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U.S. DEPARTMENT OF ENERGY | Nuclear Energy

Performance Modeling Activities in the Used Fuel Disposition Campaign

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Interagency Steering Committee on Multimedia Environmental Modeling

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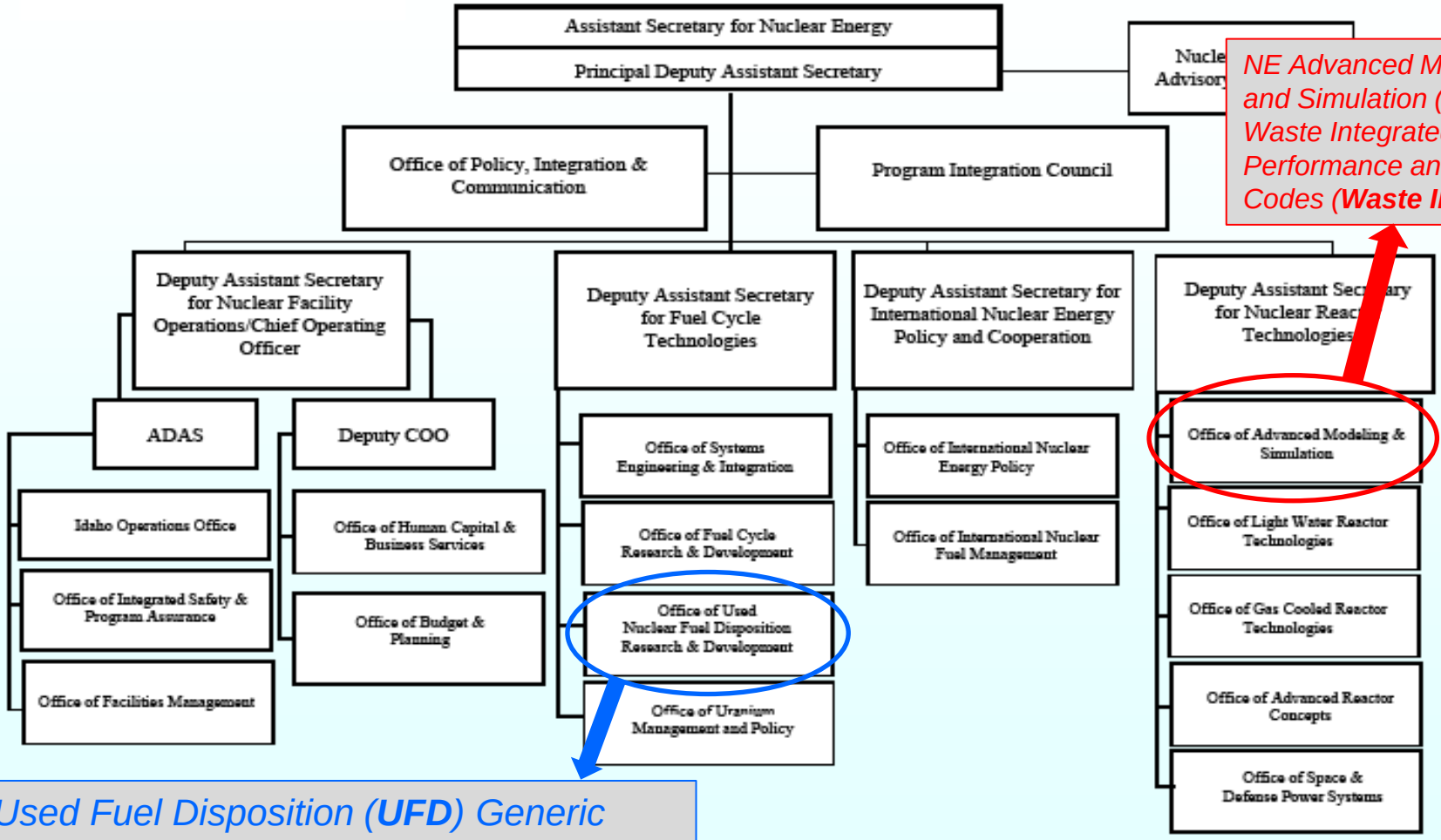
UFD Performance Modeling Activities: Outline

- **Generic Disposal System Model development**
  - Generic Performance Assessment Model (GPAM)
- **System engineering approach**
- **Reference geologic disposal concepts for assessment**
- **Waste types for disposal**
- **Integrated software environment (“framework”)**
- **Transportation-storage-disposal logistics**

U.S. DEPARTMENT OF ENERGY
Nuclear Energy

DOE Office of Nuclear Energy: Disposal Performance Modeling Activities

Effective as of July 17, 2011



*NE Advanced Modeling and Simulation (**NEAMS**), Waste Integrated Performance and Safety Codes (**Waste IPSC**)*

*Used Fuel Disposition (**UFD**) Generic Performance Assessment Modeling*

UFD Performance Modeling Activities: Technical Problem Statement

- **Apply lessons learned**
- **Range of generic (non-site specific) disposal concepts**
  - *Waste form types*
  - *Geologic settings*
  - *Engineering concepts of operation*
  - *Range of time scales and distances*
- **Appropriate consideration of uncertainty**
- **Implement high-performance computing (HPC) for multi-physics coupling**
- **Robust software quality requirements**
- **Change control & centralized data management**

Re-develop disposal system PA "from the ground up"

