INL/MIS-23-74751-Revision-0

MFC Transient Testing and Fuel Fabrication Capabilities

September 2023

Doug Crawford

Changing the World's Energy Future

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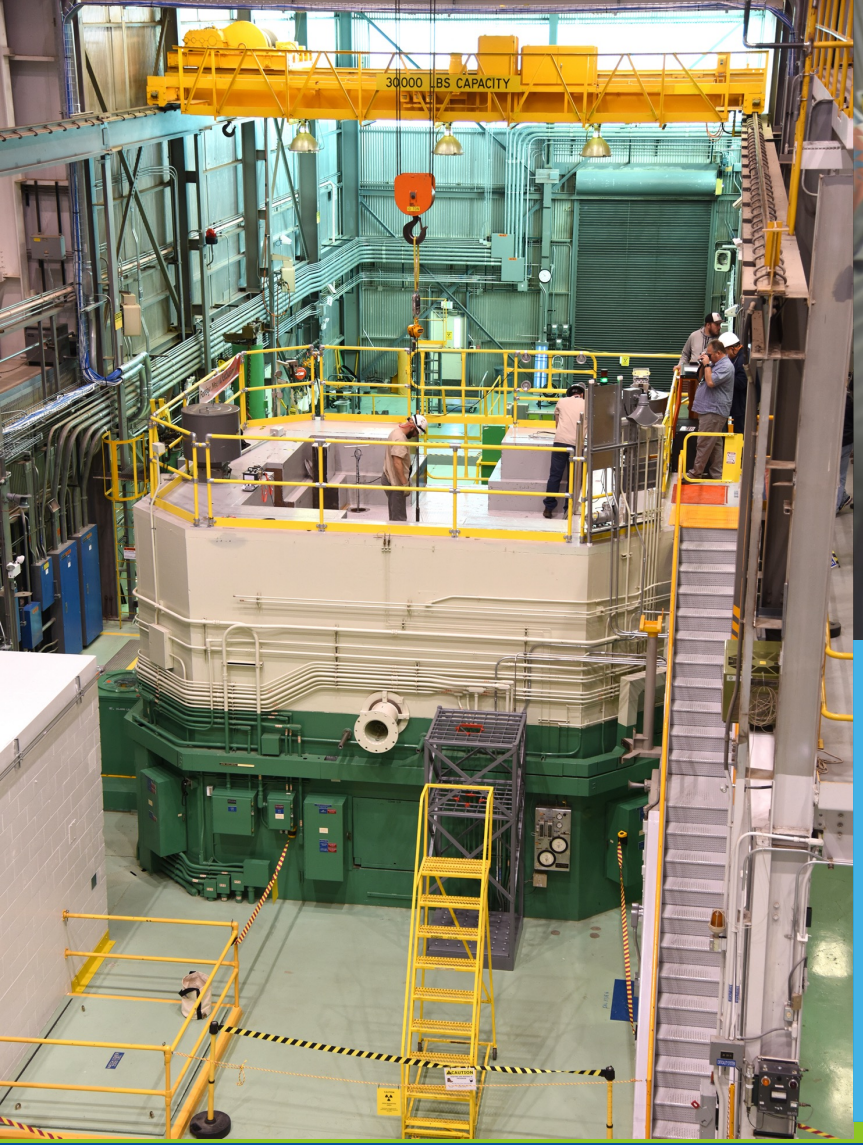


