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Next Generation System Analysis Model: Recently Added Features and Future Plans

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Changing the World's Energy Future

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Next Generation System Analysis Model: Recently Added Features and Future Plans

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This is a technical presentation that does not take into account contractual limitations or obligations under the Standard Contract for Disposal of Spent Nuclear Fuel and/or High-Level Radioactive Waste (Standard Contract) (10 CFR Part 961). For example, under the provisions of the Standard Contract, spent nuclear fuel in multi-assembly canisters is not an acceptable waste form, absent a mutually agreed to contract amendment.

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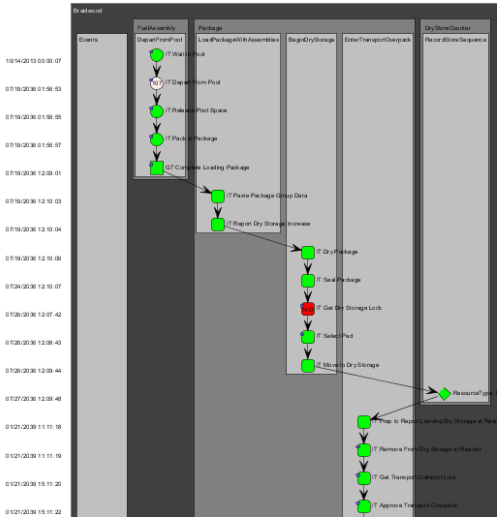
This presentation reflects technical work which could support future decision making by DOE. No inferences should be drawn from this presentation regarding future actions by DOE, which are limited both by the terms of the Standard Contract and Congressional appropriations for the Department to fulfill its obligations under the Nuclear Waste Policy Act including licensing and construction of a spent nuclear fuel repository.

NGSAM provides for flexible analysis of an integrated waste management system

- Next-generation System Analysis Model (NGSAM) is an agent-based discrete event simulation tool based on the Process Analysis Tool (PAT) framework developed at Argonne National Laboratory (ANL)
- Designed for origin site to disposition site modeling of spent nuclear fuel (SNF)*
- NGSAM allows analysts to:
  - Add, remove, and modify model logic
  - Generate custom reports
  - Analyze a wide range of integrated waste management system configurations, approaches, and scenarios
- NGSAM reference data are obtained from the Used Nuclear Fuel – Storage, Transportation & Disposal Analysis Resource and Data System (UNF-ST&DARDS) and the DOE Spent Fuel Database



*spent nuclear fuel and used nuclear fuel are sometimes used synonymously

Outline

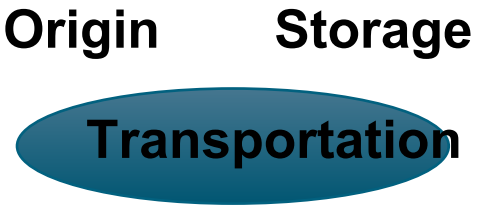
- NGSAM background
- NGSAM development, execution, and capabilities
- Outputs for system analysis produced by NGSAM
- Future planned capabilities
- Conclusions

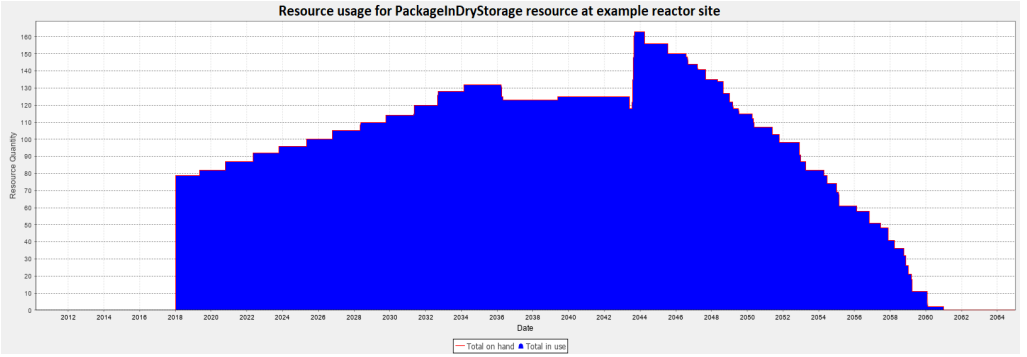
NGSAM developers and system analysis contributors:

- Argonne National Laboratory: Brian Craig, Chuck Olson, Lucas Vander Wal, Evan VanderZee
- Idaho National Laboratory (INL): Robby Joseph, Gordon Petersen
- Oak Ridge National Laboratory: Abi Adeniyi, Riley Cumberland
- Pacific Northwest National Laboratory: Mark Nutt

NGSAM helps analysts model potential waste management system strategies

- NGSAM models the backend for SNF and high-level radioactive waste (HLW)
- NGSAM allows detailed customization for options such as:
  - Storage facilities (dry/wet)
  - Packaging options
  - Costs
  - Throughputs
  - Transportation assets
- NGSAM can help answer questions related to:
  - Various scenarios involving multiple facilities
  - Shared resources required (e.g., transportation assets)
  - Site inventories as a function of time
  - Consolidated storage facilities and options





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NGSAM is used to compare numerous alternatives to answer “what if” questions

