Good Practices Relating to International Benchmark Experiments Supporting Validation

John D. Bess

Idaho National Laboratory

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Acknowledgments

- ICSBEP & IRPhEP are collaborative efforts
  - Scientists, engineers, administrative support, program sponsors
  - 25 different countries have participated
  - Without these dedicated individuals, these benchmark projects would not exist.
- Special thanks to OECD NEA for enabling the continued success of these projects
- Extra special thanks to J. Blair Briggs
  - Otherwise these projects would not exist

Purpose of the ICSBEP & IRPhEP

- Identify a comprehensive data set of verified benchmark experiment data
- Evaluate data and quantify overall uncertainties
- Compile data into a standardized format
- Perform calculations of each experiment with standard neutron physics codes
- Formally document work in a single source of verified benchmark data (handbook)

- ***Experiments represent significant investments of time, infrastructure, expertise, and cost that might not have received adequate documentation and cannot be easily reproduced today***

INTERNATIONAL BENCHMARK PROGRAMS

NEA NUCLEAR ENERGY AGENCY

OECD BETTER POLICIES FOR BETTER LIVES

INL Idaho National Laboratory

Benchmark Experiment Data

Benchmark Evaluation Process

Future Use

Externally Available Technical Journals & Reports

Internal Reports Letters & Memos

Logbooks

Drawings

Experimenter's Annotated Copy of Published Reports

Experimenters (Retired or Working on Other Projects)

Facilities Awaiting D&D

Short-Term Preservation

Evaluation Process

- Identify
- Verify
- Evaluate
- Compile
- Calculate
- Document

Peer Review (National and International Experts)

Comprehensive Source of Externally Peer Reviewed Integral Benchmark Data

Advanced Modeling and Simulation

Analytical Methods Development, Validation, and Verification

Reactor Design and Licensing

Training

Criticality and Reactor Safety Analysis

Fuel Cycle and Related Activities

Range of Applicability and Experiment Design

Nuclear Data Refinement

Well Established Handbook Format

- **Quality benchmark evaluation has 4 integral parts:**
  1) **Detailed description of the experiment**
  2) **Evaluation of experimental data to obtain parameter values that define the model and their uncertainties**
  3) **Derivation and concise description of the benchmark model**
  4) **Sample calculations results**

Standard Format Serves as Template

- Success with ICSBEP and IRPhEP has led to ongoing endeavors to similarly benchmark shielding, spent fuel composition, and multiphysics experiment data
- SINBAD
  - https://www.oecd-nea.org/science/wprs/shielding/
- EGMPEBV
  - https://www.oecd-nea.org/science/egmpebv/
- SFCOMPO
  - https://www.oecd-nea.org/science/wpncs/sfcompo/

Comprehensive Review Process

- Very stringent publication process
- Evaluator(s), Internal Reviewer(s), Independent Reviewer(s), Technical Review Group, Final Subgroup Reviewer(s), International Users
- Annual Technical Review Group meeting every October in Paris
- TRG review begins in September
- Independent reviews should be completed beforehand
- Handbooks updated annually

