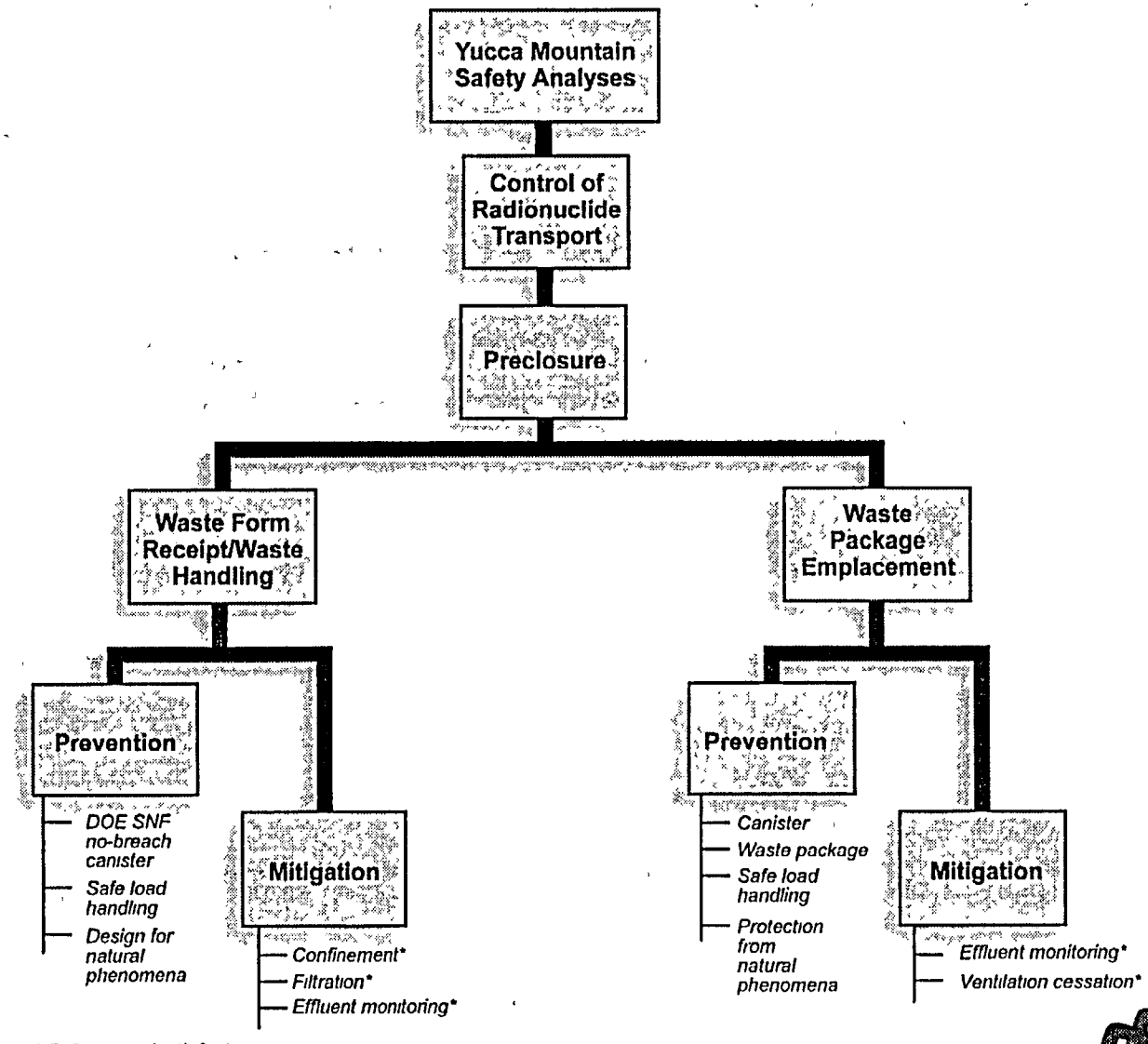
Design and Safety Analysis Principles

- Prevention preferable to mitigation
- Design features preferable to administrative controls
- Passive features preferable to active features
- Automatic initiation preferable to manual initiation
- Redundancy augmented by diversity, when appropriate

General Approach to Control of Criticality and Radionuclide Transport



Control of Radionuclide Transport from DOE Spent Nuclear Fuel During Preclosure Period

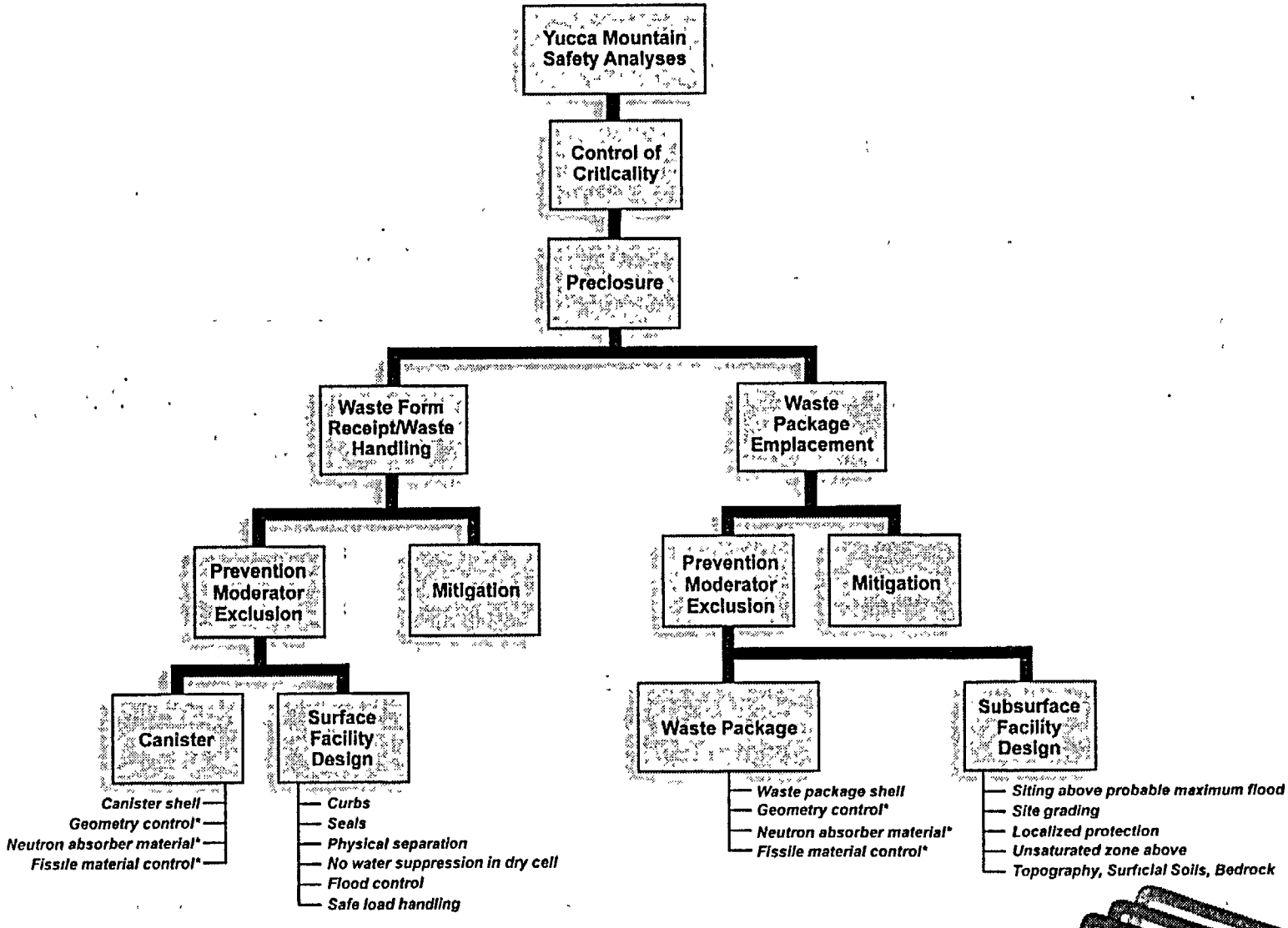


* Defense-in-depth features

Event Sequence Evaluation

- Drop and breach of the DOE SNF canister (i.e., a multi-canister overpack [MCO]) or DOE standardized canister) is a beyond Category 2 (BC2) event sequence due to:
  - DOE standardized canister will be designed and tested to withstand a 23-ft drop
  - MCO, although not specifically designed for a 23-ft drop, will be analyzed and tested for this drop
  - Repository handling systems will not lift a canister more than 23 ft above the floor
  - Defense in depth:
    - Reliable handling systems to minimize drops
    - Energy absorbing considerations