Used Fuel Disposition

Generic PA Modeling Timeline

- **Near-term (2-3 yr)**
  - Simplified system models specific for disposal concepts, but non-site specific (we are currently using GoldSim)
  - Limited multi-physics coupling
  - Centralized computational database & change control; web-based accessibility
  - Concept evaluation & integration with logistics and option studies
- **Intermediate time horizon (~5 yr)**
  - Fully implement advanced multi-physics (i.e., HPC)
- **Longer time horizon (5-10 yr)**
  - Site specific assessments
  - QA for transportation-storage-disposal system licensing

R&D (UFD campaign & other DOE and inter-national projects):

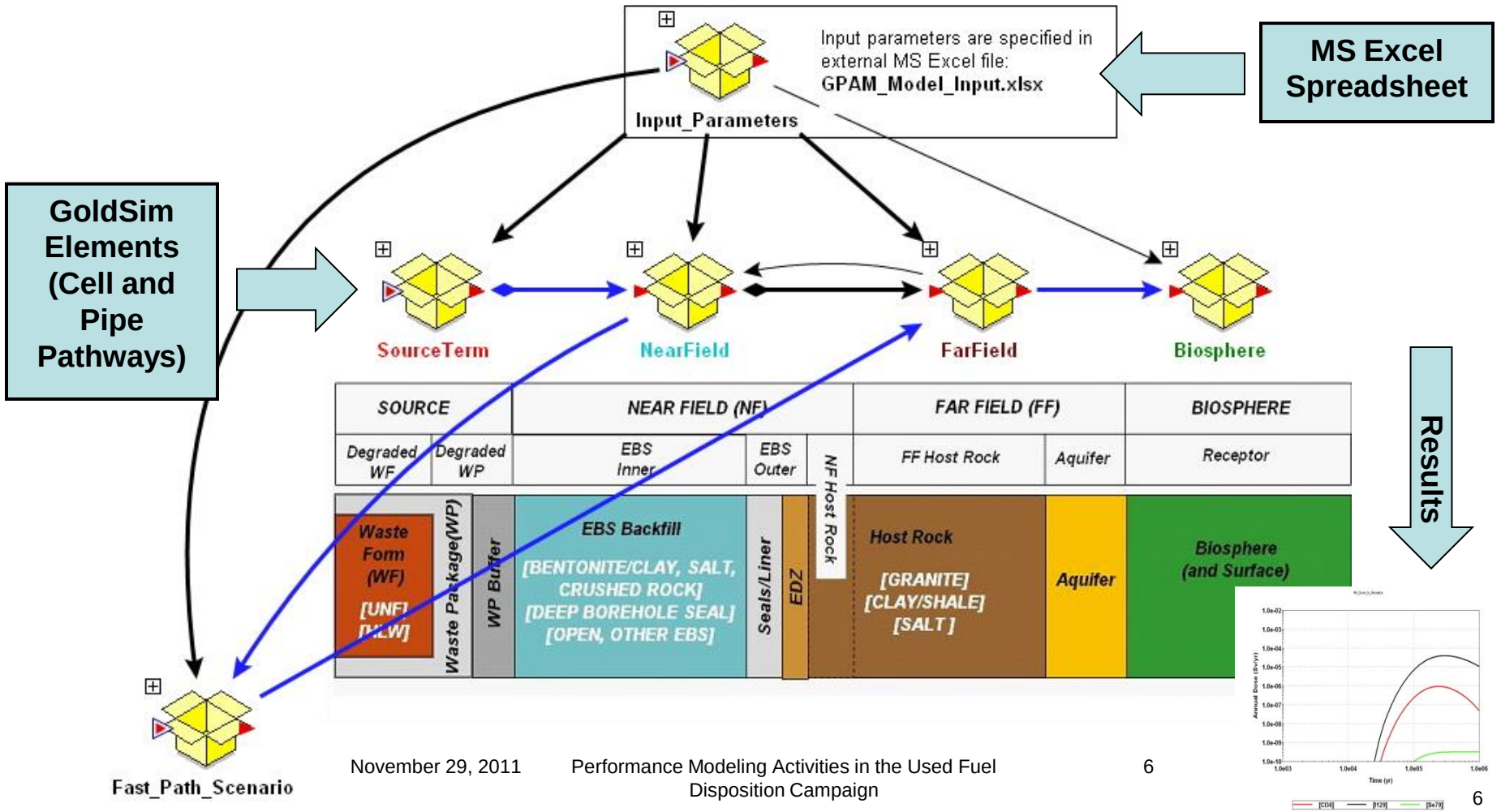
- Ongoing, multi-year
- Informs process and PA model development

Generic PA models will support programmatic decisions:

- Waste management system engineering studies
- Transportation-storage-disposal logistics
- Fuel-cycle option studies

Generic PA Model (GPAM) Implementation for SNF/HLW

- GPAM implemented in GoldSim for "generic" application (FY11)

