Depleted Uranium Dioxide (DUO_2)-Steel Cermet Multipurpose Casks

(Improving Resistance To Assault)

Dr. Charles W. Forsberg

Oak Ridge National Laboratory*
P.O. Box 2008; Oak Ridge, TN 37831-6179
Tel: (865) 574-6783; E-mail: forsbergcw@ornl.gov

DUO_2-Steel Cermet Meetings
Lawrence Livermore National Laboratory
Livermore, California
May 13, 2002

*Managed by UT-Battelle, LLC, for the U.S. Department of Energy under contract DE-AC05-00OR22725. The submitted manuscript has been authored by a contractor of the U.S. Government under contract DE-AC05-00OR22725. Accordingly, the U.S. Government retains a nonexclusive, royalty-free license to publish or reproduce the published form of this contribution, or allow others to do so, for U.S. Government purposes. File name: Multipurpose.Cask.LLNL.II

Outline

- Program Goals
- Meeting Goals
- Multipurpose Cask System Description
- Why Use DUO_2-Steel Cermet Multipurpose Casks?
- Economics
- Cermet Manufacturing
- Viability of DUO_2-steel cermet cask armor
- Conclusions

Depleted Uranium Program Objectives

Identify, develop, assess, and encourage beneficial uses of DU for repository applications

The DU Program Is Investigating A Multipurpose Cask For Storage, Transport, and Disposal of SNF

- Second generation system for phase II of the proposed Yucca Mountain repository
- Cask must meet multiple requirements (shielding, geological disposal, physical protection, etc.)
- Improved cask resistance to assault (post September 11, 2001) is desirable, if it does not conflict with other requirements

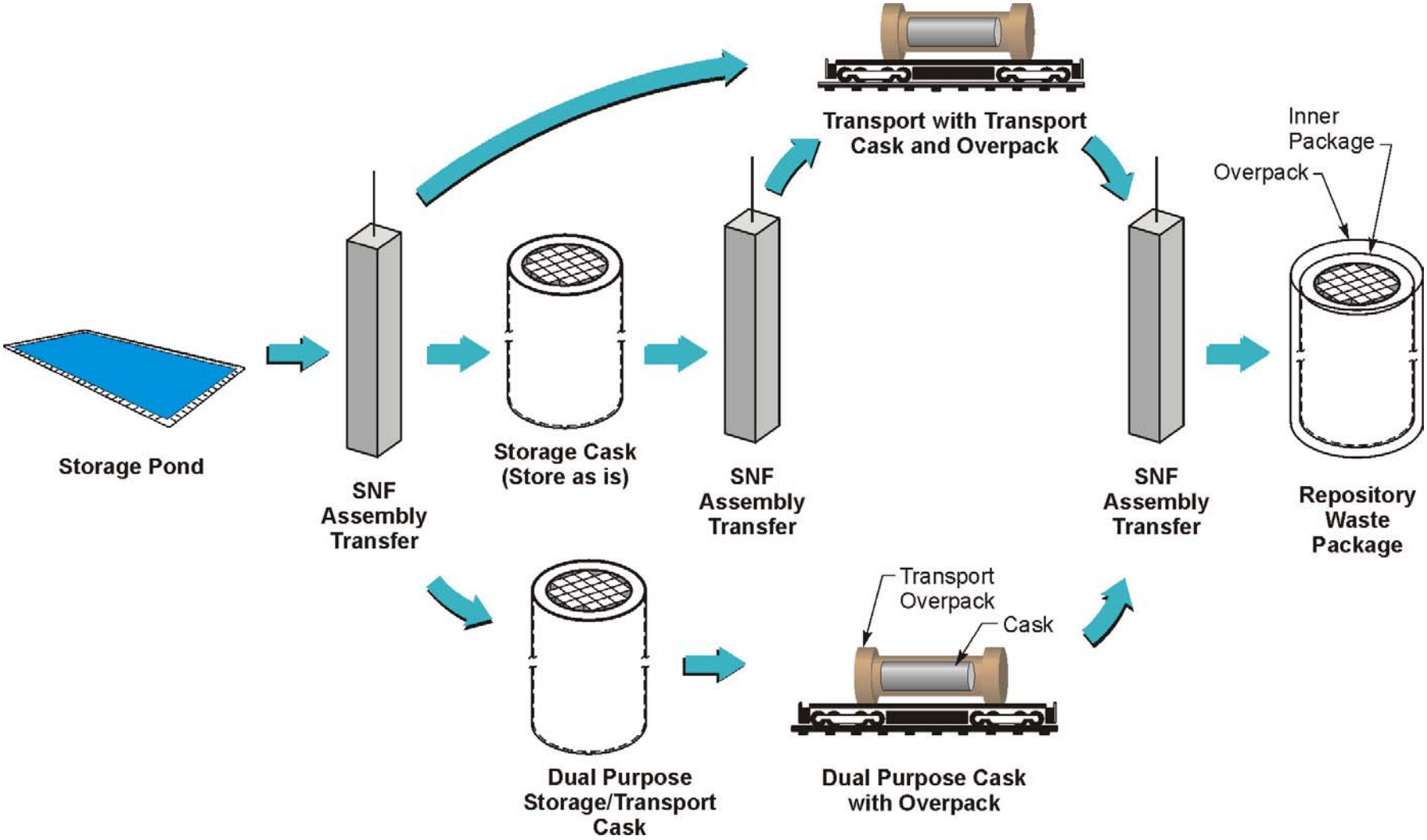
Meeting Goals

Determine if modifications of the proposed cermet cask (without changing materials) has the potential to significantly improve cask resistance to assault

