UNF-ST&DARDS: A Unique Tool for Spent Nuclear Fuel (SNF) Characterizations Using SCALE

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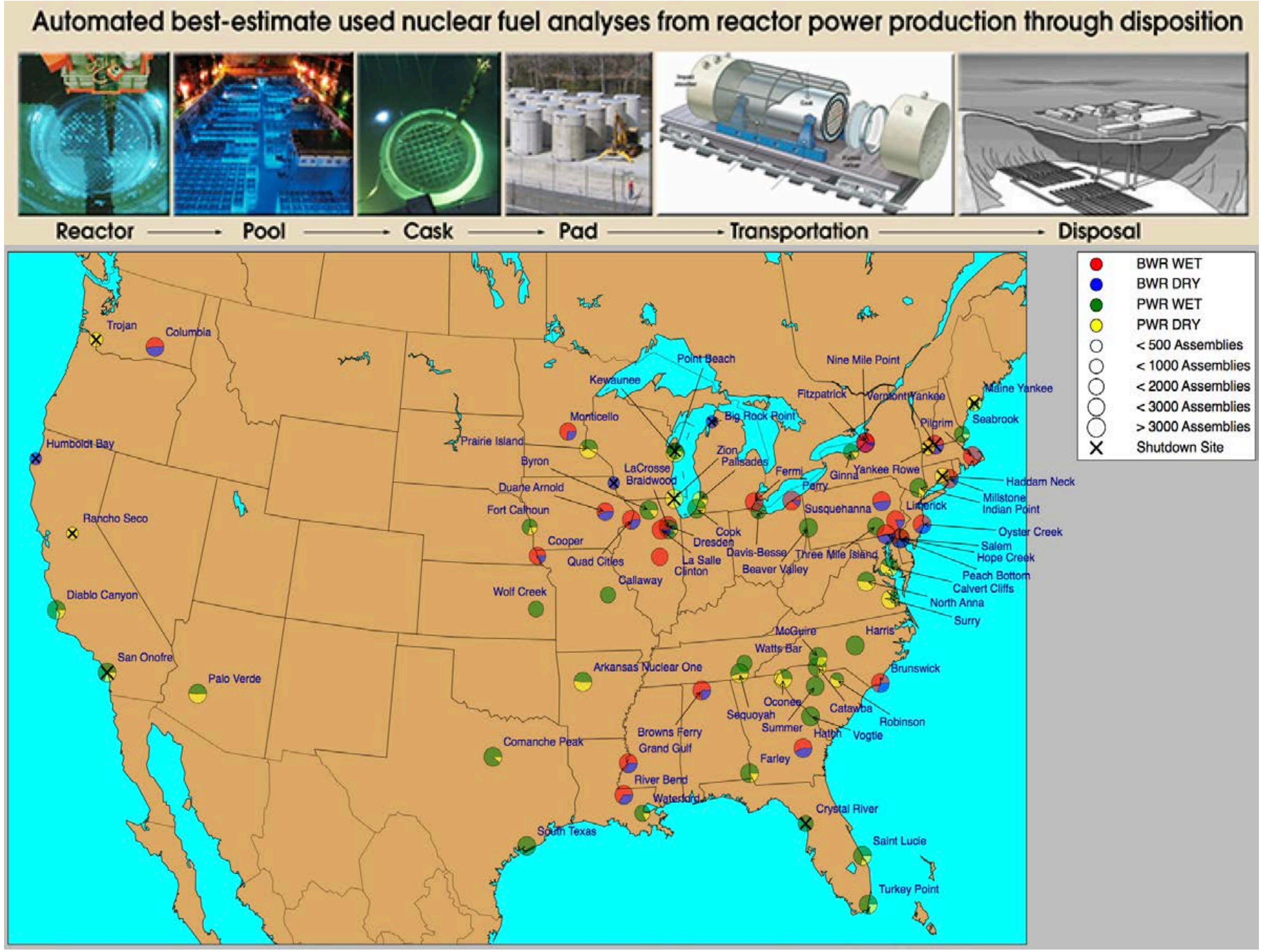
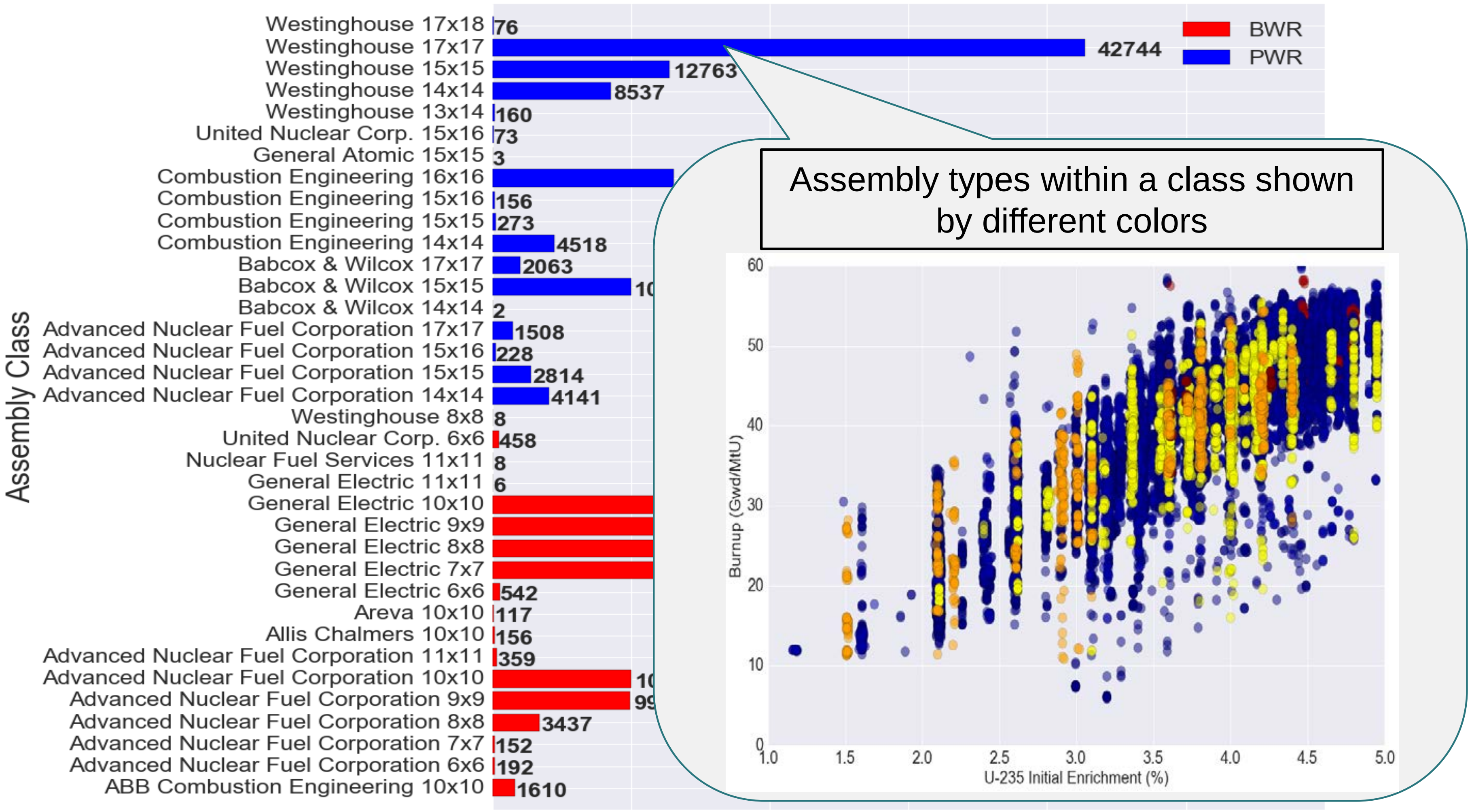
Planning for the large-scale transportation, interim storage, and ultimate disposition of the SNF is complex