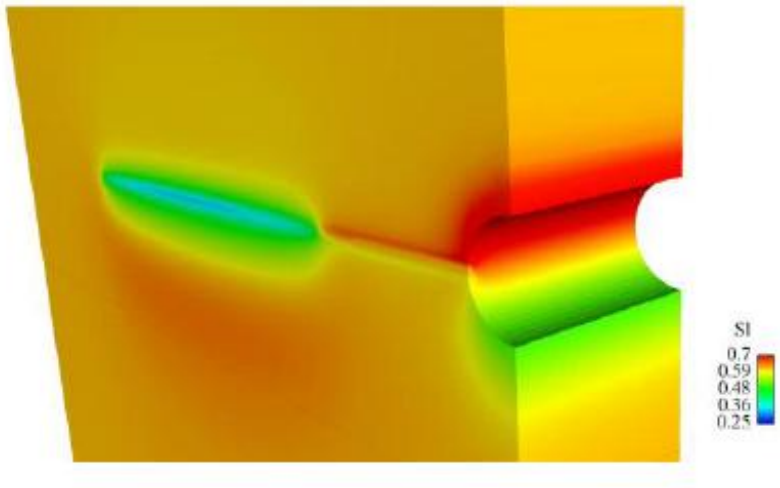


Generic Disposal System Model Development Approach (Ongoing)

- **Generic Disposal System Model requirements**
- **GPAM architecture development**
  - Spatial domains and connectivity
- **Process mapping (FEPs)**
  - Select processes and domains for sub-models
  - Apply multi-physics simulation
  - Incorporate new sub-models (e.g., corrosion, waste form degradation) in spatial-temporal framework
- **Conceptual/mathematical model development**
- **Deploy centralized computational database & integrated software environment (“framework tool”)**
- **Numerical implementation (i.e., HPC)**

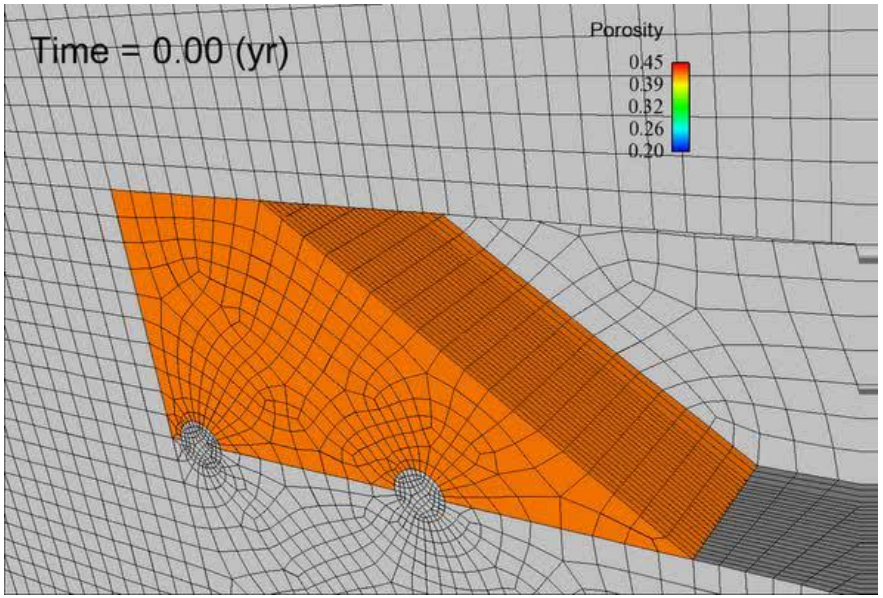
PA Modeling from an HPC Perspective: Nuclear Energy Advanced Modeling & Simulation (NEAMS) Objectives

- Coupled continuum models (e.g., SIERRA Mechanics) are under development for inclusion in the Waste Integrated Performance Safety Code (IPSC) for NEAMS



