OAK RIDGE
National Laboratory

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DOE/NRC Collaboration for Criticality Benchmarks supporting HALEU

Presentation to ANSWER

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U.S. DEPARTMENT OF ENERGY

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Overview

Mission

Activities

Accomplishments

People

Moving Forward

Q&A

Mission

Enable new data sources such that the NRC (the Commission) is able to assess the safety of HALEU-based systems in the fuel cycle stages: enrichment, fabrication, transport, staging, and storage

Authority
Energy Act of 2020 &
Inflation Reduction Act (IRA)

Budget
$60M

Timeline
Initiated in late FY23 / All commitments must be made by end of FY26 / all work finalized in FY28

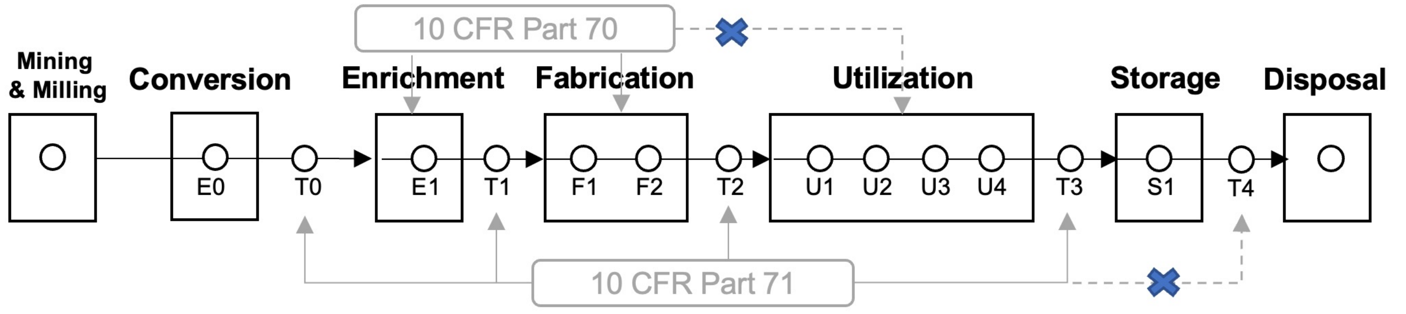
Congressional mandate

(A) shall develop, in consultation with the Commission, **criticality benchmark data** to assist the Commission in—

i. the licensing and regulation of special nuclear material fuel fabrication and enrichment facilities under **part 70** of title 10, Code of Federal Regulations; and
ii. certification of transportation packages under **part 71** of title 10, Code of Federal Regulations;

(C) Shall, to the extent practicable—

i. by January 1, 2024, support commercial entity submission of such transportation package designs to the Commission for certification by the Commission under part 71 of title 10, Code of Federal Regulations; and
ii. **encourage the Commission to have such transportation package designs** so certified by the Commission within 24 months after receipt of an application;



E0 – Conversion U3O8 to UF6
T0 – transportation of UF6 to enrichment facility
E1 – UF6 enrichment (<5w/o) and deconversion
T1 – transportation of UF6 to fuel fabrication facility
F1 – fabrication of UO2 fuel pellets
F2 – fabrication of LWR fuel assemblies
T2 – transportation of fresh fuel assemblies to the plant
U1 – fresh fuel staging and loading
U2 – power production
U3 – spent fuel pool/shuffle operations
U4 – on-site dry cask storage
T3 – transportation of spent fuel to off-site storage
S1 – off-site storage
T4 – transportation to disposition

Fuel cycle stages relevant for part 70/71

How does NRC assess license applications for criticality safety?

- Applicant must prove subcriticality according to regulations
- Applicant typically uses US software such as MCNP or SCALE in their application
- NRC uses SCALE to confirm calculations
- Software (and nuclear data) used by applicant and NRC must have validation (comparison to measurement)

Regulations

10 CFR 70.61 – Subcritical under normal and credible abnormal conditions

10 CFR 70.64 – Double contingency principle

10 CFR 70.24 – Criticality monitoring

10 CFR 71.55 - Single packages.

- 10 CFR 71.55(b): subcritical considering water in-leakage
- 10 CFR 71.55(d): subcritical under normal conditions of transport (NCT)
- 10 CFR 71.55(e): subcritical under hypothetical accident conditions (HAC)

10 CFR 71.59 – Package arrays.

- Subcritical under NCT and HAC
- Limiting number of packages under NCT or HAC used to determine Criticality Safety Index (CSI) to control package accumulation on conveyance

How does NRC and industry perform validation?

