Transportation Program
DOE Used Fuel Disposition Campaigns Session

INMM Spent Fuel Management Seminar

Crystal Gateway Marriott, Arlington Virginia
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Paul McConnell
Sandia National Laboratories
pemccon@sandia.gov

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MICROFICHE

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Considerations Applicable to the Transportability of a Transportable Storage Cask at the End of the Storage Period

T. L. Sanders, C. A. Ottinger, J. L. Brimhall, J. M. Creer, E. R. Gilbert, R. H. Jones, P. E. McConnell

Prepared by
Sandia National Laboratories
Albuquerque, New Mexico 87185 and Livermore, California 94550
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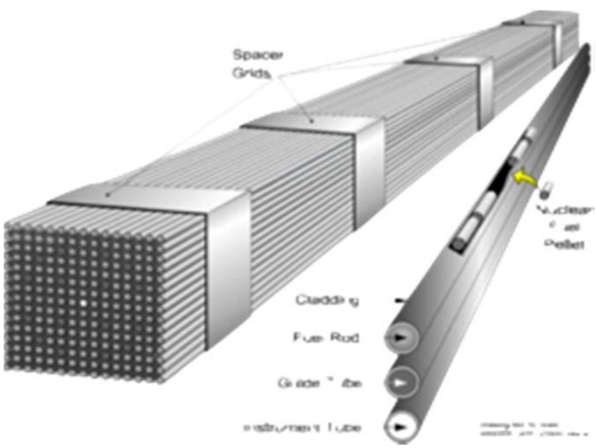
204 p.

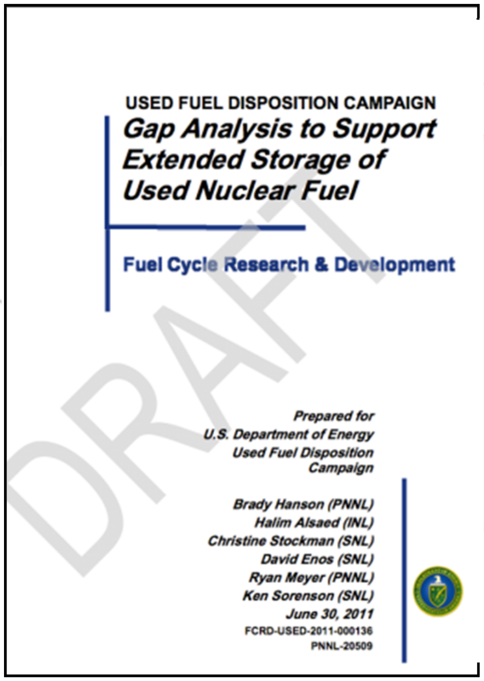
Déjà vu

Safety issues for storage and transport of used fuel

What will be the materials state 10 / 20 / 100 years from now ?

⤷ Clad / Canister / Cask must retain integrity during handling, storage, and transportation




USED FUEL DISPOSITION CAMPAIGN

Gap Analysis to Support Extended Storage of Used Nuclear Fuel

Fuel Cycle Research & Development

DRAFT

Prepared for
U.S. Department of Energy
Used Fuel Disposition Campaign

Brady Hanson (PNNL)
Halim Alsaed (INL)
Christine Stockman (SNL)
David Enos (SNL)
Ryan Meyer (PNNL)
Ken Sorenson (SNL)
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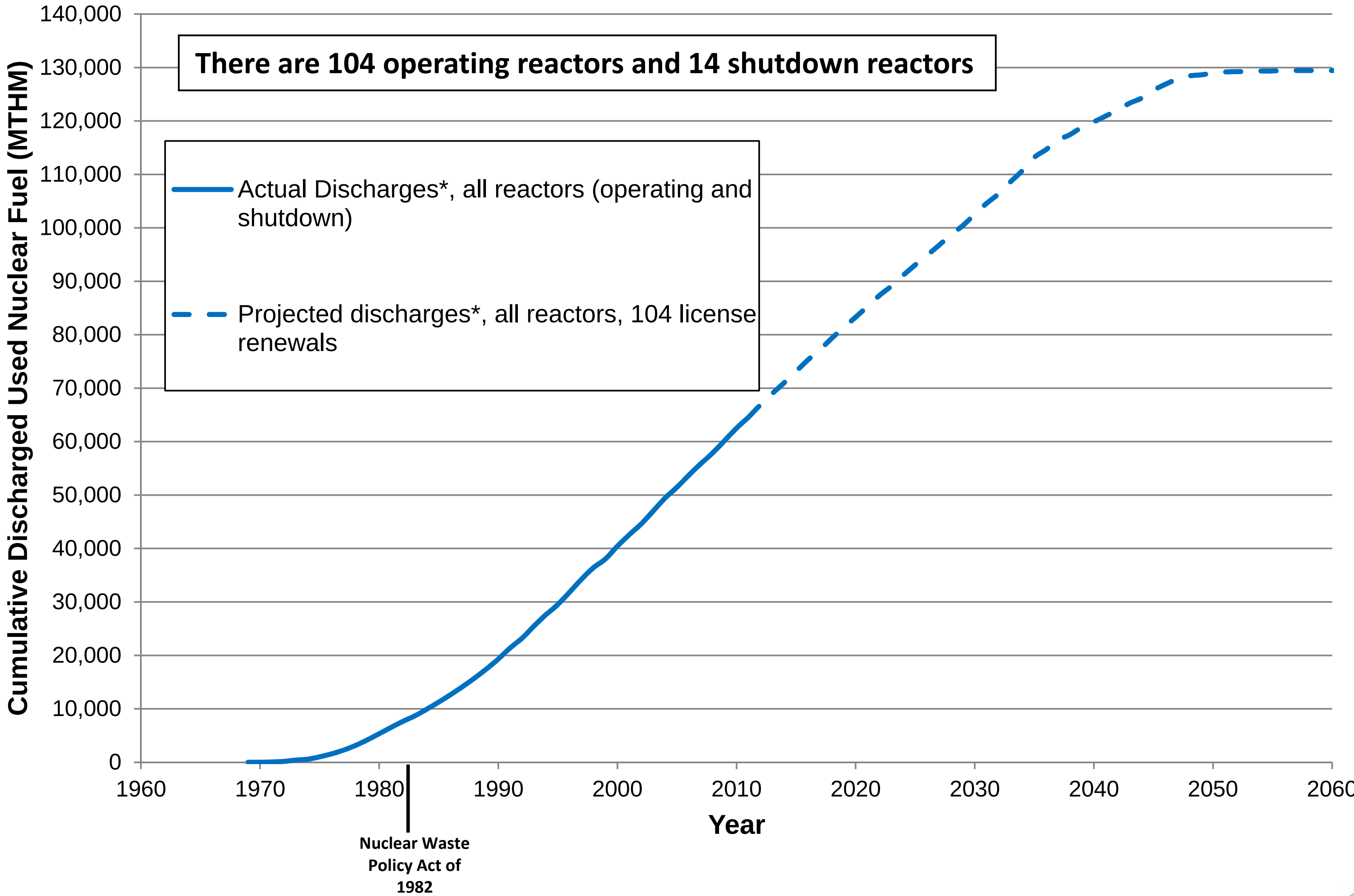
FCRD-USED-2011-000136
PNNL-20509