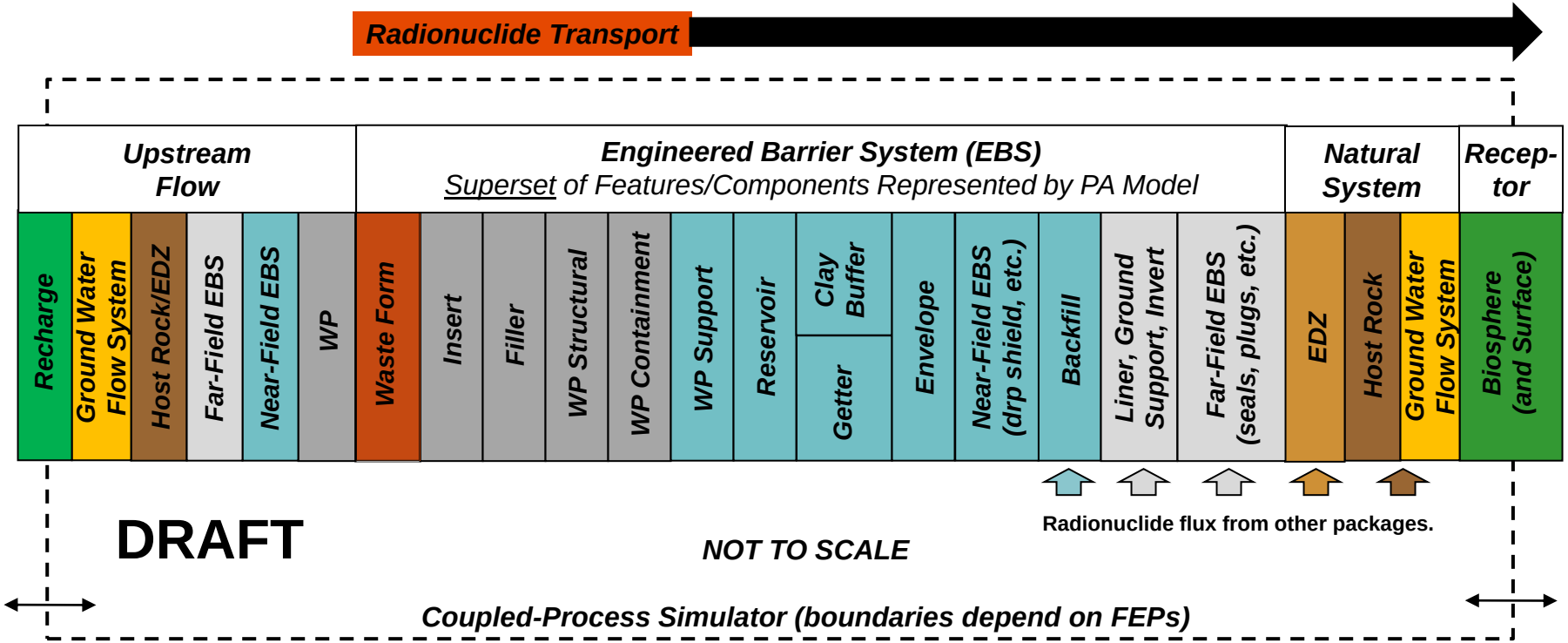
THM in a clay repository

TM in a salt repository



Generic Disposal System Postclosure Architecture

- Engineered and natural barrier components = model sub-domains
- Map processes from generic list of features, events & processes (FEPs)

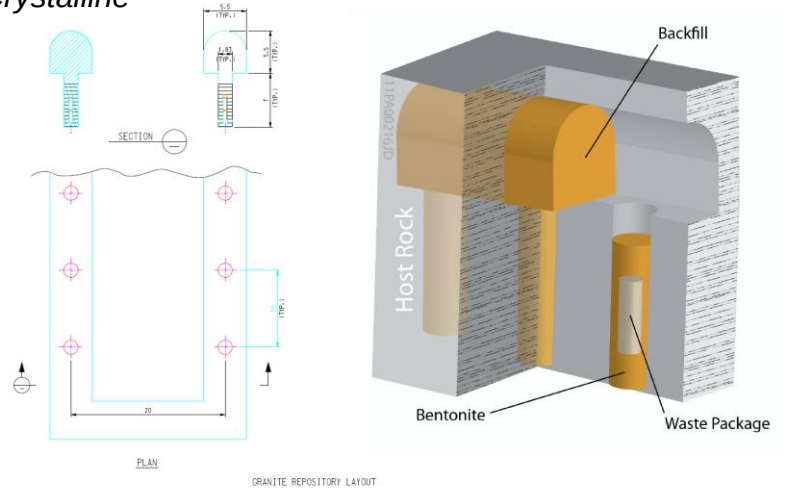


Vaughn et al. 2011. *Generic Disposal System Modeling-Fiscal Year 2011 Progress Report*. Sandia National Laboratories, SAND2011-5828P.

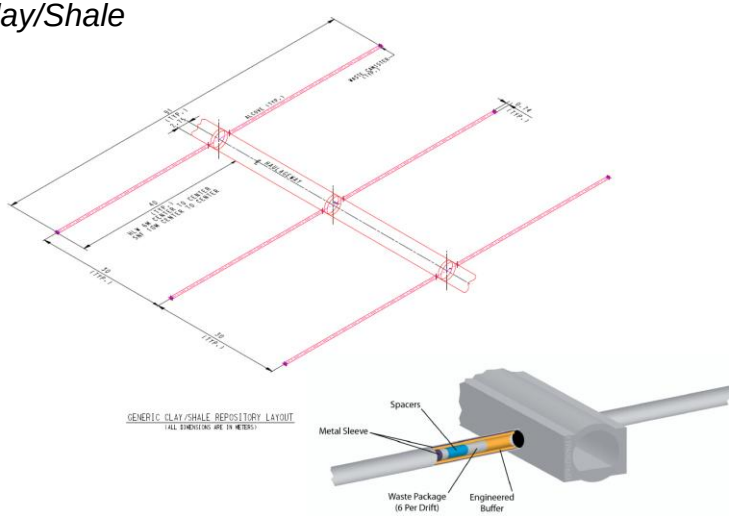
Reference Disposal Concepts

Hardin et al. 2011. *Generic Repository Concepts and Thermal Analysis (FY11)*. Sandia National Laboratories, SAND2011-6202.

