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Title: Validation of MCNP Critical Benchmark Models of PU-MET-FAST-016

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Validation of MCNP Critical Benchmark Models of PU-MET-FAST-016

2020 ANS Winter Conference

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Benchmark Significance

- Provide a standard of measurement
- Coupled with program outputs to measure bias
- A well established bias allows for an Upper Safety Limit to be confidently declared.

A Brief History…

PU-MET-FAST-016

- Nuclear Energy Agency, *International Handbook of Evaluated Criticality Safety Benchmark Experiments*
- 1982, Rocky Flats Critical Mass Laboratory
- Array of Plutonium cylinders

The Experiment

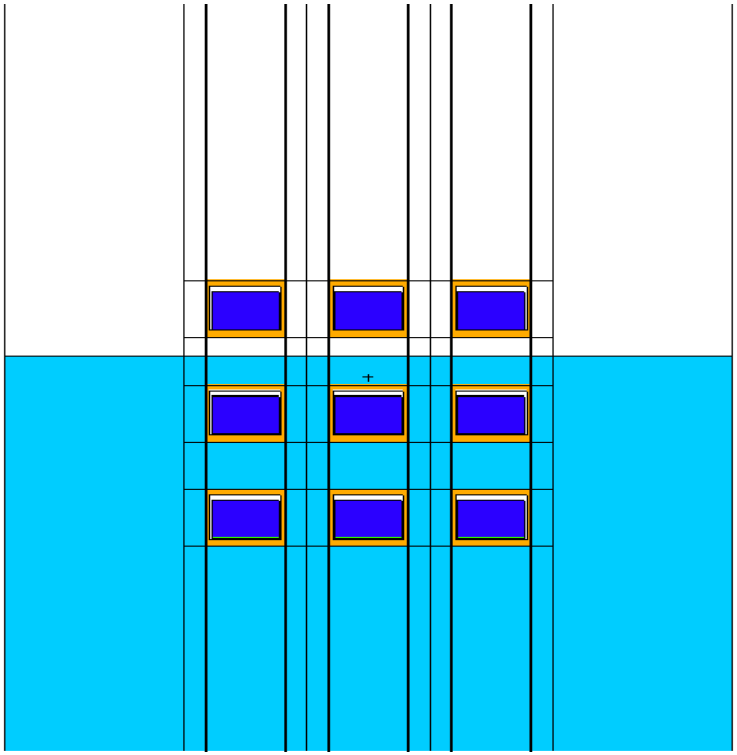


Figure 1. X-Z plane visualization using MCNP internal plotter

- Twenty seven 3-kg Pu cylinders
- Machined right cylinders
  - Diameter = 65.25 mm
  - Height = 46.33 mm
- Tight fitting Aluminum cans
- Steel outer can

- Criticality Control:
  - Spacing in X and Y direction
  - Height of water

The Experiment- Continued

- Perforated Aluminum Sleeves
- Aluminum framework
- Plastic Tank
- Slotted Horizontal Bars

