OAK RIDGE National Laboratory

Nuclear Criticality Safety Program @ ORNL

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January 24, 2022

ORNL is managed by UT-Battelle, LLC for the US Department of Energy

U.S. DEPARTMENT OF ENERGY

Background / History

- Defense Nuclear Facilities Safety Board (DNFSB) Recommendations 93-2 and 97-2:
  - 93-2 (3/23/1993): Need for a general-purpose critical experiment capability that will ensure safety in handling and storage of fissionable material.
  - 97-2 (5/19/1997): Need for improved criticality safety practices and programs to alleviate potential adverse impacts on safety and productivity of DOE operations.
- 97-2 encompassed ongoing DOE activities of 93-2 while broadening scope to address important cross-cutting safety activities needed to ensure NCS throughout the Complex.
- DOE Implementation Plan for Board Recommendation 93-2 and 97-2 resulted in establishment of the US Nuclear Criticality Safety Program (NCSP)

DEFENSE NUCLEAR FACILITIES SAFETY BOARD

March 23, 1993

The Honorable Hazel R. O'Leary
Secretary of Energy
Washington, DC 20585

Dear Madame Secretary:

On March 23, 1993, the Defense Nuclear Facilities Safety Board, in accordance with 42 U.S.C. § 2286a(5), unanimously approved Recommendation 93-2 which is enclosed for your consideration. Recommendation 93-2 deals with The Need for Critical Experiment Capability.

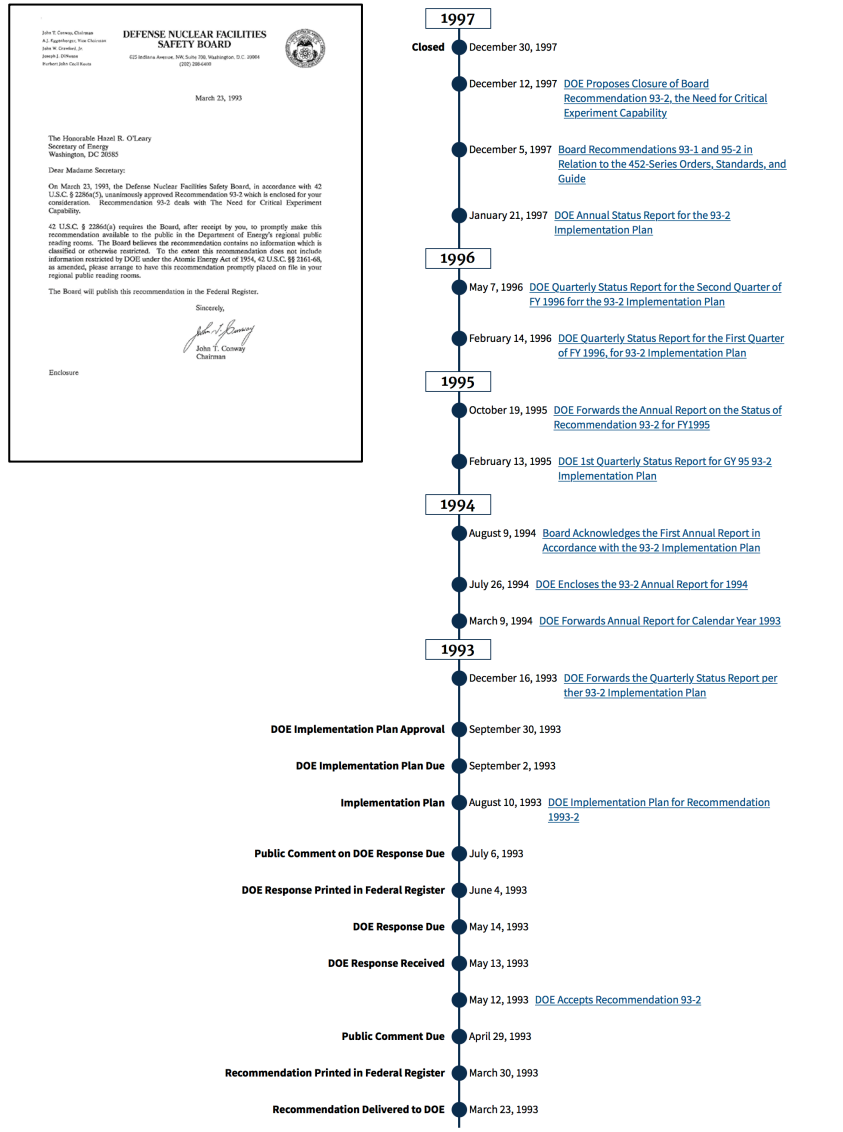
42 U.S.C. § 2286d(a) requires the Board, after receipt by you, to promptly make this recommendation available to the public in the Department of Energy's regional public reading rooms. The Board believes the recommendation contains no information which is classified or otherwise restricted. To the extent this recommendation does not include information restricted by DOE under the Atomic Energy Act of 1954, 42 U.S.C. §§ 2161-68, as amended, please arrange to have this recommendation promptly placed on file in your regional public reading rooms.

The Board will publish this recommendation in the Federal Register.

