Update on Experiment Design Preparations for TREAT

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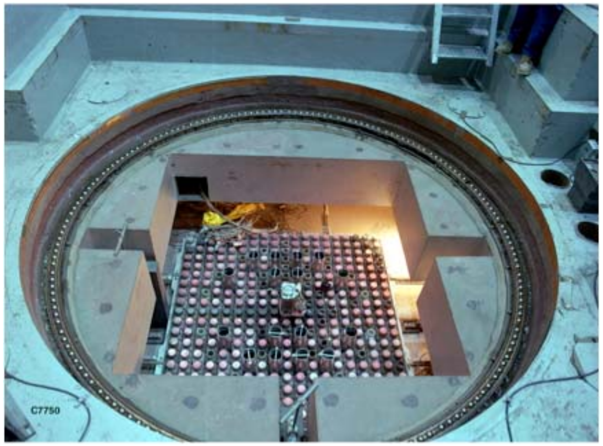
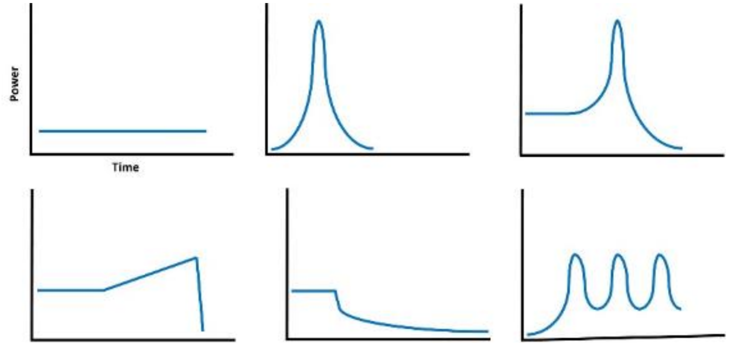
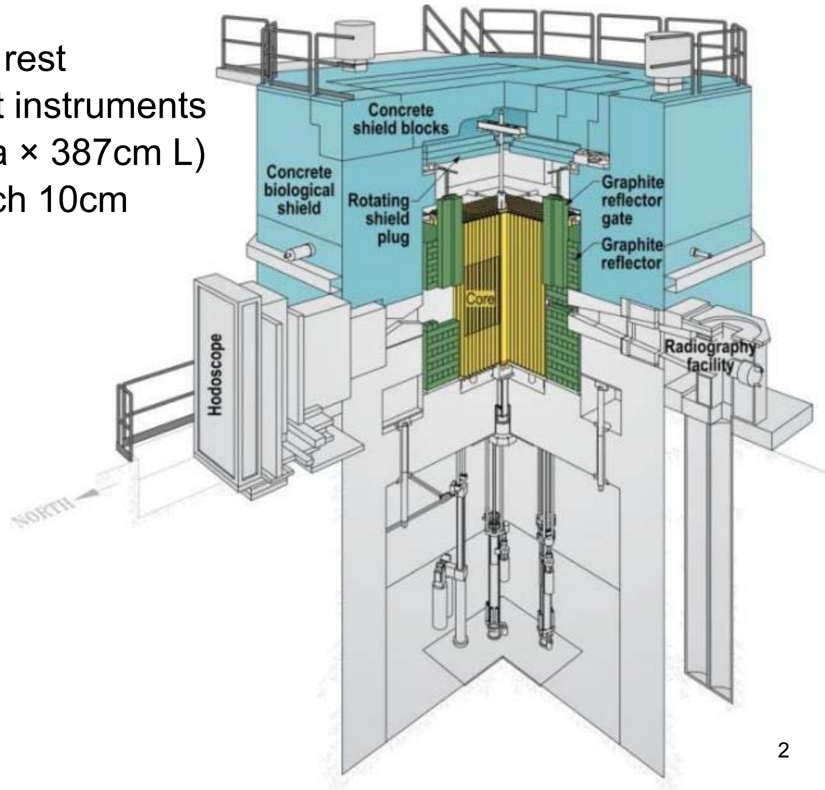


Introduction

- Transient Reactor Test (TREAT) resuming operations to support fuel safety testing
  - First tests to include baseline UO_2 in Zry fuels followed by fresh ATF specimens
- Graphite-based air-cooled reactor
  - 120 kW steady state, 19 GW peak in pulse mode
  - Virtually any power history possible within 2500 MJ max core transient energy
- Experiment design
  - Reactor provides neutrons, experiment vehicle does the rest
  - Safety containment, specimen environment, and support instruments
  - Handled outside concrete shield in cask (cavity 25cm dia × 387cm L)
  - Tests typically displace a few driver fuel assemblies (each 10cm square, 122cm L)
- 4 slots with view of core center, 2 in use
  - Fast neutron hodoscope, neutron radiography



