



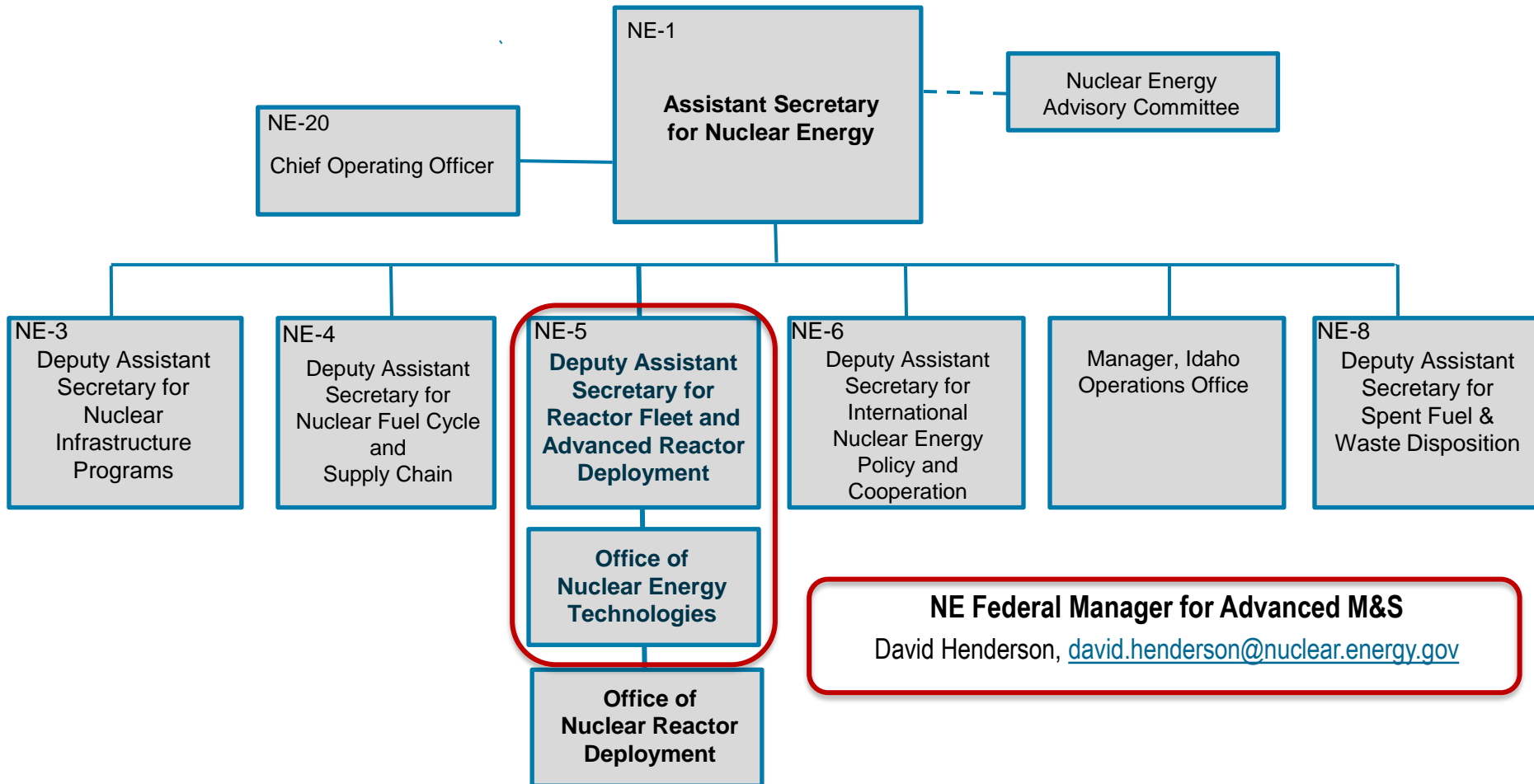
## **Nuclear Energy Advanced Modeling & Simulation**

CINR Annual Planning Webinar - August 2021

*Nuclear Energy University Programs (NEUP)  
Consolidated Innovative Nuclear Research (CINR)  
Office of Nuclear Energy  
U.S. Department of Energy*

# Office of Nuclear Energy Organization

*Where in NE are programs for developing and deploying advanced modeling and simulation tools managed? Who manages them?*

