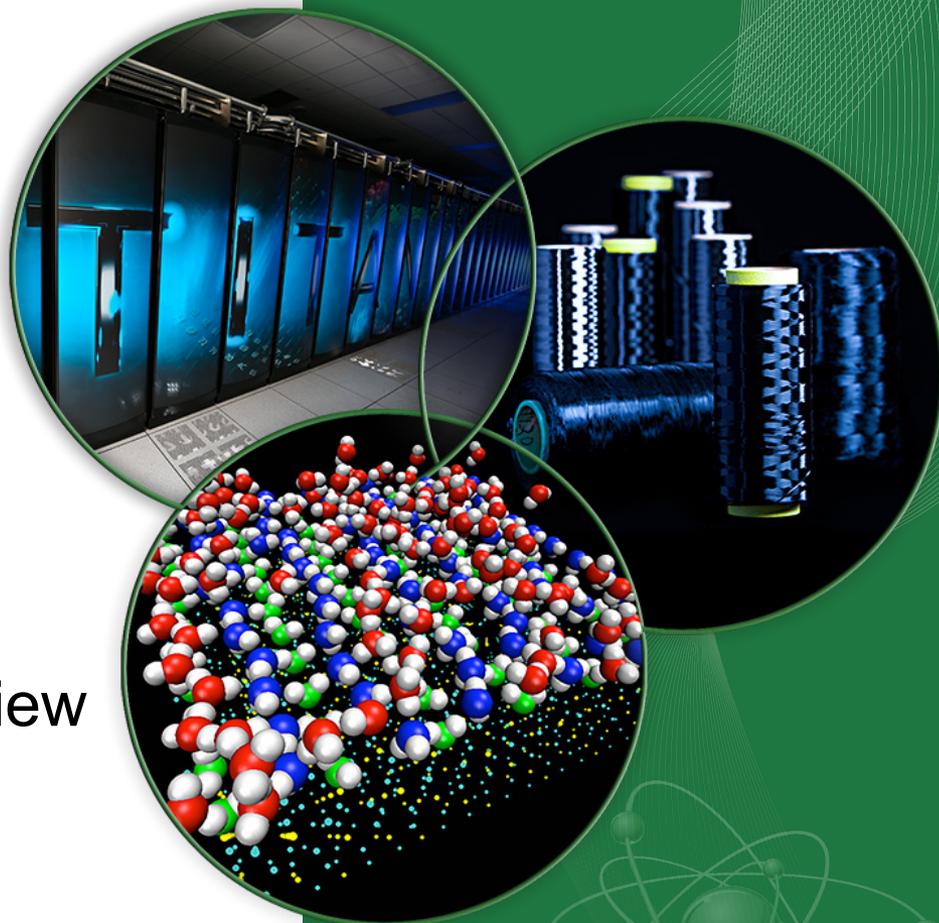# Recent Progress in Determination of Critical Experiment Correlations

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NCSP Technical Program Review

Sandia National Laboratories

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Outline

1. Recap of last year's presentation

2. Results from FY15

3. Current status

4. Brief look ahead

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Recap of FY14 work

- Criticality safety validations typically use many cases from a single series of critical experiments

- Correlation among these cases may be important for validation

  - Impacts trending analysis

  - Necessary input to constrain data adjustment

  - Uncertainty in bias increased do to reduced data independence

- Impact can be 3% Δk or more in USL for highly correlated experiments

- Indications that fuel pin pitch is the most important parameter in LEU pin arrays

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Results from FY15

- Calculations in FY15 focused on WPNCS UACSA benchmark for critical experiment correlations
  - Included some LCT-007 cases and all of LCT-039

- Fuel rods drawn from same population for all cases

- Many cases use same fuel rod pitch but different rod patterns
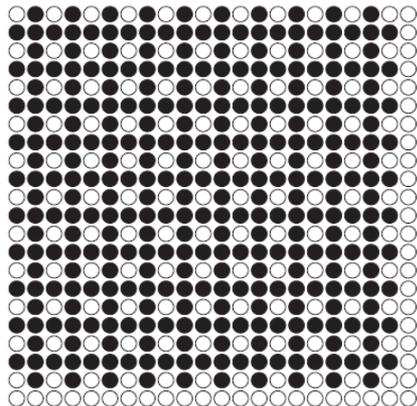
Case 5: 1 rod in 2 removed - array 21 x 21

