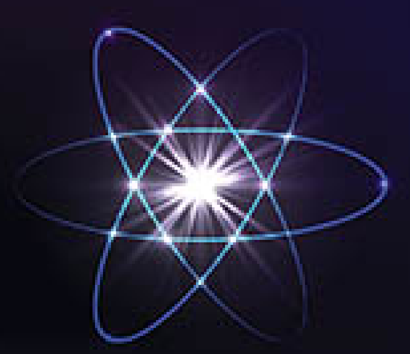
NCSP
NUCLEAR CRITICALITY SAFETY PROGRAM

NEWSLETTER

FALL 2021

IN THIS ISSUE



Please contact Marsha Henley for information or contributions: henleym@ornl.gov

DATES TO REMEMBER

Hands-On Training & Education Course Dates:
Two-week Practitioner Course Dates:
Jan 31–Feb 11, 2022
Aug 8-19, 2022

One-week Manager's Course Dates:
Sandia – April 4-8, 2022
NCERC - Jun 6-10, 2022

Course Registration:
https://ncsp.llnl.gov/trng_apply.php

LINKS TO REMEMBER

- NCSP Website
- NCSP Program Management
- NCSP Mission and Vision
- NCSP Five-Year Execution Plan
- NCSP Planning Calendar
- Previous NCSP Newsletters
- CSSG Taskings
- Nondestructive Assay Program

A Message from the NCSP Manager

I sincerely hope this fall newsletter finds you and your families all healthy and safe.

I cannot begin to express my gratitude for your unwavering dedication to continue to support the NCSP mission during this challenging year. 2021 represents the 10th year of criticality experiments at the National Criticality Experiments Research Center. In recognition of that anniversary, LANL is currently working with the American Nuclear Society on a special edition of the *Nuclear Science and Engineering* journal which will feature articles on the history and operations of the NCERC critical assembly machines and radiation test object assembly mission. Despite the challenges of the past year, you all have managed to continue our vital role meeting critical milestones and supporting the DOE/NNSA missions. This year, to better illustrate our goals and accomplishments, with your help, we have incorporated a "Make it Happen List" for the NCSP into our 5-year Plan. Our FY22 MIHL is listed below. As always, thank you for all that you do to support our mission.

No.	"Make it Happen List" Milestone	TPE	Lead Site
1	Production and delivery of hafnium to NCERC in support of TEX-Hf (IER 532)	IE	NNL
2	Conduct nuclear accident dosimetry exercise (IER 538)	IE	LLNL
3	Complete TEX low temperature DU surrogate testing (IER 547)	IE	LLNL
4	Submit TEX HEU benchmark report to the International Criticality Safety Benchmark Experiment Program (IER 297)	IE	LLNL
5	Complete critical experiments with UO_2 Rods and molybdenum foils (IER 305)	IE	SNL
6	Complete measurements for the Flattop benchmark (IER 423)	IE	LANL
7	Complete fabrication of lithium for critical experiment (IER 499)	IE	Y-12
8	Complete high multiplication neutron subcritical measurements (IER 518)	IE	SNL
9	Measure the fission neutron spectrum shape using threshold activation detectors (IER 153)	IE	LANL
10	Promote use of MCNP Version 6.3 at DOE sites (Task LANL-AM1)	AM	LANL
11	Complete prompt fission neutron spectrum (PFNS) measurement of Plutonium-240 at LANSCE (Task LANL-ND2)	ND	LANL
12	Complete Zr-91 measurements at GELINA (Task ORNL-ND1)	ND	ORNL
13	Complete site acceptance tests for accelerator section #1 at RPI (Task RPI-ND3)	ND	NNL
14	Complete GELINA neutron production target (Task Y12-ND1)	ND	Y-12
15	Complete Sandia CSO/Manager course pilot course (Task ORNL-TE1, SNL-TE1)	TE	ORNL SNL

NNSA National Nuclear Security Administration

U.S. DEPARTMENT OF ENERGY

Annual NCSP Budget Execution Meeting

For the second year due to the COVID-19 pandemic, the annual NCSP Budget Execution meeting was hosted virtually by ORNL on Wednesday, July 28th, and Thursday, July 29th. The FY2022 NCSP budget was finalized during the meeting and allowed the management team to finalize the main 5-year plan by August 15th. The 5-year plans are due to NNSA NA-50 earlier in the year now to distribute budget and task implementation plans to the NCSP sites before the end of the fiscal year.