Control of Criticality of DOE Spent Nuclear Fuel During Preclosure Period



* Defense-in-depth features

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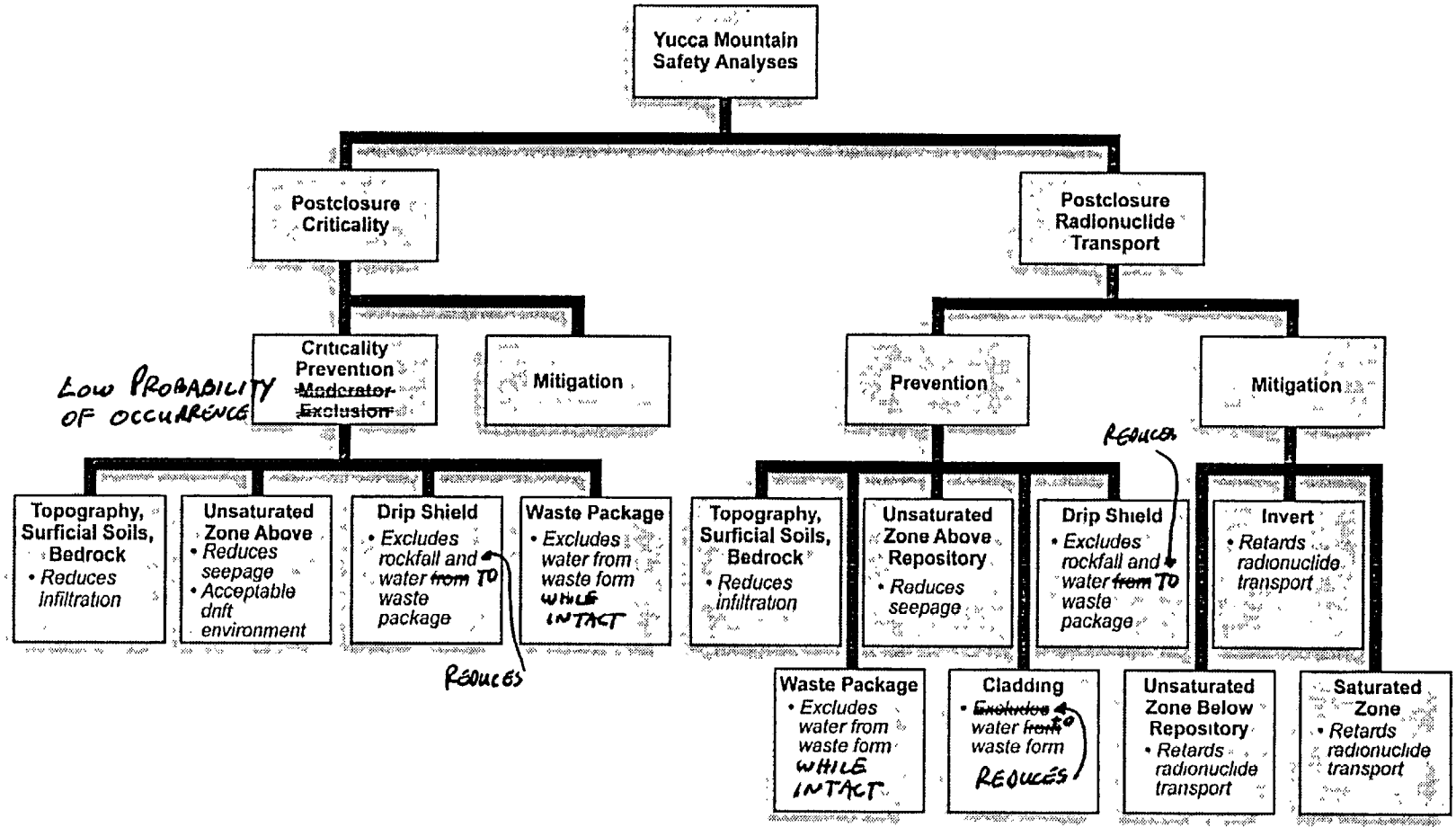
Control of Criticality and Radionuclide Transport from DOE Spent Nuclear Fuel During Postclosure Period



In postclosure performance assessment, DOE SNF treated in a similar fashion to commercial SNF

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Confidence Building Evaluations

- Performance assessment will include sensitivity evaluations to assess impacts of uncertainty of DOE SNF characterization

Summary

- Acceptable preclosure approach to control of criticality events - moderator exclusion
  - Robust canisters
  - Surface/subsurface facility structure, system, and component design prevent introduction of moderator
  - Robust waste packages
- Acceptable preclosure approach to control radionuclide transport
  - Robust canisters
  - Surface/subsurface facility structure, system, and component design prevent breach of canister
  - Robust waste packages

Summary
(Continued)

- For postclosure, DOE SNF is treated in a similar fashion to commercial SNF
  - Acceptable postclosure approach to control criticality - very unlikely event
  - Acceptable postclosure approach to control of radionuclide transport
    - Representative, conservative source term
    - Multiple barriers
    - Impacts assessed for nominal and disruptive scenario classes
- Confidence in analytical models and results
  - Performance assessment sensitivity evaluations

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Office of Civilian Radioactive Waste Management

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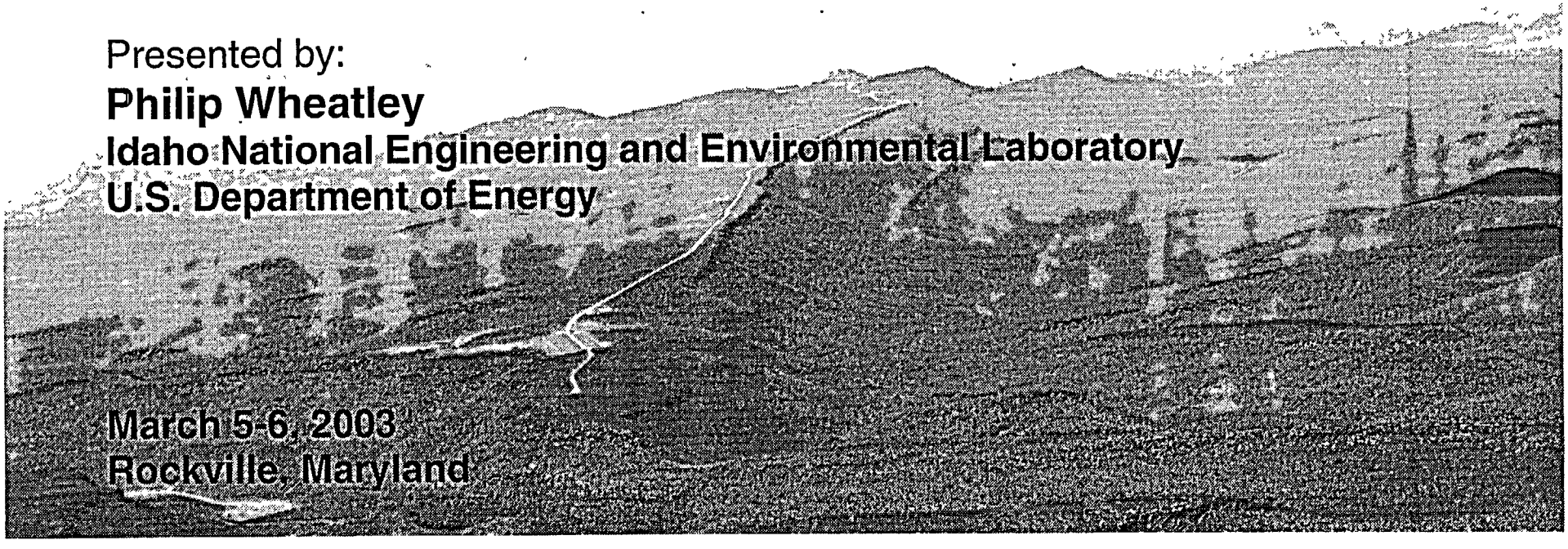
DOE Spent Nuclear Fuel Canisters

Presented to:
DOE/NRC Technical Exchange Meeting on DOE Spent Nuclear Fuel

Presented by:
Philip Wheatley
Idaho National Engineering and Environmental Laboratory
U.S. Department of Energy



March 5-6, 2003
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Outline

- Role of the Canisters in Preclosure Analysis
- Design Considerations
- Canister Design
  - Standardized DOE Spent Nuclear Fuel Canister
  - Multi-Canister Overpack (MCO)
- Qualification Plan
- Implementation of the Qualification Plan
- Canister Deployment
- Summary

Role of Canisters in Preclosure Analysis

- Important to Safety - Structure, System, and Component
- Provides radionuclide containment

Design Considerations

- Robust
  - Satisfies repository performance allocation
  - 23-ft flat bottom drop
  - 2-ft any orientation drop
- Material compatible with contents and waste package
  - Corrosion-resistant materials
  - >40-year design life
- Seal welded
  - Leak test to 1×10^{-4} ref cm^3/s
- Common interface with repository

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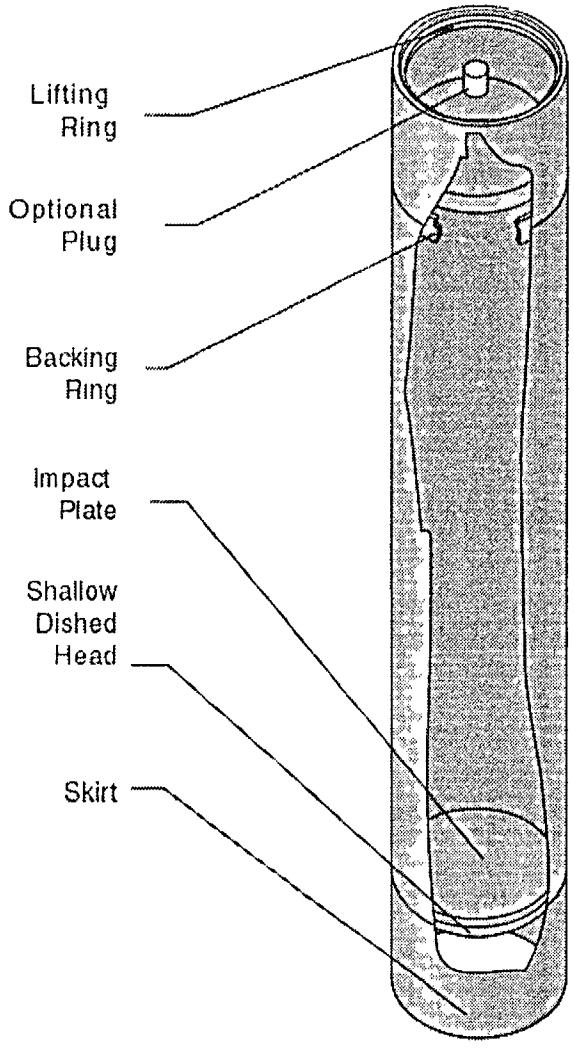
Canister Design

- Apply American Society of Mechanical Engineers Boiler and Pressure Vessel Code Section III
- Code stamp for pressure/containment boundary
- Fabricated with stainless steel (304L and 316L)

Standardized DOE Spent Nuclear Fuel Canister



Nominal Outside Diameters:
18 in. and 24 in.