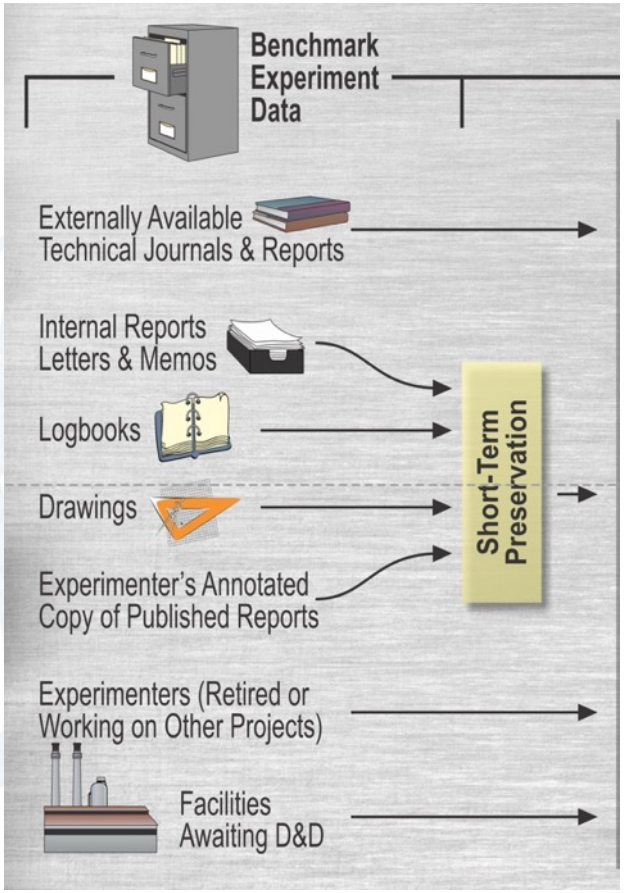
International Collaboration

- Integral component of OECD NEA activities
- Unique experience of participants
- Unique experiments performed worldwide
- Intercomparing of similar experiment types

Strongly recommend in-person over online participation

Detailed Experiment Description

- All available information gathered into a single location
- Data from facilities, experimenters, logbooks, unpublished reports, drawings, etc.
- Preserve dimensions, materials, measurements, etc.



Minimizes duplication of efforts

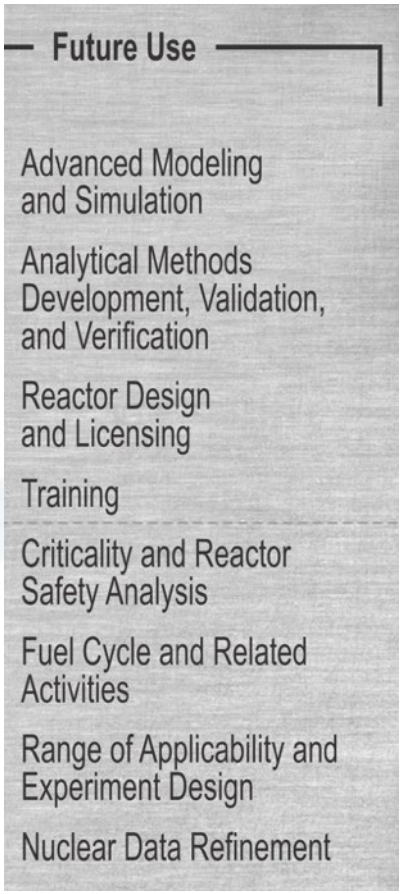
Extensive Experiment Evaluation

- Identify gaps in experimental data and fill them
- Characterize all uncertainties via measurement or modern simulations
- Use best estimates, not conservatism
- Systematic vs. random uncertainties
- Identify significantly large uncertainties that might impact the ultimate value of this benchmark

i.e. what is reality?

Benchmark Model Development

- Primary product(s) of the benchmark handbook
- Comprehensive modeling specifications
- Uncertainties: How well do you know your result(s)?
- Assess simplifications, biases, and bias corrections
- Again, this is what the user ultimately needs



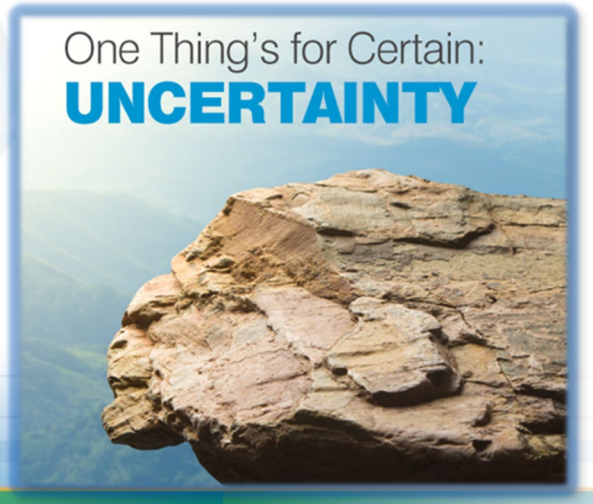
i.e. what is the best estimate of reality?