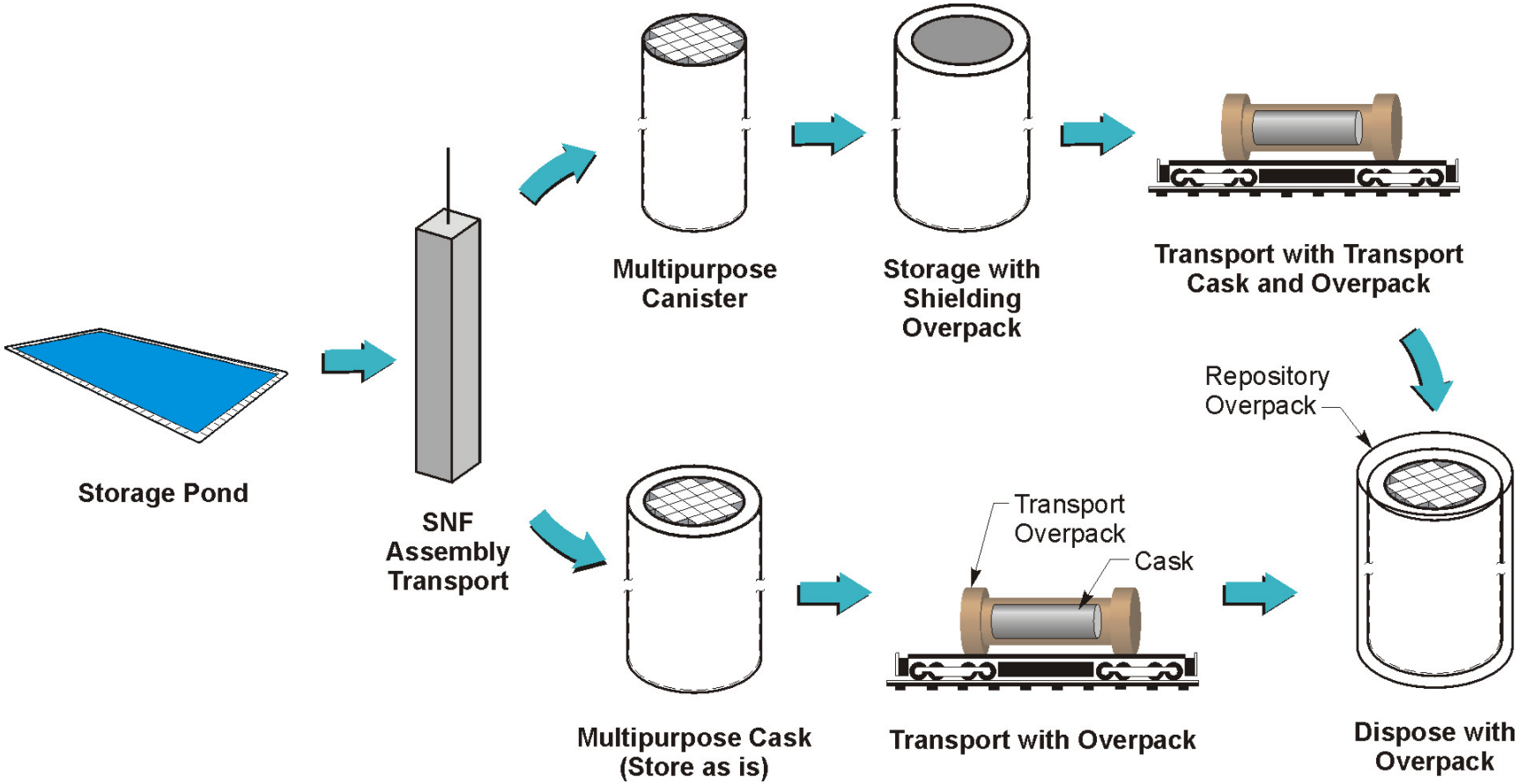
Define a path forward

Description of Proposed Multipurpose Cask System

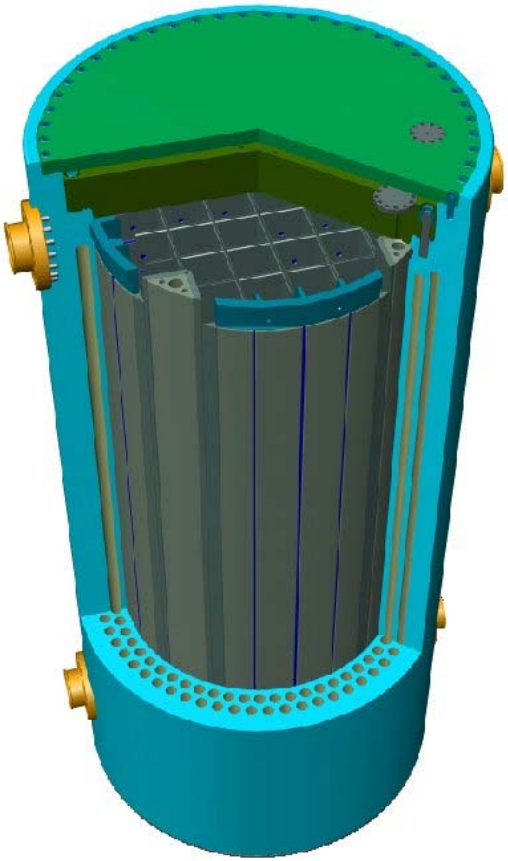
Traditional Approaches to SNF Management



Multipurpose Canister and Cask Approaches to SNF Management Minimize Handling (Potential Lower Costs and Risks)



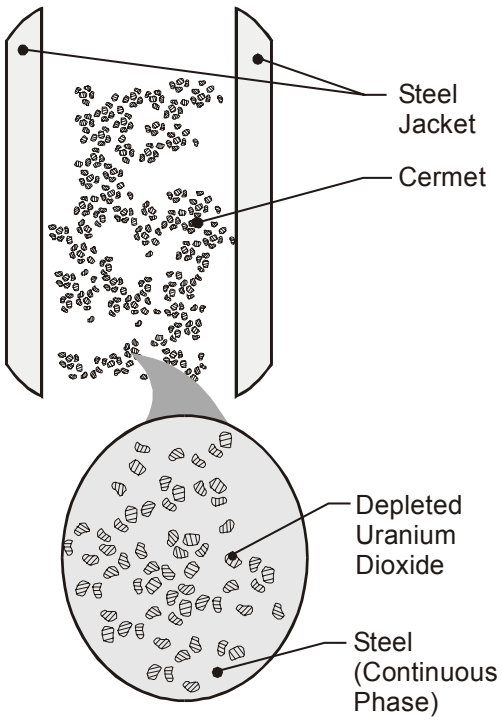
German GNS SNF Storage-Transport Cask (~100 Tons)



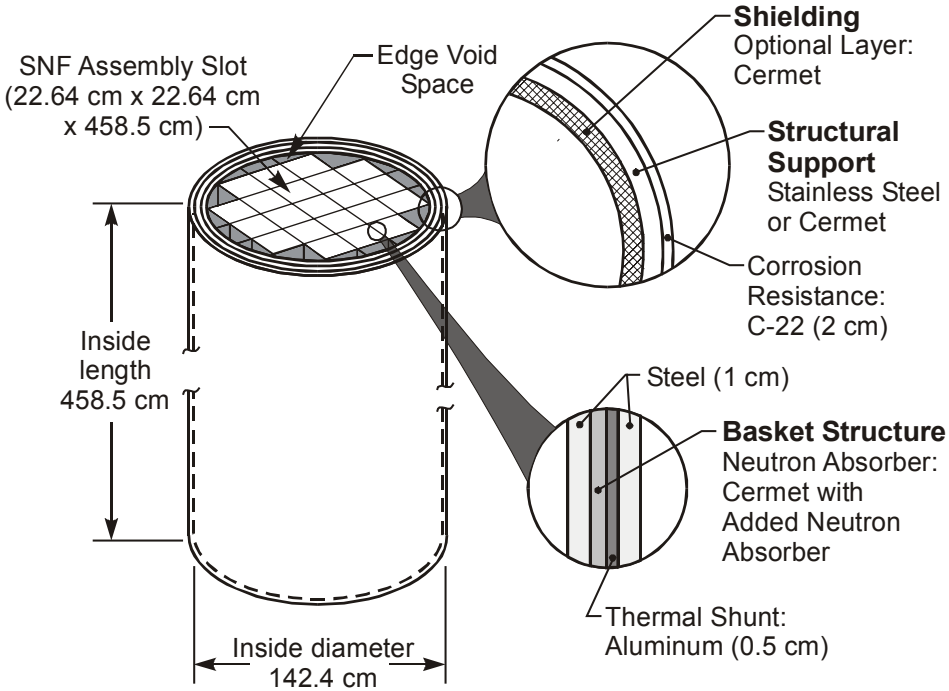
German GNS SNF Storage-Transport Cask On a Rail Car