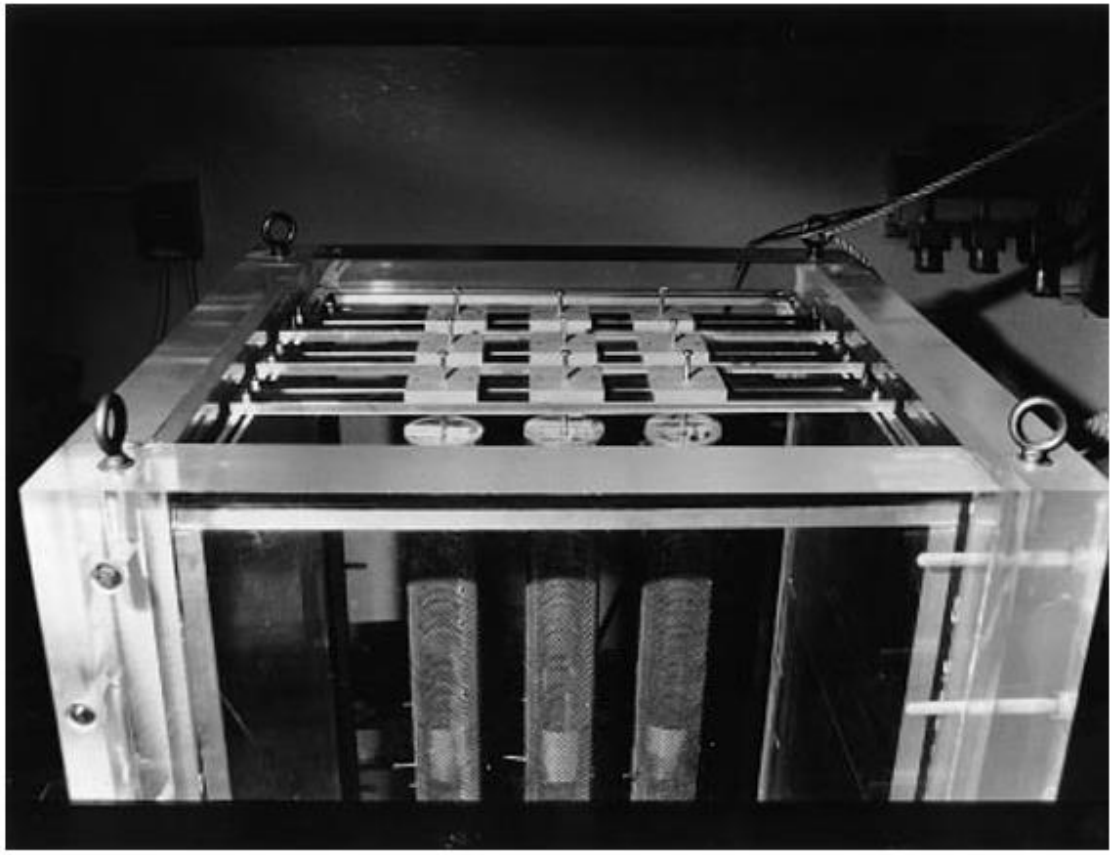


Figure 2. 3x3x3 Array and Framework (from Reference 3)

