Update on TREAT Restart and Experimental Design Preparations

OSU IRP Meeting November 2017

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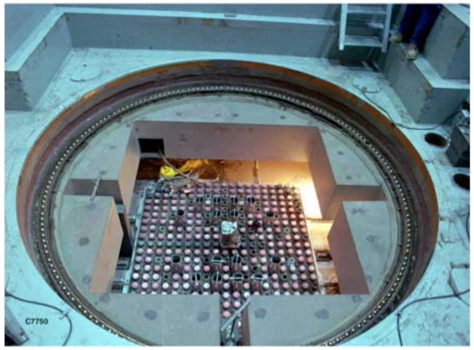

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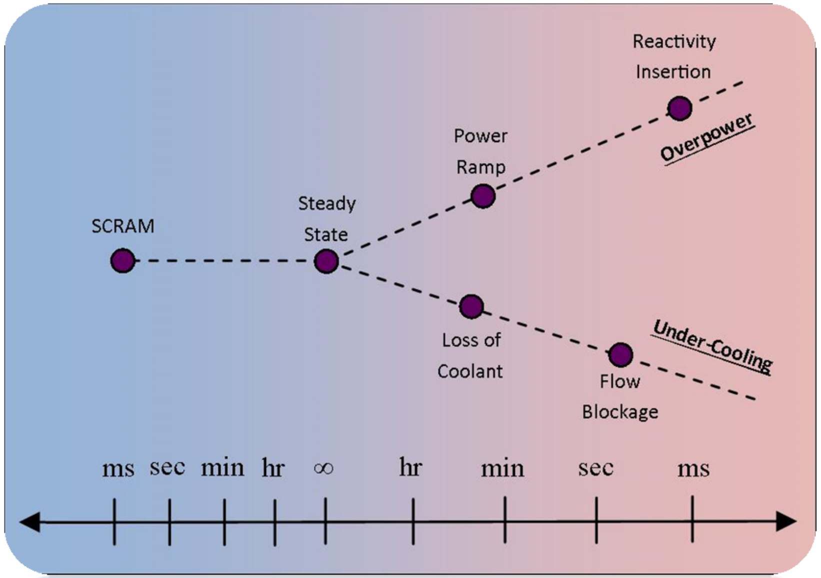
Idaho National Laboratory

Introduction

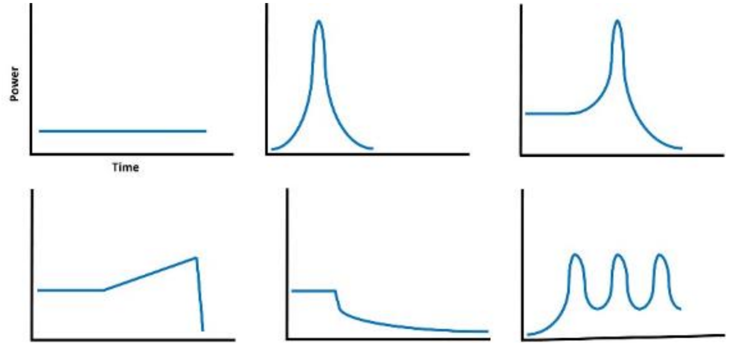
- Nuclear transient testing uses fission heating to test nuclear fuels in power-cooling mismatch conditions
  - Demonstrate performance phenomena and limits for fuel development and reactor design
  - Show consequences of hypothetical conditions for licensing



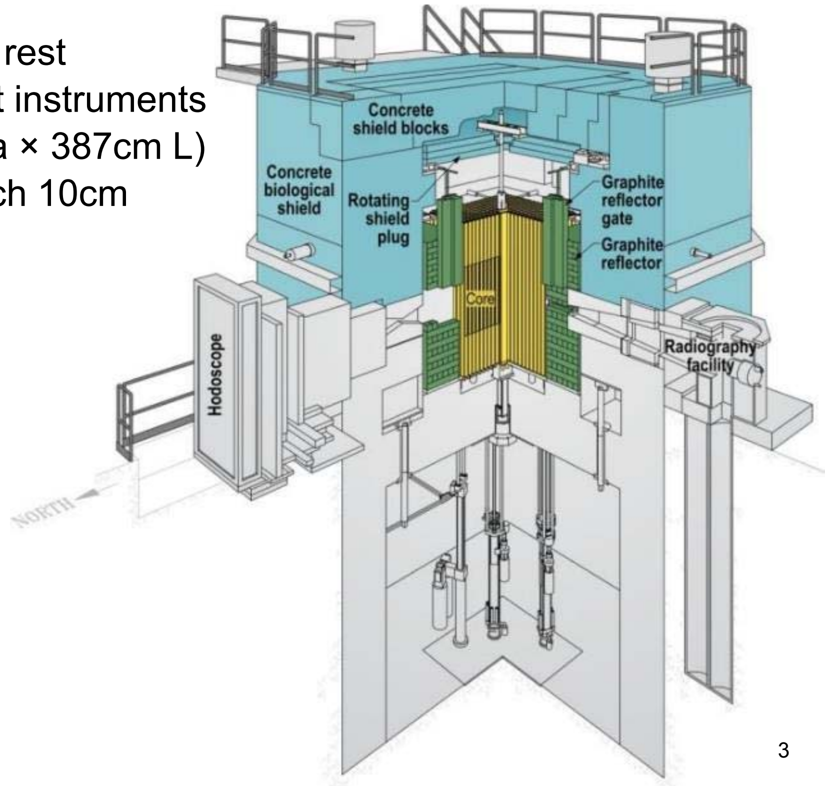
- Development of Accident Tolerant Fuels (ATF) and other nuclear fuels will require transient testing
- Imminent resumption of operations at the Transient Reactor Test facility (TREAT) at the Idaho National Laboratory is planned for this testing
- Development of irradiation devices and capabilities is underway
- Modern transient tests will differ from historic approach primarily due to advances in modeling and simulation