Example Transient Shapes

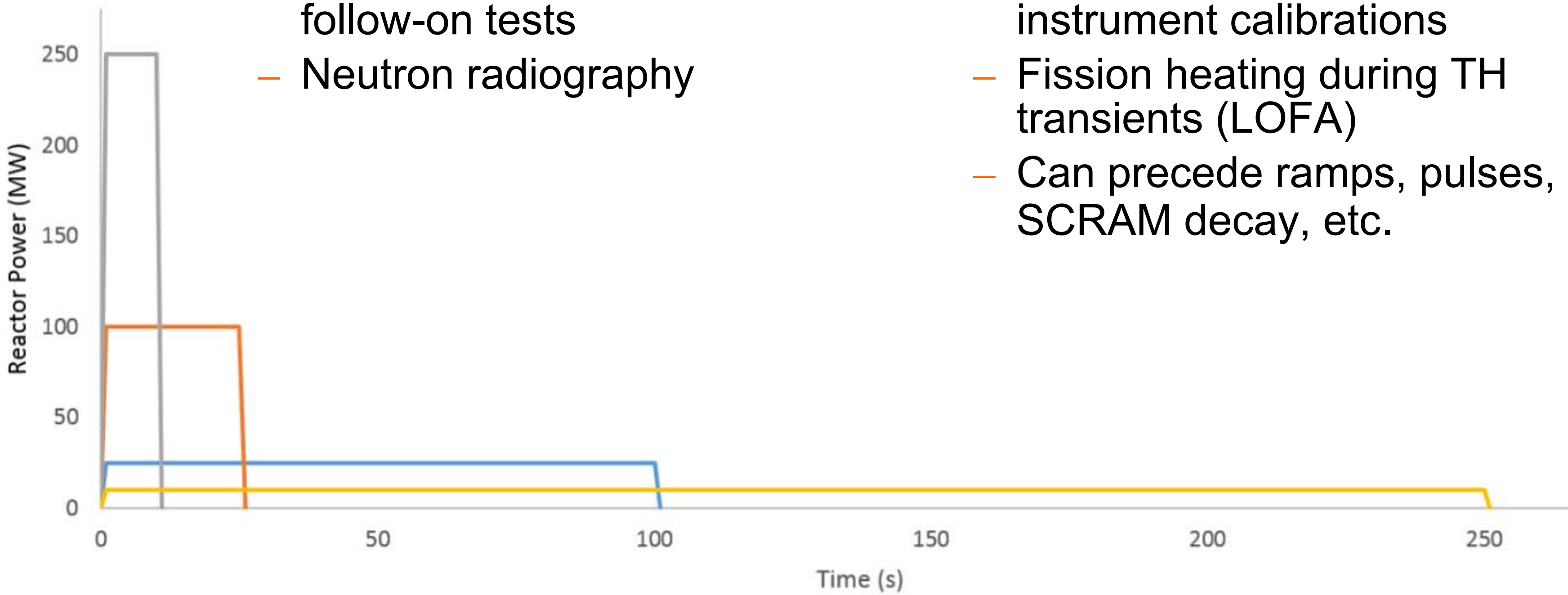


Transient Shaping

Transient Shaping

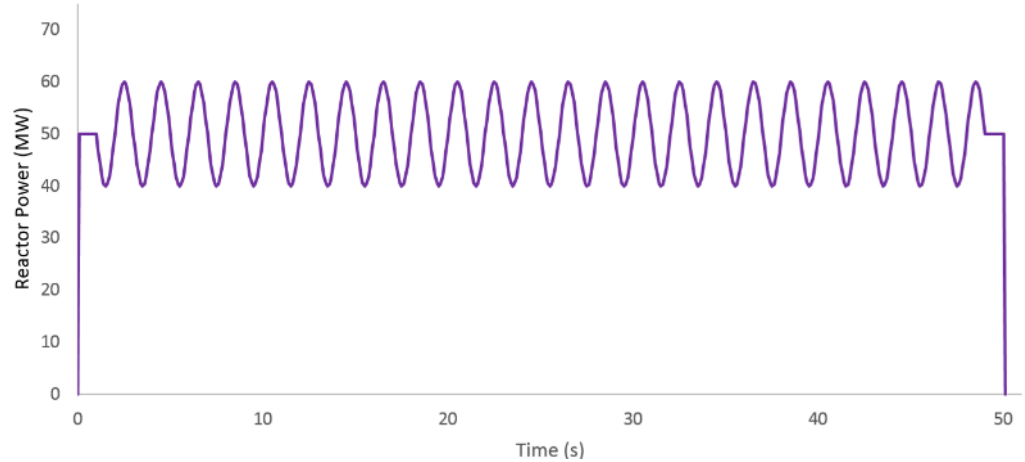
- TREAT is a <u>transient</u> reactor, not a <u>pulse</u> reactor
- Graphite heat sink, nimble control rod system → flexible power maneuvers

- Steady State
  - ≤120 kW steady state core power
  - Specimen power coupling measurements
  - Isotope build-in (e.g. ^{131}I) for follow-on tests
  - Neutron radiography
- Flattop Transients
  - "Flattops" >120 kW are considered transients
  - Virtually any power level, time limited by 2500 MJ
  - Heat balance and nuclear instrument calibrations
  - Fission heating during TH transients (LOFA)
  - Can precede ramps, pulses, SCRAM decay, etc.