Health Physics Research Reactor (HPRR) Shielding Benchmark Creation

The evaluation of specific legacy experiments data from operation of the Oak Ridge National Laboratory (ORNL) Health Physics Research Reactor (HPRR) for shielding benchmark creation has been completed at Oak Ridge National Laboratory. The work is part of a FY19 NCSP funded task from the Information Preservation and Dissemination program (ORNL IPD5). The primary goal of this project is to offer more possibilities to criticality and radiation safety analysts for validating their calculation tools and cross-section libraries. From all the experiments evaluated, two are judged to be of benchmark quality and show promising Computation to Experiment results ratios (C/E) obtained with SCALE/KENO and SCALE/MAVRIC version 6.2.4. The C/E ratios are all under 1.4 for the different benchmark metrics analyzed, such as neutron fluence and element 57 neutron dose, which is a satisfactory result for legacy shielding experiments. The availability of the evaluated HPRR data would greatly benefit the Critical Alarm Incident Systems (CAAs) and shielding benchmarking communities because of the critical assembly unique characteristics and properties.

The HPRR core was built at ORNL in 1961 and decommissioned in 1987. Also known as “Fast Burst Reactor” (FBR), it was a small unshielded and unmoderated assembly consisting in numerous elements allowing for delayed steady-state critical or prompt critical burst operations. The different fuel elements were all made from the same material, an alloy of 90 weight percent highly enriched uranium (about 93.16% ^{235}U) and 10 weight percent pure molybdenum. The main U-Mo elements composing the core were 11 stacked annulus plates of about 20 cm diameter each and measuring a total height of 23 cm. Other fuel components include, among others, 9 U-Mo hollow bolts to hold the annuli, 9 bolt inserts, three control rods and a central safety block that could be scrammed during operation. In Figure 1 are shown different representations of the HPRR critical assembly, from left to right, a mechanical drawing from 1965, a picture from 1965 and a highly detailed SCALE/MAVRIC model made in 2020.

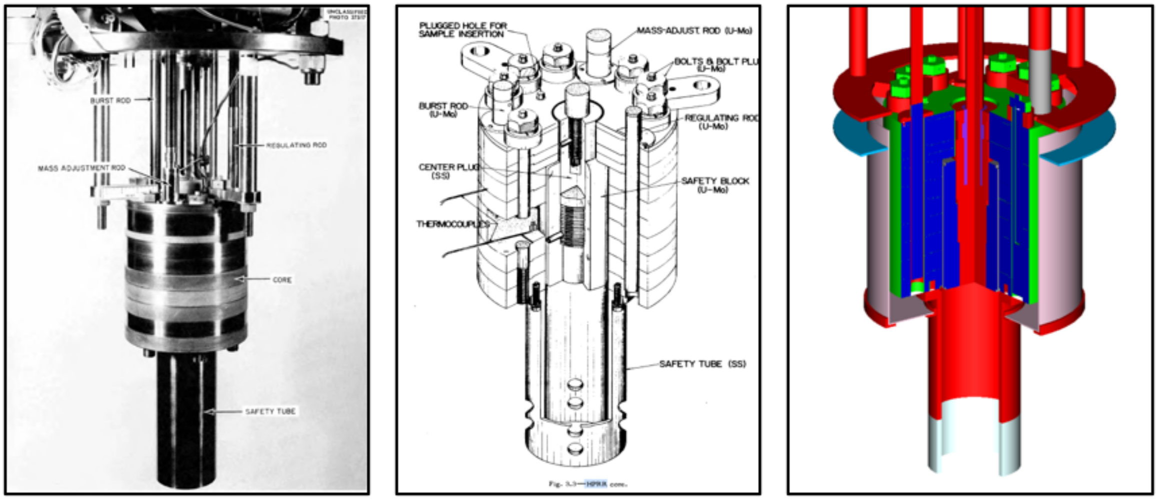


Figure 1. (Left) HPRR photography, 1965. (Center) HPRR drawing, 1965. (Right) HPRR SCALE model, 2020.

