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Nuclear Fuels Storage & Transportation Planning Project
Office of Fuel Cycle Technologies
Nuclear Energy

System Analysis Tools Used to Evaluate the Integrated Waste Management System

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Nuclear Waste Technical Review Board
August 24, 2016
Washington, D.C.

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Disclaimer

- This is a technical report that does not take into account the contractual limitations under the Standard Contract. Under the provisions of the Standard Contract, DOE does not consider spent fuel in canisters to be an acceptable waste form, absent a mutually agreed to contract modification.
- This presentation reflects research and development efforts to explore technical concepts which could support future decision making by DOE. No inferences should be drawn from this presentation regarding future actions by DOE.

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This Presentation Responds to the NWTRB Questions

I. *What is the status of the development and implementation of DOE's system analysis tools for evaluating options for commercial SNF management?*

   a. *Explain how these tools can be used to examine the pros and cons of using different types and sizes of SNF canisters at different points in the back end of the fuel cycle (e.g., storage, transportation, and disposal).*

   b. *Has DOE-NE assessed the time, cost, dose, and radioactive waste implications of repackaging SNF at different locations? If so, what are the results of the assessment?*

   c. *Did DOE-NE coordinate with DOE-EM in developing START (the Stakeholder Tool for Assessing Radioactive Transportation) and use lessons learned from DOE-EM's Web-based Transportation Geographic Interface System (WebTRAGIS)?*

   d. *In the early application of these tools, has DOE learned anything significant about the projected integration and management of SNF storage and transportation systems?*

*Red text added for emphasis

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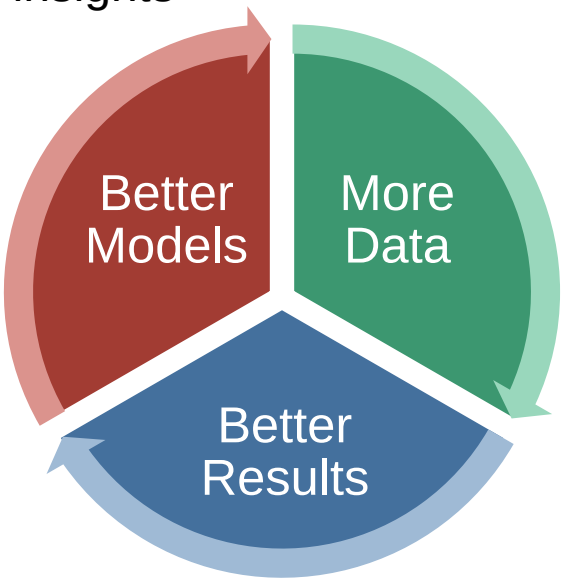
NFST is currently developing advanced modeling and simulation tools for simulating the integrated waste management system

- **Legacy tools have been modified and extended to allow system evaluations**
  - Large quantities of data have been collected
  - These extensions have allowed much more realistic insights
  - Uncertainties in system deployment have been evaluated
- **New, modern system analysis tools are currently under development**
  - Significantly more detailed than legacy tools
  - This new capability requires new, more-refined data
- **Applying the tools has provided key insights into system behavior**
  - Helps develop better models and collect appropriate data
  - Continuously improving process



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Outline

- **Overview of the Waste Management System**
  - Bottomline: It's complex
- **System Analysis Tools & Insights Learned**
  - Legacy software
  - New software
  - Data Needs
- **Conclusions**

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The future of the waste management system is complex and uncertain

- **A number of possible functions**
  - At-reactor storage
  - Transportation
  - Away-from-reactor storage (i.e., interim storage facility – ISF)
  - More transportation
  - Packaging (or repackaging) spent fuel
    - Extended storage
    - Transportation
    - Disposal
  - Disposal

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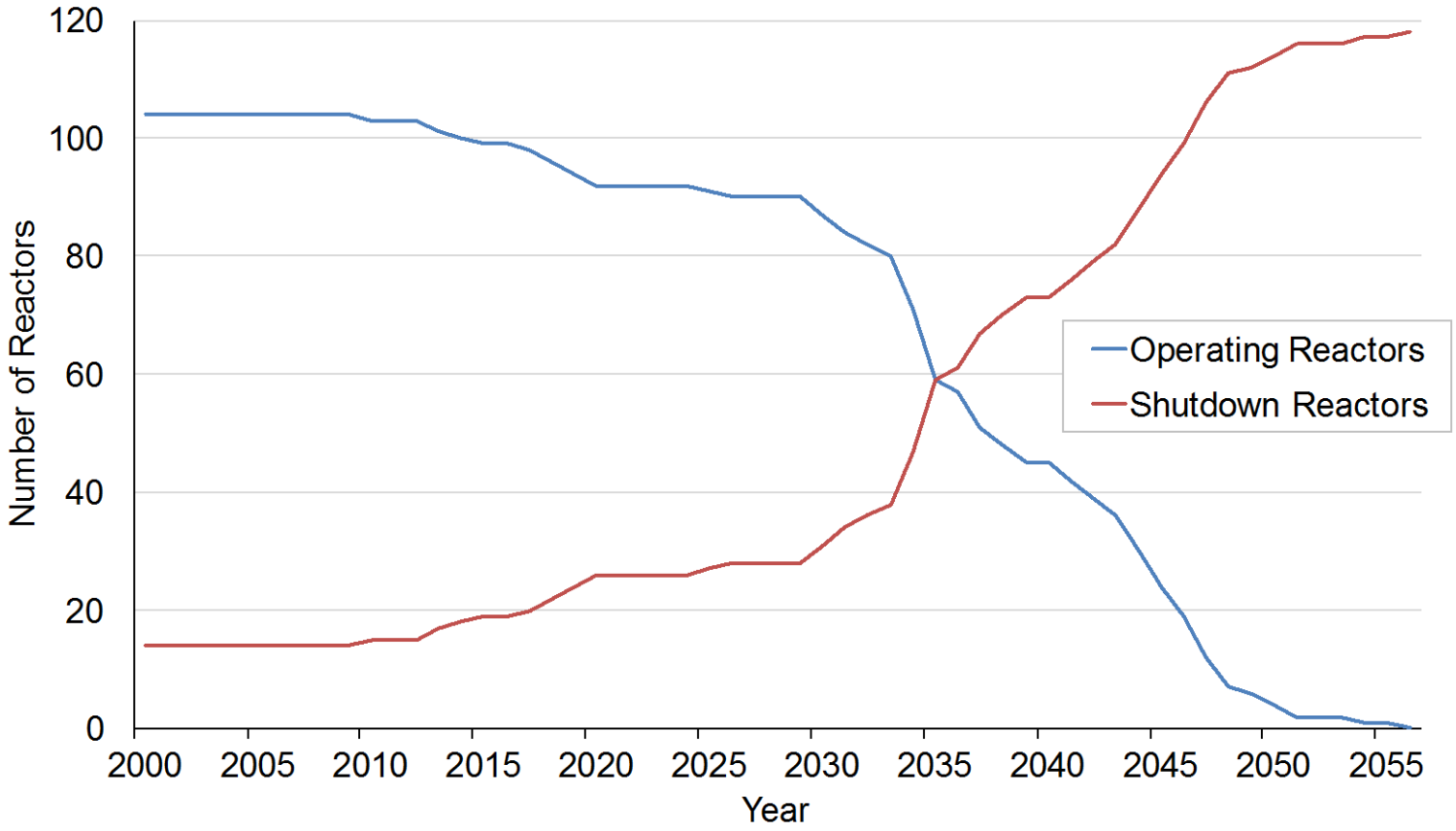
"Wave" of reactor shutdowns will impact the waste management system