DUO_2-Steel Multipurpose Cermet Casks Are Candidate Second-Generation Casks

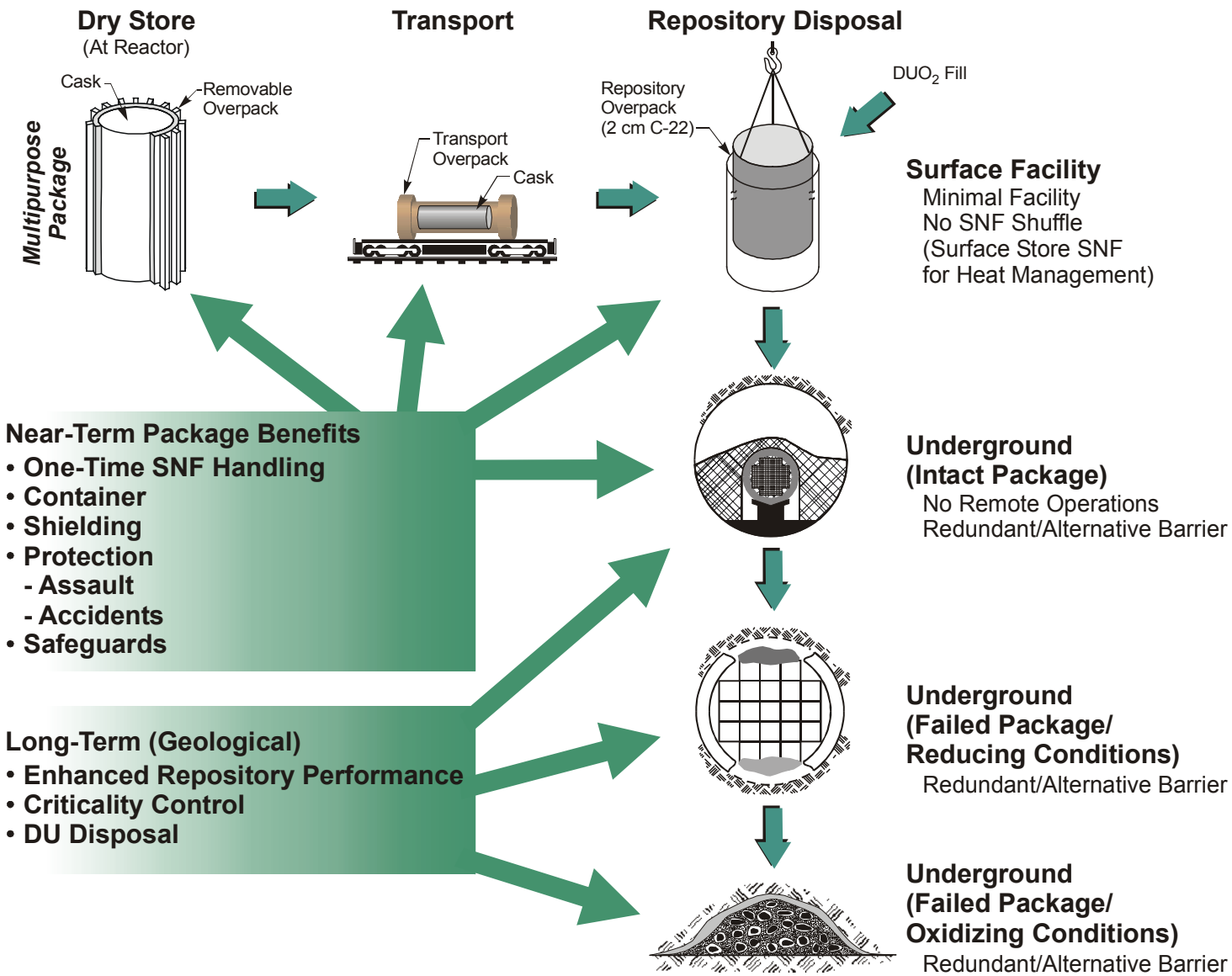
Cermet



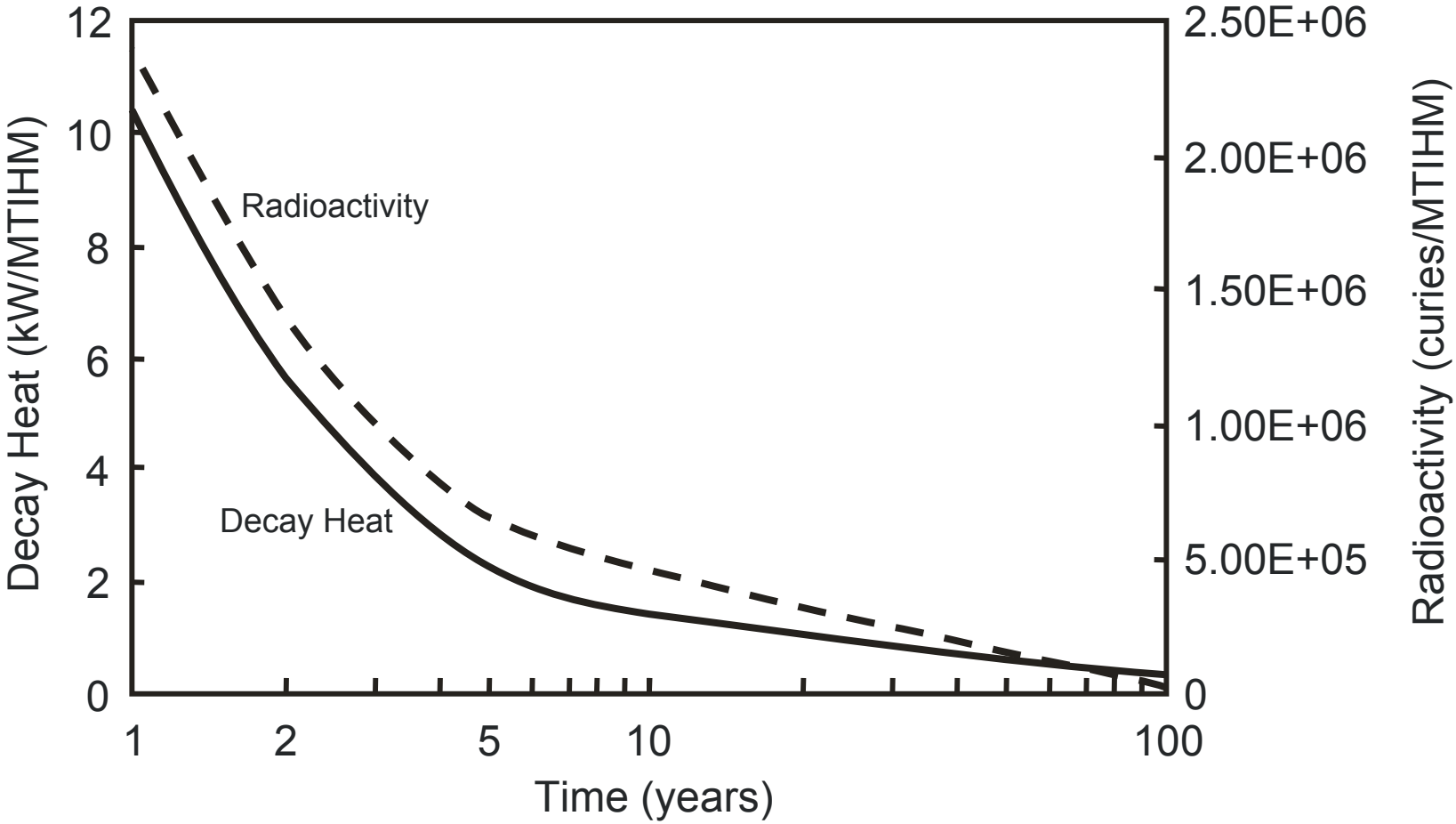
Applications



Repository System Applications And Benefits

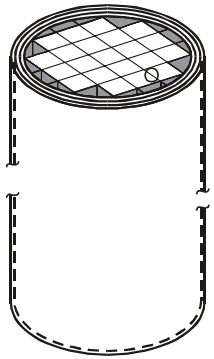


System Issue: Multipurpose Storage, Transport, and Disposal Casks Must Handle SNF with Variable Characteristics



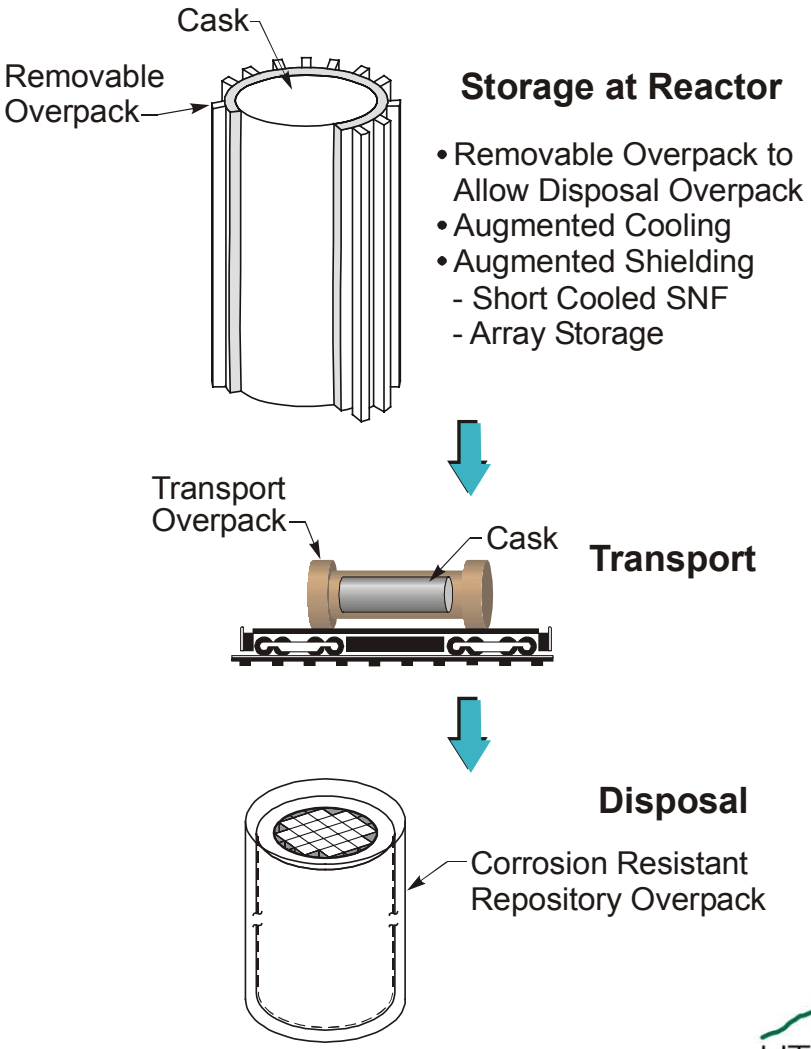
Multipurpose Cask Systems Use Overpacks To Address Variable Requirements

