Update on the Collaborative Research on Advanced Fuel Technologies for LWRs (CRAFT)

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NRC Higher Burnup Workshop IV
August 31, 2023

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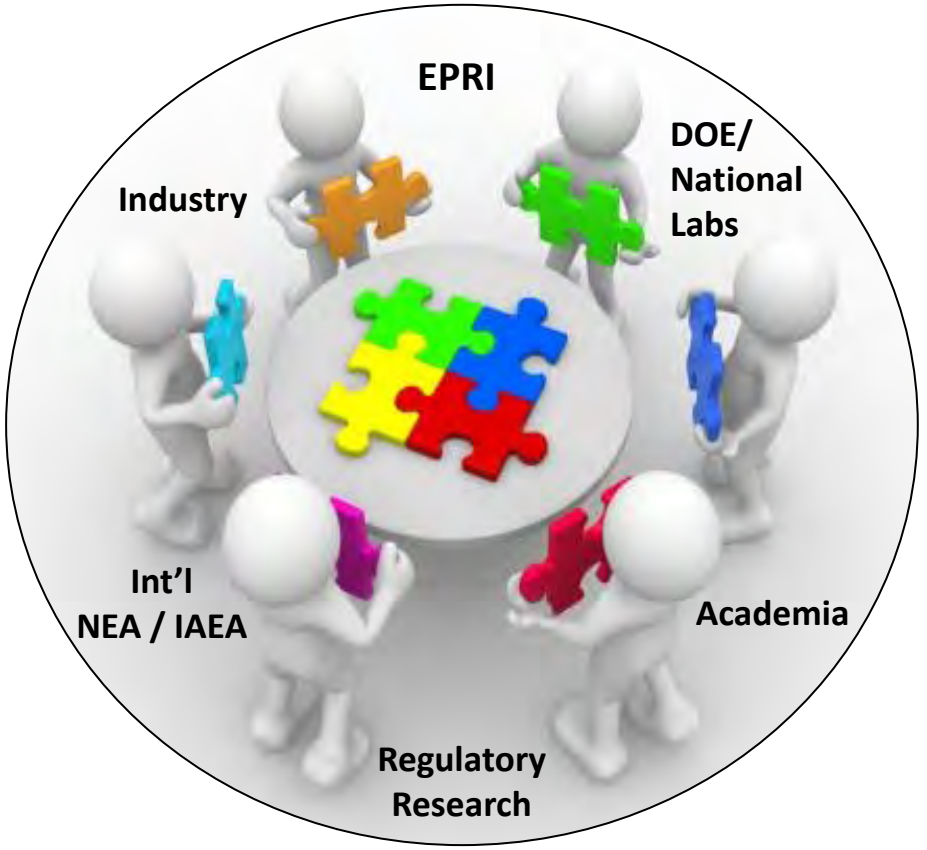
CRAFT Mission and Structure

- Support the **technical and research needs of U.S. stakeholders** through:
  - NEI ATF Working Group organizational structure
  - NRC/RES-EPRI Memorandum of Understanding
  - Various DOE-EPRI agreements

- CRAFT provides **technical exchanges, expert analyses, and bases** for addressing **generic issues of fuel behavior and performance during in-reactor operations** as identified by stakeholders to **inform deployment of advanced LWR fuel technologies** (i.e., accident tolerant fuel (ATF) with higher enrichment and burnup).

- The identified generic in-reactor issues will be continuously discussed within CRAFT, and therefore be used to define the CRAFT technical scope which will evolve as **these issues are identified, prioritized, and dispositioned**.



Current focus on LOCA-induced Fuel Fragmentation, Relocation, and Dispersal (FFRD)