Current Reactors Operate 60 Years Unless Announced Shutdown Date

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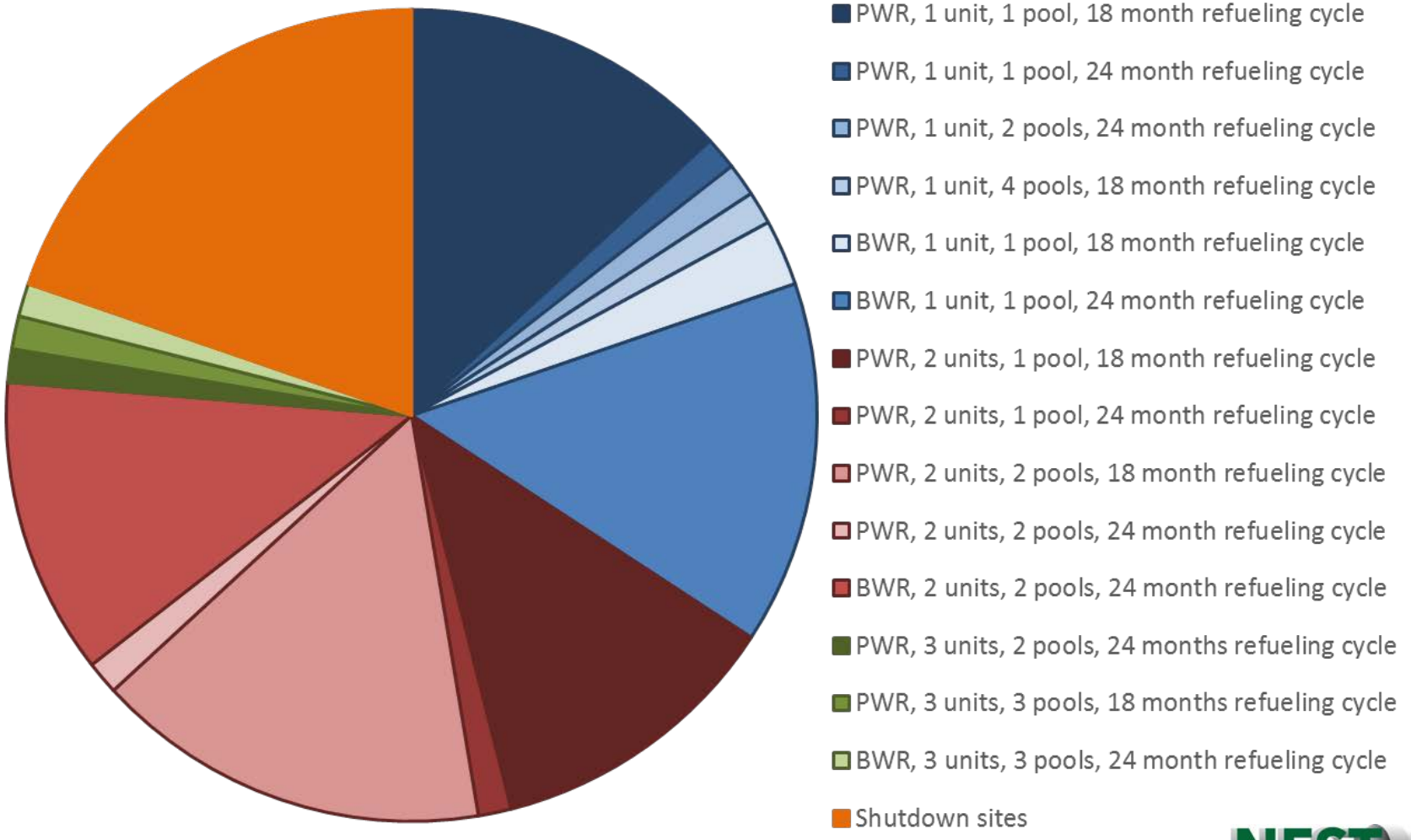
Conditions and constraints at reactor sites are variable and changing