- Validation of code/nuclear data's ability to predict criticality uses critical benchmarks
- The International Critical Benchmarks Evaluation Project (ICSBEP) handbook is a large collection of expert-reviewed benchmarks coordinated by OECD/NEA
- Metric of success is how many new (relevant) benchmarks we can add to ICSBEP—available for NRC and industry

Code validation

ANS 8.1 - *Nuclear Criticality Safety In Operations With Fissionable Materials Outside Reactors*:

Validation shall be performed by comparison to critical experiments, and the area of applicability for the validation should be established from this comparison

Establish:

- Applicability of experiments
- Code bias and bias uncertainty
- Trending analysis

ANS 8.24 - *Validation of Neutron Transport Methods for Nuclear Criticality Safety Calculations*

NUREG/CR-6698 - *Guide for Validation of Nuclear Criticality Safety Calculational Methodology*

NUREG/CR-5661 - *Recommendations for Preparing the Criticality Safety Evaluation of Transportation Packages*

NUREG/CR-6361 - *Criticality Benchmark Guide for Light-Water-Reactor Fuel in Transportation and Storage Packages*

Why do we need new benchmarks for HALEU?

- Current cases in ICSBEP do not cover anticipated fuel forms, moderators, and configurations
- NRC recently approved amendments to transportation packages for up to 8% for light water reactor fuel

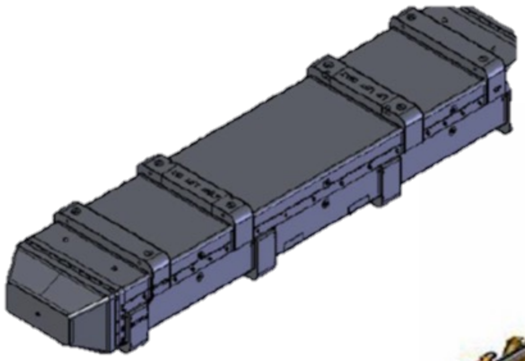
  Validation enabled in large part due to criticals performed at SPRF/CX in 2012 with 7% UO2 rods

- Possible to transport small quantities of HALEU today

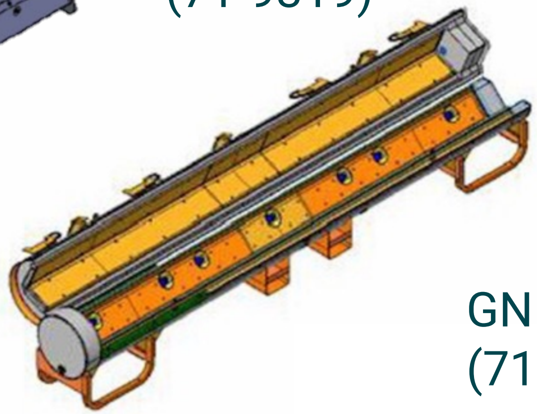
  55-gallon VersaPac can transport ~350 TRISO-fuel pebbles. A single Xe-100 would need 2 VersaPac per day.

  Optimus-L can transport up to 68kg of 20% enriched fuel, but is not optimized for fresh fuel

- Microreactors and back-end are particularly challenging



MAP 12/13 for PWR (71-9319)

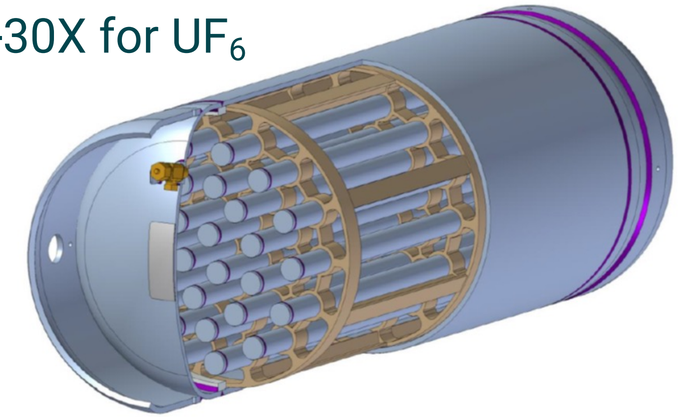


Traveller for PWR (71-9380)

