Nuclear Criticality Safety Pipeline Course - LLNL

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Shauntay Coleman

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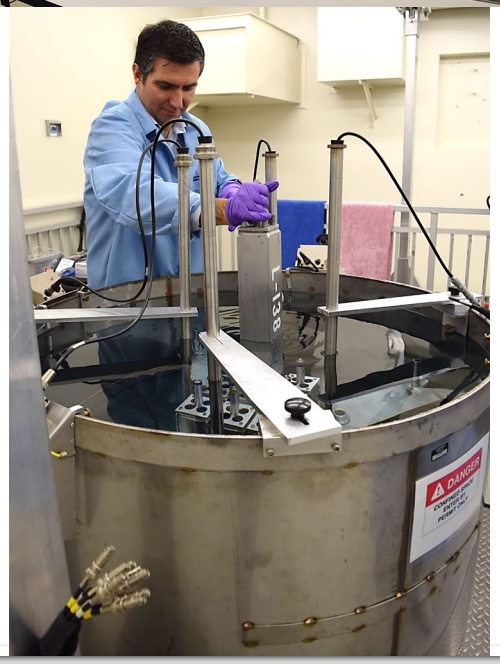
Lawrence Livermore National Laboratory

Course Overview

- UC Berkeley offers a course on nuclear criticality safety each fall semester.
  - Lawrence Livermore National Laboratory (LLNL)
  - Los Alamos National Laboratory (LANL)
  - Dr. Max Fratoni of UC Berkeley
- This course is designed to stimulate student interest in the field of criticality safety.
  - Teaches the fundamentals of criticality safety
  - Provides hands-on experience with special nuclear material
  - Guest lectures are taught by criticality safety engineers at LLNL and LANL
  - Complete a semester long project to write a criticality safety evaluation



Lecture Topics

Date	Topic	Instructor
8/25	Review instructions and submit request for MCNP license	
8/30	Factors in criticality safety: MAG-ICMERV/MERMAIDS	Fratoni
9/01	Criticality safety evaluation: an introduction	LLNL
9/06	MCNP: Intro	Fratoni
9/08	Process description	LANL
9/13	MCNP: Geometry	Fratoni
9/15	Criticality accidents	LANL
9/20	MCNP: Materials	Fratoni
9/22	Criticality accidents	LANL
9/27	MCNP: Running simulations	Fratoni
9/29	Hand calculations: One-group and modified one-group diffusion theory	LLNL
10/04	Evaluation update: process descriptions	Student groups
10/06	Criticality safety evaluation: advanced material	LANL
10/11	MCNP: Output	Fratoni
10/13	Criticality experiments	LLNL
10/18	MCNP: Tallies	Fratoni
10/20	Benchmarks and validation	LLNL
10/25	MCNP: Repeated structures	Fratoni
10/27	ANSI/ANS Standards (SD130) DOE 10 CFR 820 and 420.1C	LLNL
11/01	Evaluation update: credible process upset conditions	Student groups
11/03	Inherently Safe Subcritical Assembly (ISSA)	LLNL
11/08	MCNP: variance reduction	Fratoni
11/10	Fuel facility applications	LANL
11/15	MCNP: miscellaneous	Fratoni
11/17		
11/22		No class
11/29	Discussion	Fratoni
12/01	Criticality safety evaluation presentations	Student groups

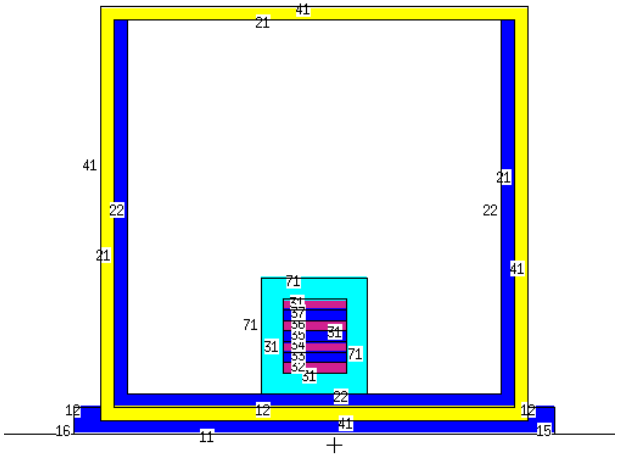
Overview of Projects

- A variety of fictional operations are provided to the students by LLNL and LANL to complete a criticality safety evaluation.
  - Students work in teams of 3 to 4 individuals
  - LLNL and LANL mentor the students by acting as Operators, Engineers, and Subject Matter Experts
  - Students present their evaluations periodically throughout the semester
- Students have the ability to approach the criticality safety evaluation how they choose.
  - Hand calculations vs handbook data vs radiation transport codes
  - Students must determine the normal and credible abnormal conditions to evaluate
  - Controls and agreed upon by the students and Operators (mentors)