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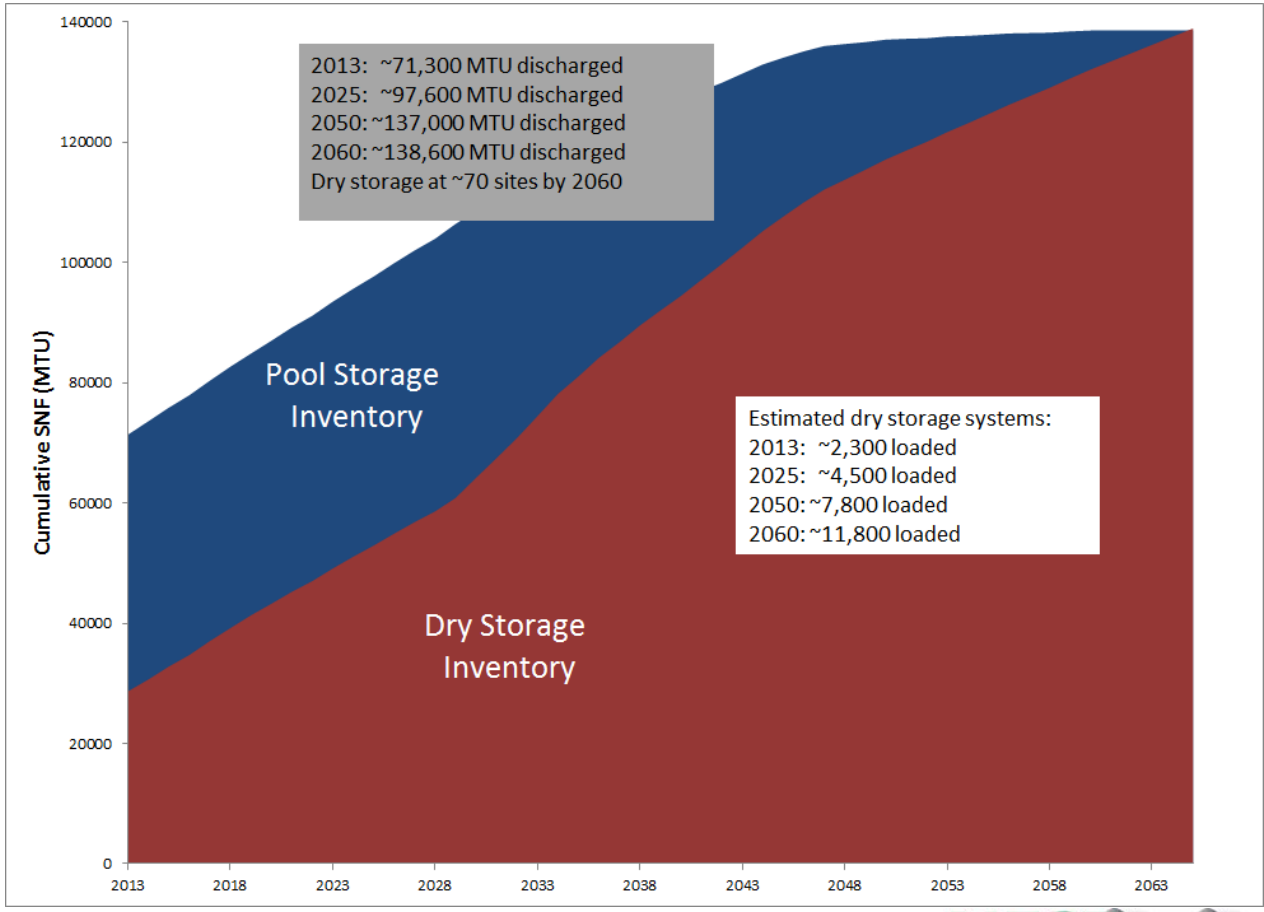
The amount and type of spent fuel is diverse and growing as are the storage options

- **As of 2016, ~77,000 MTUs of SNF and ~267,000 assemblies**
  - ~50,000 MTU in spent fuel pools
  - ~27,000 MTU in dry storage systems
- **Projected to be more than 130,000 MTUs given our current fleet**



See Carter's previous talk

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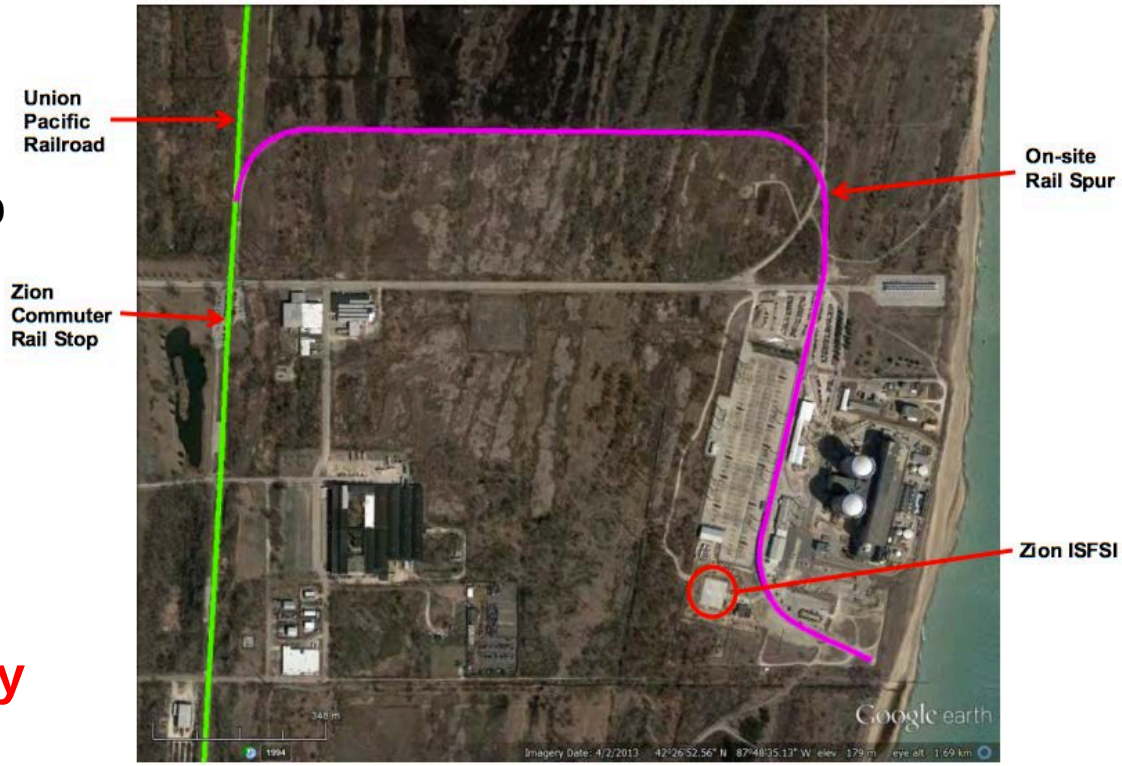
Conditions and constraints at reactor sites (and near them) are variable and changing

- **Some sites**
  - have direct rail access
  - had direct rail access but no longer do
  - never had direct rail access
- **Some sites are located on navigable waterways appropriate for barge transport**
- **Infrastructure is constantly changing**



Rail access at Zion (recently refurbished)

See *Preliminary Evaluation of Removing Used Nuclear Fuel from Shutdown sites at:*

https://curie.ornl.gov/content/preliminary-evaluation-removing-used-nuclear-fuel-shutdown-sites-september-2015-version

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Each canister or cask system has unique transportation challenges

- **Was the system designed to be transportable?**
- **Is there a transportation overpack (i.e., cask) with a valid Certificate of Compliance (CoC)?**
- **Is that overpack available?**
- **Can it be procured in a timely manner?**

See Carter's previous talk.
Transport Cask Attributes - Data Table

MP-187 Transportation Cask

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Numerous alternatives for future interim storage facility (ISF) configuration and operation