September 28, 2023

Douglas C. Crawford, PhD
MFC Reactors Chief Technologist

MFC Transient Testing and Fuel Fabrication Capabilities

WEC Cranberry Facility

Idaho National Laboratory, Idaho Falls, ID

Idaho National Laboratory

Transient Testing Capabilities

Idaho National Laboratory

MFC Aerial SE to NW

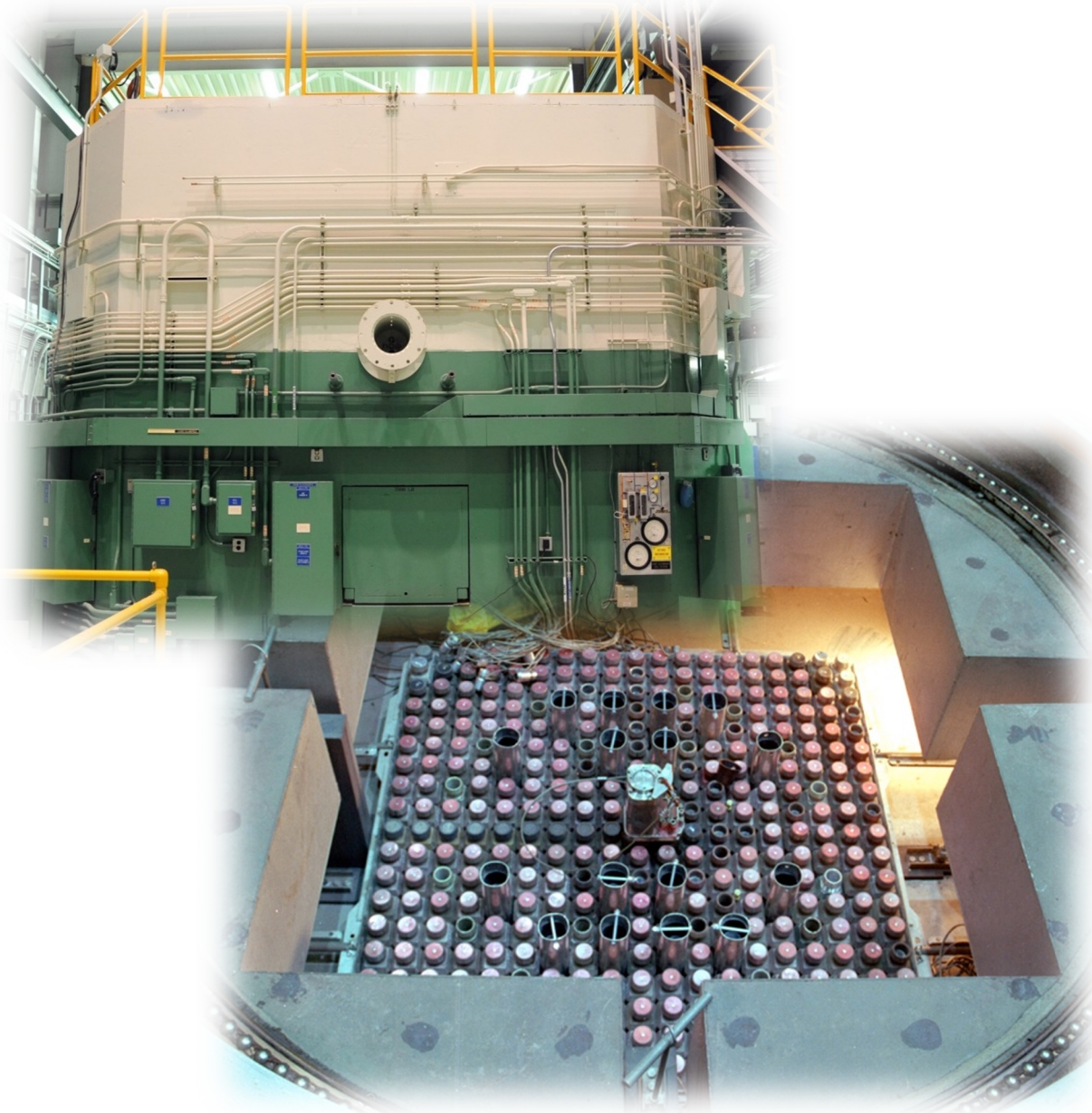
TREAT Reactor

Purpose:

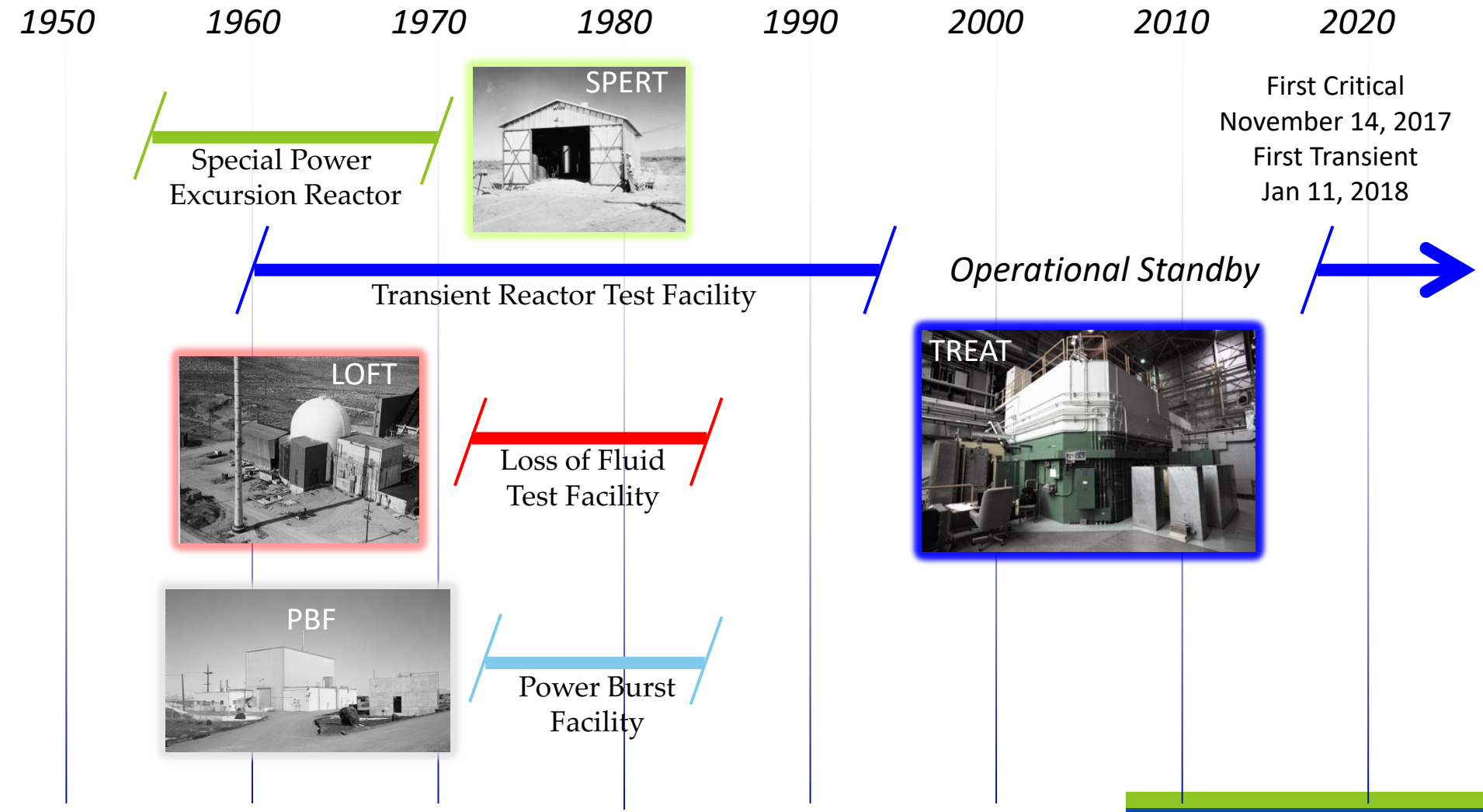
- Demonstrate reactor fuel performance phenomena under extreme (accident) conditions
- Determine safety limits of reactor fuels

Capabilities:

- High-intensity (20 Gigawatts), short-duration (<100 ms) neutron pulses for severe accident testing
- Shaped transients at intermediate powers and times (flexible power shapes up to several minutes)
- Testing capability for static capsules and flowing coolant loops
- Neutron-radiography facility for pre- and post-irradiation imaging
- Neutron “hodoscope” provides real-time imaging of fuel motion during testing
- Air cooled open-core design facilitates instrumentation for experiments