Wall Thickness:
3/8 in. for 18 in. canister
1/2 in. for 24 in. canister

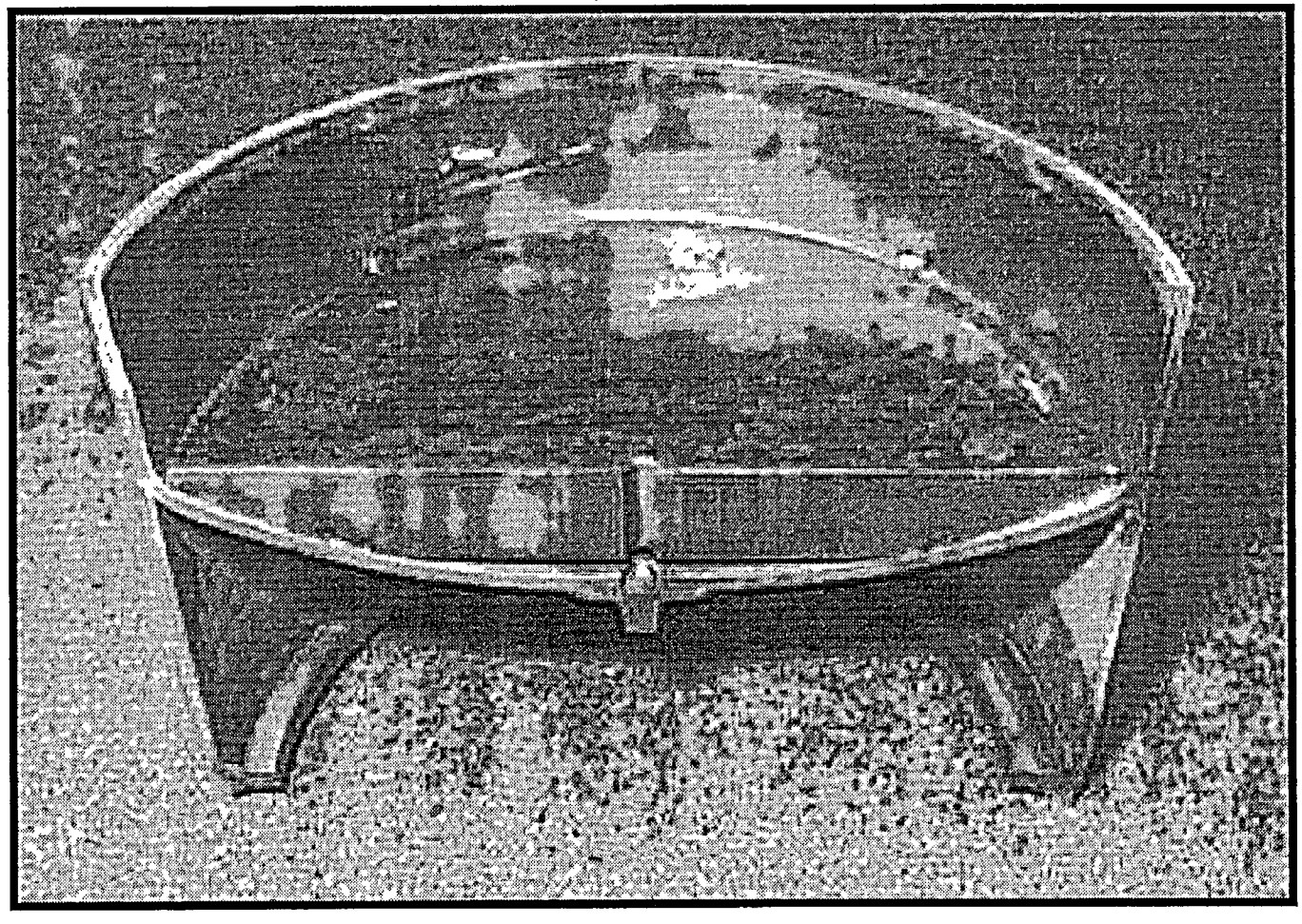
Maximum Weight with Fuel:
5,000 to 10,000 lbs.

External Lengths
Short Canister: 118.11 in.
Long Canister: 179.92 in.

Material:
Canister Body: SS316 L

GT00 0119

Standardized DOE Spent Nuclear Fuel Canister



18-in. Canister Section

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Multi-Canister Overpack

External Length:

165 in.

Outside Diameter:

24 in

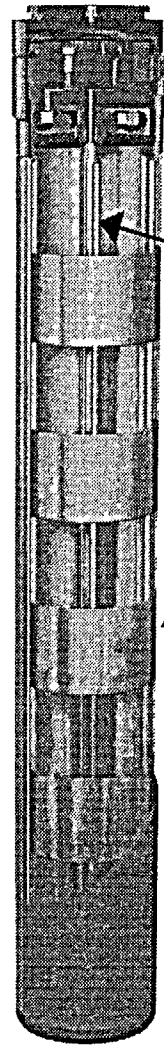
Wall Thickness:

½ in.

Maximum Weight with Fuel:
20,220 lbs

Material:

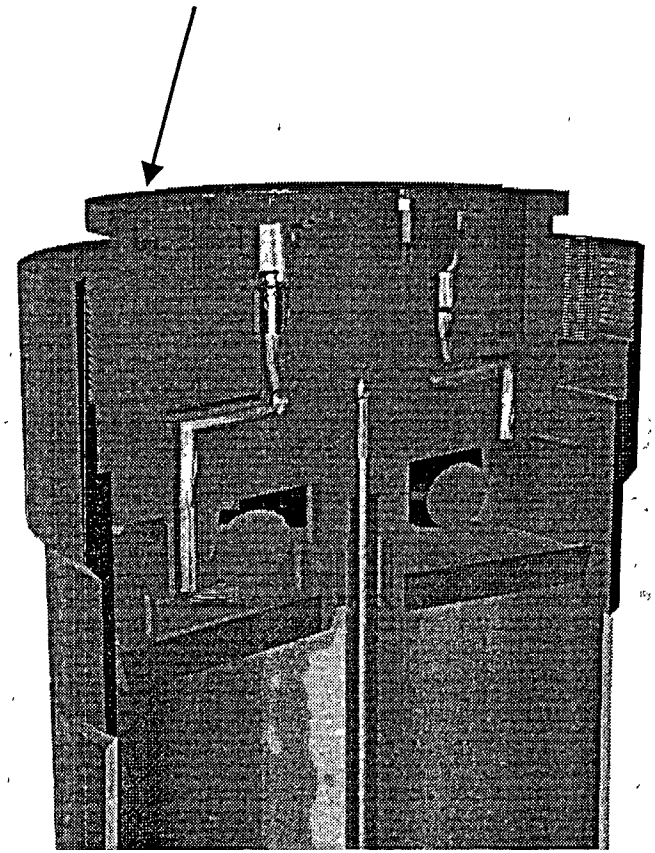
Canister Body SS 304L



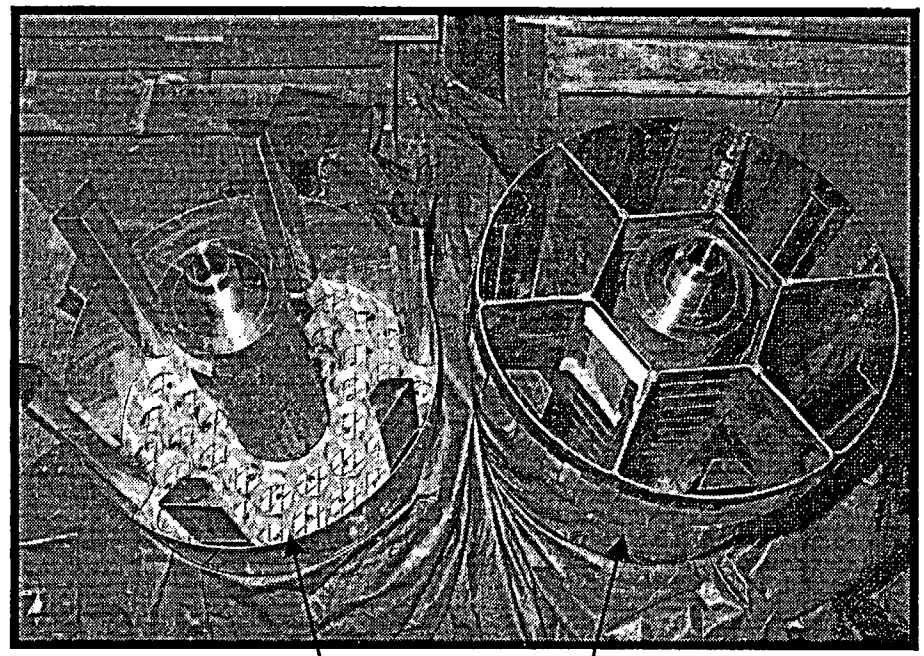
YUCCA MOUNTAIN PROJECT

Multi-Canister Overpack Internals

A final closure cover (not shown) is seal-welded over the head.