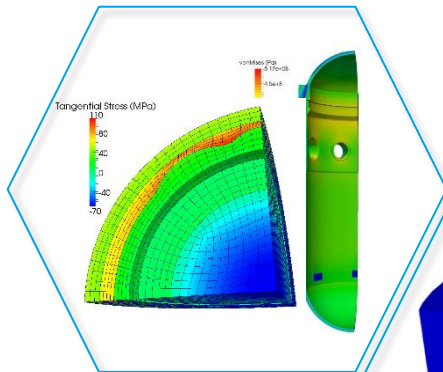


# Advanced Modeling & Simulation

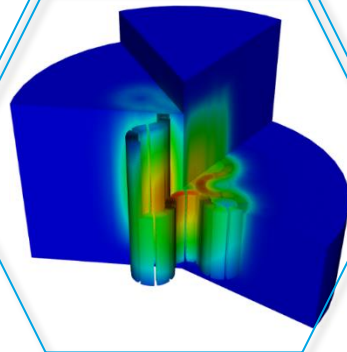
**Mission:** to develop, demonstrate, and deploy usable advanced modeling and simulation capabilities to enable the deployment of innovations that align with the NE Mission for the existing fleet, advanced reactors, and fuel cycles

**Context:** early stage R&D performed must be relevant to industry and coordinated with NRC

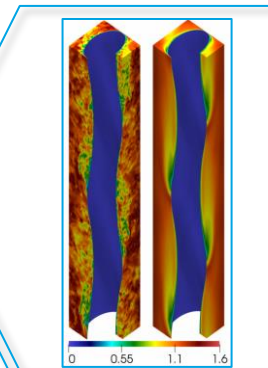
**Focusing on core competencies to fill gaps:**



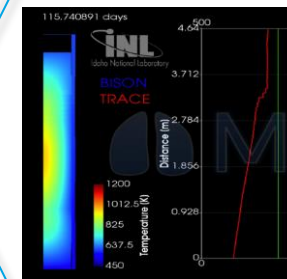
**Multiscale fuel performance and structural materials degradation modeling:**  
BISON, GRIZZLY, YellowJacket



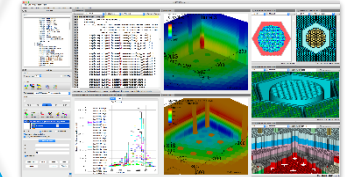
**Reactor Physics:**  
GRIFFIN, MPACT, Shift



**Multiscale thermal fluids:**  
SAM, PRONGHORN, Sockeye, Nek5000



**Multiphysics:**  
MOOSE, VERA



**Workflow Management:**  
Workbench

# Advanced Modeling & Simulation *Underpins NE's Mission Focus Areas*

## Existing Fleet

- Address core performance issues that increase operational costs
- Assure the long-term availability and market competitiveness of nuclear energy

## Advanced Reactor Pipeline

- Accelerate concept development and commercialization
- Meet otherwise cost-prohibitive data needs
- Support NRC confirmatory analyses

## Fuel Cycle Infrastructure

- Confirm higher burn-up fuel strategies to slow production of used nuclear fuel (UNF)
- Support UNF R&D with high-fidelity analysis and prediction of fuel and cladding performance

# Advanced Modeling & Simulation

## Supporting NE's Mission Focus Areas

Existing Fleet

Advanced Reactor  
Pipeline

Fuel Cycle  
Infrastructure

- **Allows the LWR vendors and utilities to develop innovative solutions to important fuel and core performance issues**
  - *Issues* – include power shifts, corrosion, fuel damage, and thermal performance, which add cost and limit affordability
  - *Solutions* – will help achieve significant reductions in reactor operational costs, which is an important component in the industry-wide initiative, “Delivering the Nuclear Promise”
- **Empowers the LWR community to take advantage of accident tolerant fuels (ATF), and implement load-following strategies for enhanced safety, improved economics, and greater versatility on the grid**
  - Accelerate development and approval of new ATF concepts (in fact, advanced M&S researchers have identified a promising new fuel, patent-pending)
  - Confirm viability of load-following with LWRs, to allow greater flexibility in meeting electrical demand, especially in combination with other renewable energy sources