Table S-1. Summary of High- and Medium-Priority Degradation Mechanisms That Could Impact the Performance of Structure, System, and Components (SSCs) During Extended Storage

SSC	Degradation Mechanism	Importance of R&D	Approach to Closing Gaps
Cladding	Annealing of radiation damage	Medium	Long-term, low temperature annealing will be analyzed through advanced modeling and simulation with some experimental work to support the model.
	H_2 effects: embrittlement and reorientation	High	A comprehensive experimental and modeling program to examine the factors that influence hydride reorientation will be performed, with a focus on new cladding materials and high burnup fuels. Additional experimentation and modeling to provide the link between unirradiated and irradiated cladding performance will be initiated.
	H_2 effects: delayed hydride cracking	Medium	Experimental work combined with modeling will be initiated.
	Oxidation	Medium	Experimental work to determine the mechanism for the rapid cladding oxidation observed will be initiated.
	Creep	Medium	Long-term, low-temperature, low-strain creep will be analyzed through advanced modeling and simulation with some experimental work to support the model.
Fuel Assembly Hardware	Corrosion (stress corrosion cracking)	Medium	Because the fuel assembly hardware components of concern are the same or similar to those that also serve as a cladding, cladding tests and analyses will be utilized. Collaboration will be initiated with the Disposal task within the UFDC performing corrosion testing on similar materials.

Courtesy Remi Dingreville/SNL

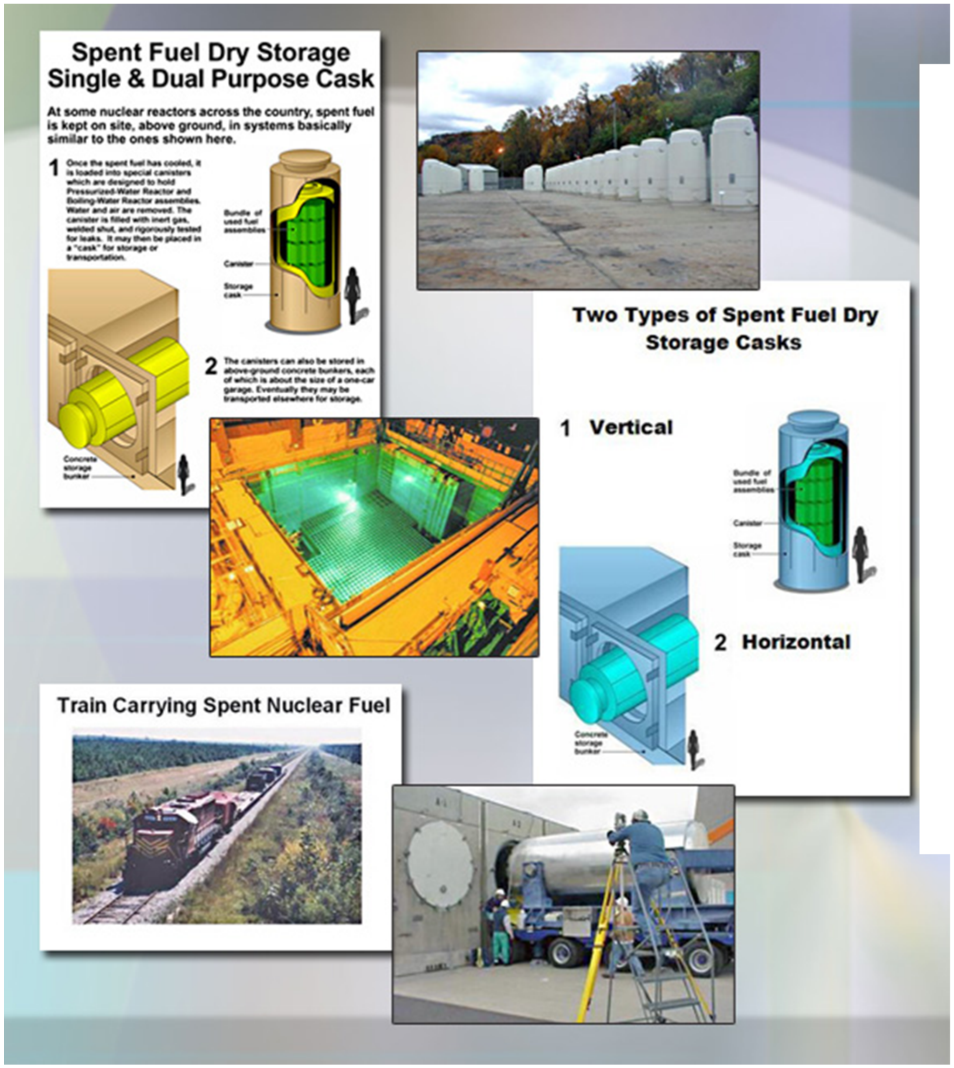
Historical and Projected Commercial Spent Nuclear Fuel Discharges