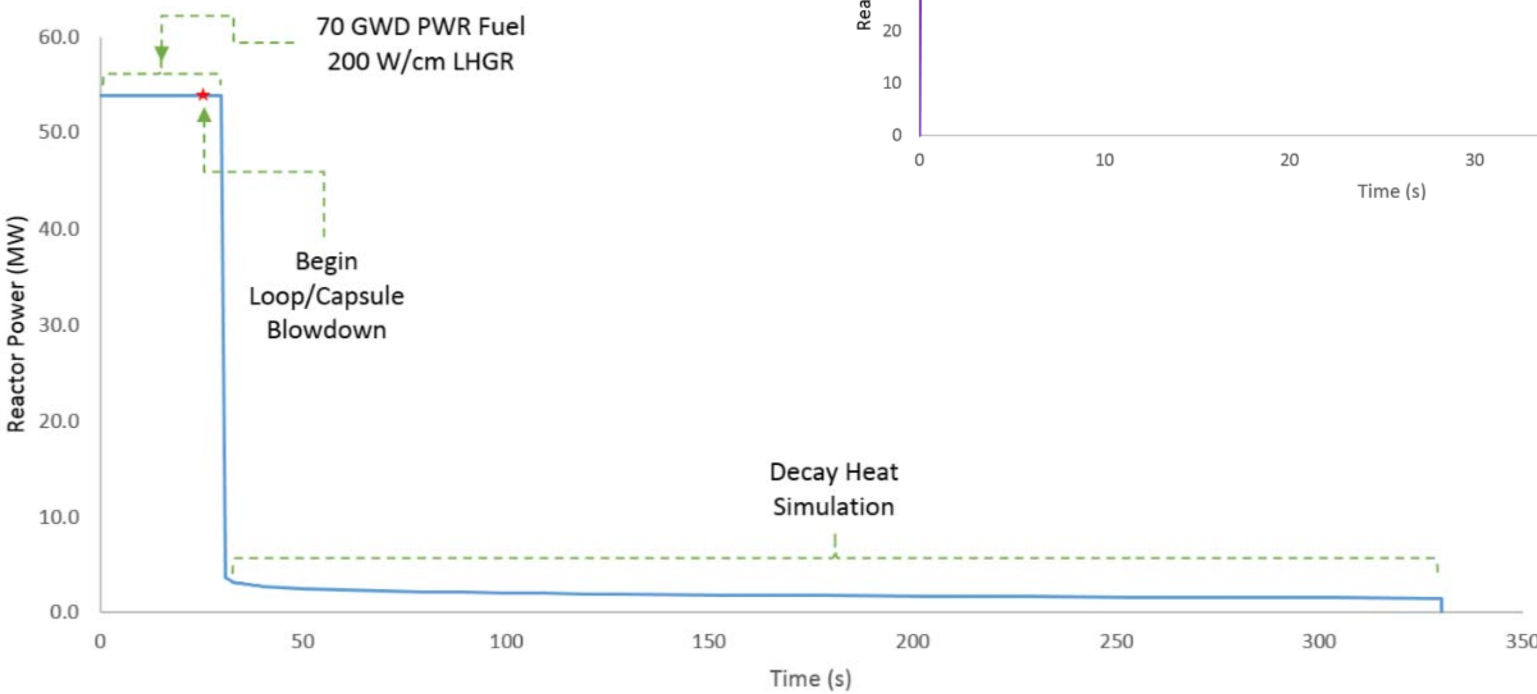


Transient Shaping

- Transient rod oscillations to simulate BWR void power instability

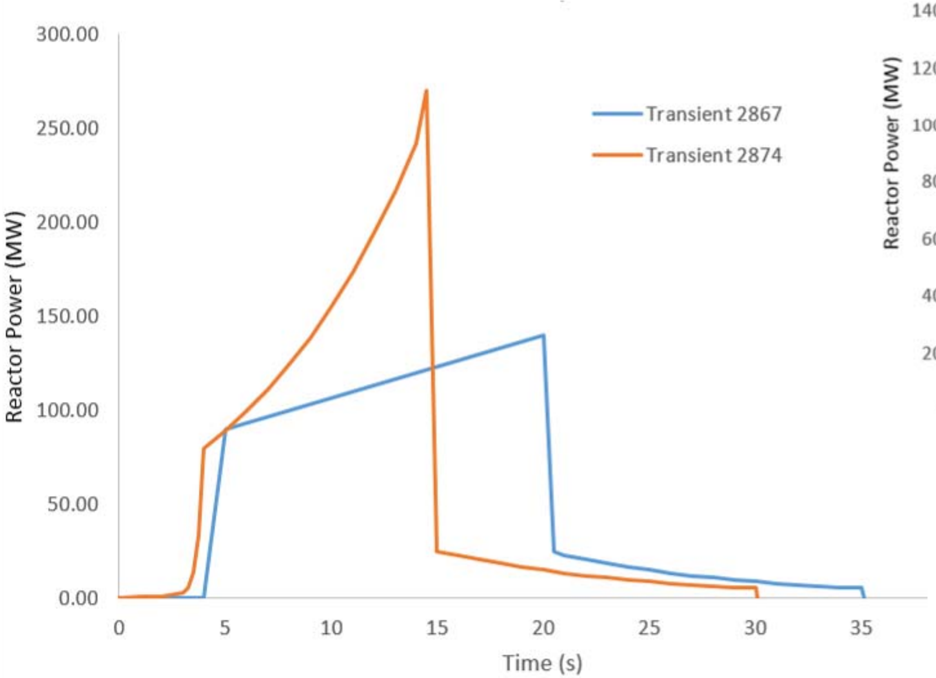


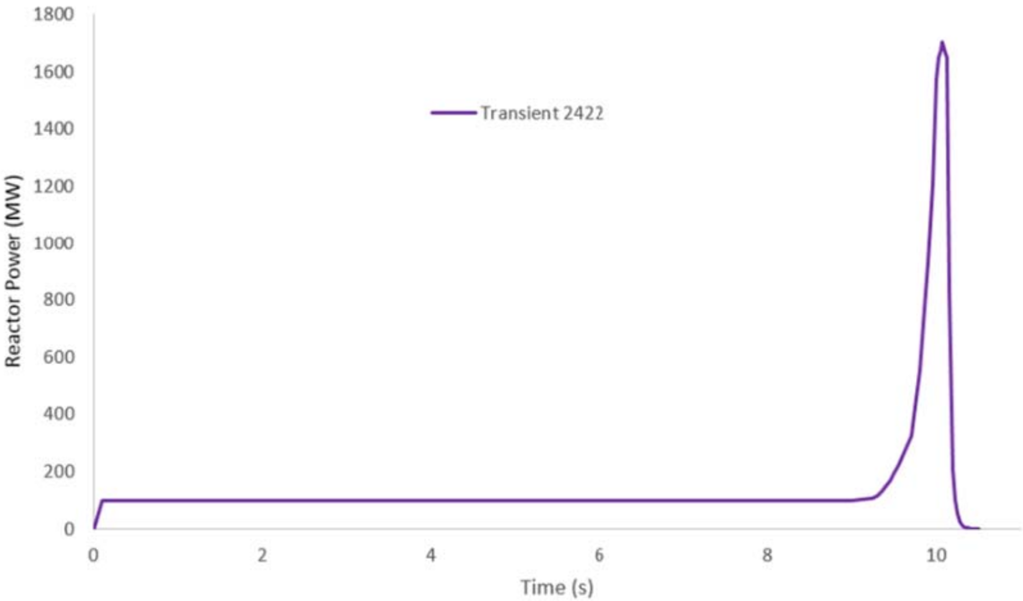
- Fission heat to provide internal heat generation (simulate LOCA decay)