- SNF is stored throughout the United States
  - 74 reactor sites including 14 shutdown sites in 33 states
  - ~3000 dry storage canisters/casks in use
- SNF inventory increasing annually
  - ~2000 MTHM/y
  - ~200 new canisters/casks/y



The large SNF volumes and diverse systems in the United States make system-wide planning more complex



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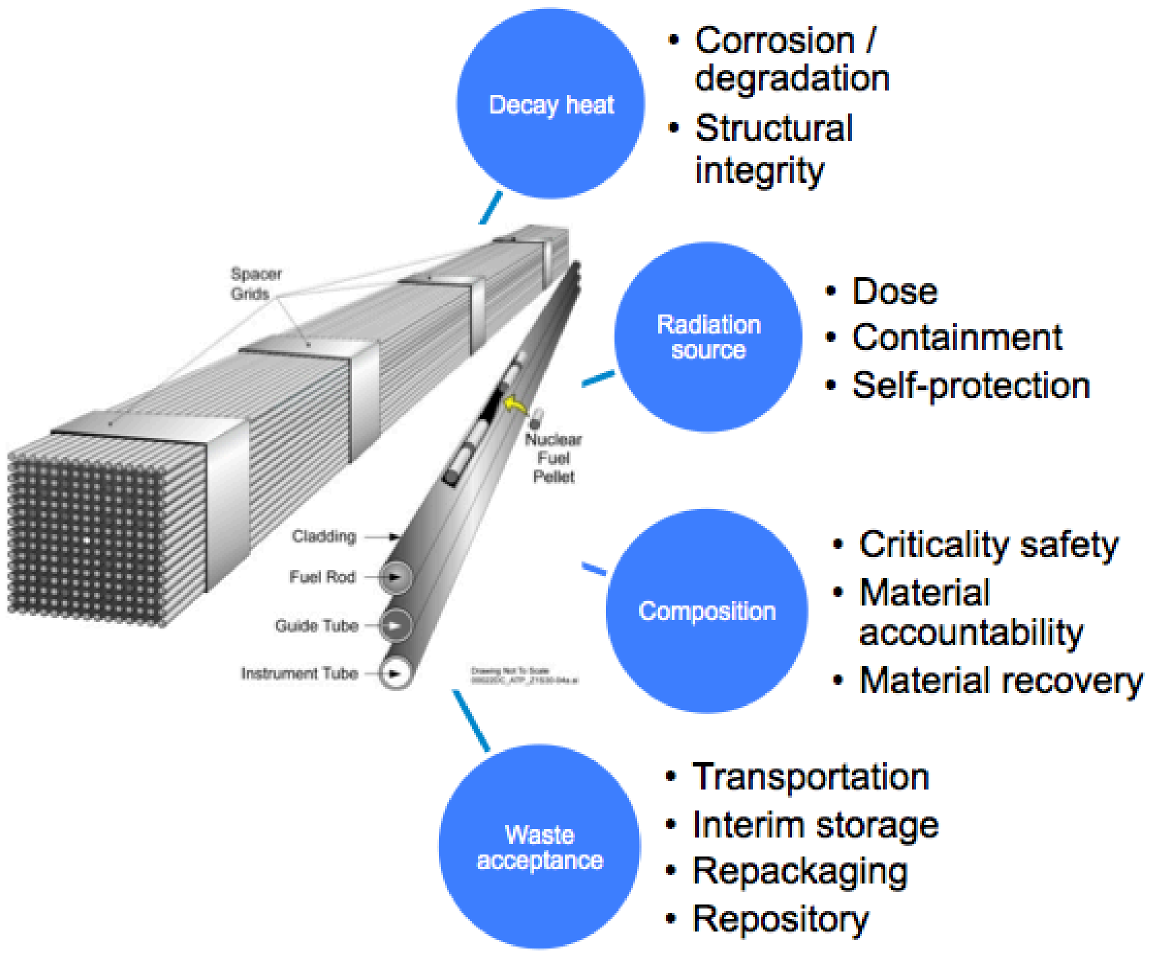
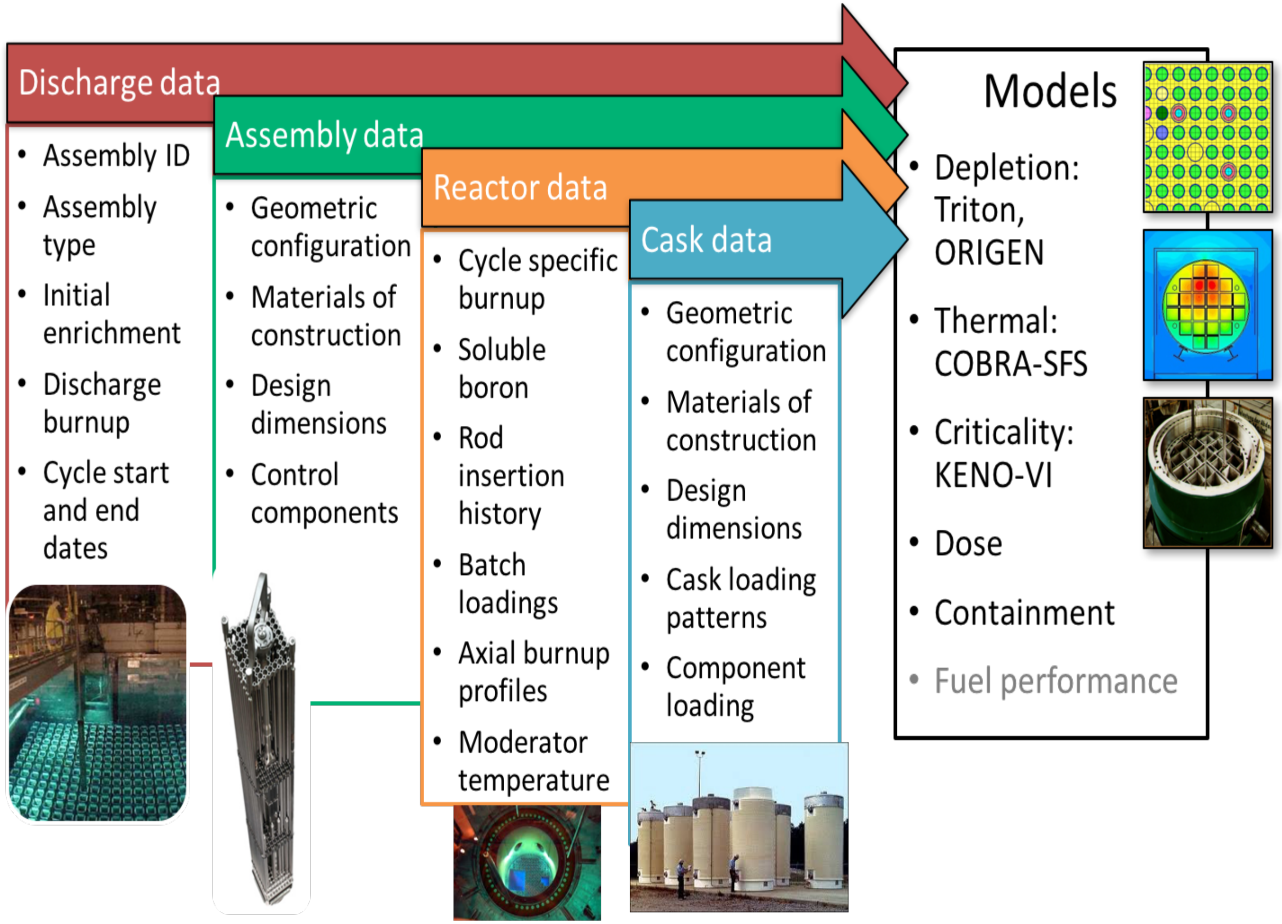
Any SNF related activity starts with understanding the SNF characteristics

