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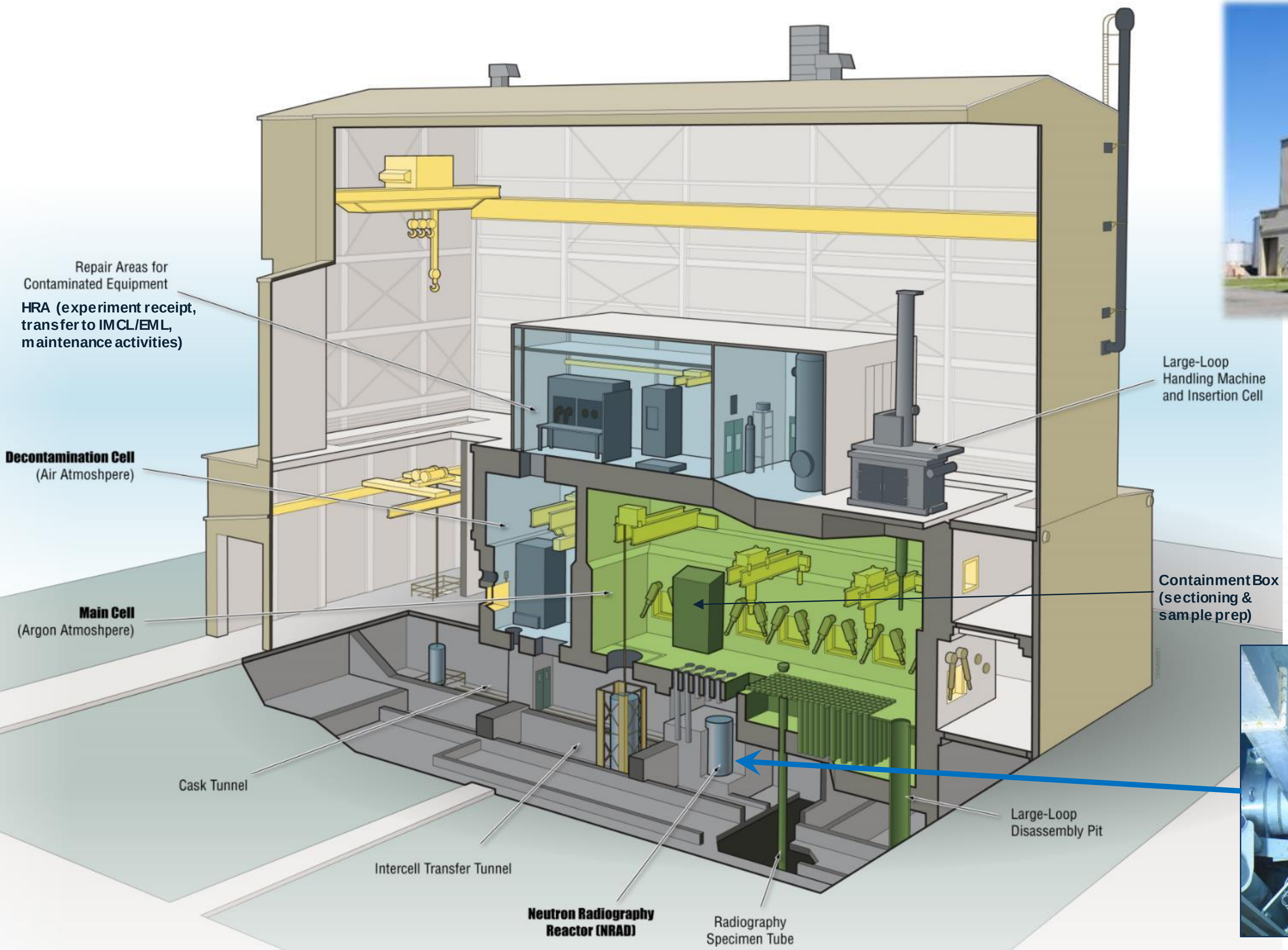
Neutron Radiography Reactor (NRAD) Irradiation Testing Capabilities