Transient Shaping

- TREAT has extensive historic with transient over power simulation
- Transient tuned to achieve desired fuel temperature and/or power history
- Ramp, pulse, shutdown, etc. can be triggered by experiment instruments

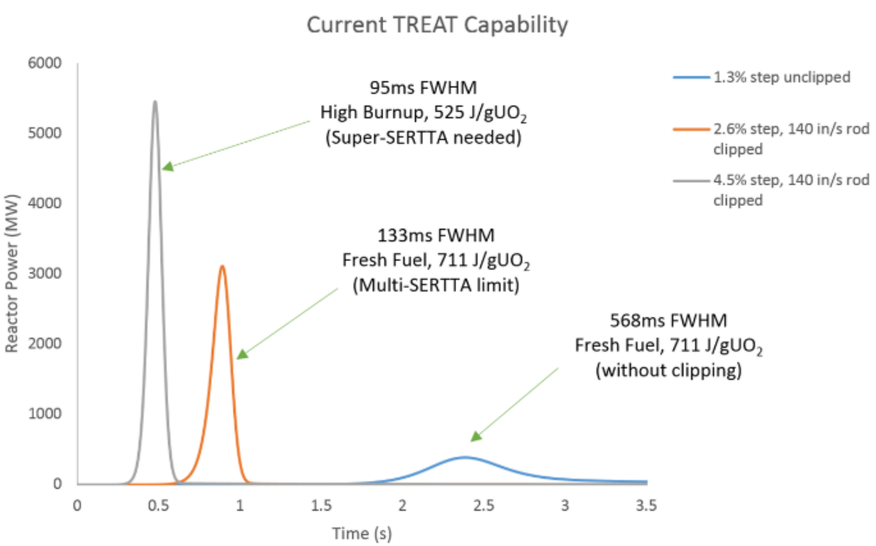


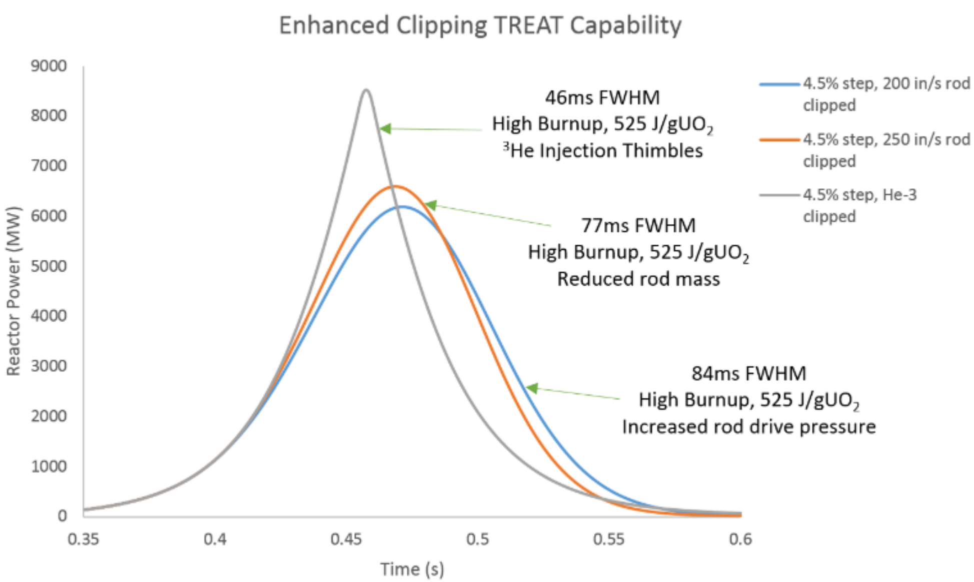


Transient Shaping

- Step insertion 4.5% Δk/k → 2500 MJ released in ~0.5 sec
  - Big dose for short-lived isotope studies
  - Facility's current energy limit
- Step insertion can follow a flattop Transient rod "clipping" → narrower pulses
  - Higher capacity vehicles needed for <100ms FWHM

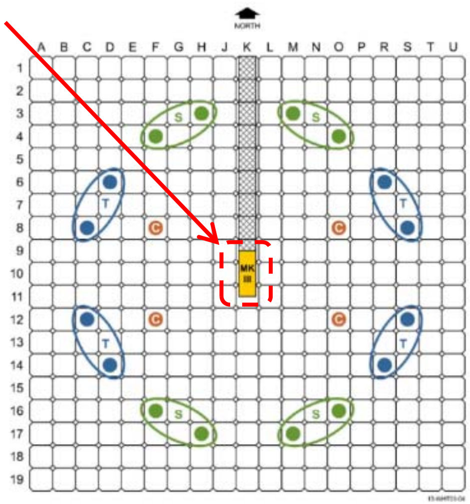
- Enhanced clipping viable for narrower pulses
  - Better simulation of LWR HZP RIA
  - Drives high burnup LWR fuel to reg. limits in **46ms FWHM**
- Current LDRD project addressing enhanced clipping design

