Advanced Fuels Campaign:

Accident Tolerant Fuels and Next Generation Fuels

Dan Wachs, National Technical Director

November 11, 2025

AFC Mission is Aligned and Responsive to Executive Orders

EOs: Executive Orders

~~1. 14156 Declaring a National Energy Emergency~~
2. 14299 Deploying Advanced Nuclear Technologies for National Security
3. 14300 Ordering the Reform of the Nuclear Regulatory Commission
4. 14301 Reforming Nuclear Reactor Testing at the Department of Energy
5. 14302 Reinvigorating the Nuclear Industrial Base

SO: Secretarial Order

1. Advance Energy Addition, Not Subtraction
2. Unleash American Energy Innovation
6. Modernize America's nuclear stockpile
7. Unleash Commercial Nuclear Power in the United States
~~8. Strengthen Grid Reliability and Security~~

BJ: President's budget justifications

1. DOE FY 2026 Volume 4 - NE

Fuel is the intersection between fuel cycle and reactor technology

Executive Order and AFC Impact

14299 Deploying Advanced Nuclear Technologies for National Security

- '… ensure the rapid development, deployment, and use of advanced nuclear technologies …'
- '… fully leverage the resources of the Federal Government to promote the United States nuclear industry in the development of commercial civil nuclear projects globally …'
- '… achieving competitive parity in the global market for high-level advocacy and representation from the Federal Government to foreign governments of potential import countries to include alignment on nuclear-related bilateral issues …'

14300 Ordering the Reform of the Nuclear Regulatory Commission

- 'Facilitate increased deployment of new nuclear reactor technologies, such as Generation III+ and IV reactors, modular reactors, and microreactors, including by lowering regulatory and cost barriers to entry ..'
- 'Facilitate the expansion of American nuclear energy capacity from approximately 100 GW in 2024 to 400 GW by 2050'
- 'Employ emerging technologies to safely accelerate the modeling, simulation, testing, and approval of new reactor designs;'
- 'Adopt revised and, where feasible, determinate and data-backed thresholds to ensure that reactor safety assessments focus on credible, realistic risks.'

14301 Reforming Nuclear Reactor Testing at the Department of Energy

- '… the Secretary shall … significantly expedite the review, approval, and deployment of advanced reactors under the Department's jurisdiction …'

14302 Reinvigorating the Nuclear Industrial Base

- '… maximize the efficiency and effectiveness of nuclear fuel through recycling, reprocessing, ….'
- '… recommendations for the efficient use of the uranium, plutonium, and other products recovered through recycling and reprocessing; …'
- '… establish a program to dispose of surplus plutonium by processing and making it available to industry in a form that can be utilized for the fabrication of fuel for advanced nuclear technologies …'
- '… prioritize contracting for the development of fuel fabrication facilities that demonstrate the technical and financial feasibility to supply fuel to qualified test reactors or pilot program reactors within 3 years from the date of such applications.'
- '… prioritize work with the nuclear energy industry to facilitate 5 gigawatt of power uprates to existing nuclear reactors …'
- '… take steps to increase access to research and development infrastructure, workforce, and expertise at Department of Energy National Laboratories for college and university students …'

Executive Order and AFC Impact

Adv Reactor Fuel Qualification

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ATF/Uprates

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Innovative Fuels & AFDQ and AI

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Pu Util and Recycle

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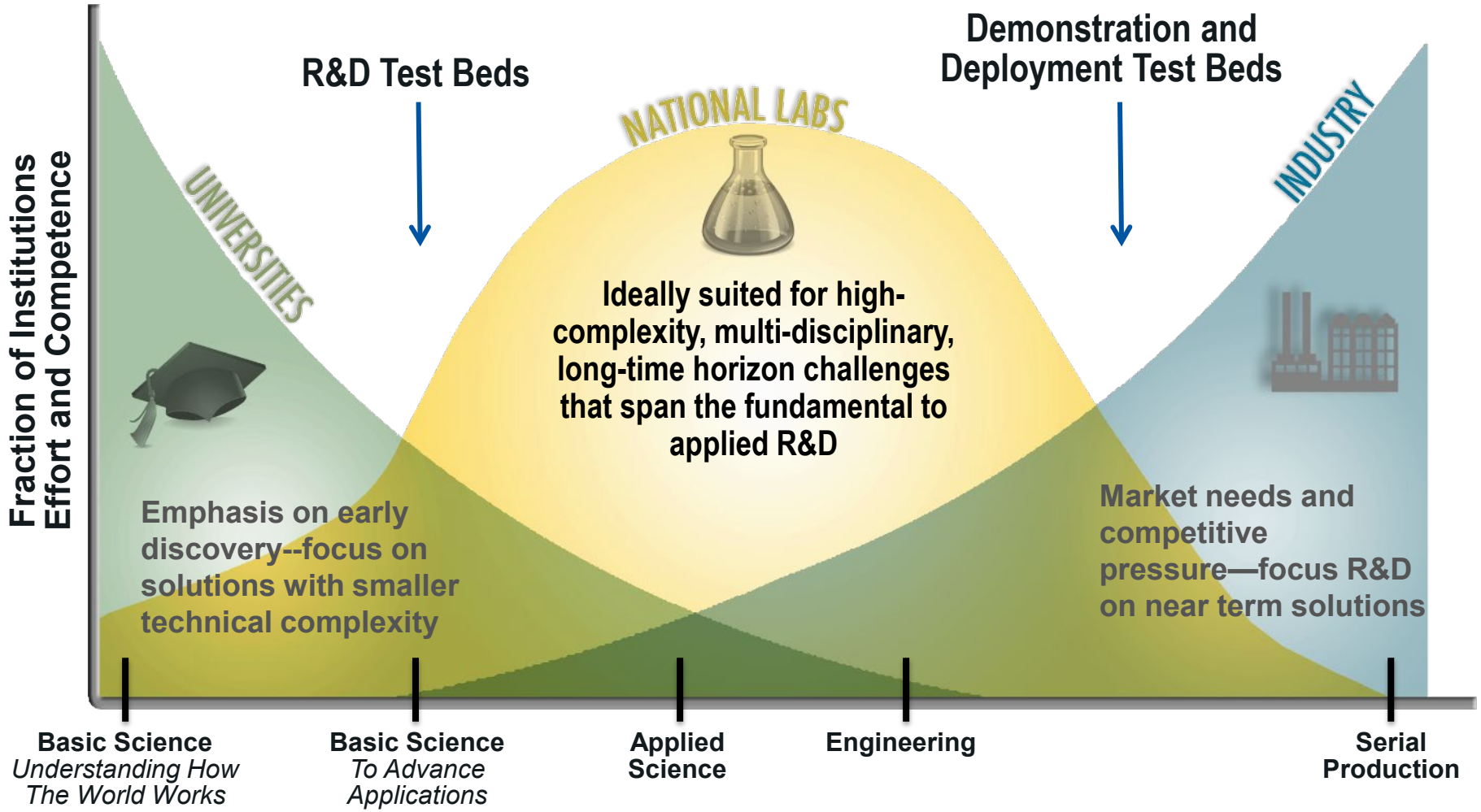
NGF Testbed