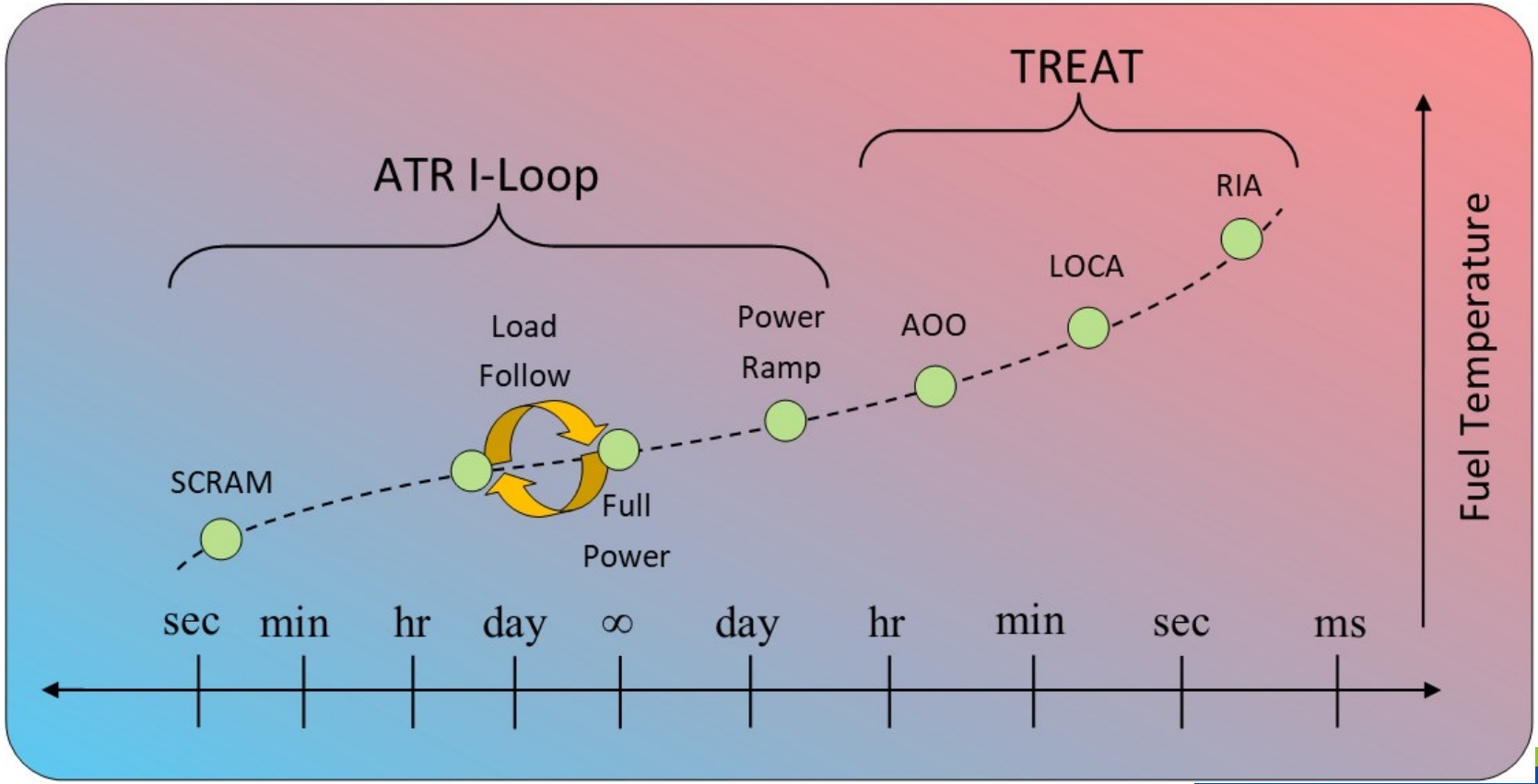


History of Fuel Safety Research at INL



Transient Timescale Domains

- ATR I-Loops and TREAT together cover full range for integral-scale nuclear-heated transient testing needs

