

# Thick-Walled Depleted Uranium Dioxide–Steel Cermets For Spent Nuclear Fuel Casks

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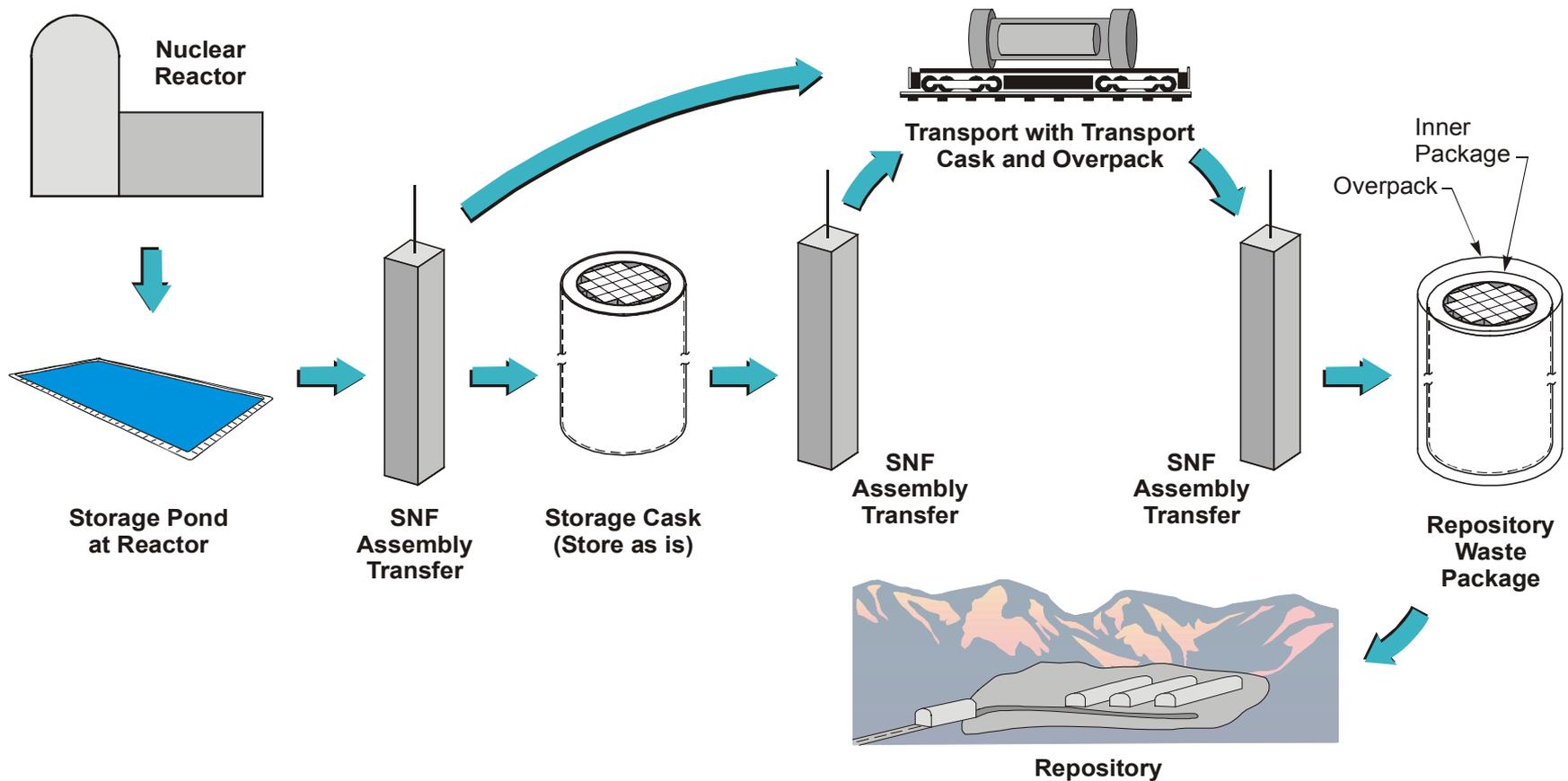
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# **Traditional Spent Nuclear Fuel (SNF) Management Strategy**

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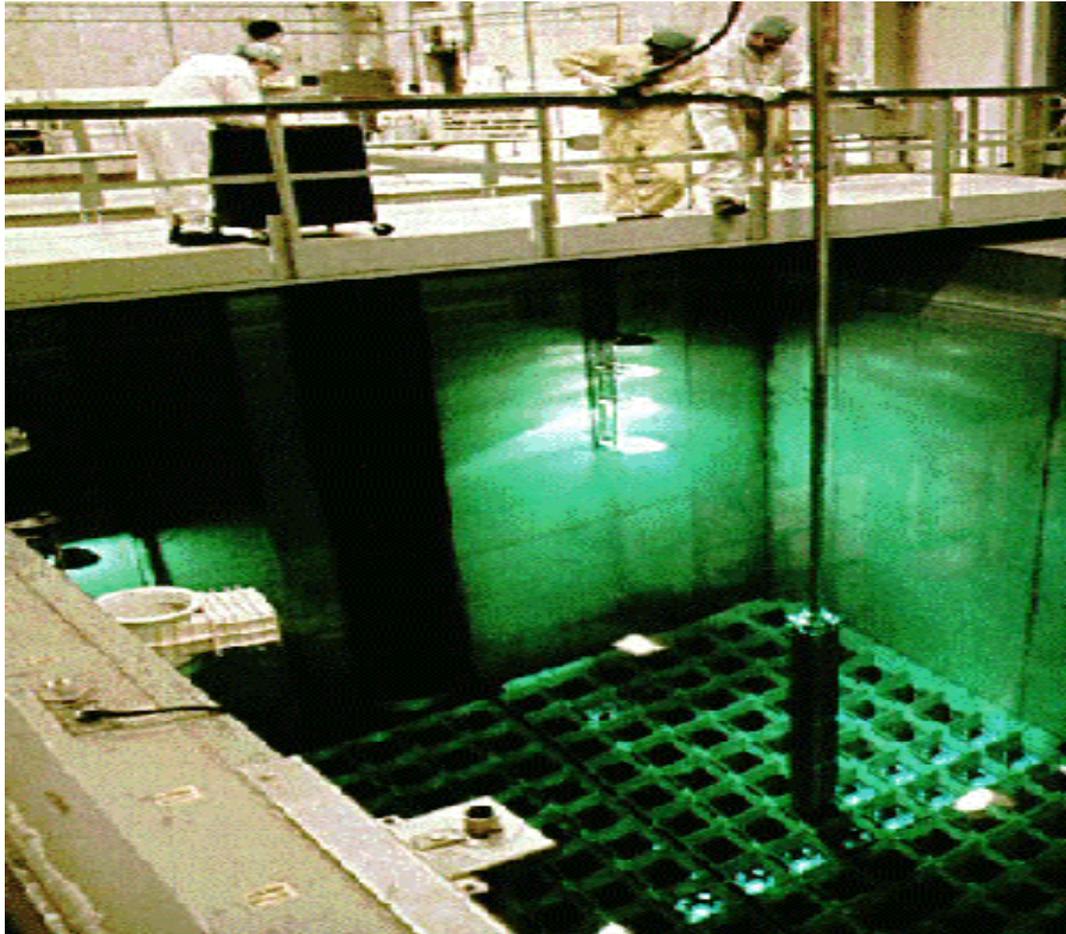
- **A nuclear power reactor generates 30 tons of highly radioactive SNF (waste)/year**
- **SNF is stored in pools or casks**
  - **Most SNF is stored in pools**
- **SNF will be shipped in metal transport casks (~10 tons/cask) to an underground repository for disposal**