Advancing Fuel Technology: Role of AFC Program



Core AFC Labs

Idaho National Laboratory

Los Alamos NATIONAL LABORATORY

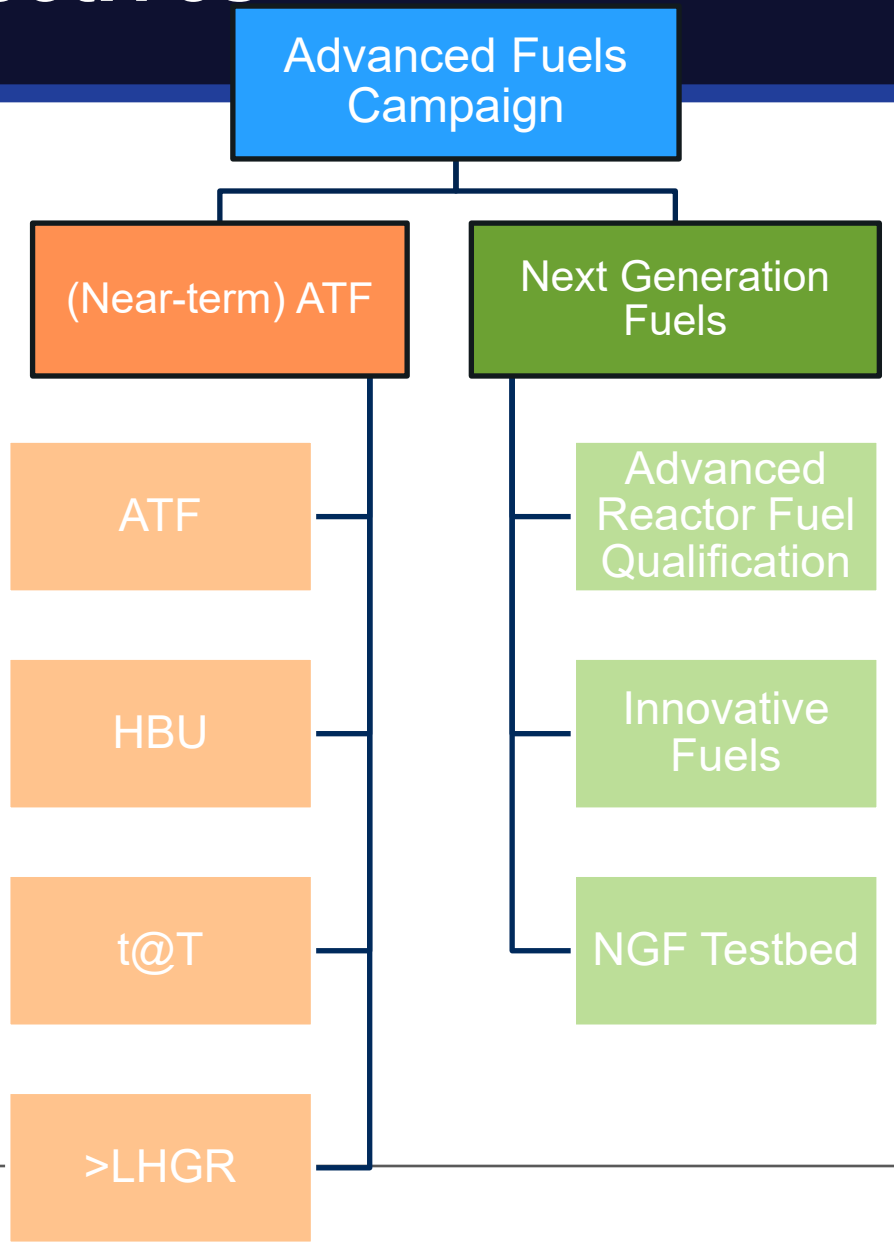
Oak Ridge National Laboratory

Argonne NATIONAL LABORATORY

Pacific Northwest NATIONAL LABORATORY

AFC Program Objectives

1. **R&D to qualify ATF technology**
   - Generate performance data relevant to normal and transient conditions
   - Document in topical reports or NUREGs
2. **R&D to enable burnup extension**
   - Execute Stakeholder Consensus LOCA Test Plan
   - Address emerging needs following NRC IE rulemaking
3. **R&D to update operational transient performance limits**
   - Execute Phase 1 of Stakeholder Consensus t@T Test Plan (assessment of behavior)
   - Execute Phase 2 of t@T plan (integral demonstration)
4. **R&D to demonstrate increased thermal-mechanical limits**
   - Establish and implement ramp testing capability required to identify high LHGR fuel performance limits
   - Establish and implement Critical Assembly Tank (CAT) to reduce uncertainty in assembly pin power



Qualification of Adv. Reactor Fuel Designs
- U-10Zr/U-xPu-10Zr metallic fuel
- UCO TRISO

R&D to Enable Design Optimization
- Expand reference fuel operating envelope
- Advanced manufacturing techniques
- Evolutionary designs (e.g. new geometry)
- Next generation variants

Innovative Fuel Technology
- Long-term LWR Technologies (**SiC**)
- Fuel cycle management fuels
- Revolutionary technologies

Current and Potential Focus