Nuclear Science User Facilities

Outline

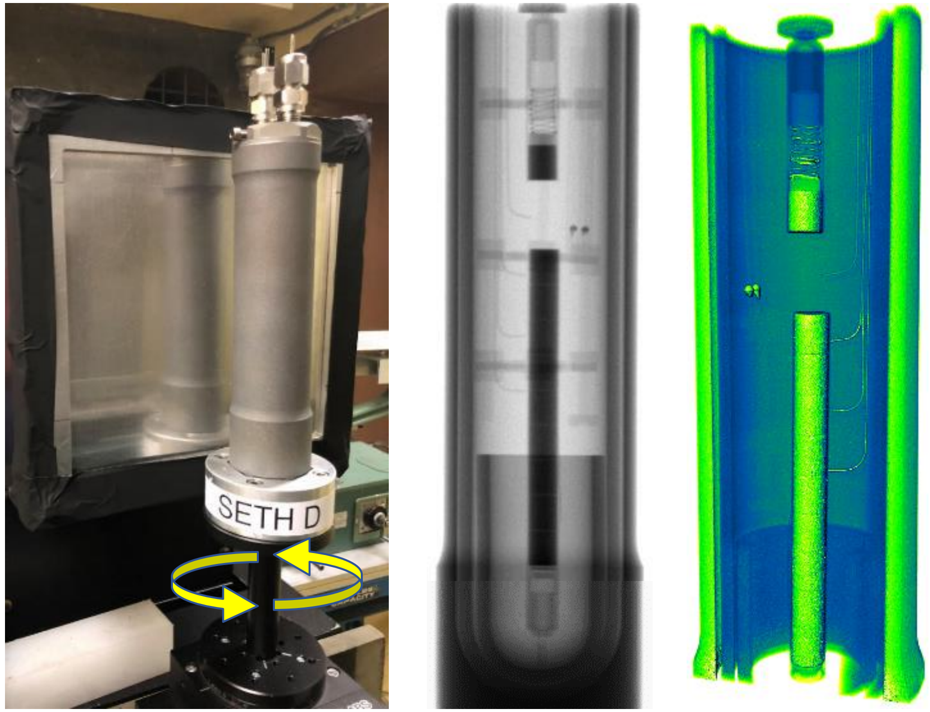
- Introduction
- Neutron Radiography
- Unique Irradiation Testing Capabilities
  - Re-irradiating fuel for additional safety testing and fission products evaluation
  - First-of-a-kind advanced reactor fuel irradiations
  - Materials activation, sensor and instrumentation irradiations
  - Irradiation of fusion materials
- Potential Future Capabilities



- The NRAD reactor beneath the HFEF hot cell
  - 250 kW TRIGA
  - A *unique* neutron radiography and irradiation facility for highly irradiated fuel and materials

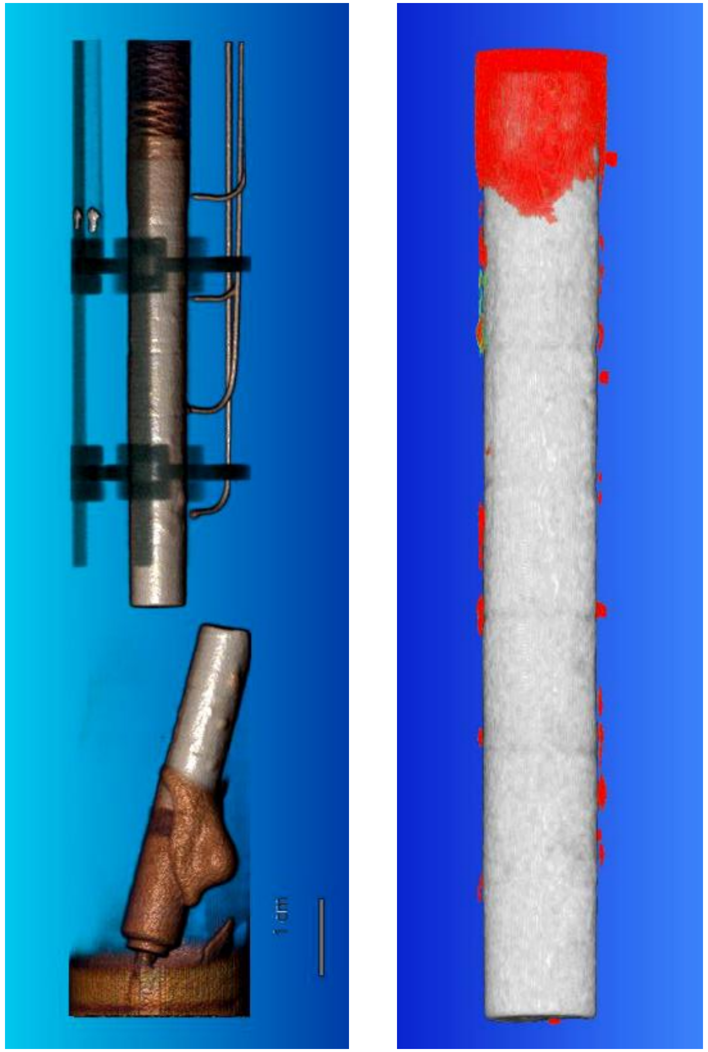
Current Neutron Radiography Capabilities – Digital Computed Tomography

- Routinely acquires 480+ radiographs in a single shift for nCT, or 1080 radiographs in 18 hours.
- Benefits of nCT:
  - Improved feature detectability
  - Direct access to dimensions and Σ/μ