After being loaned to the Nevada Test Site for a few years, the HPRR was part of the Dosimetry Application Research (DOSAR) facility where it was used for radiobiology, dosimetry, detectors testing, teaching, and training. The HPRR occupied the DOSAR reactor building, where other items were also located, as experiment tables or core lifting mechanisms. In Figure 2 are shown a photography of the HPRR in the reactor room on the left, and the corresponding SCALE benchmark model used in the evaluation on the right. The main challenges in this work were the evident lack of precise documentation or information on dimensions, materials of the core and building walls and the presence of items in the reactor room during the experiments of interest. An in-depth sensitivity and uncertainty study was performed, analyzing the influence of those uncertain parameters on the benchmark metric results. In the end, a lot of elements from the reactor room or the HPRR critical assembly were found to be statistically insignificant, and the corresponding benchmark model could be heavily simplified as shown in Figure 2.

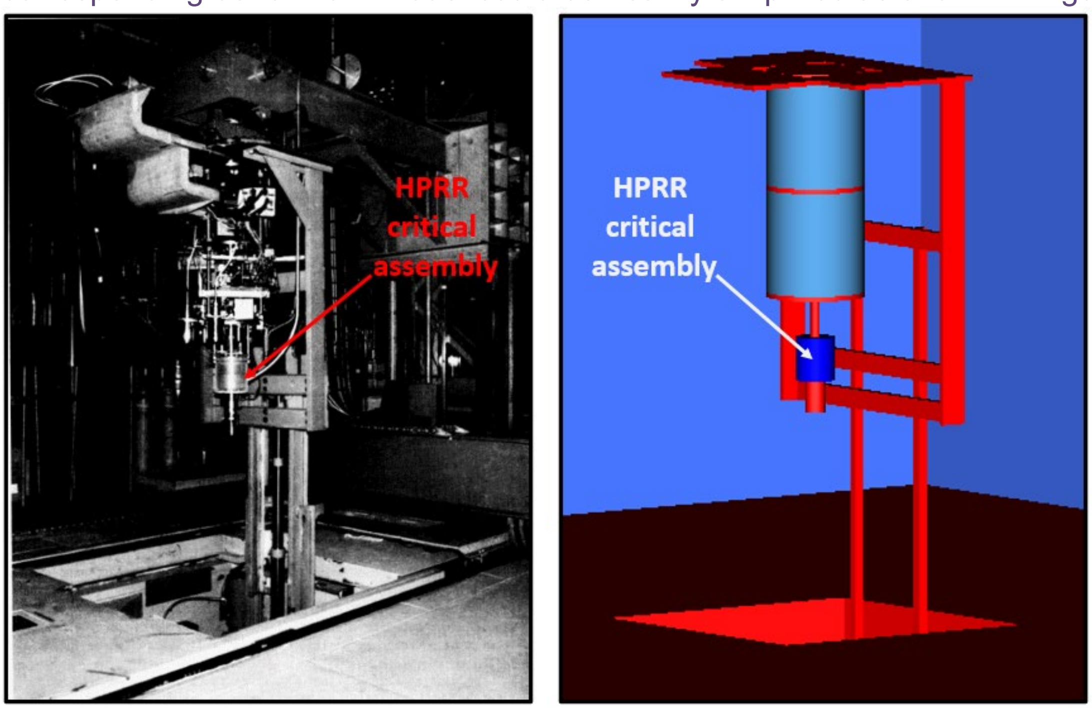


Figure 2. (Left) HPRR photography, 1985. (Right) HPRR simplified benchmark SCALE model, 2021.