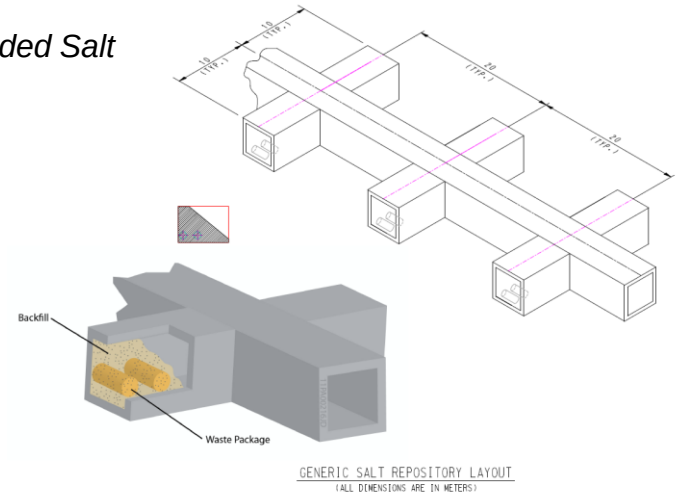
Crystalline



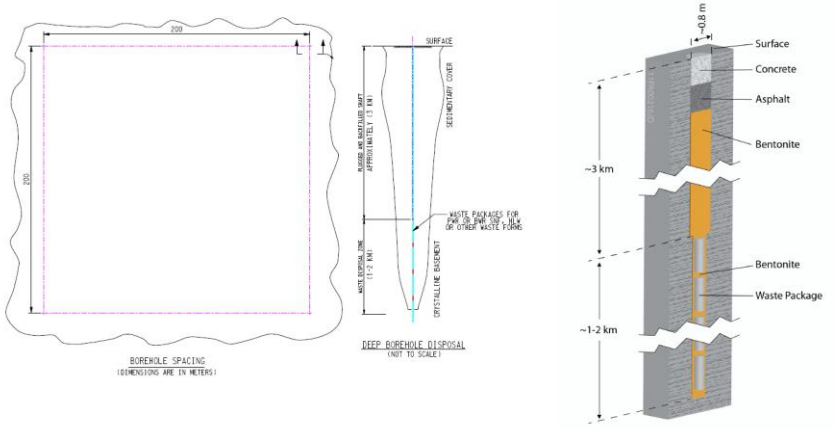
Clay/Shale



Bedded Salt



Deep Borehole



Reference Disposal Concepts and Waste Types for Generic Modeling

- **Reference HLW-SNF disposal concepts (FY11)**
  - Mined (crystalline rock, clay/shale media, bedded salt)
  - Deep borehole
- **Six heat-producing waste types (FY11; see note)**

Case	Waste Generating Process	Burnup (GW-d/MT)	Waste Type	Elemental/Isotopic Content
1	Direct disposal	60	**UOX SNF**	All components of LWR UOX UNF
2	COEX[a] reprocessing of LWR UOX UNF	51	**Borosilicate HLW Glass**	All comps. of LWR UOX UNF except Pu
	Direct disposal	50	**Pu-MOX SNF**	All components of Pu-MOX UNF
3	Aqueous reprocessing of LWR UOX UNF (New extraction[b] method)	51	**Borosilicate HLW Glass**	All comps. of LWR UOX UNF except TRU
	Electrochemical reprocessing of fast-reactor metal fuel	100	**Bonded Zeolite ("ceramic")**	Fission products and excess salt
		100	**Metal Alloy**	Hulls, hardware and noble metal fission products
		100	***Lanthanide Glass*** [c]	*Lanthanides*

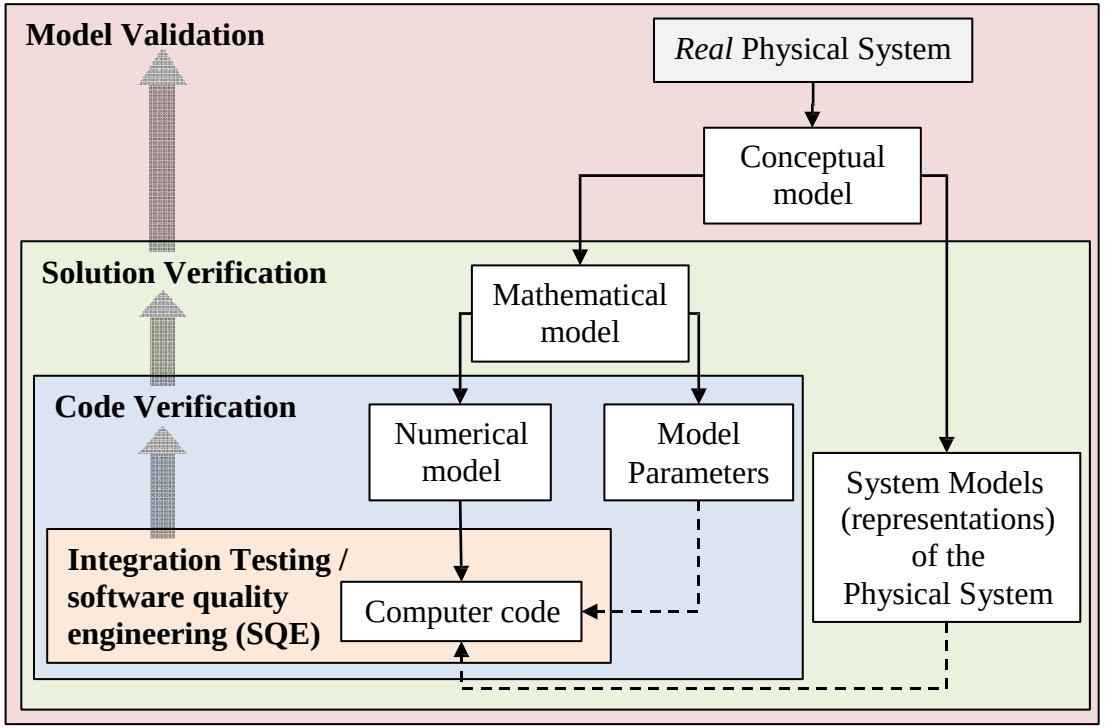
[a] Co-Extraction method similar to the current generation of deployed reprocessing technology (e.g., Rokkasaho plant, Japan).