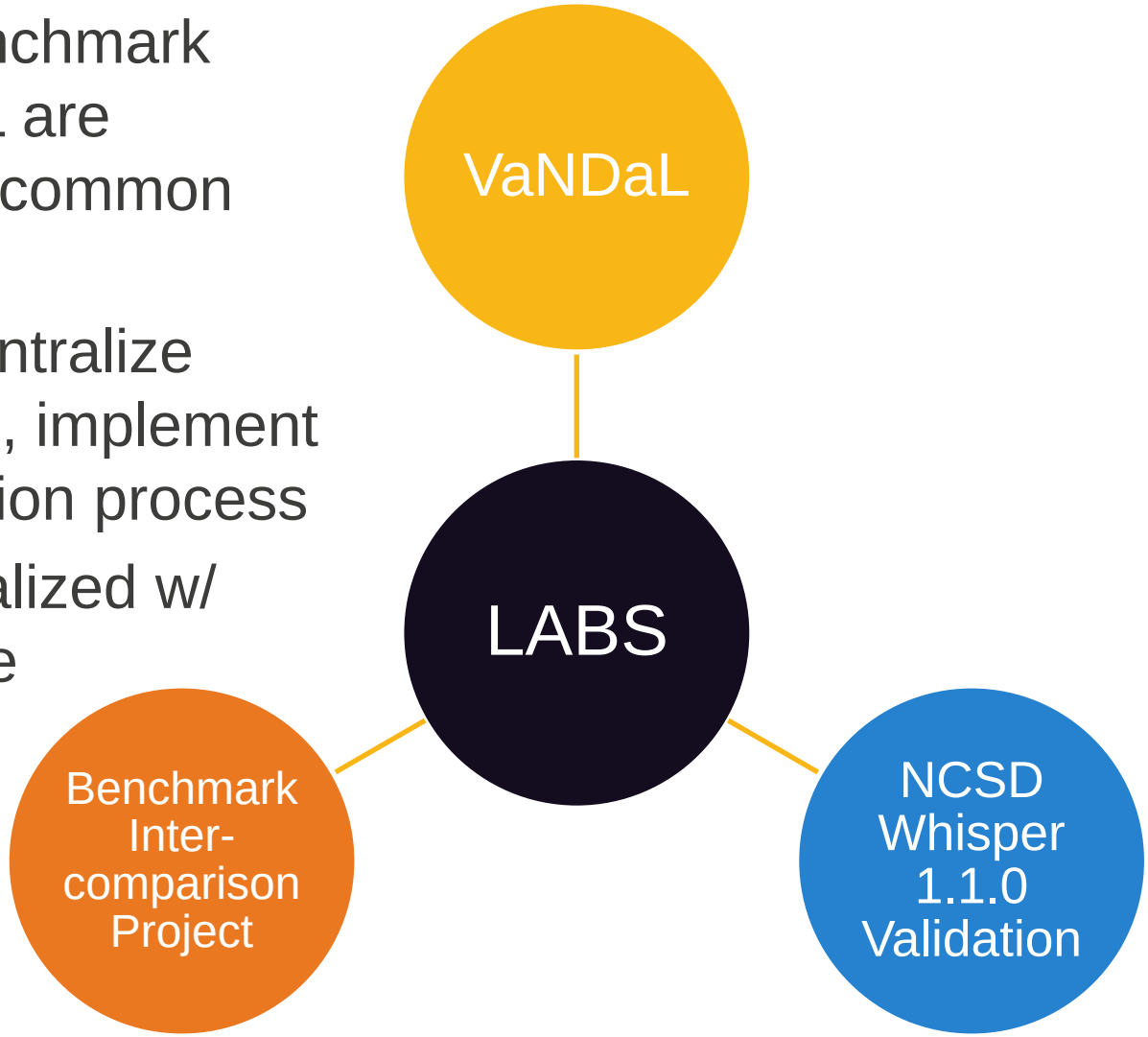
Experiment to Benchmark Comparison

Experiment Number	Benchmark Case #	Lateral Spacing (ΔX = ΔY) (cm)	Vertical Spacing (ΔZ) (cm)	Water Heights (cm)
1	1	12.00	12.75	48.30
2	2	12.70	12.75	58.40
3	3	12.90	12.75	60.60
6-9	4	13.00	12.75	62.78
10	5	13.05	12.75	65.80
13	6	12.80	13.10	65.60

Table 1. Spacing and Critical Water Heights (from Reference 3)

Background: Los Alamos Benchmark Suite

- Multiple MCNP benchmark collections at LANL are believed to have a common origin
- LABS – effort to centralize benchmark models, implement formal review/revision process
- LABS is being initialized w/ Whisper 1.1.0 Suite
- GitLab repository



PU-MET-FAST-016 MCNP Input file Review

- Part of the NCSD software quality assurance of Whisper 1.1.0
- Performed in 2017 by Ethan Moll and Raymond F. Sartor
- Issues found:

1. **Minor geometry errors.**
2. **Minor material card inconsistencies.**
3. **Typographical errors.**
4. **Major material card issue regarding the perforated Al sleeves.**

PU-MET-FAST-016 Revision

- All of these issues were corrected.
- Input files were rerun.
  - –For material change only
  - –Complete Revision

$$\text{Bias} = k_{Calc} - k_{Bmk}$$

- K_{eff} values were then compared.