- Develop the next generation of fuel technologies
- Establish driver and target technologies needed to improve fissile utilization and waste management
- Implement modern development methodologies (AFQ and AI)

NGF Enabling Testbed
- SPARC fuel supply
- TREAT experiment support building

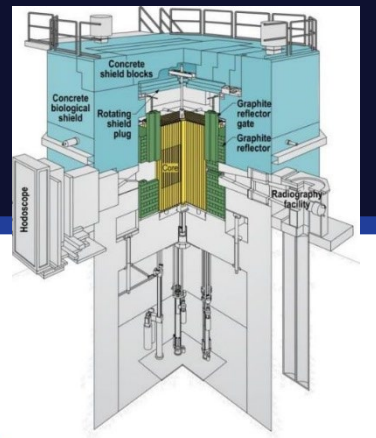
Current and Potential Focus
- Identify and conceptualize R&D infrastructure required to meet long term AFC mission

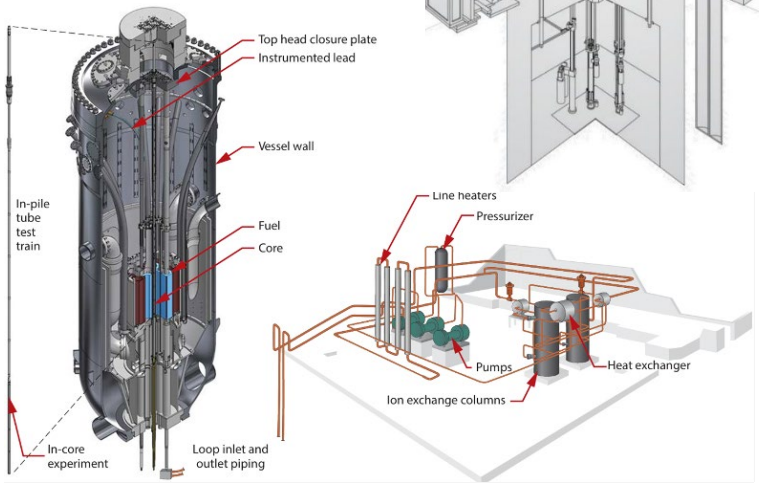
AFC near term ATF Program

1. **R&D to qualify ATF technology**
   - PIE including integral performance and material properties of Commercially Irradiated Chrome Coated Cladding and Doped Fuel at INL and ORNL Hotcells (~8 WEC rods from 1st cycle, 2nd cycle, and 3rd cycle irradiation)
   - Transient testing on ATF pre-irradiated segments including two 2nd cycle RIA tests at TREAT, additional fresh fuel RIA tests (including SiC), and several semi-integral LOCA tests in SATS
   - Irradiations of Coated Cladding rodlets in ATR water loop and subsequent PIE

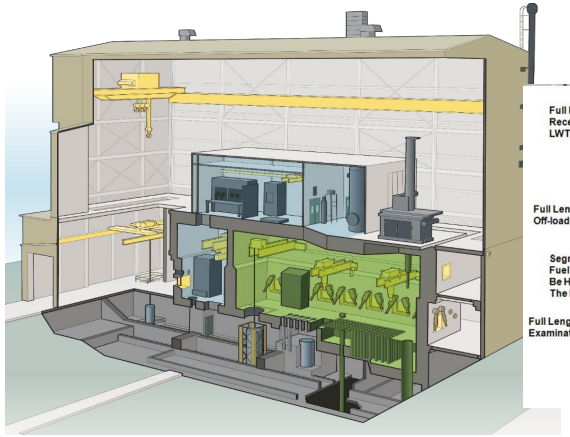
2. **R&D to enable burnup extension**
   - PIE including integral performance and material properties of Commercially Irradiated HBU Fuel at INL, ORNL, and PNNL Hotcells (~40 WEC rods and 15 GE rods)
   - Transient testing of HBU commercial rod segments including two RIA tests in TREAT, first fresh LOCA test (FY27) at TREAT, and several semi-integral LOCA furnace testing in SATS