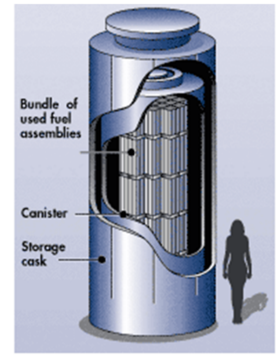
*Based on actual discharge data as reported on RW-859s through 2002, and projected discharges for 104 license renewals

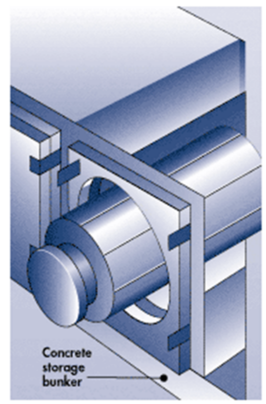
Courtesy Jeff Williams/DOE

Dry Storage Systems



Some canisters are designed to be placed vertically in robust above-ground concrete or steel structures.





Some canisters are designed to be stored horizontally in above-ground concrete bunkers, each of which is about the size of a one-car garage.

Courtesy NRC

DRY FUEL CANISTER CASKS

CASK VENDOR	CANISTER Type	NUMBER OF CANISTERS (12/2011)	TRANSPORT CASK(S)	NUMBER OF FABRICATED TRANSPORT CASKS
FUEL SOLUTIONS	W150	8	TS-125	0
	VSC-24	58	None-Storage Only	-
TN (NUHOMS)	24PT1, 24PT4 24PT	68	MP-187/MP-197HB	1 / 0
	7P, 12T, 24P **24PHB[1], 32P[1]**, 52B	258	None-Storage Only	-
	24PTH, 32PT, 32PTH 61BT, 61BTH	263	MP-197/MP-197HB	0 / 0
NAC	MPC-26, MPC-36	59	NAC-STC	2[2]
	UMS-24	204	NAC-UMS	0
	TSC-37	0	NAC-MAGNATRAN	0
HOLTEC	MPC-24[3], MPC-32 MPC-68, MPC-80	439	HISTAR 100	12

[1] Still being loaded as of 12/2011, All others "Storage Only" canisters have not been loaded in at least the last five years
[2] NAC-STC Casks Fabricated for Offshore Use Only
[3] Includes Trojan 24E/EF

Courtesy Dan Leduc/SRNL & Jeff Williams/DOE

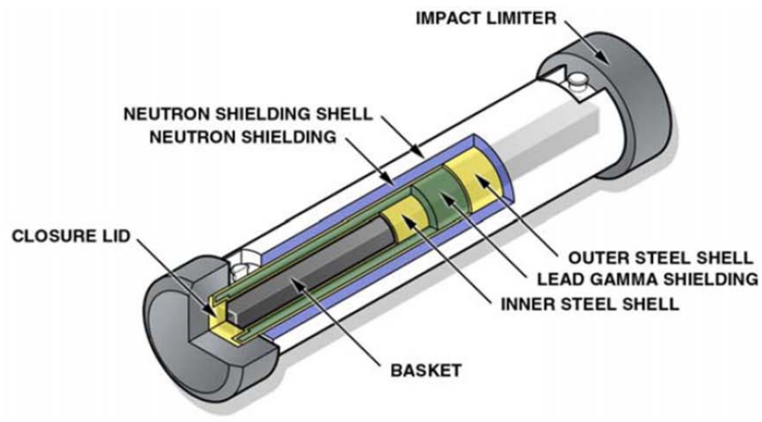
BARE FUEL DRY STORAGE CASKS

	VENDOR	CASK	NUMBER OF CASKS (12/2011)	TRANSPORT LICENSE	LOCATION
ACTIVE CASKS (STILL LOADED)	TN	TN-68	53	71-9239	Peach Bottom
		TN-40	29	71-9313	Prairie Island
LEGACY CASKS (NO LONGER LOADED)	TN	TN-32	63	NO	Surry, McGuire, North-Anna
	GNB	CASTOR V21&X33	26	NO	Surry
	NAC	I-28	2	NO	Surry
	Westinghouse	MC-10	1	NO	Surry

Courtesy Dan Leduc/SRNL & Jeff Williams/DOE

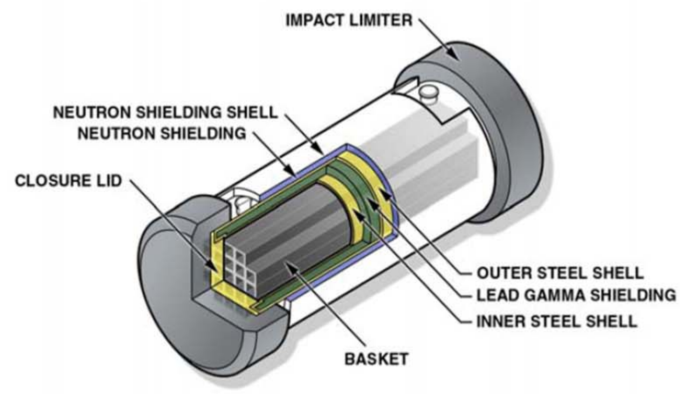
Transportation Casks

TYPICAL SPENT FUEL TRANSPORTATION CASKS



Generic Truck Cask for Spent Fuel

<u>Typical Specifications</u>
Gross Weight (including fuel): 50,000 pounds (25 tons)
Cask Diameter: 4 feet
Overall Diameter (including Impact Limiters): 6 feet
Overall Length (including Impact Limiters): 20 feet
Capacity: Up to 4 PWR or 9 BWR fuel assemblies



Generic Rail Cask for Spent Fuel

<u>Typical Specifications</u>
Gross Weight (including fuel): 250,000 pounds (125 tons)
Cask Diameter: 8 feet
Overall Diameter (including Impact Limiters): 11 feet
Overall Length (including Impact Limiters): 25 feet
Capacity: Up to 26 PWR or 61 BWR fuel assemblies