# Traditional Approaches to SNF Management

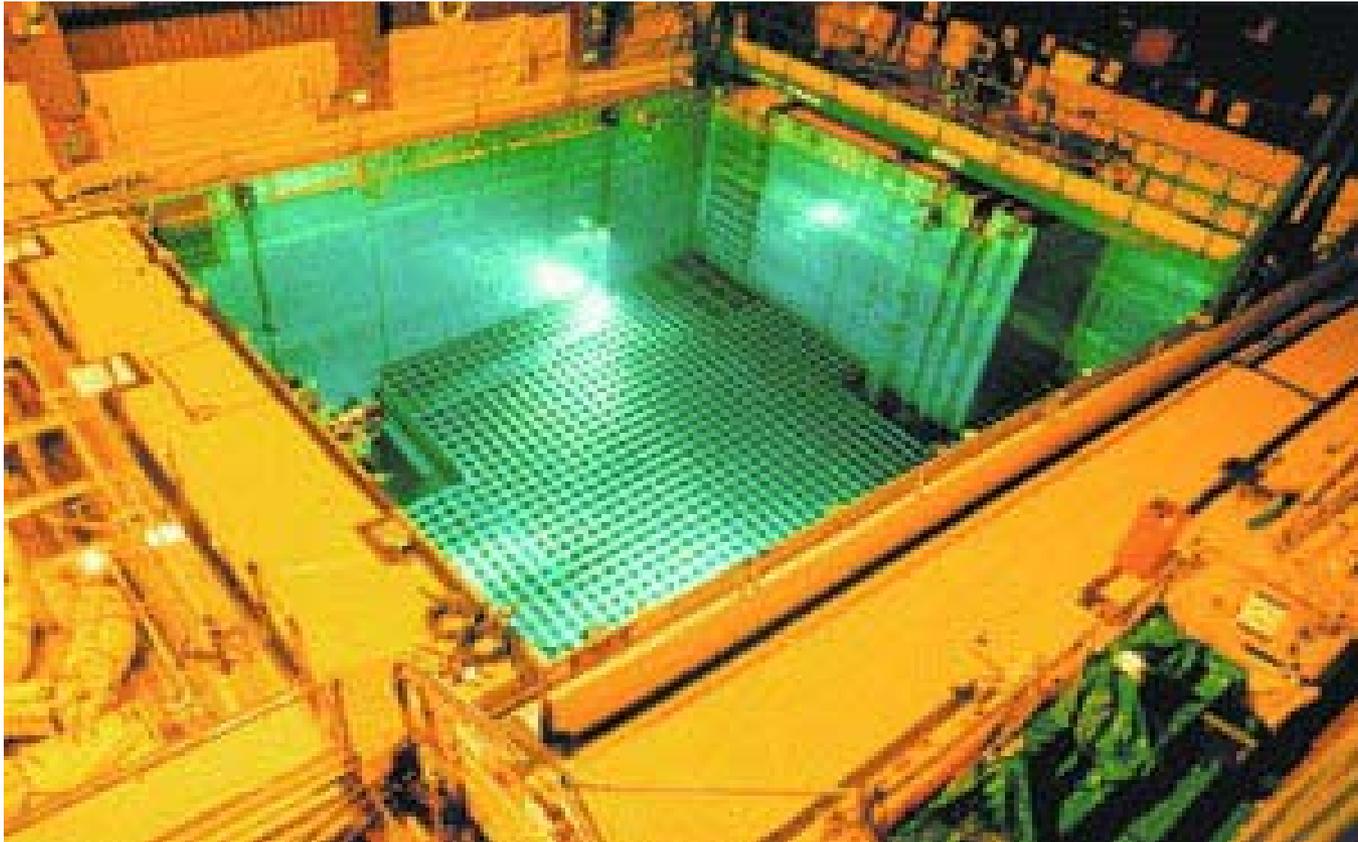


# Handling SNF in Fuel Pool

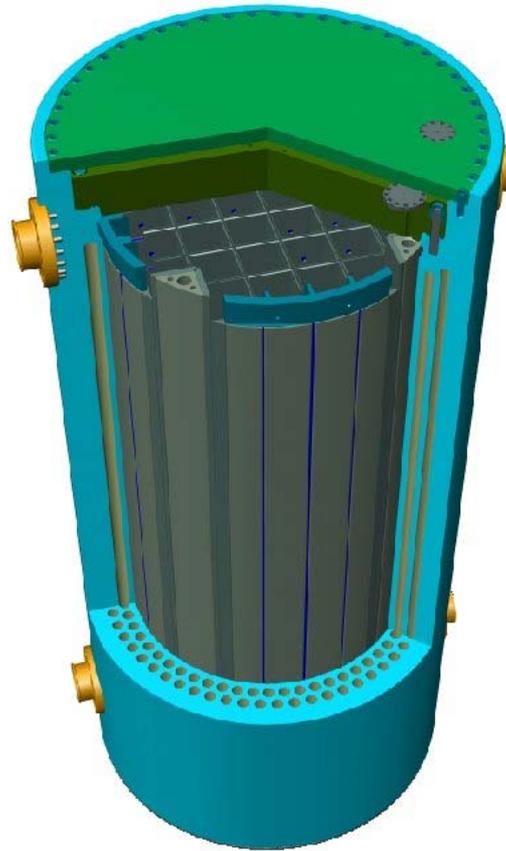
(Pool Provides Cooling and Radiation Shielding)