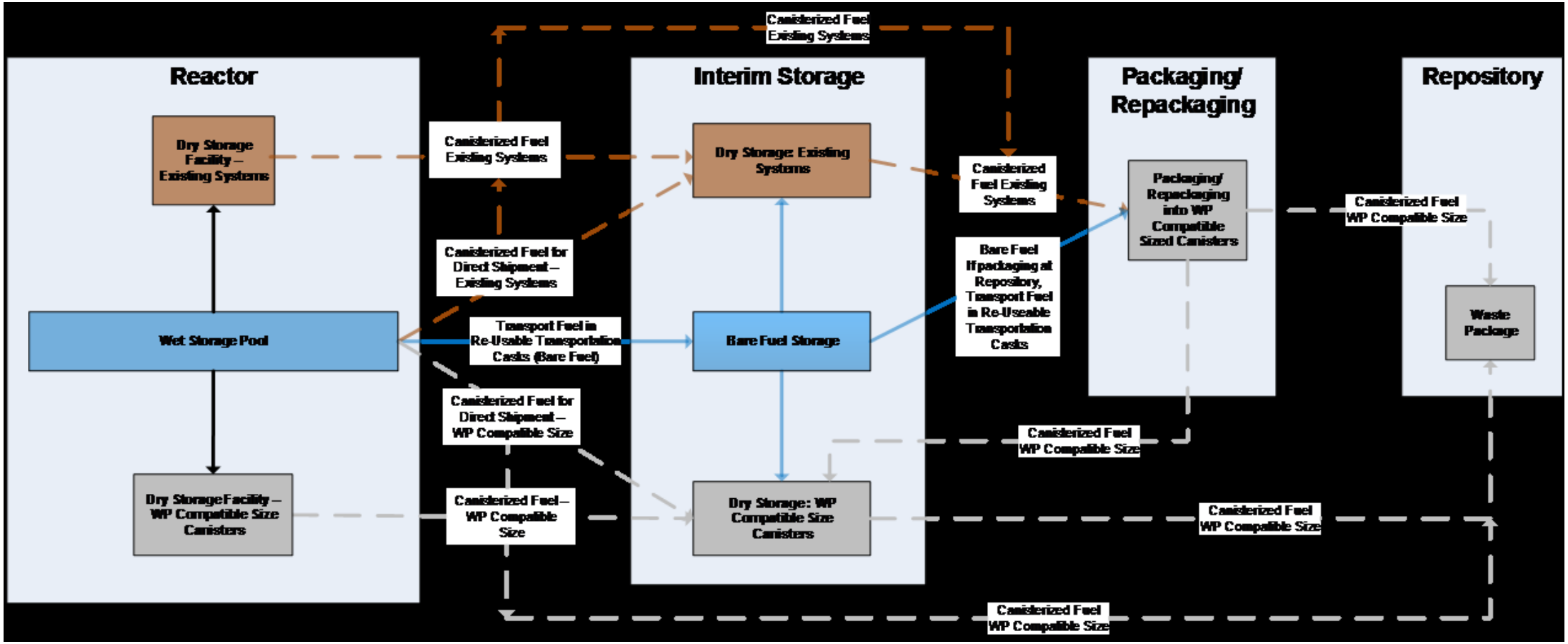
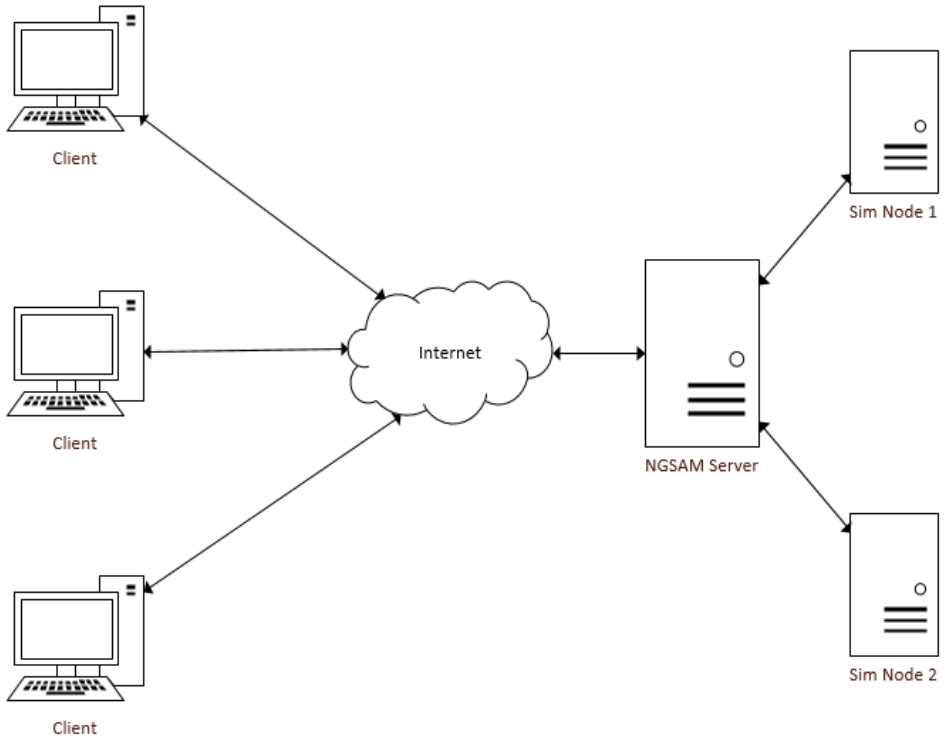