The experiments and results of interest were all obtained from *ORNL-6240*, the latest published dosimetry report in 1987, right before the decommissioning of the reactor. The data judged to be worthy of a benchmark creation corresponds to the neutron fluence and neutron dose results obtained from an equivalent pulse of 10^{17} fissions of the HPRR at 3 meters from the HPRR centerline. The same experiment was also repeated with shields of different materials placed between the detector and the HPRR, but due to high uncertainty in material data, only the bare and steel shield configurations were retained in the current evaluation. The experimental neutron fluence was measured through Bonner spheres detectors, sulfur pellets analysis and/or threshold detector unit data, and the neutron dose was obtained from the measured neutron fluence and different dose-per-unit fluence conversion factors. Using SCALE/KENO, SCALE/MAVRIC and the results of the uncertainty and sensitivity study, sample calculations were performed from the benchmark model specifications and a few of the obtained results are shown in Table 1, for neutron fluence and element 57 dose for the HPRR in bare and steel shield configurations. The benchmark relative uncertainties were derived to be about 25 % for the bare configuration and 71 % for the steel shield configuration. The C/E ratios are within the derived uncertainty for the element 57 dose results.

TABLE I. Results of preliminary sample calculations of the neutron fluence and element 57 dose at 3 meters from a HPRR burst equivalent of 10^{17} fissions compared with experiment results from ORNL-6240

Model	Neutron fluence (cm^{-2})			Element 57 Dose (Gy)		
	Measured	Calculated	C/E	Measured	Calculated	C/E
Bare	1.73×10^{11}	2.41×10^{11}	1.39	3.98	4.99	1.26
Steel Shield	9.50×10^{10}	1.18×10^{11}	1.24	1.63	1.83	1.12

The encouraging sample calculation results and relative agreement with experiment obtained during this work show that a good quality shielding benchmark can be created from legacy HPRR reactor operation data. The evaluation has been submitted for review by the International Criticality Safety Benchmark Evaluation Project Working group (ICSBEP) committee to be considered for inclusion in the ICSBEP Handbook. The benchmark will include, at minimum, unshielded and steel-shielded neutron fluence and element 57 dose at 3 meters from a burst of 10^{17} fissions. The evaluation is currently under the independent review step of the ICSBEP review process and will be presented during the 2021 ICSBEP Technical Review Group (TRG) meetings. The work will also be the object of conference and peer-reviewed publications. This article is by Mathieu Dupont (ORNL).

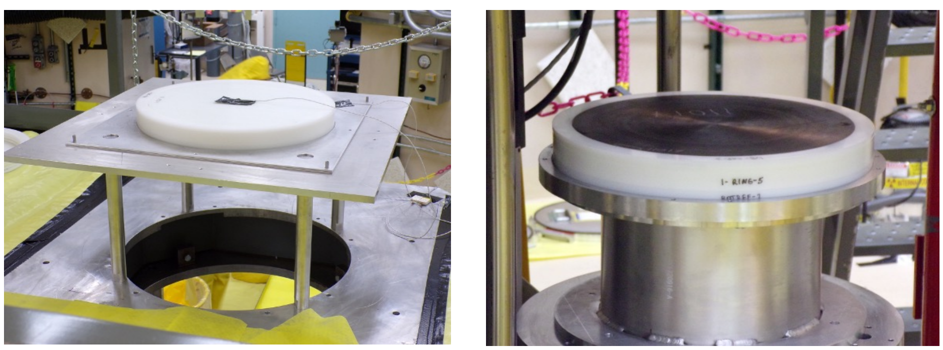
TEX-HEU-Hf Critical Experiment (IER 532)