Introduction

- Transient Reactor Test (TREAT) resuming operations **[very soon]** in order to support fuel safety testing and other transient science
- Zircaloy-clad graphite/fuel blocks comprise core, cooled by air blowers
  - 120 kW steady state, 19 GW peak in pulse mode
  - Virtually any power history possible within 2500 MJ max core transient energy
  - No reactor pressure vessel/containment, facilitates in-core instrumentation
- 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

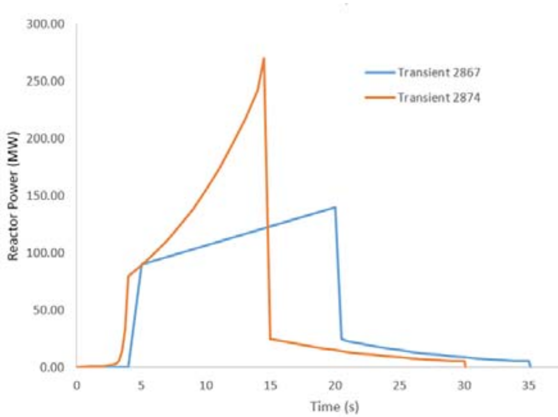


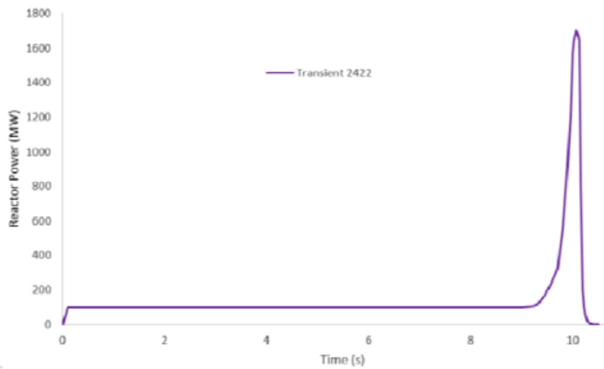
Example Transient Shapes

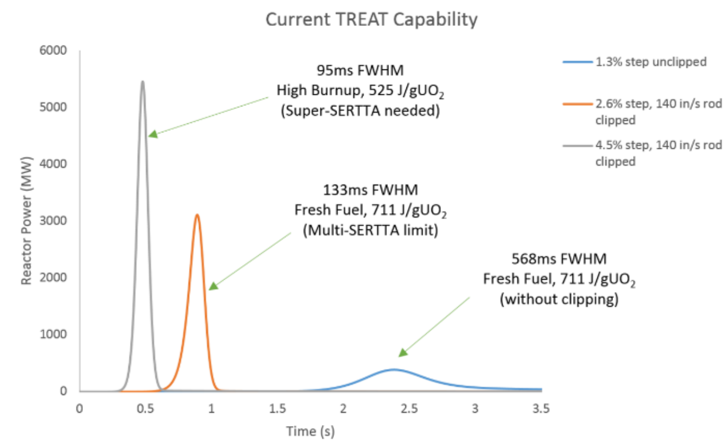


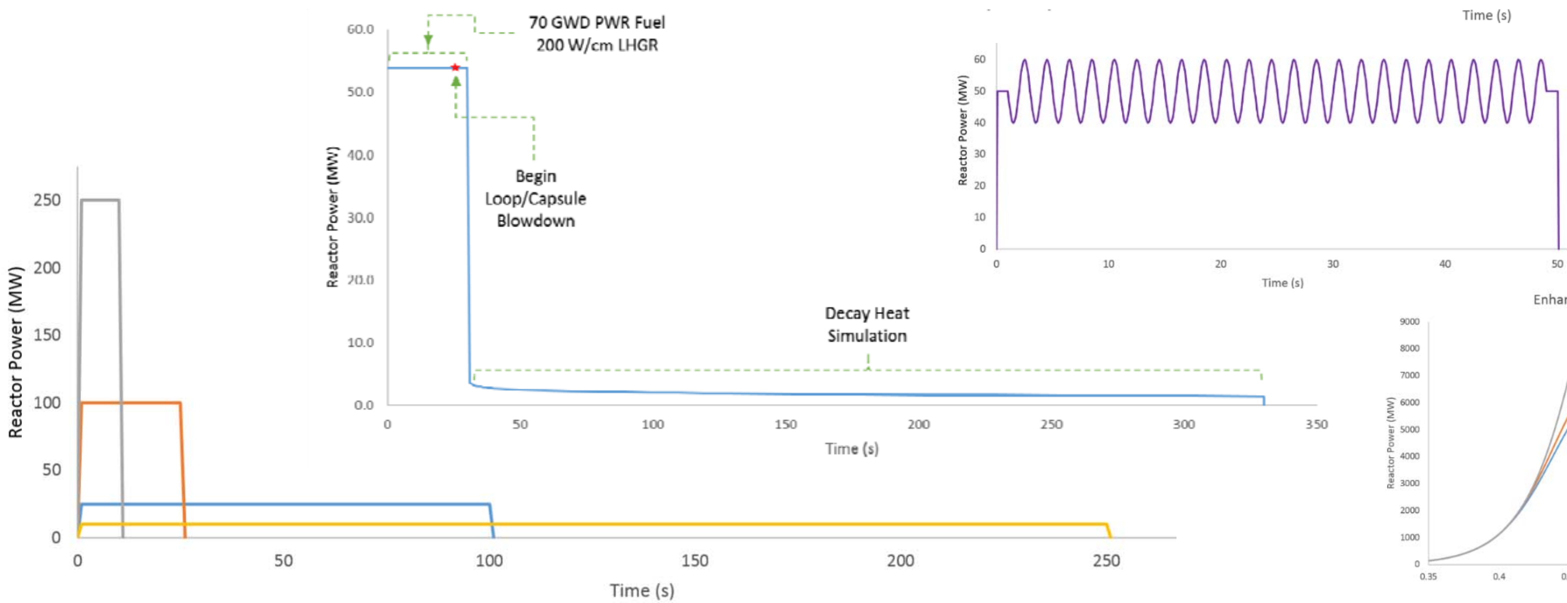
Transient Shaping

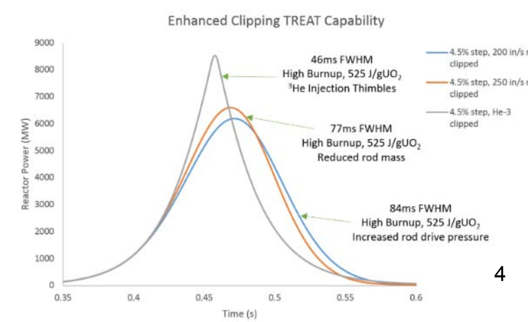
- TREAT is a transient reactor, not just a pulse reactor
- Graphite heat sink, nimble control rod system → flexible power maneuvers