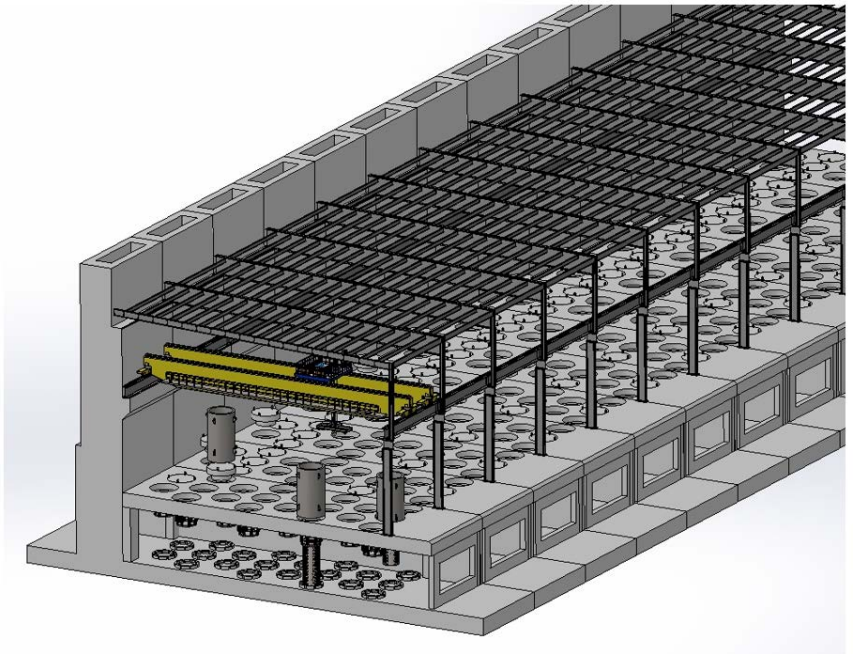
NAC MAGNASTOR Storage System at the McGuire ISFSI

Source: NAC International

AREVA Transnuclear NUHOMS Storage System at the ISFSI

Source: AREVA TN

3D Rendering of a Conceptual Vault



For additional conceptual designs, see the CB&I, Holtec International, and Longenecker & Associates Task Order 16 report at:

https://curie.ornl.gov/content/task-order-16-generic-design-alternatives-dry-storage-spent-nuclear-fuel-1

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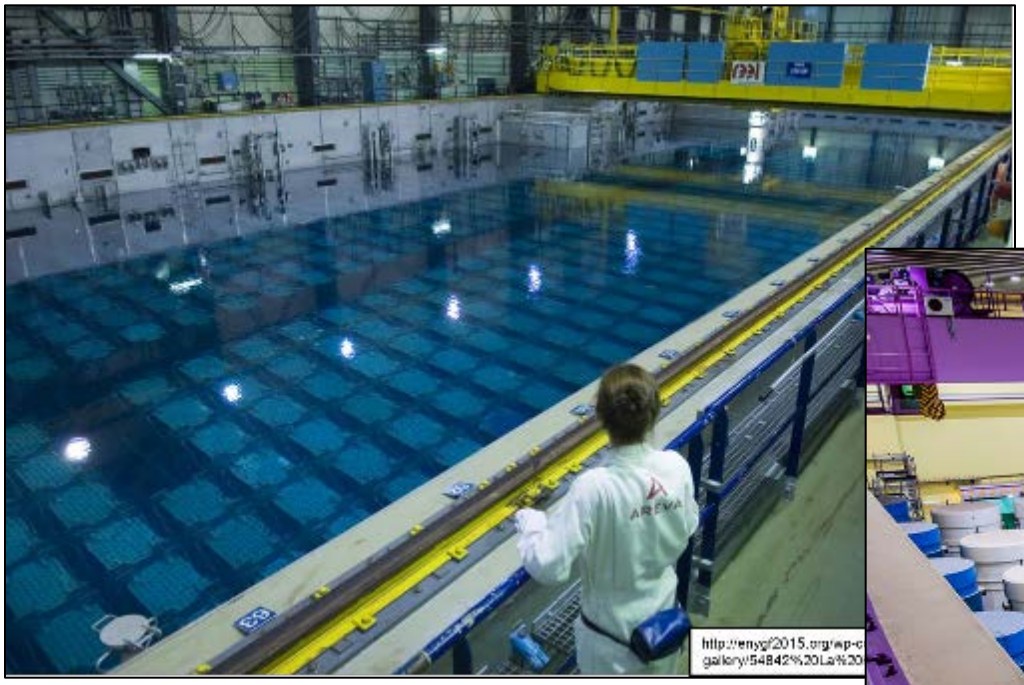
Numerous alternatives for future interim storage facility (ISF) configuration and operation



Each design introduces different receipt facilities, procedures, and (potentially) package designs throughout the system

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The need for packaging and/or repackaging is unknown at this time


Task Order 14 - AREVA

- **~11,800 DPCs could need to be opened**
  - Disposal
  - Transportation
  - Extended Storage
- **Location of facility(s) to be determined**
- **Repository requirements will influence repackaging facility design and operation**
  - Disposal canister size

See Rob Howard's 2013 NWTRB presentation for more details.

http://www.nwtrb.gov/meetings/2013/nov/howard.pdf

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Repository requirements are unknown

- **Size of waste package is unknown and varies based on disposal concept**
  - *Evaluation of Direct Disposal of Spent Fuel in Existing Dual-Purpose Canisters*
    - E. L. Hardin, D. J. Clayton, R. L. Howard, J. Clarity, J.M Scaglione, J.T. Carter, W.M. Nutt, and R.W. Clark, *Radwaste Solutions* **21**, 26-39, January 2014.
  - *Evaluation of Options for Permanent Geologic Disposal of Spent Nuclear Fuel and HighLevel Radioactive Waste in Support of a Comprehensive National Nuclear Fuel Cycle Strategy Volume I,* April 2014
    - https://curie.ornl.gov/content/evaluation-options-permanent-geologic-disposal-spent-nuclear-fuel-and-high-level-radioactive
- **Thermal constraints differ – has affect on when material could be emplaced in a repository**
  - Could affect when SNF can be shipped
  - ISF can act as a buffer, reducing impact on from-reactor transport due to repository constraints or delays

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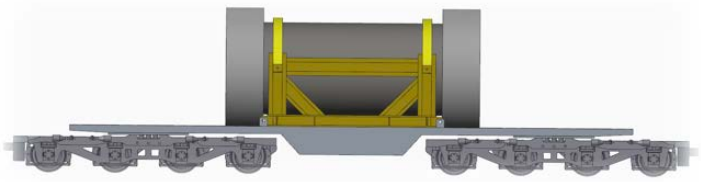
Transportation responsive to all other design and operation considerations

- **Different concepts of operation affect transportation infrastructure and acquisitions**
  - Number of assets
  - Asset designs


USN M-290 Railcar

- **Reactor site infrastructure influences transportation operation**



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NFST is using a combination of legacy and new tools to analyze this complex system