GNF RAJ-II for BWR (71-9309)

Optimus-L for HALEU

DN-30X for UF_6



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Technical activities

Activities distributed over 9 areas supporting development of criticality-related benchmarks with ***primary customer: US NRC***

Key program element

Benchmark Execution

Highlights

- Call #1, completed in FY24, funded 17M in new benchmarks
- Additionally, intend to enhance the only two US facilities producing benchmarks
    - SPRF/CX SNL facility with 19.75% UO2 fuel rods
    - NCERC LANL facility with 19.75% TRISO-fueled compacts

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Area Lead

Coordination across labs and related programs

- **1** Planning
- **2** Quality Assurance
- **3** Surveys and Summaries

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Direct contributions to international critical benchmark handbook (ICSBEP)

- **4** Facility Enhancement — LANL
- **5** Model Development — ORNL
- **6** Benchmark Execution — LLNL

Indirect contributions to nuclear data, validation efficiency

- **7** Nuclear Data
- **8** Computational Methods
- **9** Validation Methodology

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Call #1 breakdown

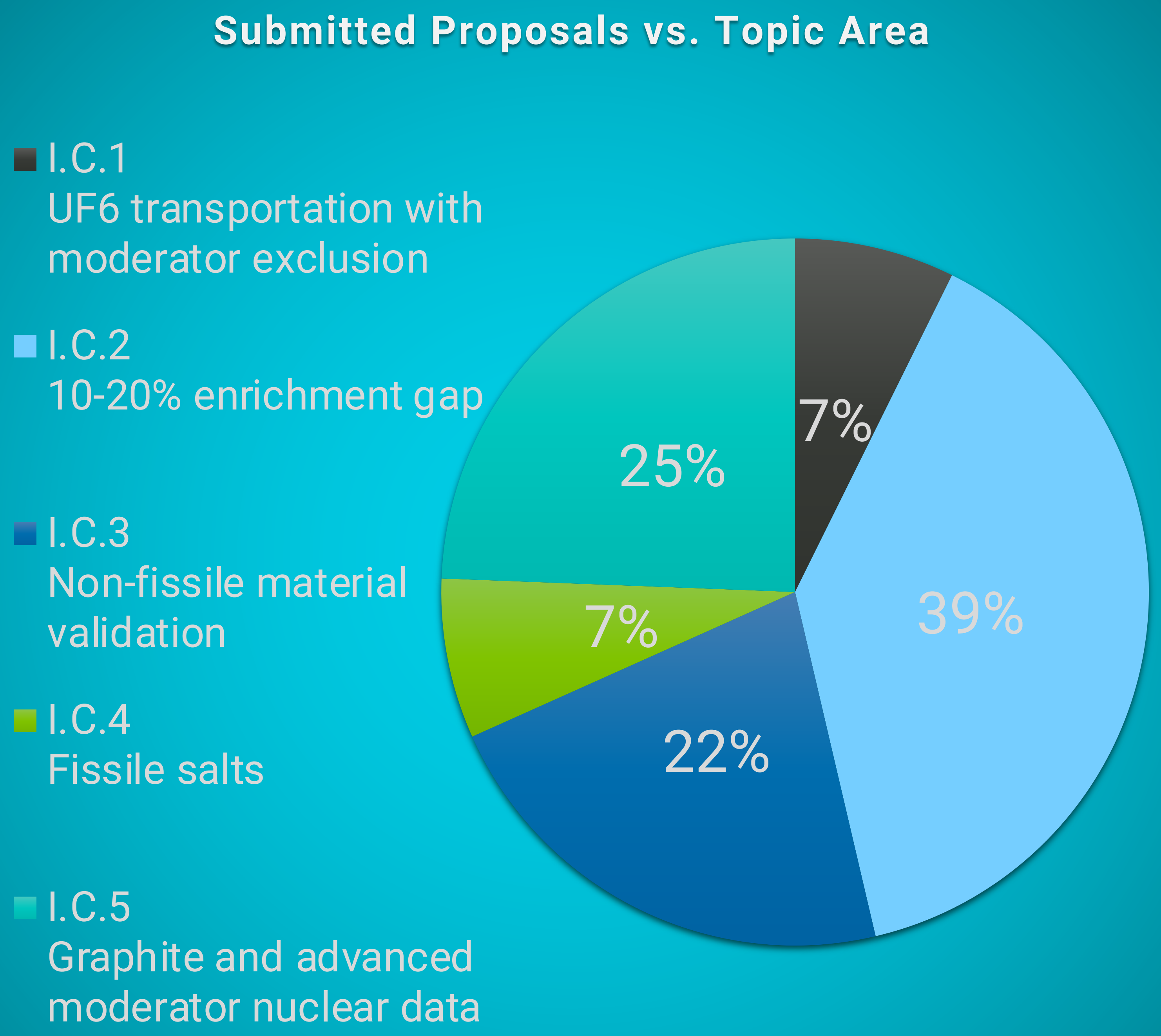
Held a public workshop Feb. 29, 2024 to collect information