Courtesy NRC

UFD Transportation – Priorities

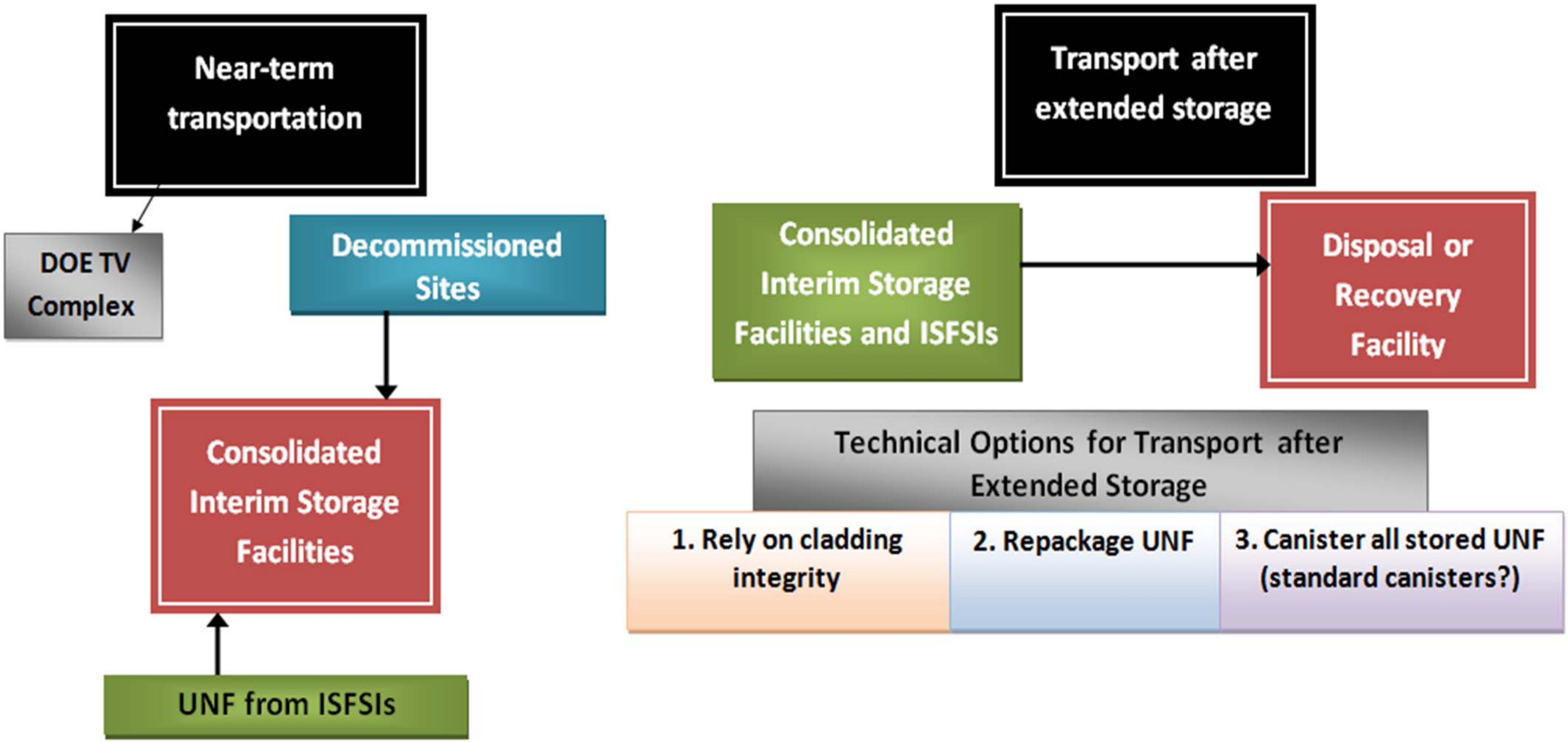
- **<u>Near term</u>: transport of selected fuel rods to support possible off-site testing.**

- **<u>Medium term</u>: possible transport of UNF from Independent Spent Fuel Storage Installations to Consolidated Interim Storage Facilities.**
  - **Key transportation emphasis:**