Multipurpose Cask

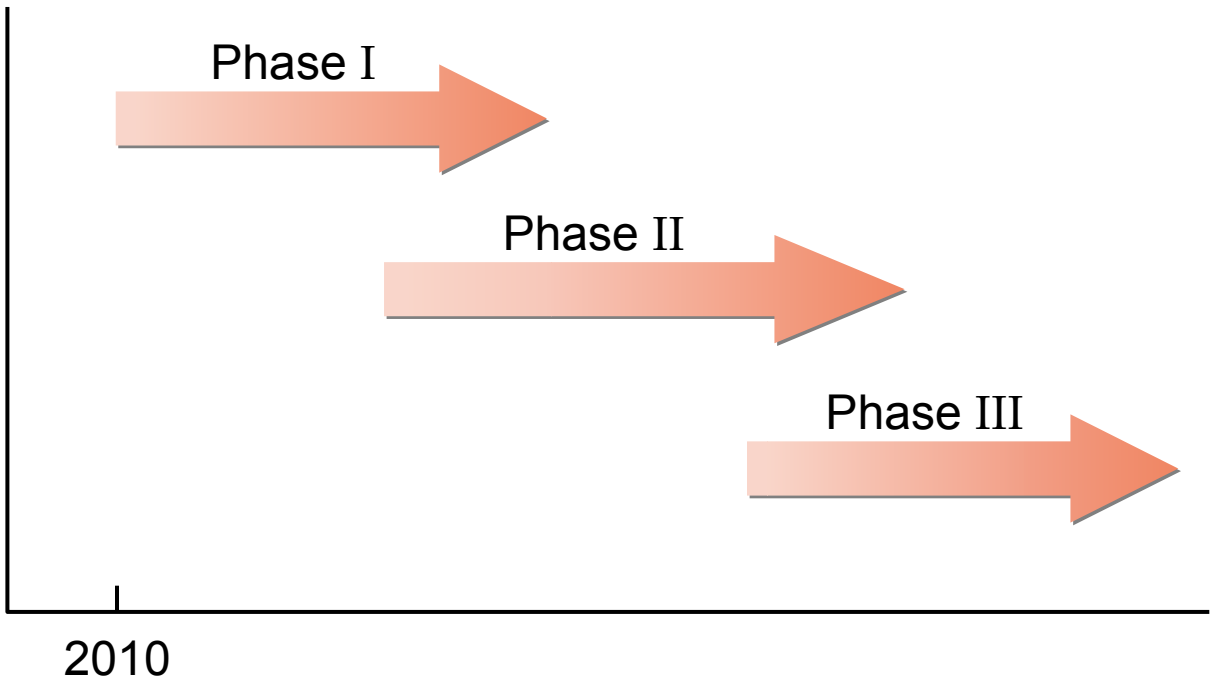


- Radiation Shielding
- Accident/Assault Protection: Multilayer Cermet
- Safeguards and Theft Resistance
- Decay Heat Removal

Multipurpose Cask System



The Repository Will Be Developed in Phases with Multiple Introduction Times for New Technologies



Why Use DUO_2-Steel Cermet Multipurpose Casks?

Disposal of Depleted Uranium

Improved Repository Performance

Improved Multipurpose Cask System Operation

Depleted Uranium Dioxide (DUO_2) Is the Preferred Form of DU

- Applications must be consistent with NRC policies and positions
  - DU oxides acceptable in repository
  - DU metals questionable, fluorides unacceptable
- Applications must be consistent with repository performance goals
  - Avoid materials defined as unacceptable by YMP: concrete, organics, RCRA materials, etc.
  - Use acceptable materials (ideally, materials that are used in the existing repository design): UO_2, Steel

Disposal Of Depleted Uranium

The United States Has More Than 600,000 Tons of Excess DU

Repository Use Has Major Advantages As DU Disposal Option

- Repository options may consume the existing and future inventory
- Use/disposal option is acceptable
  - Meets NRC/EPA requirements (deep disposal)
    - Radioactivity: ~300 nCi/g
    - Chemical hazard: heavy metal
  - Meets YMP performance requirements
- Strategic disposal option (SNF and DU co-located if required by future generations)