Sincerely,

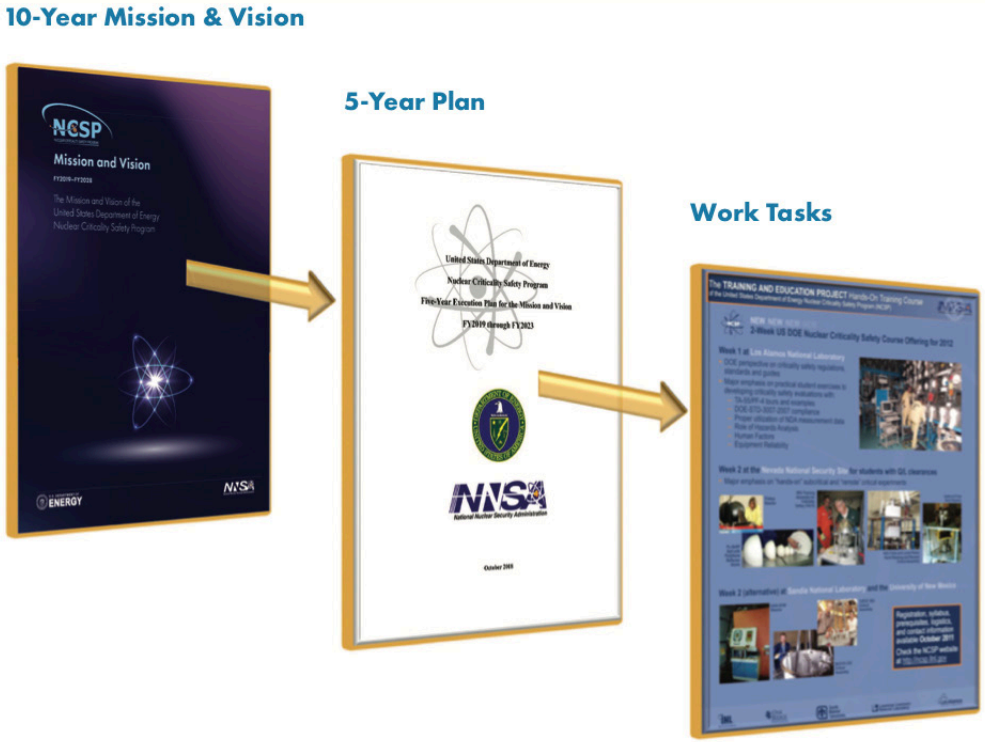
John T. Conway
Chairman

Enclosure



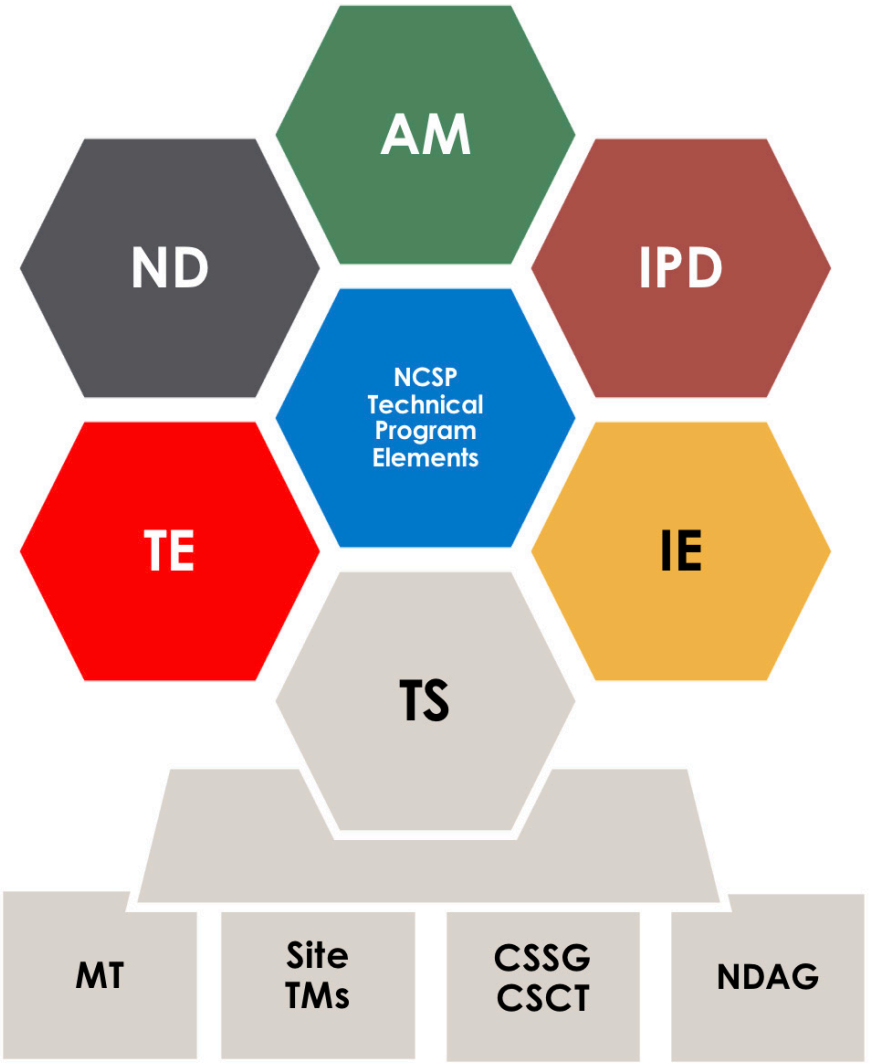
NCSP Organization and Overview

- Mission
  - Provide sustainable expert leadership, direction and the technical infrastructure necessary to develop, maintain and disseminate the essential technical tools, training and data required to support safe, efficient fissionable material operations within the Department of Energy.
- Vision
  - Continually improving, adaptable and transparent program that communicates and collaborates globally to incorporate technology, practices and programs to be responsive to the essential technical needs of those responsible for developing, implementing and maintaining nuclear criticality safety.



NCSP Technical Program Elements

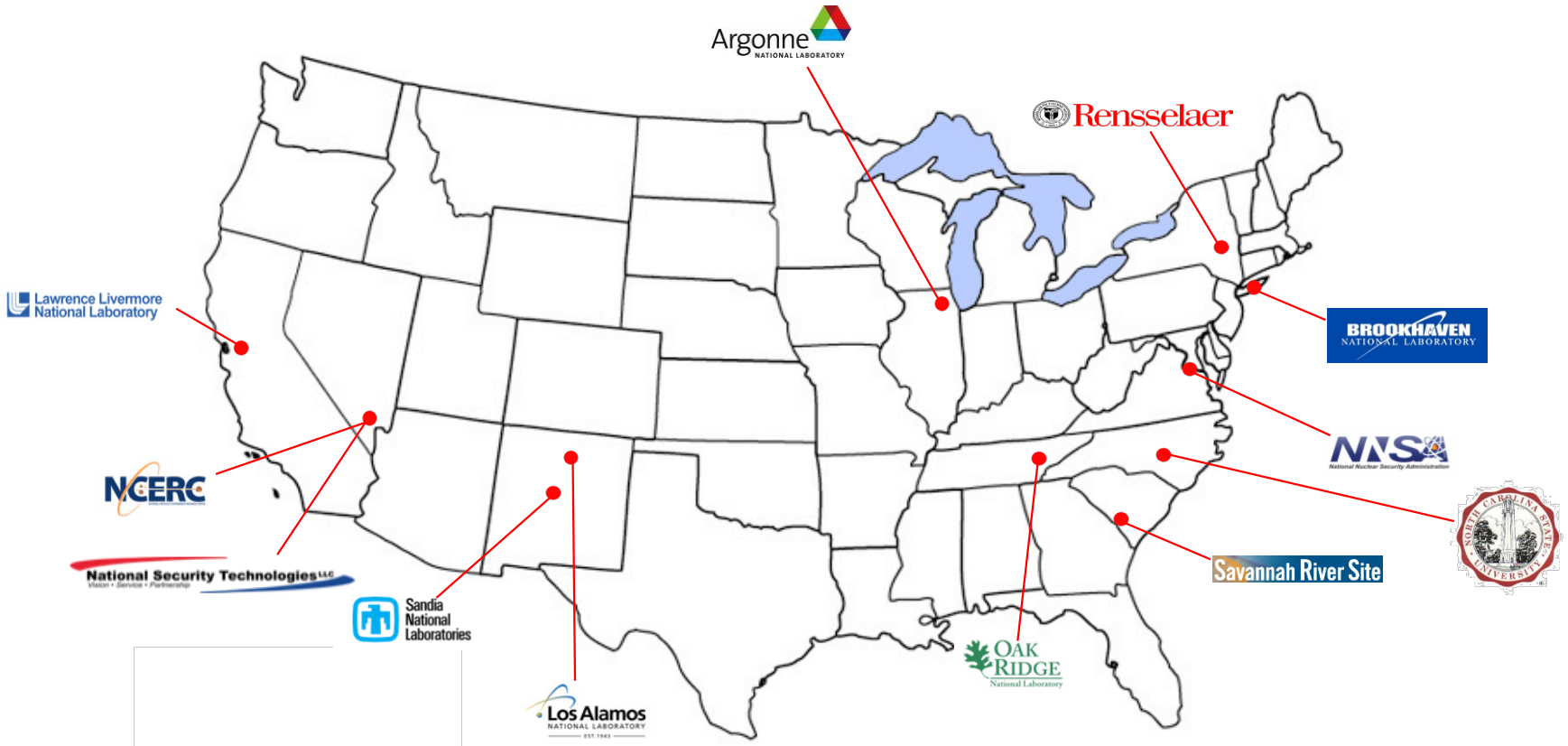
- **Analytical Methods (AM) – 15% of budget**
  - Maintain and improve the Production Codes and Methods for Criticality Safety Engineers (MCNP/SCALE, NJOY/AMPX)
- **Nuclear Data (ND) – 13% of budget**
  - Perform Measurements of Basic Nuclear (Neutron) Physics Cross-Sections and Generate New Evaluated Cross-Section Libraries and Covariance Data for Use in Production Criticality Safety Codes
- **Information Preservation and Dissemination (IPD) – 4% of budget**
  - Protects Valuable Analyses and Information Related to Criticality Safety (includes ICSBEP)
- **Integral Experiments (IE) – 52% of budget**
  - Critical and Subcritical Experiments at the Critical Experiments Facility (CEF) at the Device Assembly Facility (DAF) in Nevada and Sandia National Laboratory Pulse Reactor Facility– provides integral tests of codes and data
- **Training and Education (TE) – 6% of budget**
  - Web-based training modules and 1- & 2-week Hands-On Criticality Safety courses for Criticality Safety Engineers, Line Management, and Oversight Personnel
- **Technical Support (TS) – 10% of budget**
  - Managerial and technical support