- **I will discuss three tools today**
  - Used Nuclear Fuel Storage Transportation & Disposal Analysis Resource and Data System (UNF-ST&DARDS) and its **Unified Database**
    - Data collection, fuel characterization, and package information
  - Transportation Storage Logistics (TSL)
    - Legacy systems analysis tools
  - Next Generation Systems Analysis Model (NGSAM)
    - Advanced systems analysis tool

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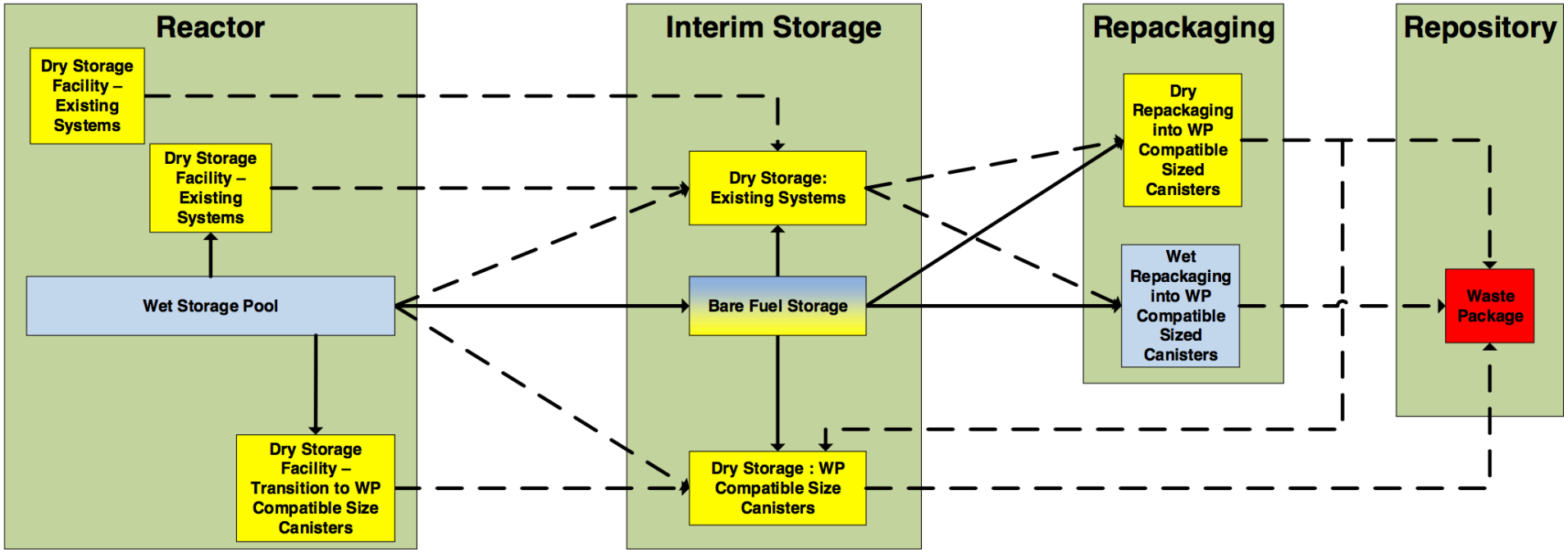
System analysis tools are requirements focused

- Model all constraints and steps of an integrated waste management system
- Flexibility to explore yet to be determined system alternatives
- Output metrics for evaluation of integrated system performance
- MUST HAVE GOOD DATA



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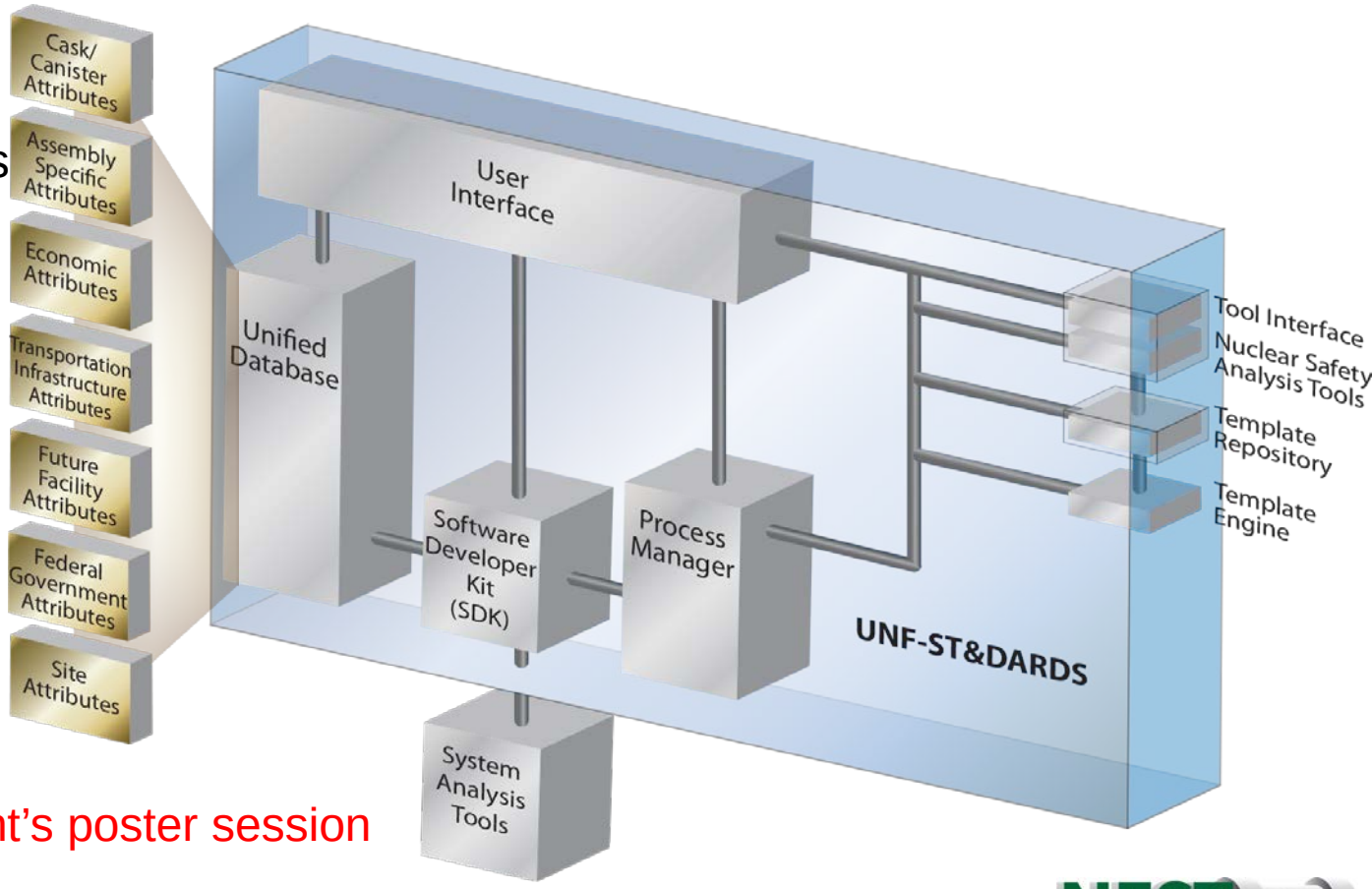
An integrated database has been established as a foundation for waste management system analysis