Improve Repository Performance

Reduced radionuclide release

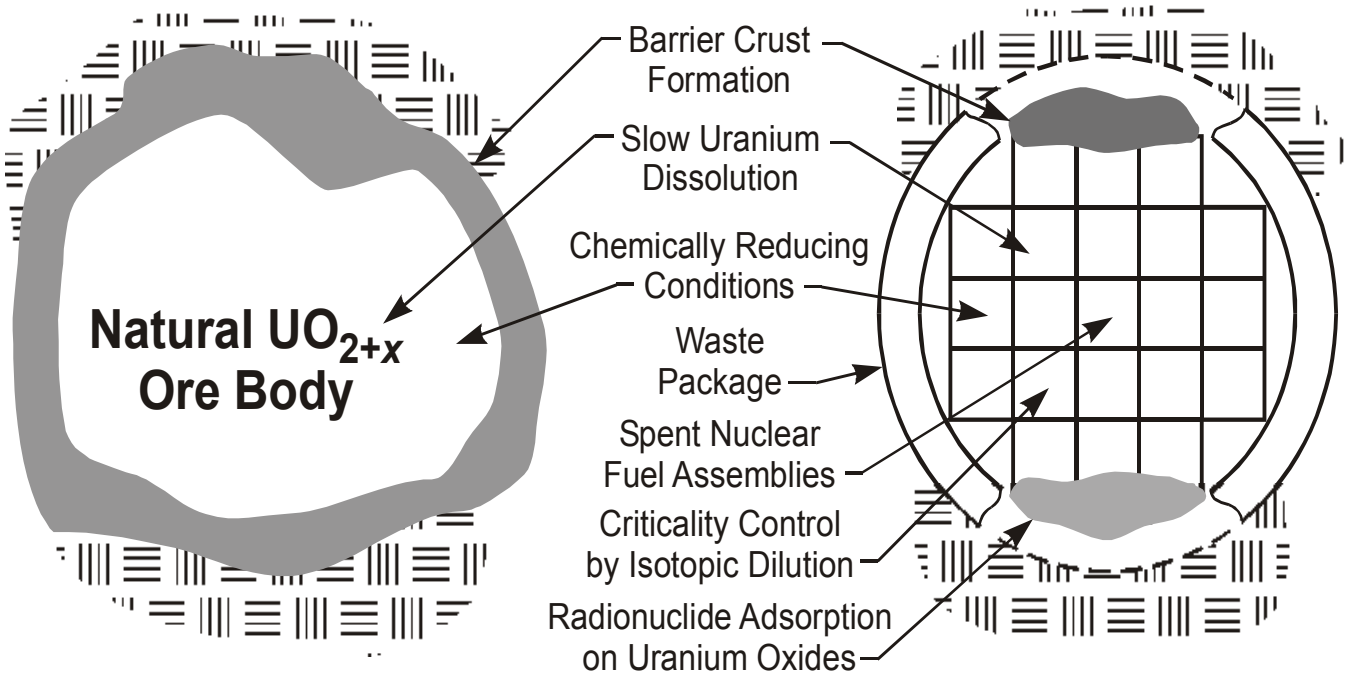
Criticality control

Addition of DUO_2 To The Waste Package May Improve Repository Performance

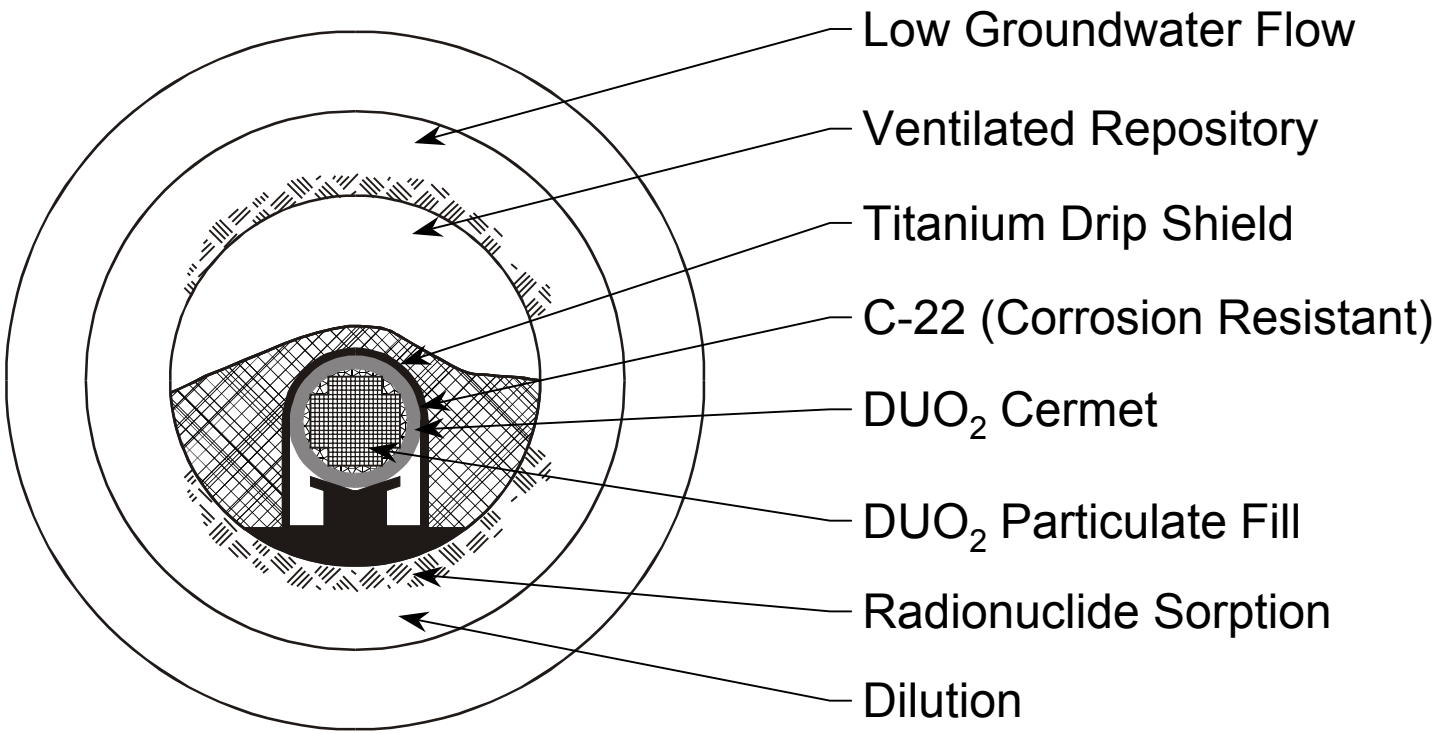
- DUO_2 acts as a sacrificial material to delay
  - DUO_2 alone has the same chemical form as UO_2 in SNF
  - Protection under all geochemical conditions
  - Multiple complex chemical benefits
- Assists long-term criticality control by isotopic dilution of fissile uranium isotopes (Navy and DOE high-enriched SNF)

Some Uranium Ore Deposits Have Remained Intact for Millions of Years: The Same Mechanisms Should Protect SNF in Failed WPs Containing DUO_2

(DUO_2 Is The Only Sacrificial Compound to Preserve SNF UO_2 Under All Conditions)



The DUO_2 Is an Independent Barrier to Radionuclide Release That Operates Sequentially with Other Barriers



Improved Multipurpose Cask System

Incentives For Use of Multipurpose Casks

Incentives For *Cermet* Multipurpose Casks

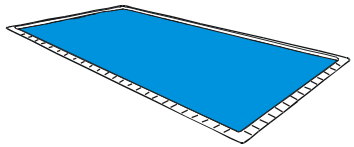
(Excluding Repository Benefits)

Changing Conditions May Change The SNF Management System In The United States

- Current system
  - Store SNF in pools
  - Transport using transport cask
  - Unshielded waste packages in the repository
- Proposed system: shielded multipurpose cask for storage, transport, and disposal

Incentives: Terrorist Events May Result in Adoption Of a Modified German Multipurpose SNF Cask System By the United States

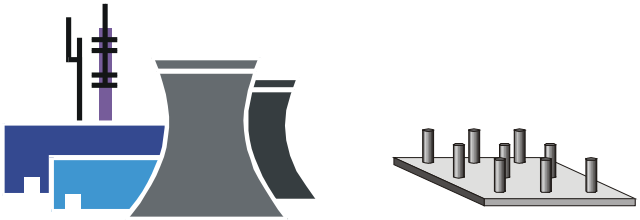
United States



Storage Pond

- Aircraft/assault not credible
- Pool storage outside containment
- Low SNF handling cost
- Some dry storage

Germany



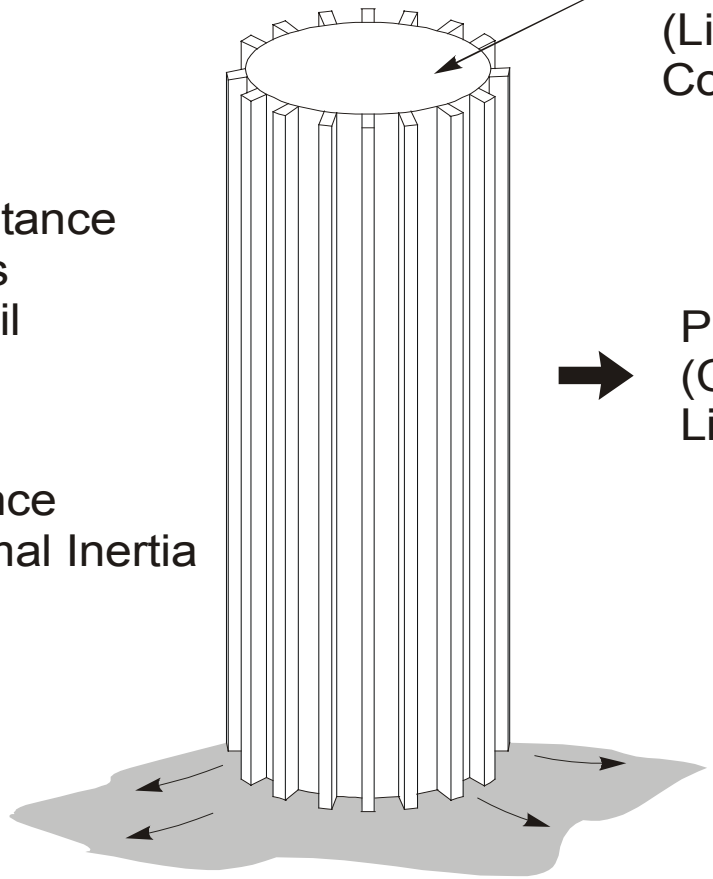
- Aircraft/assault credible
- Small pool in containment
- SNF handling in containment
- Multipurpose dry cask storage for all SNF

In Severe Environments, Casks Have Potential Advantages over Pools and Other SNF Storage Methods