# Advanced Modeling & Simulation

## Supporting NE's Mission Focus Areas

Existing Fleet

Advanced Reactor  
Pipeline

Fuel Cycle  
Infrastructure

- **Critical role in accelerating design and deployment of advanced reactors**
  - Design optimization is required to fully realize the economic and technological advantages of advanced concepts
  - Advanced M&S tools will help the NRC expand capabilities as needed to perform confirmatory analysis on advanced reactor concepts
- **Only way for vendors to economically address data needs, which otherwise could require cost-prohibitive experimentation**
  - Reduce the amount of experimental testing needed
  - Identify, design, execute, and analyze more effective high-value experiments
- **The advanced reactor industry is already using our Advanced M&S tools to:**
  - Reduce cost and time for license applications to the NRC
  - Enhance potential for successful commercialization - accelerated development crucial to economic viability

# Advanced Modeling & Simulation: Tools to Solve Advanced Reactor Priority Problems

		LWR	Non-LWR
<b>Integration</b>		MOOSE	MOOSE
<b>System Analysis</b>	Plant	VERA	SAM
<b>Core Analysis</b>	Neutronics-Pin Resolved	MPACT	Griffin (Rattlesnake, Proteus)
	Neutronics-Monte Carlo	Shift	Shift
	Neutronics-Kinetics/Depletion	MPACT	Griffin (MAMMOTH)
	Neutronics-Cross Sections	SCALE	Griffin (MAMMOTH)
	T-H Low Res	Cobra-TF (CTF)	SAM
	T-H Med Res		Pronghorn
	T-H Hi Res (CFD)	External codes/Nek5000	Nek5000
	Structural Mechanics	Grizzly Diablo	Grizzly Diablo
<b>Fuel Analysis</b>	Continuum	BISON	BISON
	Microstructure	Marmot	Marmot
	Component Aging	Grizzly Marmot	Grizzly Marmot
	Chemistry	MAMBA	MAMBA Yellowjacket (future)

# Advanced Modeling & Simulation

## *NEAMS-1: Low-Order Transport Methods*

### **NEAMS-1 IMPROVEMENT OF LOW-ORDER TRANSPORT METHODS**

(up to 3 years & \$600,000; University Led)

TECHNICAL POC: Matt Jessee (ORNL)

- **Scope:**
  - Applications should focus on development of low order transport methods to replicate Monte Carlo results applicable over a wide range feedback mechanisms including:
    - changes in fuel temperature, coolant density, control material configurations, and structural geometry
  - Particular interest: effect and modeling of isotopic depletion history on the creation of multigroup cross section libraries for advanced reactor multiphysics simulation.
  - Proposals should provide detailed discussion of the methods and model proposed including:
    - the process for generation of nuclear cross section data applicable to a wide range of feedback mechanisms and depletion histories, and
    - the application of the method and benchmark against continuous energy Monte Carlo depletion.
  - Applicants should demonstrate knowledge of previously awarded work in related areas, such as multigroup cross section generation methods
- **Note:** This call is focused on methods for improvement of low order transport method itself, in contrast to the previous call that focused specifically on multigroup cross section generation methodologies applied to existing methods



# Advanced Modeling & Simulation

## *NEAMS-2: Automated Optimization*

### **NEAMS-2: AUTOMATED OPTIMIZATION FOR REACTOR CORE DESIGN**

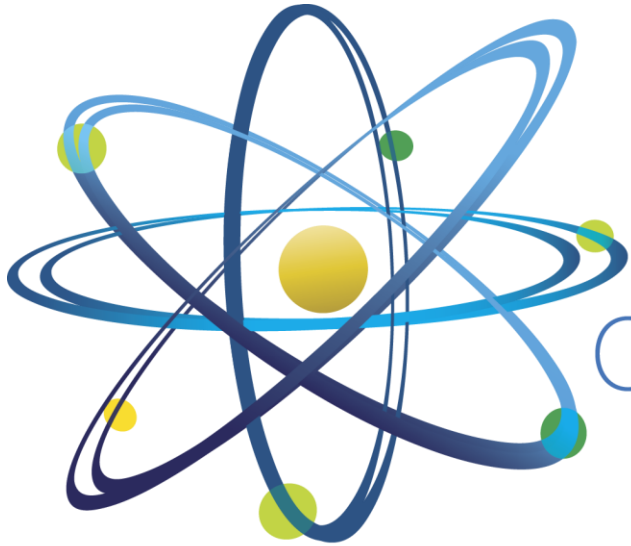
(up to 2 years and \$400,000; University Led)

TECHNICAL POC: Fande Kong (INL)