Z-test:

$$\sigma_{Bias} = \sqrt{(\sigma_{keff,Calc})^2 + (\sigma_{keff,Bmk})^2}$$

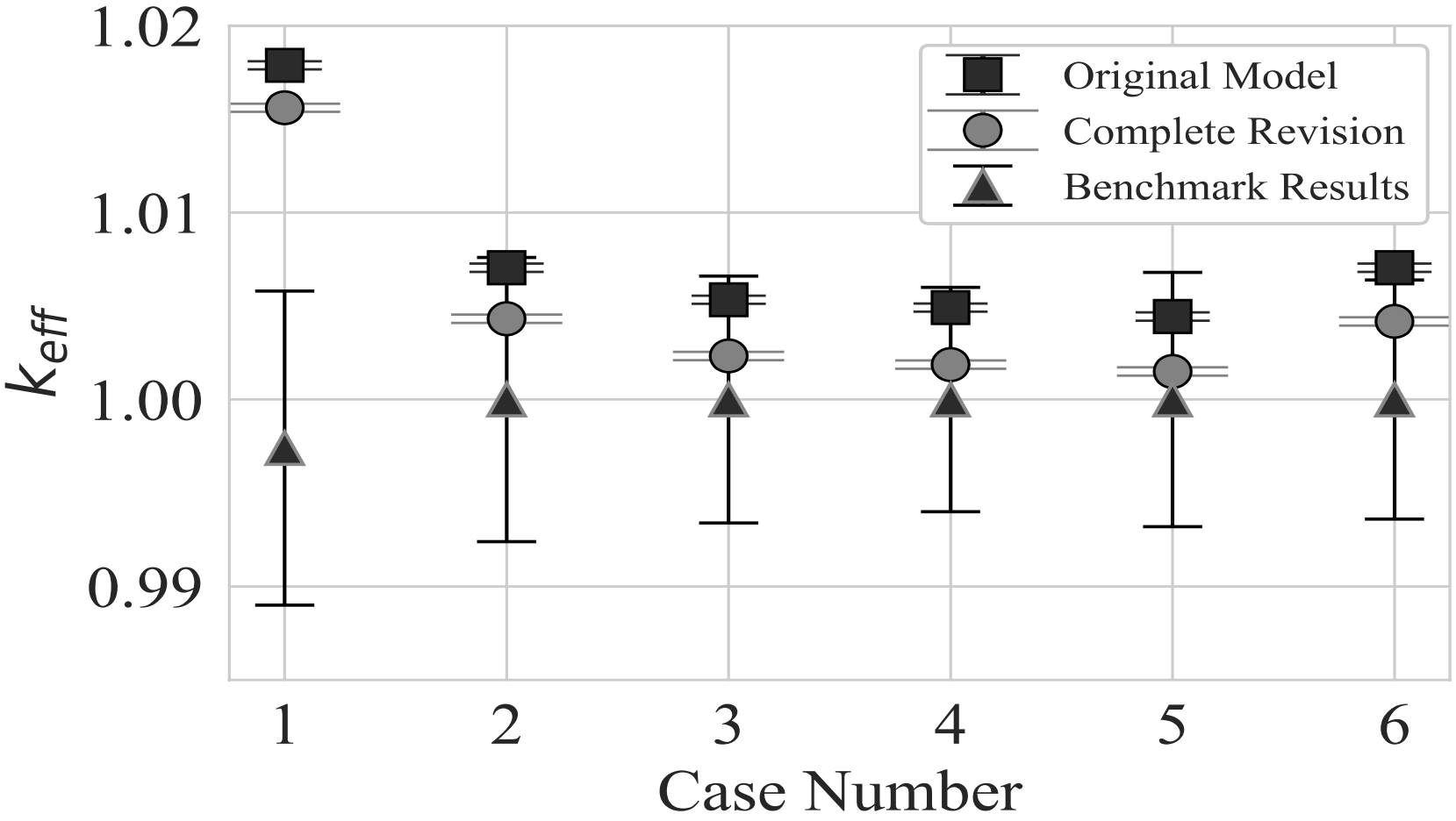
Any z-value greater than 1.96 confidently states that the two values are statistically not equal (95% confidence, two-sided test)