Closure head



Fuel and scrap baskets

Qualification Plan

- Model canister using finite element analysis computer program ABAQUS/Explicit
- Applied plastic material behavior with 20 percent increase in the stress-strain curve to account for dynamic strengthening of the material (permitted per American Society of Mechanical Engineers Code)
- Drop test including helium leak testing
- Compare deformation to model predictions

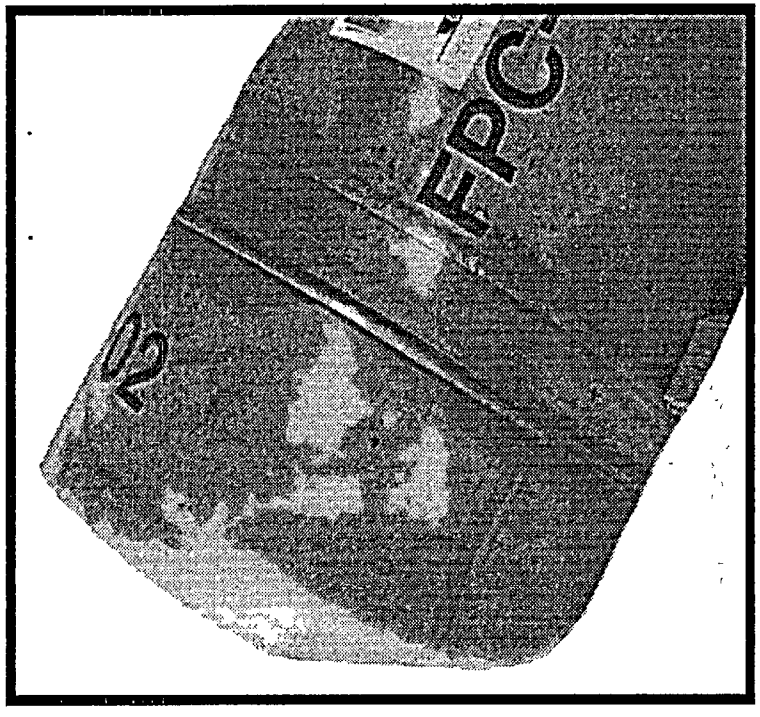
Implementation of the Qualification Plan

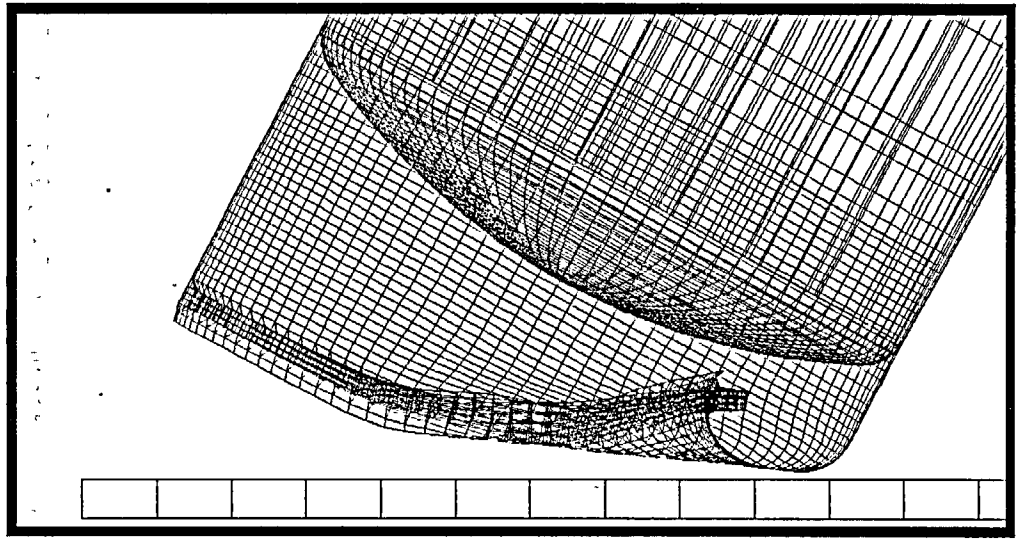
- Successfully completed qualification plan for 18-in. standardized canisters
  - Modeled
  - Proof tested
  - Documented results
- Initiated qualification plan for 24-in. standardized canister and multi-canister overpack

Demonstration of Robustness of DOE Standardized Canister

- Early drop tests performed in 1998 proved design concept
- Full-scale testing of nine canisters in 1999 at Sandia drop test facility
  - Completed eight drop tests
    - Per 10 CFR 71.73(c)
    - 30-ft drop onto an essentially unyielding horizontal surface
    - 40-in. drop onto a 6-in.-diameter bar
  - One test to simulate a drop onto a waste package (or transportation cask) during the loading sequence