FY22 budget: $29.6M

TS – Technical Support
MT – Management team
TMs – Task managers
CSSG – Criticality Safety Support Group
CSCT – Criticality Safety Coordinating Team
NDAG – Nuclear Data Advisory Group

Current NCSP Work Sites



FY2019 NCSP Budget: $26.8 million

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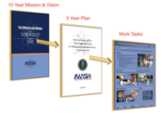
NCSP Main Functions and Execution

TS provides management support for daily NCSP execution. The CSSG and NDA groups provide NCS and ND expertise to the DOE through the NCSP manager. CSCT plays a key role in ensuring DOE's criticality safety programs stay within the framework of Integrated Safety Management Principles

NCSP Technical Support



NDAG
CSCT
CSSG

MCNP6

scale
Nuclear Systems Modeling & Simulation

Analytical methods provides support for the development and maintenance of SCALE/MCNP & NCSP site and international collaborations.

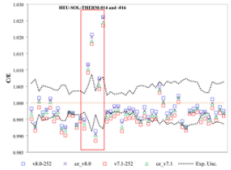
Analytical Methods

Training and Education

DOE NCSP training and education program provides NCS training for NCS engineers per ANSI/ANS-8.26 and CSOs/Managers. TE also provides resource pipelines to attract and train new NCS staff at DOE/NNSA sites.

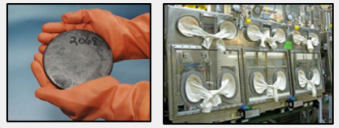
NCERC

NATIONAL ATOMIC TESTING MUSEUM



Nuclear Data testing involves using MCNP/SCALE to model critical benchmarks. Calculated differences from a critical configuration could indicate a code or nuclear data issue.

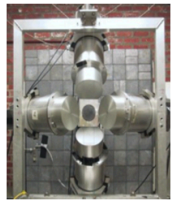
DOE Nuclear Criticality Safety Applications



The NCSP Website provides training registration and NCSet training modules and references for use by the community

Nuclear Data

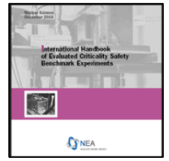
Nuclear data provides support for nuclear data evaluations (SAMMY) and cross section development (AMPX, NJOY). Also, differential nuclear data measurements are performed at RPI and IRMM in Belgium to fix nuclear data issues based on nuclear data testing activities with benchmark IEs. NCSP collaborates with the National Nuclear Data Center at BNL in the development of new Evaluated Nuclear Data Files for use by the NCS community.

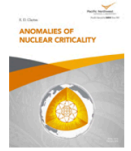


NJOY
AMPX
SAMMY
ENDF B-VIII.0
irmm
Rensselaer

Information Preservation & Dissemination

IPD involves sharing resources with the community via a modern website. Includes news, program management, training registration, references, and training aides





Integral Experiments

Benchmark integral experiments are needed to fill gaps in nuclear data libraries. Nuclear Data deficiencies are used as justification to eventually improve ND libraries

NCSP IE programs Involve applications of nuclear energy, basic measurements of nuclear parameters, kinetic behavior of chain-reacting systems, nuclear weapons safety, detector development, and nuclear criticality safety.

NCERC

Accomplishments, Challenges, Initiatives

ACCOMPLISHMENTS

- Completed UPF CAAS testing
- 7 Critical Experiment Campaigns Executed (CED 3b completed during FY21)
- 5 Critical Experiment Benchmark Reports Completed for ICSBEP Handbook
- 9 NCSP Criticality Safety Classes
- 94 Hands-on NCS students
  - Had 1st ever virtual course work
- 391 MCNP students (all virtual)
- 173 SCALE students (all virtual)
- 1st Ever MCNP Users' Group Workshop (500+ attendees)
- 5th Annual SCALE Users' Group Workshop (173 attendees)
- 1st ever NCSP ND measurement at LANSCE (U-233)
- NCSP IE Managers using G2 for IEP process
- Planet Leveling Upgrade

CHALLENGES

- RPI accelerator refurbishment schedule impacted by COVID (NR reported 8-month delay)
- NCERC-FO personnel impacted by LANL vaccination LWOP policy
- Travel costs are low due to COVID restrictions => more carryover
- TEX-Hf IE delayed to FY22 due to delayed NR Hf procurement
- RTO operations were impacted by COVID
- SPRF/CX Facility activities impacted by COVID
- COVID impacts to training
- Criticality Accident Dosimetry Exercise delayed due to COVID travel restrictions
- ICSBEP Chair leaving INL
- CSSG Panel discussion at ANS meeting delayed
- Nuclear Data measurements at GELINA delayed due to COVID closure
- Supplies - Prices rising; lead times increasing

INITIATIVES

- Capabilities Based Investment (NA-19) funding ($2.3M for FY21) for NCERC Control Room upgrades
- Horizontal split table
- FY22 NCSP MIHL
- Implemented wait-list function on T&E section of webpage
- New chairs for CSCT and CSSG
- Pu-240 Measurement at LANSCE
- Low temperature TEX
- Criticality Accident Dosimetry Exercise
- Working with OSTI to create NCS library
- DRACO

FY22 NCSP Make It Happen List

1. Production and delivery of hafnium to NCERC in support of TEX-Hf (IER 532) - NNL
2. Conduct nuclear accident dosimetry exercise (IER 538) – LLNL
3. Complete TEX low temperature DU surrogate testing (IER 547) - LLNL
4. Submit TEX HEU benchmark report to the International Criticality Safety Benchmark Experiment Program (IER 297) - LLNL
5. Complete critical experiments with UO_2 Rods and molybdenum foils (IER 305) - SNL
6. Complete measurements for the Flattop benchmark (IER 423) - LANL
7. Complete fabrication of lithium for critical experiment (IER 499) – Y-12
8. Complete high multiplication neutron subcritical measurements (IER 518) - Multiple
9. Measure the fission neutron spectrum shape using threshold activation detectors (IER 153) - LANL
10. Promote use of MCNP Version 6.3 at DOE sites - LANL
11. Complete prompt fission neutron spectrum (PFNS) measurement of Plutonium-240 at LANSCE - LANL
12. Complete Zr-91 measurements at GELINA - ORNL
13. Complete site acceptance tests for accelerator section #1 at RPI - NNL
14. Complete GELINA neutron production target – Y-12 **Complete**
15. Complete Sandia CSO/Manager course pilot course - SNL