- Used Nuclear Fuel Storage Transportation & Disposal Analysis Resource and Data System (UNF-ST&DARDS)
- **Unified Database** consolidates, controls, and archives key information from multiple sources
- Integration of data with analysis capabilities facilitates analysis with quality data



More details at tonight's poster session

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Updated legacy waste management system analysis tools can be used for analysis

- **Updated Legacy Tool - Transportation Storage Logistics (TSL)**
  - Briefed at October 2012 NWTRB Meeting
  - Added ability to model an interim storage facility
  - Improved and coordinated input data
  - Fixed ”bugs” as appropriate
- **Available to analyze multiple “scenarios” to evaluate uncertain future decisions**
  - Insights are valuable with the understanding that modeling is done at an “average” level
    - Lack of fidelity when modeling at-reactor logistics and constraints
    - No incorporation of detailed ISF designs
    - Limited canister/cask loading algorithms

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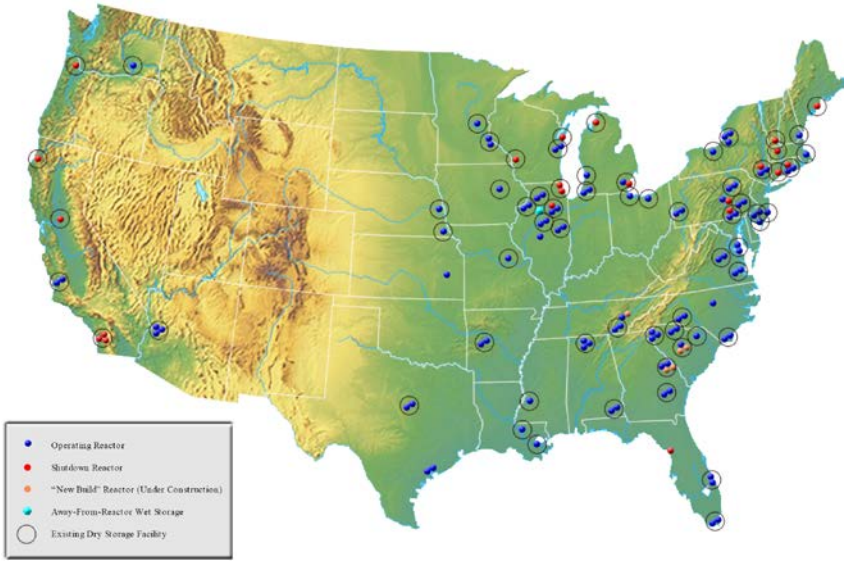
Strategies for accepting SNF from reactor sites significantly impact reactor site closure

- **Order of fuel pickup (i.e., acceptance) is important**
  - 2012 studies only explored Oldest Fuel First (OFF) acceptance of SNF from the reactor sites
  - More recent studies have explored the impact of alternative acceptance strategies
- **The rate of acceptance will impact the system**
- **Key Metrics**
  - Final year fuel is onsite
  - Total number of years fuel is at shutdown sites
  - ISF capacity (and cost)



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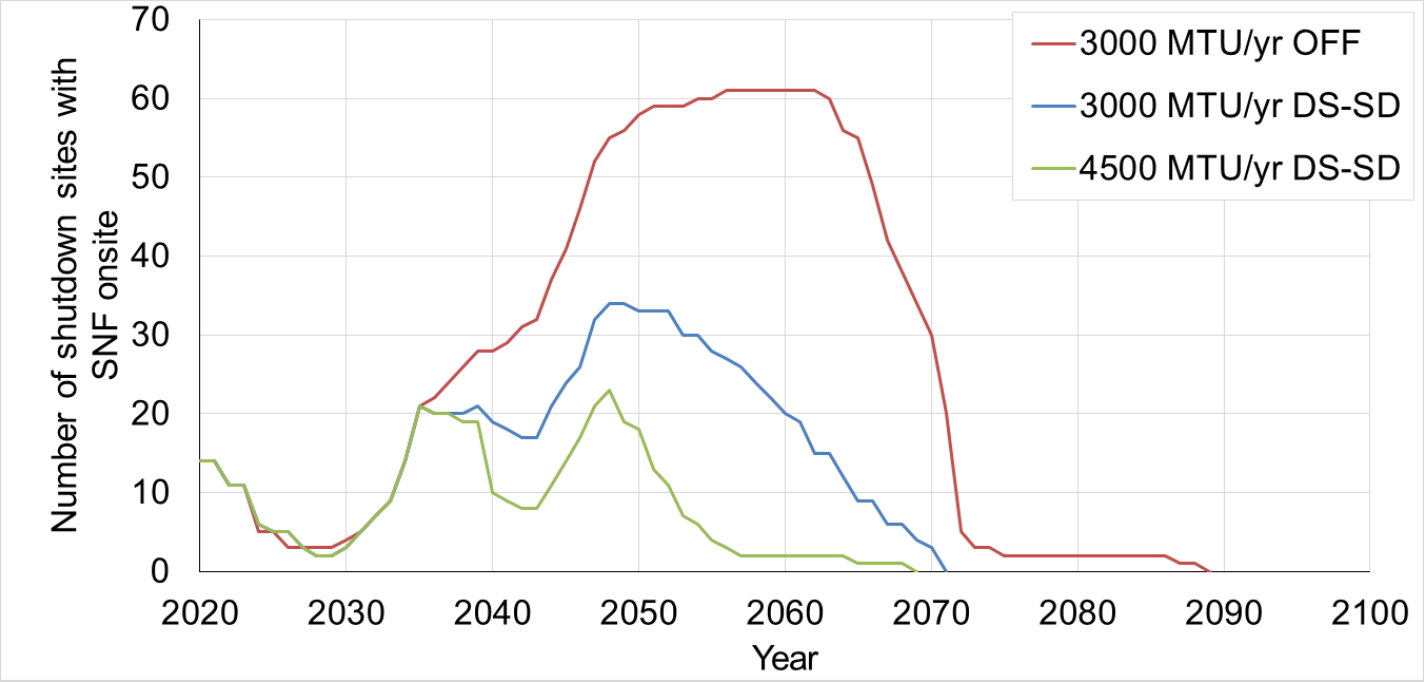
Strategies for accepting SNF from reactor sites significantly impact reactor site closure