Actual Drop Test Match with ABAQUS Explicit Model

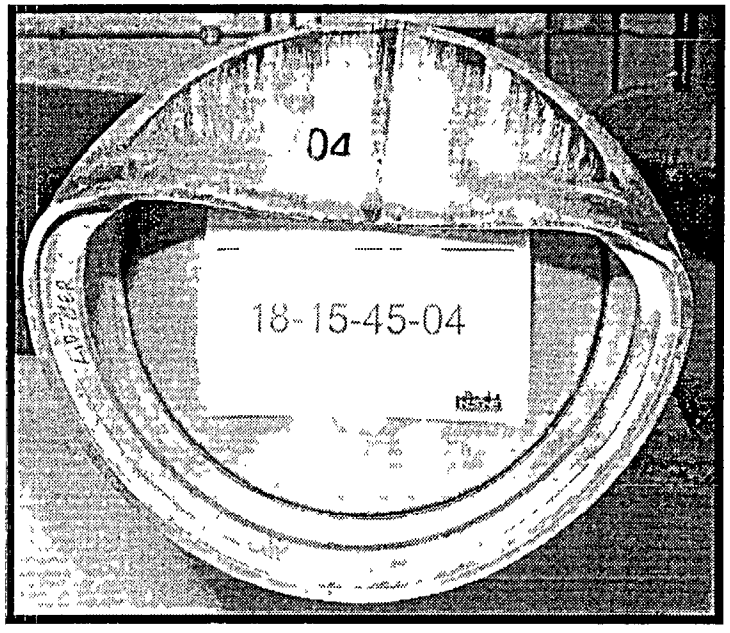


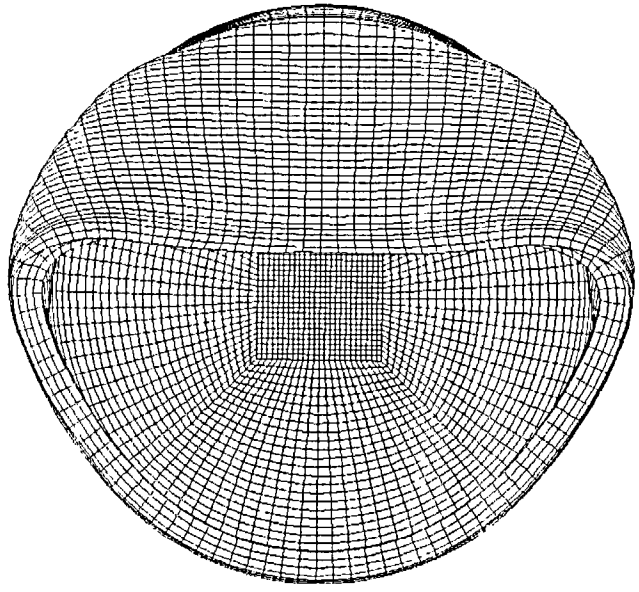


18-in. Canister Results

Actual Drop Test Match with ABAQUS Explicit Model

Impact angle of 45 degrees

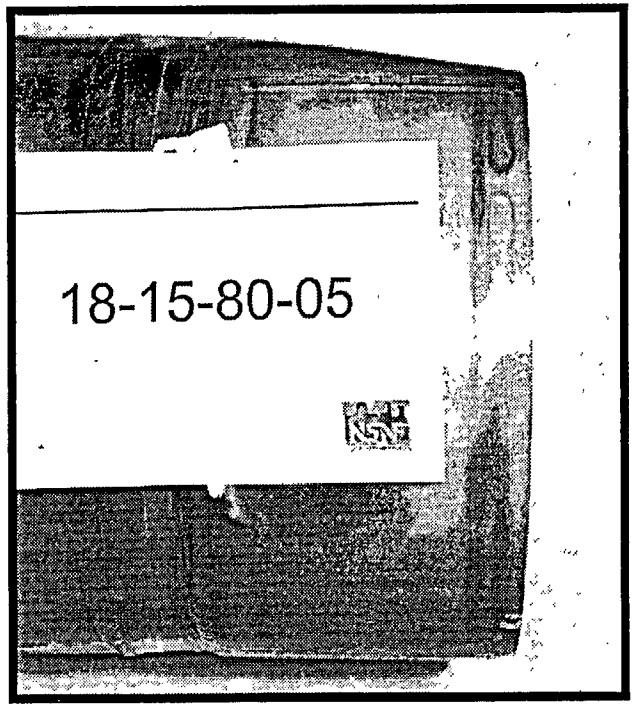


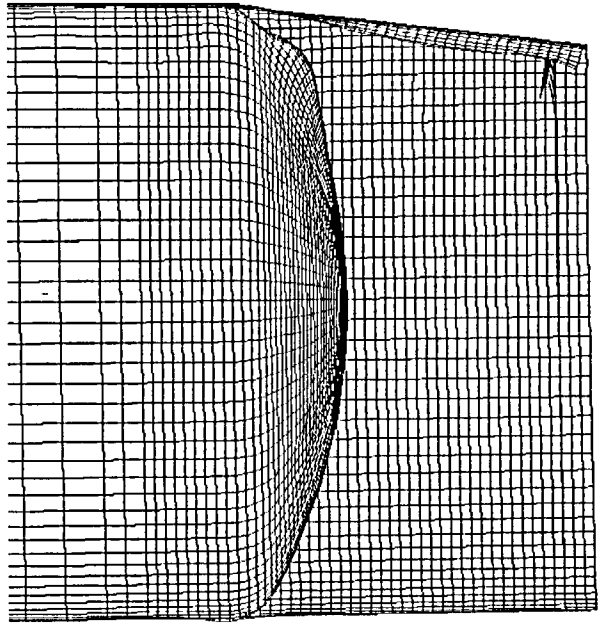


18-in. Canister Results

Actual Drop Test Match with ABAQUS Explicit Model

Impact angle of 80 degrees

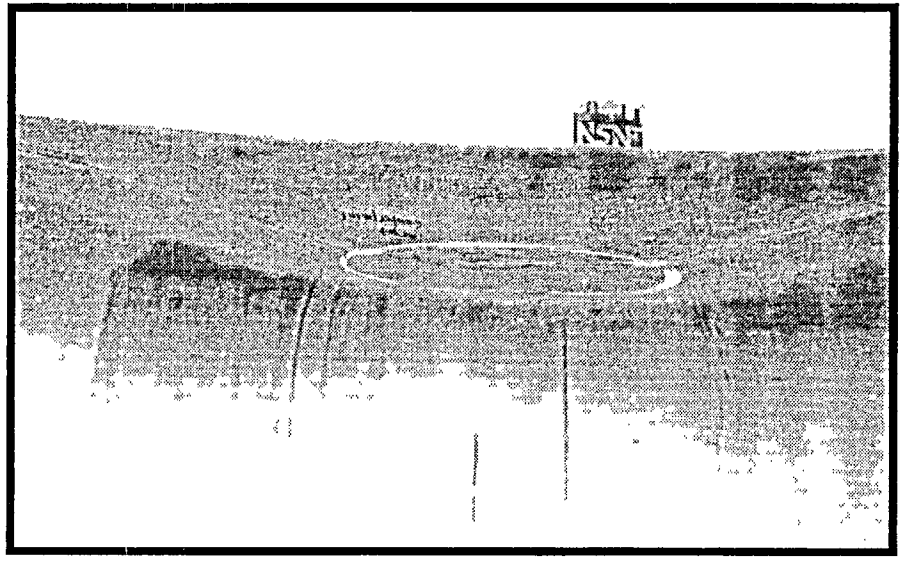


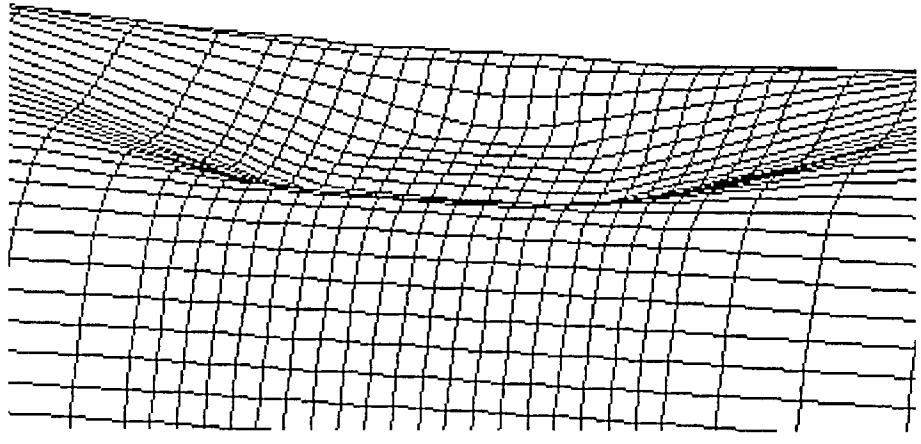


18-in. Canister Results

Actual Drop Test Match with ABAQUS Explicit Model

6-in. puncture bar test





18-in. Canister Results

Drop Test Results

- All standardized DOE Spent Nuclear Fuel canisters passed a pressure test, holding 50 psig air for 1 hour
- Observed no changes in initial weld seam flaws when comparing pre- and post-drop radiographs
- The four most heavily damaged standardized DOE SNF canisters had helium leak rates $<10^{-7}$ ref cm^3/s
- Resulting deformations are acceptable, and computer predictions matched very well
- Identified need to understand the friction parameter response during drop tests

Canister Deployment

- Approximately half of multi-canister overpacks are loaded
- Standardized canister preliminary specification included in contract for Idaho Spent Fuel Facility

Summary

- Canister qualification plan provides confidence in the ability of the DOE canisters to provide containment under design basis conditions
  - Designed to American Society of Mechanical Engineers Section III
  - Analysis
  - Proof testing

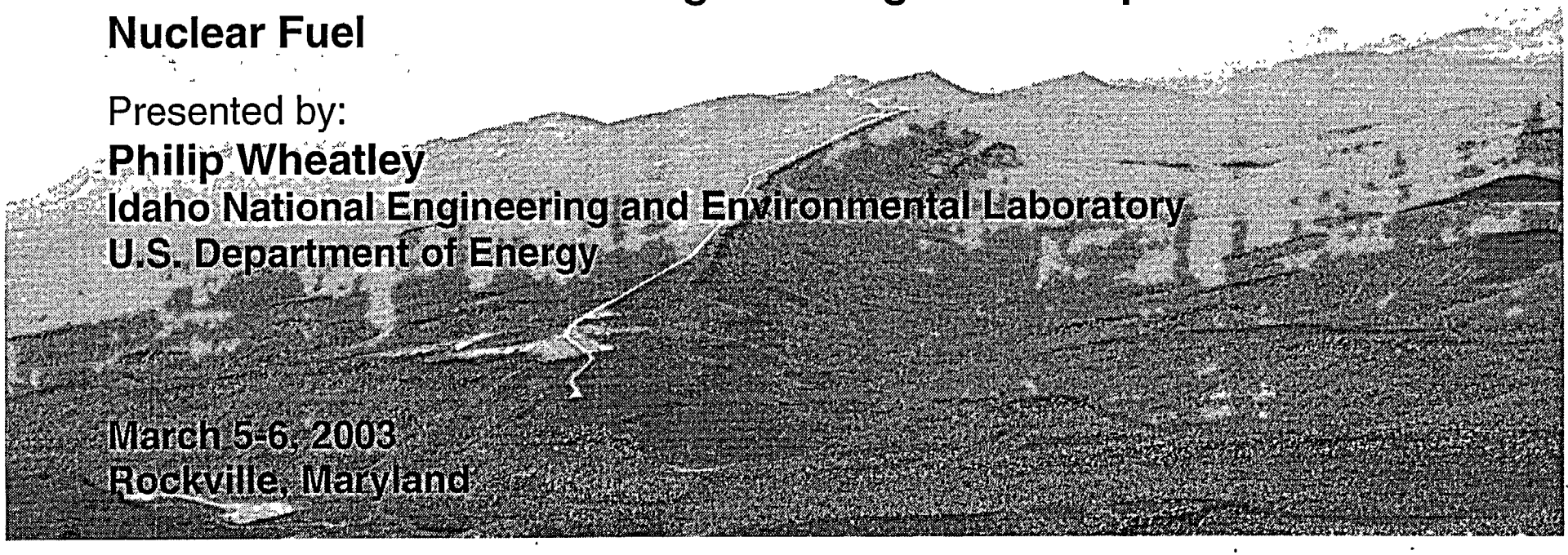
U.S. Department of Energy
Office of Civilian Radioactive Waste Management

YUCCA MOUNTAIN PROJECT

DOE Spent Nuclear Fuel Source Term Development

Presented to:
DOE/NRC Technical Exchange Meeting on DOE Spent Nuclear Fuel

Presented by:
Philip Wheatley
Idaho National Engineering and Environmental Laboratory
U.S. Department of Energy



March 5-6, 2003
Rockville, Maryland

Outline

- Objective
- Applications
- Methodology
- Conservatisms
- Estimated Radionuclide Inventory
- Adequacy for Postclosure
- Summary

Objective

- Develop a consistent and defensible method to estimate radionuclide inventory for all DOE Spent Nuclear Fuel (SNF)
  - Standardize DOE site approaches
  - Utilize existing DOE SNF information
  - Ensure all DOE SNF is represented

