UNCERTAINTY EVALUATION OF REACTIVITY FOR LONG-TERM DRY CASK STORAGE

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INTRODUCTION

- Evaluation of uncertainties in a given data library can provide assurances of the safety of recycling, storage, shipping and disposal of used nuclear fuel, along with the operation and safety of critical and subcritical experimental facilities.
- The future for used nuclear fuel in the United States is uncertain due to several factors, including:
  - uncertainty of Yucca Mountain Project fate,
  - lack of plans to reprocess fuel.
- As such, on-site, long-term storage of fuel may be necessary.
- The TRITON and TSUNAMI-3D modules in SCALE 6.1 were used to model both PWR and BWR used fuel assemblies at various enrichments and burnups at several time steps over a 300-year decay period to determine the amount of uncertainty in k_{eff} due to uncertainties in ENDF/B-VII.0 cross-section data.

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METHODOLOGY
TRITON

- TRITON provides fluxes, calculated by NEWT, to ORIGEN, which is used to calculate the isotopic depletion for each assigned burnup step.
- ORIGEN then calculates decay at specified periods of time.
- OPUS extracts user-specified data from the ORIGEN output, performs unit conversions, and generates plot data as desired.
- What was modeled:
  - 15x15 PWR and 8x8 BWR were chosen as representative fuel assemblies
  - Same burnups and initial enrichments used for both PWR and BWR
  - 4-wt% ^{235}U enrichment with 45 GWd/MTU
  - 5-wt% ^{235}U enrichment with 60 GWd/MTU
  - After removal from reactor core, the fuel assemblies were decayed at several increments up to 300 years

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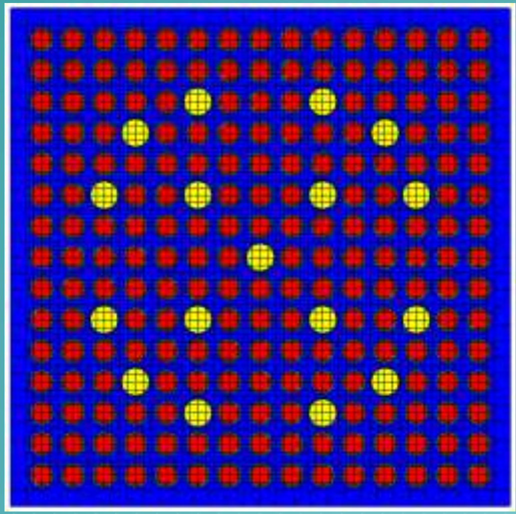
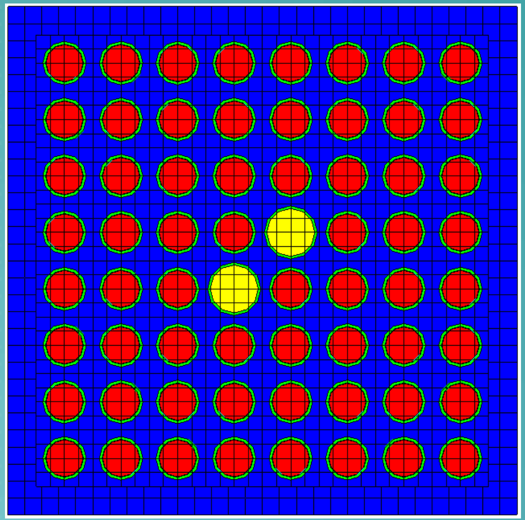
METHODOLOGY
TRITON





PWR

BWR

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METHODOLOGY
TSUNAMI-3D

- TSUNAMI-3D is a control module used for the sensitivity and uncertainty analysis in SCALE.
- TSUNAMI-3D calls the SAMS functional module, which computes sensitivity coefficients
- HI-STAR 100 cask system chosen as a commonly used fuel storage system for this study
- Cask holds 24 PWR assemblies or 68 BWR assemblies