Sample Calculations and Input Decks

- Use of contemporary codes and data to demonstrate ability to accurately simulate experiments
  - You can't evaluate a material without proper cross section data!!
- Input decks not checked for accuracy and are not recommended for blind use
  - (OECD NEA WPEC VaNDaL project)

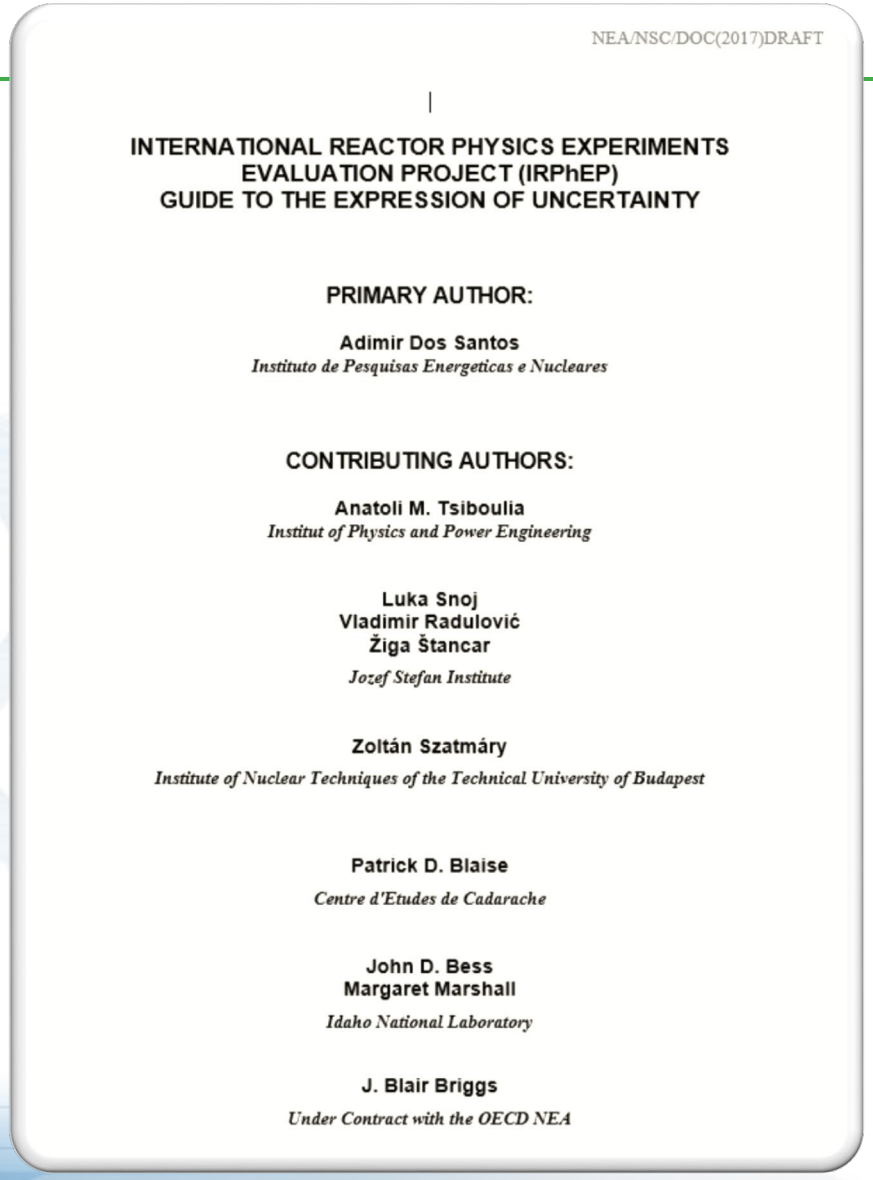
Uncertainty Guide Development

- **Preservation of best practices**
- **Characterization and quantification of typical uncertainties**
  - ***ICSBEP Guide to the Expression of Uncertainties***
    - **k_{eff}**
  - ***International Reactor Physics Experiments Evaluation Project (IRPhEP) Guide to the Expression of Uncertainty***
    - **See next slide**