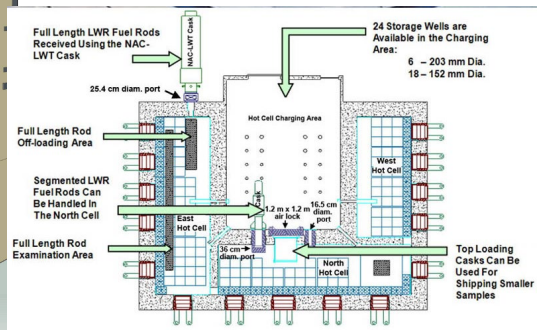
3. **R&D to enable time at temperature**
   - Cladding sample thermal treatment and micro-structural characterization of available cladding materials (INL & ORNL)
   - Cladding coupon irradiations at HFIR and annealing tests at ORNL on standard cladding technology (provided by vendors)
   - Integral annealing tests of commercially irradiated cladding tubes at ORNL SATS and preparations for re-irradiation at ATR water loops (both PWR and BWR)
   - Develop new BWR water loop at ATR (formerly i-loop)





World class test reactors (above)
State of the art hotcells (below)



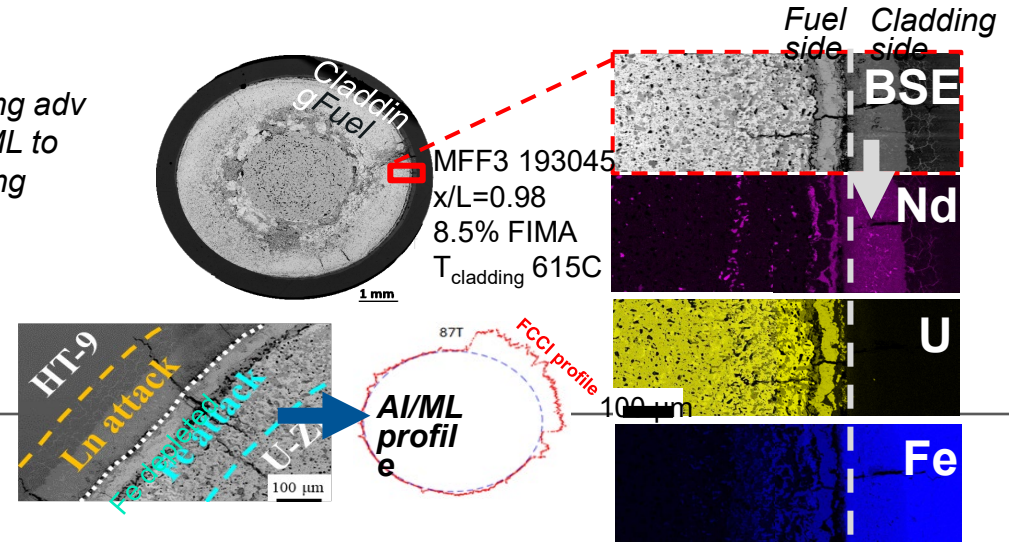


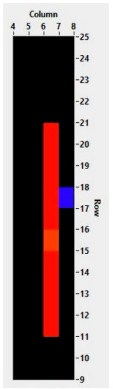
Metal Fuel Development and Qualification

Objectives

- **Short term:** Complete fuel design basis R&D (U-Pu-Zr) ensuring design limits are robustly supported by data for initial deployment needs by 2027.
  - Detailed evaluation of FCCI and transient eutectic formation in prototypic length fuel pins (PIE)
  - PIE on three transient fuel performance tests in TREAT, furnace based separate effects tests to support design limits, and the first sodium loop test in TREAT
  - Qualify legacy fuels database and fuel performance models.
  - Fuel qualification basis development for U-Zr and U-Pu-Zr
- **Long term:** R&D for expanded fuel limits and innovative fuel designs including recycled fuels to support technology expansion and fuel cycle optimization (fabrication, irradiation performance, recycle)

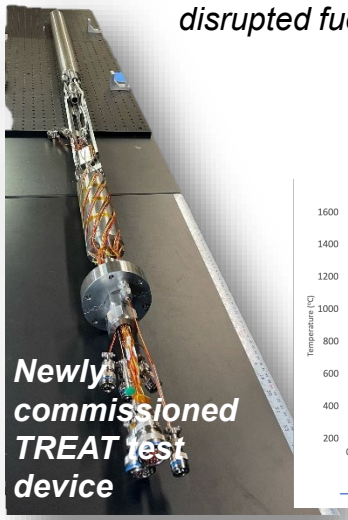
- *First of a kind data using adv characterization & AI/ML to understand fuel-cladding chemical interaction*

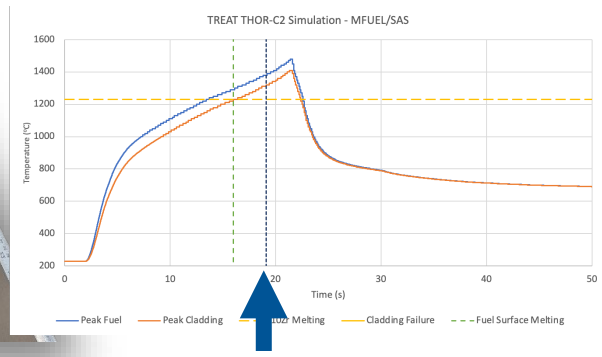




Unique fresh fuel results in THOR-C-2: (left) Hodoscope data showing time and location of pin breach (right) post-test neutron tomography of disrupted fuel