Applications

- Support postclosure Total System Performance Assessment-License Application (TSPA-LA) analyses
  - Nominal case
  - Disruptive events
  - Beyond regulatory period

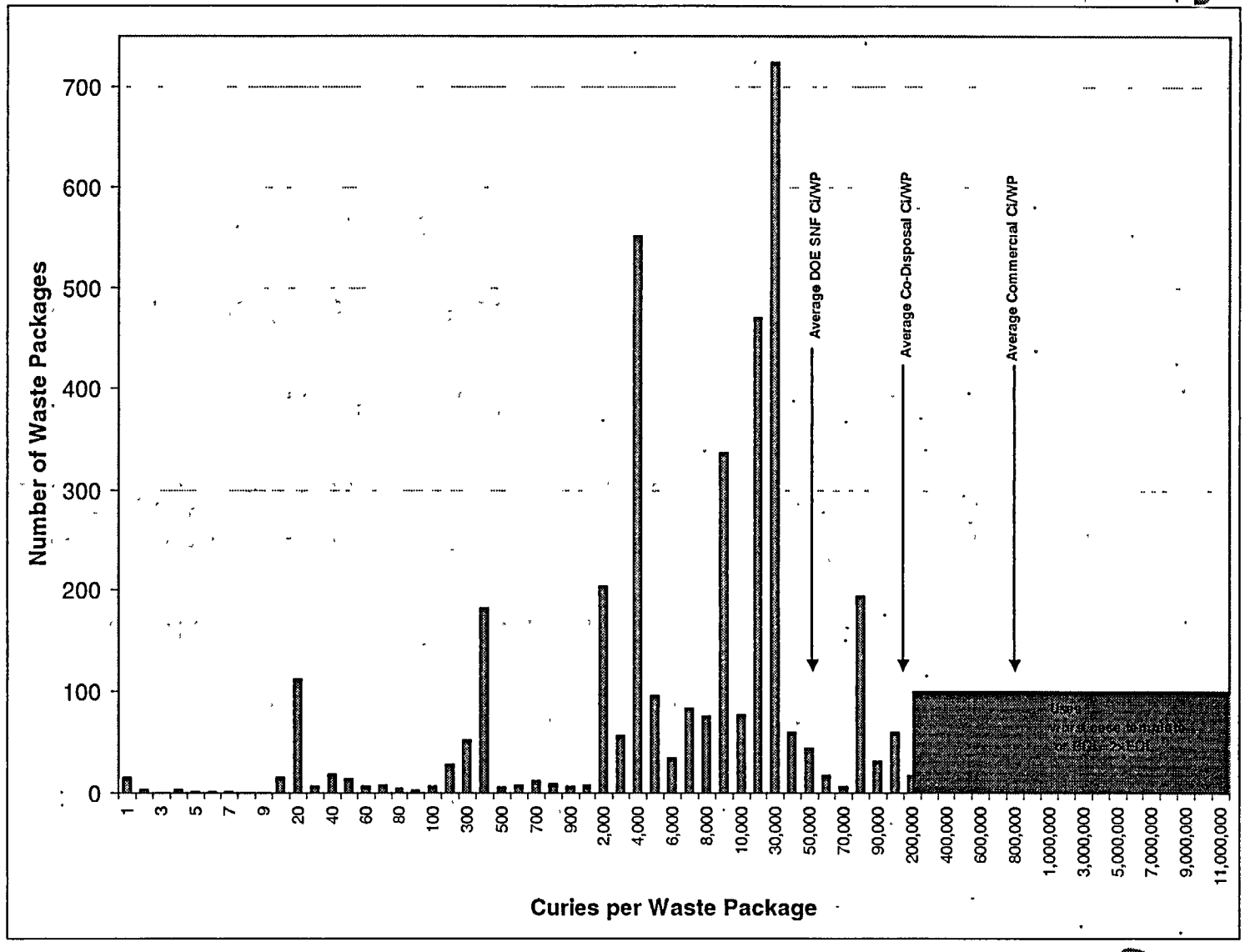
Methodology

- Developed templates for reactor types based on enrichment, moderator, cladding, fuel compound
- Selected appropriate template for each fuel record
- Scaled template inventories based on burn-up
- Added conservatism to account for fuel information uncertainties

Conservatisms

- Scaling of templates produced conservative results
- Selection of template assumed conservative characteristics when unknown
- Composite template developed to bound worst case
- Highest burn-ups were used
  - Burn-ups were cross-checked using independent inputs where possible

Estimated Radionuclide Inventory



Adequacy for Postclosure

- Risk-informed performance-based analyses
  - Use average waste package inventory
  - Large margin of compliance
  - Sensitivity analyses demonstrate minor contribution of DOE SNF inventory to overall performance
- Built-in conservatisms
  - Radionuclide inventories
  - Release rate model

Summary

- Consistent methodology used to conservatively estimate the radionuclide inventories of DOE SNF
- DOE SNF is a small fraction of overall repository radionuclide inventory
- Radionuclide inventory results are appropriate to represent DOE SNF in postclosure analyses

U.S. Department of Energy
Office of Civilian Radioactive Waste Management

YUCCA MOUNTAIN PROJECT

DOE Spent Nuclear Fuel Approach for Postclosure Assessment - (Total System Performance Assessment–License Application)

Presented to:
DOE/NRC Technical Exchange Meeting on DOE Spent Nuclear Fuel

Presented by:
Jerry McNeish
Manager
Total System Performance Assessment Department
Bechtel SAIC Company, LLC

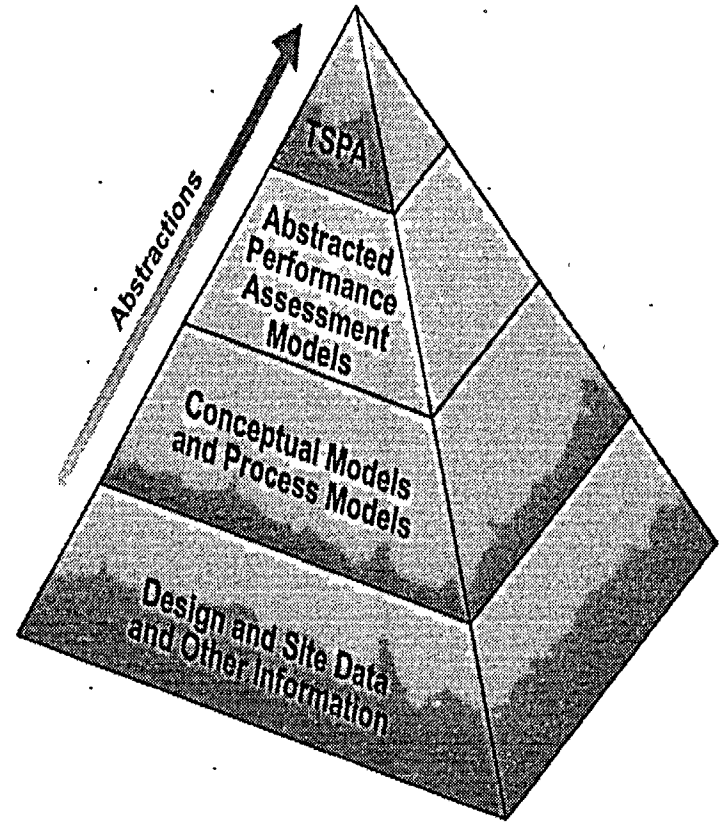
March 5-6, 2003
Rockville, Maryland

Outline

- Introduction to Total System Performance Assessment–License Application (TSPA-LA) Model
- Approach to Include DOE Spent Nuclear Fuel (DOE SNF) in TSPA-LA
- DOE SNF Groups for TSPA-LA
- Summary

Introduction to Total System Performance Assessment–License Application Model

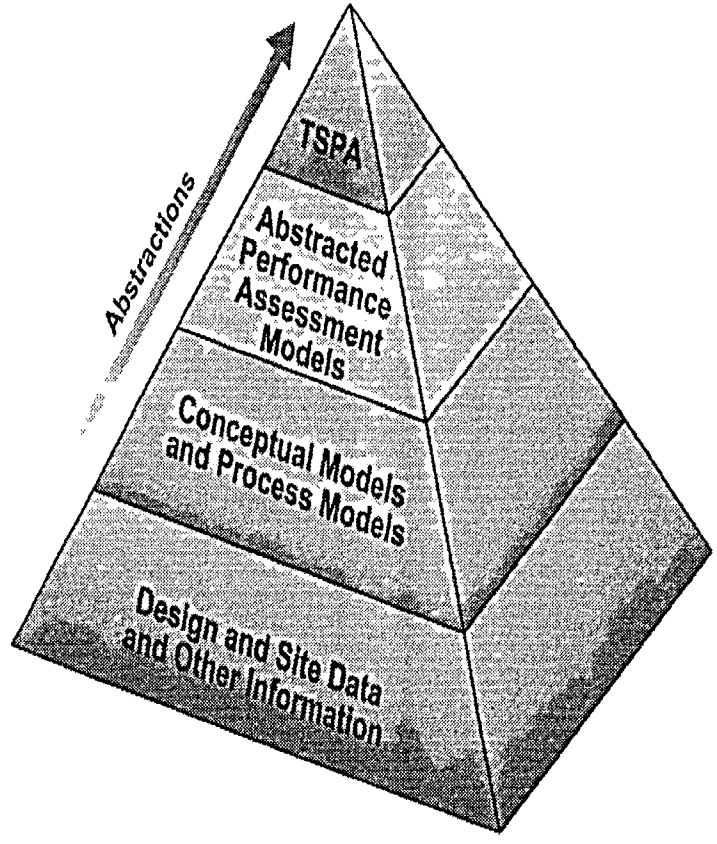
- Similar to TSPA–Site Recommendation model approach
- TSPA pyramid of information: data, process models, abstractions, TSPA model
- Updates/changes in design or models require modification of analysis at appropriate place in the hierarchy
- TSPA model has numerous submodels, many of which are connected to the waste form component