Illustration of potential alternatives in a future waste management system

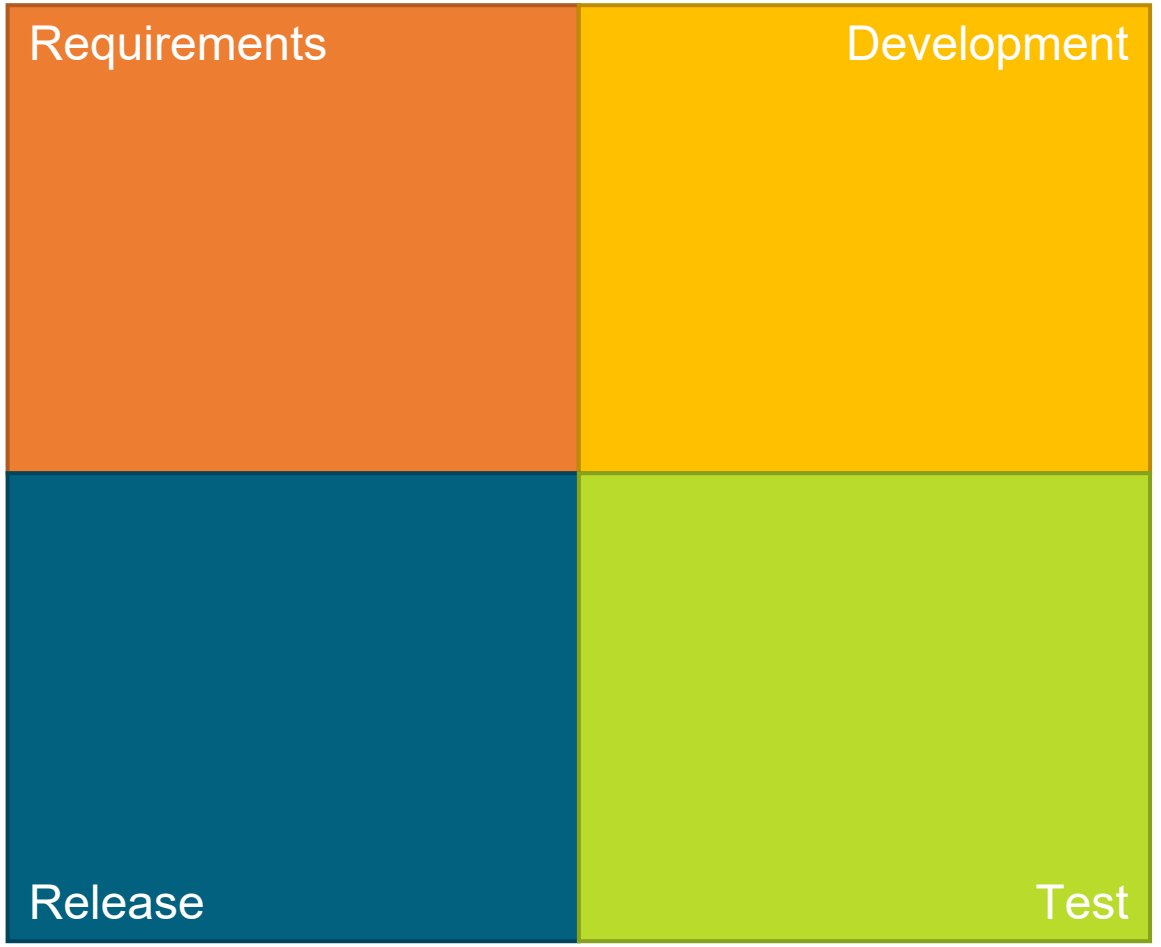
NGSAM can execute in two different modes

- Stand alone
  - All setup and simulations are performed on the analyst's machine
  - Useful for testing small changes to the logic before running larger simulations
  - Does not require internet connection
- Client-server
  - All setup is performed on the analyst's machine
  - Simulation is executed in the NGSAM cluster at ANL
  - Results are retrieved from the server after execution
  - Useful for running large scenarios that require intensive resources
  - Current cluster can run ~12 simulations simultaneously



NGSAM continues to be developed using a spiral methodology

- Typically released 2–3 times per year
- Analysts are typically involved in the requirements period of the development cycle
- NGSAM utilizes a close relationship with analysts to provide constant feedback throughout the entire development lifecycle
- NGSAM can now model the entire waste management system from generation to disposal
  - Enhancements are added as needed