Case 6: 1 rod in 2 removed

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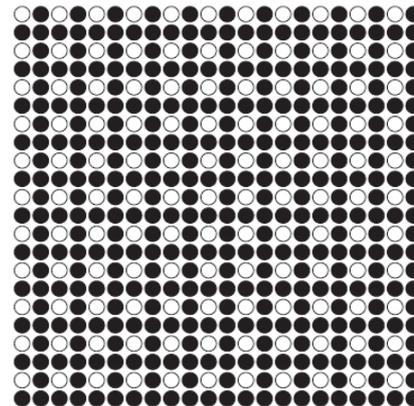
Range of scenarios

- Early drafts of benchmark included fully correlated fuel rod parameters and pitch
  - Initial results indicated high correlation coefficients for virtually all cases
  - This approach has been retained as Scenario A

- Later drafts examined impact of individual rod parameters and placement
  - Fully randomized individual rod parameters and placement in Scenario E

- These end points bracket the range of possible modeling choices

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Results from the different scenarios

Partial correlation matrix – Case A

Correlation coefficients for cases with the same pitch vary between 0.92 and 0.99

	7-1	7-2	7-3	39-1	39-2	39-3	39-4
7-1	1	0.93	0.39	0.98	0.98	0.97	0.97
7-2		1	0.56	0.92	0.92	0.93	0.93
7-3			1	0.41	0.39	0.41	0.42
39-1				1	0.98	0.97	0.97
39-2					1	0.97	0.97
39-3						1	0.97
39-4							1

Partial correlation matrix – Case E

All correlations between 0.18 and 0.71, most between 0.2 and 0.4

	7-1	7-2	7-3	39-1	39-2	39-3	39-4
7-1	1	0.36	0.46	0.45	0.20	0.20	0.32
7-2		1	0.64	0.29	0.30	0.32	0.33
7-3			1	0.42	0.45	0.45	0.44
39-1				1	0.23	0.24	0.23
39-2					1	0.24	0.24
39-3						1	0.24
39-4							1

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Uncertainty in correlation coefficient

- Convergence of and uncertainty in correlation coefficients largely unknown

- Plots of k_{eff} and standard deviation for each case as a function of realization checked for convergence
  - Similar plots of correlation coefficient itself
  - Convergence achieved between 150 and 300 realizations

- Uncertainty estimated from repeated calculations
  - One pair of cases, same realizations, different random number seeds in KENO
  - Correlation coefficients from 0.250 – 0.336
  - Average 0.296, standard deviation 0.023

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Current status: what we know

1. Very high correlation coefficients are possible

2. In-depth knowledge of experiment needed for correct, defensible modeling assumptions

3. For LCT systems, very sensitive to assumptions on fuel rod pitch

4. Shared materials not necessarily problematic

5. Current approaches are computation intensive

6. Reducing individual case uncertainties increases the correlation coefficient

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Current status: International collaboration

- Attended workshop on critical experiment correlations at GRS in Munich, March 9-11

- Attendees included:
  - IRSN: Evgeny Ivanov and Nicolas Leclaire
  - OECD/NEA: Tatiana Ivanova and Ian Hill
  - GRS: Maik Stuke, Fabian Sommer, Elisabeth Peters
  - BfS: Ingo Reiche and Benjamin Ruprecht
  - AREVA: Axel Hoefer and Oliver Buss
  - Amec Foster Wheeler: Christopher Baker
  - PSI: Alexander Vasiliev
  - Dennis Mennerdahl and Maksim Chernykh (WTI)

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Brief look ahead

- Interest in community to work with Gary Harms on one of his experiment series
  - Same rod in same spot every time
  - More information for each rod
  - Recently performed and well documented

- ORNL interest in moving forward with solutions and then metal systems

- Need to develop methods and guidance for practitioners and regulators

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