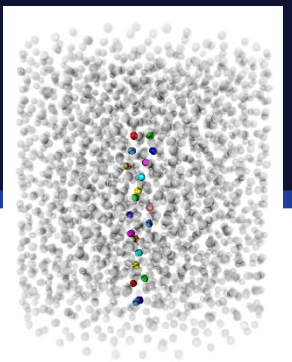
- *Quantified overpower failure threshold for fresh U-10Zr in HT9 cladding*





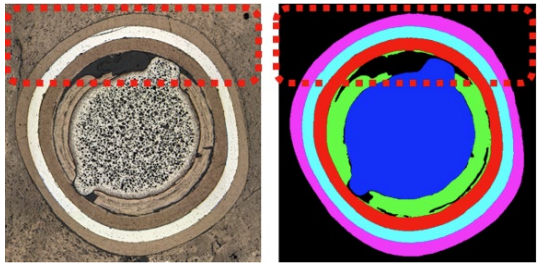
Measured time of failure in TREAT

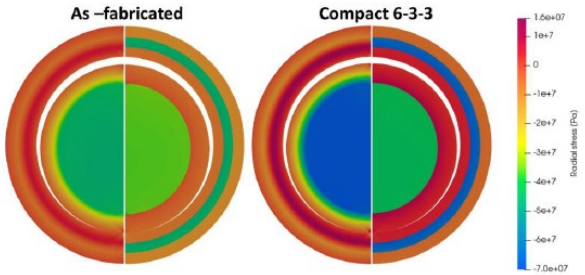
Coated Particle Fuel

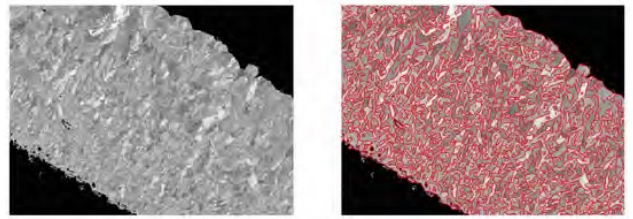


Objectives

- ❑ **AGR-3/4 – Fission product source term experiment**
  - Experimental work completed; effort focused on data analysis and reporting
- ❑ **AGR-5/6/7 – Pilot-scale fuel qualification experiment**
  - Complete final high-temperature safety (severe accident) tests
  - Complete fuel compact and particle destructive exams
  - Particle microanalysis to measure key properties and evaluate performance
- ❑ **Fuel performance modeling – Develop predictive models**
  - Update models using experimental data from AGR irradiation campaigns
- ❑ **Oxidation testing – Fuel performance during steam/air ingress**
  - Install AMIX in FCF air cell; complete first oxidation test
- ❑ **Advanced coated particle fuel – Develop novel CPF technologies to address future reactor needs**
  - Draft strategic plan for this next phase of CPF work
  - Explore new fuel concepts and develop new QA/QC methods





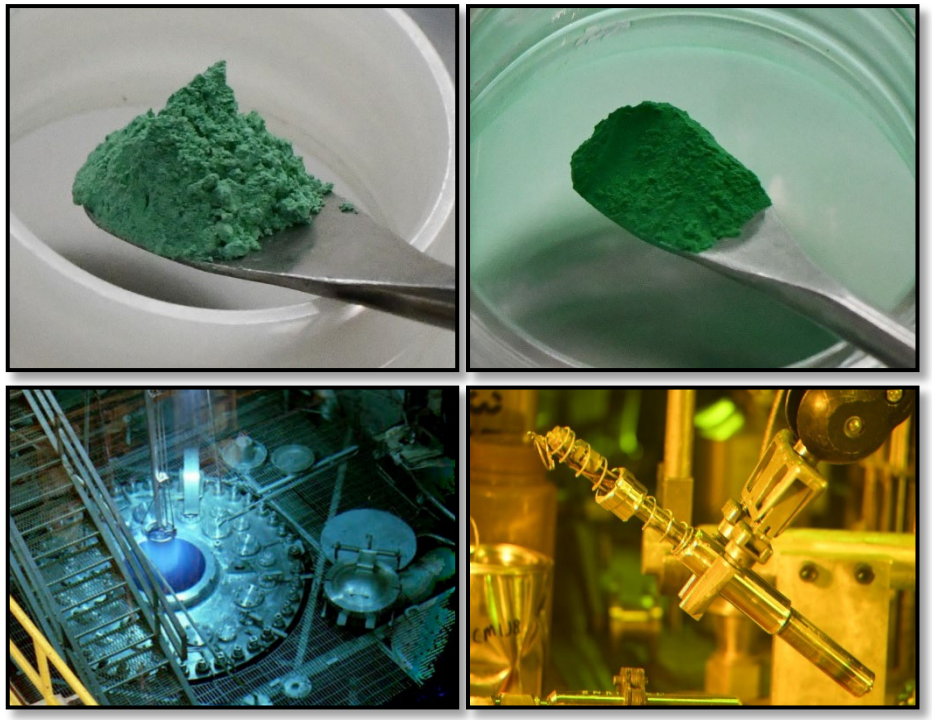


Molten Salt Fuels

Synthesis, Purification, and Scale-up	Develop and demonstrate engineering scale fuel salt synthesis and purification activities from a variety of feedstock materials while simultaneously developing a library of fuel salts
Methodology and Qualification	Establish a fuel salt specification outlining performance and safety requirements. Develop the necessary techniques and standard reference materials to quantify/characterize salt components
Irradiation and Post Irradiation Examination	Develop fuel salt irradiation testbeds including standard irradiation capsules and instrumented irradiation vehicles to deploy a domestic fuel salt irradiation and PIE program.
Modeling & Simulation	Utilize experimental data for model validation and fuel salt performance