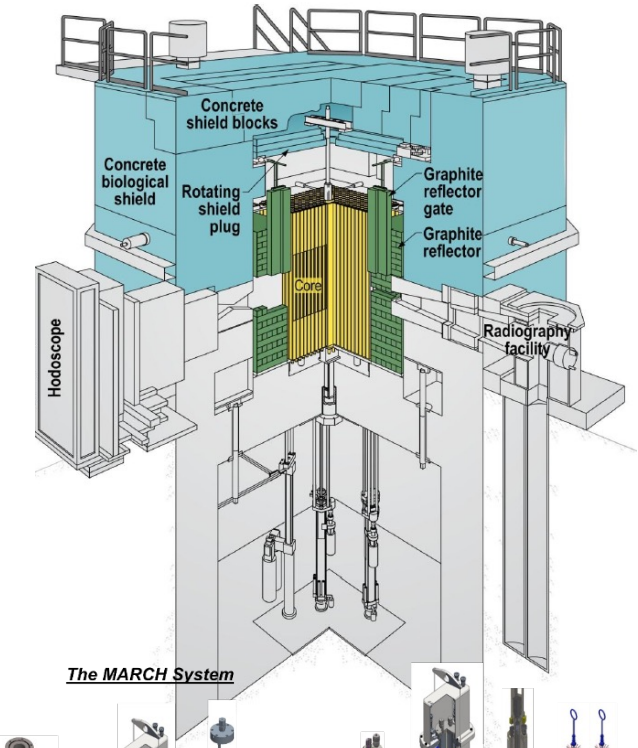


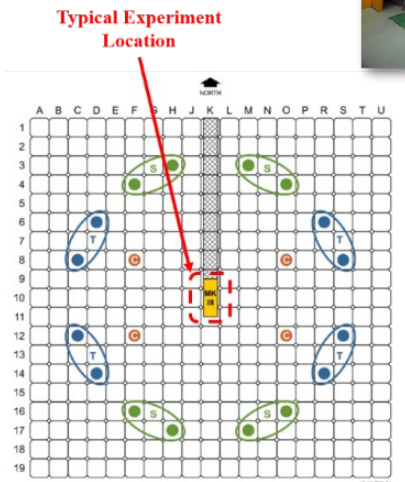
Transient Reactor Test Facility (TREAT)

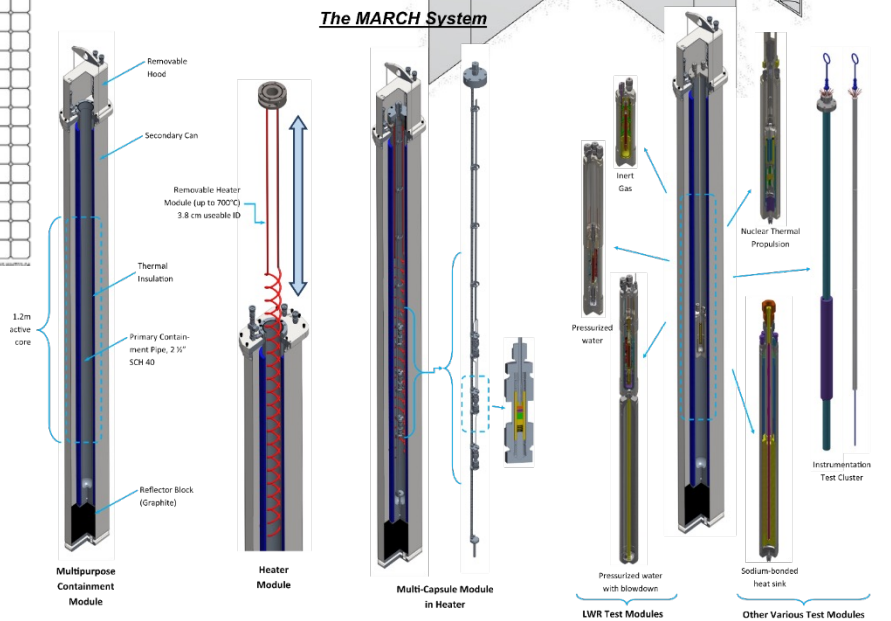
- Up to 120 kW Steady-state power with 20 GW Peak Transient Power
- Core: ~1.2 m high x 2 m. dia.; surrounded by 0.25 m graphite reflector
- 19 x 19 array of 10 x 10-cm. configurable fuel and reflector assemblies
- Fuel: UO_2 dispersed in graphite
- 12 steady-state and 8 transient control rods
- Instantaneous, large negative temperature coefficient (self protecting driver core)
- Co-located at MFC with hot cells and fuel fabrication facilities