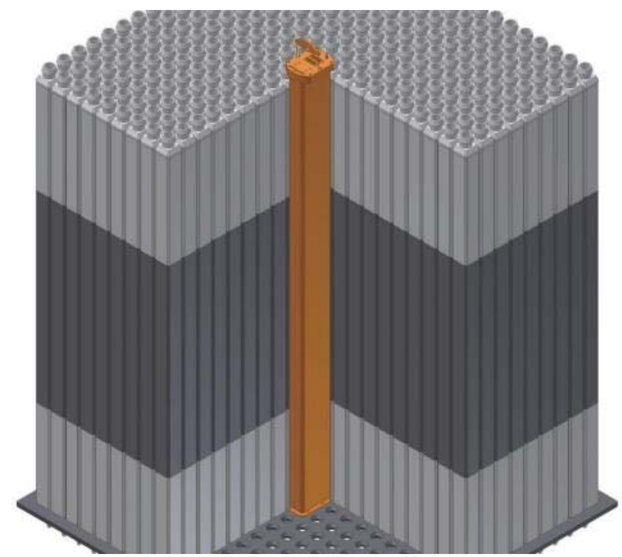




Experiment Design Status

- TREAT is a brilliantly basic machine
  - But all it really does is provide neutrons
- The experiment vehicle (e.g. loop, capsule, etc.) does the rest of the work
  - Boundary conditions (heat transfer, coolant environment)
  - Specimen support and instrumentation
- Current status:
  - **Multi-SERTTA** nearly complete to support ATF-3-1 fresh fuel baseline testing (UO_2 in Zry)
    - Commissioning tests in 2018
  - **MARCH** vehicle recently funded under LDRD
    - Ready in 2019
  - **RETINA** video-capable vehicle
    - Funding pending, design starting 2018
  - **Super-SERTTA** planned for ATF-3-2 (pre-irradiated specimens)
    - Funding pending, design starting 2018
  - **TWERL** water loop still planned,
    - Design not likely to be concurrent with this IRP
  - **Sodium** capsules and loop very much in the plan
    - Plan emerging shortly, stay tuned…





SERTTA shown in TREAT core ¾ section view
Secondary containment "can" visible

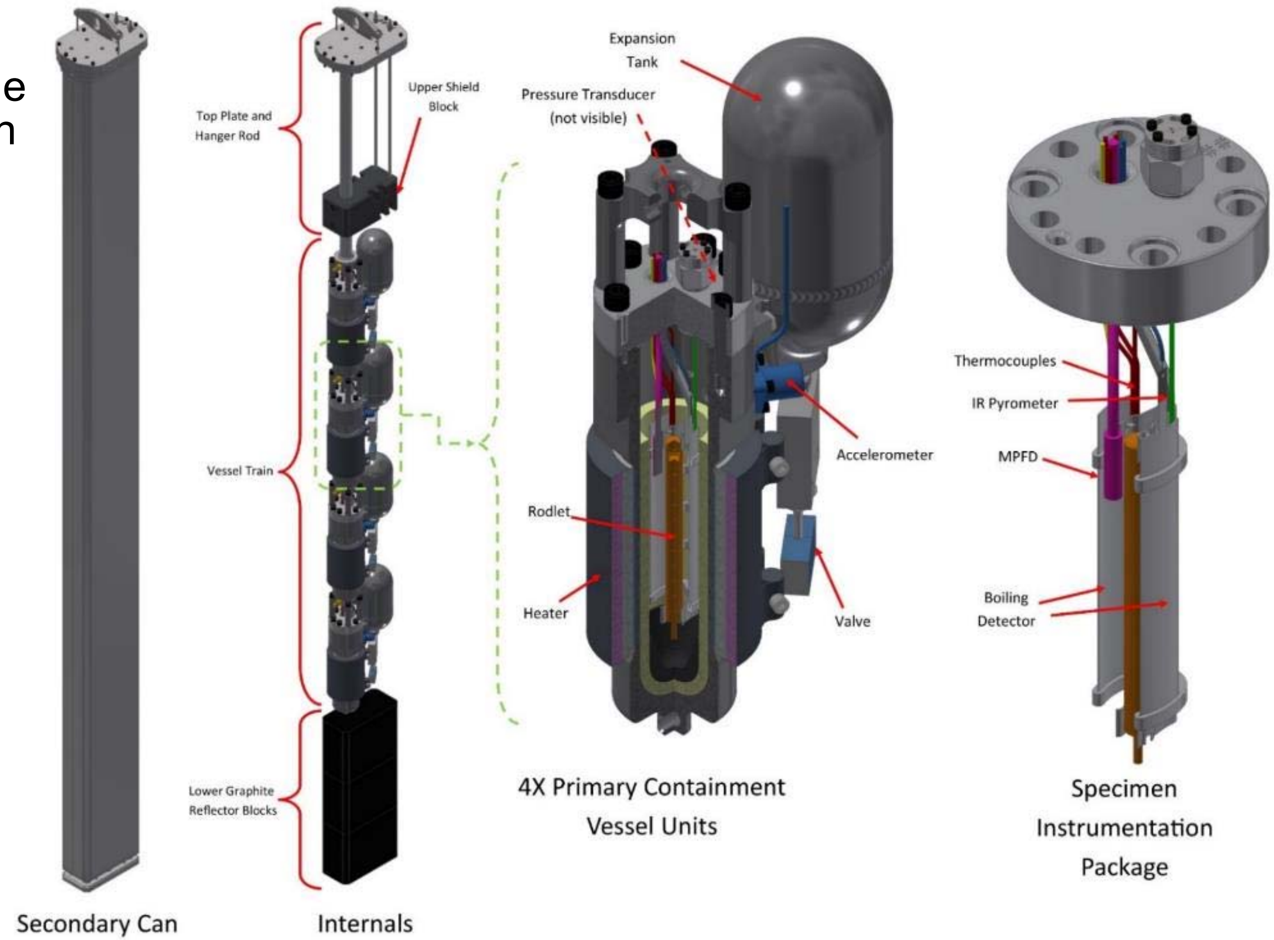
Multi-SERTTA

Multi-SERTTA

- Impressive instrument array, despite compact geometry
- Specimen instrument package modular, simplifies adaptation for different tests