IRPhEP Uncertainty Guide

- Criticality
  - ICSBEP
- Buckling (ref report)
  - Zoltán Szatmáry
  - U. Budapest
- Spectral Characteristics
- Reactivity Effects
  - Reactivity Coefficients
- Kinetics
- Reaction-Rate Distribution
  - Power Distribution
- Not yet available
  - Isotopic measurements
  - Other miscellaneous types



NEA/NSC/DOC(2017)DRAFT

INTERNATIONAL REACTOR PHYSICS EXPERIMENTS
EVALUATION PROJECT (IRPhEP)
GUIDE TO THE EXPRESSION OF UNCERTAINTY

PRIMARY AUTHOR:

Adimir Dos Santos
Instituto de Pesquisas Energeticas e Nucleares

CONTRIBUTING AUTHORS:

Anatoli M. Tsiboulia
Institut of Physics and Power Engineering

Luka Snoj
Vladimir Radulović
Žiga Štancar
Jozef Stefan Institute

Zoltán Szatmáry
Institute of Nuclear Techniques of the Technical University of Budapest

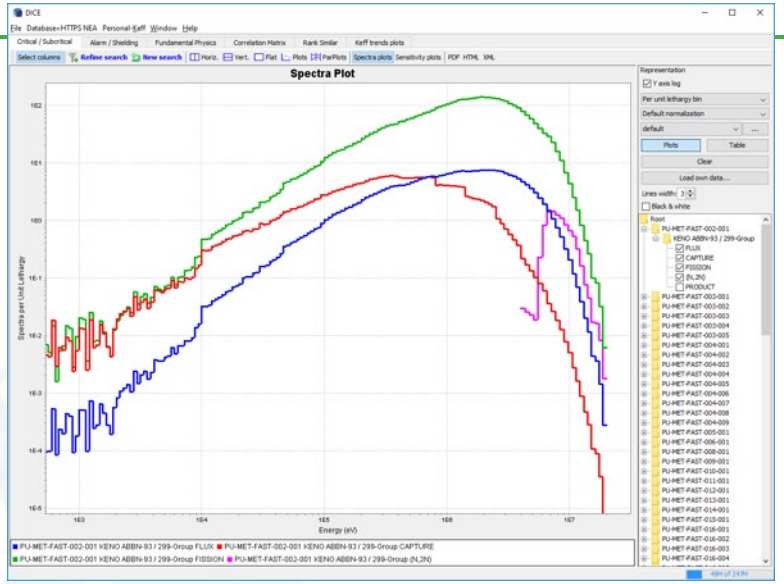
Patrick D. Blaise
Centre d'Etudes de Cadarache

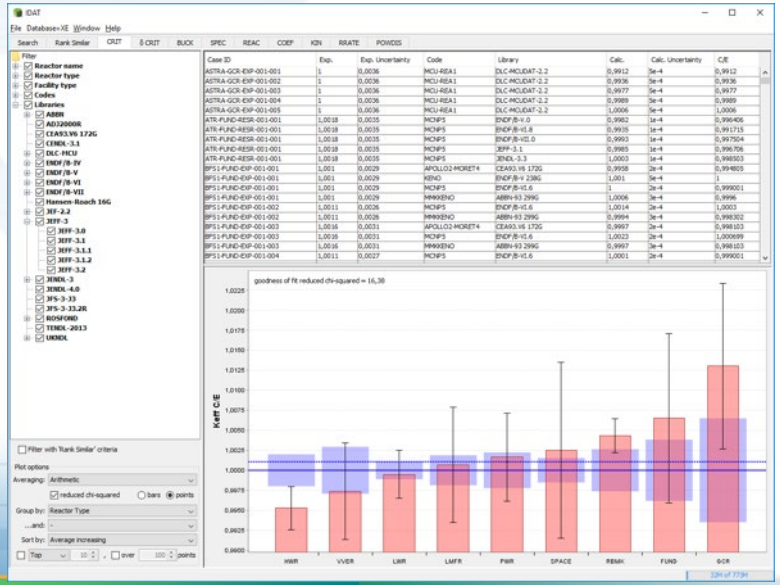
John D. Bess
Margaret Marshall
Idaho National Laboratory