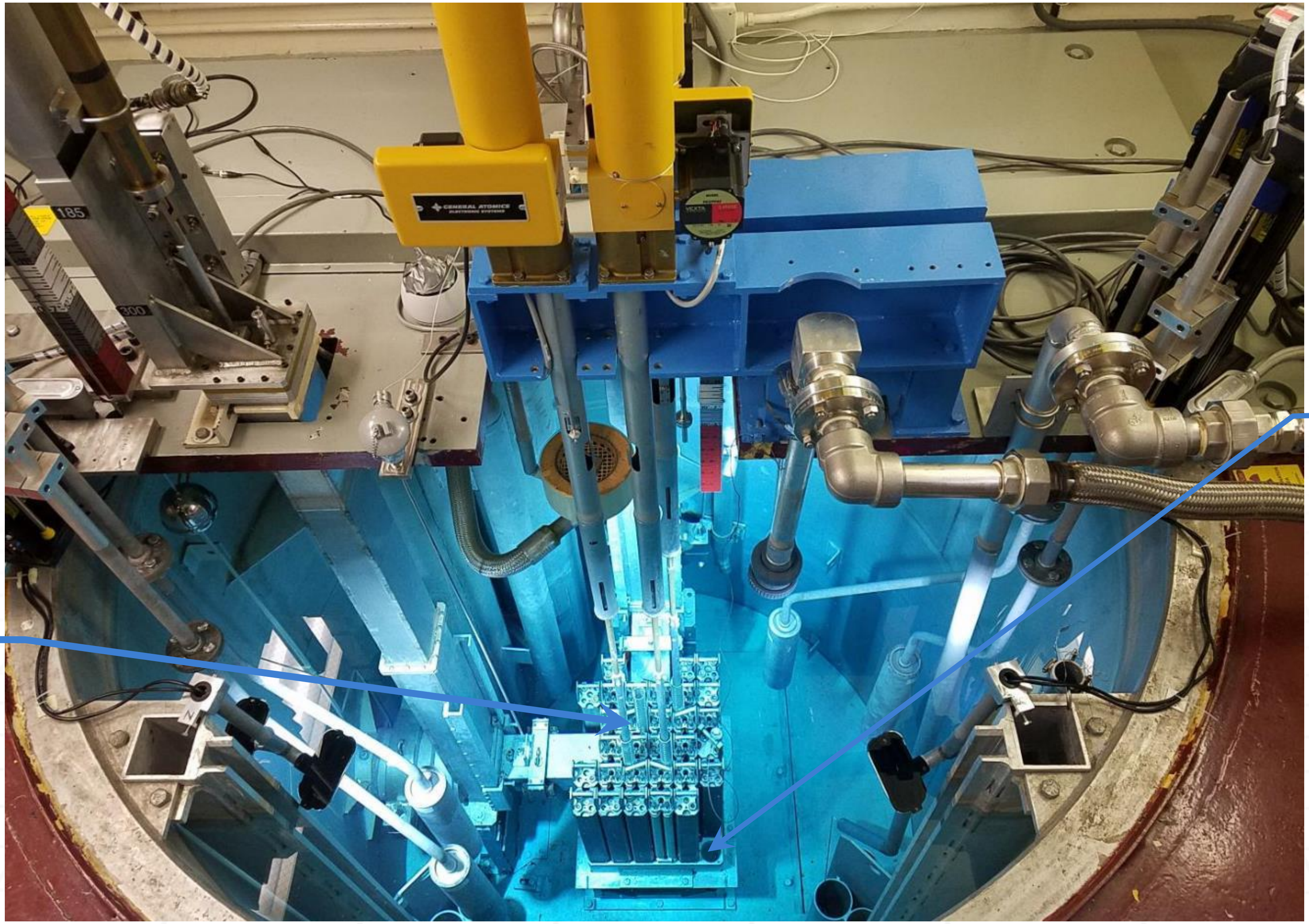
(left) Picture of SETH-D experiment mounted in front of the nCT system, (center) example neutron radiograph, and (right) tomographic reconstruction of the SETH-D experiment capsule.

Neutron radiographs of the transient irradiated ATF SETH-E experiment.



Segmented tomographic reconstruction highlighting the (left) whole fuel pin and (right) solidified Zircaloy droplets.