- **The rate and order in which SNF is accepted impacts…**
  - The final year of SNF at reactor sites (30 year difference)



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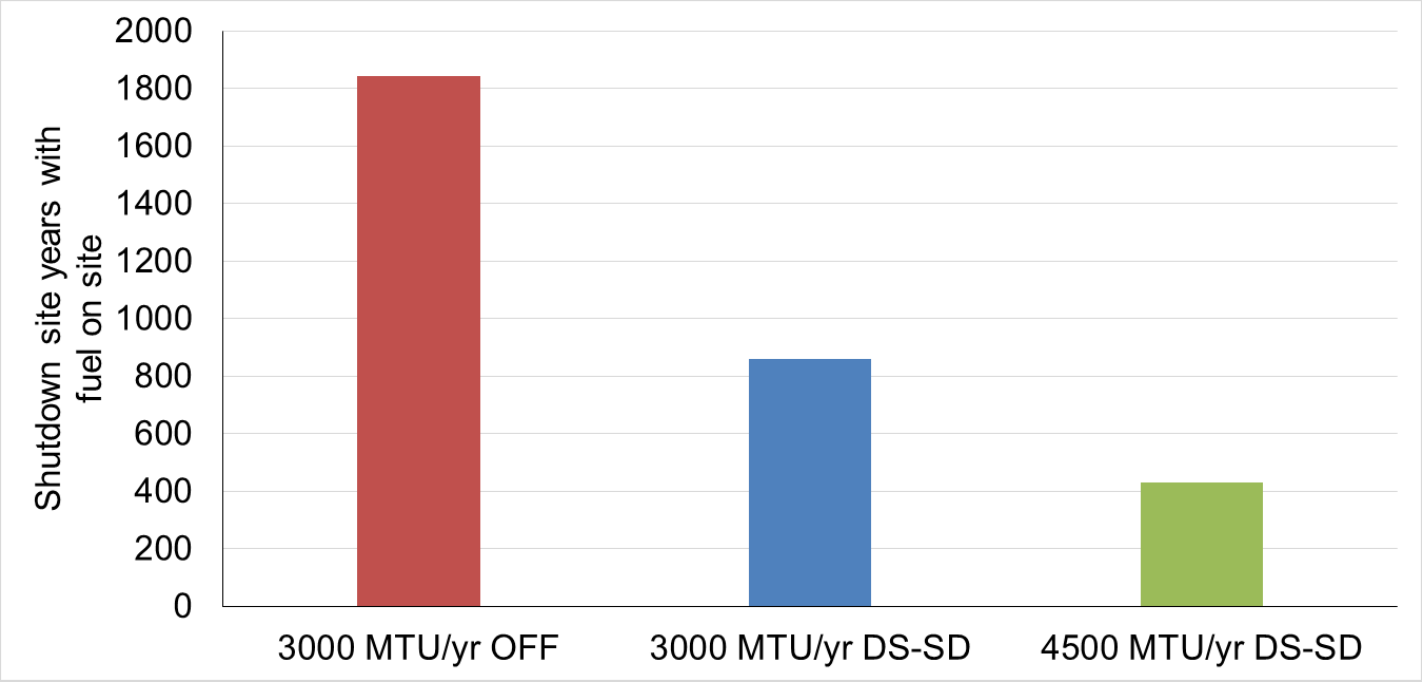
Strategies for accepting SNF from reactor sites significantly impact reactor site closure

- **The rate and order in which SNF is accepted impacts…**
  - The final year of SNF at reactor sites (30 year difference)
  - The amount of time fuel is on shutdown reactor sites



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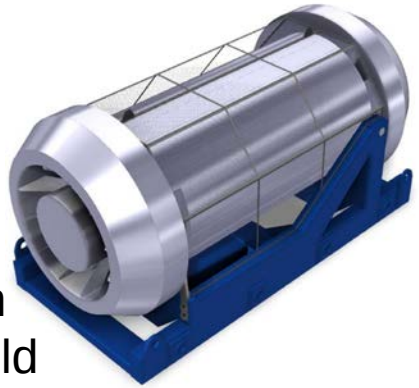
Canister/cask loading strategies significantly impact all areas of the waste management system

- **The package in which SNF is transported from reactors has system wide impacts**
  - Canister only ISF(s) may require opening of 11,800+ canisters
  - ISF(s) that can receive bare fuel transportation casks and store individual fuel assemblies could require opening fewer than 5,000 canisters
- **Another option is to develop a canister that can be loaded, stored, transported, and then disposed of without opening**
  - Integrating Standardization into the Nuclear Waste Management System, November 2013 http://www.nwtrb.gov/meetings/2013/nov/jarrell.pdf
  - Standardized Transportation, Aging, and Disposal (STAD) Canister Design, June 2015 http://www.nwtrb.gov/meetings/2015/june/jarrell.pdf



Bolted-lid Bare Fuel Transportation Cask https://curie.ornl.gov/content/energysolutions-task-order-17-spent-nuclear-fuel-transportation-cask-design-study

Cutaway Transportation Cask with STAD canisters and Carrier https://curie.ornl.gov/content/task-order-18-updated-final-report-generic-design-small-standardized-transportation-aging-1