#### ▪ **Scope:**

- Proposals are sought for methods development in robust, automated optimization of reactor designs that integrate multiphysics simulation capabilities with engineering design processes for development of safe, efficiently manufacturable nuclear reactors.
- Application areas of interest include:
  - control rod/blade/drum shape and operation,
  - fuel shape,
  - coolant channel shape, and
  - core configuration.
- Use of existing NEAMS tools is preferred, such as BISON, Griffin, SAM, Pronghorn, Nek5000, and Grizzly.
- It is suggested that the proposed work builds on existing capabilities within MOOSE, such as automatic differentiation, displaced mesh, stochastic tools, and inverse solvers.
- The final goal of the study is to enable a shape optimization platform for MOOSE-based codes to better address nuclear energy design challenges.

# Questions?



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**Mission Supporting:  
Benchmarks & Nuclear Data  
(MS-NE-1 & MS-NE-2)**

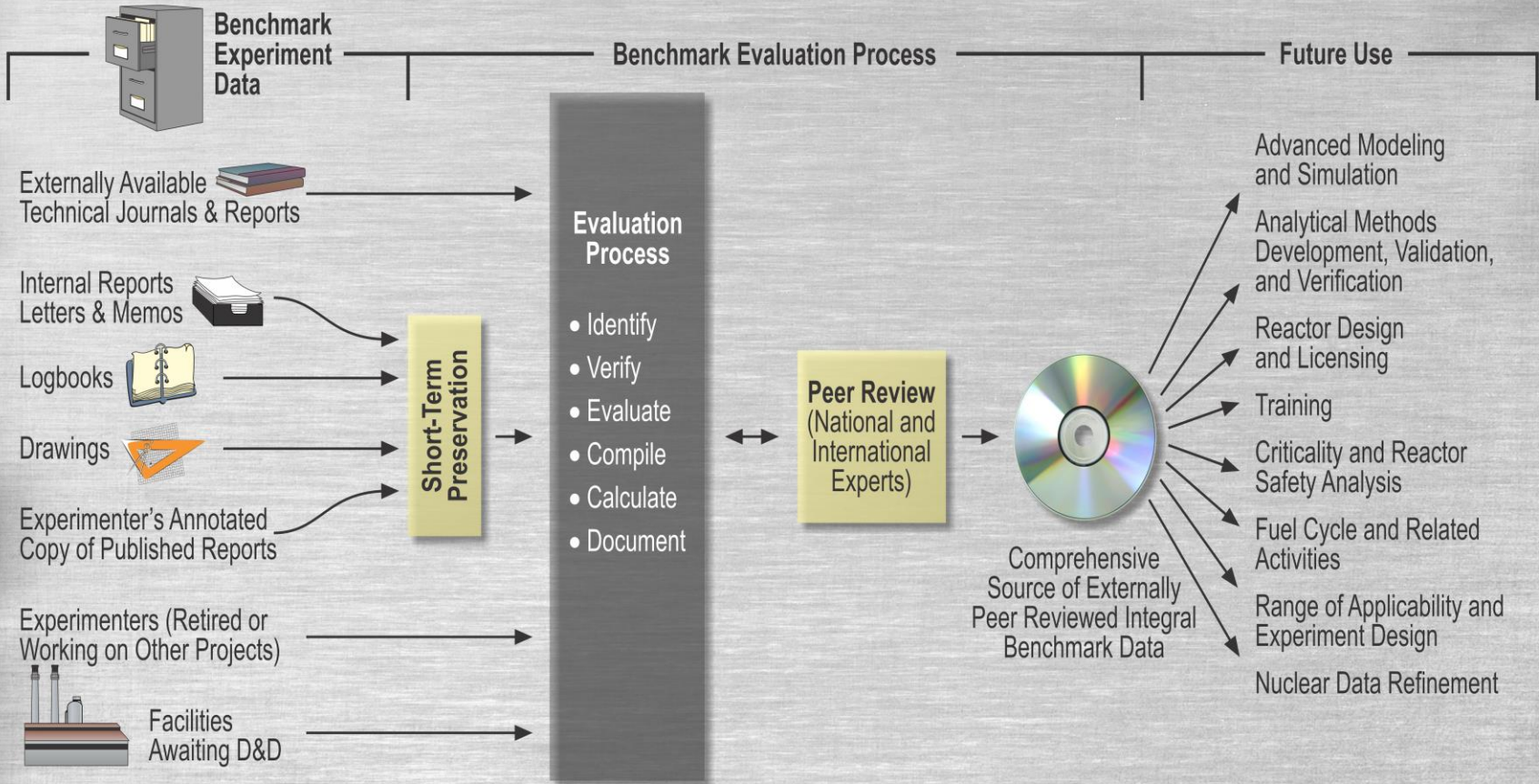
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*Nuclear Energy University Programs (NEUP)  
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- **These are OECD NEA international activities involving expert groups focused on updating and publishing Handbooks that support:**
  - characterization of reactor core and methods
  - neutronics components of multiphysics measurements
  - validation of nuclear data; including cross sections; and
  - reactor and criticality safety, including modeling, simulation, and training
- **These benchmark development efforts:**
  - Compile benchmark-experiment data into standardized format
    - *Can be readily used to validate computational techniques and cross section data*
  - Evaluate the data
    - *Quantify overall uncertainties through various types of sensitivity analyses*
  - Eliminate a large part of the tedious and redundant research and processing of experiment data that other researchers/analysts/designers would have to perform
  - Streamline necessary step of validating computer codes and nuclear data with experimental data
  - Preserve valuable experimental data
    - *Experiments represent significant investment of time, infrastructure, expertise, and cost that might not have received adequate documentation*
    - *The opportunity to repeat most of these measurements has long since passed*