- SNF and related systems characteristics can be categorized into:
  - **Base Characteristics:** fuel geometry, materials, reactor irradiation histories (e.g., cycle length, specific power etc.), cask system, cask loading patterns used to store SNF
  - **Derived Characteristics:** decay heat, isotopic composition, radiation sources, cask criticality, transportation cask dose rates



UNF-ST&DARDS integrates data with analysis capabilities to simplify SNF characterization process

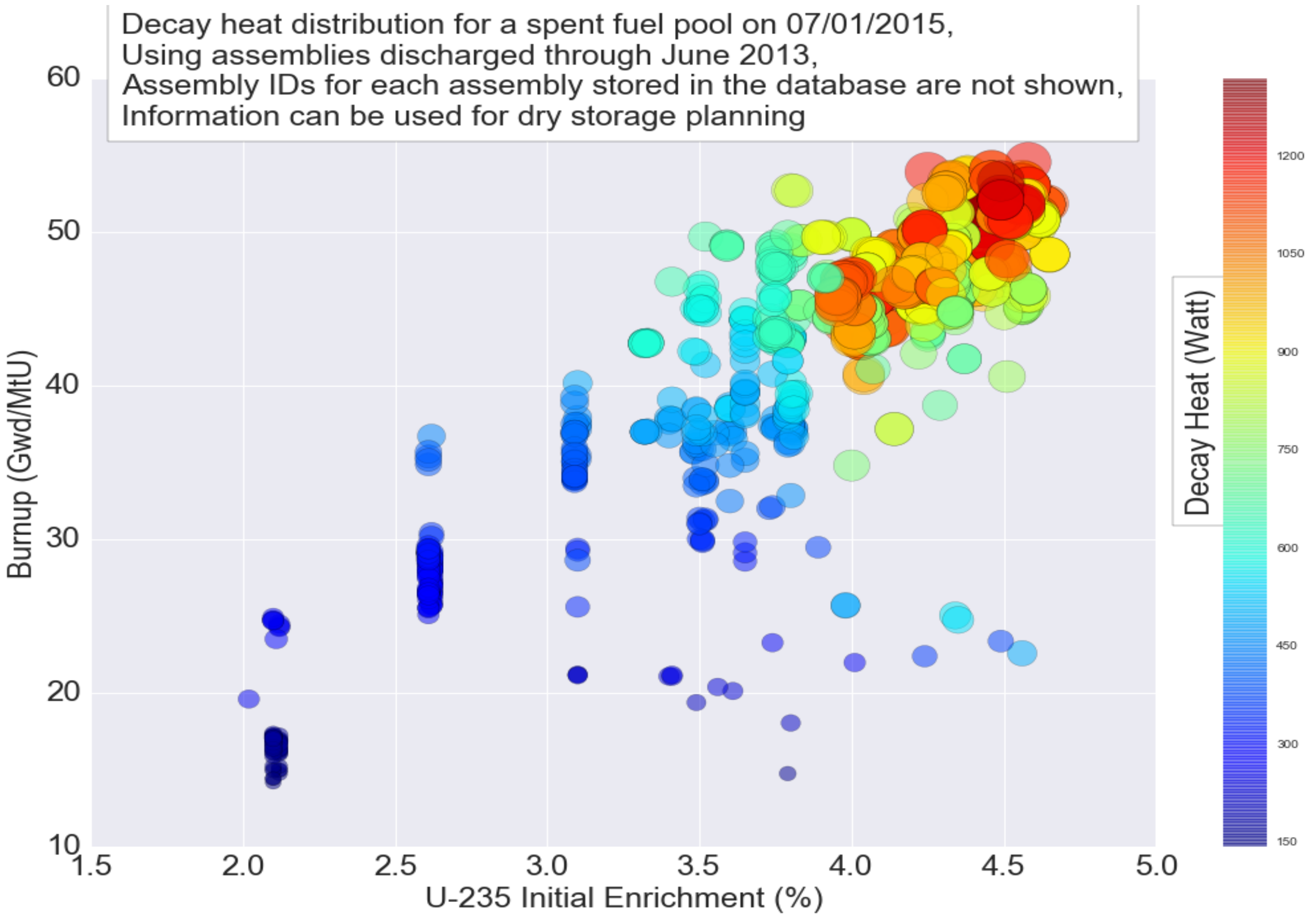
- Used Nuclear Fuel-Storage, Transportation & Disposal Analysis Resource and Data System (UNF-ST&DARDS) provides an SNF database and integrated analysis tools
- Unified Database consolidates key information from multiple sources and preserves data
- Data relations facilitate analysis automation