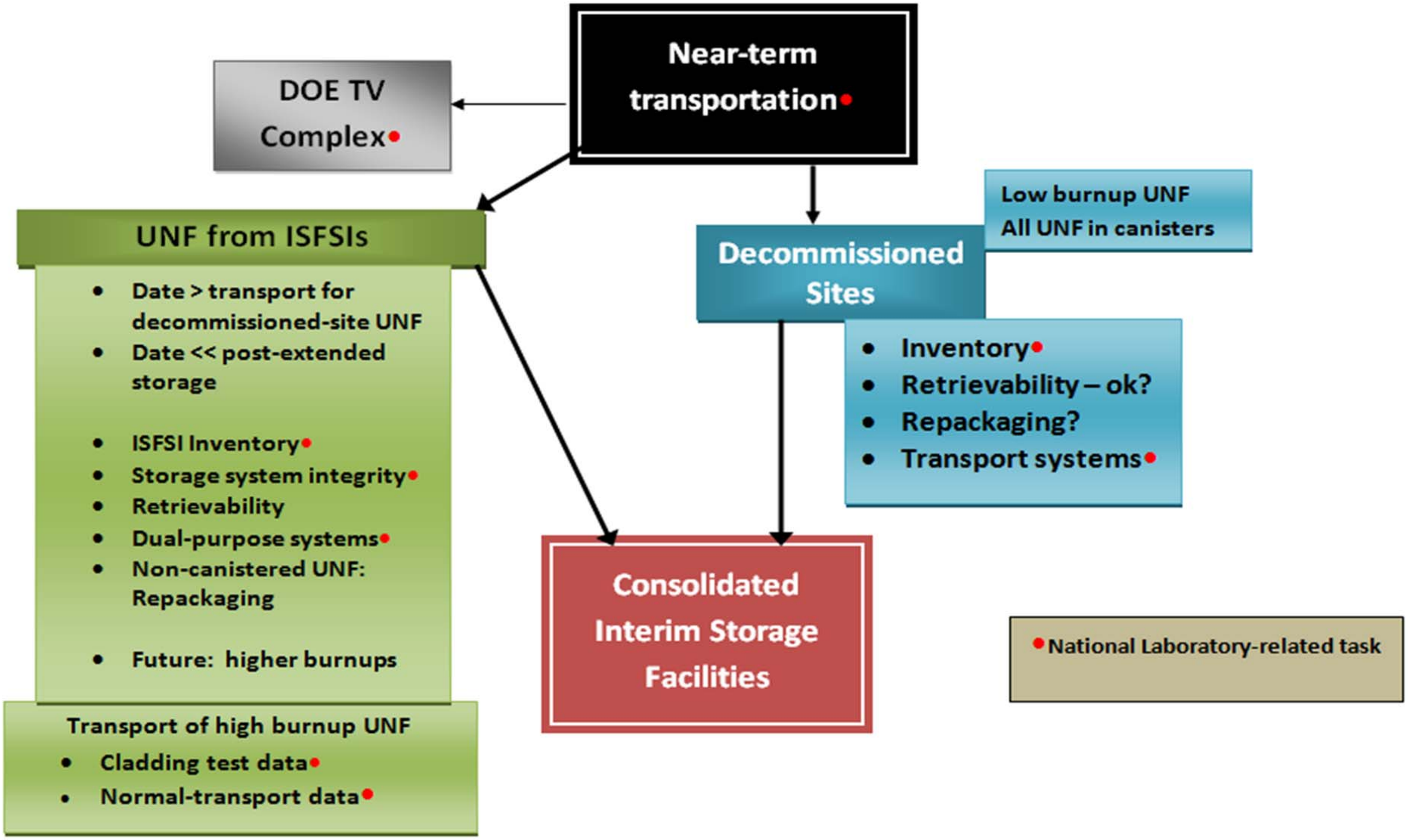
    Inventory of UNF in dry storage and transfer / transport systems available
    Are storage canisters currently transportable?
    Repackaging? Standard canisters?
    Are transfer systems / transport casks available?
    Dual-purpose casks transportable?
    Decommissioned sites "first"

- **<u>Long term</u>: transport of used nuclear fuel after extended storage**
  - **Key transportation emphasis for R&D:**
    - **UNF may be degraded after extended storage.**
    - **Canisters may be degraded.**
    - **Retrievability issues must be addressed.**
    - **Evaluation of "off-ramps" to mitigate full-spectrum of testing requirements**

Possible Transportation Campaigns



Possible "near-term" transportation campaigns and issues

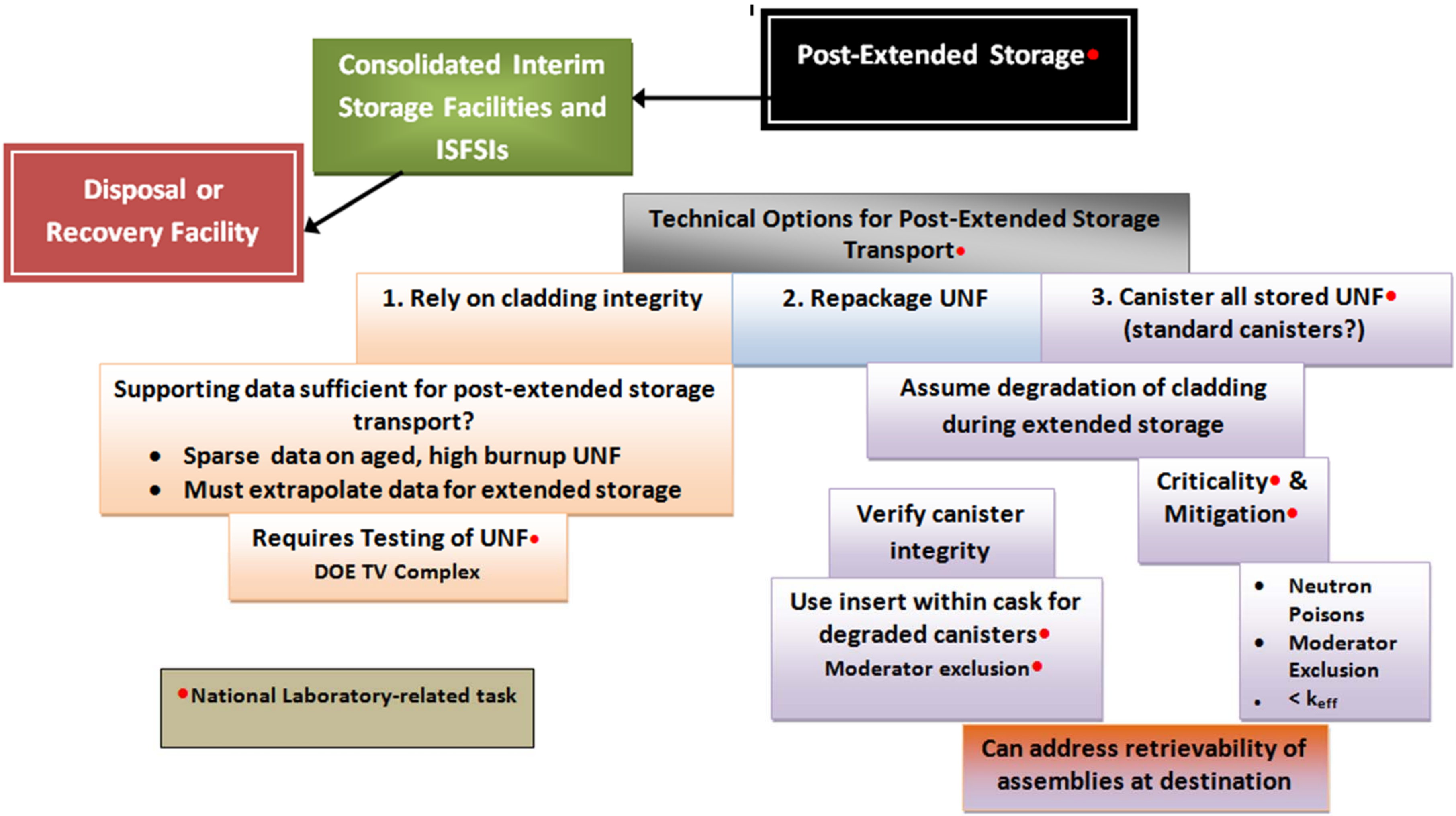


One potential scenario requiring near-term transport of UNF

Regional / centralized interim storage

Decommissioned UNF first

Post-extended storage transportation: issues and options



Options for post-extended storage transportation

Identify advantages and disadvantages of the following options for the post-storage handling of UNF assemblies prior to transport.