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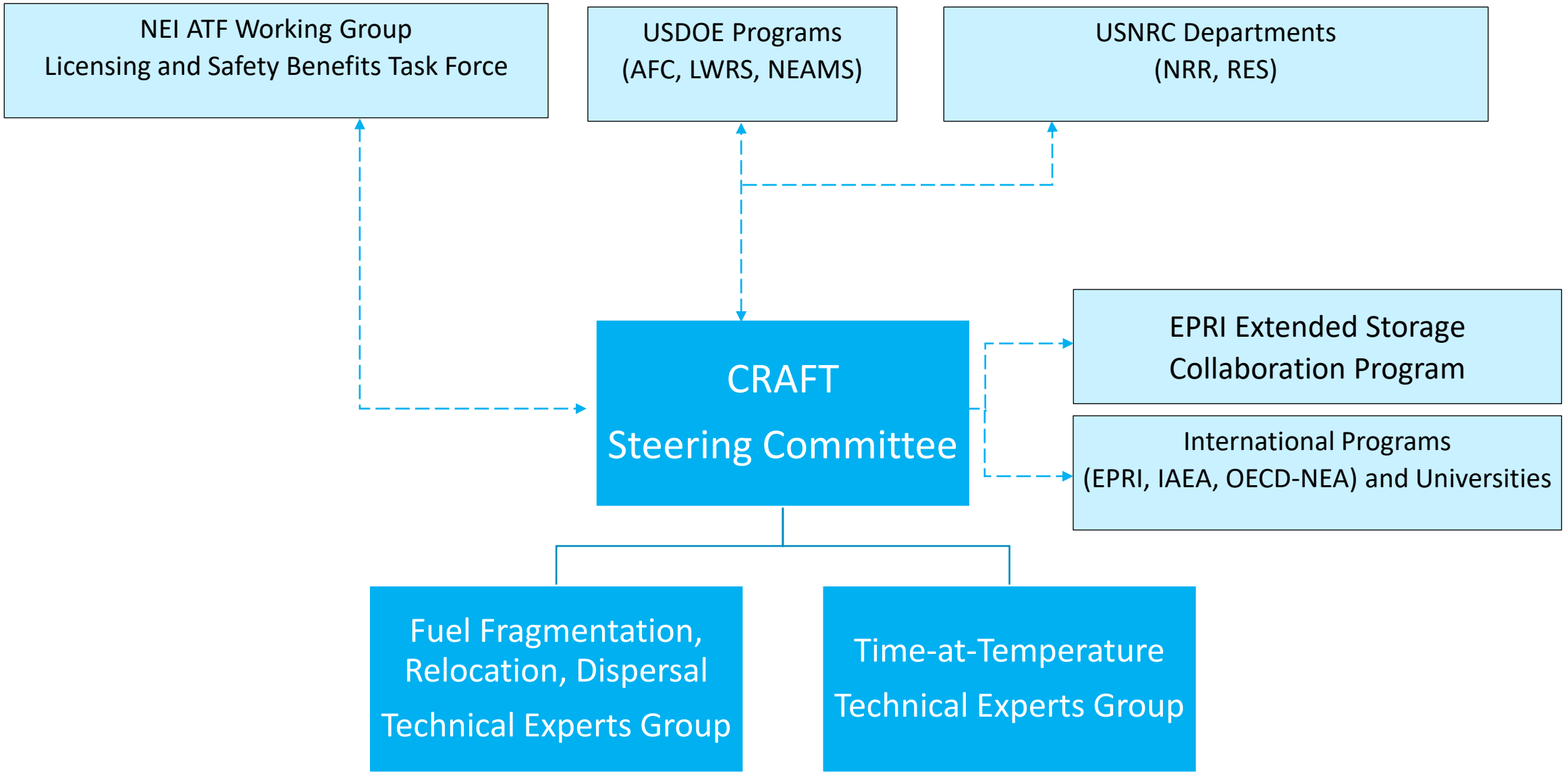
CRAFT Structure and Key Stakeholder Interfaces



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CRAFT Major Activities

- Revision to the CRAFT Charter
  - Support other improvements in plant safety, economic and operational flexibility including power uprates and extended cycles
  - Issue-based TEGs rather than function-based
- Develop a R&D roadmap of FFRD Issue Tracking Matrix (ITM)
- Develop Time-at-Temperature Material Testing Plan
- Provide feedback on the Technical Expert Panel Assessment of Existing Fuel Fragmentation Relocation and Dispersal Data

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CRAFT Deliverables

- 2022
  - Consensus DOE-AFC LOCA Test Plan (formal report) – Q3
  - Peer review of white paper on FFRD experimental database (informal communication to EPRI) – Q3
- 2023
  - Preparing a revised FFRD white paper that provides a best-estimate interpretation of the experimental database – Q4
  - For the Time-at-Temperature initiative, the material testing plan including identification of testing facility, defining the test protocol, and selection of materials – Q4
  - 2023 LOCA Test Plan Accomplishments Report – Q4

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CRAFT ITM – Research Evaluation Activities