(Casks Used In Germany: Aircraft Collision Resistance Requirement)

Limited Inventory (Limited Consequences)

Impact Resistance
- Thick Walls
- Cask Recoil



Passive Cooling (Consequence of Limited Inventory)

Fire Resistance
- High Thermal Inertia
- Drain Fuel

German Rail Gun For Testing Casks: 1 Ton Projectile At 300 m/s

If Dry Casks Are Used For Storing All SNF, The Optimum System Design May Change

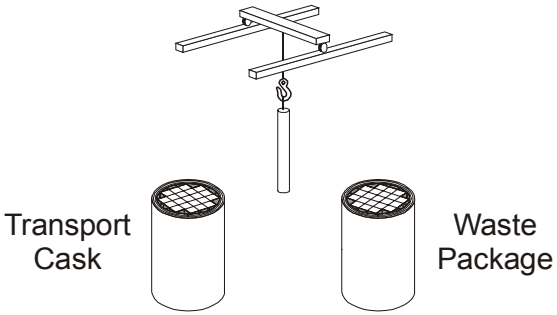
- Existing system: pool storage with limited number of transport casks
- Dry cask system
  - Heavy casks required for every ton of SNF
  - Small incremental cost allows casks to be used for transport
  - If casks used in transport, incentive to consider already purchased casks for disposal system (versus disposal costs for used casks)

Incentives: Multipurpose Casks Have International Safeguards Advantages

- Sealed system (option of welding)
- Easy surveillance
  - Radio
  - Satellite surveillance
- Difficult to steal
  - ~100 tons
  - Special equipment

Incentives: Multipurpose Casks Reduce Repository Surface Operations, Risks, and Costs

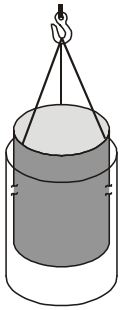
Current System



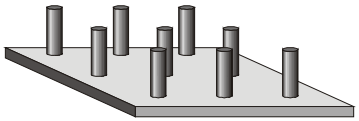
Remote Transfer of SNF

Adjusting Waste Package Heat Load for the Repository

Multipurpose Cask System



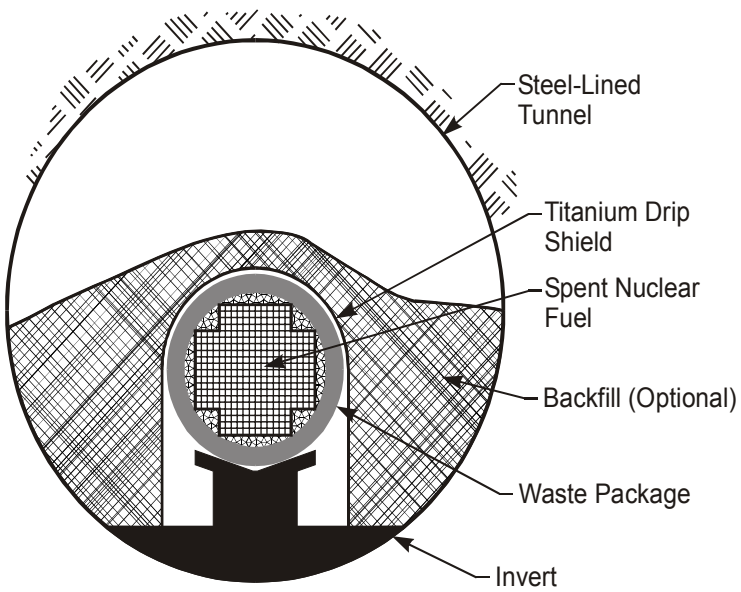
Addition of Overpack



Surface Storage Until Repository Acceptable Heat Load

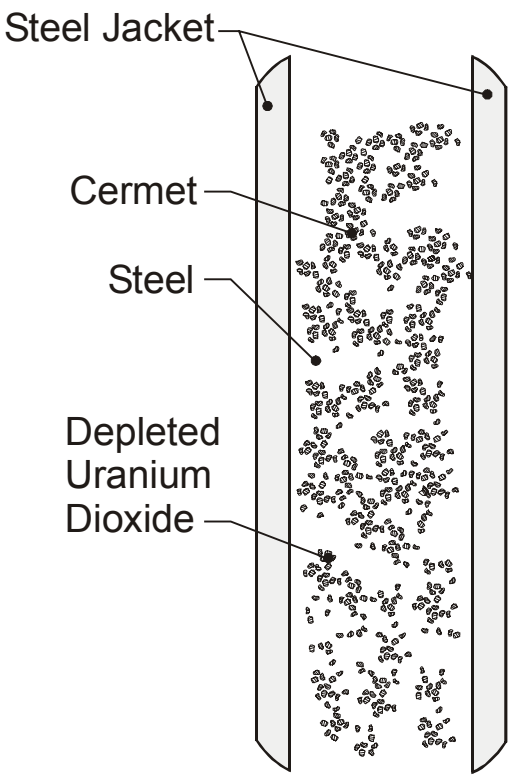
Incentives: Multipurpose Shielded Casks Simplify Underground Operations

(WP Placement, Inspection, Maintenance, and Backfill)



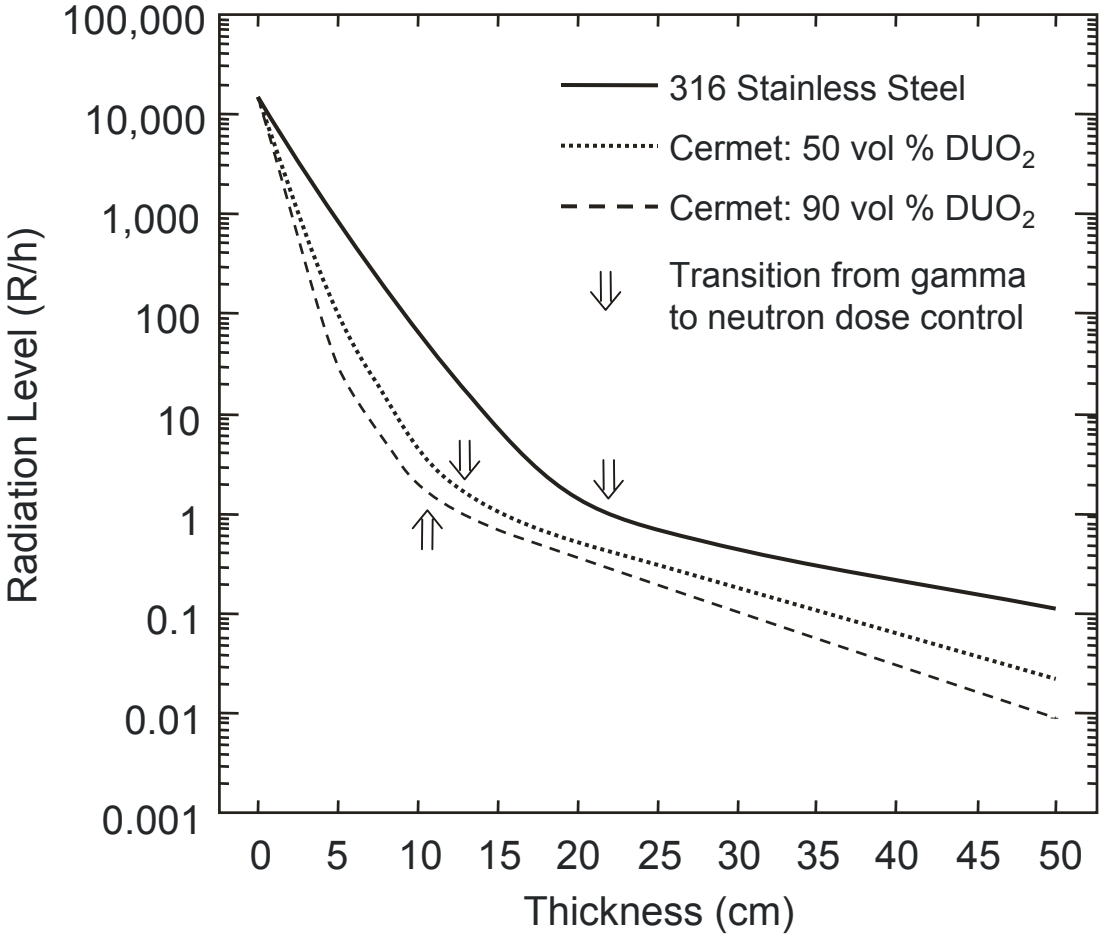
- **Cold repository option**
  - Ventilated repository lowers temperature; may reduce need for titanium drip-shield
  - Open repository with maintenance for 100+ years
  - Shielding simplifies maintenance
- **Simplify backfill placement**
  - Richards barrier
  - Fill to limit volcanic consequences