NRAD Currently Has Two In-core Irradiation Positions

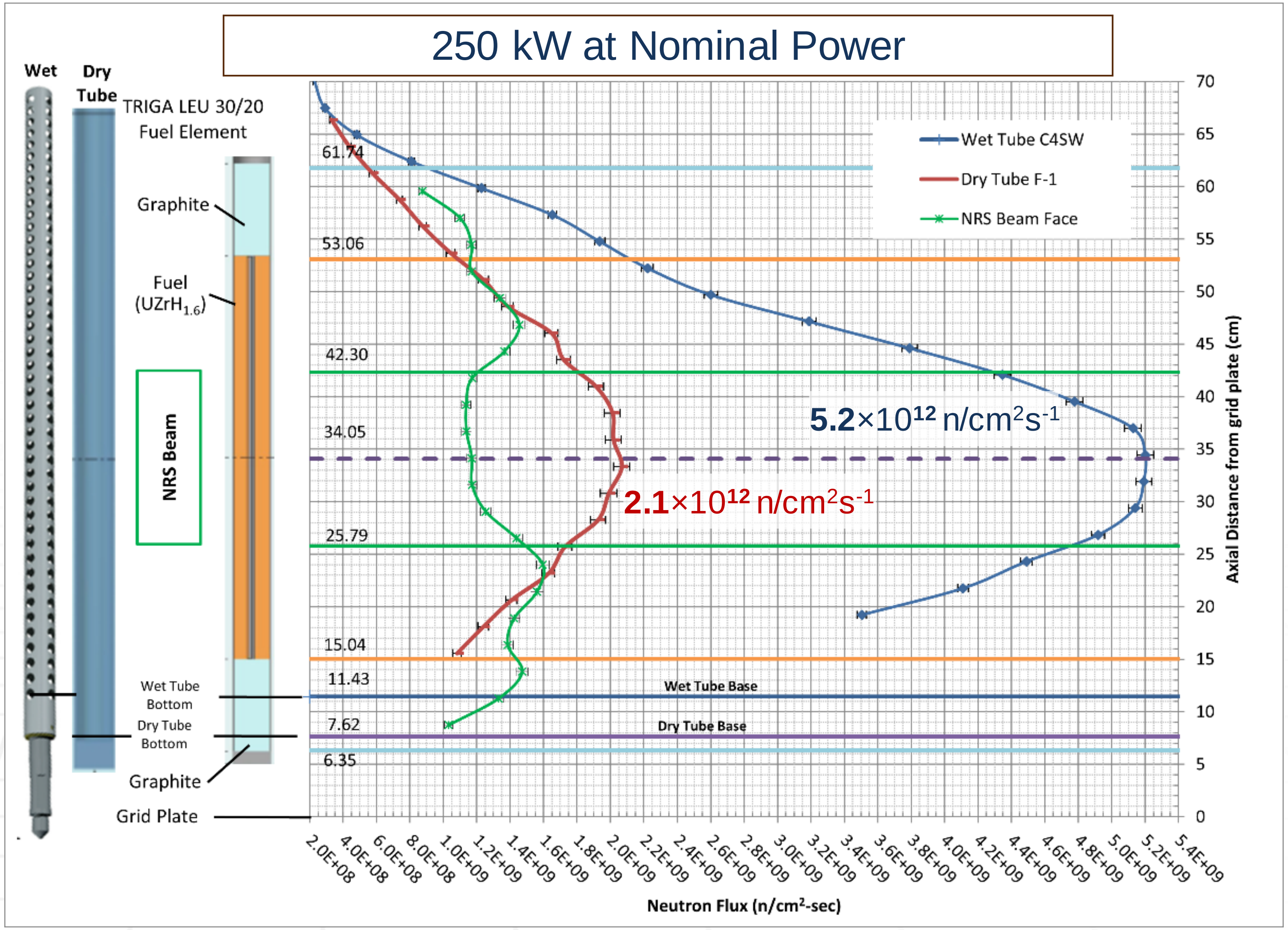


C4SW is a small position but near the center of the core and used for higher flux irradiations.

F1 is a larger position at periphery of the core with a lower flux and easier for access.

NRAD Axial Fluxes and Flux Shapes

- Instrumentation for fueled experiments at various conditions with on-line monitoring and performance assessment
- Rapid transfer to hotcell for short-lived fission products analysis and failed fuel experiments
- Performed over 30 irradiation tests
  - Fuel re-irradiation and safety testing
  - First-of-a-kind advanced reactor fuel irradiations
  - Materials activation, sensor and instrumentation irradiations
  - Fusion materials irradiation

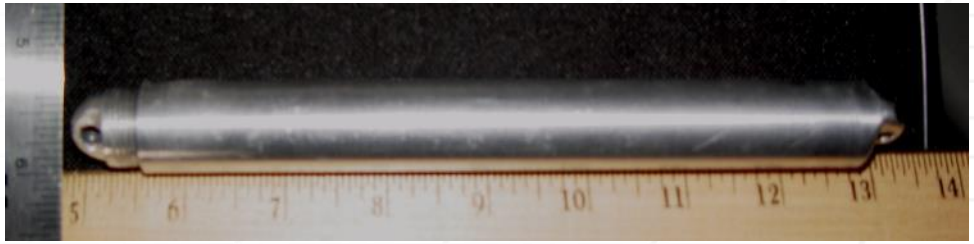


Routine Drop-in Experiments

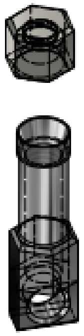
Dry Tube positioned in empty core position F-1. Experiment is suspended from titanium wire at core centerline.

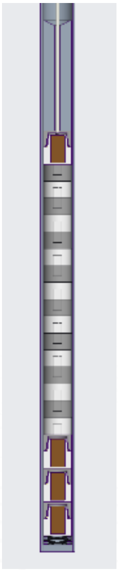
Contact handling RWP limit <25 R/hr on contact.