[b] New Extraction is an advanced aqueous process that combines existing technologies and recovers all TRUs for re-use.

[c] Low heat output is enveloped by "ceramic" waste type.

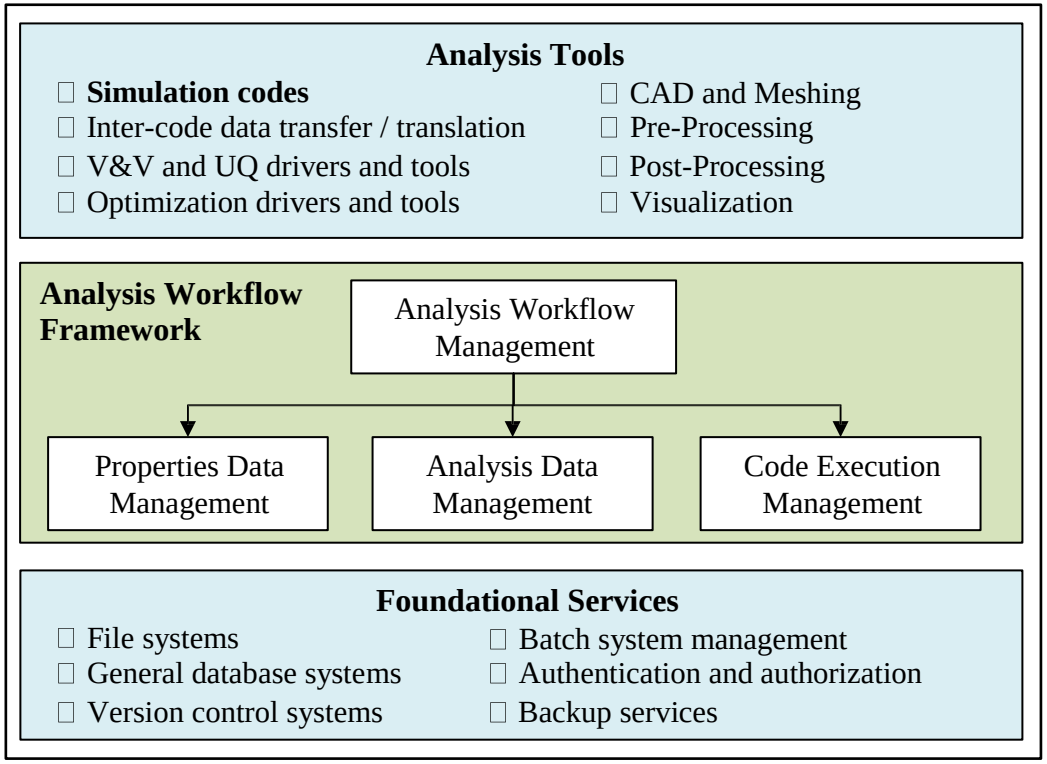
Note: These are potential waste types identified in FY11, and do not represent the future nuclear fuel cycles (or the resulting waste streams) as recommended by the March, 2011 DOE/Fuel Cycle Technologies screening study.

Performance Modeling Activities: Framework Tool Applications



Edwards, et al. 2011. *NEAMS Nuclear Waste Management IPSC: Evaluation and Selection of Tools for the Quality Environment*. Sandia National Laboratories, SAND2011-3599.