# Spent Fuel Storage Pond



# German GNS SNF Storage and Transport Cask (~100 tons)

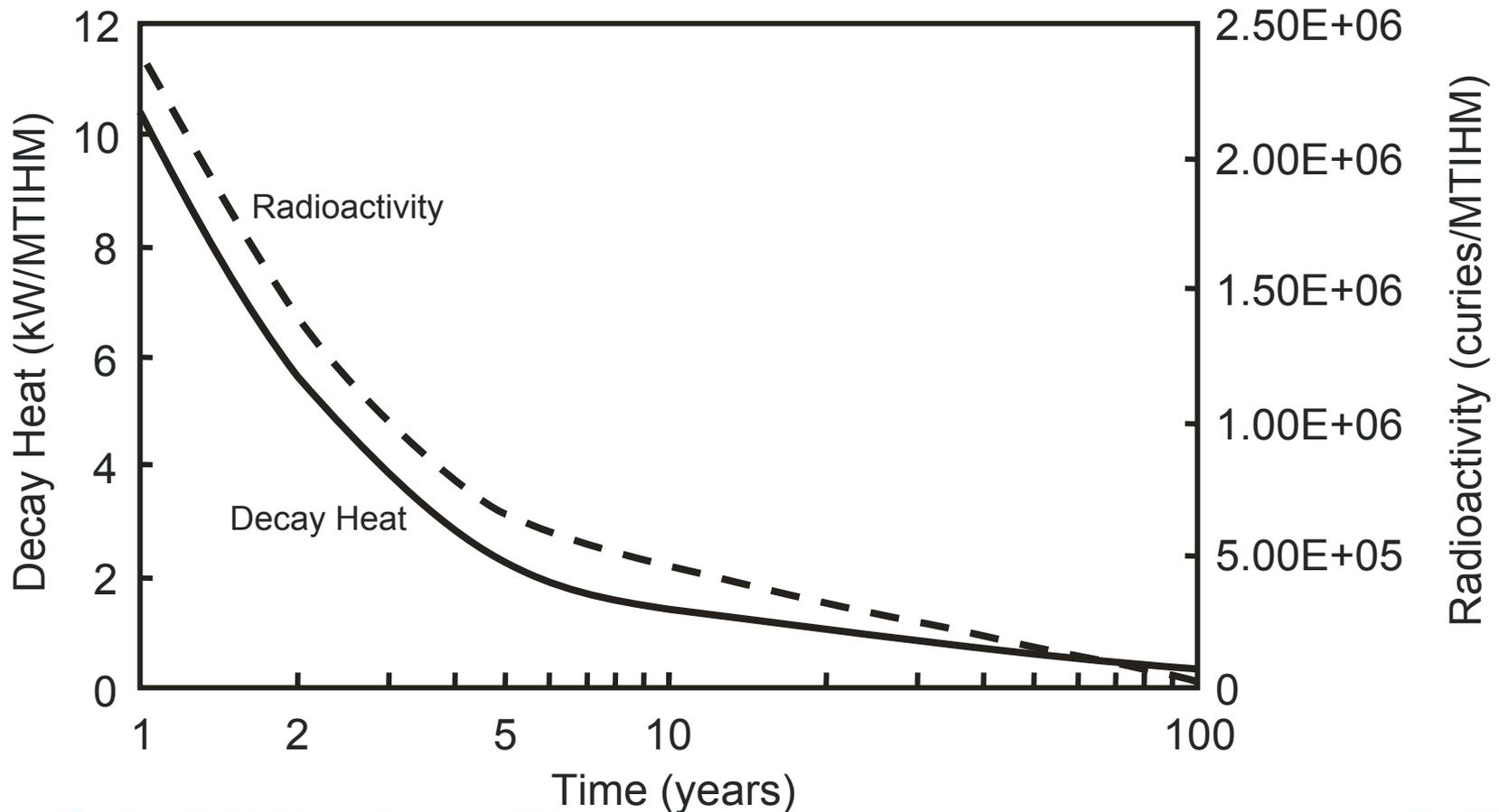


# German GNS SNF Storage and Transport Cask on a Railcar



# Basis for Waste Management

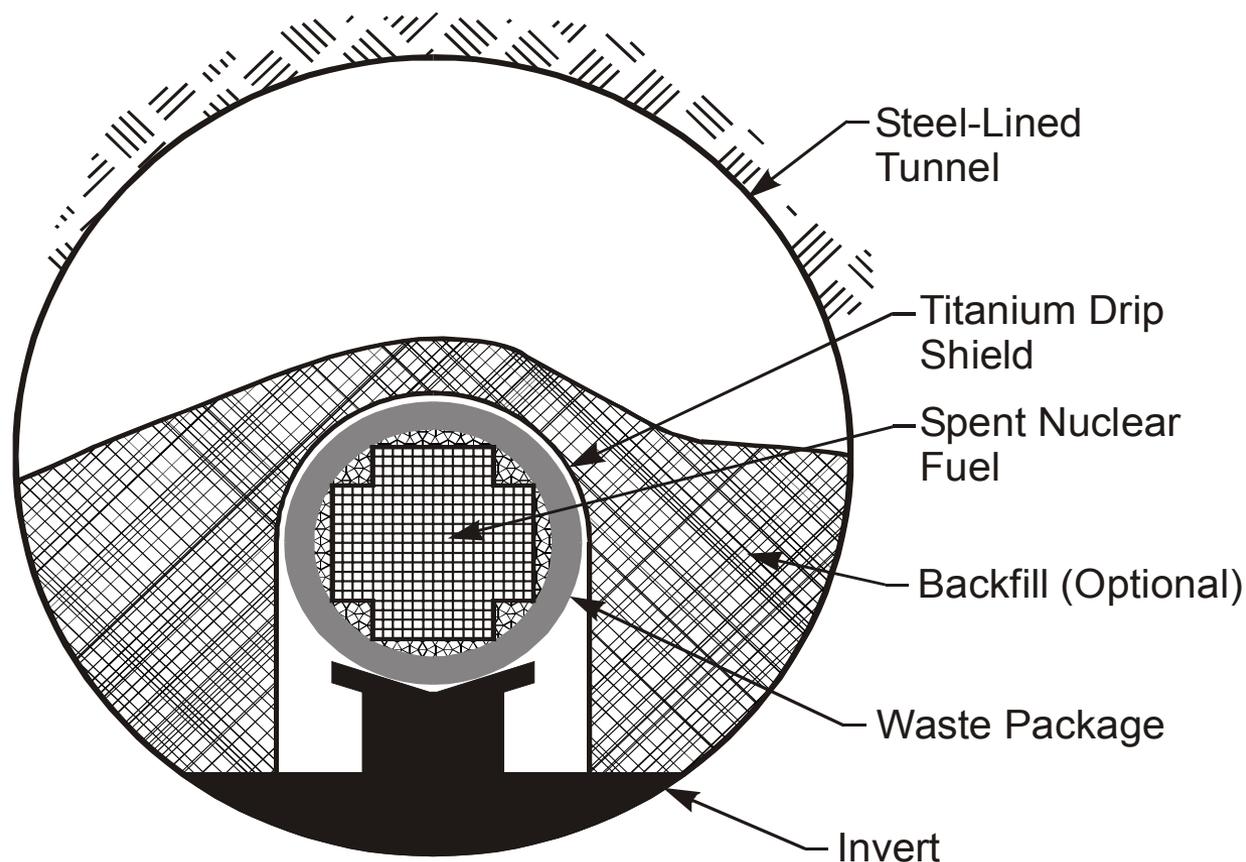
Radioactive Atoms Decay to Non-Radioactive Atoms:  
Basic Strategy: Isolate SNF Until Non Hazardous



# Methods to Isolate SNF For Long Periods of Time

- **Bury deep underground (avoid disturbance by man or nature)**
- **Package SNF in corrosion-resistant waste packages**
- **Add sacrificial materials to protect SNF (new strategy using cermets)**
- **Use geology to delay transport of radionuclides via groundwater to man**

# The SNF Will Be Buried 300m Underground: Proposed Site Is Yucca Mountain, Nevada



# Repository Waste Package With Outer Corrosion-Resistant Container

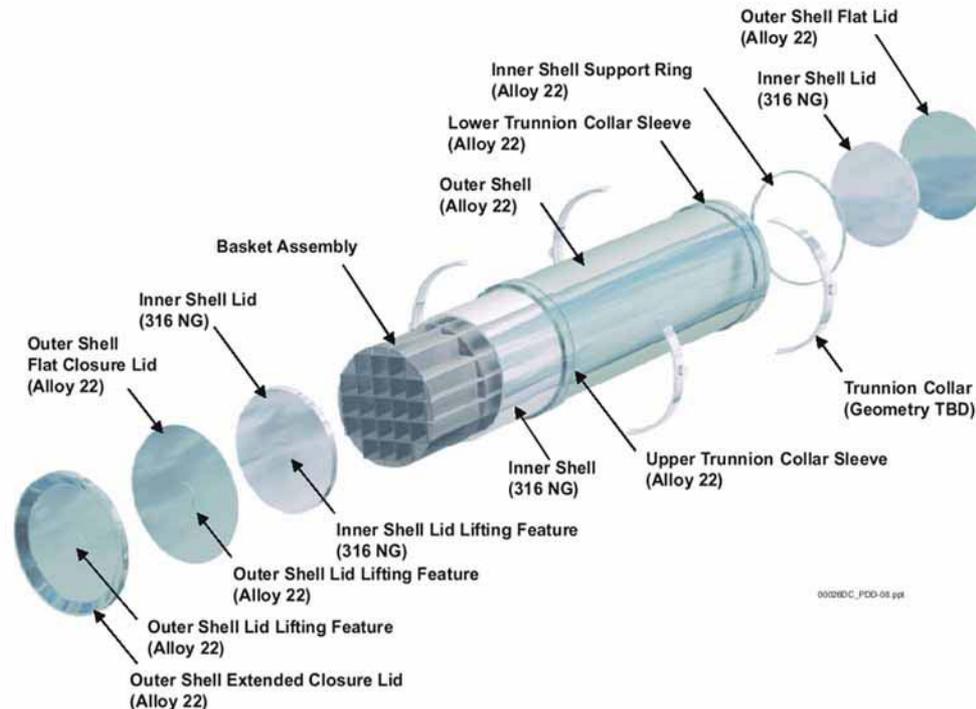


Figure 2-13. Uncanistered CSNF Waste Package

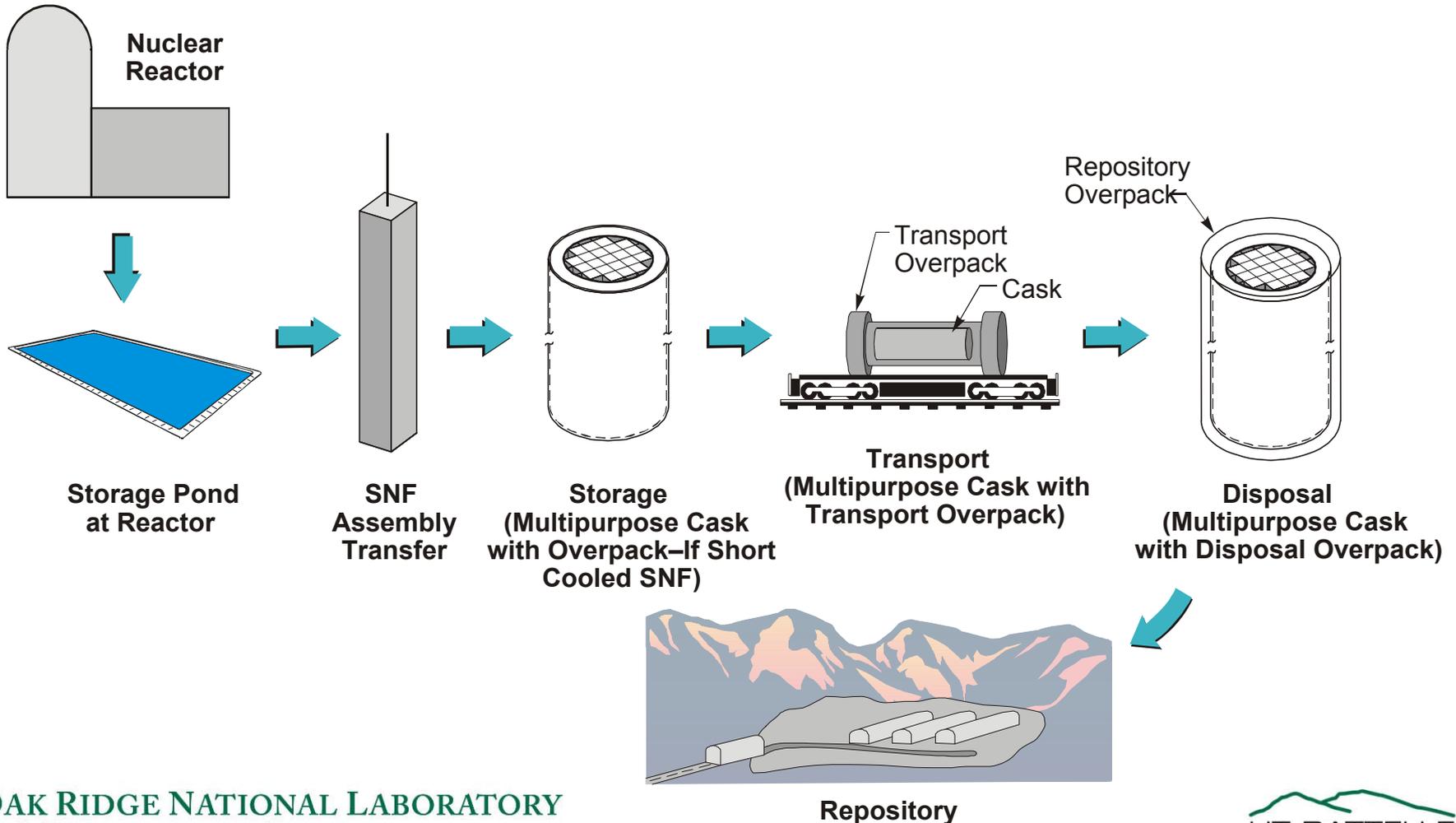
# **New SNF Strategies May Be Needed Because of Changing Conditions**