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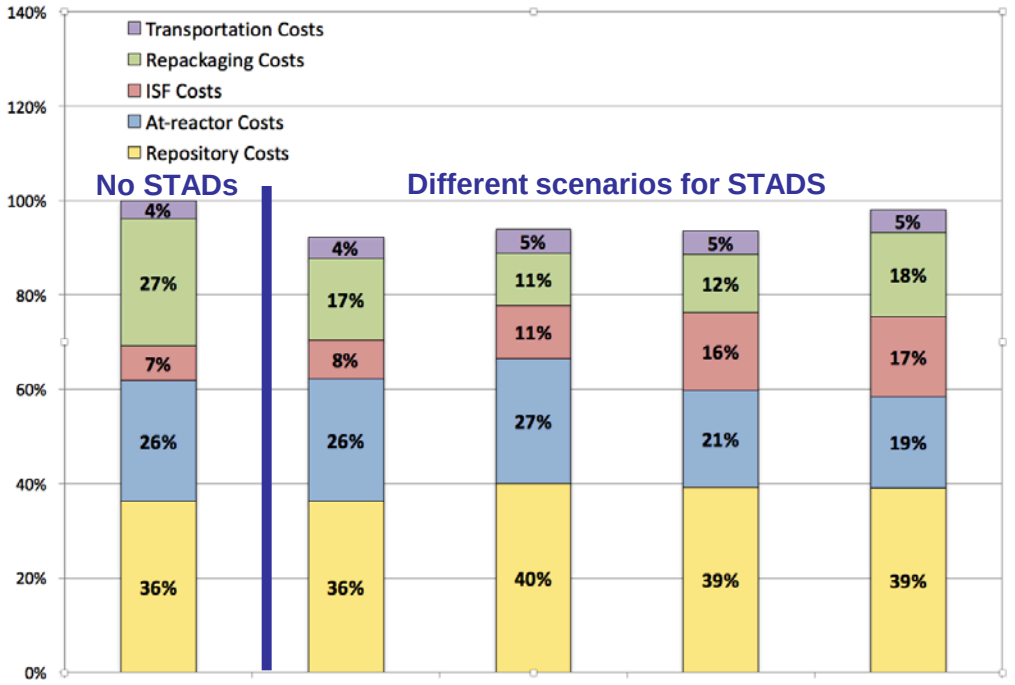
STAD canisters appear feasible (on paper) – Engineering confirmation is logical next step

- The use of standardized canisters could reduce total system costs by 2% - 8% over continuing to load DPCs
- Design and operational concepts have been developed for loading, storing and transporting small STADs in multi-canister "carrier"
- Loading "small" STADs (4P/9B) provides the greatest flexibility to the system but poses operational concerns



Order of magnitude cost of different scenarios broken down by system functions

- Need demonstration of welding STAD lids in parallel (planned for FY17)
- Detailed design, licensing, and demonstration would provide additional engineering confirmation

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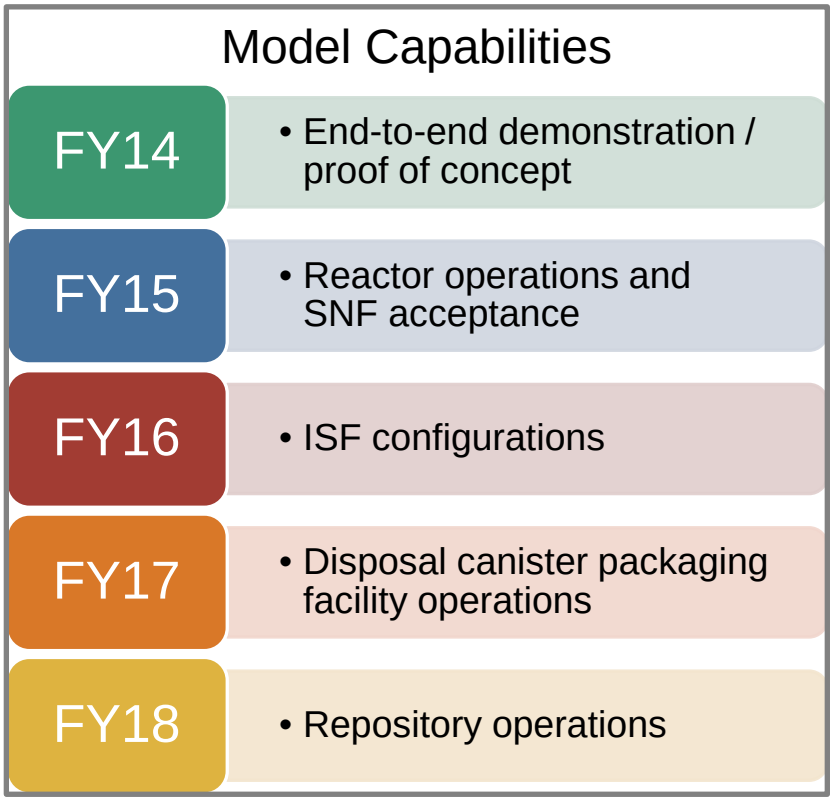
Next generation tools are almost ready to replace updated legacy tools for more realistic simulations

- **Next Generation System Analysis Model (NGSAM)**
  - Agent based model using modern simulation methodology
  - Developed by professional software engineers using agile software design
  - Government Off-the-shelf software built on open source libraries
    – DOE owns the source code
- **Transitioning from legacy tools to improved system analysis capabilities has started in this fiscal year**
  - At-reactor V&V complete
  - ISF and transportation benchmarking to be completed during next FY
  - Additional details for packaging and repository operations in FY17/18



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NGSAM development has already identified a number of issues

- **Studies have indicated canisters could be "trapped" at sites waiting to cool below transportation thermal limits**
  - Current CoCs have low (~20 kW) limits, future CoCs will probably have much higher limits (~32 kW: NUHOMS-MP198HB CoC No. 9302 – Rev 7)
- **Dose requirements may be more limiting than thermal limits**
- **NFST is incorporating latest CoC amendments and evaluating potential amendments**
- **Developed an improved algorithm for predicting SNF canister loads**
  - NFST actively developing optimization algorithms for future loadings
- **Identified data needs**
  - Predicting "windows" for dry loading and transportation campaigns
  - Actual loading maps to calculate doses that may impact transportation

Recap

- **Legacy tools have been modified and extended to allow system evaluations**
  - Large quantities of data have been collected
  - These extensions have allowed much more realistic insights
  - Uncertainties in system deployment have been evaluated
- **New, modern system analysis tools are currently under development**
  - Significantly more detailed than legacy tools
  - This new capability requires new, more-refined data
- **Applying the tools has provided key insights into system behavior**
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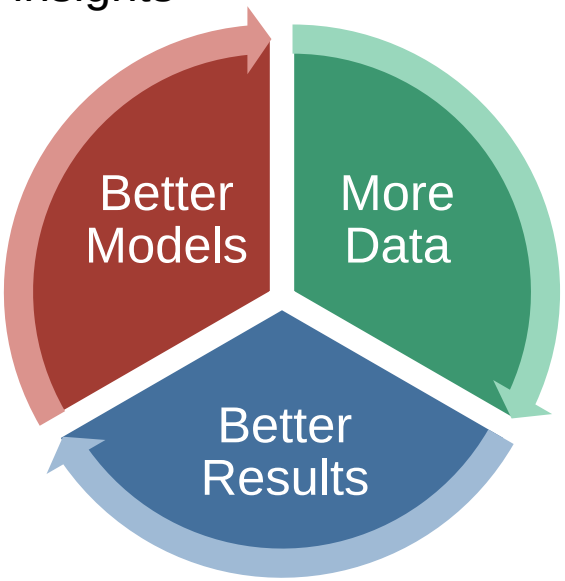

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Questions?