# INTERNATIONAL BENCHMARK PROGRAMS



# MS-NE-1 – Integral Benchmark Evaluations

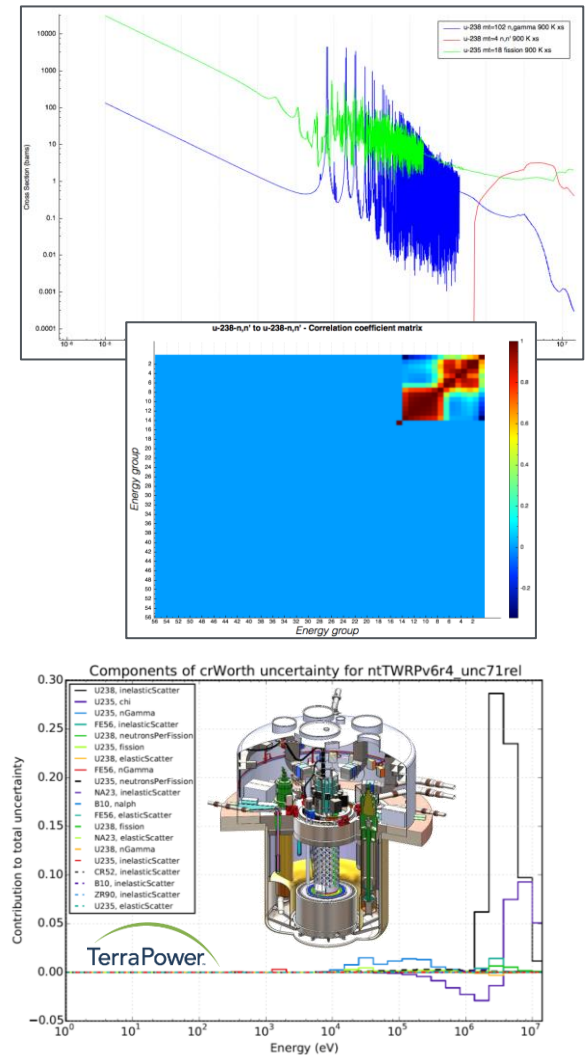
## *Work-scope Description*

**MS-NE-1:** Integral Benchmark Evaluations for inclusion in the International Reactor Physics Experiment Evaluation Project (IRPhEP) and International Criticality Safety Benchmark Evaluation Project (ICSBEP) Handbooks  
(TPOC – John Bess, [john.bess@inl.gov](mailto:john.bess@inl.gov))

- Benchmark evaluation proposals are sought which would use existing experimental data, and would **support NE programs** (e.g., TREAT, VTR, LWRs, FCT, ART, and NE's Advanced Modeling and Simulation Program)
- Measurements of interest include critical, subcritical, buckling, spectral characteristics, reactivity effects, reactivity coefficients, kinetics, reaction-rate and power distributions, and other miscellaneous types of neutron and gamma transport measurements
- A growing area of interest includes evaluation of transient benchmark experiment data for light water reactor systems, such as PWRs and BWRs
- Applicants should demonstrate knowledge of existing work through competitive awards (NE, SC, and others) as well as DOE-directed work.
- All evaluations **must be completed according to the IRPhEP and ICSBEP requirements, including peer review**
- **Clearly identify (and support with documentation) the importance of your proposal to industrial needs**