# Current System Used Worldwide Has Weaknesses

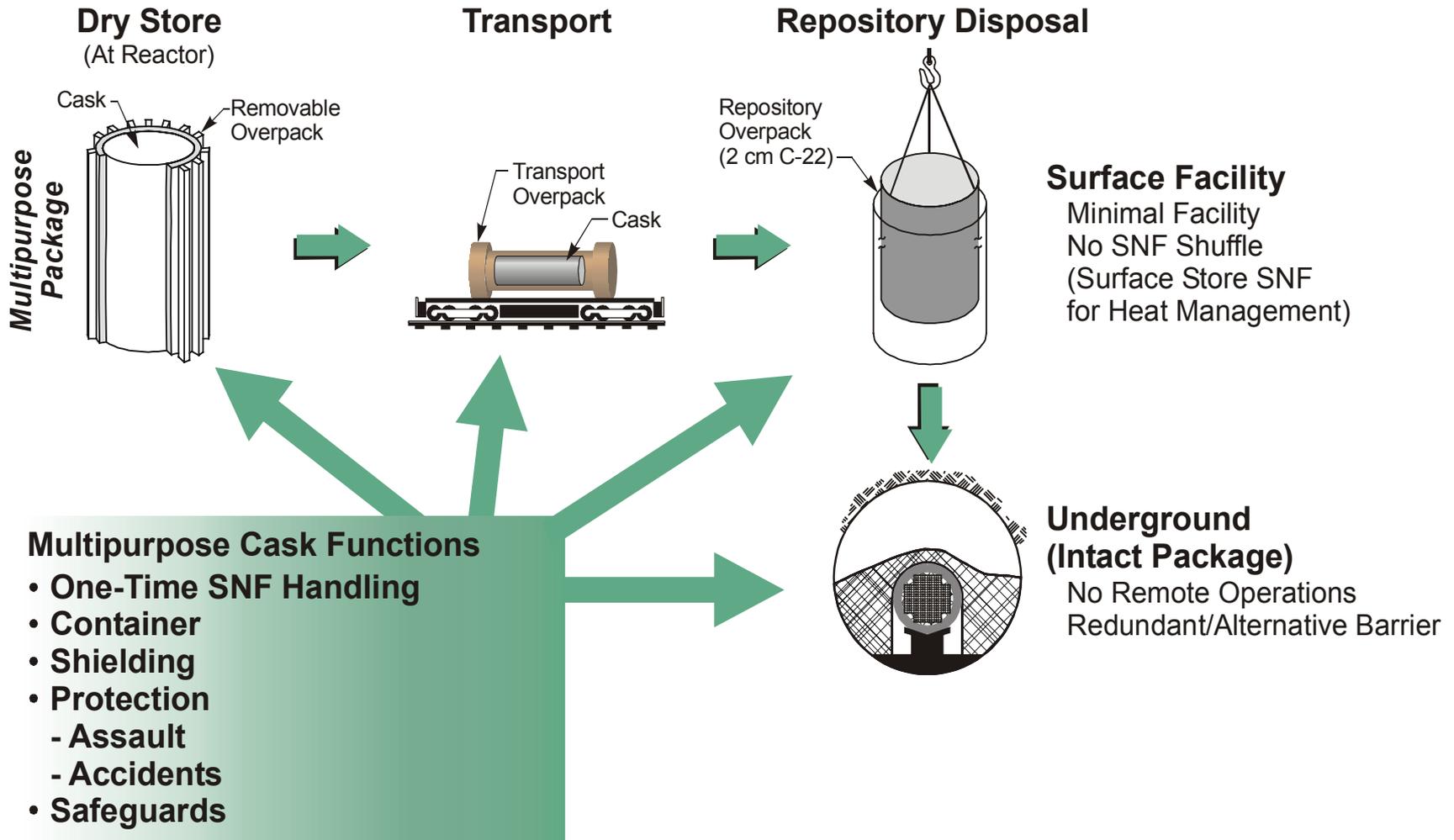
- **History**
  - Originally designed for recycle of SNF (Process SNF to recover plutonium and uranium)
  - Evolved into a system for direct disposal of SNF
- **Security was not originally a major consideration**
  - Multiple handling of SNF
  - High dependence on active security (guards) with high costs
  - New environment suggests alternative approaches should be considered
- **New approach: DUO<sub>2</sub>-steel cermet multipurpose cask system**
  - Multipurpose casks have been considered in the past
  - DUO<sub>2</sub>-steel cermet may be an enabling technology for a cost effective multipurpose cask system

# SNF Is Placed in a Multipurpose Cask (Mobile 100-ton Vault) and Never Removed

(SNF Is Loaded at Reactor into Cask; Cask Is Used for Storage, Transport, and Disposal)



# The Multipurpose Cask Has Multiple Functions (Handling, Protection, Shielding, and Safe Disposal)



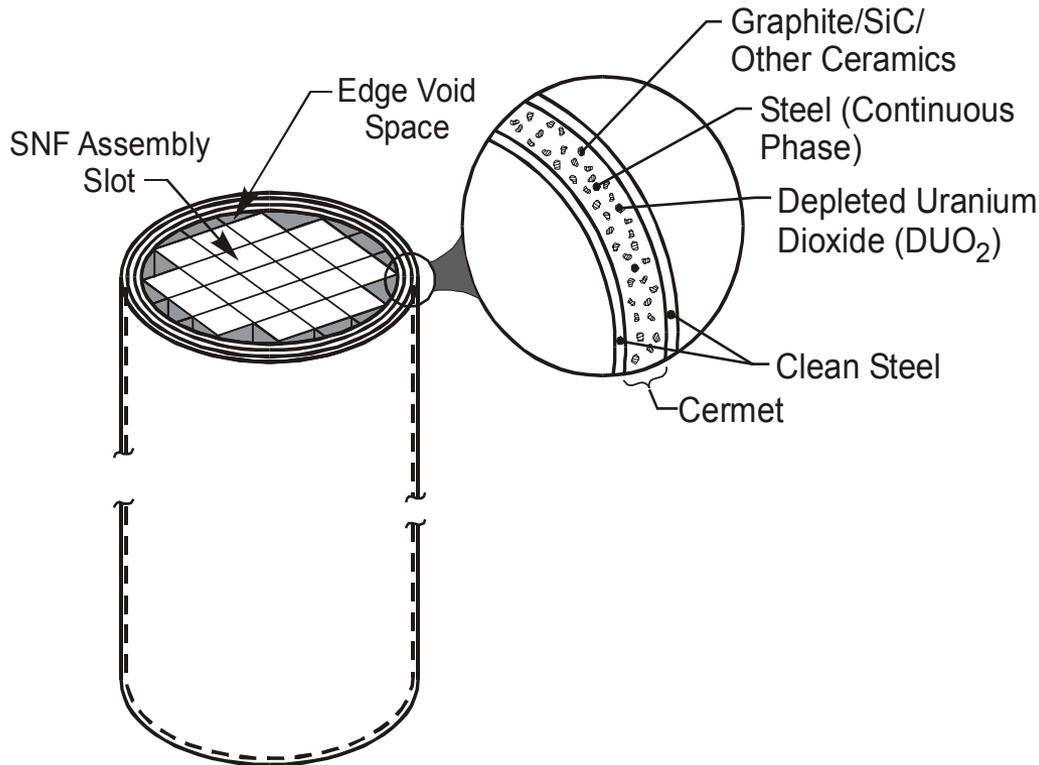
# **DUO<sub>2</sub>-Steel Cermet Multipurpose Spent-Nuclear-Fuel Cask**