Standard Al or Ti capsules with Swagelok (Rabbit capsules)

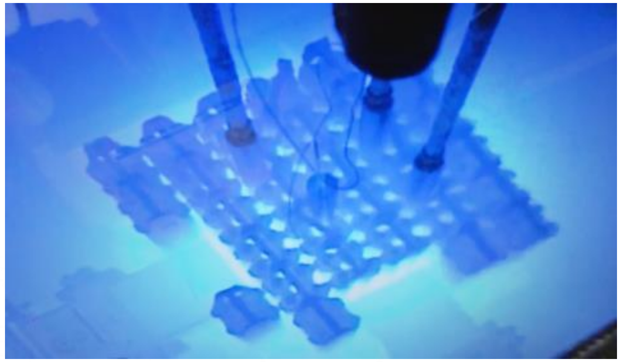


Fueled Irradiation and Instrumented Testing with Cask Transfers





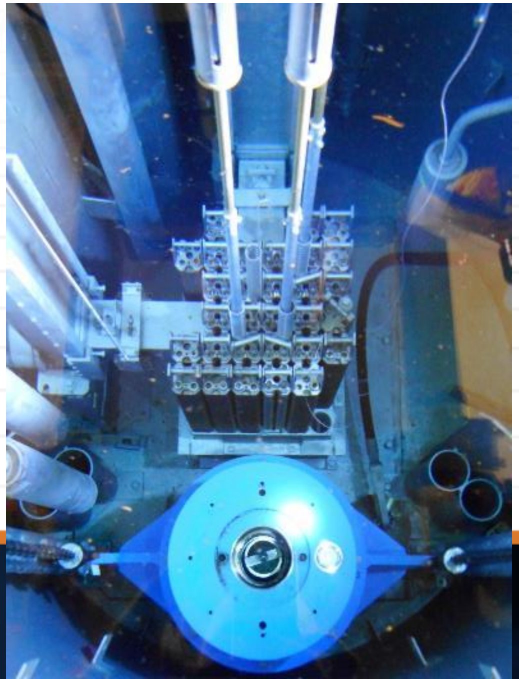
C4SW Sample Irradiation – In-tank camera



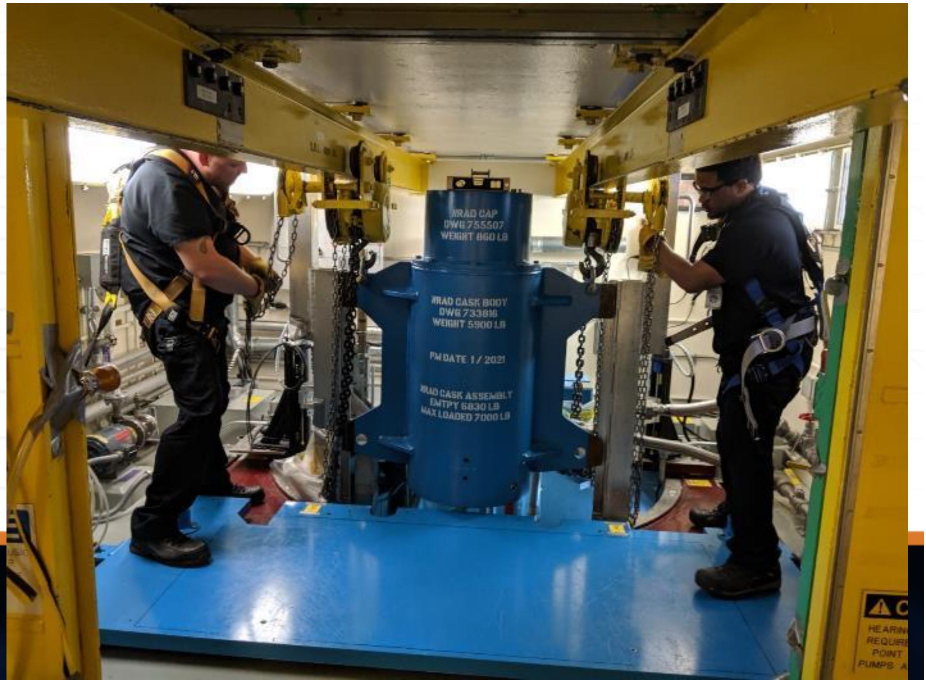
Standard capsules

Titanium and aluminum available for single or multiple sample holders available

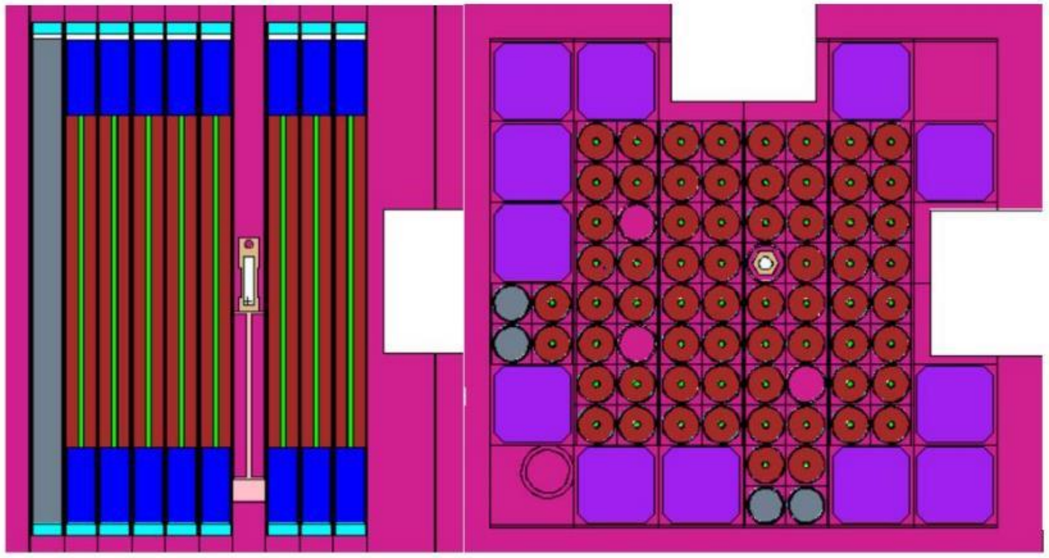
NRAD Cask on tank bottom.
Plug removed for sample transfer.