The TEX-HEU-Hf critical experiments have been designed to provide fast, intermediate, and thermal spectrum critical assembly benchmarks to support improvements to the hafnium cross sections in the US national ENDF/B nuclear data libraries. Accurate hafnium cross sections are essential to the Naval Nuclear Propulsion Program. The benchmarks sensitive to hafnium currently available in the ICSBEP Handbook are insufficient and new benchmarks with lower experimental uncertainties and a broader range of neutron energy spectra are needed. This critical experiment program involves a collaboration between Lawrence Livermore National Laboratory (LLNL) who is responsible for the design and evaluation of the experiment, Los

Alamos National Laboratory (LANL) who is responsible for execution, and Naval Nuclear Laboratory (NNL) who is supplying the hafnium test plates used in the experiment. Fabrication of the long lead components for the TEX-HEU-Hf critical experiment has begun to support execution in the Summer of 2022. The hafnium ingot has been melted, forged to slab, and is currently undergoing hot rolling operations. The finished hafnium test plates are on schedule to be shipped to NCERC by March 31, 2022.

Hafnium ingot (left) and slab following forging operations (right).

These TEX-HEU-Hf critical experiments will complement the baseline TEX-HEU critical experiments, successfully executed by NCSP at NCERC during FY20. Both experiments are based on a similar design using highly enriched uranium fuel and polyethylene moderation and reflection. However, the TEX-HEU-Hf experiments will incorporate the hafnium test plates as a diluent throughout the critical assemblies. In doing so, the results of the TEX-HEU and TEX-HEU-Hf critical experiments can be directly compared to infer the effect of the added hafnium. Article provided by Mike Zerkle (NNL).



TEX-HEU experimental configuration upper half (left) and lower half (right).

Neutrons cluster in nuclear reactors

A recent article published in [Nature Communications Physics] and [Physics World] by the French Alternative Energies and Atomic Energy Commission (CEA), the French Institute for Radiological Protection and Nuclear Safety (IRSN), and Los Alamos National Laboratory (LANL) explores the concept of neutron clustering. Understanding space–time fluctuations of the neutron population in a system is key to nuclear safety. This is especially important in connection with reactor control at startup and shutdown. The appearance of fission-induced correlations in nuclear systems has been extensively investigated and a large attention has been devoted to the development of simulation capabilities relying on high-performance computing to characterize the fluctuations and correlations. The occurrence of a spontaneous clustering of the neutron population has drawn attention in recent years and questions were raised as to whether this phenomenon was a simulation artifact or if it could be experimentally detected.

The theoretical work in this field was developed at CEA and IRSN but further studied by several other organizations. It is known that a collection of independent particles that move, reproduce, and die may undergo wild fluctuations at the local and global scales inducing a characteristic patchiness in the spatial distribution of the individuals observed in the context of life sciences, including the spread of epidemics, the growth of bacteria on Petri dishes, the dynamics of ecological communities, and the mutation propagation of genes. The central ingredient behind the appearance of clustering is the asymmetry between death occurring everywhere and birth being only possible close to a parent particle.

The evolution of the neutron population in a nuclear reactor is also subject to random displacements (diffusion), births (fission events on heavy nuclei leading to secondary neutrons), and deaths (capture events on nuclei leading to the disappearance of the colliding neutrons). It has been therefore suggested that clustering might occur within nuclear reactors operated at low power, i.e., low neutron density and that it might be experimentally observable. This motivated an international collaboration gathering IRSN, CEA and LANL with three objectives: designing experiments and dedicated detectors to extract information on neutron fluctuations at low reactor power—below the detectors saturation threshold; building a numerical twin of the operating reactor based on Monte Carlo simulation so as to support experimental results and to fill the gaps of experimental measurements while extrapolating them at higher power; and interpreting the obtained results in the framework of stochastic branching processes.

The experiments took place at the Reactor Critical Facility (RCF) of the Rensselaer Polytechnic Institute over a week in August 2017 and were followed by the analysis of measured data using the MORET6 Monte Carlo neutron transport code. The results of this work show that fluctuations can persist up to unexpectedly high reactor powers and cause a “blinking” behavior of the reactor. Strong spatial correlations affecting neutron distributions were reported and characterized. A stochastic modeling using branching random walk techniques underlines the key role played by spontaneous fissions to understand both qualitatively and quantitatively the neutron clustering phenomena detected at the RCF.