$$z = \frac{|Y_2 - Y_1|}{\sqrt{\sigma_2^2 + \sigma_1^2}}$$

Comparison of K_{eff} Values

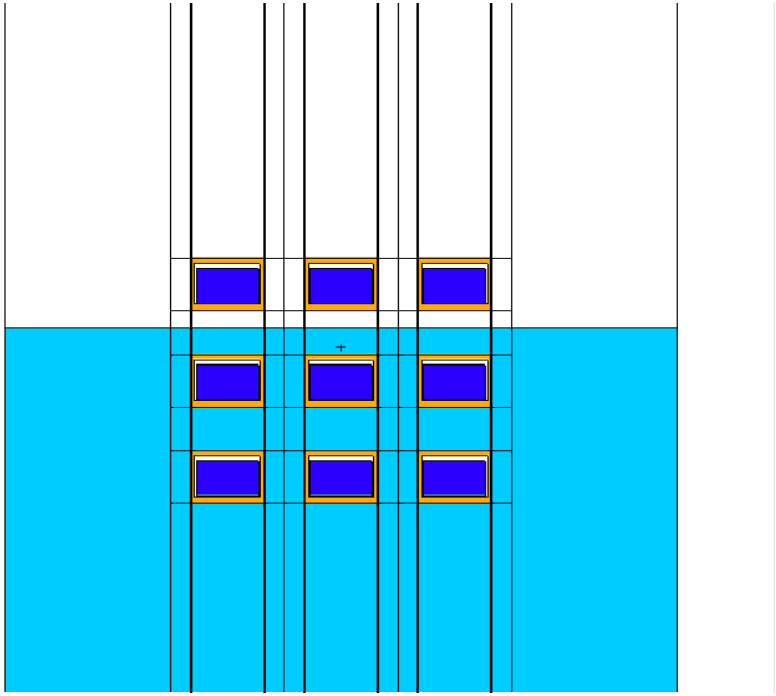
Benchmark Case #	Original Model	Only Material Change	Complete Revision	Benchmark results
1	1.0179	1.0155	1.0156	0.9974±0.0042
2	1.0071	1.0044	1.0043	1±0.0038
3	1.0053	1.0026	1.0023	1±0.0033
4	1.0049	1.0019	1.0019	1±0.003
5	1.0044	1.0017	1.0015	1±0.0034
6	1.0071	1.0041	1.0042	1±0.0032