LLNL Criticality Safety Evaluation Projects

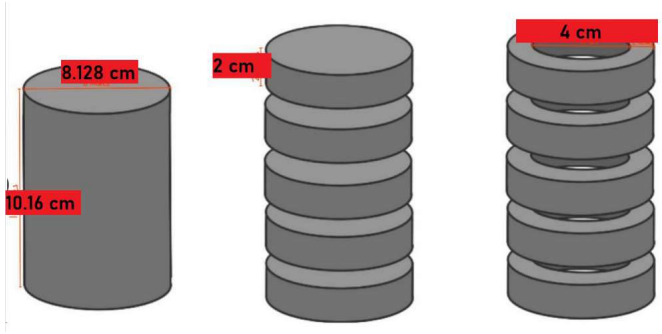
Experiments with Uranium-233 and Shielding

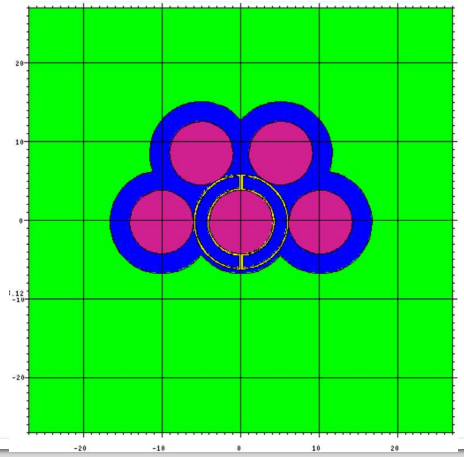
Scientists at LLNL are performing experiments with large quantities of ^{233}U metal, which generates significant radiation exposure to workers, due to the presence of ^{232}U impurities. To reduce worker exposure, scientists want to use varying thicknesses of tantalum, lead, and/or tungsten.



Machining Highly Enriched Uranium Rings

Engineers at LLNL are receiving five 10-kilogram cylinders of highly enriched uranium (93% by weight percent ^{235}U) metal from another laboratory and need to machine each solid cylinder into 5 identical rings for a total of 25 rings.

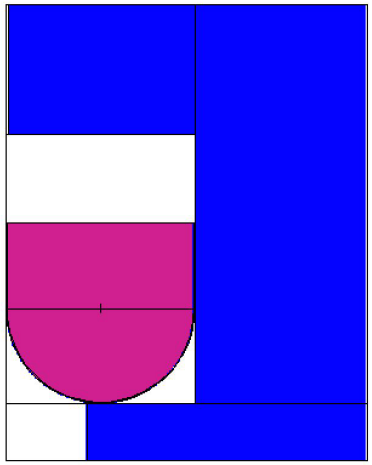




LLNL Criticality Safety Evaluation Projects

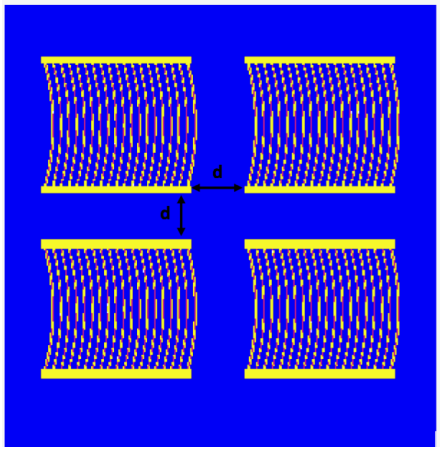
Hobart Model HL120 Mixer

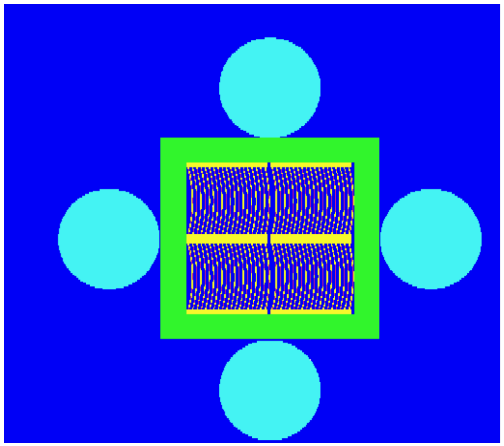
Fissile material handlers at LLNL wants to use a Hobart Model HL120 Mixer to blend plutonium liquid waste with a solidifying mineral.