- **Fuel Fragmentation (Pulverization)**
  - Higher burnup PIE
  - Advanced fuel characterization and tests
  - In- and out-pile testing
  - Transient Fission Gas Release testing
  - Modeling / Simulation
  - Quantification of fuel susceptible to fragmentation
- **Fuel Relocation**
  - Clad balloon propensity, size, and dynamics
  - Effect of rod internal pressure and clad creep and associated thermal ramp conditions
  - No rupture and rupture cases
  - Quantification of fuel susceptible to relocation
  - Acceptability and applicability of relocated fuel (core, ATF, non-ATF)
- **Fuel Dispersal**
  - Experimental methodologies for quantifying fragment dispersal
  - Quantification of fuel susceptible to dispersal
  - Acceptability and applicability of dispersed fuel (core, ATF, non-ATF)
  - Tracking of dispersed fuel
  - Consequence analyses of dispersed fuel

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CRAFT Issue Tracking Matrix (ITM)

- ITM was developed for capturing generic technical issues and attributes of advanced fuel technologies, including Accident Tolerant Fuel, Higher Burnup, and Increased Enrichment
  - Stakeholders focused on FFRD at higher burnup and during postulated design basis accident conditions

- Provide experts reviews and interpretation of technical bases for informing stakeholders on licensing bases and potential consequence analyses
  - Deterministic / Best Estimate usage of FFRD experimental database and modeling/simulation
  - Risk-informed or alternate approaches

- FFRD TEG is working on the development of a R&D roadmap from ITM

Being Reviewed and Updated with Latest Understanding and Stakeholder Needs

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Progress towards Consensus DOE-AFC LOCA Test Plan

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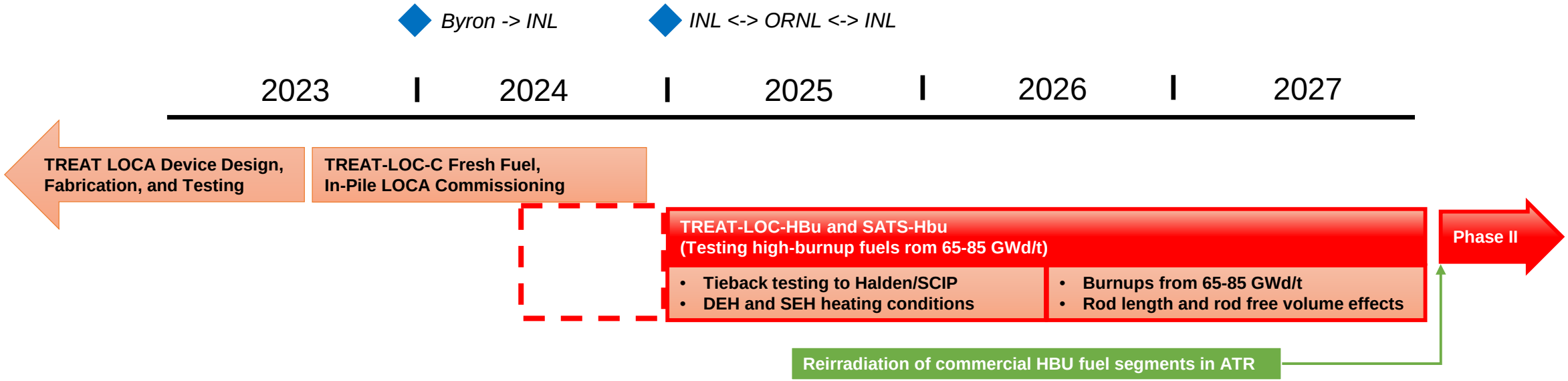
Progress and Outlook: Upfront Summary

- DOE-AFC LOCA plan completion and endorsement by CRAFT
- Byron shipment of HBu test materials receives green light
- Completed final design, fabrication, and assembly of first LOCA capsule in TREAT to begin commissioning test plan next month
- Nearly completed out-of-cell evaluations and testing to support hot-cell readiness of SATS enhanced capabilities to support faster temperature ramp rates for the test plan
- On schedule to date, BGNS shipment slightly delayed impacting schedule and budgetary pressures are increasing with inflation effects