**Consideration of a new material with  
unique characteristics**

# What Is a Cermet?

- **Cermets are CERamics embedded in a continuous METAl matrix**
- **Cermets create materials with characteristics of metals and ceramics**
- **Traditional cermet applications**
  - Tank armor
  - Vehicle brake shoes
  - Nuclear fuel for test reactors
- **DUO<sub>2</sub>-steel cermet**
  - **Ceramic: Depleted uranium dioxide (DUO<sub>2</sub>)**
  - **Metal: steel**

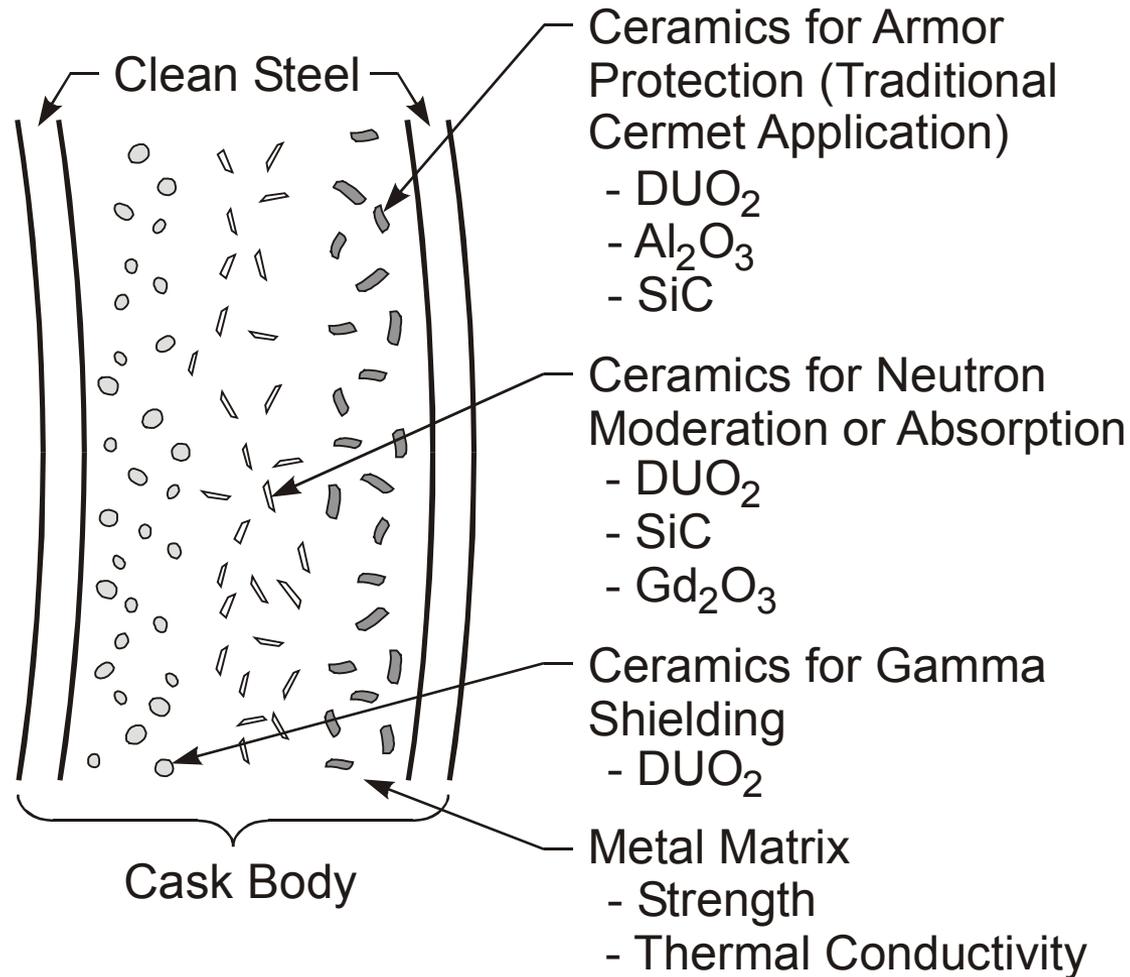
# Cermets (Ceramics in Metal Matrix) Are the Enabling Technology for a High-Performance Super Cask



## Functions

- Radiation Shielding
  - Gamma: High-Density DUO<sub>2</sub>/Other
  - Neutron Moderation/Absorption
    - Oxygen in DUO<sub>2</sub>
    - Carbon in SiC and Graphite
- Assault Protection: Multilayer Cermet (Traditional Armor)
  - Ceramic (Al<sub>2</sub>O<sub>3</sub>, DUO<sub>2</sub>, SiC, Other)
  - Metal
- Safeguards and Theft
  - Large Mass
  - Vault Construction: Multilayer Cermet
- Decay Heat Removal
  - High Conductivity Steel Matrix

# The Composition Across the Cermet Can Be Varied to Maximize Performance



# **Requirements for Cermet Multipurpose Casks (Serious Demands on Materials)**

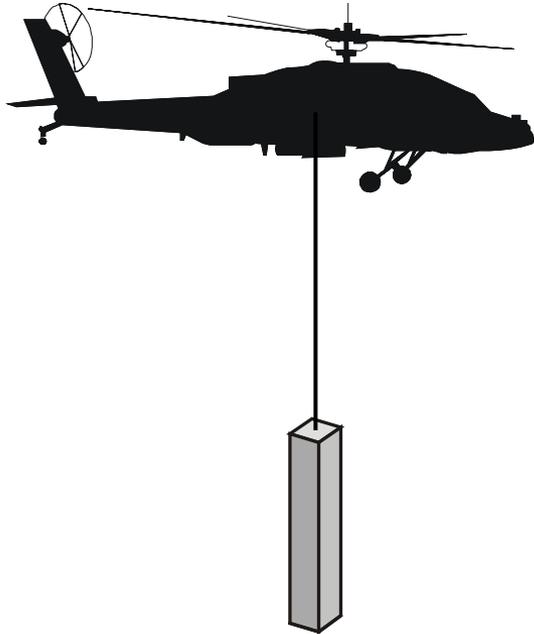
- **Security**
- **Radiation shielding**
- **Disposal**

# Requirements for Cermet Multipurpose Casks

## Security

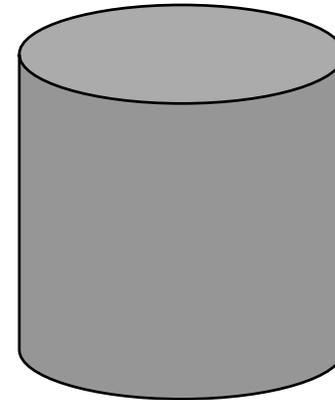
# Multipurpose Casks Provide Protection Against Theft Or Diversion

*Fuel Assembly*



**Low weight (~1 ton),  
small size**

*Multipurpose Cask*



**Large weight (>70 tons),  
large size, visible from orbit**

# Armor Is a Traditional Cermet Application

(Hard Ceramic Breaks Up Projectile;  
Ductile Metal Absorbs the Energy)



- **Hard/soft layers used in bank vaults and tank armor**
- **Non-uranium cermets are used in tank armor**
- **Cermet properties may harden casks against assault**
  - **DUO<sub>2</sub> hard layer**
  - **Steel soft ductile layer**
- **Design trade-offs not well understood**