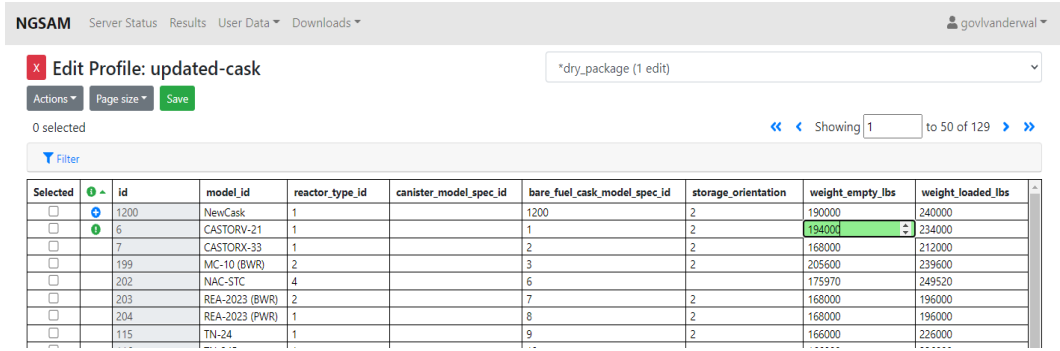


Spiral methodology schematic

Recent NGSAM enhancements have expanded capabilities and improved user experience

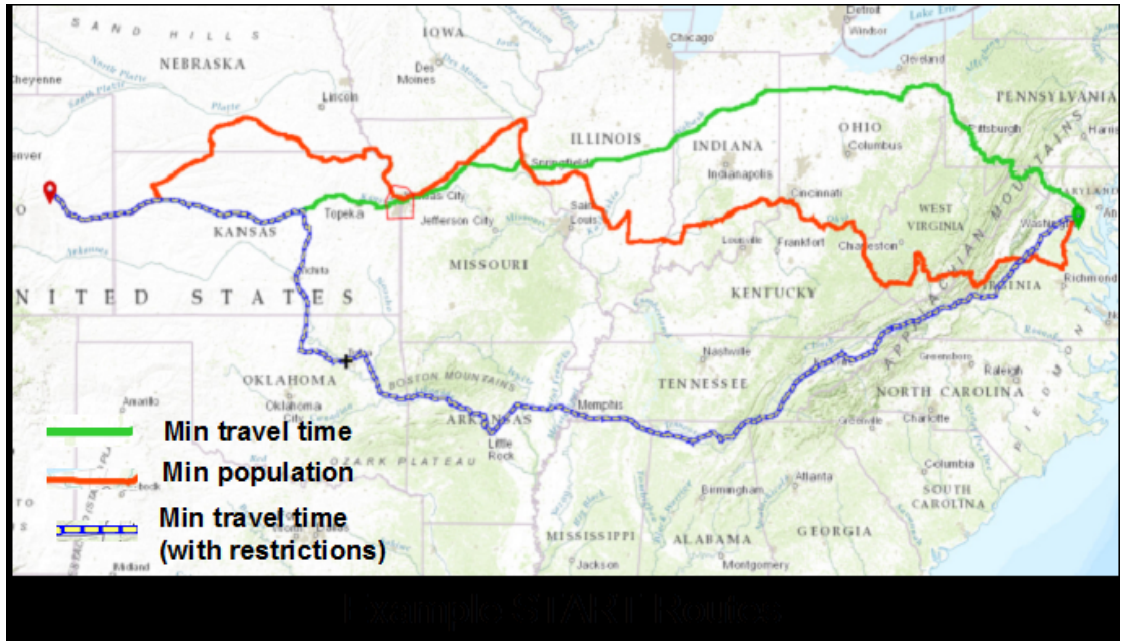
- Additional output reports or modification of existing ones
- Ability to use logic that simulates allocation of SNF shipment opportunities to utilities/custodians first, before making allocation to specific sites
- A hypothetical allocation method that seeks to reduce the number of packages loaded into dry storage at reactor sites
- Added support for multiple canister loading map options and packages with multiple compatible transportation overpacks
- Ability to model hypothetical scenarios where repackaging occurs at reactor sites
- Ability to model loading SNF from pool storage at a consolidated interim storage facility (ISF) into dry storage at the ISF
- Ability to generate and implement user edits via the

NGSAM website



Recent transportation-related NGSAM enhancements have expanded capabilities and improved user experience

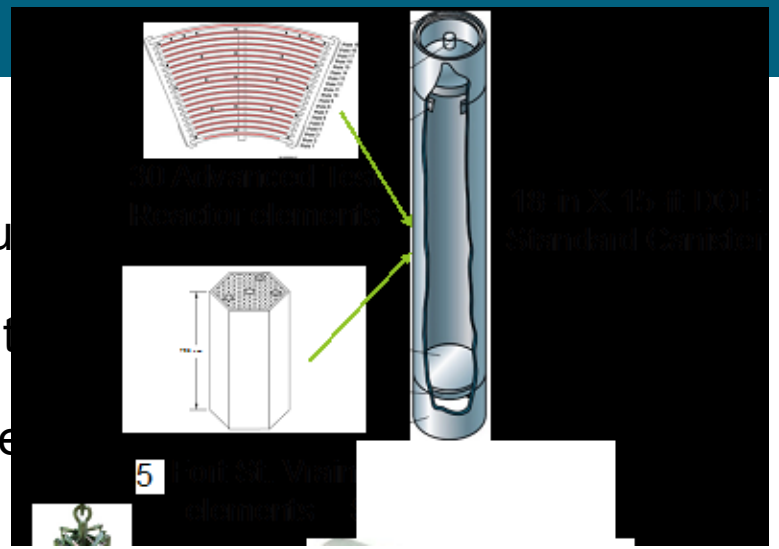
- Tracking of railroad escort car and buffer car acquisition
- Addition of heavy haul truck and barge routes for some sites and support for user-defined intermodal routes
  - Example transportation routes incorporated from Stakeholder Tool for Assessing Radioactive Transportation (START) analyses
- Updates to logic that checks the transportation cask thermal limit maps prior to package transport
- Ability to model transloading (moving SNF casks from one transportation mode to another)