Performance Modeling Activities: Framework Tool Services

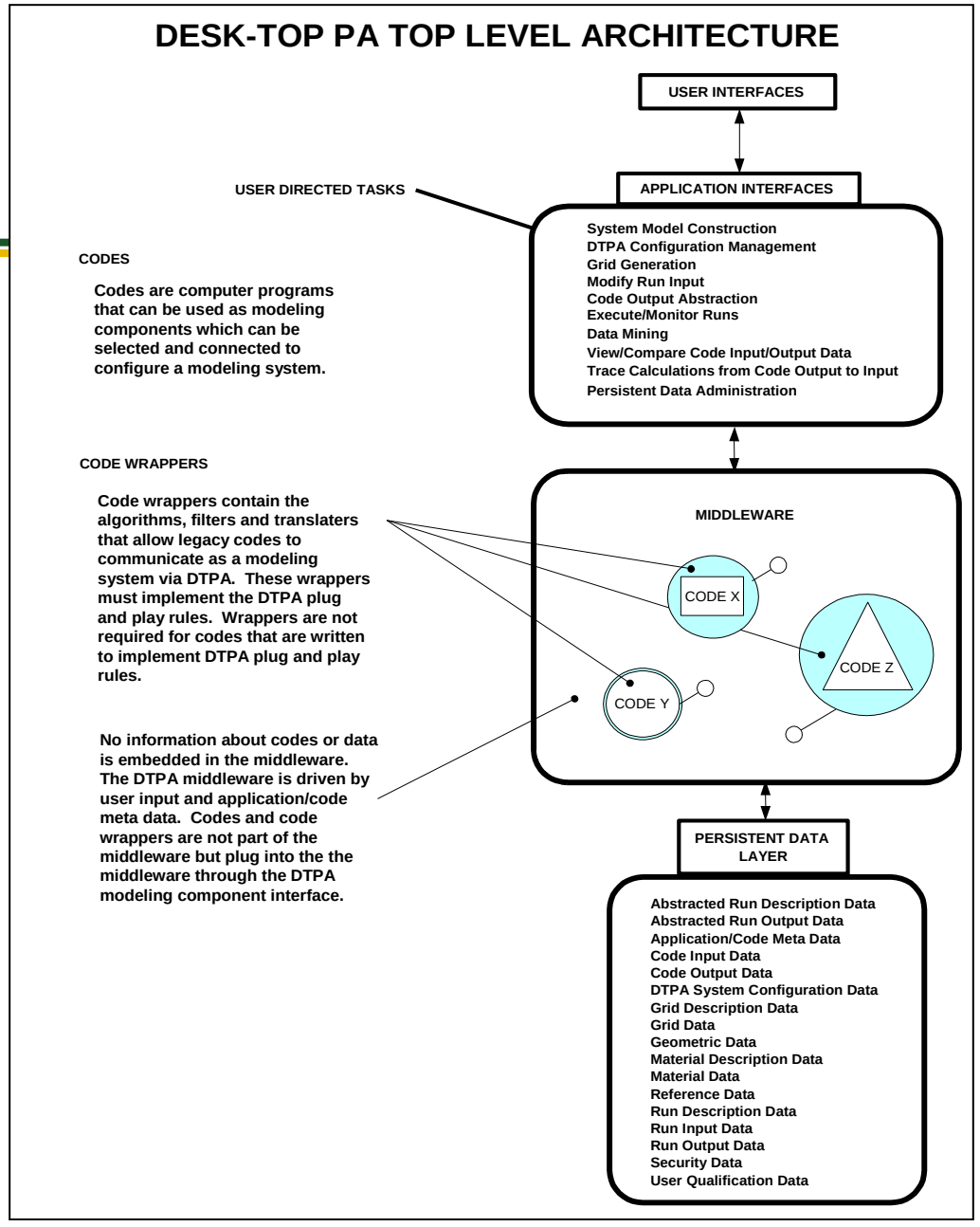


Edwards, et al. 2011. *NEAMS Nuclear Waste Management IPSC: Evaluation and Selection of Tools for the Quality Environment*. Sandia National Laboratories, SAND2011-3599.

Used Fuel Disposition

Performance Modeling Activities:
Framework Tool Architecture Example

Fewell et al. 2000. *DeskTop PA Software Architecture*. Sandia National Laboratories, SAND2000-0506.

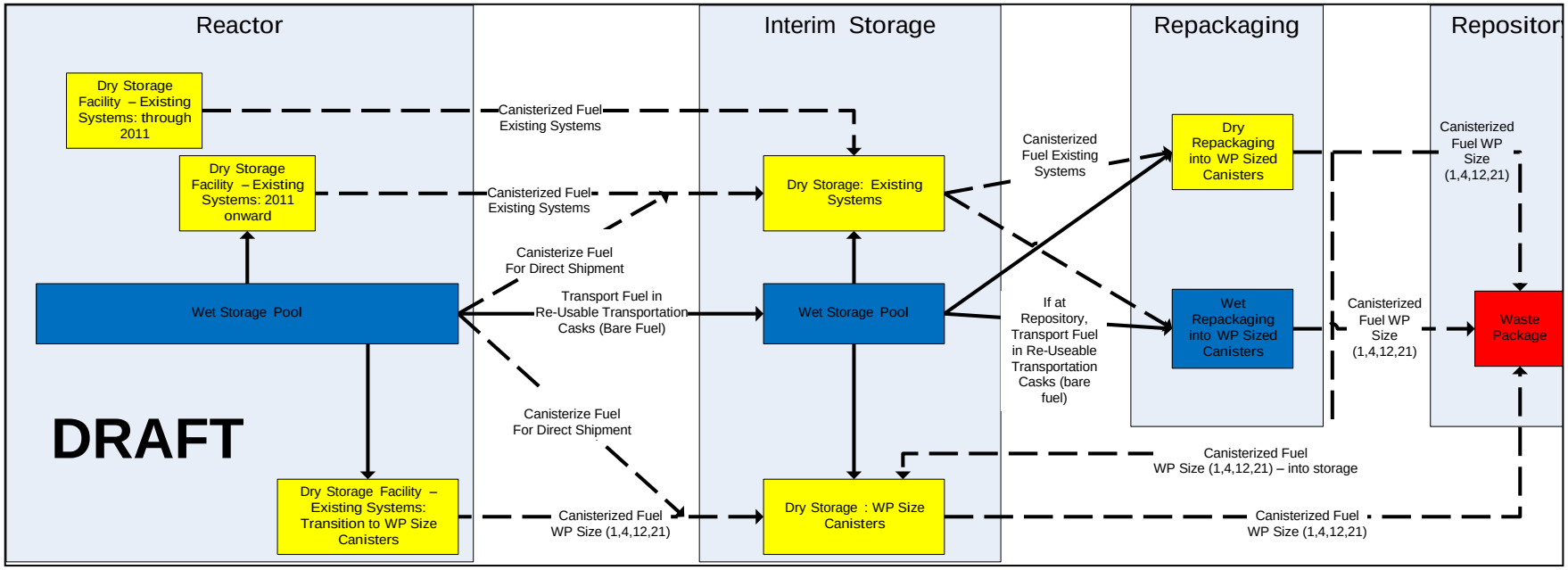


Performance Modeling Activities: Framework Tools

- **Some available framework tools:**
  - ASAP (“Desktop PA”; SNL developed)
  - Sierra Mechanics (SNL developed)
  - GoldSim (proprietary; www.goldsim.com)
  - OpenTurns (open source; www.openturns.org)
  - Salome (open source; www.salome-platform.org)
  - QPAC (www.quintessa-online.com)
  - ASCEM-Velo/GS3 (open source; PNL developed)
  - Enthought Python (www.enthought.com)