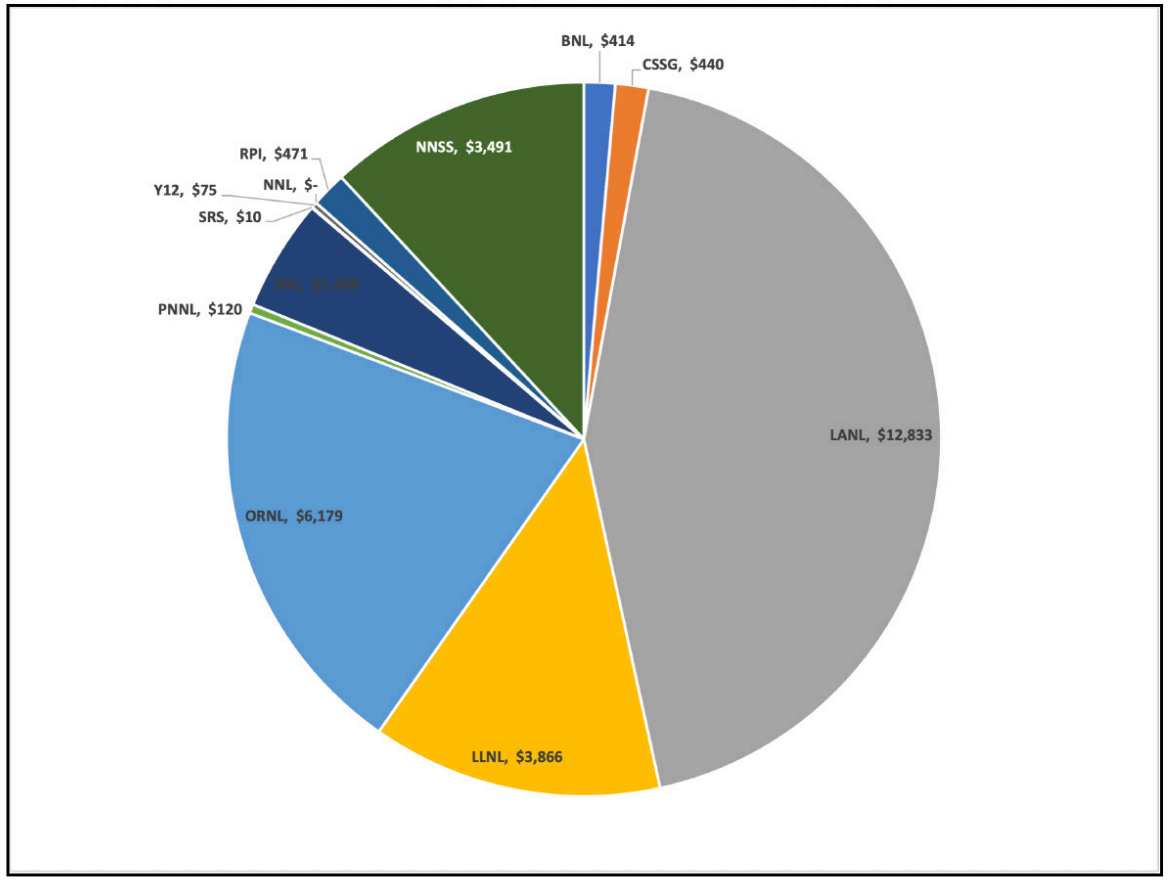
NCSP Budget

Table 2.1 NCSP Final Site Splits (FY2022 – FY2026)**

NCSP Site	FY 2022 ($k)**	FY 2023 ($k)	FY 2024 ($k)	FY 2025 ($k)	FY 2026 ($k)
Lawrence Livermore National Laboratory	3,916	3,368	3,439	3,534	3,605
Los Alamos National Laboratory	12,958	12,814	12,840	12,915	13,173
Nevada Nuclear Security Site	3,491	3,892	3,892	3,892	3,970
Sandia National Laboratory	1,488	1,845	2,120	2,350	2,397
Savanah River Site	60	75	85	90	92
Y-12 National Security Complex	105	150	162	167	170
Argonne National Laboratory	0	0	0	0	0
Brookhaven National Laboratory	414	525	530	530	541
Oak Ridge National Laboratory	6,364	6,629	6,850	6,959	7,098
National Nuclear Laboratory (Rensselaer Polytechnic Institute + NDAG Chair)	471	510	429	429	438
CSSG (Headquarters)	0	470	600	700	714
Pacific Northwest National Laboratory	120	40	0	0	0
Total	**29,387**	**30,318**	**30,947**	**31,566**	**32,197**

** CSSG funds for FY22 have been distributed to the NCSP sites. For the outyears, the CSSG funds and funds for NDAG chair use are in the "CSSG (Headquarters)" cell.