The experimental and simulation work performed to support the neutron clustering research greatly benefitted from previous NCSP-sponsored research. This included the use of models from the SCRaP benchmark and previous Rossi-alpha experiments (ZEUS, Class Foils, IER-150/151, and Godiva IV). In addition, previous NCSP subcritical benchmarks were useful in the design and execution of the neutron clustering measurements at the RCF. This article was provided by Joetta Goda (LANL).

Acknowledgements
This work was supported in part by the DOE Nuclear Criticality Safety Program, funded and managed by the National Nuclear Security Administration for the Department of Energy, as well as by IRSN. The authors would also like to thank Dr. Peter Caracappa for his help with the experiment, Dr. Yaron Danon for his support, and the Senior Reactor Operators who operated the reactor during the experiments: Glenn Winters, Dr. Jason Thompson, Emily Frantz, and Alexander Roaldsand.

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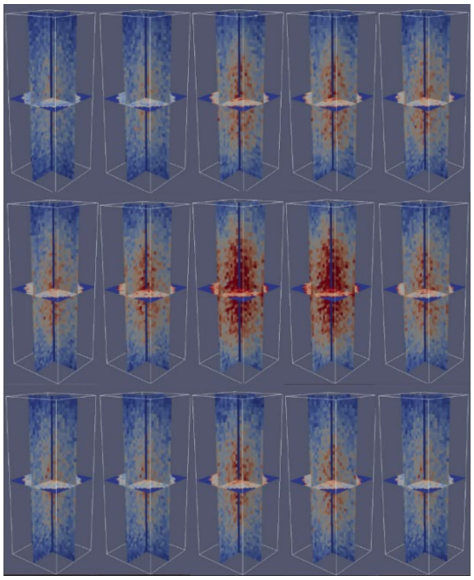
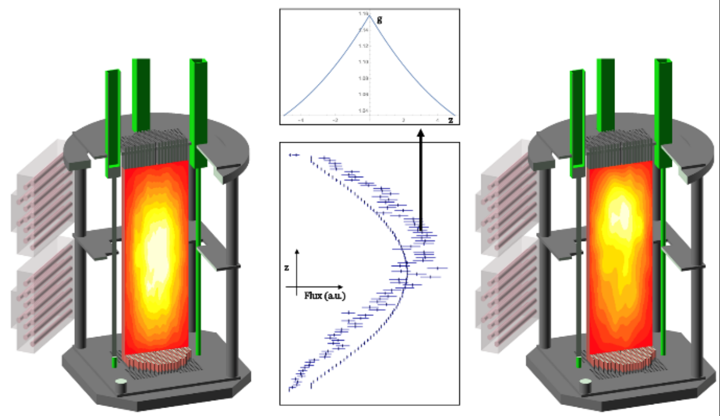
<tr><td></td><td>
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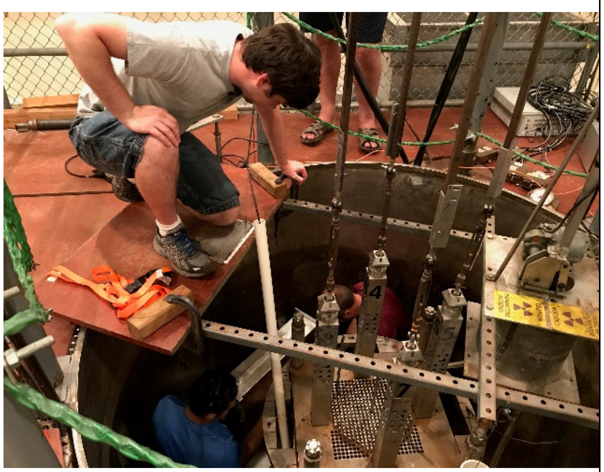
<tr><td colspan="2">*Simulation Results*</td></tr>
<tr><td></td><td></td></tr>
<tr><td>*Nick Thompson above the reactor as other researchers install detector systems. The water was drained from the system for installation and then later refilled*</td><td>*Eric DuMonteil, Wilifred Monange, Rian Bahran, Nick Thompson, Alex McSpaden, and Jesson Hutchinson*</td></tr>
</table>