Cermet Benefit: Cermets Are Good Shielding Materials with Some Unique Capabilities



- Gamma Shielding Better Than Steel
  - Steel: 7.86 g/cm^3
  - DUO_2: 10.9 g/cm^3
- Neutron Shielding
  - High-density oxygen (DUO_2) moderator
  - Other neutron absorbers can be added
- Good Physical Properties
  - High thermal conductivity
  - No organics (no fire; acceptable to repository)

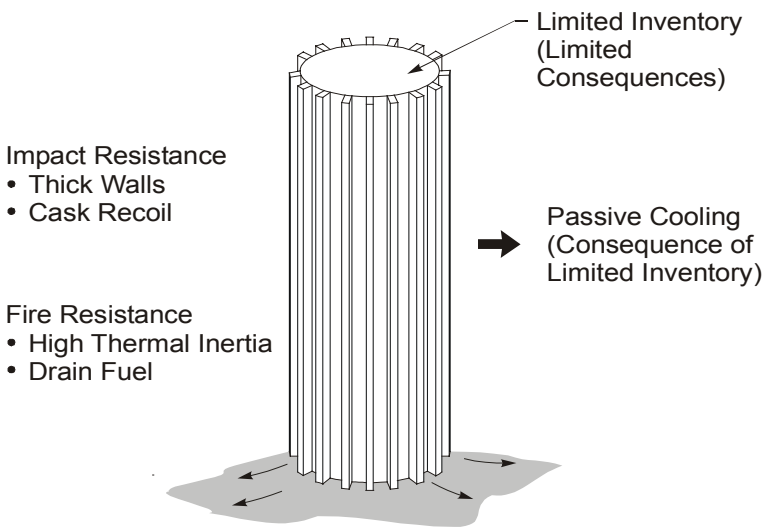
Shielding Effectiveness (R/h) of Different Materials
(Source Term from 21-PWR Yucca Mountain Waste Package)



Cermets Maximize Cask Capacity: Potential Economic/Operating Advantage

- **Better shielding materials result in higher capacity casks for a given weight limit**
- ***Cermets may be the best shielding material***
- **Other candidates eliminated because of repository requirements**
  - **Unacceptable neutron absorbers**
    - **Cement (adverse pH and geochemistry)**
    - **Organics (corrosion of WP)**
  - **Unacceptable gamma shields**
    - **Lead (RCRA metals not accepted)**
    - **Tungsten (high costs)**

Cermet Benefit: Cermet Casks *May* Enhance Protection Against Assault (Today's Discussion and Question)



- **Hard/soft layers used in bank vaults and tank armor**
- **Non-uranium cermets are used in tank armor**
- **Cermet properties harden casks against assault**
  - **DUO_2 hard layer**
  - **Steel soft ductile layer**
- **Design trade-offs not well understood**

Economics

Economics of DU Use Depend on System and Application Costs

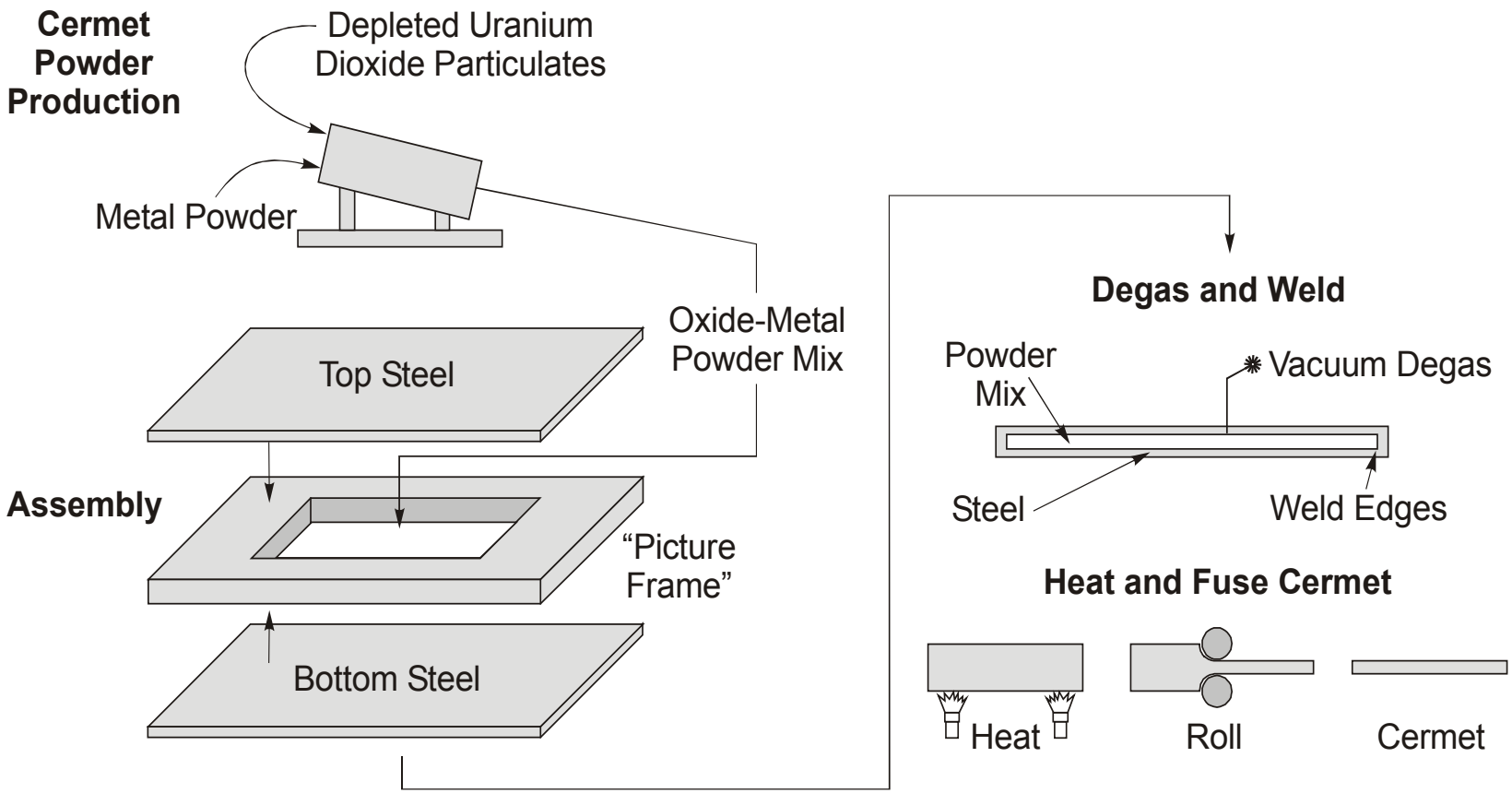
- Future SNF storage and transport requirements (dry storage for all SNF?)
- Need to avoid repository front-end costs
- Potential to replace one or more engineered barriers (titanium drip shield, etc.) with DU: an alternative barrier
- DU disposal costs
- Cost of DU applications (cermet and fill)

Cermet Economics And Manufacturing

- Non-nuclear cermets manufactured inexpensively on a large scale
- UO_2 cermet experience with fuel production (low volume, high costs)
- Industrial partnerships (ORNL/other) to explore manufacturing methods