Introduction to Total System Performance Assessment–License Application Model

(Continued)

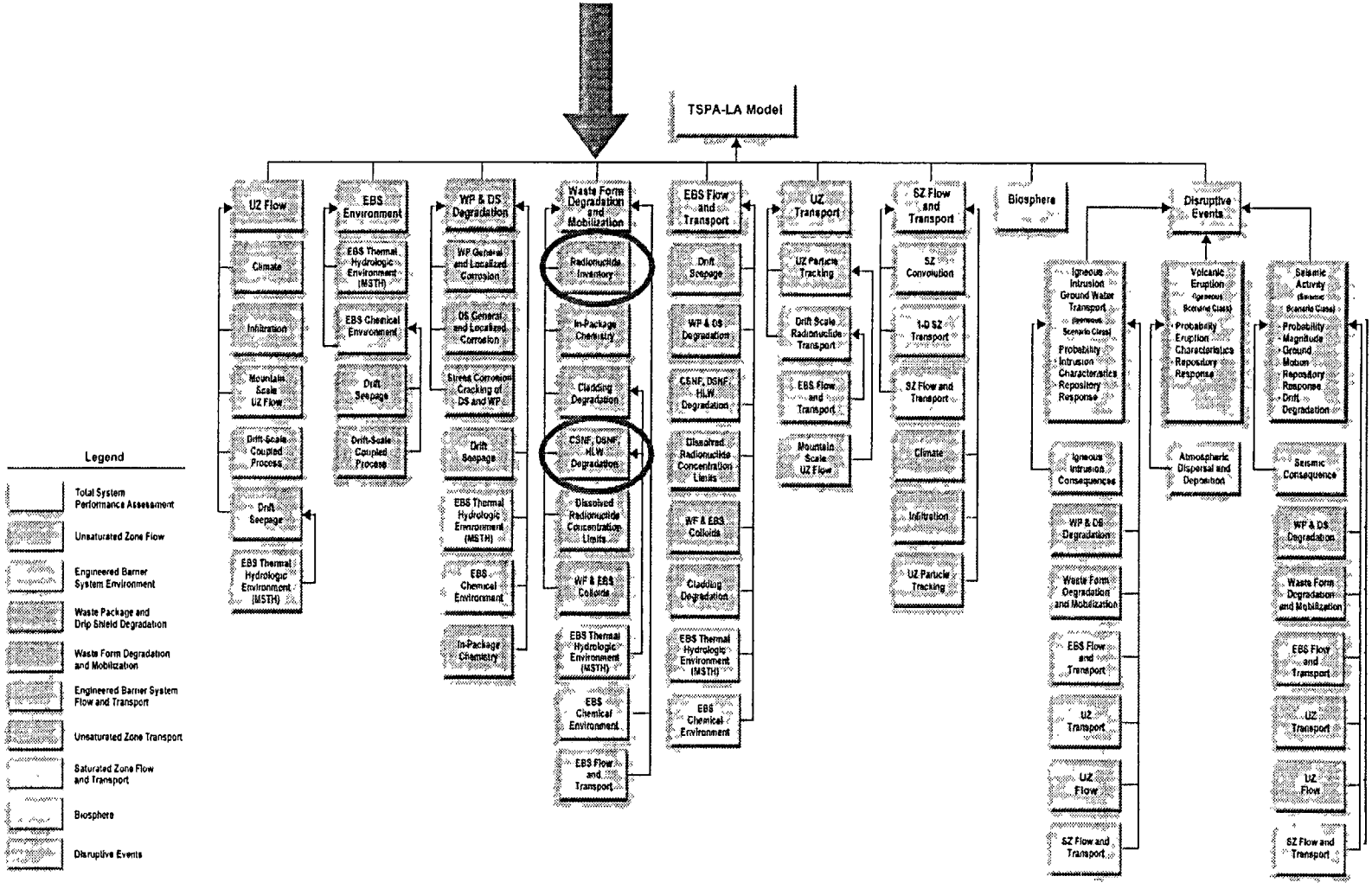
- Analyses will be presented for nominal and disruptive scenario classes for 10,000-year simulations in License Application (LA)
- TSPA-LA model includes multiple barriers (9 barriers) that contribute to prevention and mitigation of radionuclide release and transport



Introduction to Total System Performance Assessment Documentation

- TSPA-LA Model Document - December 2003
  - Software, inputs, assumptions
  - Model components/description
  - Validation/confidence building
- TSPA-LA Technical Document - May 2004
  - Compliance analysis (includes analyses of waste form contribution to dose)
- License Application (Chapter 2) - December 2004
  - Provide support and postclosure analyses to LA

TSPA-LA Model Architecture



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Approach to Include DOE Spent Nuclear Fuel in TSPA–LA

- Disposal of 2,333 metric tons heavy metal (MTHM) of DOE SNF in repository (only 3 percent of total MTHM and 1 out of 3 waste packages)
- Determine the degradation mode and the inventory for the DOE SNF
- Waste Form Degradation
  - 250 types of DOE SNF consolidated into 10 groups based on material properties, plus naval fuel
  - TSPA-LA will assume all DOE SNF (except naval fuel) alters according to N Reactor fuel degradation model (about one time step)
- Inventory (from National Spent Nuclear Fuel Program [NSNFP] 2003)*
  - Uncertainty incorporated into the radionuclide inventories as necessary
  - Develop and implement surrogate waste inventory for the DOE SNF into the TSPA-LA, based on weighted average of the inventories of the 10 groups

*REFERENCE: NSNFP 2003. *Source Term Estimates for DOE Spent Nuclear Fuels.* DOE/SNF/REP-078 Rev. 0.

Abstraction of DOE Spent Nuclear Fuel

250 DOE Spent Nuclear Fuel types

10 DOE SNF groups

TSPA-LA surrogate inventory

Comparison of Radionuclides in DOE Spent Nuclear Fuel, Commercial Spent Nuclear Fuel, and High-Level Waste*

Isotope	Surrogate DOE Spent Fuel (g/waste package)	Commercial Spent Fuel (g/waste package)	High-Level Waste (g/waste package)
^{227}Ac	1.05E-04	3.09E-06	4.36E-04
^{241}Am	7 87E+01	8.76E+03	5.43E+01
^{243}Am	1.68	1.29E+03	1.55
^{14}C	6 63E-01	1.37	7.11E-03
^{137}Cs	5.52E+02	5 34E+03	4.04E+02
^{129}I	8.08E+01	1.80E+03	4.41E+01
^{237}Np	4.26E+02	4.74E+03	1.78E+02
^{231}Pa	3.02E-01	9 87E-03	7.44E-01
^{210}Pb	1 38E-08	0	1.31E-07
^{238}Pu	8.79E+01	1.51E+03	5.69E+01
^{239}Pu	2.13E+03	4.38E+04	3.52E+03
^{240}Pu	4 55E+02	2.09E+04	3.39E+02
^{242}Pb	1.15E+01	5.41E+03	6.25E+00
^{226}Ra	2 21E-06	0	1.52E-05
^{90}Sr	3 01E+02	2.24E+03	2.67E+02
^{99}Tc	4 53E+02	7.68E+03	7.01E+02
^{229}Th	2.46E-02	0	3.79E-03
^{230}Th	1.75E-02	1.84E-01	7.00E-03
^{232}U	1.37E-01	1.01E-02	7.64E-04
^{233}U	1.98E+02	7.00E-02	1.02E+01
^{234}U	2.77E+02	1.83E+03	3.39E+01
^{235}U	1.74E+04	6.28E+04	1.56E+03
^{236}U	5.27E+03	3.92E+04	3.65E+01
^{238}U	4 67E+05	7 92E+06	7.86E+05

*REFERENCE: Duguid et al. 2001. *Performance Assessment of U.S. Department of Energy Spent Fuels in Support of Site Recommendation.* CAL-WIS-PA-000002 Rev. 00. Similar distribution of radionuclides expected in LA analysis.