Figure 2.0-5 NCSP Funding Overview (FY2022) – By Site



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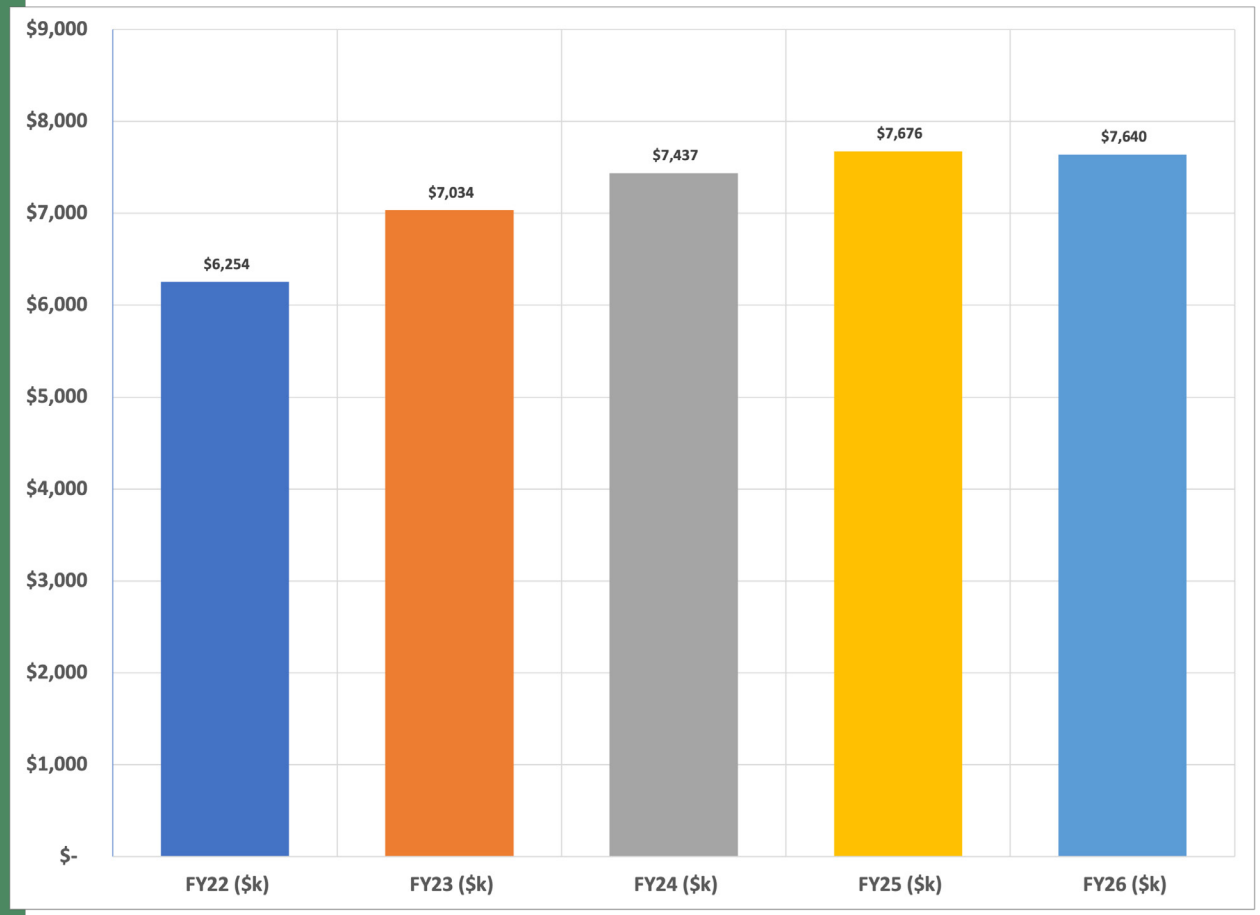
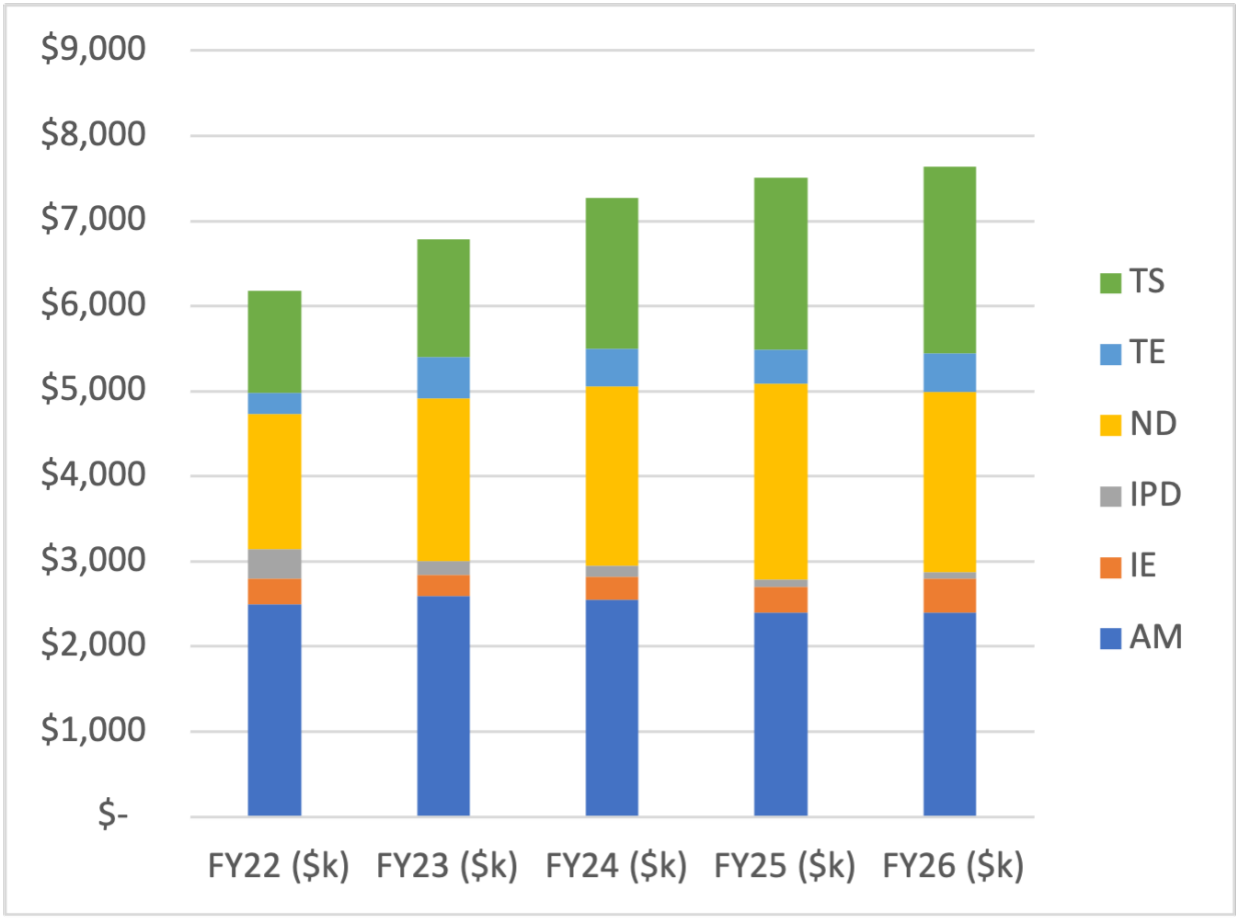
ORNL NCSP Budget