NRAD Cask Transfer for High Dose Samples



MCNP model of capsule in C4SW on Al sample stand.



Fuel Reirradiation For Safety Testing

TRISO Goal: Determine short-lived fission product release.
(^{131}I and ^{133}Xe are major contributors to offsite dose during accident scenarios)

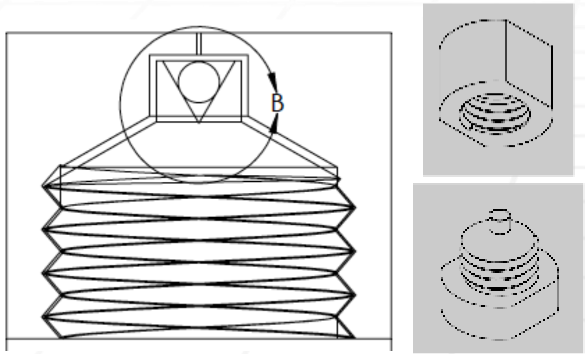
Executing Research in Three AGR Specimens

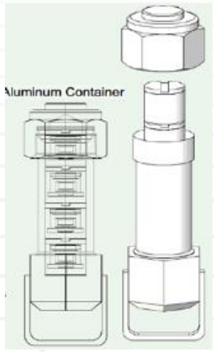
1. Loose kernels
2. Mechanically-cracked, irradiated particles
3. Designed-to-failed particles

Mission Realization

Utilize the Neutron Radiography Reactor (NRAD) to re-irradiate TRISO particles followed by rapid transfer to hotcell for heating test and PIE

Graphite particle holder for insertion in NRAD and FACS



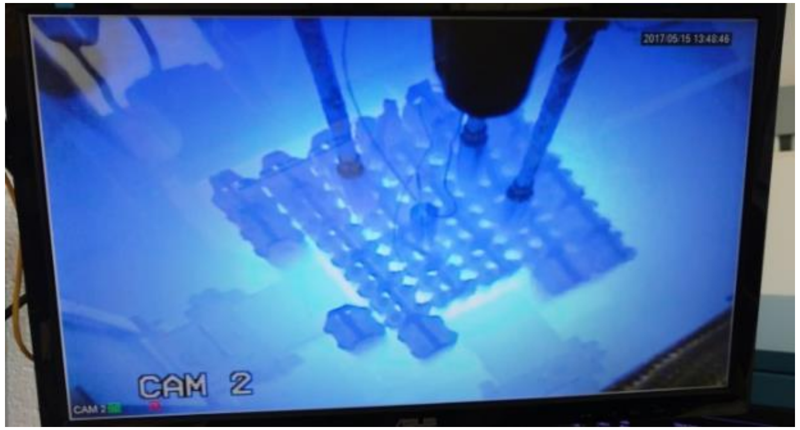


Al capsule

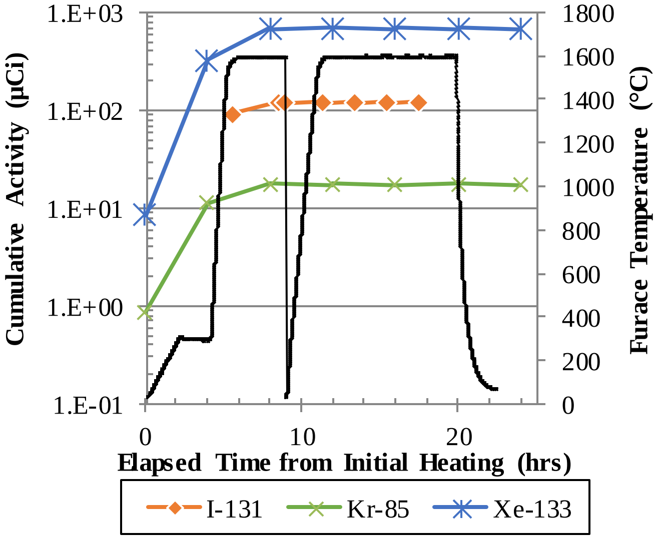
AGR-2 Compact 6-4-1 Particle 99953-19 held on the end of a pneumatic needle after cracking to remove TRISO coatings