# MS-NE-2 – Nuclear Data for Nuclear Energy Applications

- Many nuclear data measurements and evaluations are decades old and updates are needed, especially for new high-fidelity analysis approaches and emerging nuclear energy systems
- Nuclear data measurements are very complex, yet only a few neutron scattering facilities remain, and new capabilities are needed
- Changes in cross section data from one ENDF evaluation to the next can have a significant impact on design, licensing, and operational decisions including:
  - ENDF/B-VII.1 updates to uncertainties in  $^{235}\text{U}$  and  $^{239}\text{Pu}$   $\nu$  change the uncertainty in used fuel systems and affect applicability of benchmark experiments for validation
  - ENDF/B-VII.1 update to  $^{35}\text{Cl}(n,p)$  reaction leads to 1000s of pcm reactivity change for fast-spectrum molten chloride salt reactors
  - Missing nuclear data or older evaluations with large uncertainties for materials of interest can be a limiting factor in the design of advanced reactors
  - Pending thermal scattering data for graphite leads to a 900 pcm improvement in reactivity of TREAT with similar effects for HTGR and FHR systems
  - Many other nuclear data needs can be demonstrated through the use of sensitivity/uncertainty methods for relevant applications



From: N. Touran, "Sensitivities and Uncertainties due to Nuclear Data in a Traveling Wave Reactor", NEA/OECD OS SR Meeting 2016-05-10



# MS-NE-2 – Nuclear Data

## *Work-scope Description*

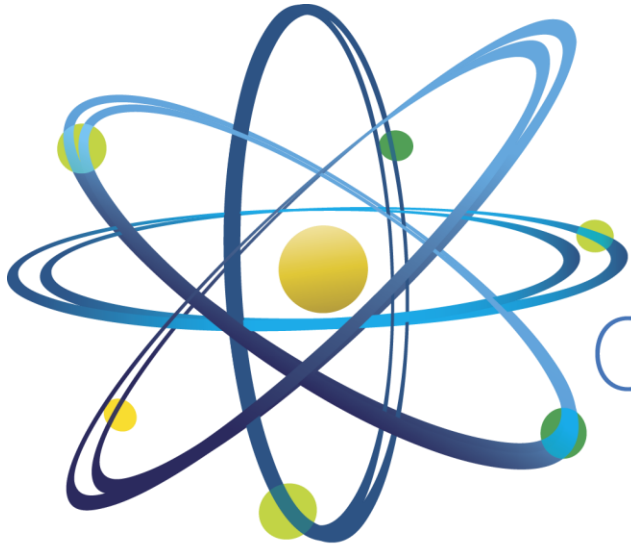
**MS-NE-2:** Improvements to address nuclear data needs that are clearly demonstrated to be a limiting factor in nuclear fuel and reactor design, analysis, safety, and licensing calculations in NE missions areas.

**(TPOC – Matt Jessee, [jesseema@ornl.gov](mailto:jesseema@ornl.gov))**

- Proposals are sought for achieving relevant nuclear data improvements that address one or more stated needs by developing and demonstrating the enhancements through the entire nuclear data pipeline, from:
  - 1) *new nuclear data measurements*
  - 2) *evaluation in the appropriate format (e.g. ENDF)*
  - 3) *inclusion of nuclear data covariances*
  - 4) *processing into usable forms for application codes*
  - 5) *confirmation of improved predictions and uncertainties through application studies and validation; &*
  - 6) *deployment through the National Nuclear Data Center at BNL for inclusion by external users in quality-assured design, analysis, safety, and licensing calculations*
- Use of sensitivity and uncertainty analysis methods in proposed efforts is encouraged to demonstrate these needs and how they are being met
- NEA’s High Priority Request List (HPRL) (<https://www.oecd-nea.org/dbdata/hprl/>) lists many data needs, but this list is not exhaustive and may not be “high priority” for DOE/US needs
- **Proposals must demonstrate:**
  - The importance of the proposed work to deployment or operation of a reactor and
  - Knowledge of existing work through competitive awards (NE, SC, and others) as well as DOE-directed work.



# Questions?



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