Resulted in a call for proposals

Received 30 proposals totaling $28M across 5 topic areas in June 2024

Funded **$17M** in proposals starting in FY25

- 9 to turn **existing experiments** into benchmarks
- 5 for **new experiments** with existing fuel
- 2 for new experiments **needing new HALEU fuel**



Call #1 funded activities (1/3)

https://www.ornl.gov/dncsh

Title	Lead lab	Partners	Facility
Benchmark Validation for Transportation of TRISO HALEU Fuel for Advanced Reactors	INL	BWXT, Kairos, X-Energy, Radiant, JFoster & Associates, Univ. of Michigan	PROTEUS PSI, Switzerland
THETA: TRISO-form HALEU-fueled Experiment for Transport Applications	LANL	Kairos	NCERC, USA
Benchmark of Historical Y-12 Critical Experiments with UF6 Cylinder Model 8A Containers	LLNL	ORNL, CS Engineering, University of Tennessee	Y-12, USA
PETALE benchmark	LLNL	EPFL, University of California-Berkeley	CROCUS at EPFL, Switzerland
Thermal/Epithermal eXperiments (TEX) Additional Chlorine Configurations to Provide Validation for TerraPower's Molten Chloride Salt Fuel	LLNL	LANL, Terrapower	NCERC, USA

Call #1 funded activities (2/3)

https://www.ornl.gov/dncsh

Title	Lead lab	Partners	Facility
Critical experiments for new 19.75 wt% 235U enriched IPEN/MB-01 core	ORNL	GE Vernova, IPEN	MB01 at IPEN, Brazil
SLOWPOKE-2 Refuel Measurements	ORNL	Canadian Nuclear Laboratories	Royal Military College, Canada
High-Temperature Graphite Double Differential Scattering Cross Sections: Measurement, Evaluation, and Validation	ORNL	Yarmouk University	Spallation Neutron Source, USA
RPI Reactor Criticals with Noteworthy Non-fissile SS Element Sensitivity	ORNL	INL, Rensselaer Polytechnic Institute	RCF at RPI, USA
Characterization of ISU's AGN-201 Reactor for Qualification as an ICSBEP Benchmark	ORNL	GE Vernova, Idaho State University	AGN-201 at ISU, USA
Evaluation of Critical Configurations of the Missouri S&T Reactor	ORNL	Missouri S&T	MSTR at MST, USA

Call #1 funded activities (3/3)

https://www.ornl.gov/dncsh

Title	Lead lab	Partners	Facility
ZED-2 Measurements with In-Core Absorbers	ORNL	Canadian Nuclear Laboratories	ZED-2 at Chalk River, Canada
Temperature Dependent Transmission and S(alpha, beta) Measurements of Advanced Nuclear Moderators	ORNL	X-Energy	Spallation Neutron Source, USA
eDeimos Experiments with Westinghouse for new HALEU Benchmarks	LANL	Westinghouse	NCERC, USA
HALEU Critical Experiments in Water Moderated UO2 Fuel Rod Lattices	SNL	Orano	SPRF/CX at SNL, USA
Critical Experiments Targeting Optimum Moderation Conditions	PNNL	ORNL, SNL	SPRF/CX at SNL, USA

Management team

Project within DOE NE-41
Bill McCaughey (Acting)

DOE-NE Project Manager
Don Algama

DOE-NE Project Analyst
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NRC Lead
Drew Barto