Post-Irradiation Testing and Fission Products (Source Term) Quantification for Irradiated TRISO Fuels

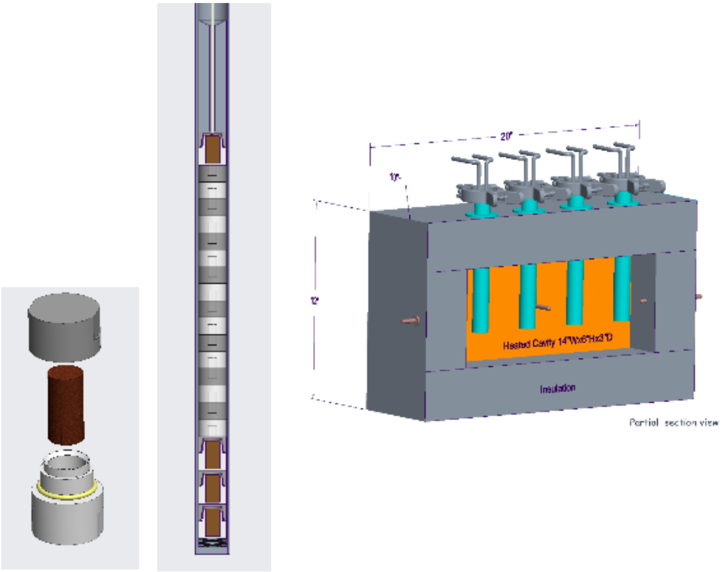
- Irradiation conducted over consecutive, 8-hr irradiation days
  - Drop-in type irradiation, no instrumentation or temperature control
- A brief period of decay (15-hr) was allowed prior to handling the irradiation capsule, followed by disassembly, gamma counting, heating tests, and fission product measurements



NRAD camera monitoring the core during the first of two reirradiations of AGR particles



Measured activity of select isotopes released from the graphite holders holding four cracked particles



New holder design and furnace for compact irradiation and testing

Courtesy: David Laug, John D. Stempien, Paul A. Demkowicz

First-of-kind Advanced Reactor Molten Salt Fuel Tests

Goal: Establish a domestic neutron irradiation capability for HEU fissile material UCl_3-bearing salts at INL for Molten Salt Reactor (MSR) R&D.

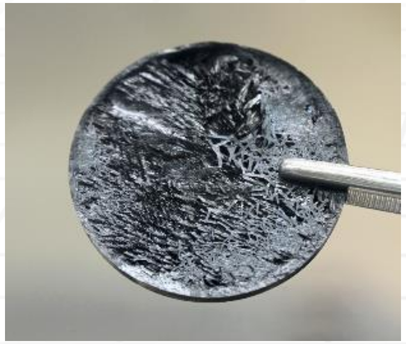
Executing Research in Three Primary Areas

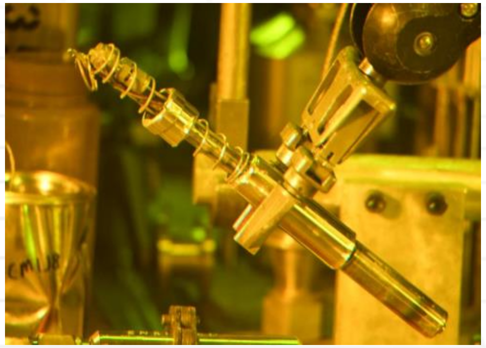
1. Radioactive Source Term Quantification
2. Thermophysical Property Evolution
3. Salt-facing Materials Corrosion

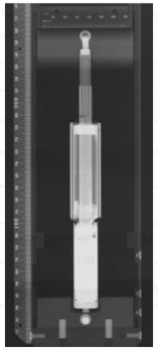
Mission Realization

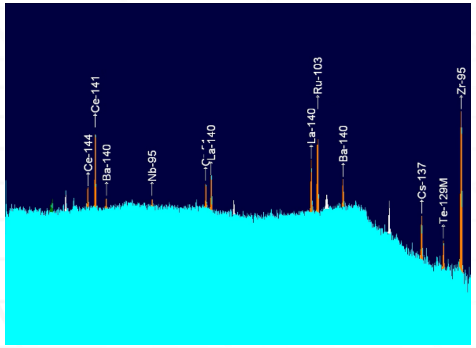
Utilize the Neutron Radiography Reactor (NRAD) to irradiate molten fissile material-bearing chloride salt with salt-facing materials relevant to MSR development