Inherently Safe Subcritical Assembly (ISSA) Heavy Water Experiment

Scientists at LLNL want to perform experiments with ISSA but replacing the light water with heavy water.



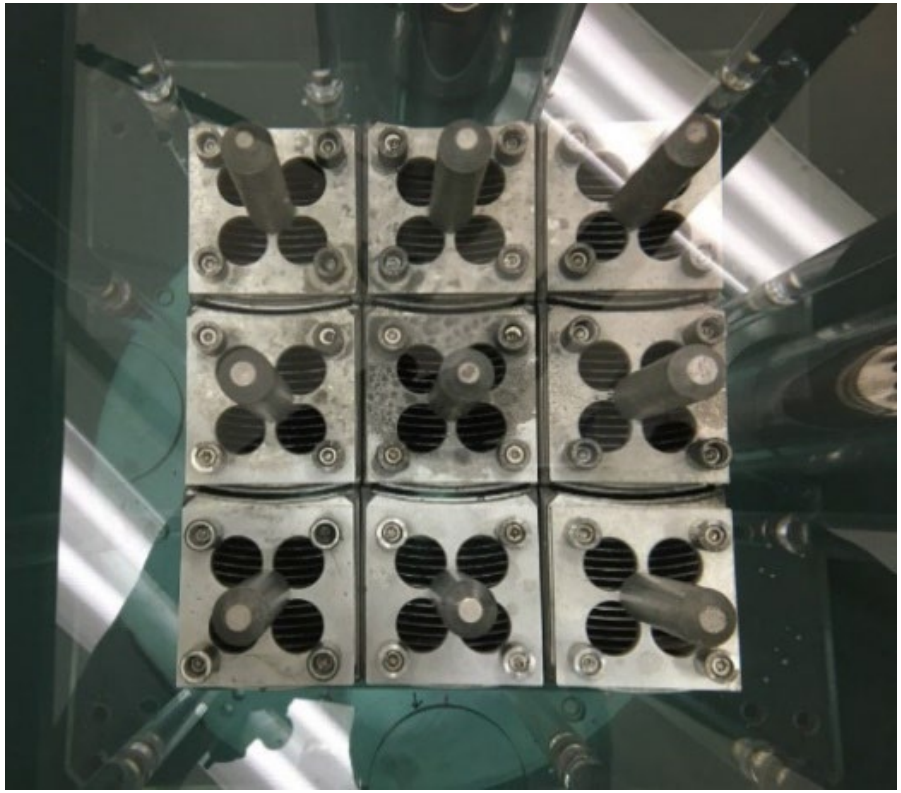


Hands-on Learning with ISSA

- Two days out of the semester, students visit LLNL to perform subcritical measurements with LLNL's Inherently Safe Subcritical Assembly (ISSA).
- ISSA is a safe and simple system making it ideal as a training resource.
- ISSA provides hands-on experimental training to illustrate criticality safety and reactor physics.

ISSA Training Facility

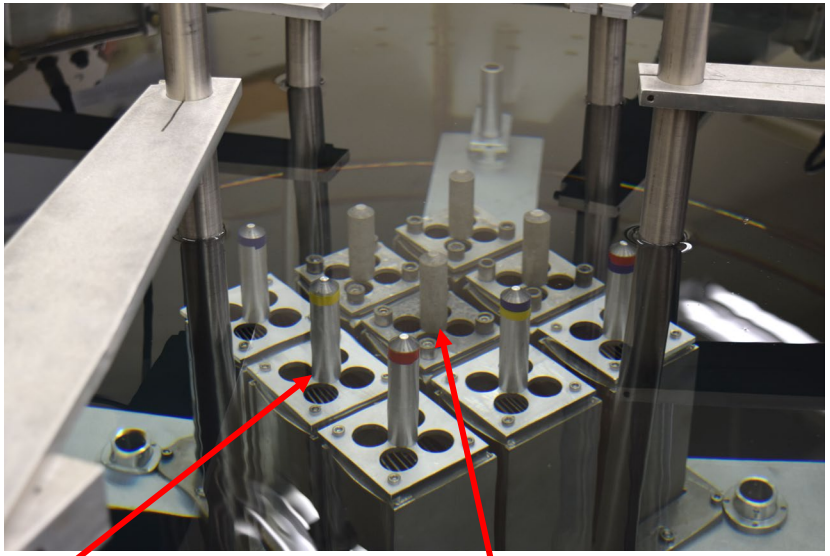
- ISSA consist of 9 repurposed nuclear fuel assemblies from the Omega West Reactor manufactured by the Naval Nuclear Fuel Division of Babcock & Wilcox.
  - Each assembly consists of highly enriched uranium dispersed in a matrix of aluminum and fully clad in pure aluminum
  - Assemblies were cut by LLNL to 2-feet in length for ease of handling
- Under the supervision of qualified criticality safety engineers, students are able to handle the fuel assemblies.
- Students use the ISSA handbook to perform experiments demonstrating the effects mass, spacing, reflection, and moderation have on neutron multiplication.