NCSP Training and Education

Two-week Practitioner Course Dates:

Jan 31–Feb 11, 2022 – registration is open for Sandia, closed for NCERC (course to be held in person)
Aug 8–12, 2022 – registration is open (course to be held in person)

The first week (lectures and workshops) will held at the National Atomic Testing Museum (NATM) while the second week (hands-on portion) will be held at the National Criticality Experiments Research Center (NCERC) and Sandia National Laboratories. The courses are designed to meet the ANSI/ANS-8.26, "Criticality Safety Engineer Training and Qualification Program," requirement for hands-on experimental training. The NATM portion of the course involves virtual classroom lectures and workshops for NCS Evaluation development and the NCERC and SNL portions of the course involve hands-on experiments with the critical assemblies. MSTS, LANL, ORNL, LLNL, SNL, Y12 and NFO staff participate in the course execution.

One-week Manager's Course Dates:

SANDIA Manager Course – Apr 4-8, 2022 (course to be held in person)
NCERC Manager Course – Jun 6-10, 2022 (course to be held in person)

The courses are designed for fissile material handlers, process supervisors, line managers and regulators with criticality safety responsibilities. Mission Support and Test Services (MSTS), LANL, ORNL, LLNL, SNL, Y12 and Nuclear Facility Operator (NFO) staff participate in the course execution.

MCNP6

MCNP® Courses

Class Information: https://mcnp.lanl.gov/classes/classinformation.shtml

Fees and Registration Information:
https://laws.lanl.gov/vhosts/mcnp.lanl.gov/classes/CostsRegistrationInfo.shtml

Oct 4 – 8, 2021	Intermediate MCNP6 (online)
Oct 18 – 22, 2021	Unstructured Mesh with Attila4MC (online)
Nov 15 – 19, 2021	Introduction to MCNP6 (online)
Nov 29 – Dec 1, 2021	Variance Reduction with MCNP6 (online)

MCNP® 2021 User Symposium

The 2021 MCNP® User Symposium was held from July 12–16, 2021. The symposium was designed to provide a venue for two-way communication between MCNP developers and users and was comprised of almost 30 hours of presentations, questions, and open discussion.
There were over 500 individuals registered for the symposium who represented over 30 countries. A total of 75 excellent presentations were made during the week. Of those:

- 18 were from the MCNP development team,
- 7 were from the Los Alamos nuclear data team,
- 14 were from Los Alamos MCNP users,
- 25 were from U.S. MCNP users outside LANL (representing a variety of national laboratories, universities, and industry),
- and 11 were from international MCNP users.

The symposium featured nine topical sessions that followed a brief introduction session that included a welcome from LANL Director Thom Mason and an overview of what new features and capabilities users can expect in MCNP6.3. The nine topical sessions were:

1. Fusion
2. Reactors and Criticality
3. Unstructured Mesh and CAD
4. Tools
5. Accelerators and Experimental Design
6. Data and Physics
7. Applications and Experimental Design
8. LANL Monte Carlo History and Looking Ahead Beyond MCNP6.3
9. Shielding

There were also three free-form sessions designed to maximize opportunities for dialogue among all participants. All were well attended and resulted in substantial conversations. These sessions were:

- A nuclear data "office hour" providing the opportunity for Q&A and general discussion with the Los Alamos nuclear data team
- A general Q&A session with the MCNP development team
- A roundtable to discuss MCNP parallelism performance on various platforms.

For those who would like to see the agenda, it is available as a PDF file by clicking on the "agenda" tab at https://www.lanl.gov/mcnp2021.