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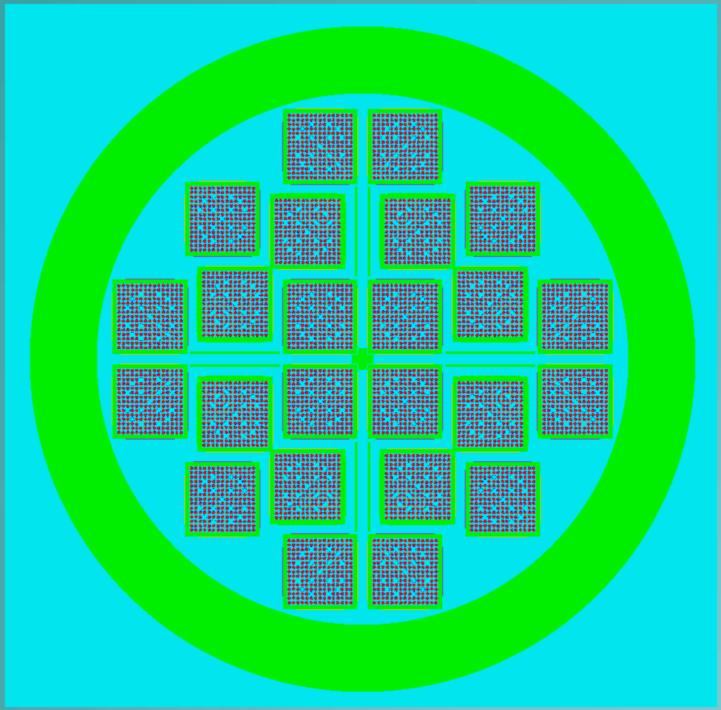
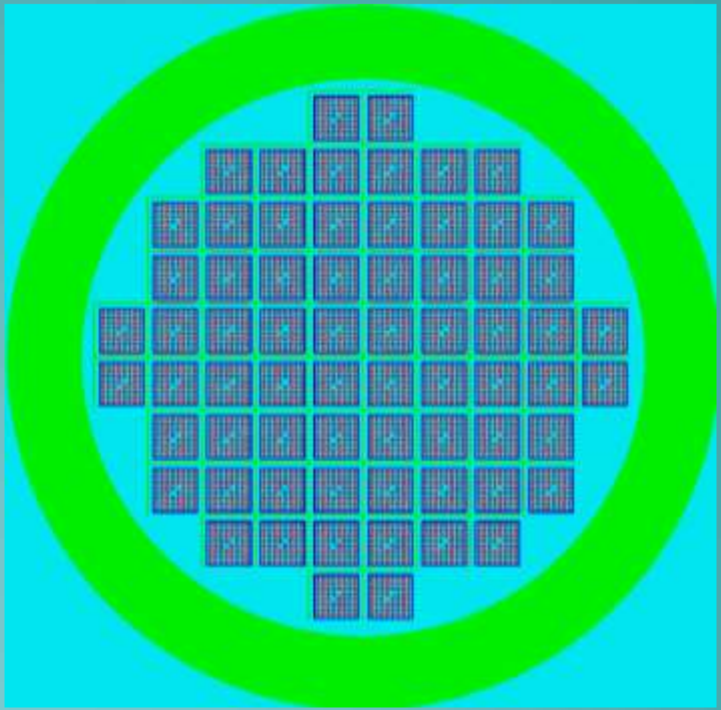
METHODOLOGY
TSUNAMI



PWR Uniform Cask Loading



BWR Uniform Cask Loading

RESULTS

Nuclide	Sensitivity		Std. Dev.
^{234}U	-3.4817E-03	±	1.0400E-05
^{235}U	1.7217E-01	±	2.5666E-04
^{236}U	-5.2160E-03	±	2.1428E-05
^{238}U	-8.0118E-02	±	4.8351E-04
^{238}Pu	-6.1694E-04	±	1.1092E-06
^{239}Pu	**2.6236E-01**	**±**	**3.7373E-04**

Select Total Sensitivity Coefficients by Nuclide Representative of PWR Configurations

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RESULTS

Covariance Matrix		Contributions to Uncertainty in k_{eff} (%Δk/k) Due to Matrix
Nuclide	Reaction	
^{239}Pu	nu-bar	5.7100E-01 ± 2.2131E-05
^{239}Pu	fission	3.0037E-01 ± 3.6224E-05
^{238}U	n,gamma	2.3201E-01 ± 1.9324E-05
^{239}Pu	n,gamma	1.6965E-01 ± 8.6668E-06
^{238}U	nu-bar	1.2016E-01 ± 2.6477E-06
^{239}Pu	n,gamma	1.1156E-01 ± 5.3998E-06
^{241}Am	n,gamma	9.9829E-02 ± 5.2360E-06
^{235}U	nu-bar	9.7657E-02 ± 1.0163E-06

Greatest Uncertainty Contributors by Reaction (PWR Configuration)