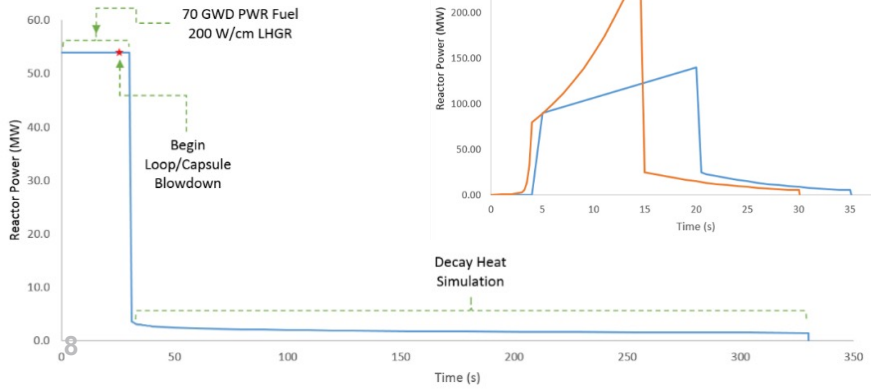
TREAT Features

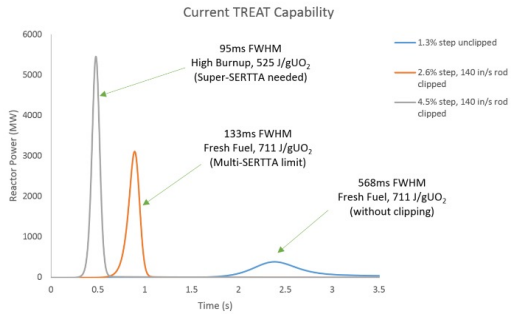
- Zircaloy-clad graphite/fuel blocks comprise core, cooled by air blowers
  - 120 kW steady state, ~20 GW peak in pulse mode
  - Virtually any power history possible within 2500 MJ max core transient energy
  - No reactor pressure vessel, facilitates access for in-core instrumentation
- 4 slots view core center
  - 2 in use for fuel motion monitoring system and neutron radiography
- Experiment design
  - Reactor provides neutrons, experiment vehicle does the rest
  - Safety containment, specimen environment, in-situ instruments
  - Handled outside concrete shield in cask
  - Tests displace a few driver fuel assemblies
- Collocated at INL with other complimentary facilities
  - ATR, HFEF, Fuel fab





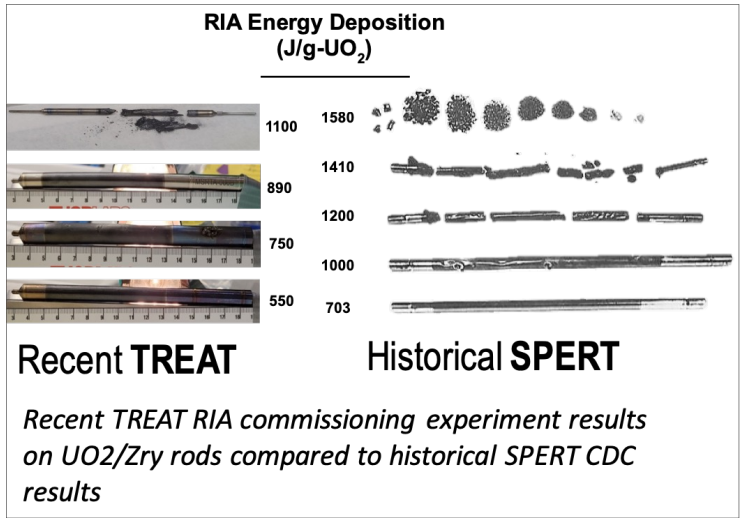






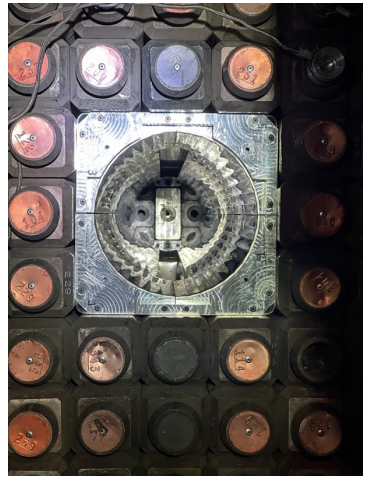
Transient Reactor Test Facility Capabilities