Approach to Include DOE Spent Nuclear Fuel in TSPA–LA

- Additional comparative analyses (confidence building) to demonstrate reasonable and conservative approach to inventory development
  - Use 10 groups as basis
  - Conduct sensitivity analyses to compare these waste forms with surrogate DOE SNF, as well as commercial SNF
  - Evaluate key radionuclides
  - Use appropriate waste form degradation model for each group (e.g., metallic fuel, ceramic fuel, commercial SNF, etc.)
- TSPA-LA will assume no performance credit for canisters in postclosure analyses

DOE Spent Nuclear Fuel Groups for TSPA-LA

Group	Fuel Type	Typical Fuel	DOE SNF for LA (MTHM)	Percent (of total)
1	Zircaloy Clad Naval	Surface Ship/Submarine Assemblies	65.0	2.60
2	Plutonium/Uranium alloy	Enrico Fermi Reactor core 1 & 2	8.50	0.37
3	Plutonium/Uranium carbide	Fast Flux Test Facility (FFTF) Test Fuel Assembly	0.10	0.00
4	Plutonium/Uranium oxide and Plutonium oxide	Fast Flux Test Facility (FFTF) Driver Fuel Assembly	11.59	0.50
5	Thorium/Uranium carbide	Ft. St. Vrain	24.52	1.05
6	Thorium/Uranium oxide	Shippingport Light Water Breeder Reactor	46.98	2.02
7	Uranium metal	N Reactor	1,984.81	85.23
8	Uranium oxide	Three Mile Island core debris	166.22	7.14
9	Aluminum based fuel	Foreign Research Reactor pin cluster	19.54	0.84
10	Misc. fuel	Miscellaneous	4.24	0.18
11	Uranium-Zirconium hydride	Training, Research, and Isotope General Atomic (TRIGA)	1.51	0.07
TOTAL			2,333.00	100.00

Previous Results of Total System Performance Assessment Analyses of DOE Spent Nuclear Fuel*

- Relatively small portion of total MTHM in repository
- Few waste packages failed in nominal scenario class
- Releases using the DOE SNF surrogate degradation model (N Reactor fuel model) are controlled by solubility limits, not the simulated rapid degradation of the waste form
- Surrogate waste form contributes to lower dose than commercial SNF
- Surrogate waste form dose is similar to the composite dose from each of the 10 DOE SNF groups

*REFERENCE: Duguid et al. 2001. *Performance Assessment of U.S. Department of Energy Spent Fuels in Support of Site Recommendation.* CAL-WIS-PA-000002 Rev. 00.

Summary

- DOE SNF fuel will be evaluated in TSPA-LA
- TSPA-LA approach includes DOE SNF multiple waste forms combined into surrogate inventory, with rapid degradation of the waste form
- Defensibility of surrogate contained in sensitivity analyses of 10 DOE fuel groups, documented in TSPA-LA technical document
- TSPA-LA and supporting documents (NSNFP 2003) will provide justification and comparison for approach
- TSPA-LA analyses expected to produce similar relatively minor contributions of DOE SNF to overall performance due to minor changes in inventory and approach

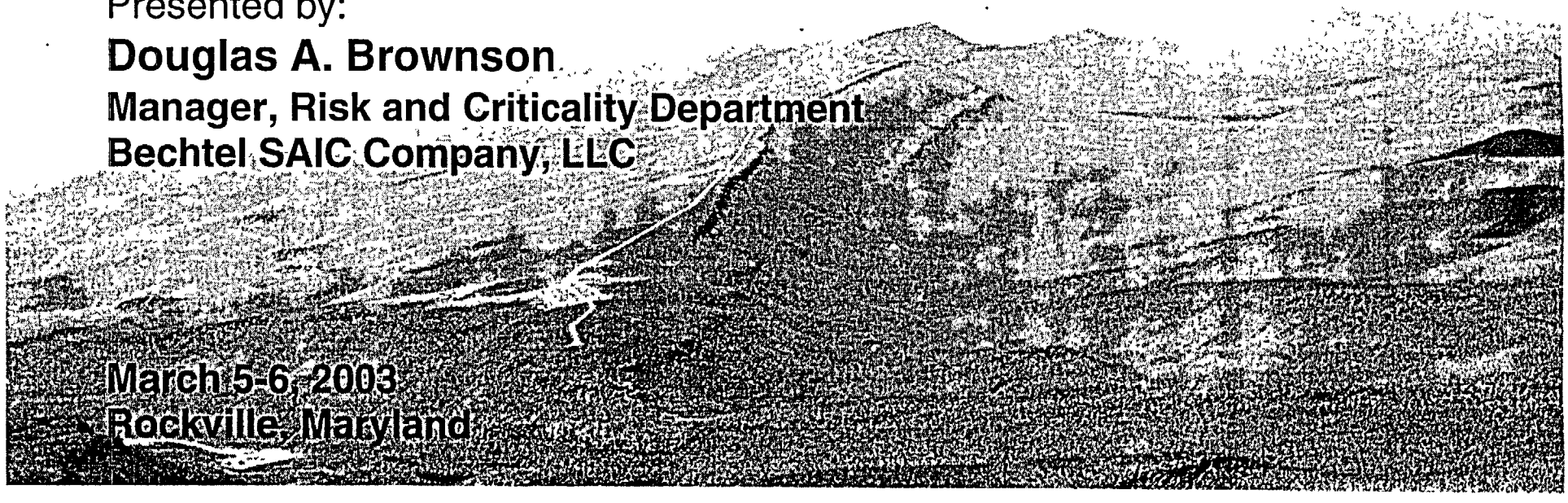
U.S. Department of Energy
Office of Civilian Radioactive Waste Management

YUCCA MOUNTAIN PROJECT

Preclosure Criticality

Presented to:
DOE/NRC Technical Exchange Meeting on DOE Spent Nuclear Fuel

Presented by:
Douglas A. Brownson
Manager, Risk and Criticality Department
Bechtel SAIC Company, LLC



March 5-6, 2003
Rockville, Maryland

Outline

- Preclosure Criticality Approach
- Event Sequence Evaluation Process
- Non-Waste Package Criticality
  - Event Sequences
  - Methodology
- Waste Package Criticality
  - Event Sequences
  - Methodology
- Summary

Preclosure Criticality Approach

- No credible criticality event by design for normal operations, Category 1 event sequences, and Category 2 event sequences

Event Sequence Evaluation Process

- Identify conditions requiring criticality evaluation
  - Normal operations
  - Category 1 and 2 event sequences
- Perform k_{eff} calculation for each operation/event sequence that exceeds probability threshold
- Evaluate design features to prevent and control criticality if k_{eff} exceeds the upper subcritical limit
  - DOE spent nuclear fuel in canisters compared to individual commercial spent nuclear fuel assemblies
  - DOE spent nuclear fuel canister is watertight

Non-Waste Package Event Sequences

- Category 1 and 2 event sequences
- Internal hazards
  - Insertion of moderator or reflector
  - Geometric alteration due to a drop, or tip-over/slap-down
  - Misloading
  - Fire
- External hazards
  - Flooding
  - Seismic event

Non-Waste Package Criticality Methodology

- Use Monte Carlo N-Particle software code to calculate k_{eff} as required
- Determine the most reactive configuration or condition
- Use relevant laboratory critical experiments for fresh fuel to obtain bias for non-waste package issues

Waste Package Event Sequences

- Preclosure waste package criticality event sequences to be potentially evaluated include events related to:
  - Waste package flooding
  - Geometry reconfigurations of waste package internals
  - Waste package misload
- Criticality not of concern if moderator is excluded

Waste Package Criticality Methodology

- Use Monte Carlo N-Particle software code to calculate k_{eff} as required
- Determine the most reactive configuration or condition
- Use relevant laboratory critical experiments and commercial reactor criticals to obtain bias for waste package issues

Summary

- Moderator exclusion during preclosure period will preclude potential for a criticality event either in the surface facility or in the waste package
- Preclosure criticality methodology to be documented in the Preclosure Criticality Analysis Process Report scheduled to be completed and available to the Nuclear Regulatory Commission in third quarter of FY-2003
- Results of preclosure criticality event sequence evaluations to be documented in the Preclosure Safety Assessment to be provided as part of the License Application submittal

U.S. Department of Energy
Office of Civilian Radioactive Waste Management

YUCCA MOUNTAIN PROJECT

Postclosure Criticality

Presented to:
DOE/NRC Technical Exchange Meeting on DOE Spent Nuclear Fuel

Presented by:
Douglas A. Brownson
Manager, Risk and Criticality Department
Bechtel SAIC Company, LLC

March 5-6, Rockville
Rockville, Maryland

Outline

- Postclosure Criticality Methodology
- DOE Spent Nuclear Fuel Groupings
- DOE Spent Nuclear Fuel Waste Packages
- Postclosure Criticality Analysis

Postclosure Criticality Methodology

- Postclosure criticality analysis methodology established in *Disposal Criticality Analysis Methodology Topical Report*, Rev. 1
- The Topical Report covers the evaluation of all waste forms proposed for disposal at Yucca Mountain including DOE Spent Nuclear Fuel (SNF)

DOE Spent Nuclear Fuel Groupings

- 250 Fuel types grouped into 9 representative fuels based on similar neutronic characteristics
  - Fermi
  - Fast Flux Test Facility (FFTF)
  - Fort St. Vrain
  - Melt and Dilute (aluminum-based fuels)
  - N Reactor
  - Shippingport Light Water Breeder Reactor (LWBR)
  - Shippingport Pressurized Water Reactor (PWR)
  - Three Mile Island-2
  - Training, Research, Isotopes, General Atomics (TRIGA)

DOE Spent Nuclear Fuel Waste Packages

- DOE SNF is to be disposed in three canister and waste package types
  - 5-DHLW/DOE SNF Short Waste Package
  - 5-DHLW/DOE SNF Long Waste Package
  - 2-MCO/2-DHLW Long Waste Package

Postclosure Criticality Analysis

- Most reactive state assumption utilized for DOE spent nuclear fuel (i.e., no burn-up credit)
- Expectation to screen criticality from further Total System Performance Assessment analysis based on low probability during regulatory period