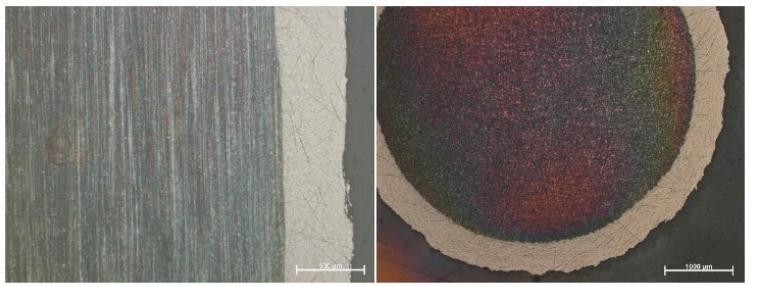
Mission Statement

Innovate and enable technologies needed to support fuel salt research and development, focusing on emergent and future needs to derisk fuel salt utilization in advanced reactors.

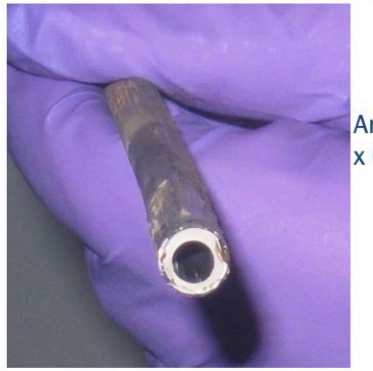


Innovative Fuels Call

- Call for proposals completed in FY2025 to identify ‘fuel cycle 2050’ concepts
- 1-3 year projects to elevate TRL and assess critical questions on new ideas
- ~30 proposals generated by national lab staff
- 4 projects to be funded in FY26 (~5% of AFC-NGF budget)



Zr/U-10Zr co-extrusion



Annular U-10Zr 8.6 mm OD x 6 mm ID

4

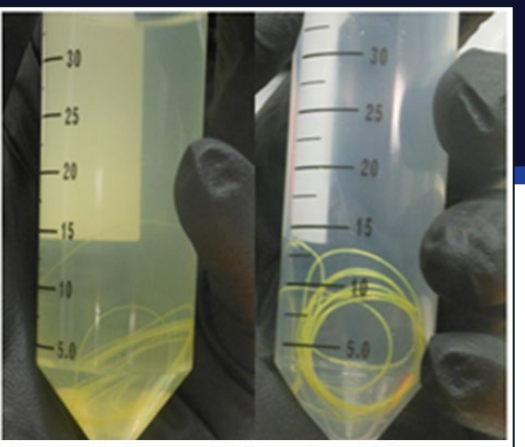
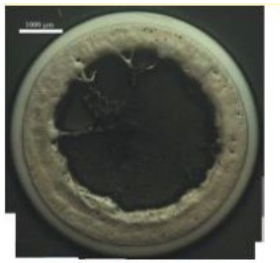
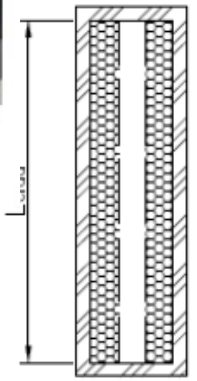


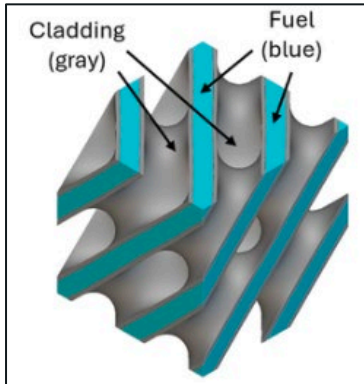
Figure 3. Intact U-bearing Filament. A green U-bearing monofilament has been successfully fabricated.



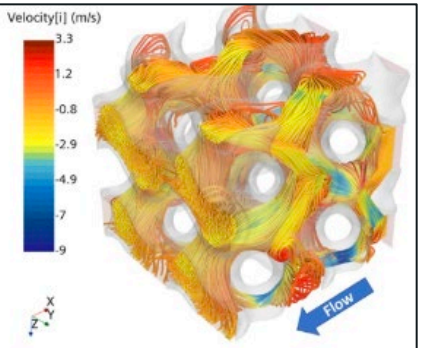
AFC-3C R2 (U-10Mo, 55% SD, annular, He, 3.3%FIMA, 625° C)