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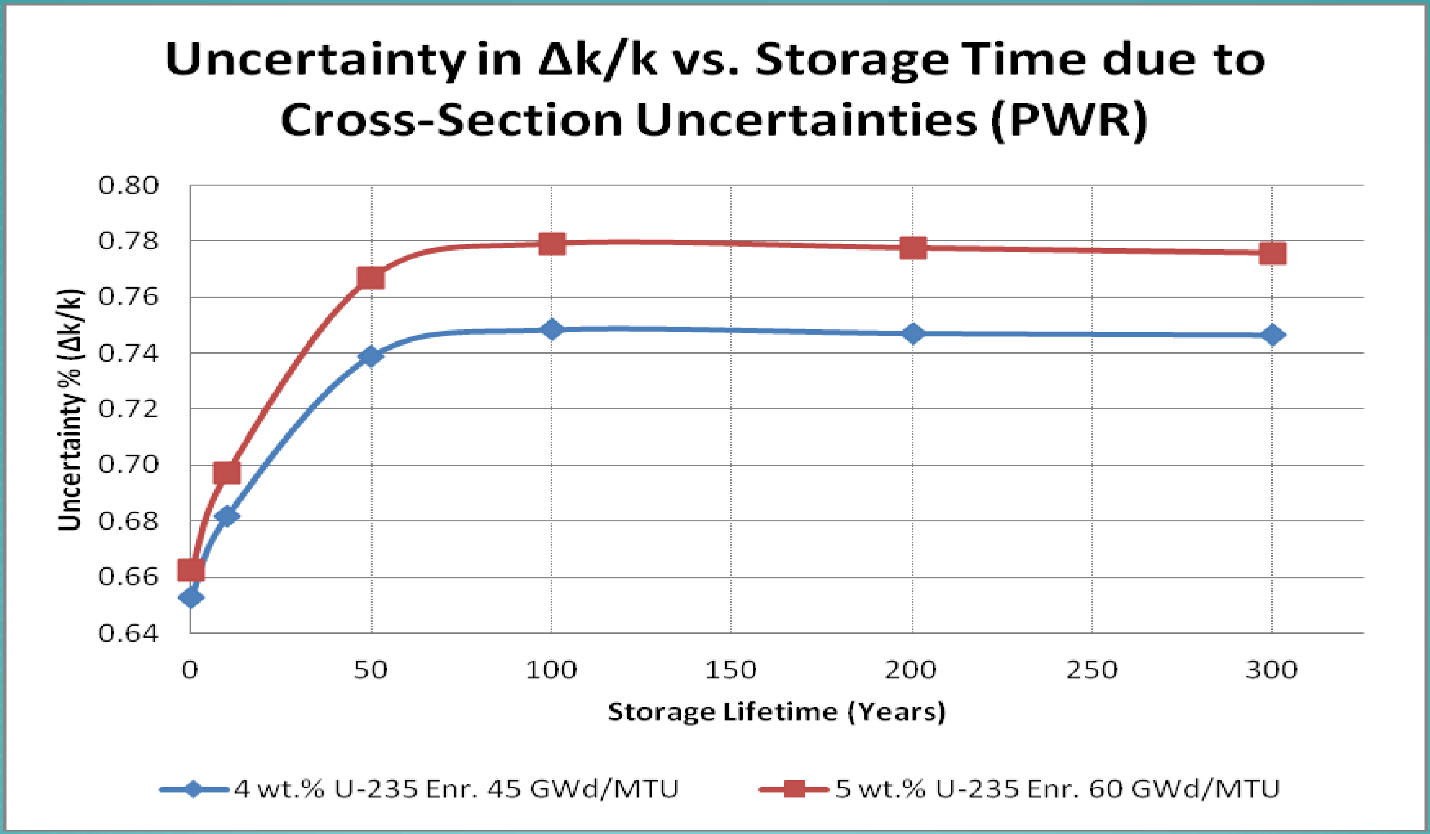
RESULTS