National Technical Director
Will Wieselquist
Project Manager
Lindsey Aloisi

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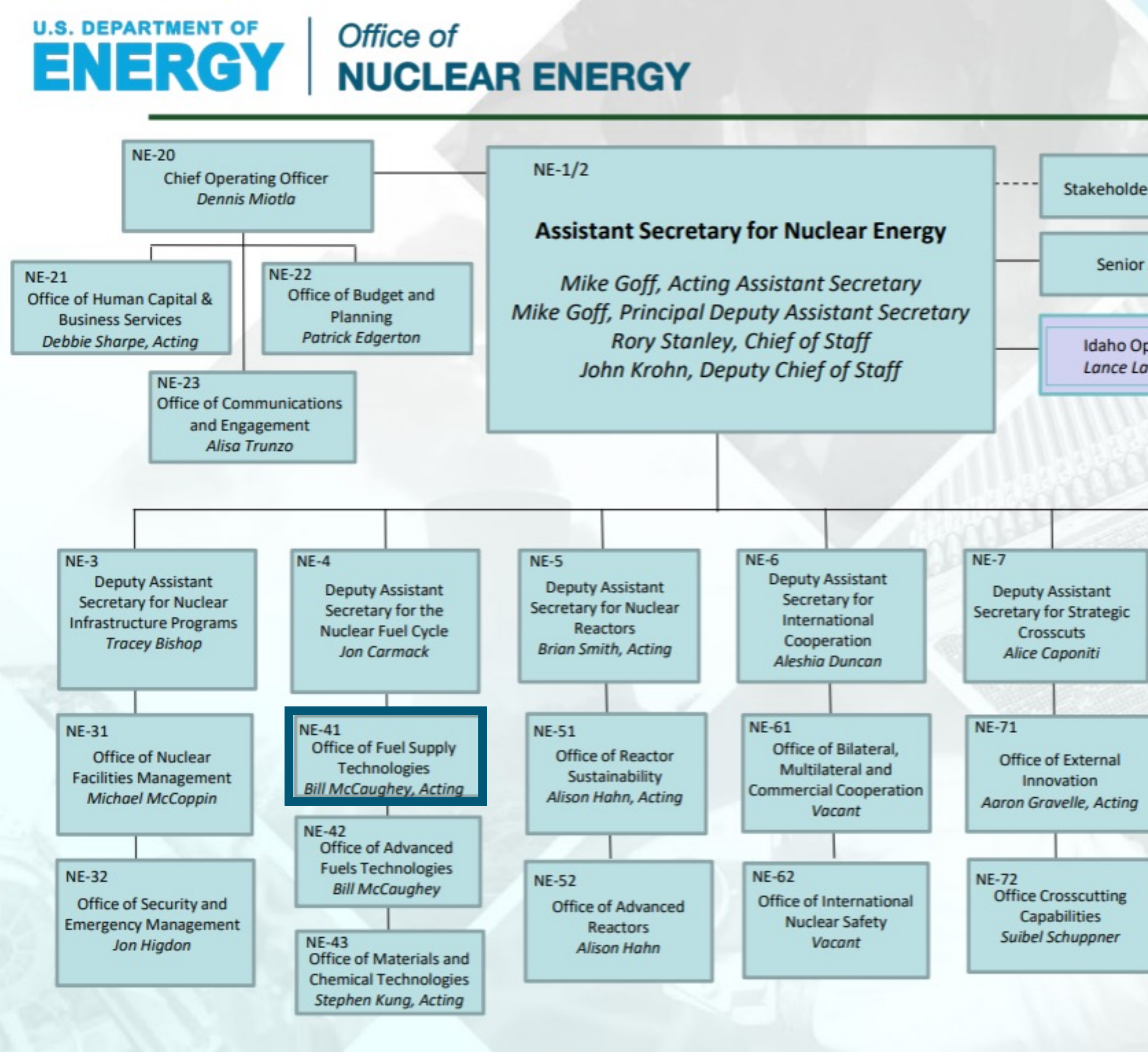
Doug Bowen, NNSA/NCSP