Molten Salt Reactor
PROGRAM

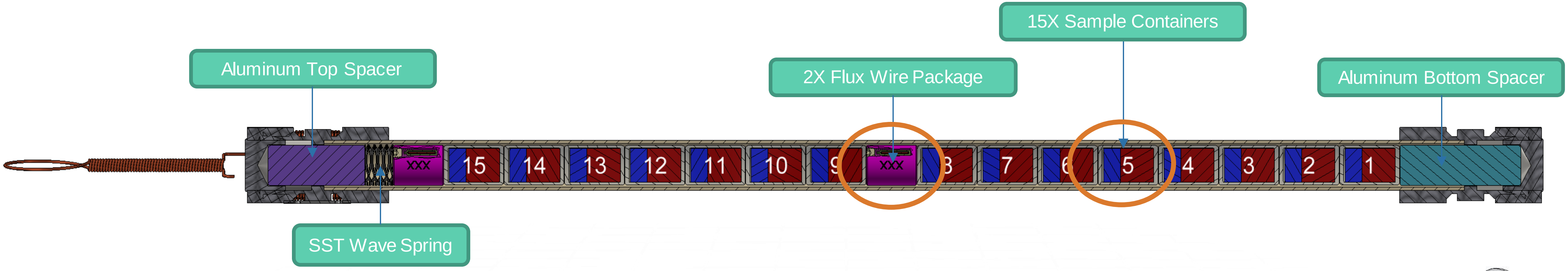




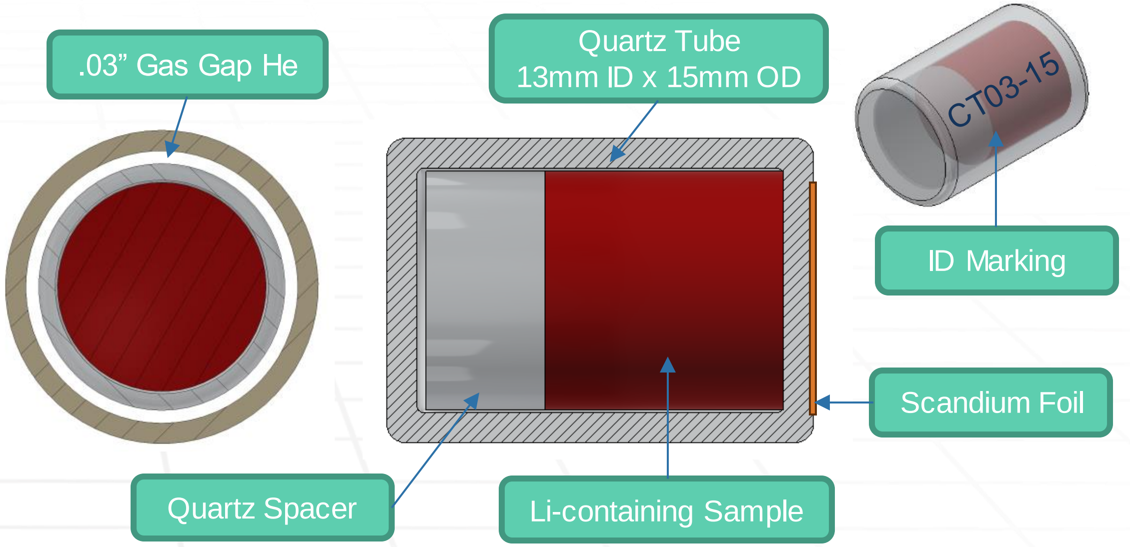




Fusion Materials Irradiation Tests



- Irradiating lithium-based tritium breeding materials
  - Characterize tritium breeding and release characteristics ex-situ
  - Measure mechanical properties such as swelling
- Data will assist US fusion programs development and testing of solid breeder materials and tritium extraction technologies for fusion blanket research



NRAD Current Irradiation Capabilities and Future Capabilities under Consideration

Rapid transfer to hotcell for short-lived fission products analysis and failed fuel experiments

Instrumentations for fueled experiments at various conditions with on-line monitoring and performance assessment

Light Water Reactors	Advanced Reactors	Space Nuclear	Homeland Security	Basic Science and Sensors
In-Pile Creep Test	TRISO Re-Irradiation and Safety Testing	Nuclear Thermal Propulsion	Plate Fuel Re-irradiation and Safety Testing	Sensor and Detectors Irradiation
In-pile Corrosion Test	Molten Salt Irradiation and Corrosion			Actinide Science
	Recycled Pu Fuel Irradiation			Radiation assisted diffusion and corrosion
	Heat Pipes Irradiation			

Future Capabilities Enhancement for cheaper, faster, and high throughput irradiation experiments

- Standardized capsule to perform routine instrumented, heated experiment irradiation with bounding safety documentation
- Develop pneumatic transfer system (Rabbit) for more efficient sample transfers between the reactor and the hotcell
- Core reconfiguration and possibly core-power uprate to accommodate larger experiments and provide higher radiation fluxes

Why NRAD?

- How can NRAD help meet your scientific mission needs
  - Unique capabilities that can handle highly enriched or highly irradiated fuel and materials
  - Located in the world's largest hotcell for rapid PIE and source term quantification
  - Access to the world's largest irradiated fuels and materials library (NFML) in the same facility
- The Nuclear Science User Facilities (NSUF) provide users access to its NSUF facilities at no cost to the users
  - Rapid Turnaround Experiment
  - Super Rapid Turnaround Experiment
  - Consolidated Innovative Nuclear Research
- For more information, please visit NSUF website
  - https://nsuf.inl.gov/