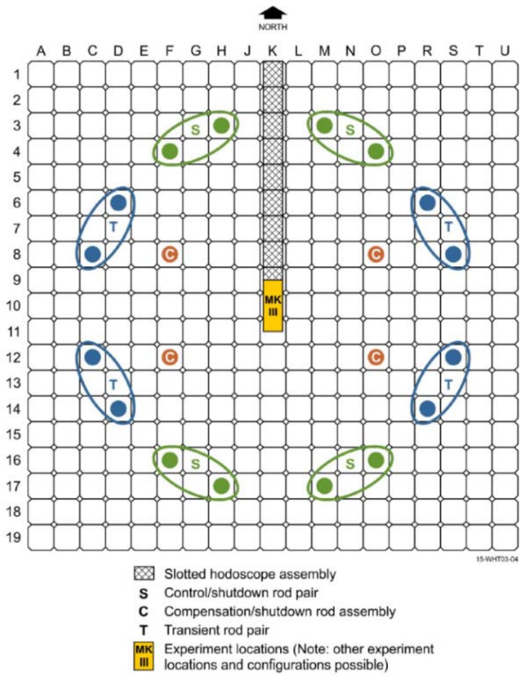






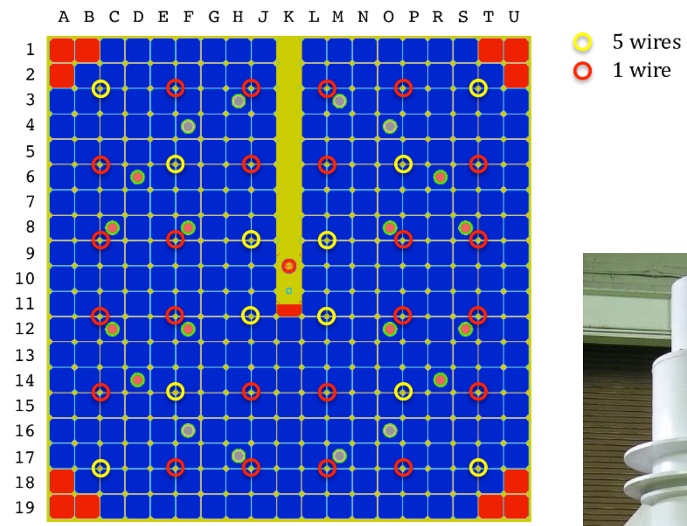
Status of TREAT Restart

- Major facility refurbishments complete
- Readiness assessments complete
  - Authorization for restart provided prior to end of FY17
- M8-CAL remains in core, configuration neutronically equivalent to M8 half-slotted core
  - Borated assemblies removed from core, replaced with fuel
  - Reconfiguring instrumented fuel assemblies into desired locations
- First critical planned for mid November



Status of TREAT Experiment Support

- Dosimeter holder design and fabrication underway
  - Will enable spatial/spectral mapping in core
- Gamma spec equipment received
  - Needed to measure dosimeters
- Gas control system preparations underway
  - Needed to service TREAT experiment vehicles
- Experiment DAS Equipment Received
  - To be installed at TREAT late spring 2018
- HFEF-15 cask reactivation
  - Inspections complete, maintenance underway
  - Will be needed for highly radioactive experiments in 2-3 years (TREAT to HFEF transport)
- HFEF complete infrastructure evaluation and cost estimate
  - First step to establishing capabilities for handling highly radioactive experiments



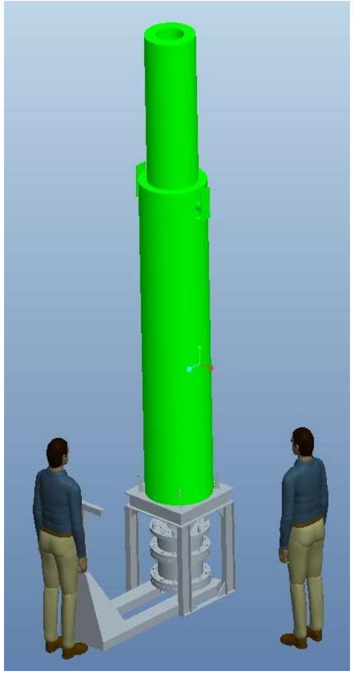
Example Core Dosimeter Map
Image Courtesy of J. Parry

HFEF-15 Cask
Image Courtesy of J. Angell

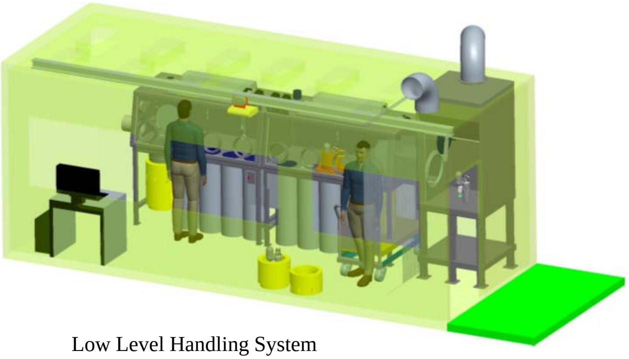
Status of TREAT Experiment Support

- Limited view hodoscope installed
  - 96 detectors adequate for near-term capsule tests
- Low-level disassembly station design specs written, requisition forthcoming
  - Slightly-shielded glovebox for basic PIE and sample breakdown
  - Perfect for slightly-radioactive fresh-fuel capsule tests
- TREAT disassembly equipment design underway
  - Will support capsule extraction at TREAT
  - Needed prior to shipment to low level handling system or other PIE facility

96 Refurbished Hodoscope Detectors
Installed at TREAT
Image Courtesy of D. Chichester



Capsule Disassembly Design
Image Courtesy of C. Knight & S. Swanson



Low Level Handling System
Image Courtesy of C. Knight & S. Swanson

Overview of TREAT Near Term Schedule

FY18 Q1 | FY18 Q2 | FY18 Q3 | FY18 Q4 | FY19

First Critical
-

Restart Plan
-New Core Config.
-Worth Curves
-Steady State
-Temp. Lim. Transients
-Final Operator Quals
-Hodoscope Data for Core