Changes to K_{eff} Values

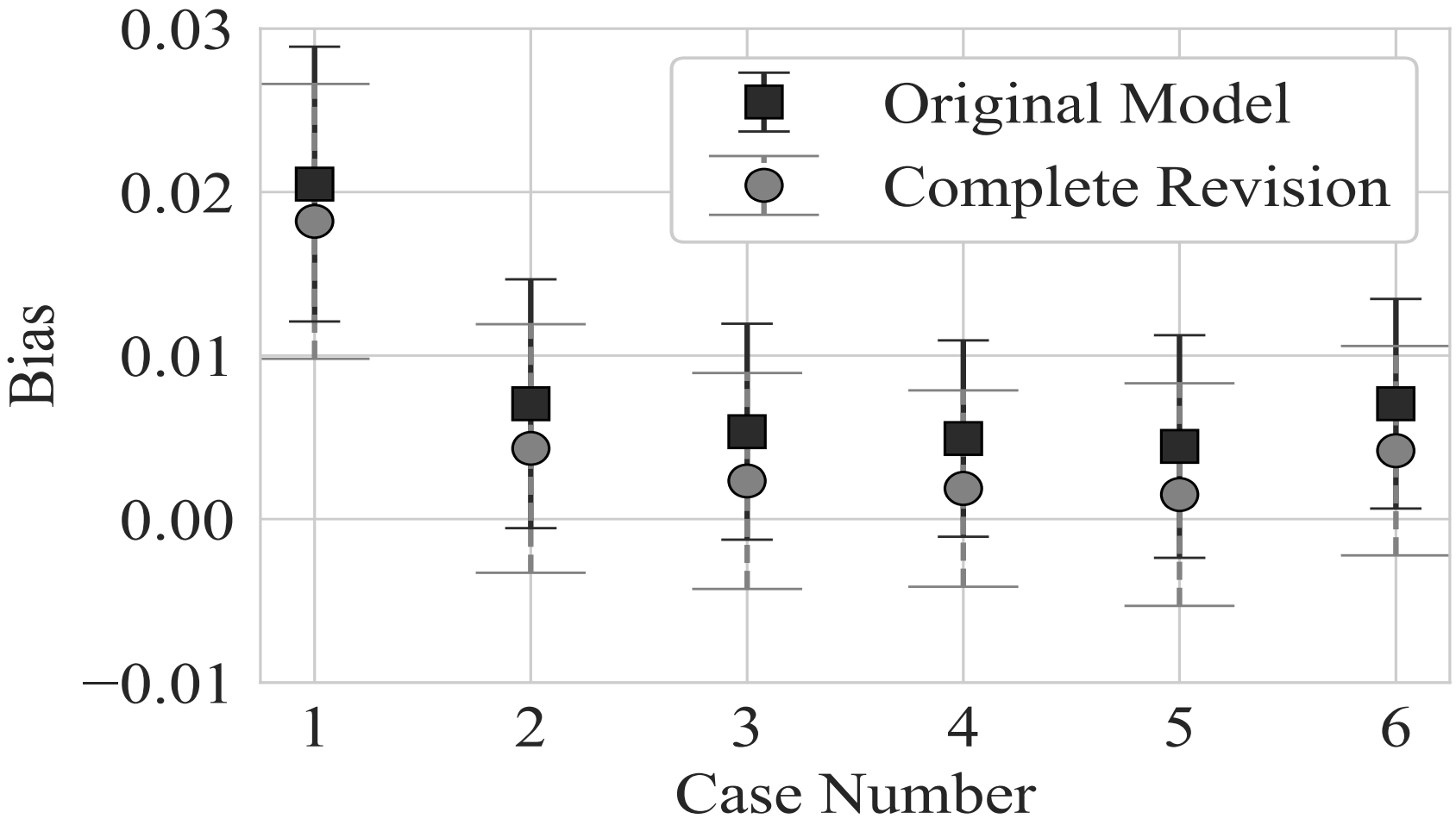


Case 1 K_{eff} dicrepancy

- Water height measurement error ± 2 mm
- Water height extrapolated error ± 2.7mm
- Rerunning Case 1 MCNP input with a water height 4mm below the ICSBEP reported height resulted in a K_{eff} of 1.00492