"Picture-Frame" Method for Cermet Production

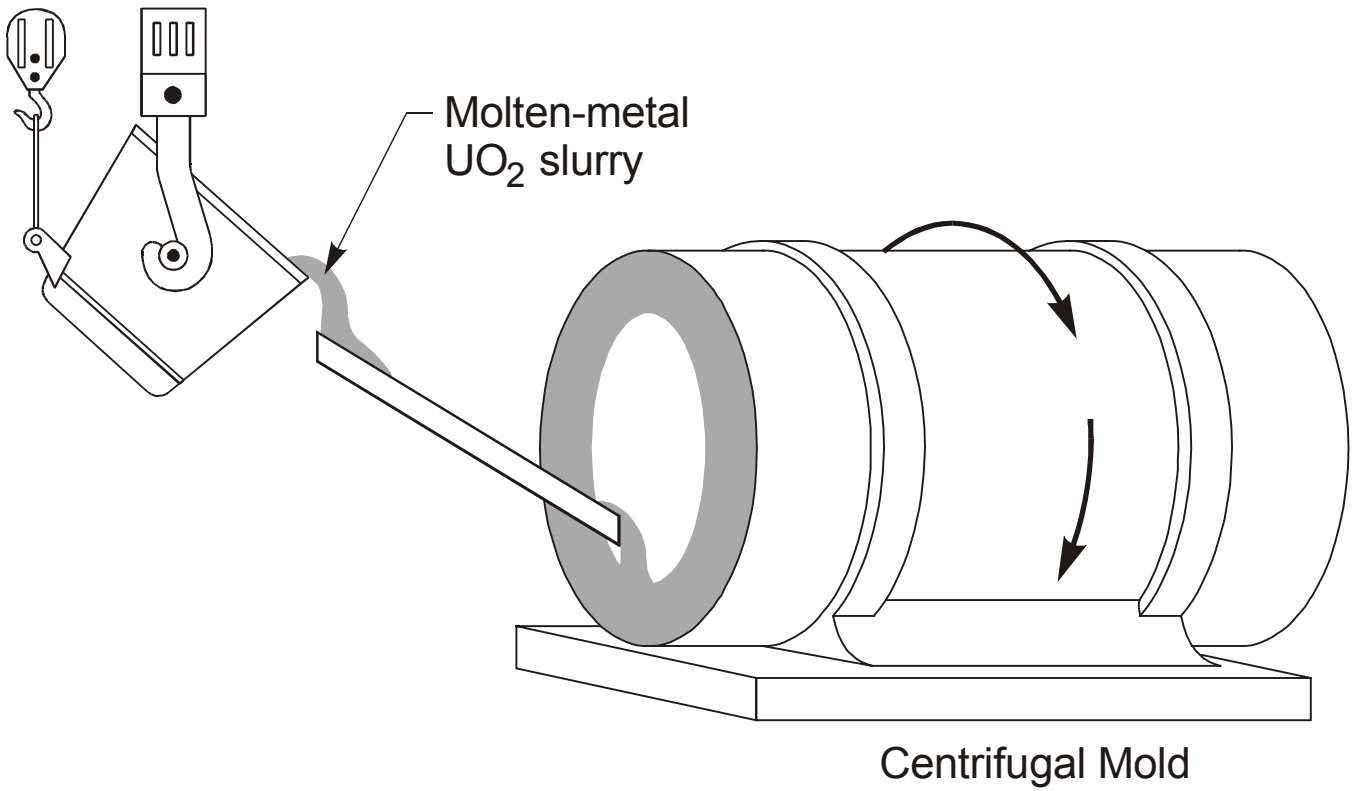
(Used for Some Nuclear Reactor Fuels and Some Nonnuclear Applications)



Centrifugal Casting May Allow Low-Cost Fabrication of Cask Body

- Some nonnuclear cermets manufactured by molten-metal ceramic-particulate slurry casting with solid ceramic particles
- Centrifugal casting is used for sewer pipes and other low-cost products
- R&D is required to develop method for DUO_2-steel cermets (need to ensure wetting of steel and DUO_2 surface)

Centrifugal Casting of Cask Body
(Potentially Very-Low-Cost Option)



Path Forward

- Partnerships
  - Cask vendors (CRADA underway)
  - Russian cooperative effort (initial discussions)
  - Commercial cermet manufacturing vendor
- R&D issues
  - System performance
  - Repository performance
  - Heat load/radiation shielding optimization
  - Cermet manufacturing techniques
  - Improved resistance to assault

Key Question: Viability of DUO_2-Steel Cermet Multipurpose Cask Designed For Assault Resistance

Can Appropriate Design of the Cermet Significantly Improve Cask Resistance To Assault While Meeting Other Requirements?

(Add-on armor is a separate issue: not part of this effort)

Multipurpose Cermet Cask Has Multiple Design Constraints

- Enable storage of short-cooled SNF
- Safe transport
- Improve repository performance (Acceptable cermet materials-of-construction defined)
- Assault protection
- Dispose of DU
- Economics
  - Low cost
  - High volume (~1,000,000 tons)

Cermet Cask Armor Constraints

- Dimensions specified
  - Cylinder
  - Thickness: 15 to 30 cm
  - Height: 4 to 5 m
  - Weight limit (controlled by shielding needs)
- Materials of construction specified
  - DUO_2
  - 316SS or mild steel
- Economic Requirements
  - Low cost
  - Total volume: ~1,000,000 tons

Cermet Properties That Can Be Modified To Improve Assault Resistance

- Number and composition of layers
  - Allowable materials defined by other needs
- DUO_2 particulate size and geometry within any cermet layer
- DUO_2 volume fraction in any layer
- Additives?
- Other?

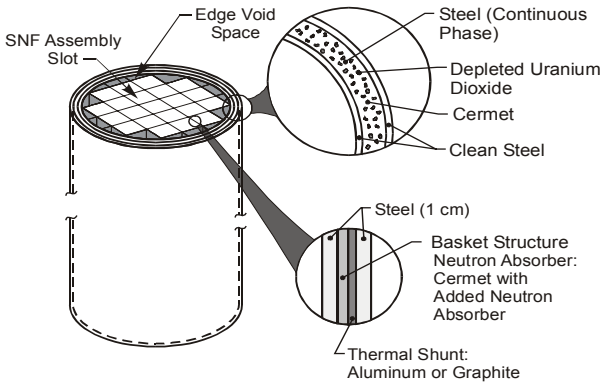
Conclusions

- DU program examining multipurpose cask (storage, transport, and disposal)
- Multiple requirements
- Recent events indicate need to consider better protection against assault
- Need to understand potential for DUO_2-steel cermet for resistance to assault
- Economics is a big issue
- Interested in LLNL capabilities in armor design and testing

Backup Information

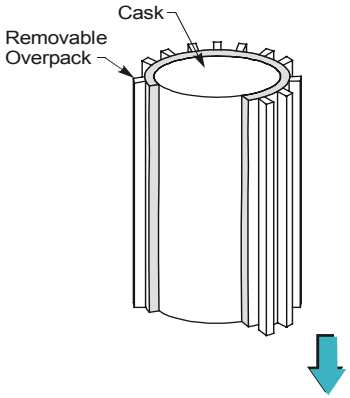
Multipurpose Cask for Storage, Transport, and Disposal

Multipurpose Cask



- Radiation Shielding
  - Gamma: High-Density Cermet
  - Neutron Moderation/Absorption
    - Oxygen in Cermet
    - Carbon in Cask
- Assault Protection: Multilayer Cermet
- Safeguards and Theft
  - Large Mass
  - Vault Construction: Multilayer Cermet
- Decay Heat Removal
  - Carbon Shunt (also Neutron Moderator)
  - Aluminum

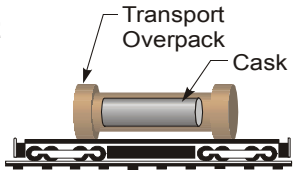
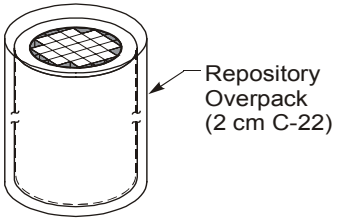
Multipurpose Cask System



Storage at Reactor With Overpack for Short-Cooled SNF

Removable Overpack
- Augmented Cooling
  - Dry Fin
  - Liquid Fin
- Augmented Shielding

Transport



Disposal at Repository With Overpack