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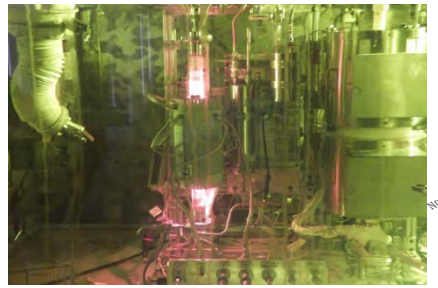
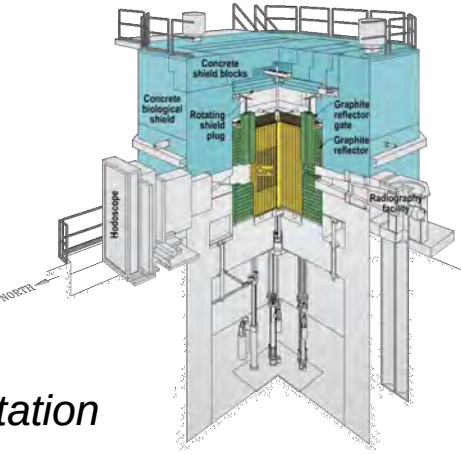
Consensus Integral LOCA Test Plan

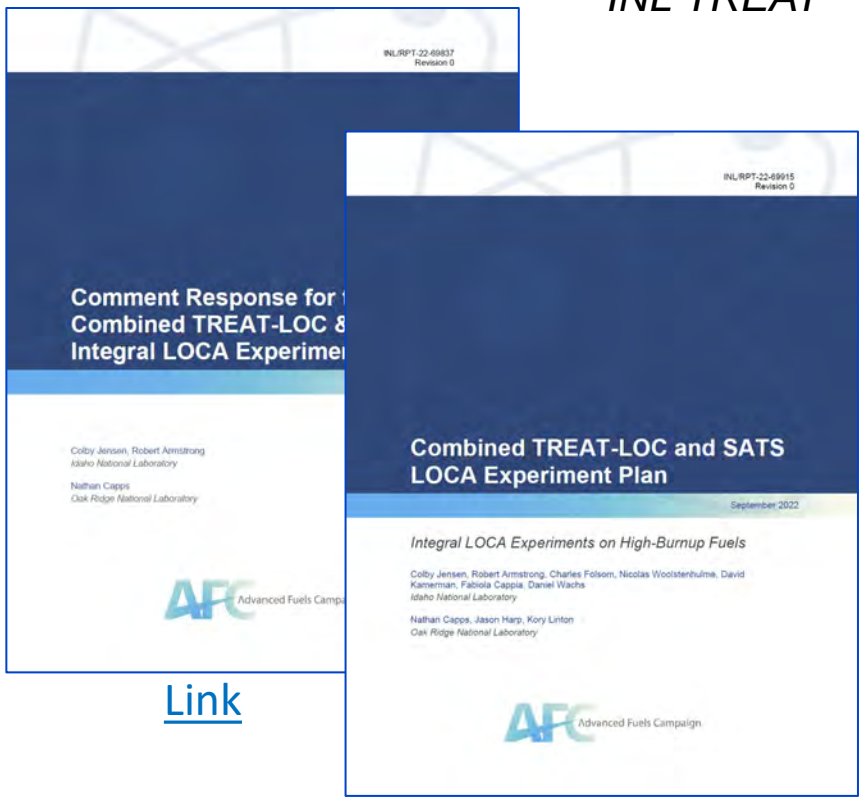
- Combined integral and semi-integral LOCA test plan developed to address cross-cutting stakeholder needs
- Formally endorsed by CRAFT in Jan 2023
- Test matrix tailored to LB LOCA conditions
- Primary emphasis on experimental evaluation of identified R&D gaps in FFRD
  - First of a kind approach using both in-pile and hot cell testing facilities
  - Novel in-situ instrumentation
    - Fuel motion monitoring, tFGR, cladding balloon extent, and non-contact cladding temperature measurement
  - World-leading PIE capability for pre-/post-test characterization
- Test plan to remain living document relying on CRAFT advisory role



ORNL Severe Accident Test Station



INL TREAT



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Test Matrix: Rev 0

- Each line represents TREAT/SATS companion tests
  - Primary goal of comparing in-pile vs out-of-pile and SEH effects to traditional DEH conditions
  - Each companion tests use materials from same parent rod (to extent possible)
- Detailed material characterization accompanying all pre & post testing

Strong focus on SEH and comparison with DEH conditions. Primary variations include segment ave. burnup, failure point during SEH condition, rodlet length, plenum size effect