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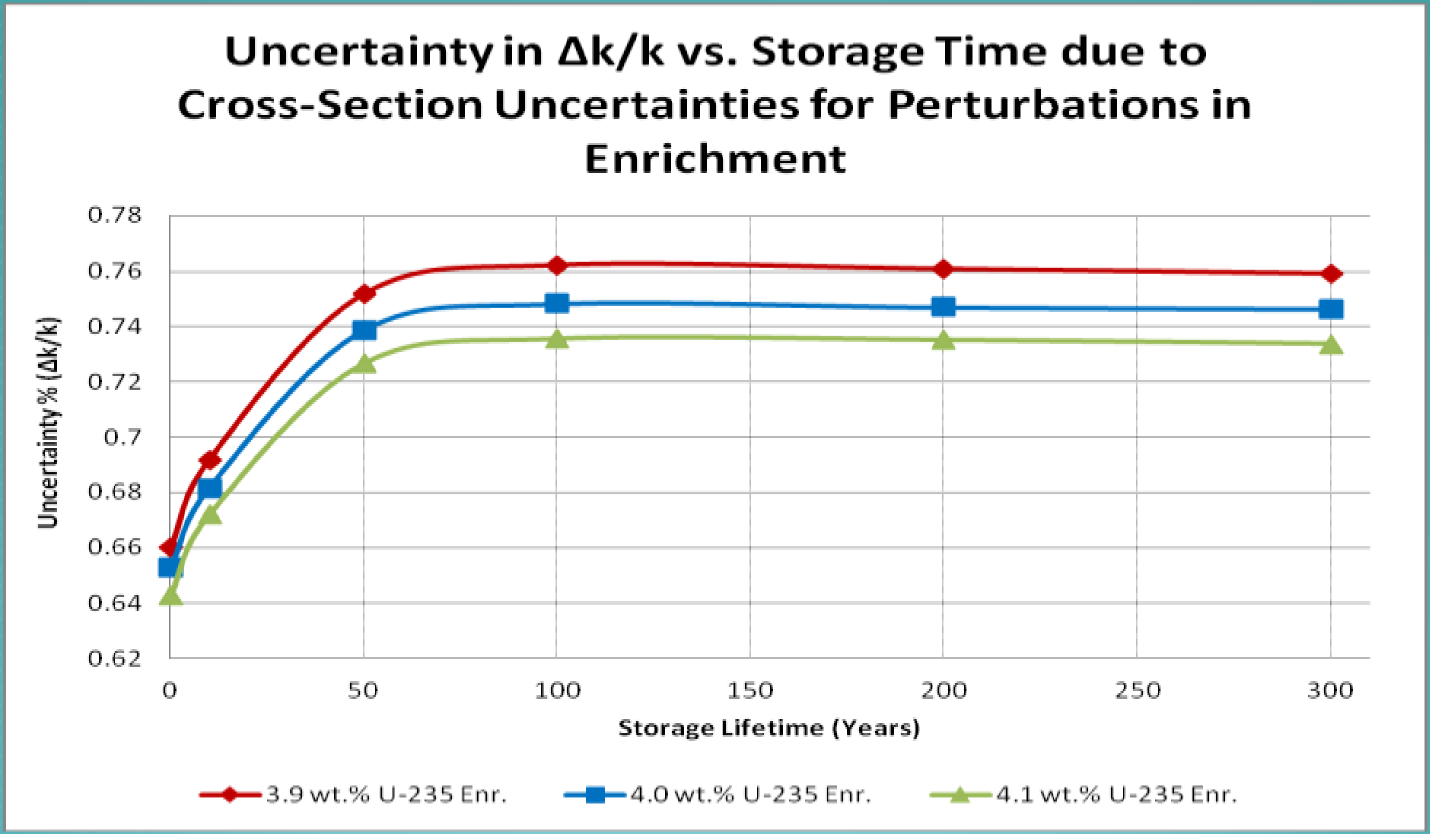
RESULTS



PWR – 45 GWd/MTU

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RESULTS

	BWR (45 GWd/MTU)		PWR (45 GWd/MTU)	
	10 years cooling	100 years cooling	10 years cooling	100 years cooling
$k_{eff,}$ Forward	0.55913	0.51985	0.61645	0.57108
$k_{eff,}$ Adjoint	0.55900	0.51920	0.61550	0.57060
% Difference	0.02	0.13	0.15	0.08

Comparison of Forward and Adjoint Calculated k_{eff} Values

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RESULTS

- In order to confirm the accuracy of the sensitivity coefficients calculated by SAMS, direct perturbation calculations were performed for ^{235}U and ^{239}Pu at two different decay times for the BWR configuration.
- These two isotopes were chosen because they showed the largest sensitivity coefficients.
- The SAMS-produced and direct perturbation sensitivity coefficients for ^{239}Pu agree well; however, ^{235}U results did not agree as well.
- For future work, modeling with a multi-region approach may provide more accurate results and better understanding of the effects on reactivity for these larger systems.

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CONCLUSIONS

- This study showed how uncertainties in the cross-sections create and influence uncertainties in k_{eff}.
- These uncertainties, while seemingly nominal in their own accord, can compound the uncertainty of the solution when added to the uncertainty from using the Monte Carlo method and/or burnup extrapolations.
- The total sensitivity data for ^{238}U shows that it is expected to decrease the reactivity of a given system.
- Further analysis is being considered in order to determine the specific effects of reaction probabilities that are unique to ^{238}U, and to investigate the uncertainties in the reactivity due to the effects of the plutonium cross-sections. Additional research is also needed to investigate the behavior of the sensitivity coefficients based on a multi-region model.

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QUESTIONS?

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