Performance Modeling Activities: Logistics Modeling Overview

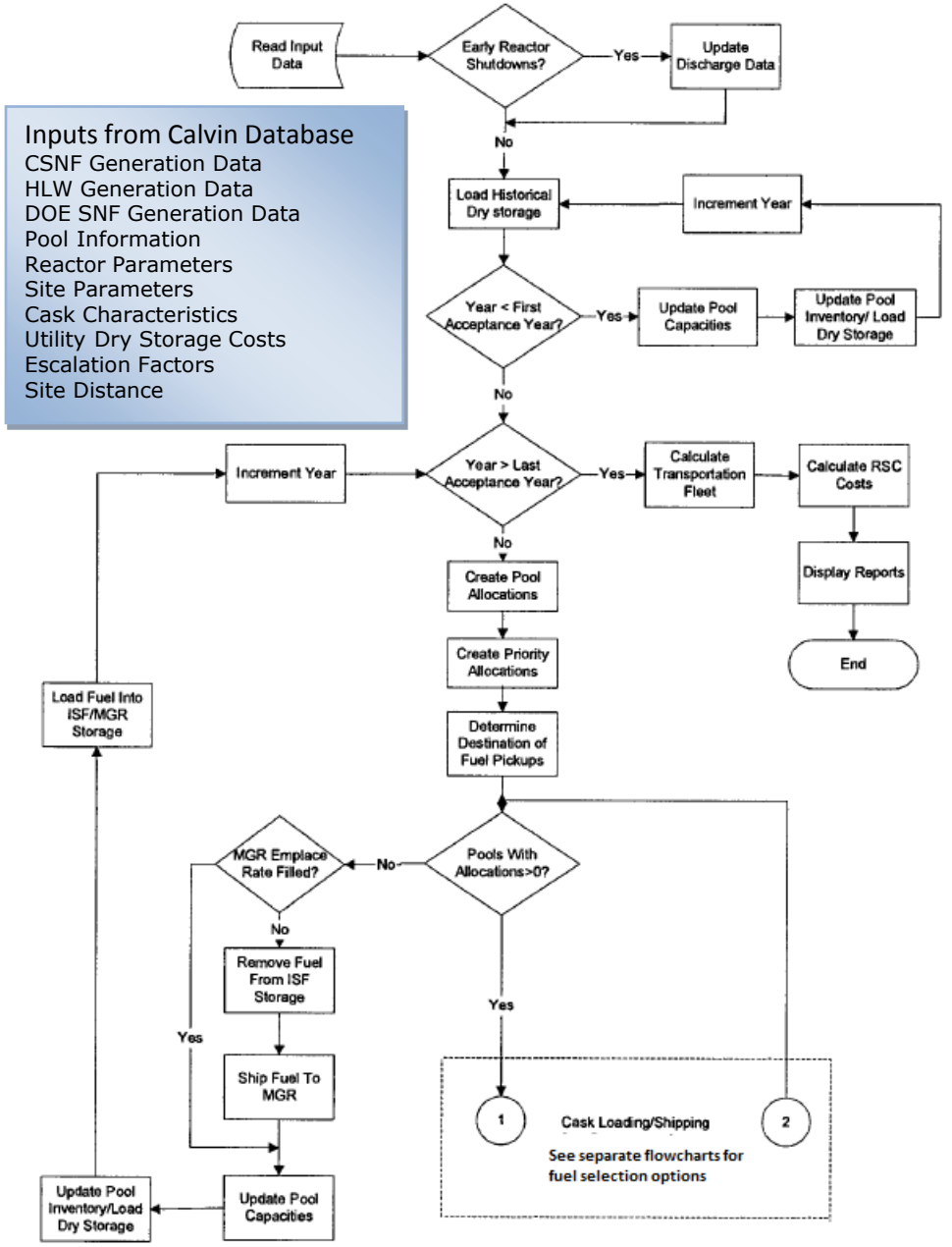
- **Transportation-Storage Logistics Model (FY12)**
  - Combine features of existing codes CALVIN & TSM (OCRWM) and TOM (ORNL)
  - Support system engineering and resource estimation scenarios



Used Fuel Disposition

Performance Modeling Activities:
Existing Transportation-Storage-Disposal Models (e.g., CALVIN)

- **Flowchart of CALVIN processing**
- **UNF pickup, storage, transportation, disposal**
- **Cost/schedule**
- **Developed prior to *Total System Model* (Yucca Mtn. repository specific)**



Performance Modeling Activities: Enhanced Logistics Modeling Capabilities

Example questions:

- Multiple centralized storage and/or multiple disposal sites
- Co-located storage and disposal
- Transportation infra-structure
- Standardized canister

Performance Modeling Activities: Summary

- **System engineering approach**
  - Disposal system architecture
  - Reference geologic disposal concepts
  - Representative waste types (e.g., from ongoing Fuel Cycle Technologies option studies)
- **Generic Disposal System Model**
  - Generic PA Model
- **Integrated software environment**
  - Centralized computational database
  - “Framework tool”
- **Transportation-storage (and disposal) logistics**