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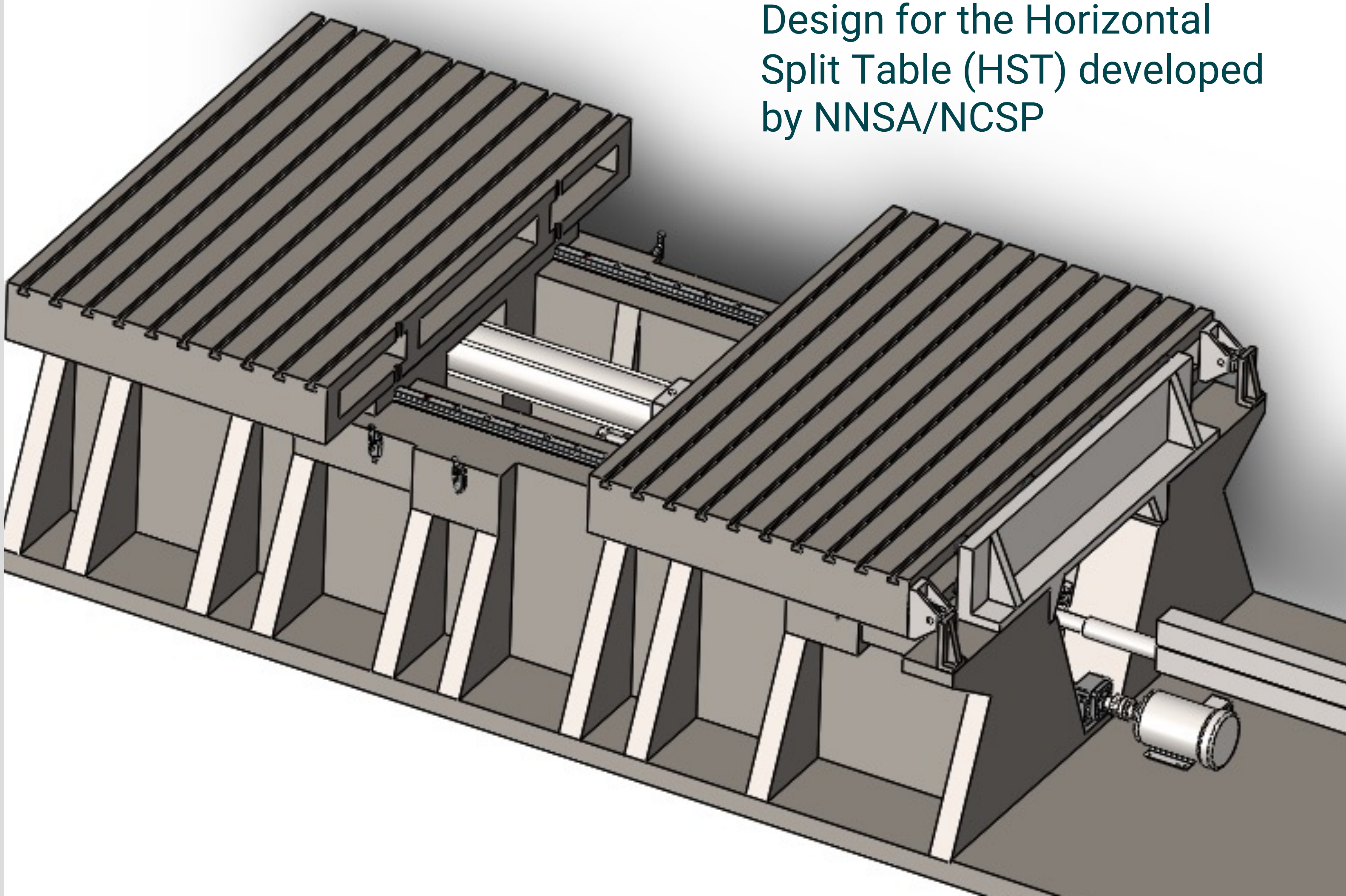
What are we doing now in DNCSH?

DOE/**N**RC collaboration for **C**riticality **S**afety support for commercial-scale **H**ALEU fuel cycles and transportation

- Ramping up the **16 new benchmark** activities
- Working to **procure fuel** for NCERC and SPRF/CX
- Developing gap analyses for **call #2 targeting micro reactor transport and facility operations**
- Developing **gap analyses for call #3 targeting back end/spent fuel**
- Developing a strategy document for a **horizontal split table (HST) at INL** to give the US a 3rd complimentary facility for benchmarks



Design for the Horizontal Split Table (HST) developed by NNSA/NCSP

Questions?