MPEA Cladding



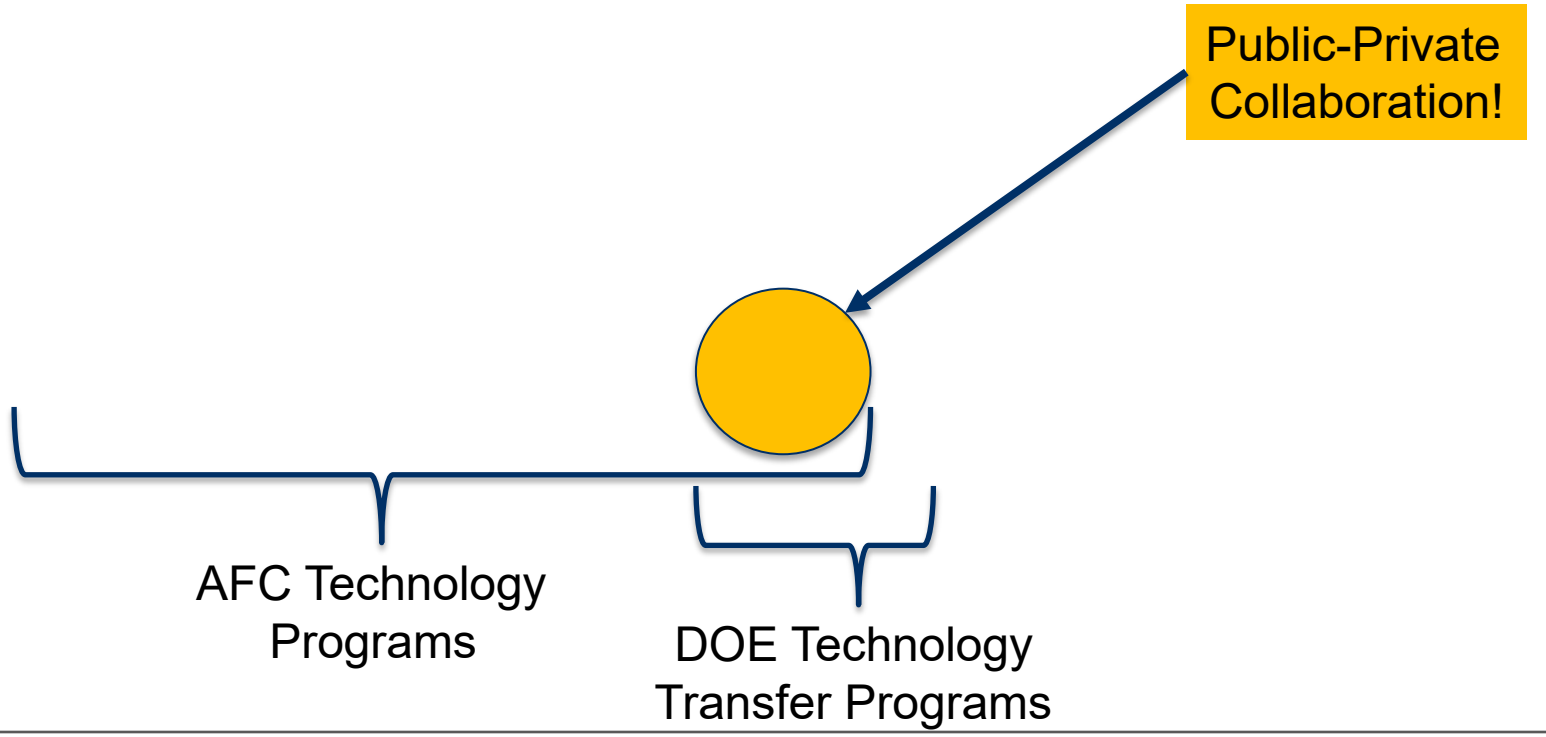


One INFLUX unit cell, can be “tiled” in 3D to create fuel assemblies & reactor cores