UNF-ST&DARDS uses SCALE modules for evaluating derived nuclear characteristics of SNF

- Derived characteristics are calculated using base characteristics from the database
- Derived characteristics include
  – Assembly-specific decay heat (TRITON/ORIGAMI)
  – Assembly-specific isotopic composition (TRITON/ORIGAMI)
  – Assembly-specific radiation sources (TRITON/ORIGAMI)
  – Cask-specific criticality (KENO)
  – Cask-specific transportation dose rates (MAVRIC)
  – Cask-specific thermal attributes (e.g., clad temperature, canister surface temperature)

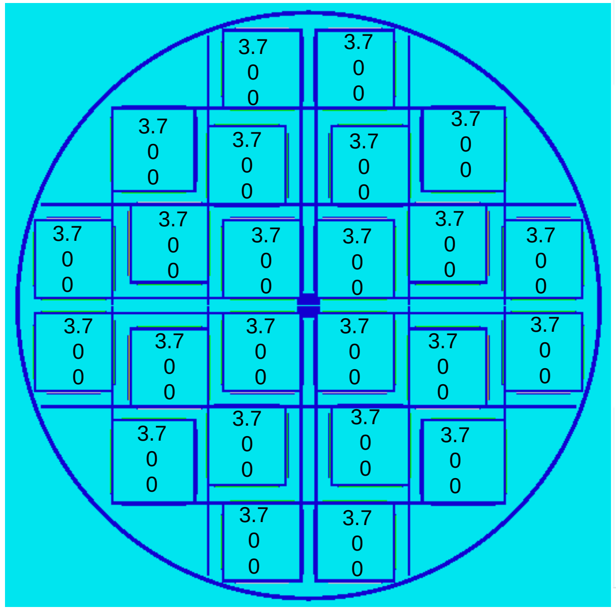
UNF-ST&DARDS assembly-specific decay analysis can be used for dry storage planning (TRITON/ORIGAMI)



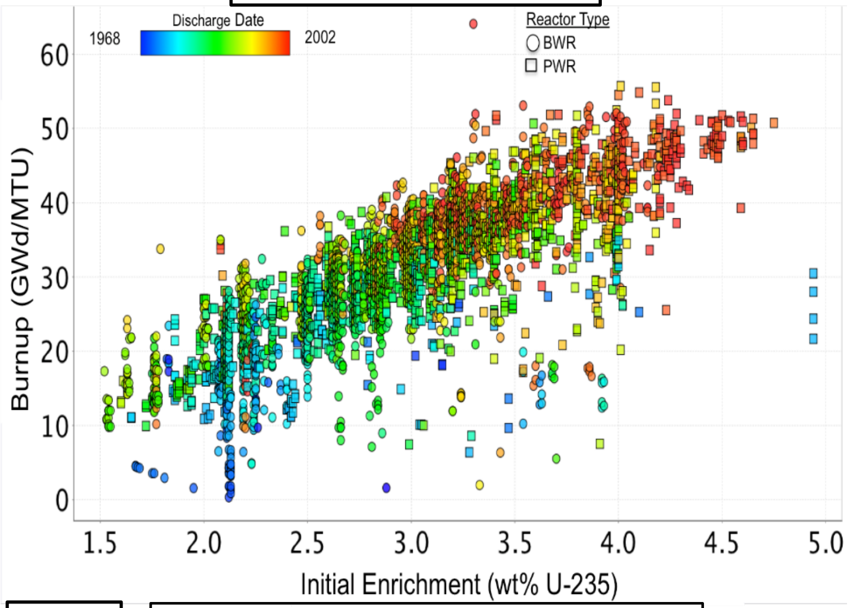
UNF-ST&DARDS performs criticality analysis using as-loaded configuration (KENO-VI)

- Current design-basis approach uses bounding fuel characteristics (e.g., fuel type, initial enrichment, and discharge burnup) for canister certification process
- In practice, discharge SNFs available for loading are diverse (e.g., wide variation in SNF assembly burnup values)