Physics Tests
-Worth of various fuel assemblies
-Core temperature mapping
-N. radiography measurements

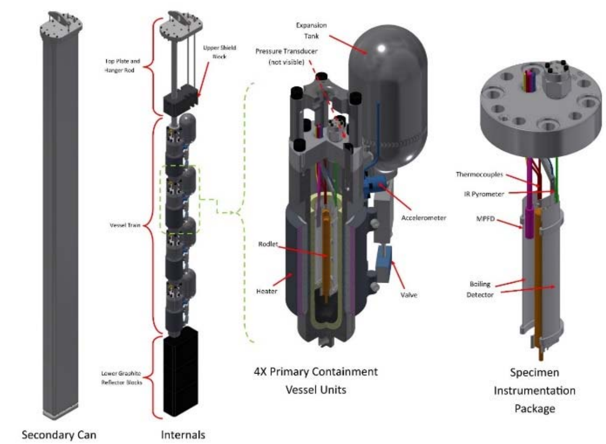
ATF Tran. Rx Tests
-Perform M-SERTTA's transients with M8-CAL in core
-2.6% step with fast clip
-2% step unclipped

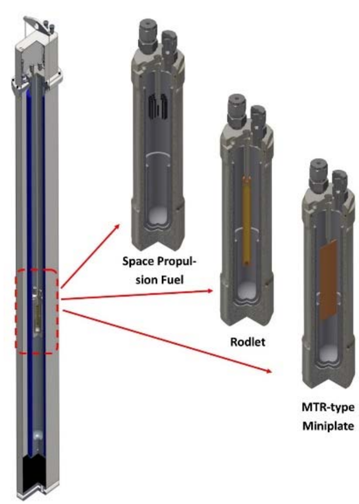
IRP
-Opportunity for testing instruments under this IRP

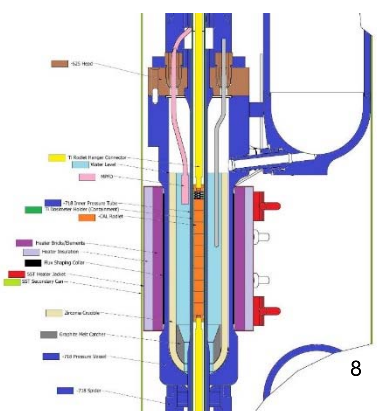
Fueled Tests in MARCH
-ATF in SETH
-CINDI
-NEET Inst. in TIMMIE
-THOR
(probably in that order)

More Physics & MARCH Tests

Multi-SERRTA-CAL



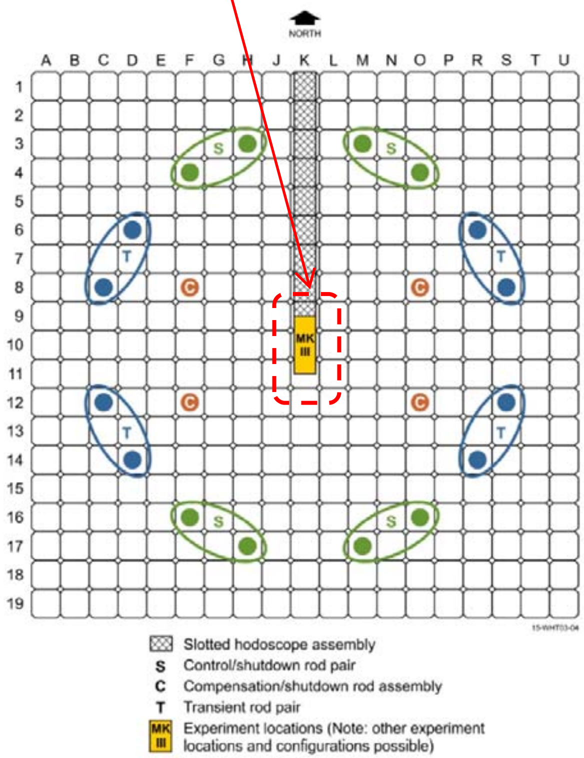




Experiment Design Status

- TREAT provides the neutrons, experiment vehicle (e.g. loop, capsule, etc.) does the rest of the work
  - Boundary conditions (heat transfer, coolant environment)
  - Specimen support and instrumentation

Insert Experiment Here
(or anywhere else really)



Current status:

- **MARCH** system (multipurpose modular capability)
  - First irradiations in Summer 2018
  - More module capabilities shortly thereafter
- **Multi-SERTTA** (PWR-condition static water, fresh rods)
  - Nuclear calibration test mid 2019
  - First fuel transient tests in 2020
- **Super-SERTTA** (PWR-condition static water, irradiated rod)
  - Conceptual design FY18, deployed ~1-2 years after Multi-SERTTA
- **TWERL** (PWR convective water, irradiated rods/bundles)
  - Working some potential funding avenues, stay tuned
- **RETINA** (Video-capable vehicle)
  - Working some potential funding avenues, stay tuned
- **Mk-IV Sodium Loop** (Convective liquid metal, irradiated pins/bundles)
  - Working some potential funding avenues, stay tuned

The MARCH System

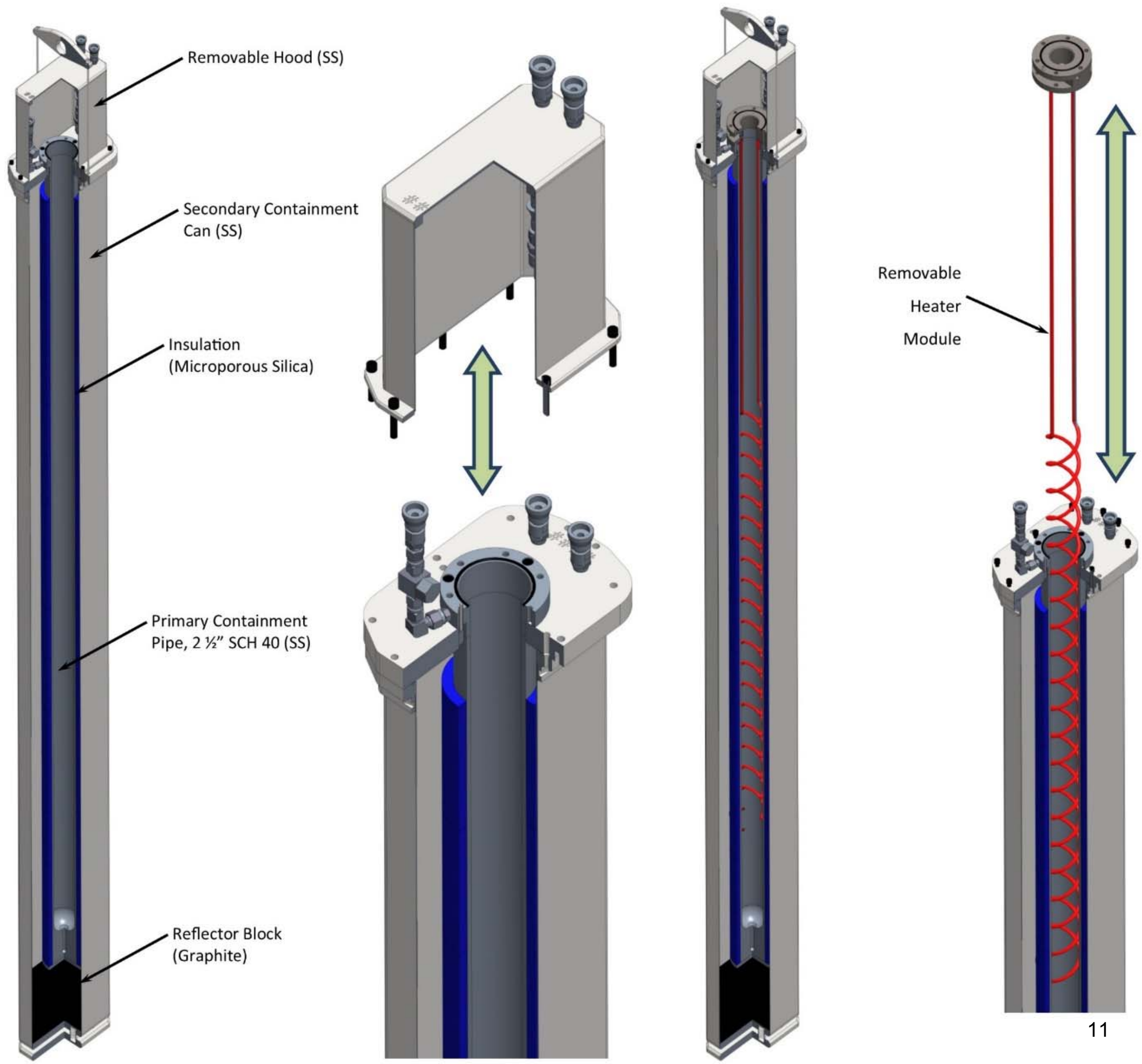
- Initially funded as FY17 LDRD → Minimal Activation Retrievable Capsule Holder (MARCH)
- Small samples, brief irradiations, and low-activation hardware materials
  - Post-irradiation examination (PIE) in gloveboxes within weeks of test
- Small fuel specimens (“rodlet” scale or smaller)
- Reduced cost of irradiation
  - Broadly applicable experiment safety envelope
  - Mostly reusable hardware with off-the-shelf consumables, modular design philosophy
- FY18 LDRD funding will be devoted entirely to deploying a MARMOT-validation experiment
- At least three programs branching off from the LDRD to develop their own modules in FY18

It’s also an acronym party,
so get ready!

