Not All Benchmark Experiments are Created Equal: Words of Caution for Data Adjusters

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Integral Experiments

- Tests multiple data (isotopes, reactions, energies) at once
  - May be designed to be particularly sensitive to one piece of data

- Examples:
  - Critical assemblies
  - Subcritical assemblies
  - Engineering mockup critical assemblies
  - Reactor startup experiments
  - Reactor operation data
  - Shielding experiments
Benchmarks Are Evaluated Experiments

- Well characterized experiments
- Evaluate all experimental uncertainties
- Bias and uncertainty for model simplifications
  - Geometry simplifications
  - Room return
  - Material impurities
- Describe benchmark model
- Sample calculation results
- Disseminate for broader use
Sources of Benchmark Uncertainty

- **Experimental**: How certain are the experimenters of the data reported?
  - Uncertainty in measurement technique, reproducibility measurements, etc
  - Small contribution for $k_{\text{eff}}$ and reactivity worth
  - Larger contribution for direct radiation measurements

- **Benchmark Model Uncertainties**: How certain are the evaluators of the benchmark model? Model vs. Reality
  - Mass (are all masses or densities well known?)
  - Dimensions (were all parts measured? How do they fit together?)
  - Composition (what are the constituents of all parts, including impurities?)
  - Irradiation history

- **Complication**: Many benchmarks were evaluated decades after the experiment without access to the original experimenters
Established Integral Benchmark Handbooks

- **International Criticality Safety Benchmark Evaluation Project (ICSBEP)**
  - >5000 Critical, subcritical, and physics configurations

- **International Reactor Physics Evaluation Project (IRPhEP)**
  - 200 Reactor benchmarks
  - 200 Spectra benchmarks

- **Shielding Integral Benchmark Database (SINBAD)**
  - reactor shielding (46)
  - fusion neutronics shielding (31)
  - accelerator shielding (23)

- **Spent Fuel Composition (SFCompo)**
  - 700 Samples
Remember Context of the Benchmarks

- For ICSBEP, Criticality safety validation was the driving force behind many of the evaluations, not nuclear data validation or adjustment.

- Expectations have evolved over time with increasing computational power:
  - Earlier evaluated benchmarks tend to be more brief
  - Many evaluated benchmarks are missing major sources of uncertainties

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Total Page Count for Fast Pu Metal Cases over Time (excluding appendices- sample inputs, etc)
Uncertainty Analysis for Fast Pu Metal Cases over Time (Length of Chapter 2)
Some Benchmarks Have Significantly Less Uncertainty Assessment

- HMF-001, Benchmark is subcritical shell experiments completed to inform Lady Godiva design.

- “Uncertainties” are only experimental - from extrapolation to idealized critical sphere from subcritical shells
  - Shell radii were not well known!

- Missing **MAJOR** Uncertainties:
  - Uranium Mass
  - Dimensions of shells
  - Uranium composition
  - 100 pcm uncertainty is likely not right
Simplified Benchmark Models can have Marked Physics Differences from Detailed

MCNP6.1 Calculated Sensitivities for ICSBEP PU-MET-INTER-002, ZPR-6 Assembly 10: A Cylindrical Plutonium/Carbon/ Stainless Steel Assembly with Stainless Steel and Iron Reflectors for both detailed and simplified (homogenized) models
Words of Caution for Benchmark Users

- Current OECD/NEA Working Party for Nuclear Criticality Safety (WPNCS) Subgroup working to document ICSBEP evaluation concerns
  - WPNCS SG-8: Preservation of Expert Knowledge and Judgement Applied to Criticality Benchmarks

- Ongoing Effort to Revitalize SINBAD and create a format and content guide for shielding benchmarks

- All users of benchmarks should read through the available documentation with a critical eye before using the benchmark
Designing Modern Critical Experiments for Benchmarks

- Optimize experiment design to provide the best possible test of some variable
  - Targeting averaging neutron energy of a system
  - Sensitivity to specific reaction of specific nuclide at a specific energy
  - Representativity of criticality safety application

- Can be ideal use for Machine Learning, to find unique solutions and minimize designer and simulation time

Figures from D. Siefman (LLNL)
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