- **Reactivity Initiated Accident testing**
  - Commissioning test series complete,
  - Demonstrated capability for RIA testing of ATF rod prototypes and previously-irradiated fuel
  - He-3 injection system to narrow power pulses
- **Nuclear Thermal Propulsion Testing**
  - Static capsule tests of short CERMETs and a CERCER
    - Optical pyrometer developed and implemented
  - Static capsule log-rod test and tests in flowing hydrogen coming
- **LOCA Blowdown Capsule**
  - First commissioning test scheduled for this week
  - Commissioning tests and a RIA test scheduled for FY24
- **Sodium-Cooled Fast Reactor Fuel Test**
  - Static capsules
  - In-reactor Mark-IIIR loop to be delivered by EoCY23
  - Supporting infrastructure to be ready in early CY25
  - TerraPower Natrium tests beginning in 2025

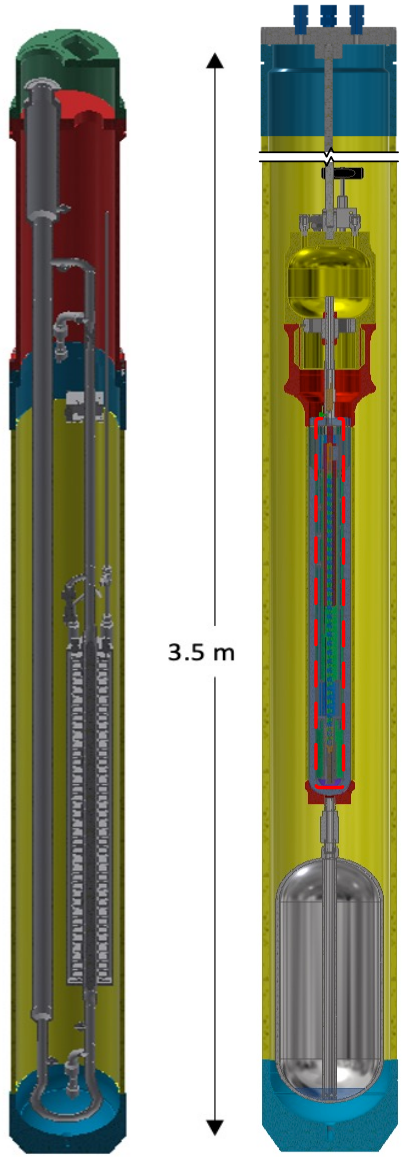


Recent TREAT RIA commissioning experiment results on UO2/Zry rods compared to historical SPERT CDC results

Big-BUSTER container



Large Experiment position with moderators



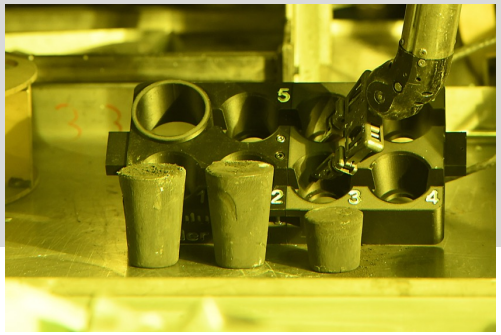
Sodium Loop (Mk-IIIR) in Big-BUSTER

LOCA rig (TWIST) in Big-BUSTER

Timothy Hyde
Director

Fuel Fabrication Capabilities

Fuel Feedstock



- DOE Controlled
  - Formal Low Quantity Requests
  - Formal Large Quantity Requests
- Highly-Enriched Uranium (HEU)
  - MCRE

- High Assay Low-Enriched Uranium (HALEU)
  - Existing inventory
  - Fuel Conditioning Facility (FCF) product regulus
    - OKLO, 5MT committed
    - Polishing

Experimental Fuels Facility (EFF)

Purpose:

- Repurposed for fuel fabrication research and development

Equipment/capabilities:

- Uranium machining (full enrichment)
- Welding glovebox

Fuels & Applied Science Building (FASB)

Purpose:

- Fuel fabrication development and characterization

Equipment/capabilities:

- Inert gloveboxes
- Radiological and clean fume hoods
- Hot cells for irradiated structural materials testing
- Thermomechanical materials characterization area
- Scanning electron microscopes
- Sample preparation area
- Fuel fabrication equipment (furnaces, rolling mill, hot isostatic press, etc.)