BUSTER Module

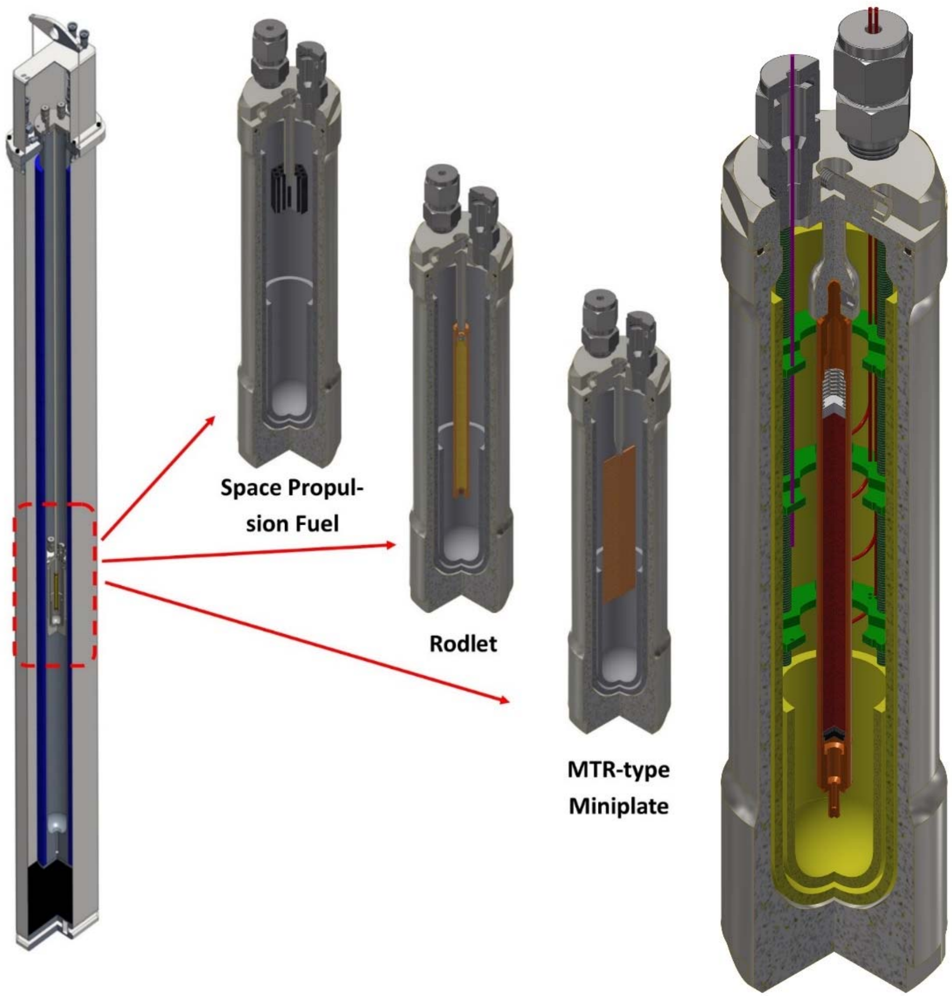
- Broad Use Specimen Transient Experiment Rig (BUSTER)
- Simple SST structure with reactor interfaces
- Can operate in single or double containment mode (Pu specimens requires double containment)
- Removable heater Module capable of 700°C electrical preheat
- Bears safety containment burden

Affectionately named since it will bust the myth that all irradiation tests are expensive