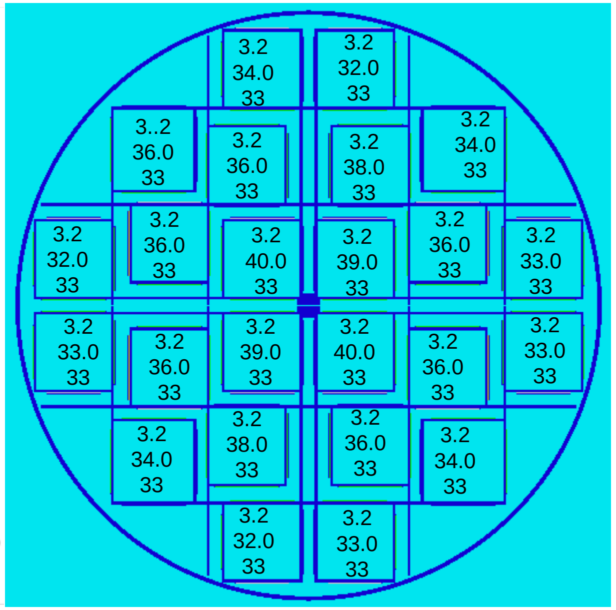
Design-basis k_{eff} = 0.90



Discharged inventory



As-loaded k_{eff} = 0.66

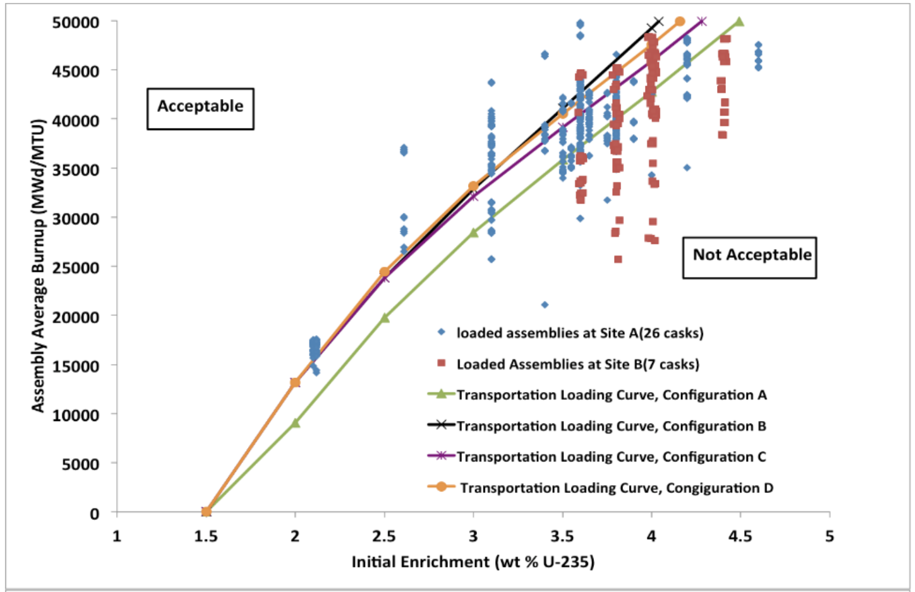


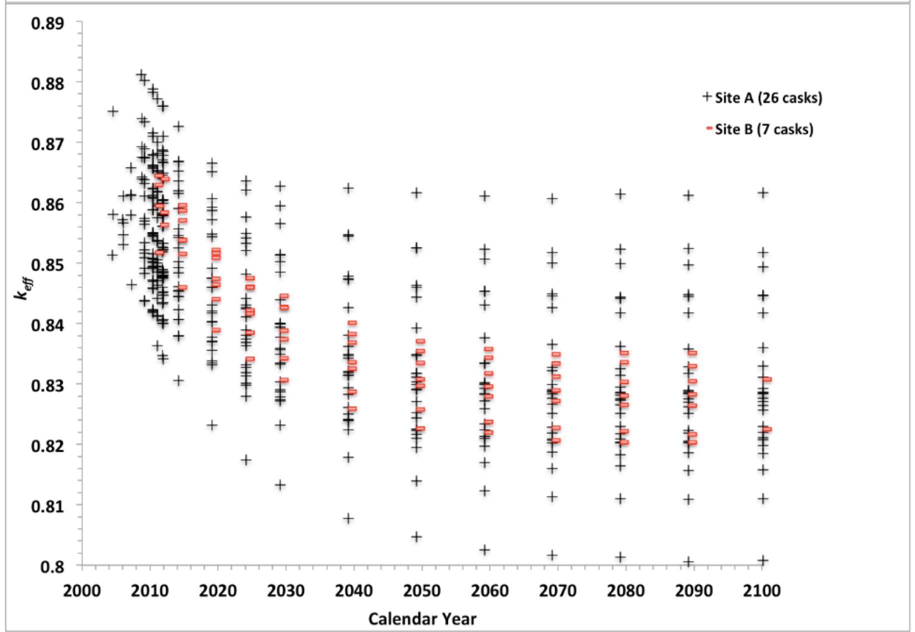
Uncredited margin = 0.90-0.66 = 0.24 Δk_{eff}

X	Assembly average initial enrichment (wt %)
Y	Assembly average burnup (GWd/MTU)
Z	Cooling (years)

UNF-ST&DARDS as-loaded criticality analysis can be used to determine whether a loaded canister is transportable from a criticality standpoint

- SNF loaded following the storage COCs may not be transportable
  - Storage: soluble boron credit with fresh fuel assumption
  - Transportation: Burnup credit and loading is restricted by the loading curves in COC
- However, loaded canisters generally possess excess and uncredited criticality margins (difference between licensing and as-loaded)
  - As-loaded analysis can be used for license amendment and integrating storage and transportation analysis approaches





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UNF-ST&DARDS as-loaded criticality analysis is being used to determine the feasibility of direct disposal of loaded canisters

- 76% of loaded canisters are below the representative subcritical limit (considered as 0.98 k_{eff}) with as-loaded analysis with fresh water

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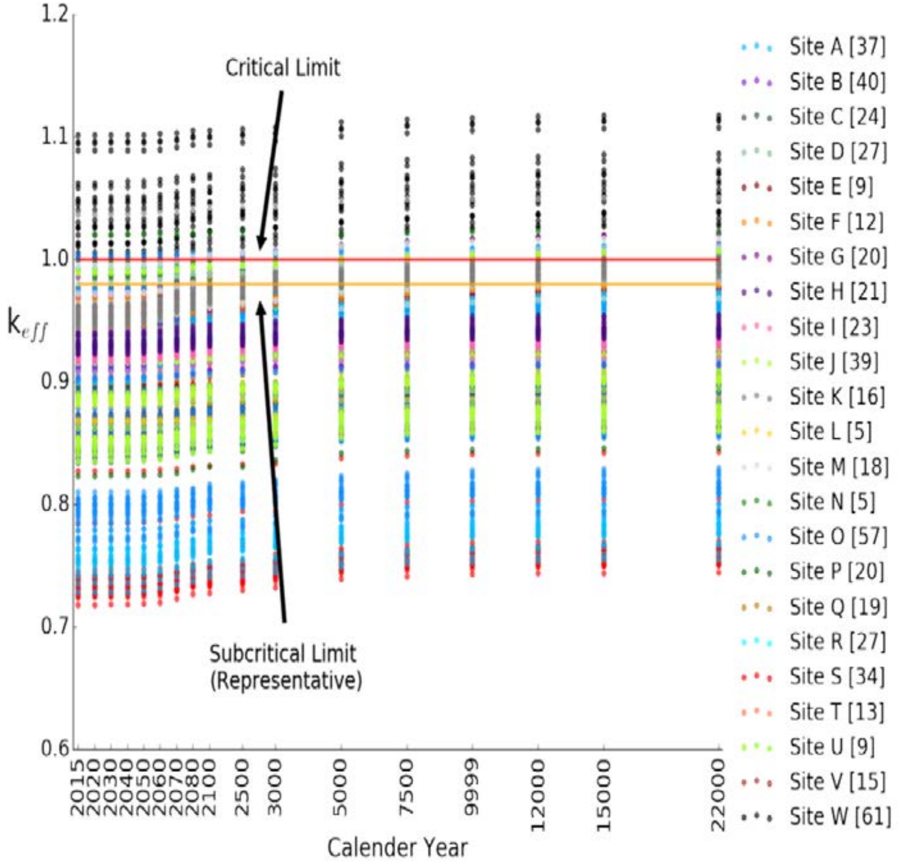
Description (Analysis year: 12000)	Value
Total DPCs analyzed	616
Total DPCs below subcritical limit with loss of neutron absorber (design-basis loading)	0 (0%)
Total DPCs below subcritical limit with loss of neutron absorber (as-loaded)	473 (~76%)
Total DPCs below subcritical limit with loss of neutron absorber and carbon steel structures (as-loaded)	420 (~68%)
Total DPCs below subcritical limit with loss of neutron absorber and carbon steel structures (as-loaded) considering misload*	397 (~64%)