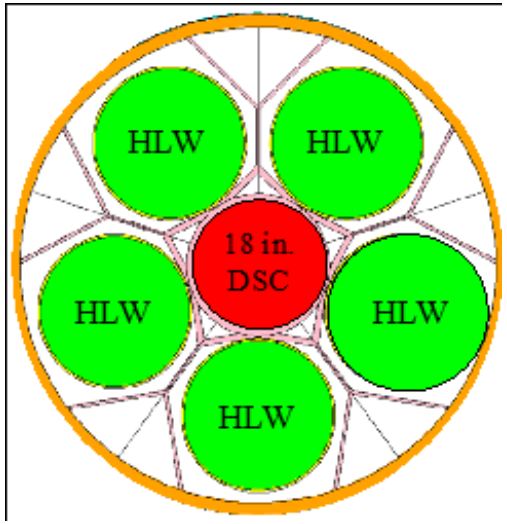


Note: example routes are for illustrative purposes only and do not reflect a selected destination site

Updates to the modeling capabilities and database structure for DOE-managed SNF

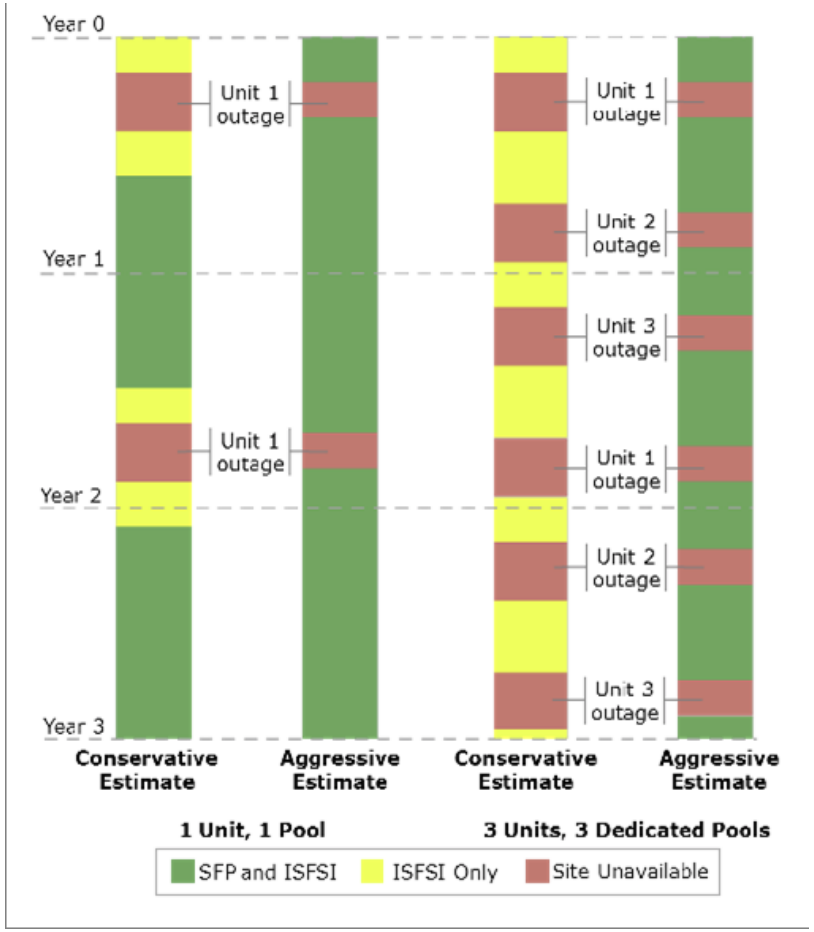
- Initial improvements included:
  - Changed level of modeling from the canister to the individual fu element
  - Additional packaging logic for DOE-managed SNF because of t variety of geometries
    - Multiple different DOE-managed fuel types can be package in the same type of canister
  - Additional disposal overpack packaging logic so packages containing DOE-managed SNF could be co-loaded with HLW in disposal overpacks
- Improving the modeling capabilities for DOE-managed SNF:
  - Enables analysts to more accurately estimate the number of canisters required to package DOE-managed SNF and, in turn, the number of overpacks and transportation resources that may be required





Added reactor site family operational limits to restrict the number of SNF loads taken from the pool and from dry storage at a given reactor each year

- Sites were categorized into 14 families based on the following criteria:
  - Number of operating reactors on site (0–3)
  - Operating reactor type
    - Pressurized-water reactor (PWR)
    - Boiling water reactor (BWR)
  - Length of refueling cycle (18 or 24 months)
  - Number of spent fuel pools (SFPs) (0–4)
  - Configuration of SFPs (shared or dedicated)
- This information is useful for estimating in NGSAM how many casks can be shipped per year from each site