1 of 4 fabricated prototype vessels (welding to be performed shortly)

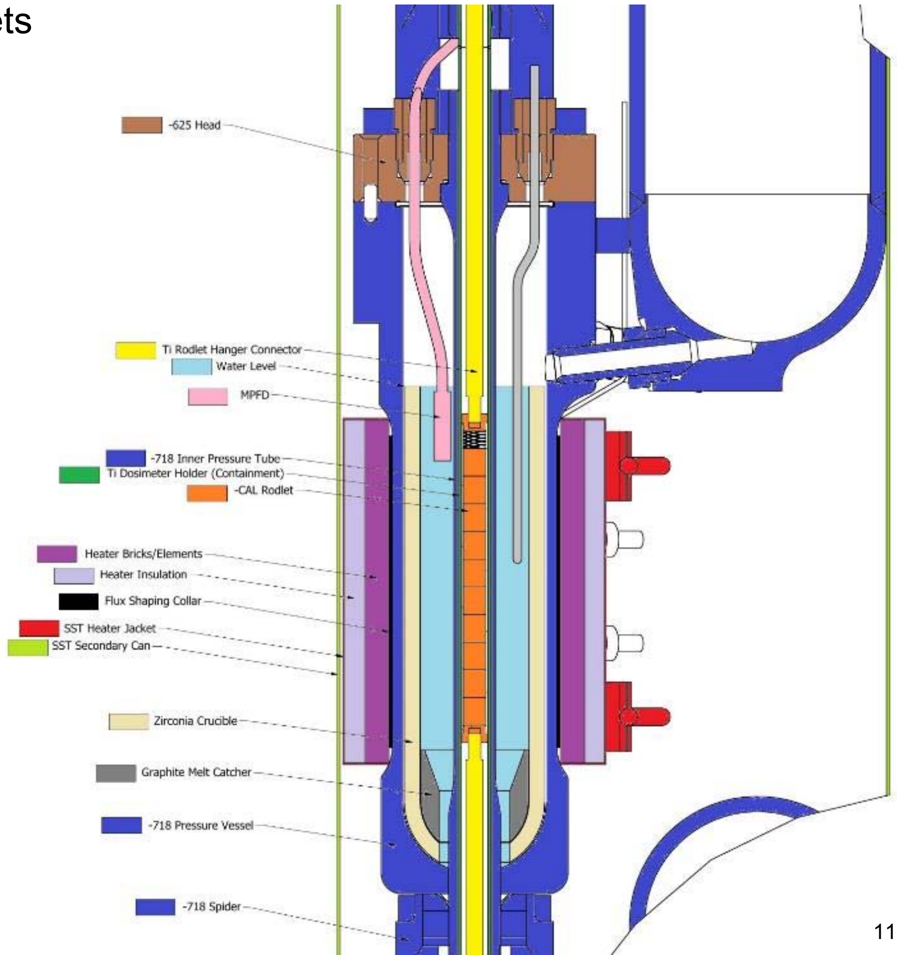
Crane-Suspended Handling Mockup in Front of Reactor



- Current efforts to construct and test a full scale prototype

Multi-SERTTA-CAL

- Multi-SERTTA nuclear equivalent calibration (-CAL) vehicle recently designed
- Will precede ATF-3-1 transients in Multi-SERTTA to measure:
  - Steady state power coupling factor (PCF) on uranium wires
  - Transient PCF on uranium wires to compute transient correction factor (TCF)
  - Steady state PCF on nuclear-equivalent -CAL rodlets
- First-of-a-kind -CAL vehicle
  - Fissionable dosimeters surrounded by hot pressurized water
  - Easily extracted through dry well for gamma counting and radiochemistry
  - Like Multi-SERTTA, each vessel surrounded by different flux collar to equilibrate PCF
- First-of-a-kind transient for TREAT
  - Prompt pulse with fast clip to minimize pulse width (transient rods out and back in again)
  - Could potentially measure a different TCF for each vessel
  - More about pulse width later…
- Whole -CAL campaign essential for Multi-SERTTA final transient approvals
  - One of the most interesting transient physics experiments to date *(adventurous bench-markers rejoice!)*



MARCH

Imagine an irradiation vehicle capability based around this thought experiment:

What would you do if a <u>(insert lab instrument of choice)</u> was surrounded by a nuclear reactor?

- What if that reactor could achieve practically any flux level?
- What if that reactor could perform practically any power history?
- What if that power history could be controlled based on experiment/specimen instrumentation?
- What if that reactor could accept nearly any material including transuranics and irradiated fuel?
- What if PIE could be done within weeks of irradiation?
- What if the tests were affordable?