* Misload includes assemblies are placed in wrong location within canister

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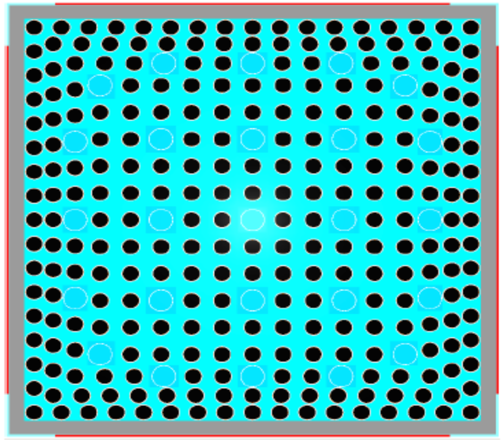
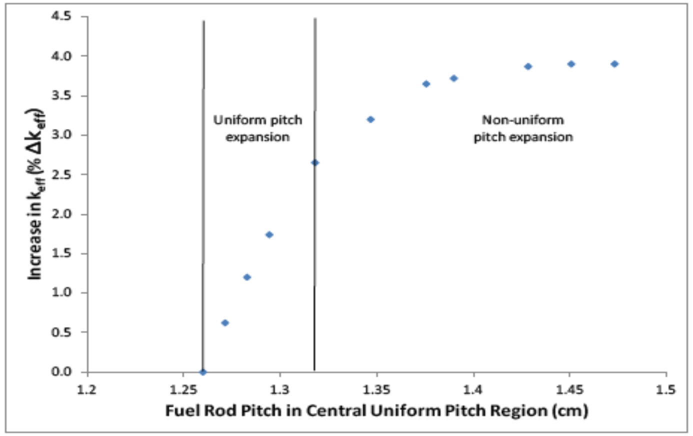
Uncredited criticality margin can be credited to offset system aging-related reactivity increases

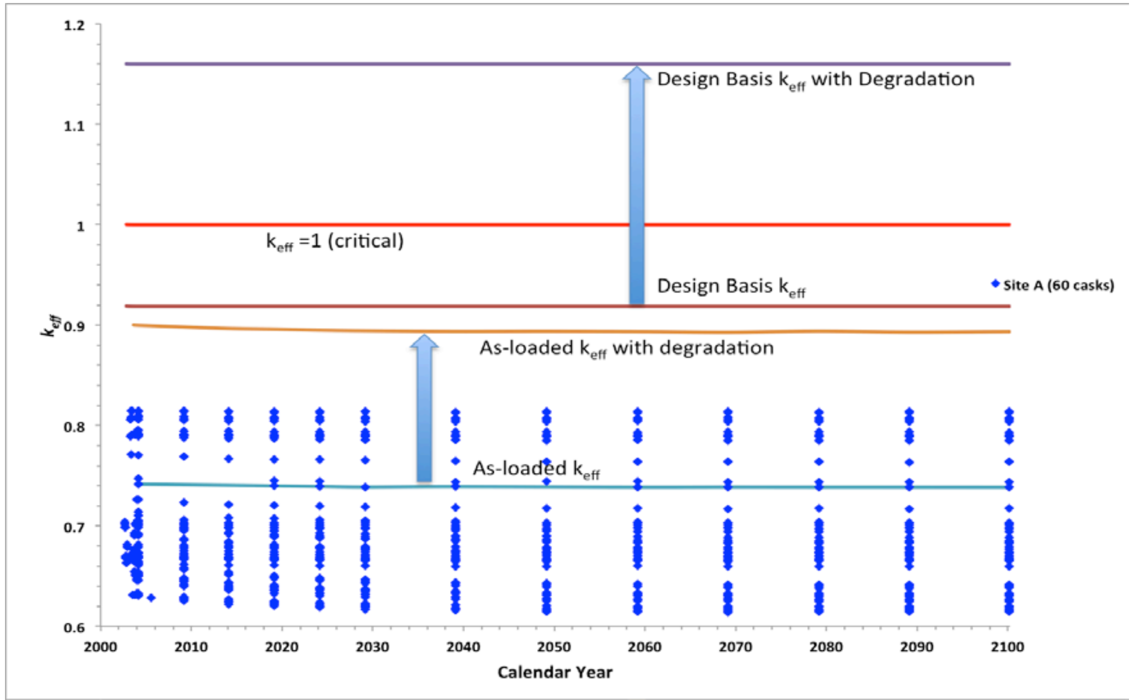
- Potential changes in as-analyzed geometric configuration
  - Fuel reconfiguration



Notes: Both shades of light blue are identical water compositions
Neutron absorber panels are shown in red