1. **Develop the technical bases for the assertion that UNF *cladding and canisters* shall be *intact* after extended storage:**
   – Thermal performance
   – Radiological performance
   – Confinement
   – Sub-criticality
   – Retrievability

Technical Bases for Post-Extended Storage Transport OPTIONS		
1. Cladding / canister integrity	2. Repackage	3. Canister all stored UNF

2. ***Repackage* UNF assemblies prior to transport into new canisters.**
3. ***Canister* all future UNF assemblies prior to storage in transportable canisters.**
   – Provide criticality mitigations within canisters (assume UNF will degrade).
   – "Canister" canisters if they are degraded after extended storage.

FY11 Transportation activities (1)

Developed database of UNF currently dry stored

- **Exactly how much fuel is stored at each ISFSI and at the** decommissioned sites**?**
- **How is the fuel packaged – bare within dual-purpose casks; canisters**
- **What UNF would require repackaging prior to transport? Are the canisters transportable?**
- **What transfer systems and transport casks would be used to transport UNF?**
- **Inventory existing dual-purpose casks being used for dry storage that may be used for transportation in the future – which d-p casks do we need to assess for degradation mechanisms should they ever be used for transport?**

U.S. Dry Storage Details (12/22/2012)

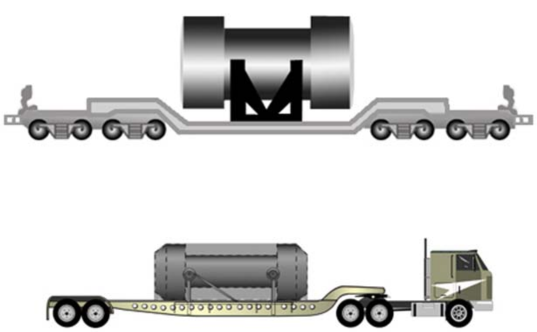
Utility	Reactor	Type	License Type	Year of First Load [14]	Vendor	Cask System	Canister or Cask Type	Total Canisters or Casks Loaded	Assemblies Stored	Storage Configuration	Primary Canister Transportation Cask (License Num.)	Primary Transport Cask Fabricated?	Alternative Canister Transportation Cask	Alternate Transport Cask Fabricated?	Bare Fuel Cask Transportation License (License Number)	"Storage Only" Canisters	Minimum Lead Time for Shipment

FY11 Transportation activities (2)

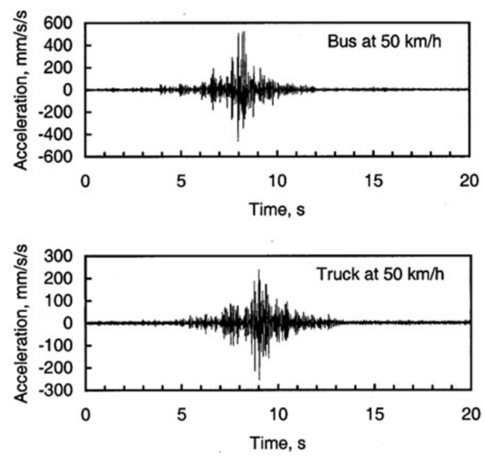
Test plan for obtaining energy input to cask internals during normal transport.

UNF may degrade during very long term storage or high burnup. It is important to know what forces cladding is subjected to under **normal transport conditions** ***to justify transport after extended storage.***

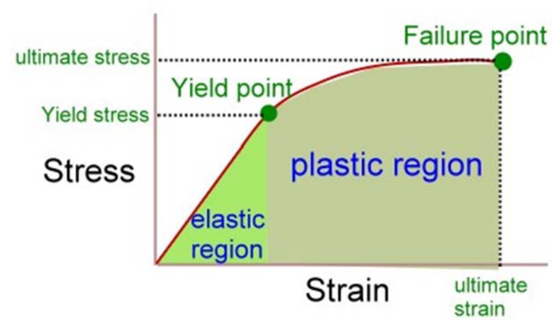
Compare applied loads and cladding material properties



vibrations



cladding properties



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FY11 Transportation activities (3)

Generated a set of Features, Events, and Processes tables that apply to transportation.

The Storage Work Package prepared a report that listed Features, Events, & Processes for very long-term stored used nuclear fuel.

The *Importance of R&D* for some FEPs is higher for Transportation than for Storage, e.g., canister weld integrity.

Pacific Northwest NATIONAL LABORATORY

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FY11 Transportation activities (4a)
Criticality analyses

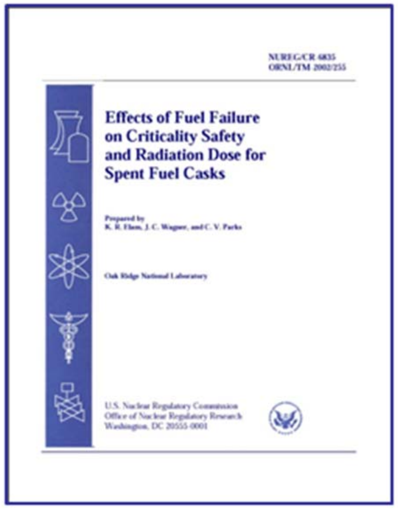
- **Relevant observations and points**
  - **Most UNF is, and will be, stored in multi-assembly canisters.**
  - **There is no assurance (data) that UNF and baskets will not be degraded after very long term storage.**
  - **This lack of assurance exists regardless of aging-study R&D conducted on UNF, including high burnup UNF, in the near future due to uncertainty in extrapolating test results to long periods of storage.**

- **If it can be assured that UNF within canisters will remain subcritical under all credible conditions after extended storage, there would be no need to open the canisters after extended storage prior to transportation.**

Degradation of UNF during extended storage may not preclude transportation.