MARCH

- Recently funded under LDRD → Minimal Activation Retrievable Capsule Holder (MARCH)
- Small samples, brief irradiations, and low-activation hardware materials
  - Post-irradiation examination (PIE) within weeks of test
  - Simplified post-test shipment, enables glove-box PIE (depending on specimen composition)
- Ditches baggage of high-pressure & liquid-coolant to emphasize cost-effective separate-effects or screening tests
- Heater module capable of 700°C
  - Heat treatment studies in the presence of neutron bombardment
- Ease in instrument penetration
  - General purpose location for instrument testing
  - High potential for in-situ metrology and thermo-mechanical properties measurements
- Accepts fuel (including Pu) size from TEM disc to 15cm rodlet
- Reduced cost of irradiation
  - Broadly applicable experiment safety envelope
  - Mostly reusable hardware with off-the-shelf consumables
- The backbone for TREAT-irradiation academic proposals

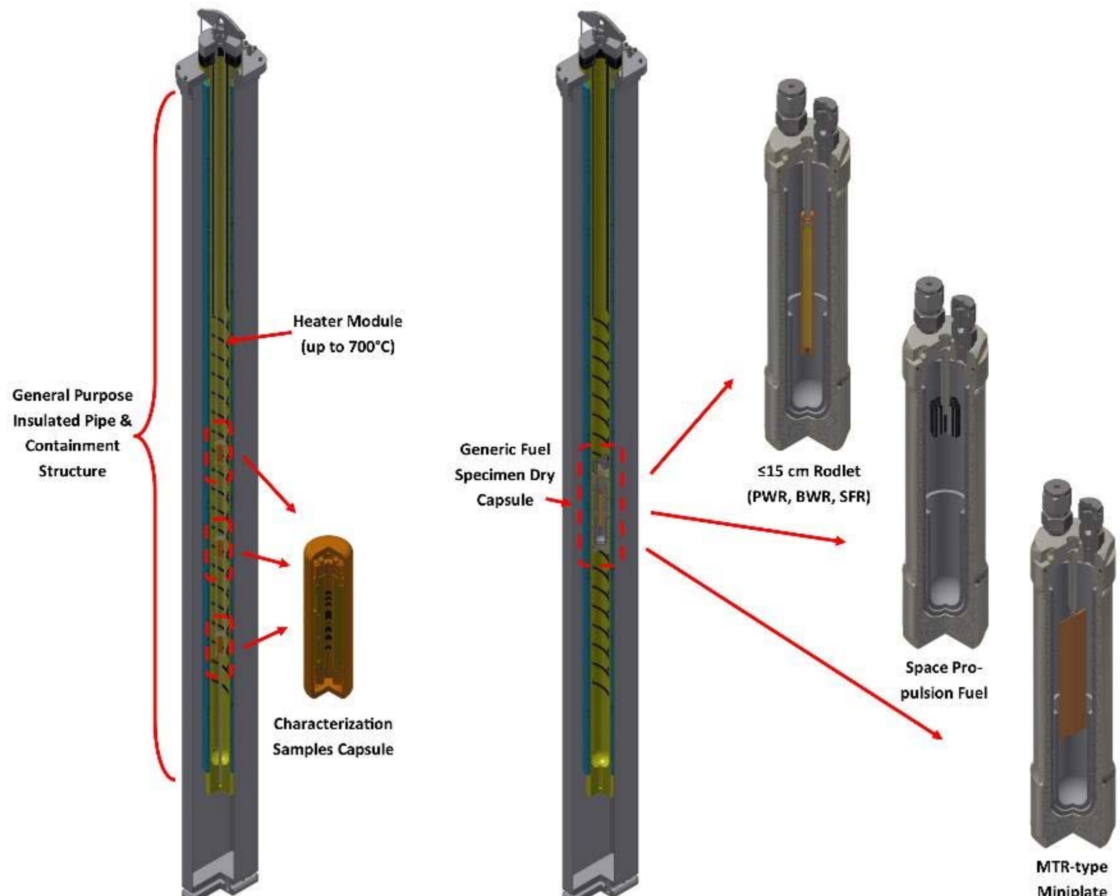


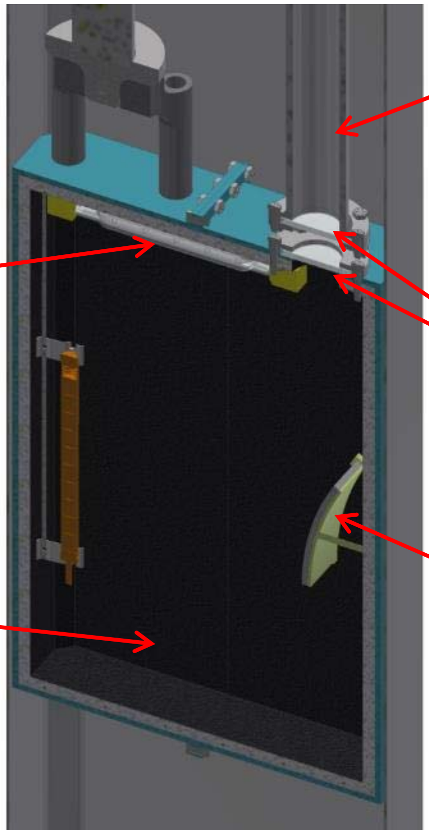
Image courtesy of C. Baker

Other Future Experiment Capabilities

RETINA

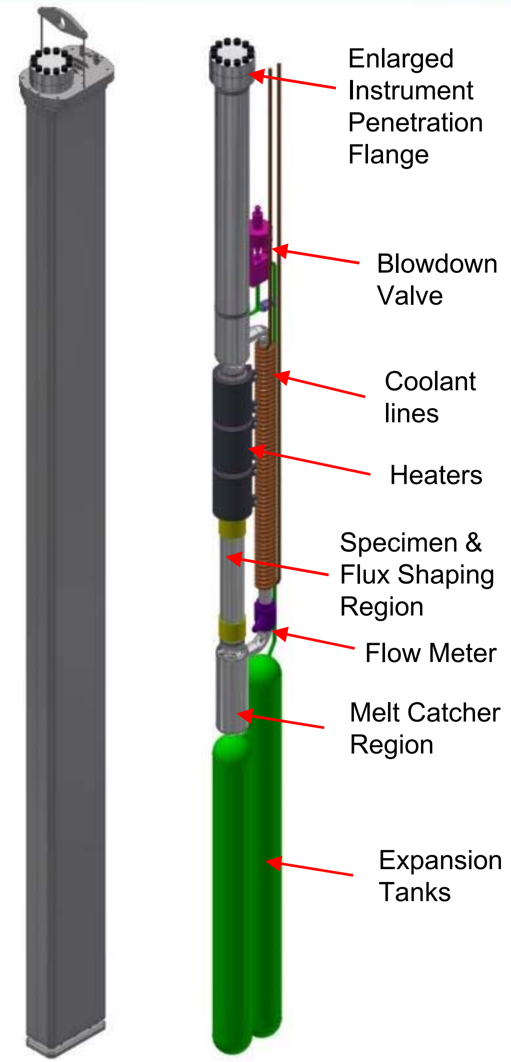
- Reactor Experiment for Transient Imaging of simulated Nuclear Accidents (RETINA)
  - High-speed video for real-time imaging of fuel performance during transients
  - Also facilitates access for optical fiber-based measurements
- Potential capabilities:
  - High speed IR video
  - Stereoscopic 3D video
  - Speckle pattern interferometry
  - Laser metrology

RETINA (concept only)



Super-SERTTA

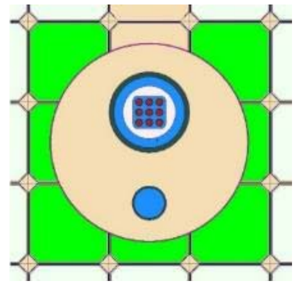
- Super-SERTTA will follow for enhanced data capabilities