SCALE Fall Courses

The next training block to be held by ORNL will be in October - November 2021. The courses will be held virtually, Mon – Thurs 9am-12pm and 1-4pm ESD.

Oct 11 – 14, 2021	SCALE/TRITON Lattice Physics and Depletion
Oct 18 - 21, 2021	SCALE/ORIGEN Standalone Fuel Depletion, Activation, and Source Term Analysis
Oct 25 - 28, 2021	SCALE Computational Methods for Burnup Credit
Nov 1 - 4, 2021	Nuclear Data Fundamentals and AMPX Libraries Generation
Nov 8 – 11, 2021	SCALE Criticality Safety Calculations

2021 SCALE Users' Group Workshop

The 5th annual SCALE Users' Group Workshop (https://scalemeetings.ornl.gov/) was successfully held virtually from Oak Ridge National Laboratory (ORNL), August 4-6, 2021. A total of 173 participants from 94 organizations in 29 countries attended the meeting, with 138 of them external to ORNL (see Fig. 1).

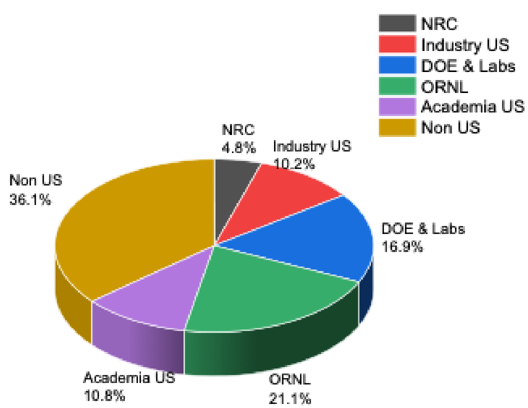
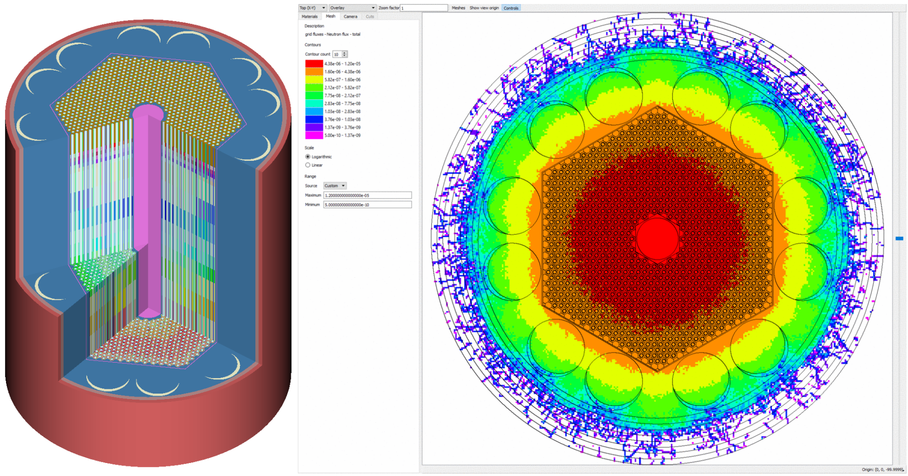


Fig. 1. Summary of participation (173 total attendees).

The meeting included 32 presentations and 10 hands-on tutorials on impactful and innovative applications of SCALE. The topics of interest addressed status of research and development in nuclear data, criticality safety, radiation shielding, reactor physics, and covered recent work on SCALE validation and non-LWR applications. This year, the top three winners for the "Best SCALE Model Contest" are Erik Walker (ORNL), Cihangir Celik (ORNL), and Peter Wolniewicz (SKB/Sweden). The first-place model is illustrated in Fig. 2.



(a) HPR core model (b) Flux as control drums are rotated

Fig. 2. Winner of Best SCALE Model contest

All technical and tutorial presentations made at this meeting are publicly available on the SCALE website under https://www.ornl.gov/content/2021-scale-users-group-workshop and on the meeting website at https://scalemeetings.ornl.gov/previous-workshops/ .