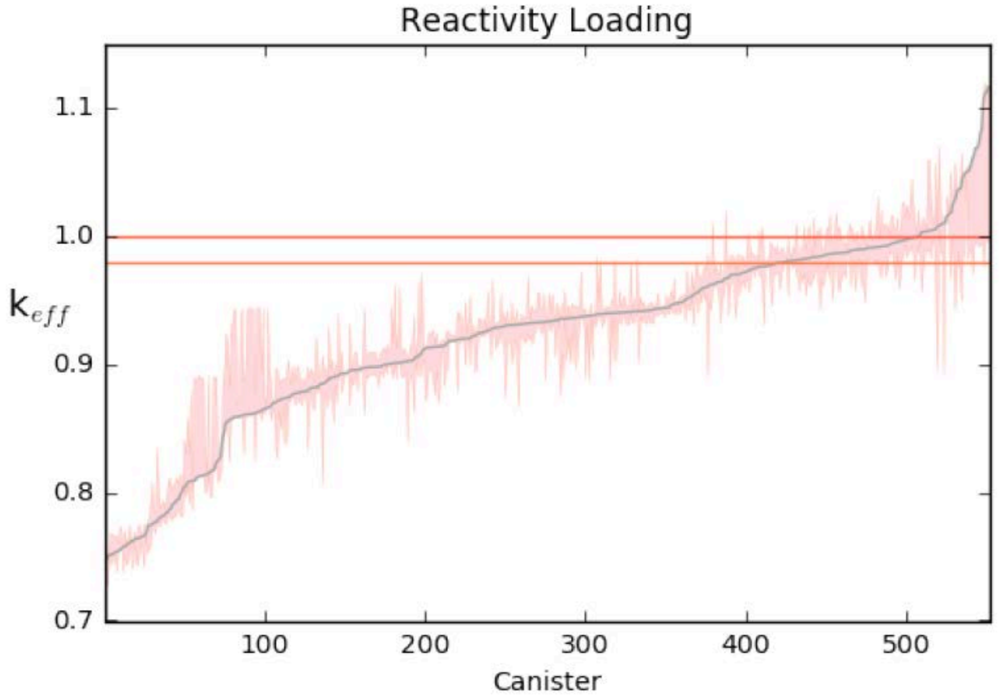
- Effects of neutron absorber degradation



UNF-ST&DARDS can be used to optimize canister loading to avoid canister criticality in disposal time frame with postulated flooding and degradation

- Given canister inventory (list of assemblies) and a canister type, UNF-ST&DARDS can provide least reactive loading map (configuration)

- Current loading strategy
  - Reduce dose (low reactivity)



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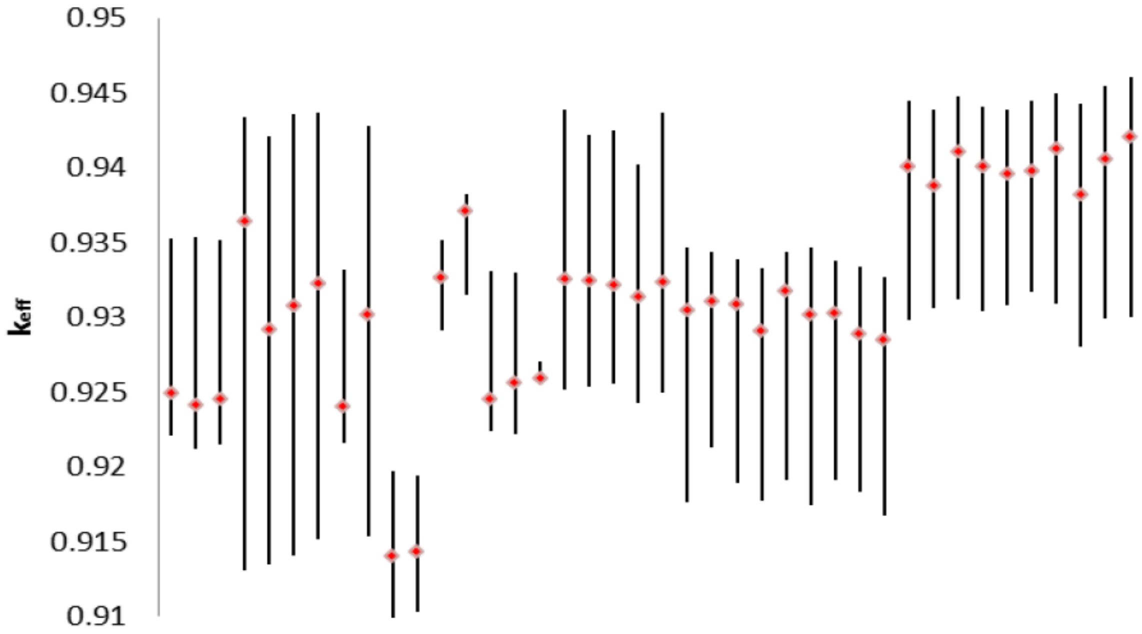


Red markers indicate the reactivity of the loaded canisters, and black lines are the range between optimized and worst possible loading using the same canister inventory.

The reactivity of 556 canisters, as well as a band spanning from the least reactive to most reactive configuration. Note: **Most of the analyzed canisters with a k_{eff} above 1 have been loaded in a very reactive configuration and could have been loaded with k_{eff} between 1 and 0.98 using the same inventory with the assumed degradation scenario**

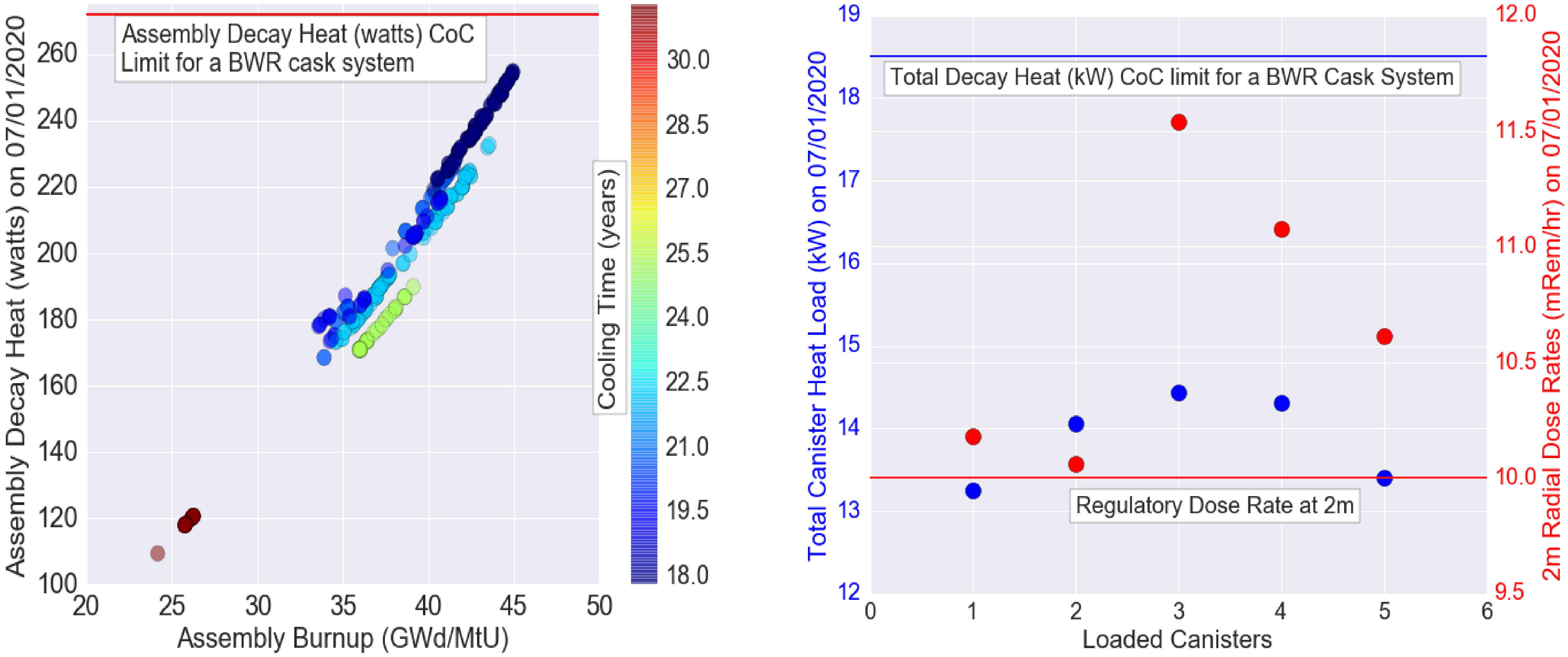
UNF-ST&DARDS uses MAVRIC for as-loaded dose analysis for transportation casks