Loading windows example

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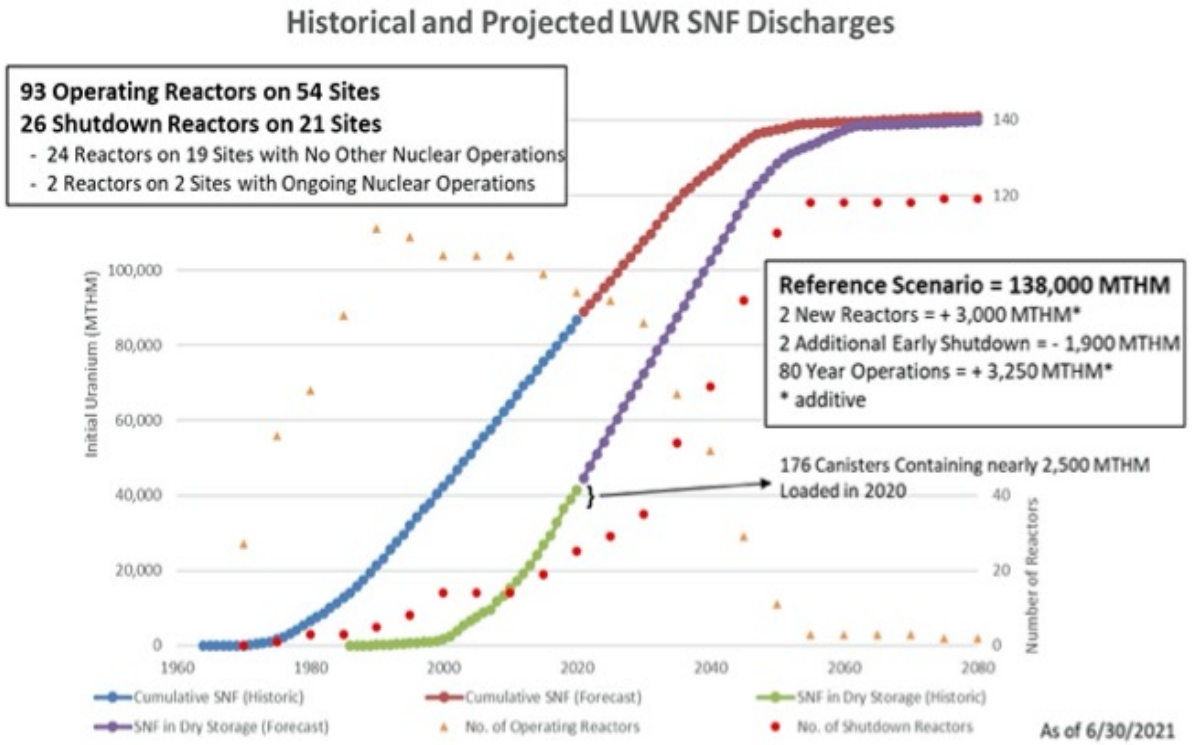
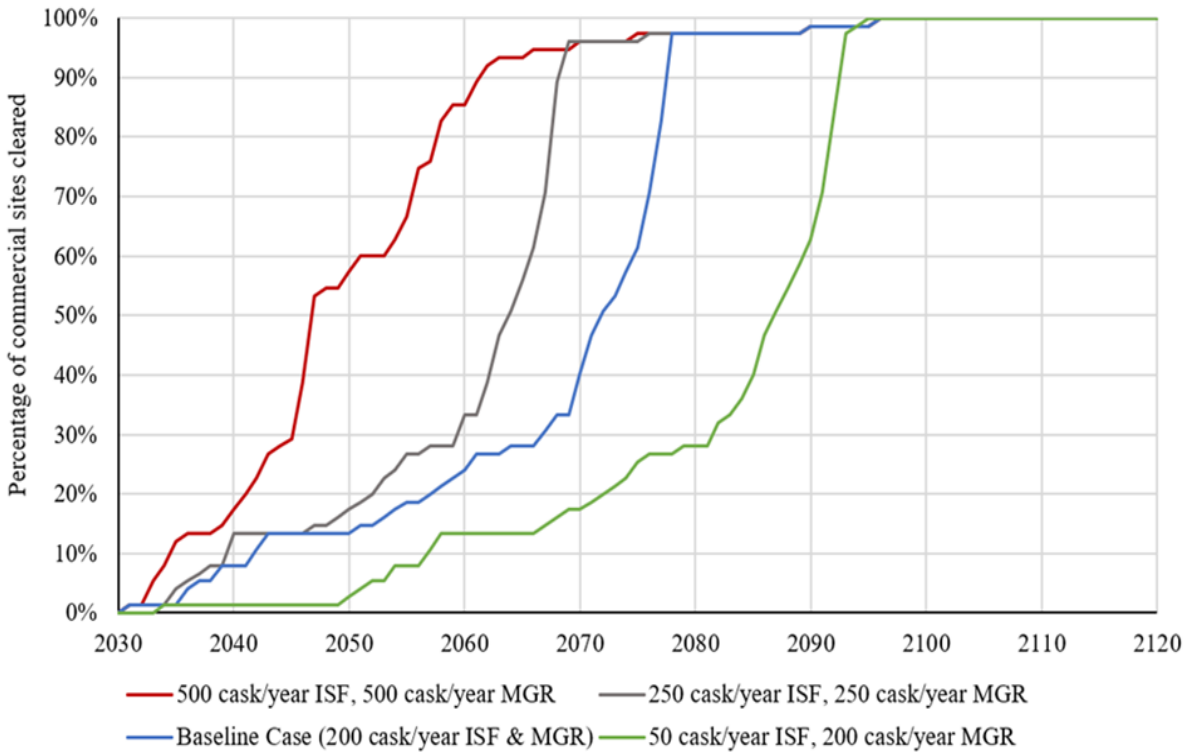
Why NGSAM and system analysis? The existing U.S. light water reactor fleet has and continues to generate SNF that must be managed