J. Blair Briggs
Under Contract with the OECD NEA

Comprehensive Database Searching Tools

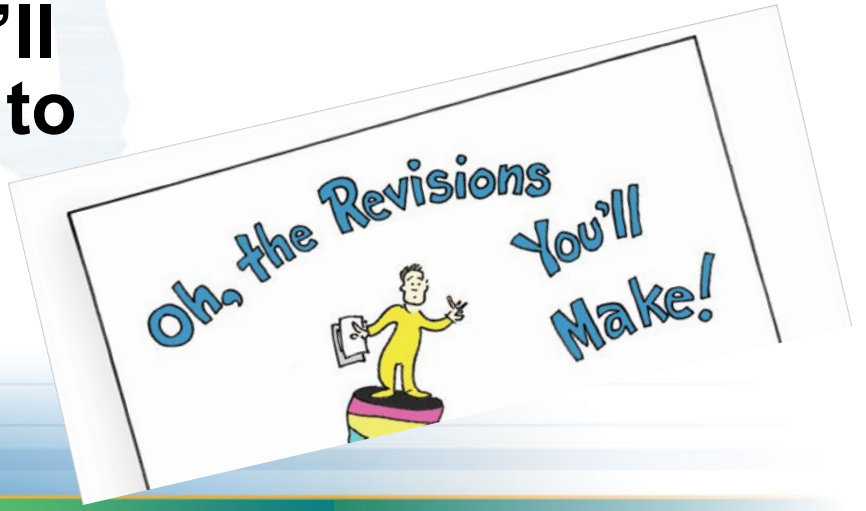
- DICE (ICSBEP) and IDAT (IRPhEP)
- Enable ability to best utilize ever-growing handbook content
- User's interface with plotting capabilities





Revisions Process

- "Revision is one of the exquisite pleasures of writing." – Bernard Malamud
- Even after extensive review, there are minor errors, clarifications, additional data located, new data to be added, updated computational codes and cross section data, etc.
- Just let us know and we'll update the handbook(s) to the best of our ability



Conclusions

- The ICSBEP and IRPhEP continue to provide high-quality integral benchmark data
- Past and current practices of these benchmark projects sets the “standard” for contemporary benchmark handbooks
- Enable current and future activities supported by benchmark experiment validation
- Always room for improvement

¿Questions?

Open Discussion on Best Practices

1) What do you utilize to perform benchmark evaluations?

2) How do you ensure benchmarks satisfy your validation needs?

3) How do you document identified errors in benchmarks and relay that information?

4) What other practices do you want to share?

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Extra Slides

International Handbook of Evaluated Criticality Safety Benchmark Experiments

September 2019 Edition

- 22 Contributing Countries
- ~70,000 Pages
- 577 Evaluations
  - 4,973 Critical, Near-Critical, or Subcritical Configurations
  - 45 Criticality-Alarm-Placement/Shielding Configurations
  - 237 Configurations with Fundamental Physics Measurements
  - 838 Unacceptable Experiment Configurations