FY11 Transportation activities (4b)
Criticality analyses

Analyses performed to quantify the increase in reactivity associated with fuel reconfiguration in multi-assembly canisters.


NUREG/CR 6835
ORNL/TM 2002/255

Effects of Fuel Failure on Criticality Safety and Radiation Dose for Spent Fuel Casks

Prepared by
K. R. Elam, J. C. Wagner, and C. V. Parks

Oak Ridge National Laboratory

U.S. Nuclear Regulatory Commission
Office of Nuclear Regulatory Research
Washington, DC 20555-0001

The condition of the UNF for these analyses encompasses a range of damaged conditions.

Options for mitigating the increase in reactivity due to fuel reconfiguration will be investigated.

Mitigation options include:

- Safety analyses performed for a $k_{eff} \leq 0.95 - \Delta k_{reconfig}$
  - where $\Delta k_{reconfig}$ = the maximum possible reactivity increase
  - due to fuel reconfiguration.
- Package design modifications.
- Use of control rods or burnable poison rod assemblies in the fuel assemblies.
- Crediting inherent margins /conservatisms, including credit for burnup and cooling time in the safety analyses, perhaps moderator exclusion.

FY11 Transportation activities (5)

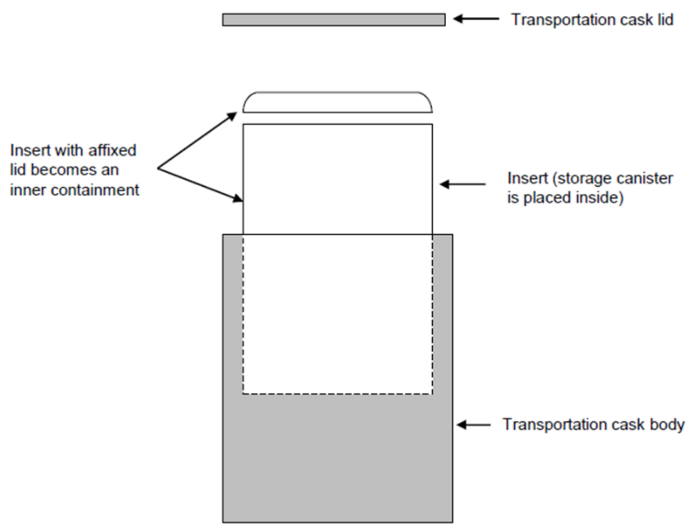
Moderator exclusion: technical basis and process for transport.

This is an alternative to trying to justify the integrity of cladding after very long-term storage or implementing criticality control mitigations.

Provide a separate component inside of a transportation cask to perform the watertight function needed to achieve moderator exclusion ensuring no single packaging error would permit in-leakage of moderator

Inner component can be physically leak tested to demonstrate its watertight containment function

This concept is believed to satisfy the conditions of 10 CFR 71.55(c)



Courtesy Keith Morton/INL

Idaho National Laboratory

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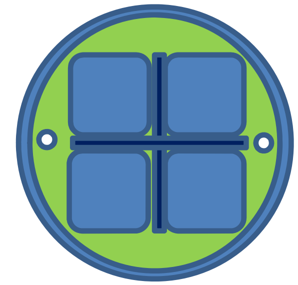
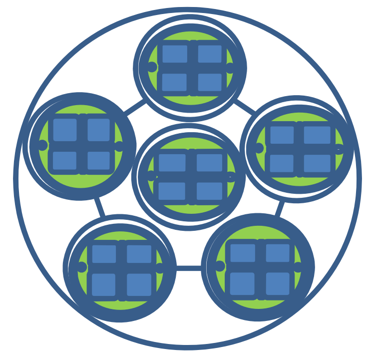
Integrated Canister-in-Canister Concept (example from ORNL)

Flexible Integrated Modular Nuclear Fuel Storage, Transportation, and Disposal Canister System (FIRST)

- Multi-modal use and flexibility in all operations while working within existing utility framework
- Unique design features to accommodate future, current, and past proposed disposal concepts
- Allows direct disposal (similar to YMP TAD concept)
- Many secondary benefits
  - *Including improved characteristics to accommodate extended storage*
- Repackaging could be done at a consolidated interim storage facility

Small canister provides flexible disposal options





Small canisters in larger canister for storage and transportation

Courtesy Jeff Williams/DOE

FY12 Transportation Priorities

Proceed with a test program to measure the response of UNF cladding to actual loadings imposed during normal conditions of transport.

Identify criticality mitigation measures for degraded fuel rods contained within storage canisters.

Continue moderator exclusion efforts – engage the NRC.

Thermal analyses of degraded used nuclear fuel in canisters.

Identify issues related to dry repackaging of bare UNF at ISFSIs into canisters or transportation containers.

Maintain database of UNF in dry storage. Include dry transfer concepts for canistered fuel with emphasis on decommissioned sites.

ASME and IAEA collaborations.

DOE System Architecture Evaluation for UNF Management

- **The Blue Ribbon Commission on America's Nuclear Future July 29 draft report to the Secretary of Energy recommends prompt efforts be undertaken to develop one or more consolidated storage facilities and one or more geological facilities.**

- **The Nuclear Waste Technical Review Board has provided input and comments to the BRC recommending that a "systems" approach to radioactive waste management be undertaken when considering consolidated interim storage of used nuclear fuel.**

- **The U.S. DOE has initiated system-level analyses of the back-end of the nuclear fuel cycle pertaining to the management of used nuclear fuel from the current LWR fleet.**