Ongoing Improvements:

- Facility aesthetics
- Pyroprocessing GB

Fuel Manufacturing Facility (FMF)

Purpose:

- Originally built to manufacture fuel for EBR-II, FMF houses gloveboxes for supporting various programs, including Fuel Cycle Research and Development (FCRD) and Nuclear Materials Disposition.

Equipment/capabilities:

- Various inert gloveboxes that support advanced fuel fabrication, LDRD experiments, fissionable material handling, packaging and shipment
- Vault for receipt/storage of materials for programmatic use at INL

Ongoing improvements:

- CAS upgrade
- VTR Fuel fabrication development
- Uranium Casting

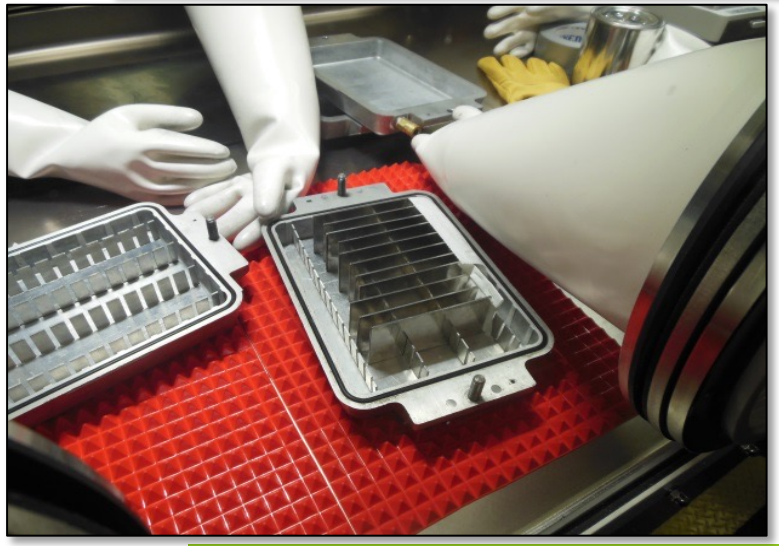
Zero Power Physics Reactor (ZPPR)

Purpose:

- Former reactor facility, repurposed after reactor was dismantled and removed from the cell. Supporting various INL programmatic activities, including National & Homeland Security and Nuclear Material Disposition.

Equipment/capabilities:

- Inert glovebox system that supports material inspections, fissionable material handling, packaging and shipment
- Optimal area for training/research activities for DOE and N&HS customers needing access to DOE owned nuclear material
- Vault for receipt/storage of materials for programmatic use at INL



Ongoing improvements:

- Aesthetics and functionality

Advanced Fuel Facility (AFF)

Purpose:

- Research and development of uranium-bearing fuels
- Focusing on Advanced Manufacturing

Equipment/capabilities:

- Spark plasma sintering (SPS) furnace
- Dry bag isostatic press system
- Crystal grower system
- Laser welder
- Admatec 3D printer

Ongoing improvements:

- Facility aesthetics and installation of equipment
- Facility HVAC and Suspect exhaust

Fuels Fabrication Modernization Capability

- Purpose
  - Space for engineering-scale fabrication process development and execution
  - First cores for microreactors; LTAs or LUAs for large reactors
  - Hazard category authorization for amounts of LEU and HALEU beyond MFC laboratory authorization
  - Ceramic, metal, composite fuels as plates, pellets or slug; liquid fuels
- Status
  - Line-item capital construction project
  - Mission Need Statement (Critical Decision [CD]-0) submitted April 2022; Approval expected Sept. 2023
  - Indirect investment in pre-conceptual activities (F&ORs establishment, Building models)