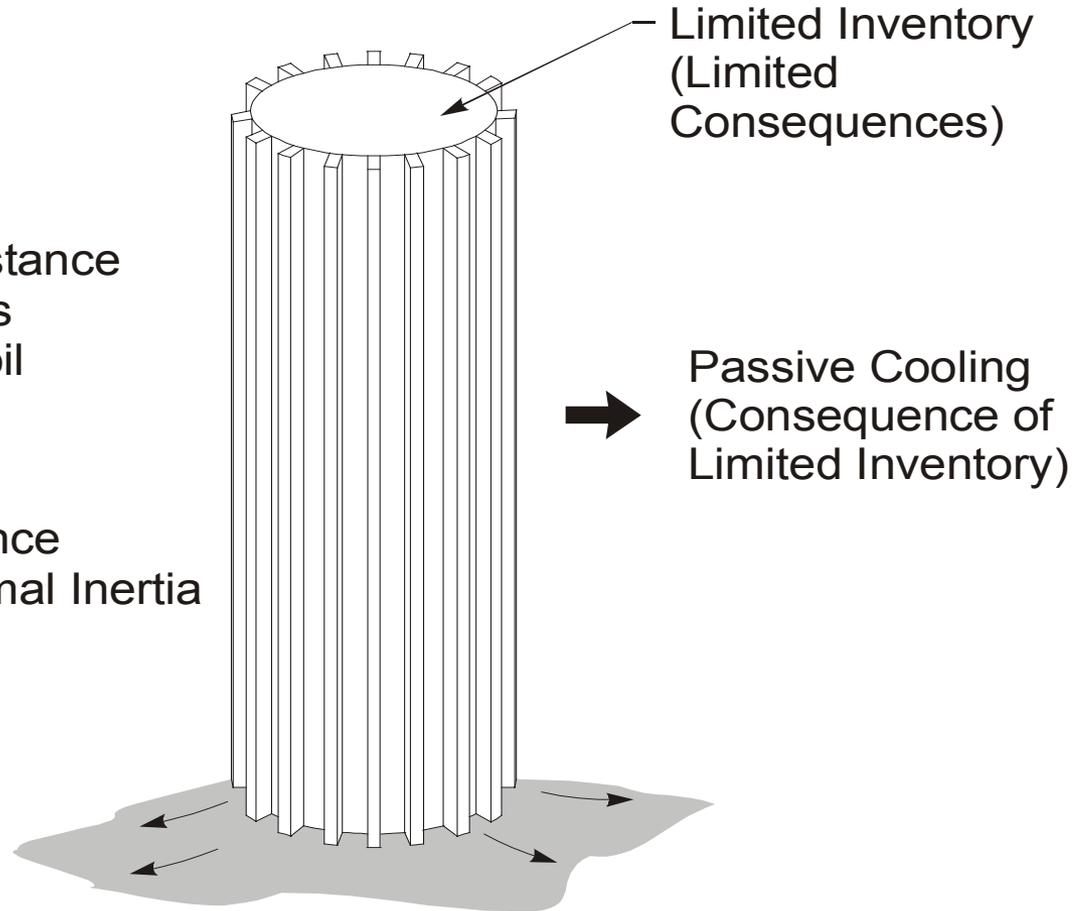
# In Severe Environments, Casks Have Potential Advantages over Pools and Other SNF Storage Methods (Casks Used to Meet German Aircraft Collision Resistance Requirements)

## Impact Resistance

- Thick Walls
- Cask Recoil

## Fire Resistance

- High Thermal Inertia
- Drain Fuel



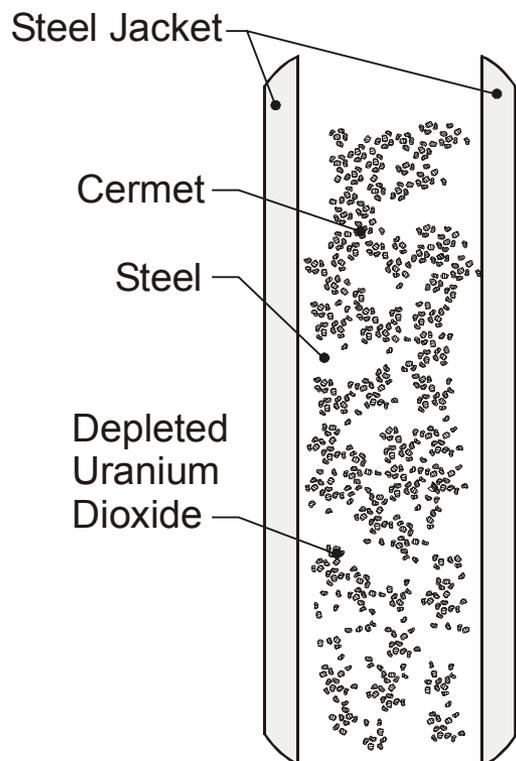
# German Rail Gun For Testing Casks: 1 Ton Projectile At 300 m/s



# Requirements for Cermet Multipurpose Casks

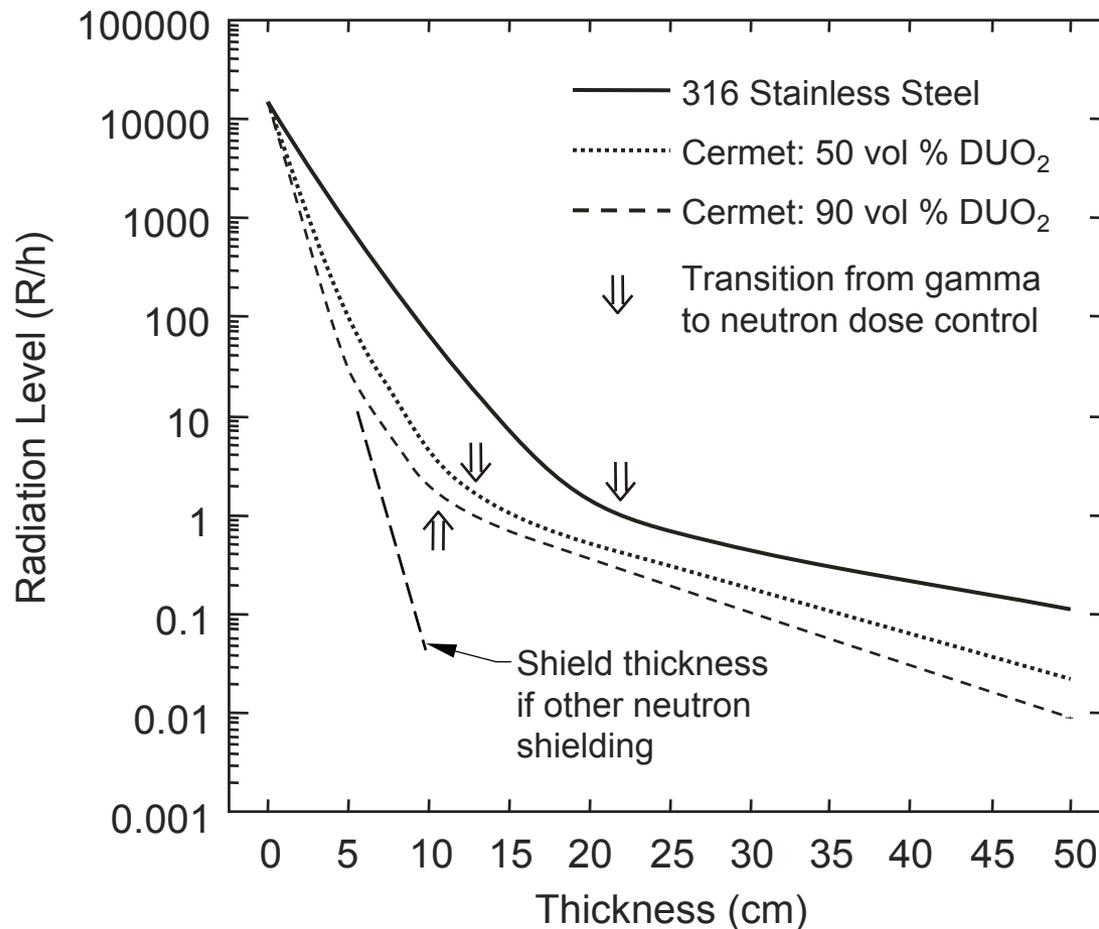
## Radiation Shielding

# DUO<sub>2</sub>–Steel Cermets Are Excellent Shielding Materials Because the Steel Enables The Use of an Excellent (But Brittle) Shielding Material—DUO<sub>2</sub>



- Gamma Shielding Better Than Steel
  - Steel: 7.86 g/cm<sup>3</sup>
  - DUO<sub>2</sub>: 10.9 g/cm<sup>3</sup>
- Neutron Shielding
  - High-density oxygen (DUO<sub>2</sub>) moderator
  - Other neutron absorbers can be added
- Good Physical Properties
  - High thermal conductivity
  - No organics (no fire; acceptable to repository)