ORNL budget by fiscal year FY22-FY26



ORNL budget by fiscal year and technical program element FY22-FY26

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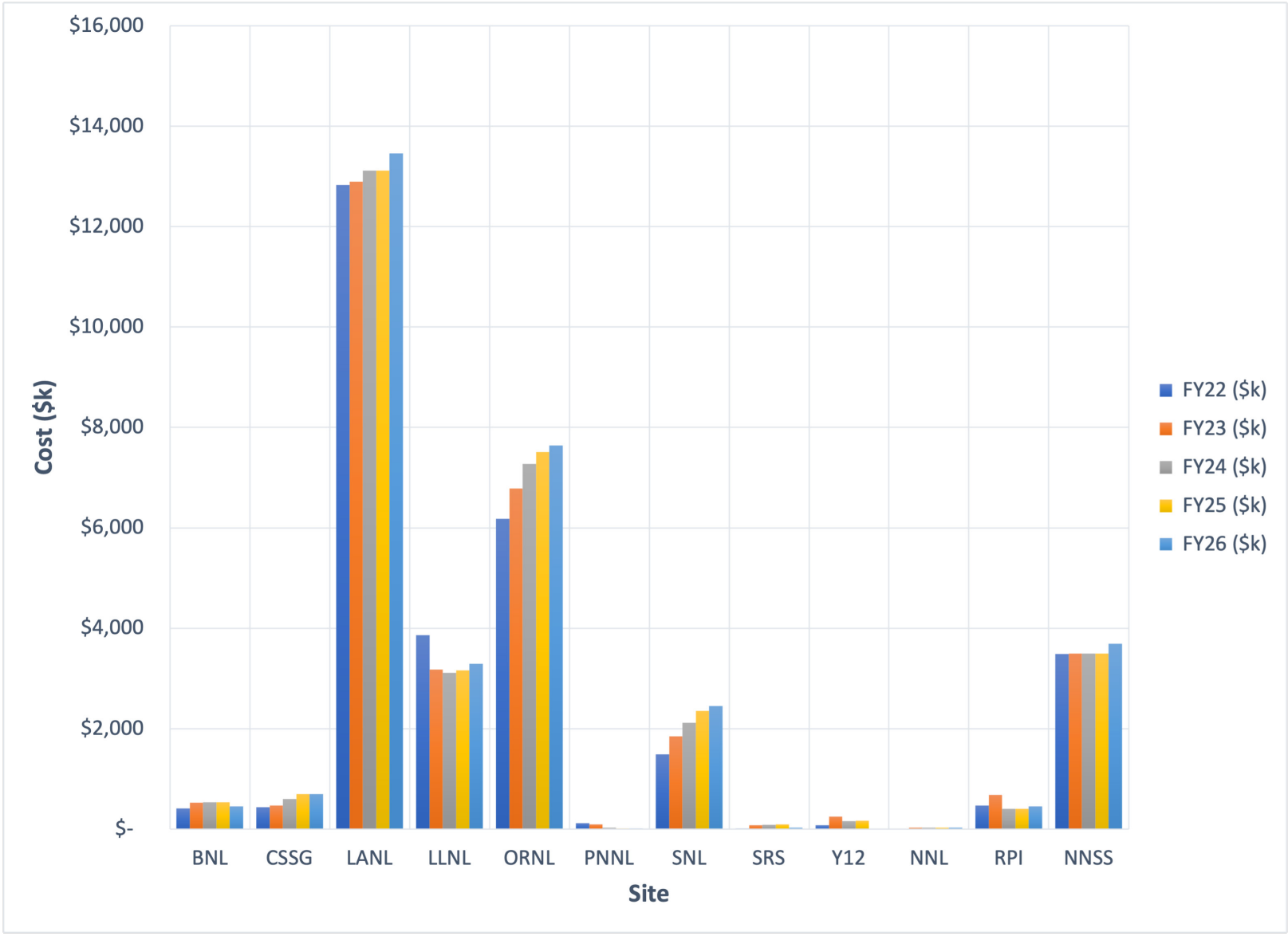
ORNL NCSP Budget



ORNL NCSP Tasks – Analytical Methods

Task Type	Proposal Number	TASK NAME	Task Title	Task Description	FY21 ($k)	**FY22 ($k)**	FY23 ($k)
AM	FY22-02	ORNL-AM10	Proposed Benchmark Intercomparison Study	This proposal is to expand the focus and continue the Benchmark Intercomparison Study for another three years beyond its initial term of three years.	0	**50**	50
AM		ORNL-AM1	Radiation Safety Information Computational Center (RSICC)	Collect, update, & distribute software & libraries; test & disseminate data	674	**700**	748
AM		ORNL-AM15	The Effects of Temperature on the Propagation of Nuclear Data Uncertainty in Nuclear Criticality Safety Calculations	Develop an analytic methodology and implement it in a module of the AMPX nuclear data processing code to allow the nuclear data covariance to accurately reflect the degree of knowledge of the cross section at different temperatures.	99	**0**	0
AM	FY20-04	ORNL-AM17	Expansion of the Verified, Archived, Library of Inputs and Data (VALID)	Improve analytical methods and nuclear data tools for ensuring accurate criticality safety analyses that appropriately balance safety margins with operational flexibility.	139	**50**	50
AM	FY20-05	ORNL-AM18	Determination of Appropriate Integral Parameters for Critical Experiment	Provide a Rigorous Technical Basis for Selecting Critical Experiment Benchmarks	0	**100**	50
AM	FY20-06	ORNL-AM19	Analysis of Sum-of-Fractions for Nuclide Mixtures	Develop a technical foundation for the use of Sum-of-Fractions for nuclides in optimally moderated and fully reflected systems	0	**60**	40
AM		ORNL-AM2	SCALE/KENO/TSUNAMI Maintenance and Support/Cross-Section Generation/Modernization/etc.	SCALE NCS SQA & V&V; computing platforms; improved interfaces & documentation; and transition criticality safety capabilities of SCALE to a new, modern software framework	1188	**1188**	1200
AM		ORNL-AM3	AMPX Maintenance & Modernization	Maintain AMPX for conformance as necessary; Update the AMPX cross-section processing system for use with SCALE and MCNP	297	**297**	400
AM		ORNL-AM6	Slide Rule Application	Handheld Nuclear Criticality Safety Slide Rule application and work with LLNL/IRSN to generate a Criticality Slide Rule for Plutonium Systems	30	**50**	50

ORNL NCSP Tasks – Integral Experiments

Task Type	Proposal Number	TASK NAME	Task Title	Task Description	FY21 ($k)	**FY22 ($k)**	FY23 ($k)
IE		ORNL-IE1	IE CEDT Support	Optimize current year's experiment designs, within experimental constraints, to maximize similarity to targeted applications	178	**190**	200
IE		ORNL-IE2	Provide Safety Committee Support at DAF/NCERC	Provide Fast Reactor Expertise to LANL NCERC Experiment Review Committees to Provide Independent Expert Advice/reviews	37	**15**	50
IE		ORNL-IE4	Funding to support U-233 ZPPR plate shipments to DAF NCERC	Funds to support the preparation for shipping U-233 ZPPR plates from ORNL to DAF/NCERC in FY22.	50	**100**	0

Table 2.4-2 ORNL FY22 Milestone Table – ORNL IE1

IER/Title	NCSP Priority	Total ($k)+	No CED MS*	CED-1 MS*	CED-2 MS*	CED-3a MS*	CED-3b MS*	CED-4a MS*	CED-4b MS*
LANL									
498									
Design, execute, and document needed measurement data for a shielding benchmark with a metal critical source, beneficial to CAAS analysis	24	0				6			
557									
Godiva-IV Pulse Characterization	35	25			1	2	3		
ORNL									
304									
Temperature dependent critical benchmarks	4	25				3	6		
554									
Neutron absorber plate experiments using the 7uPCX fuel	13	150		4					
SNL									
441									
Epithermal HEX Lattices with SNL 7uPCX Fuel for Testing Nuclear Data	17	15				2	4		
Grand Total	–	**215**	**0**	**1**	**1**	**4**	**3**	**0**	**0**

+ Budget figures are task manager estimates. Budgets are limited to ORNL IE1 task description.