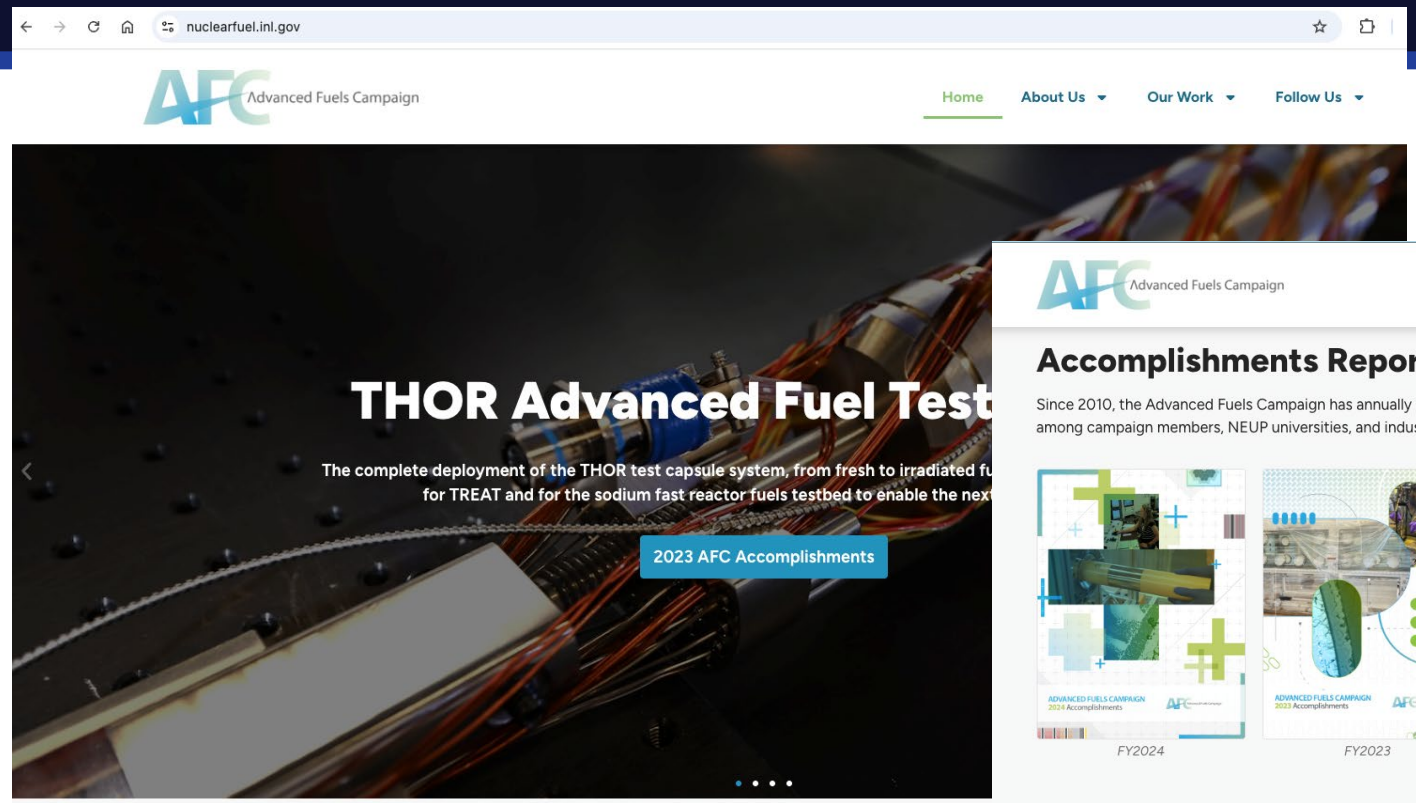


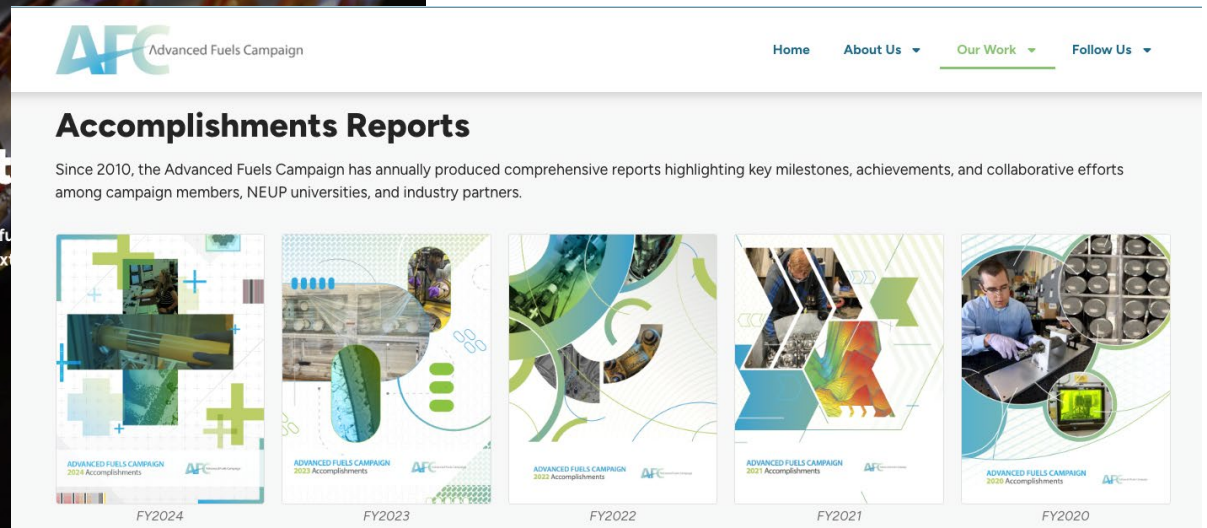
CFD model of INFLUX unit cell

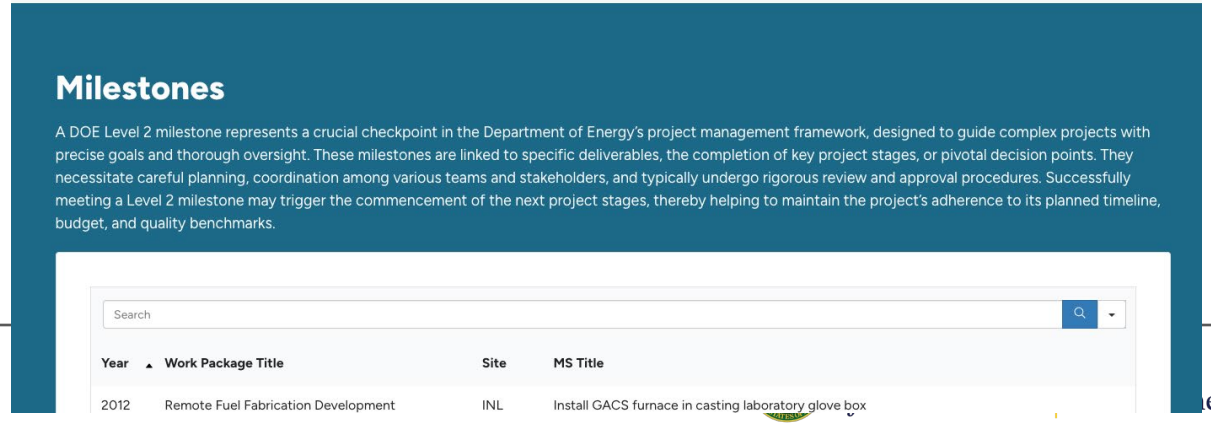
Advancing Fuel Technology: Role of AFC Program



Nuclearfuel.inl.gov







Questions and Discussion

U.S. DEPARTMENT OF
ENERGY