Test ID	Seg. Burnup (GWd/t)	PCT (K)	Max. Temp. Ramp Rate (K/s)	Fuel Length (cm)*	Rod Free Volume (cc)	Purpose
LOC-1 SATS-1	~65	1173	5	25	15	HBWR IFA 650.10/15 and SCIP test 36U-N05 tieback, simulate "classic" Halden/furnace condition
LOC-2 SATS-2	~65	1173	<100 50	25	15	SEH heat-up comparison to test #1
LOC-3 SATS-3	~75	1173	5	25	15	SCIP tieback with higher burnup
LOC-4 SATS-4	~75	1173	<100 50	25	15	SEH vs. DEH heat-up comparison with higher burnup (comparison test #3)
LOC-5 SATS-5	~75	1173	<100 5	25	15	Evaluate different failure condition. Target failure of the rod at a distinct point in the heat up – blow down vs refill phases.
LOC-6 SATS-6	~75	1173	<100 5	25	15	Evaluate non-failure condition. Target similar conditions to #3-5 without rod burst. tFGR data with no burst and no burst effects.
LOC-7 SATS-7	~85	1173	<100 5	25 25	15	Very high burnup
LOC-8 SATS-8	~75	1173	<100 5	50 25	15	Length effects, plenum size, axial gas communication effects, SCIP complements
LOC-9 SATS-9	~75	1173	<100 5	50 25	2.5	Length effects, plenum size, axial gas communication effects, SCIP complements

* Fuel length will be limited to distance between grid spacers or would include a grid spacer if present in the commercial irradiation (likely applicable for 50 cm length specimens in TREAT). Most semi-integral furnace tests have been on segments with a length near 30 cm.

- Halden/Studsvik Tieback Testing
- Store-energy Heating vs Decay Heat Driven
- Higher burnup DEH testing (SCIP tie?)
- Failure fast ramp end vs after alpha-beta transition, pressure effects
- No burst effect – total in-pile tFGR
- Burnup Threshold (just above)
- Long rod comparison, confirmation of SEH results
- Plenum size effect

Test specimens from Byron Nuclear Generating Station

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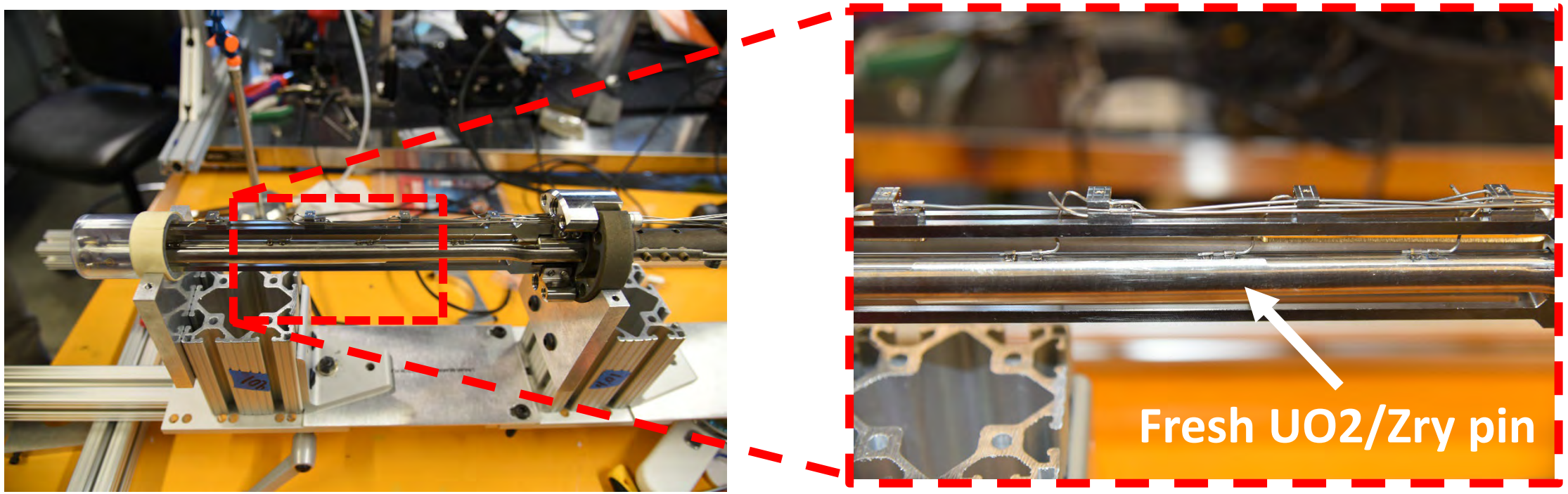
First TREAT LOCA Capsule Assembled!