Courtesy Jeff Williams/DOE

UNF Management System Architecture Evaluation Current Work

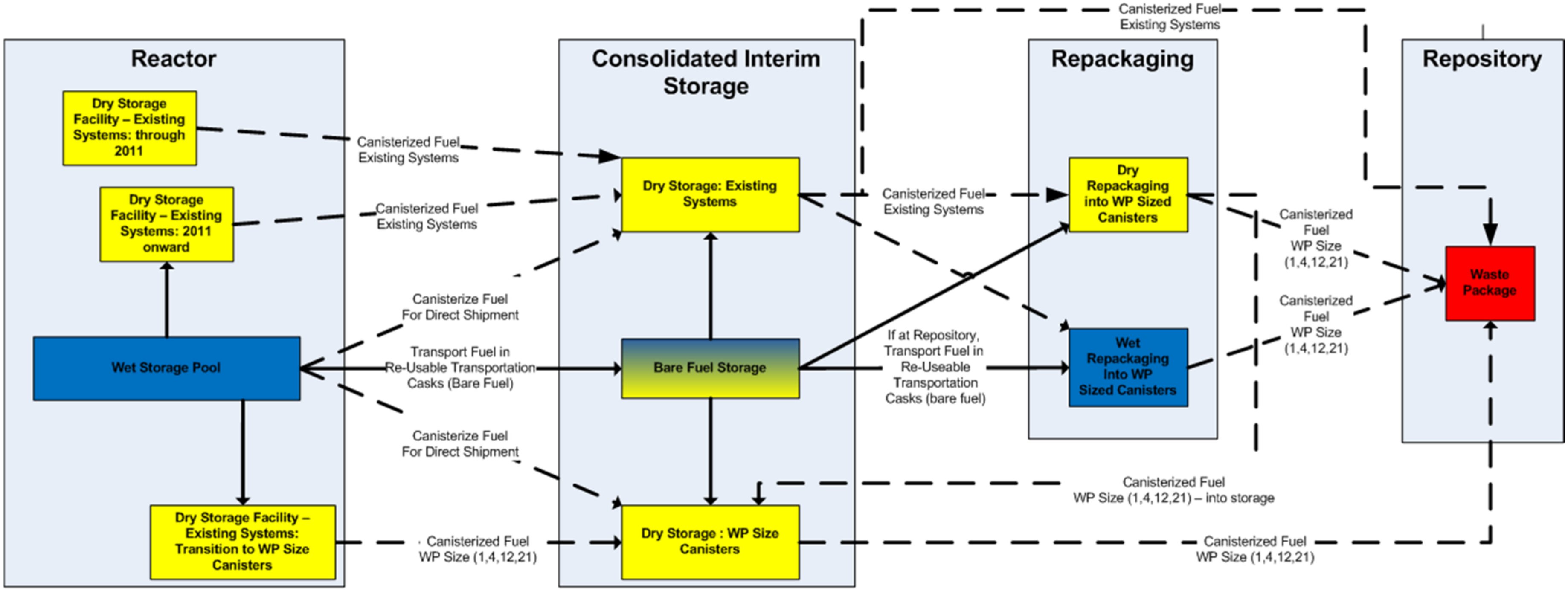
- **Evaluate an integrated approach to transportation, storage, and disposal in the waste management system.**

- **Evaluate the implications of the current strategy for on-site storage of used nuclear fuel in large dry storage systems on the subsequent direct disposal of the stored used nuclear fuel in salt, clay/shale, and crystalline mined geologic repositories and in deep boreholes.**

- **Factors including emplacement capability, thermal constraints, the need for re-packaging techniques, storage alternatives, transportation, impacts on utility operations, etc. will be considered**

Courtesy Jeff Williams/DOE

System Architecture Evaluation



At-Reactor Fuel Management: Sub-Case Options

1. Wet Storage Fuel Management
   - 1a. Transfer to dry-storage to maintain full core off-load capability
   - 1b. Accelerate transfer to dry storage (age ≥ 5 yr)
2. Continue off-loading of fuel in wet storage pools into existing sized dry storage systems
3. Initial off-loading of fuel in wet storage pools into existing sized dry storage systems – transition to WP-sized dry storage system at T = 20xx.
4. Transport all fuel in wet storage pool to ISFSI (when operational and has wet storage pool) in re-useable transportation casks
5. Canisterize fuel in wet pool for direct shipment to ISFSI (when operational and does not have a wet storage pool)
   - 5a. Existing dry storage systems
   - 5b. WP-sized dry storage systems (1,4,12,21)

CIS Fuel Management: Sub-Case Options

1. Bare fuel storage capability at CIS
   - 1a. Maintain fuel in bare storage
     - 1a-1. Wet storage pool
     - 1a-2. Bare fuel vault
   - 1b. Transfer to existing dry storage systems
   - 1c. Transfer to waste package compatible sized canisters
2. Re-packaging locations
   - 2a. Direct disposal of Canisters
   - 2b. At CIS
     - 2b-1. At receipt
     - 2b-2. Prior to transport to repository
   - 2c. At repository
3. Re-packaging technology alternatives
   - 3a. Wet
   - 3b. Dry
4. Received fuel at CIS in existing dry storage system sized canisters
   - 4a. Store as-is
   - 4b. Repackage into waste package compatible size canisters and store

Courtesy Jeff Williams/DOE

Used Nuclear Fuel:
Transportation, Storage, Disposal Logistic Simulation

- **The DOE Office of Civilian Radioactive Waste Management developed transportation, storage, and disposal simulation tools**
  - CRWMS Analysis and Visually Interactive Model – CALVIN
  - Transportation Operations Model – TOM
  - Total System Model – TSM

- **Development stopped in 2009 and existing tools are reflective of the used nuclear fuel management system in place at that time**

- **Efforts underway to update and modify the existing software (CALVIN and TOM) to support used nuclear fuel management analyses (i.e., the UFD System Architecture Study)**

- **Tool development and UFD System Architecture Study are closely integrated**

Courtesy Jeff Williams/DOE

Transportation: Collaborative Activities and Interactions

- **Industry**

EPRI Electric Power Research Institute

NEI NUCLEAR ENERGY INSTITUTE

ASME SETTING THE STANDARD

- **Government organizations and advisory groups**

DOE NRC NWTRB NEAC

- **International**

IAEA International Atomic Energy Agency Atoms for Peace