* Milestones: (1 = FY2022 Quarter 1, 2 = FY2022 Quarter 2, 3 = FY2022 Quarter 3, 4 = FY2022 Quarter 4, FY2023 Q1, 6 = FY2023 Q2, 7 = FY2023 Q3, 8 = FY2023 Q4)

Table 2.4-1 ORNL FY22 Priorities and Costs – ORNL IE1

IER/Title	NCSP Priority	No CED Cost $k+	CED-1 Cost $k+	CED-2 Cost $k+	CED-3a Cost $k+	CED-3b Cost $k+	CED-4a Cost $k+	CED-4b Cost $k+	Total ($k)+
LANL									
498									
Design, execute, and document needed measurement data for a shielding benchmark with a metal critical source, beneficial to CAAS analysis	24				0				0
557									
Godiva-IV Pulse Characterization	35			10	0	15			25
ORNL									
304									
Temperature dependent critical benchmarks	4				25	0			25
554									
Neutron absorber plate experiments using the 7uPCX fuel	13		150						150
SNL									
441									
Epithermal HEX Lattices with SNL 7uPCX Fuel for Testing Nuclear Data	17				0	15			15
Grand Total	–		**150**	**10**	**25**	**30**			**215**

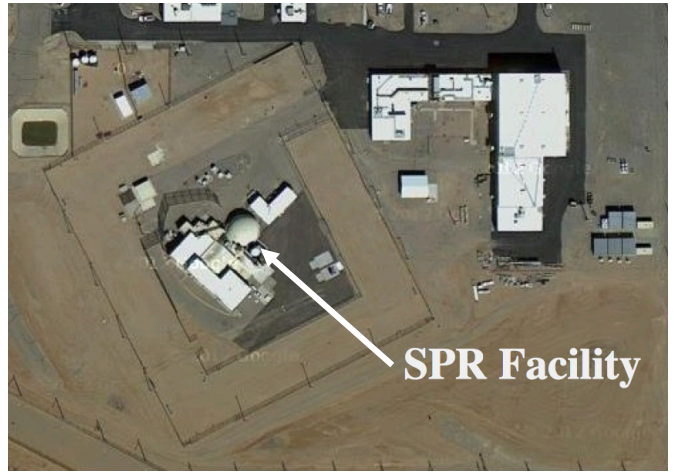
+ Budget figures are task manager estimates. Budgets are limited to ORNL IE1 task description.

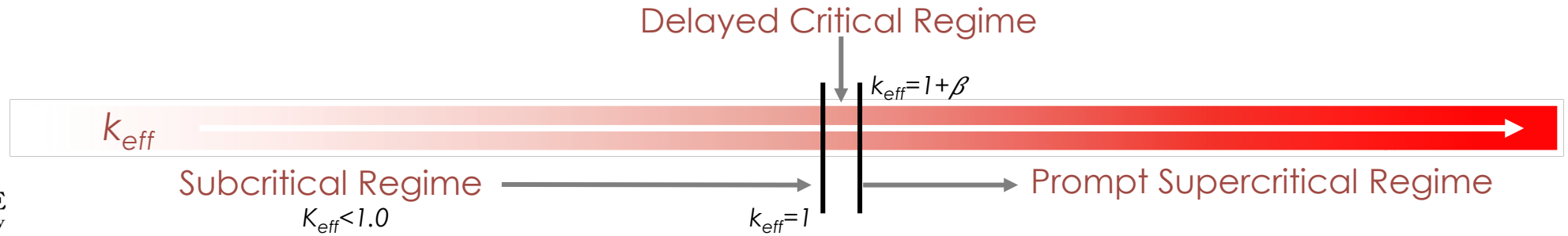
NCSP Integral Experiments

- NCSP integral measurements are performed at
  - Sandia National Laboratories (SNL) and
  - National Criticality Experiments Research Center (NCERC), currently operated by Los Alamos National Laboratory
    - NCERC is located at the Nevada National Security Site (NNSS) inside the Device Assembly Facility (DAF)
- Types of experiments that can be performed
  - Subcritical
    - Rocky Flats shells, BeRP ball, Np-237 sphere, TACS shells, etc.
  - Critical/Delayed Supercritical
    - NCERC: Planet, Comet, Godiva IV, Flattop
    - Sandia: Sandia Pulse Reactor critical assembly (2 fuel types, currently)
  - Prompt Supercritical
    - NCERC: Godiva IV (< 300 deg. C pulse)

DAF/NCERC

SNL/TA-V/SPR Facility

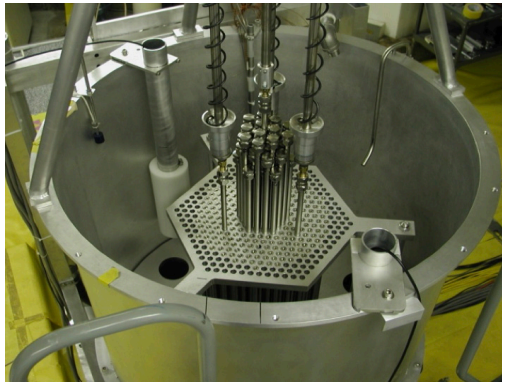


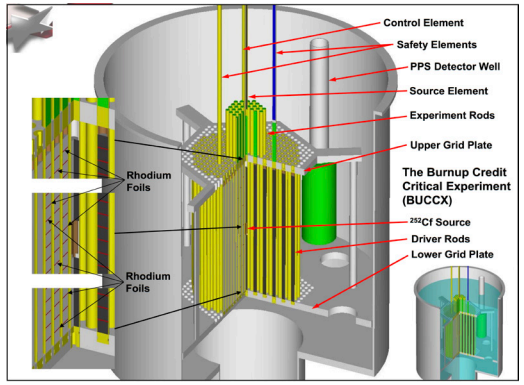


NCSP Critical Assemblies

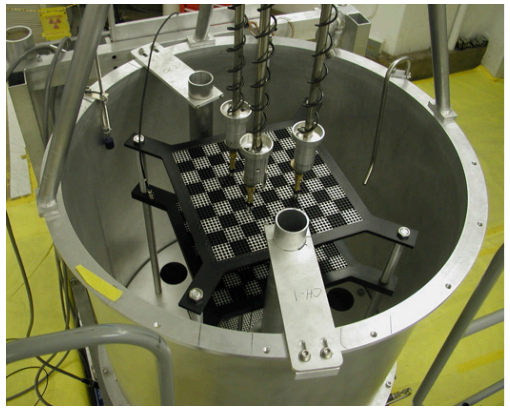
Sandia National Laboratory

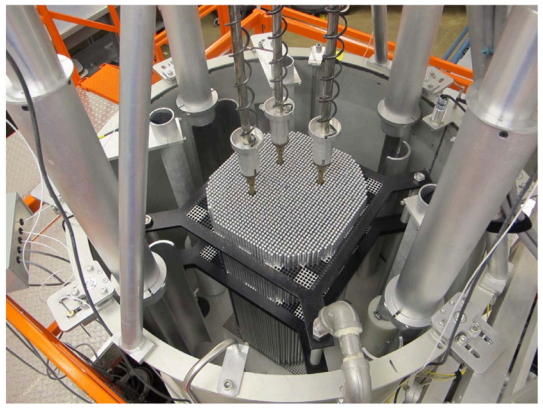
SNL – BUCCX – U(4.31)/Fission Product Experiments



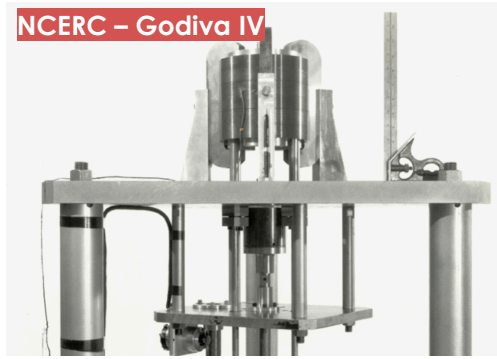


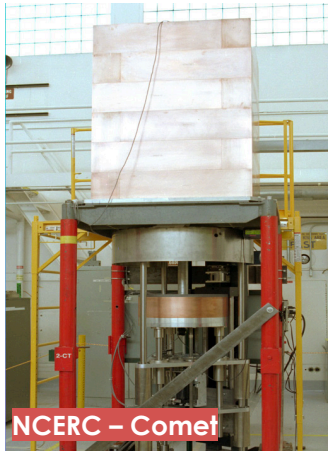
SNL – 7uPCX – U(6.9) UO_2 rods





NCERC/DAF





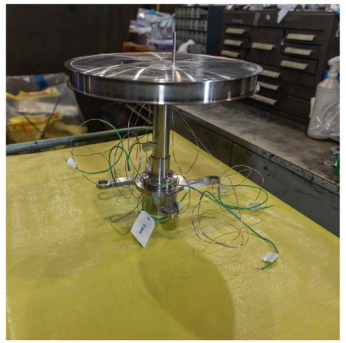
ORNL NCSP Tasks – Information, Preservation and Dissemination