- First experiment will be used to characterize specimen power input for model validation

TWIST LOCA capsule assembly for testing in September

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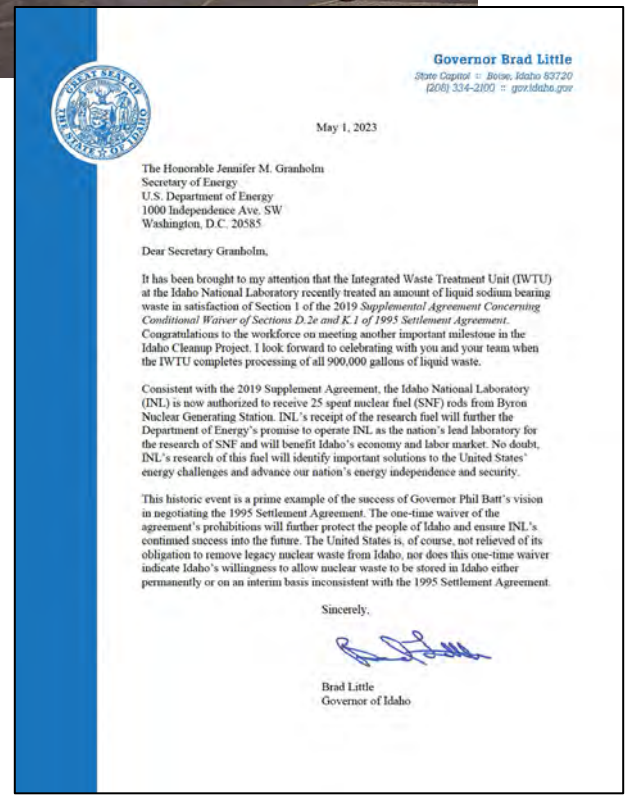
IWTU Update

- Major risk/hurdle overcome by milestone completion or Integrated Waste Treatment Unit at INL, allowing high-burnup fuel shipment from Byron Nuclear Generating Station (BNGS)
  - *(Completed processing first canister of material on April 12!)*
- Currently, receipt and preparation of BNGS materials remains primary schedule driver

Integrated Waste Treatment Unit at INL



Governor Brad Little
State Capitol :: Boise, Idaho 83720
(208) 334-2100 :: gov.idaho.gov

May 1, 2023

The Honorable Jennifer M. Granholm
Secretary of Energy
U.S. Department of Energy
1000 Independence Ave. SW
Washington, D.C. 20585

Dear Secretary Granholm,

It has been brought to my attention that the Integrated Waste Treatment Unit (IWTU) at the Idaho National Laboratory recently treated an amount of liquid sodium bearing waste in satisfaction of Section 1 of the 2019 *Supplemental Agreement Concerning Conditional Waiver of Sections D.2e and K.1 of 1995 Settlement Agreement*. Congratulations to the workforce on meeting another important milestone in the Idaho Cleanup Project. I look forward to celebrating with you and your team when the IWTU completes processing of all 900,000 gallons of liquid waste.

Consistent with the 2019 Supplement Agreement, the Idaho National Laboratory (INL) is now authorized to receive 25 spent nuclear fuel (SNF) rods from Byron Nuclear Generating Station. INL's receipt of the research fuel will further the Department of Energy's promise to operate INL as the nation's lead laboratory for the research of SNF and will benefit Idaho's economy and labor market. No doubt, INL's research of this fuel will identify important solutions to the United States' energy challenges and advance our nation's energy independence and security.

This historic event is a prime example of the success of Governor Phil Batt's vision in negotiating the 1995 Settlement Agreement. The one-time waiver of the agreement's prohibitions will further protect the people of Idaho and ensure INL's continued success into the future. The United States is, of course, not relieved of its obligation to remove legacy nuclear waste from Idaho, nor does this one-time waiver indicate Idaho's willingness to allow nuclear waste to be stored in Idaho either permanently or on an interim basis inconsistent with the 1995 Settlement Agreement.

Sincerely,

Brad Little
Governor of Idaho

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Planning for Next CRAFT Meetings

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Meetings for Remainder of 2023

- Q3/Q4 Virtual TEG Meetings (as needed)

- Q4 Hybrid Meeting
  - October 10-11 at EPRI offices in Washington D.C. (1325 G St. NW #530)
    - Held in coordination with NEI's ATF Working Group Meeting on Thursday, October 12 at the NEI's Washington D.C. office.

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