- Over 86,000 MTHM of SNF discharged and in interim storage at reactor sites
- About 2,000 MTHM discharged per year
- Over 3,000 dry storage canisters (over 41,000 MTHM)
- About 200 dry storage canisters added per year
- Potential growth to ~145,000 MTU
- Following examples show system analysis results can be used to:
  - Support DOE's consolidated interim storage effort
  - Inform stakeholders and decision makers



Illustrative system analysis: SNF receipt rates can affect how quickly sites are cleared

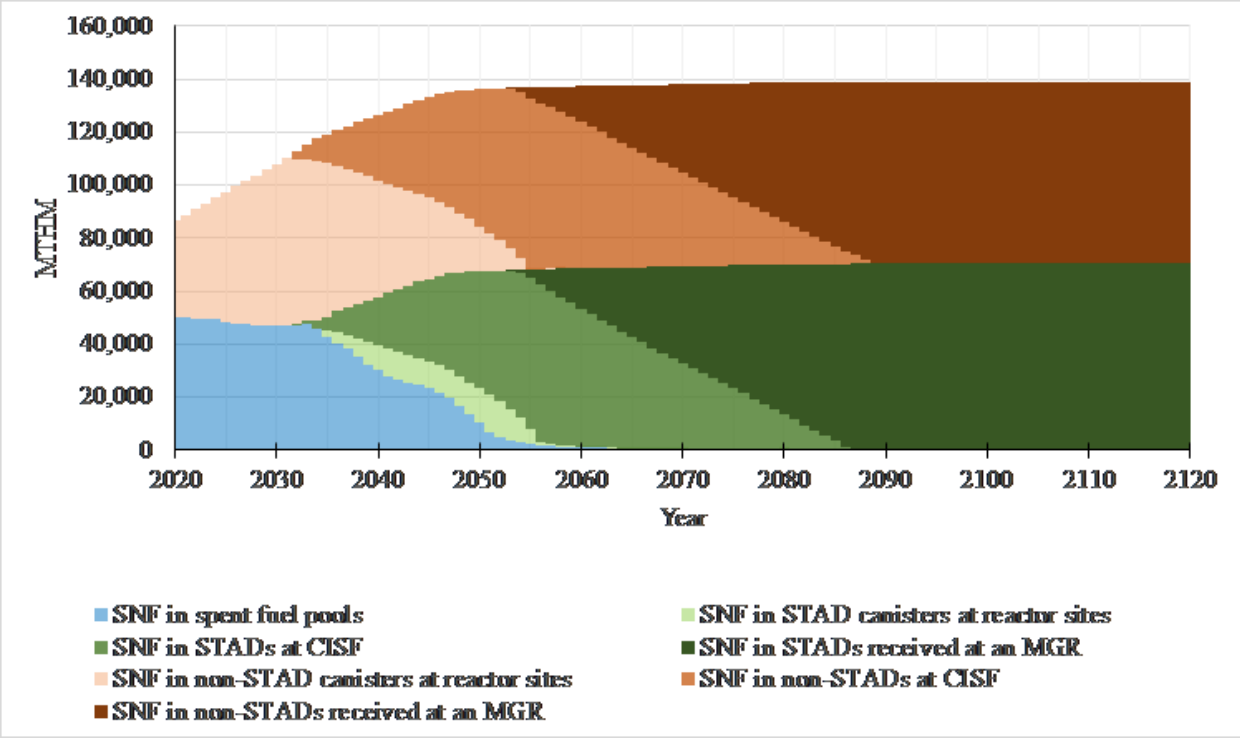
- The higher the SNF receipt rates at an ISF and Mined Geologic Repository (MGR), the faster that sites can be cleared of SNF
- Increased receipt rates would also require additional infrastructure capabilities at receiving facilities and within the transportation system
- MGR opens 20 years after ISF for these scenarios



Percentage of commercial sites cleared as a function of time

Illustrative system analysis: Implications of deploying standardized canisters

- NGSAM can be used to examine scenarios in which the nuclear power industry transitions
  - From dual-purpose canisters (DPCs) which may require repackaging prior to disposal;
  - To standardized transportation, aging, and disposal (STAD) canisters
- A portion of a consolidated ISF (CISF), or a separate CISF, could be dedicated to receiving SNF in STAD canisters, ideally shipped directly from reactor spent fuel pools
- Results indicate some dry storage for STAD canisters at reactor sites might be needed depending on assumed CISF receipt rate and reactor shutdowns with time