# DUO<sub>2</sub> Cermets Are Superior Shielding Materials (Source Term From 21-PWR Yucca Mountain Waste Package)



# Requirements for Cermet Multipurpose Casks

Improve SNF Disposal With Additional Barrier  
To Long-Term Radionuclide Release

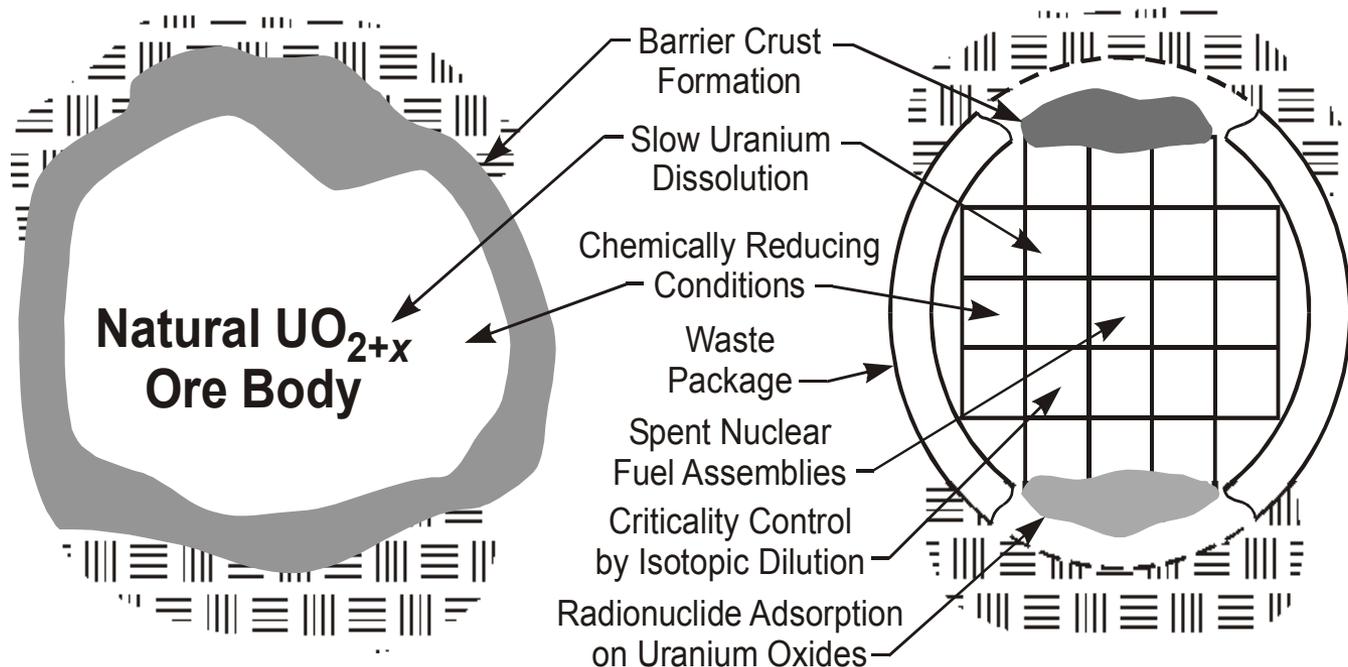
**Dispose of SNF underground**

**Corrosion-resistant waste package**

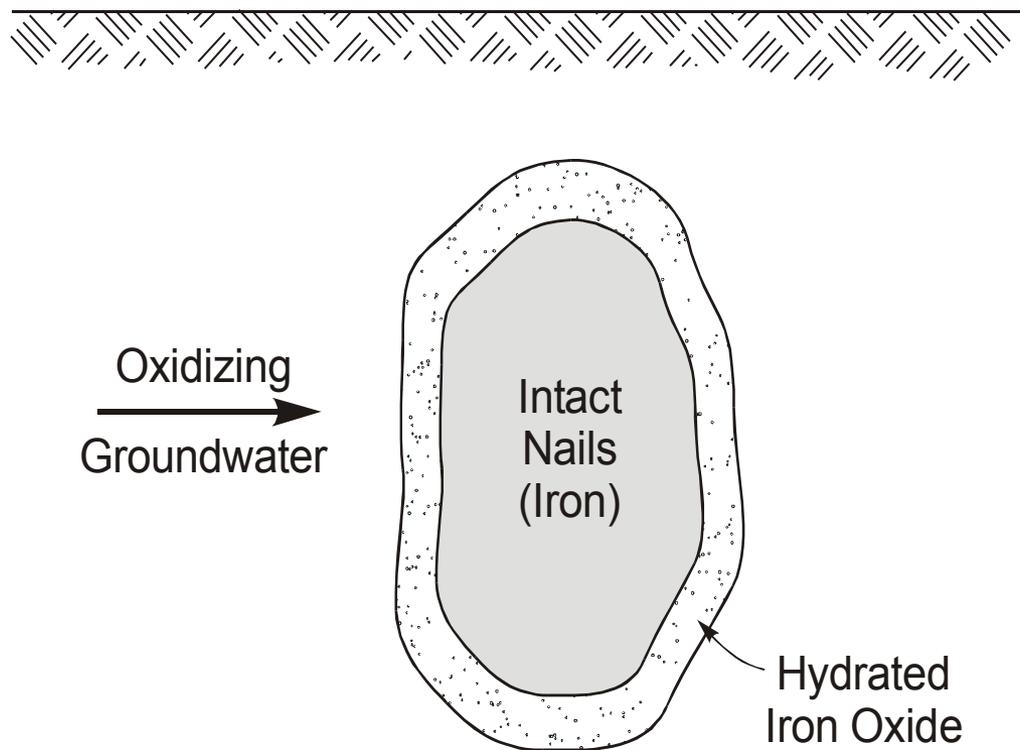
**Internal sacrificial material to preserve SNF (Cermet)**

**Geology to delay radionuclide migration**

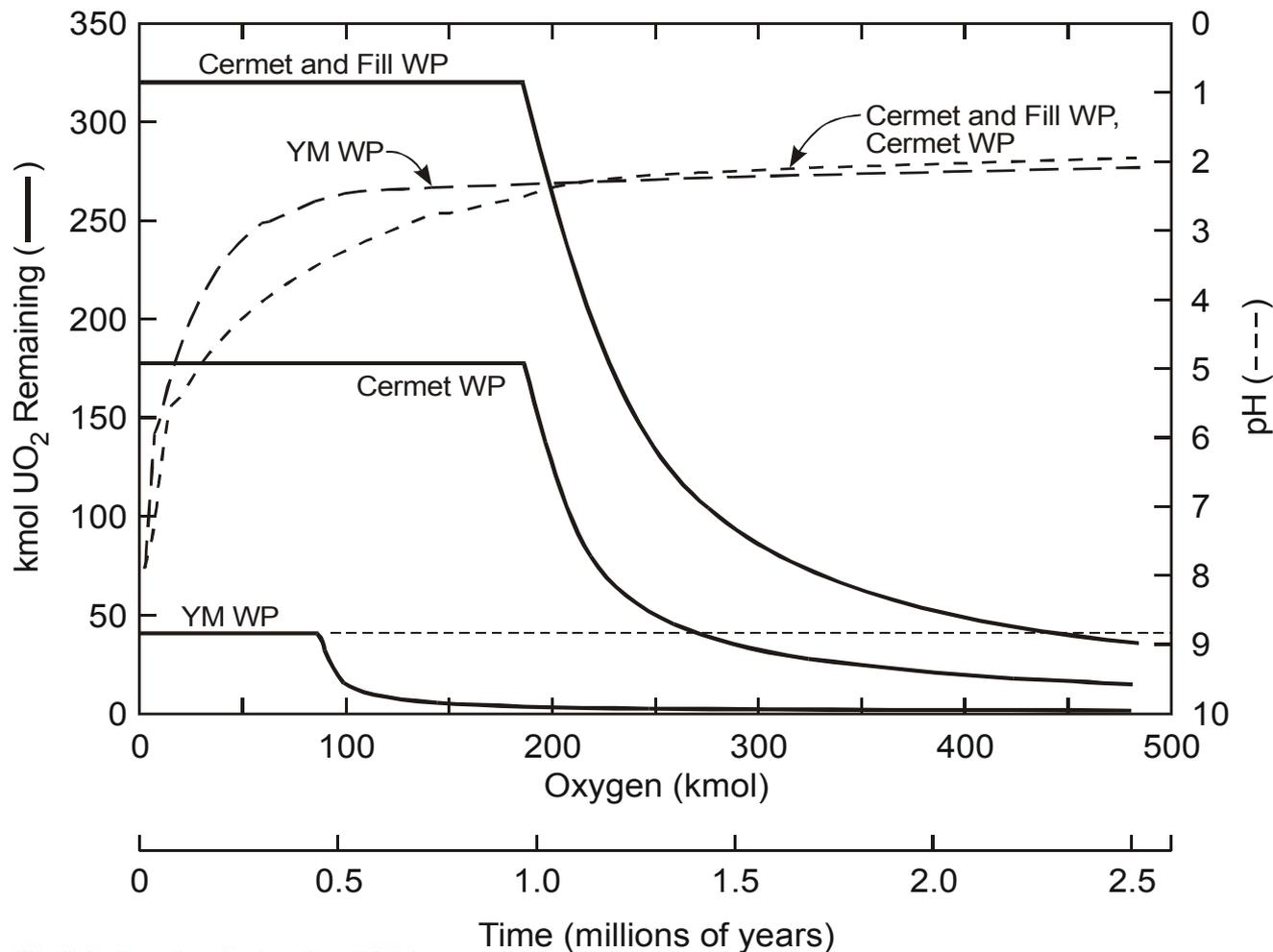
# Sacrificial Chemical Reactions Preserve the Interiors of the Uranium Ore Deposits: the Same Mechanisms Should Protect SNF in Cermet Waste Packages