Bias Reduction



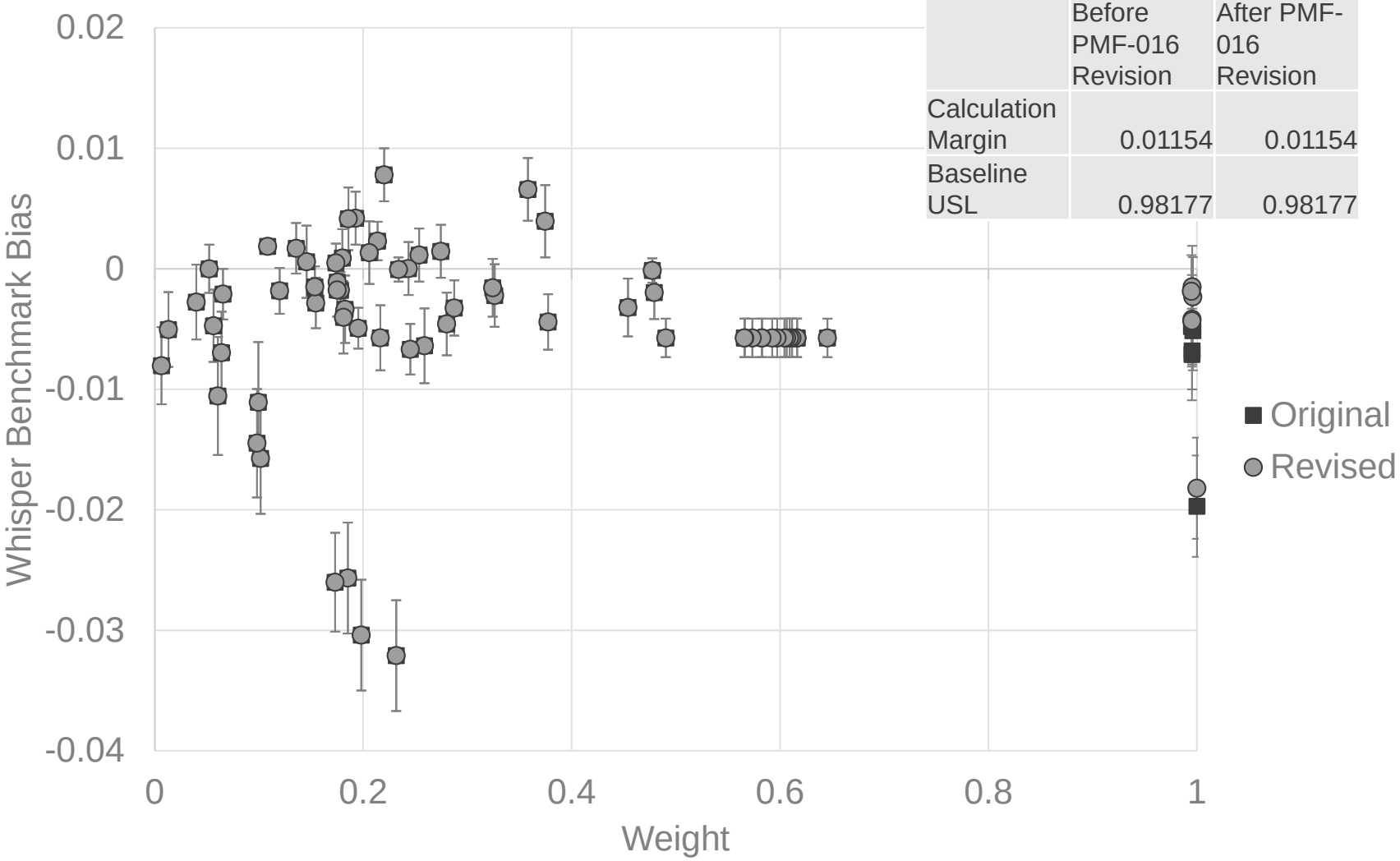
Is the Revision significant?

Results for the z-test between MCNP k_{eff} / bias values and the Original input k_{eff} / bias values.

	Only Material Change	Complete Revision
Case #	Z value	
1	15.1064	14.5921
2	17.3563	17.5491
3	17.6134	19.3490
4	19.1562	19.6061
5	17.4205	18.8990
6	19.2847	18.4491

No change in overall Bias from Whisper

	Before PMF-016 Revision	After PMF-016 Revision
Calculation Margin	0.01154	0.01154
Baseline USL	0.98177	0.98177



Conclusion

- The validation of PU-MET-FAST-016 contributed to the centralized LANL benchmark repository currently under development.
- The revisions made the MCNP models statistically, significantly more similar to the benchmark models.
- Overall impact on the USL is negligible.
- The revisions to the PU-MET-FAST-016 models provide value to the Los Alamos Benchmark Suite without invalidating past Whisper results.

References

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Questions?