Color-coded dose rate maps provides comprehensive characterization of package external dose rate

Radial and Angular Variation of Dose Rate in Air Regions External to a Transportation Package

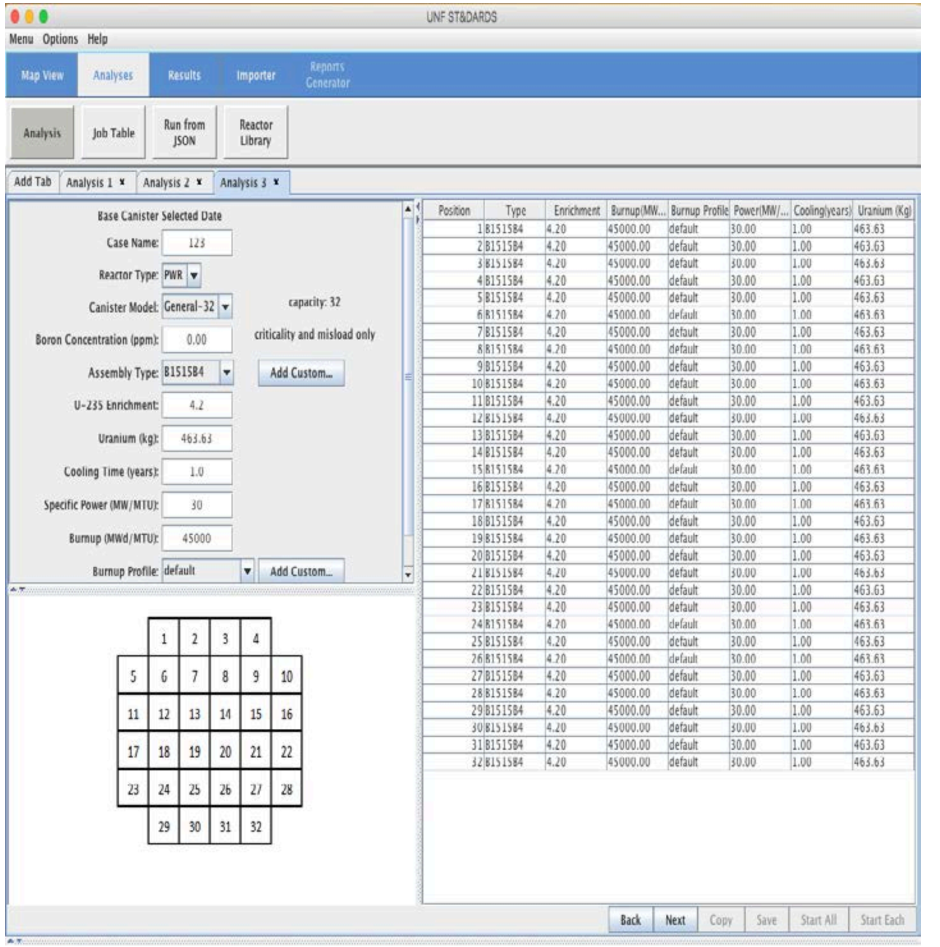
Only dose rate values greater than 10 mrem/h are shown

UNF-ST&DARDS dose analysis can be used to determine when a loaded canister is transportable from a shielding standpoint



UNF-ST&DARDS provides design-basis criticality and shielding analysis capabilities for SNF storage and transportation systems

- Design-basis (custom) analysis can be performed
  - using a loaded canister from the database and then modifying its content
  - Creating canister inventory from scratch
- Design-basis analysis capability can be used to prepare cask system license applications (e.g., by cask vendors)
- Design-basis analysis capability can be used to support cask system license application reviews (NRC)
- Design-basis analysis includes various sensitivity analyses



UNF-ST&DARDS is providing all-round spent nuclear fuel management solutions to DOE, NRC, US and International industries

- Limited (invitation only) distribution through RSICC
- Current UNF-ST&DARDS users include
  - Department of Energy (DOE) Office of Nuclear Energy (NE)
    - Integrated Waste Management (IWM): Historical and projected SNF and SNF related systems characterization, waste management system analysis
    - Spent Fuel and Waste Science & Technology (SFWST): Feasibility assessment of direct disposal of loaded canisters (mainly from criticality perspective)
    - Material Protection, Accounting and Control Technologies (MPACT): Analysis in support of used fuel safeguards and security for extended storage
  - NRC: Technical assistance in license application review (such as HI-STAR 190, WCS interim storage facility) and training
  - Swedish Nuclear Fuel and Waste Management Co (SKB): Testing, and feedback on UNF-ST&DARDS
  - China: NNSA funded UNF-ST&DARDS workshop (Last week of September, 2018)
  - EPRI : Dose consequence assessment due to potential stress corrosion cracking breach of dry canisters