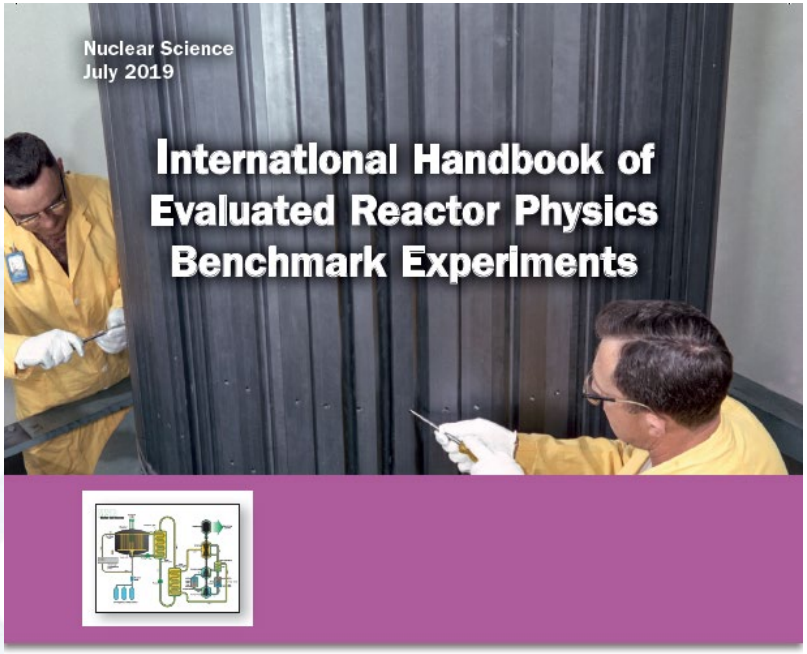
NEA
NUCLEAR ENERGY AGENCY

http://icsbep.inl.gov/
https://www.oecd-nea.org/science/wpncs/icsbep/

International Handbook of Evaluated Reactor Physics Benchmark Experiments

December 2019 Edition

- 21 Participating Countries
- 56 Reactor Facilities
- Data from 166 Experimental Series
  - 162 Approved Benchmarks
  - 4 DRAFT Benchmarks



NEA
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http://irphep.inl.gov/
http://www.oecd-nea.org/science/wprs/irphe/

Idaho National Laboratory

Countries Contributed to the ICSBEP & IRPhEP

- Argentina
- Belgium
- Brazil
- Canada
- People's Republic of China
- Czech Republic
- France
- Germany
- Hungary
- India
- Israel
- Italy
- Japan

- Kazakhstan
- Poland
- Republic of Korea
- Russian Federation
- Serbia
- Slovenia
- South Africa
- Spain
- Sweden
- Switzerland
- United Kingdom
- United States of America

Benchmarks are Integral Validation Components

- **Neutron Transport**
  - **MCNP, KENO/SCALE, MVP, TRIPOLI, etc.**

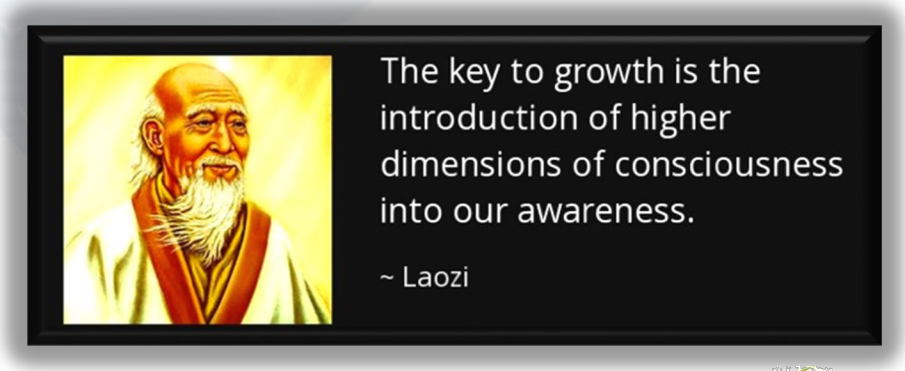
- **Nuclear Data Libraries**
  - **ENDF/B, JEFF, BROND, CENDL, JENDL, TENDL, etc.**

Verification vs. Validation

- **ANSI/ANS-8.24**
  - **Verification: the process of confirming that the computer code system correctly performs intended numerical calculations**
  - **Validation: the process of quantifying (e.g., establishing the appropriate bias and bias uncertainty) the suitability of a computer code system for us in nuclear criticality safety analyses by comparison with benchmark results**

Ever-Growing Need for Participants, Reviewers, Benchmark Experiment Data

- Preservation of history, knowledge, and experience
- International networking opportunities
- Enable cross-validation of experimental data, measurement techniques, software validation, etc.
- Enhance modern and future nuclear criticality and reactor safety



Current OECD/NEA Member Countries

Argentina	France	Latvia	Russia
Australia	Germany	Luxembourg	Slovak Republic
Austria	Greece	Mexico	Slovenia
Belgium	Hungary	Netherlands	Spain
Canada	Iceland	New Zealand	Sweden
Chile	Ireland	Norway	Switzerland
Czech Republic	Israel	Poland	Turkey
Denmark	Italy	Portugal	United Kingdom
Estonia	Japan	Romania	United States
Finland	Korea		

Available to Member Countries and Active Participating Facilities