# Large Buried Roman Nail Piles Have Remained Intact for Thousands of Years (Same Strategy to Protect SNF—Iron Corrodes First)



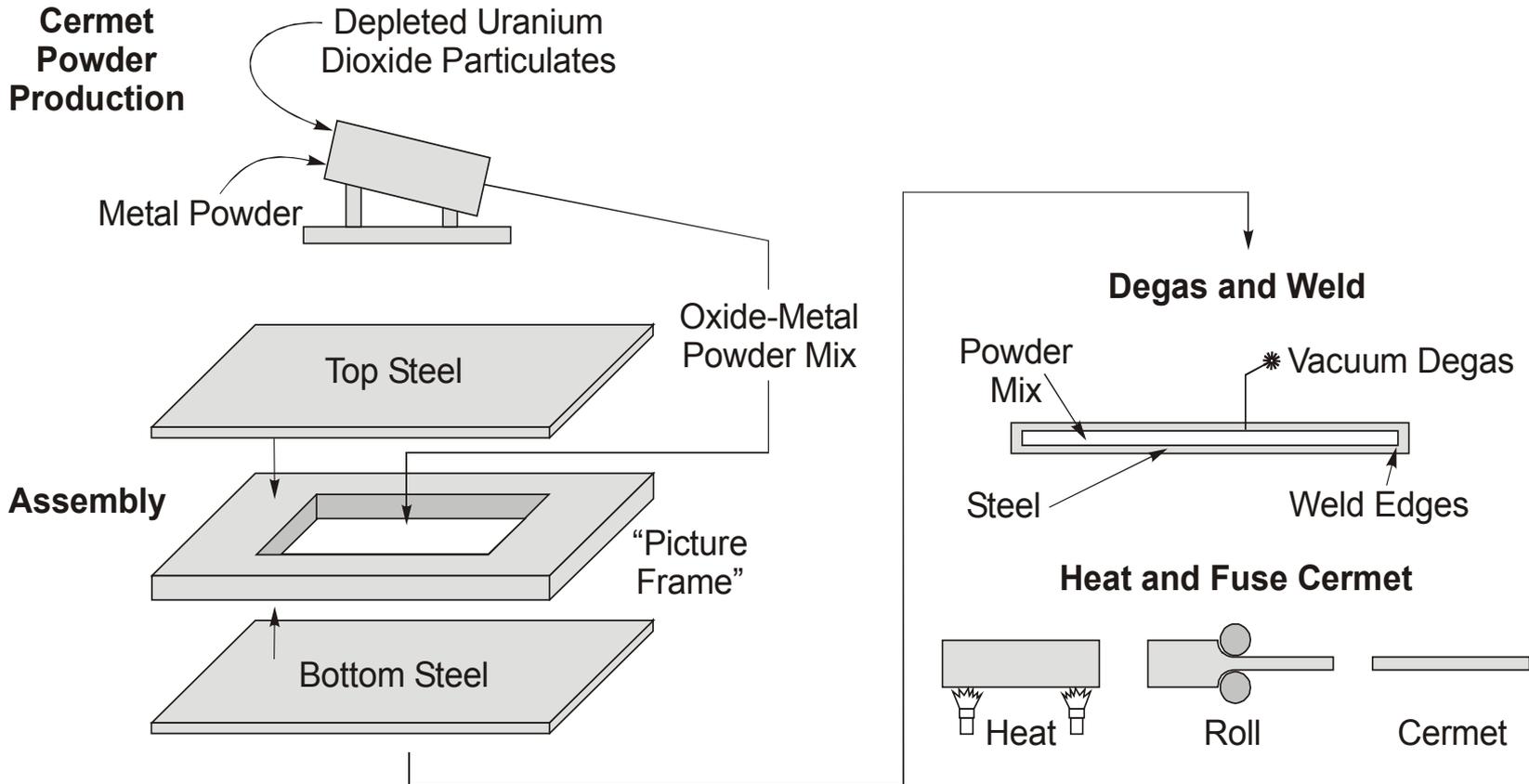
# Sacrificial Cermet Delay SNF Degradation After Outer Corrosion-Resistant Waste Package Fails



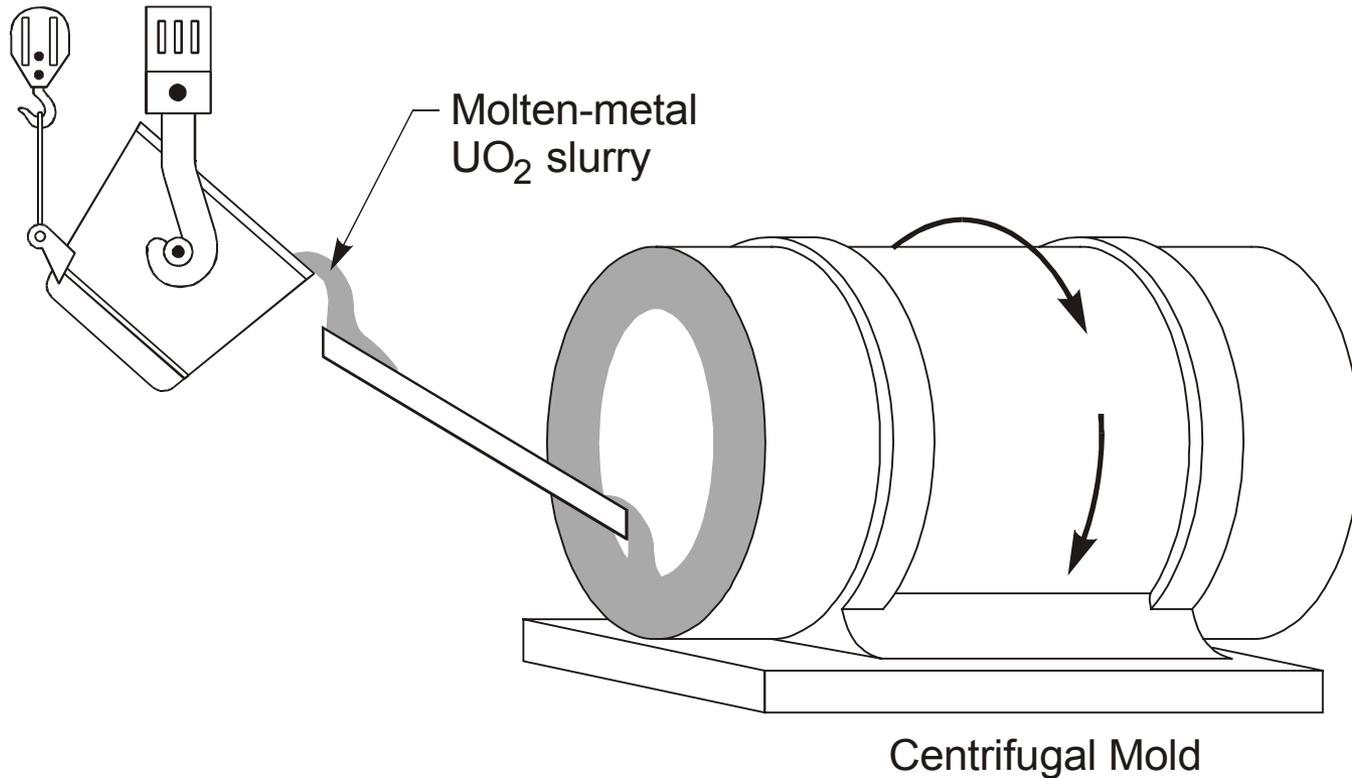
# Cermet Manufacturing

# “Picture-Frame” Method for Cermet Production

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



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



# The United States Has More Than 600,000 Tons of Excess DU: Cermets May Allow Beneficial Use



# Conclusions

- **DUO<sub>2</sub>-steel cermet multipurpose casks may create a new approach to SNF management**
- **Cermets are an enabling technology**
  - **Armor: hard brittle ceramics with ductile metal**
  - **Shielding: ceramic DUO<sub>2</sub> with ductile metal**
  - **Repository: sacrificial material**
- **Manufacturing methods allow cermets to be made with a wide variety of ceramics and metals**