SNF inventories in non-STAD canisters (DPCs) and in STAD canisters as a function of time

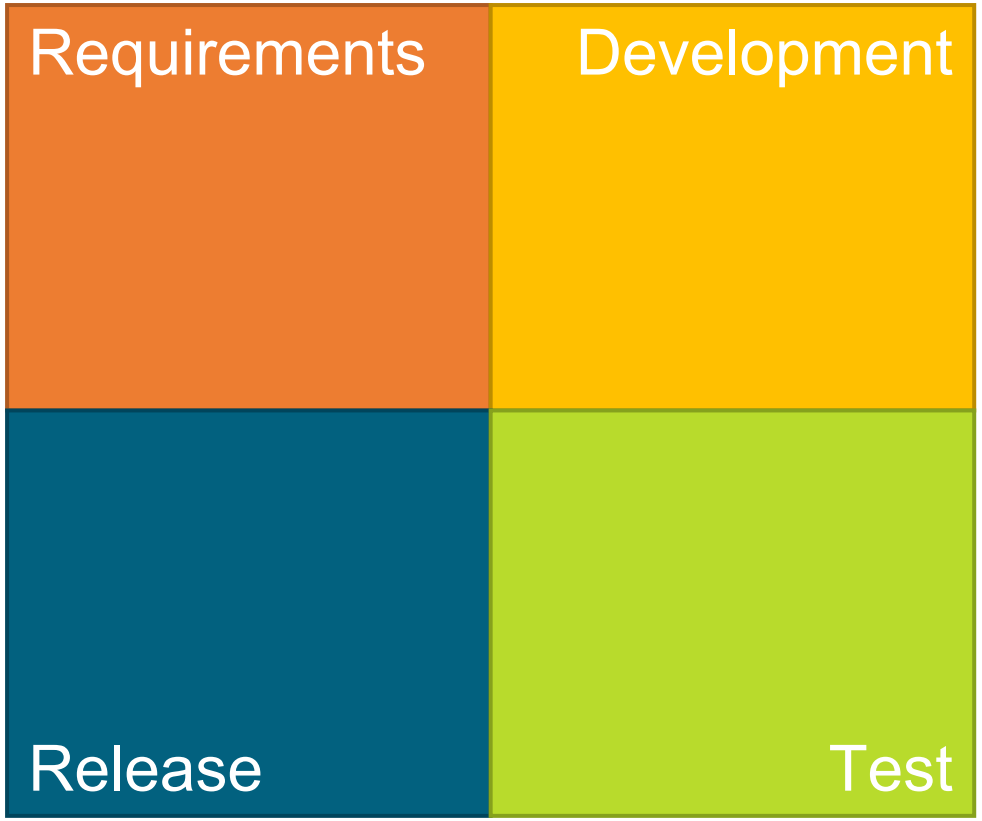
Preliminary requirements for advanced reactor fuel cycles considered

- Preliminary requirements developed for advanced reactor fuels, reprocessing, treatment, and conditioning
- Other nuclear fuel cycle system analysis tools sponsored by DOE's Office of Nuclear Energy might be better suited for initial high-level analysis
- NGSAM could add value by modeling in greater detail the transport, storage, and disposal of spent fuel and waste from advanced reactors at the fuel element and waste container levels
    - It is envisioned NGSAM could be able to estimate reprocessing and/or treatment/conditioning facility capability needs

Integrated waste management system analysis is necessary to better understand various possible options, approaches, and strategies to inform all stakeholders and future decisions about advanced reactor fuel cycles

NGSAM provides for flexible analysis using data from UNF-ST&DARDS or the Spent Fuel Database

- Designed for origin site to disposition site modeling of spent nuclear fuel (SNF)
  - It is now fully functional, and additional enhancements are implemented as necessary
- NGSAM allows analysts to:
  - Add, remove, and modify model logic
  - Generate custom reports
  - Analyze a wide range of integrated waste management system configurations, approaches, and scenarios
- Preliminary requirements for advanced reactor fuel cycles have been developed
- System analysis results generated by NGSAM can be used to inform decision makers and stakeholders



Questions?

Illustrative system analysis: Higher ISF capacity can enable more reactor sites to be cleared of SNF before an MGR opens

Maximum ISF capacity and the number of sites cleared with an ISF by the time a repository is assumed to open.

Scenario number	ISF Receipt rate (Dual Purpose Canisters/ year)	ISF opening date	MGR opening date	Maximum ISF capacity	Sites cleared by MGR opening date	Similar scenarios listed according to key difference
1	500	2030	2050	~125,000	43	1–4: shipment rate
2	250	2030	2050	~74,000	13	1–4: shipment rate
3	200	2030	2050	~60,000	10	1–4: shipment rate 5–6: MGR date
4	50	2030	2050	~15,000	2	1–4: shipment rate
5	200	2030	2040	~29,000	6	3, 6: MGR date
6		2030	2060	~89,000	19	3, 5: MGR date 7: ISF date
7		2040	2060	~60,000	10	6: ISF date