  - Especially needed for pre-irradiated specimens
  - One rodlet, up to 1.2m fueled length
  - Geometry facilitates increased instrumentation and hot cell assembly
  - Increased energy capacity (enables shorter period → more prototypic HZP-RIA pulse width)
  - Blowdown capability for LOCA simulation
- Enhanced natural circulation pre-transient
  - Enables heat balance power calibration (improves accuracy in high burnup fuel energy deposition)
  - Not full forced convection, but more stable boundary condition for steady state heat generation
    - *Helps establish more-prototypic fuel temperatures prior to accident simulation (e.g. HFP-RIA, LOCA)*
  - Stepping stone to forced-convection loop, but enables form factor of Mk-series sodium loop
    - *Facilitates timely deployment by using existing infrastructure/hardware*
- Detailed design in fairly near future



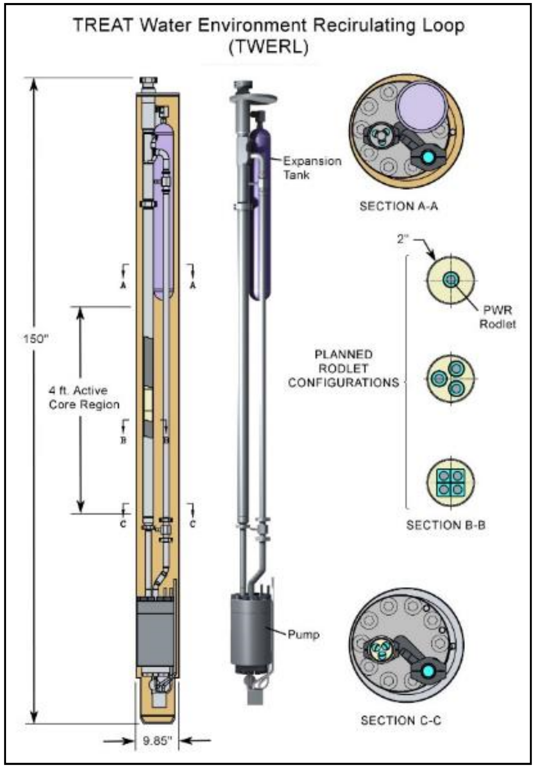
Super-SERTTA (concept only)

Future Engineering-Scale Test Capabilities

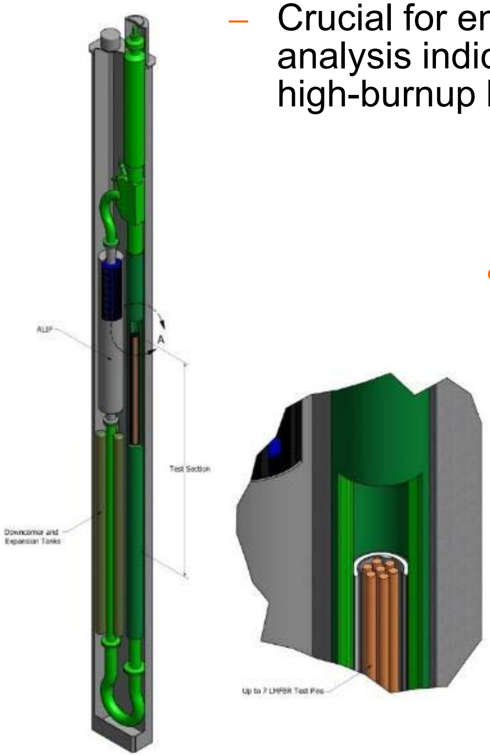
- Full forced-convection PWR loop capability to be established
  - TREAT Water Environment Recirculating Loop (TWERL)
  - Most representative boundary conditions for high-value tests
  - Crucial for engineering scale tests, nuclear analysis indicates TREAT can drive 9-rod high-burnup bundle



MCNP Rendering of 9-rod "Super-TWERL"



- Sodium capsules and loop capabilities to be reestablished
  - Update from historic designs, leveraging advances in materials, instruments, and modeling
  - Modernized to meet current needs of liquid metal-cooled reactor community



Modern CAD rendering of historic Mk-series sodium loop with 7-pin bundle