Approach-to-Critical Experiments

- Students work with 9 all aluminum “mock” fuel assemblies and 9 HEU “live” fuel assemblies.
- Students perform 1/M curves to predict the critical configuration for ISSA.

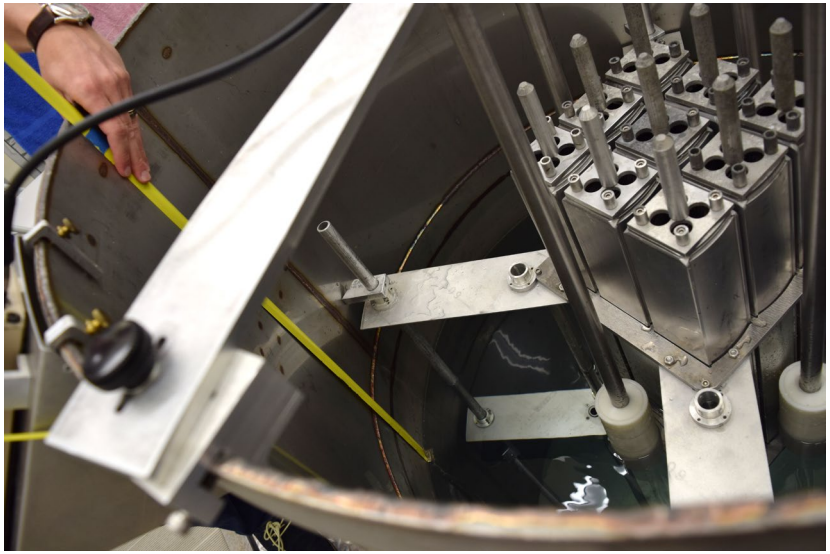
Approach by Number of Assemblies With and Without a Source



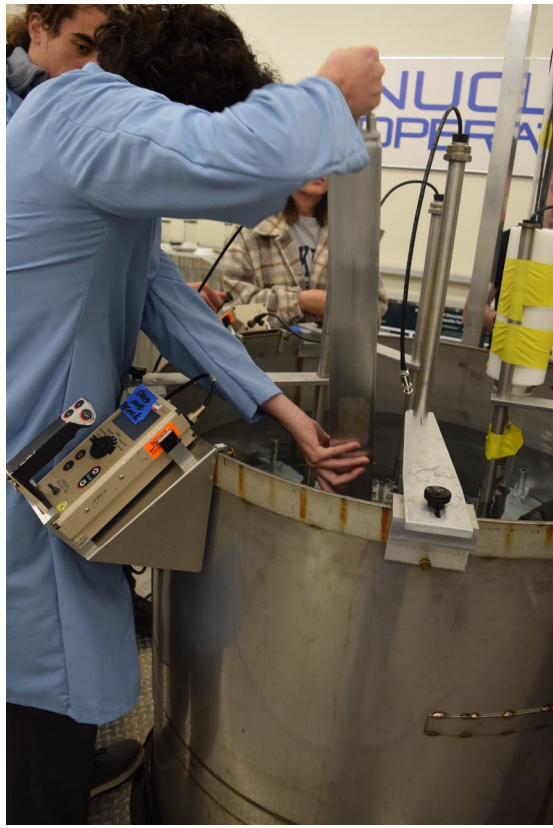
Aluminum “mock” fuel

HEU “live” fuel

Approach by Water Height



Students Performing ISSA Experiments



Academic Needs

- ANSI/ANS-8.26 requires participation in the conduct and interpretation of critical experiments in hands-on classes that demonstrate how varying the properties of a fissionable material system can affect neutron multiplication.
  - ISSA only allows for subcritical experiments but has many training capabilities for neutron multiplication and reactor physics experiments.
- Many students who take this course have no experience with a radiation transport code.
- Students benefit for getting in-field experience of seeing criticality safety controls implemented in operations to understand their projects.