Task Type	Proposal Number	TASK NAME	Task Title	Task Description	FY21 ($k)	**FY22 ($k)**	FY23 ($k)
IPD	FY22-25	ORNL-IPD4	Nuclear Criticality Safety - Learning From Experience (LFE) Database	The United Kingdom (UK) Working Party on Criticality (WPC) would like to collaborate on a "Learning from Experience Database", with the concept being favorably received by the international community at the International Conference on Nuclear Criticality (ICNC) Safety in 2019.	0	**0**	50
IPD	FY22-26	ORNL-IPD3	Nuclear Criticality Safety Repository	The Nuclear Criticality Safety Program (NCSP) is a multi-lab collaboration dating back to the mid-1990's and a repository of NCSP documents has been hosted by LLNL for some time (website at https://ncsp.llnl.gov/).	0	**345**	120

ORNL NCSP Tasks – Nuclear Data

Task Type	Proposal Number	TASK NAME	Task Title	Task Description	FY21 ($k)	**FY22 ($k)**	FY23 ($k)
ND		ORNL-ND1	Nuclear Data Measurement and Evaluation	Cross-section measurements and the production of new cross-section evaluations with covariance data	1140	**1140**	1200
ND		ORNL-ND3	Isotopic Sample Leases to Support ND1 ND Measurements	Task involves the lease of small, stable, isotopically pure, samples for ND measurements at RPI/JRC-Geel.	50	**50**	55
ND		ORNL-ND6	SAMMY Nuclear Data Evaluation Code Modernization	Modernizing the SAMMY nuclear data evaluation code used in evaluations of resonance region differential nuclear cross sections in an adaptive high-performance nuclear data evaluation framework designed to meet present and future NCSP nuclear data evaluation needs	392	**392**	400
ND		ORNL-ND9	Evaluation of Thermal and Resolved Resonance Ranges of UO2 and PUO2	Develop a new method for consistent evaluation of thermal neutron scattering libraries (TSL) and (resolved) resonance differential cross section data	0	**0**	249
ND		ORNL-ND10	Monte Carlo Evaluation of Differential and Integral Data	Develop a new Monte Carlo framework for simultaneous evaluations of integral benchmark experiments and differential cross section data	148	**0**	0
ND		ORNL-ND4	Thermal Neutron Total Cross Section Measurements for Improvement of Criticality Calculations and Propagation of Scattering Kernel Uncertainties	Continue task to develop and maintain new thermal neutron scattering measurement and analysis capabilities	148	**0**	0

Y-12 Fabricated DU Target for Use at GELINA



ORNL NCSP Tasks – Training and Education

Task Type	Proposal Number	TASK NAME	Task Title	Task Description	FY21 ($k)	**FY22 ($k)**	FY23 ($k)
TE		ORNL-TE1	Manage and Provide Instruction for the DOE Nuclear Criticality Safety Training & Education Program	Subtask 1: Manage the collaborative development and documentation for the planning, designing, and scheduling for the phased and multi-faceted NCSP Training Program Subtask 2: Provide training for the application of non-destructive analyses (NDA) measurement results to NCS evaluations AND General NCS topics as needed, e.g., standards, accidents, workshops.	99	**99**	185
TE	FY21-25	ORNL-TE11	Revision of the LA-12808 Nuclear Criticality Safety Guide	ORNL to revise this document to make clarifications and enhancements as a result of almost 25 years of NCS lessons learned since the last revision.	148	**50**	0
TE	FY21-32	ORNL-TE12	Design of an Subcritical/Critical Assembly at ORNL for Use with the CSO/FMH Courses	This is a continuing task based on the results of a feasibility study or preliminary design performed in FY2019. The inclusion of a subcritical assembly located at Oak Ridge National Laboratory allows the CSO/FMH course to be taught in close proximity to many sites in the eastern United States with CSOs and FHMs.	124	**0**	0
TE		ORNL-TE13	NDA NCSET Module	Develop NCSET module for the use of NDA as an implemtation method for Nuclear Criticality Safety	0	**0**	50
TE		ORNL-TE5	On-Site Introductory Training for the NCS Practitioner on Modern Approaches to Validation using Sensitivity and Uncertainty Analysis Tools	Provide a 1-day onsite introductory validation training class to multiple DOE sites that are selected by the NCSP Manager	0	**0**	30
TE		ORNL-TE6	SlideRule NCSET Module	Develop NCSET module on the use of SlideRule for Emergency Response	0	**0**	75
TE		ORNL-TE7	Criticality Safety Tutorials - CAAS	Develop tutorial for CAAS system placement evaluation needs and design options/considerations	0	**0**	50
TE		ORNL-TE8	Criticality Safety Tutorials - D&D	Develop tutorial for D&D related to criticality safety	0	**0**	0
TE	FY22-39	ORNL-TE14	Nuclear Criticality Safety Training and Pipeline Development	The work to be conducted under this proposal focuses on the development of a new university-based nuclear criticality training certificate program with the intent to develop a pipeline of nuclear criticality specialists into Department of Energy Laboratory complex.	0	**100**	100

ORNL NCSP Tasks – Technical Support

Task Type	Proposal Number	TASK NAME	Task Title	Task Description	FY21 ($k)	FY22 ($k)	FY23 ($k)
TS		ORNL-TS13	NDA Technical Support Group and NDA Technical Infrastructure Project	TSG support for DNFSB 2007-01 recommendation	322	**203**	325
TS		ORNL-TS2	Technical Support	Support for Lead Lab to Execute the NCSP.	654	**654**	660
TS		ORNL-TS7	AM, ND Succession Planning	Cross-Section processing developers, Radiation transport developers, Nuclear Data evaluators/ experimentalists/ developers	148	**148**	149
TS		ORNL-TS8	NCSP Program Management Tools Development	ORNL/NNSA G2 Team to develop modern NCSP management CEdT capability to support Management Team Program Management Tasks	198	**198**	250

Discussion Points

- ORNL NCSP support is well received by NA-50
- SCALE funding will mirror MCNP funding in the short term
  - TSUNAMI funding high priority under AM2
- SAMMY/AMPX funding likely not to increase significantly – need to show the value of the funding for this task
- Reimagine goals require specific funding beyond the NCSP redundant funding
  - Brainstorming sessions to be scheduled
  - PD funds available for FY22
- NCSP is task based – funding must be backed up with a completed deliverable
- Issues with staff charging to project codes without a task to work on
- Need a new NCSP task manager
  - Contact Doug Bowen if interested

Questions