SETH Module

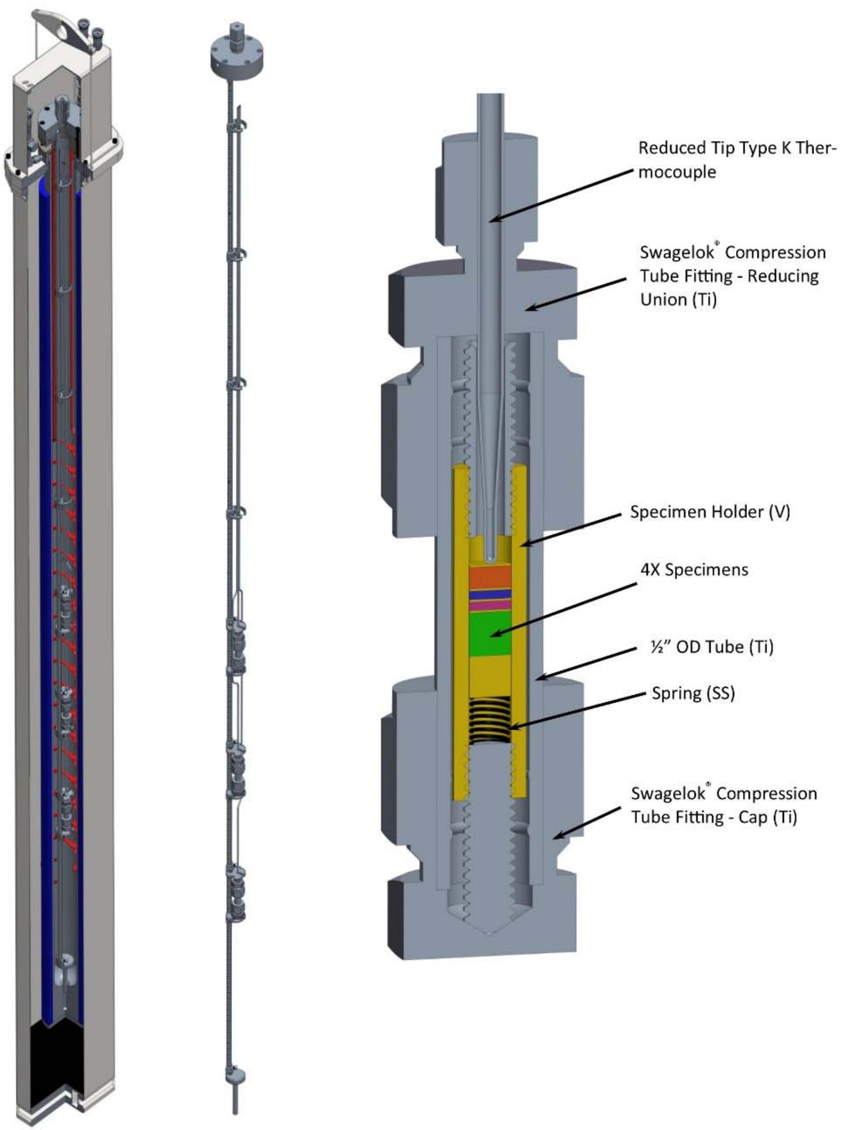
- Separate Effects Test Holder (SETH)
  - Large enough for "engineering" scale fuel irradiations
  - Displaces heater module (starting conditions 20°C, 1.0 atm inert gas)
- Practically adiabatic in fast transient
  - Melt progression and phenomena identification
  - Stable boundary condition facilitates separate effect and semi-integral scale tests
- Easy, affordable, testing
  - Conax seals, 8X 1mm leads into capsule
  - Reusable capsule, off-the-shelf consumables
  - Configurable instrument supports
- First fueled tests to be performed in SETH summer 2018
  - ATF program, starting with UO2 in Zry baseline rodlets
  - USU IRP to use SETH shortly thereafter
- Potential phase 2 adaptations
  - Pre-heated version
  - 20°C, 1.0 atm water filled version

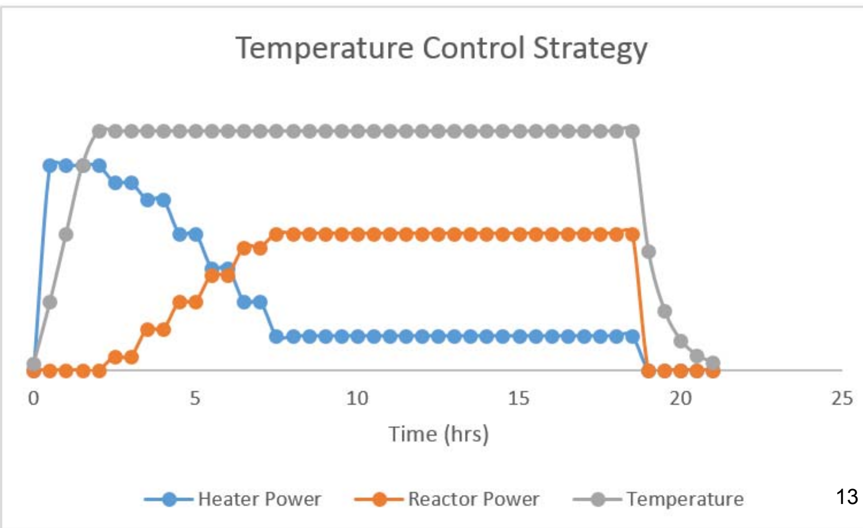


SETH Module for
ATF FY18 Tests

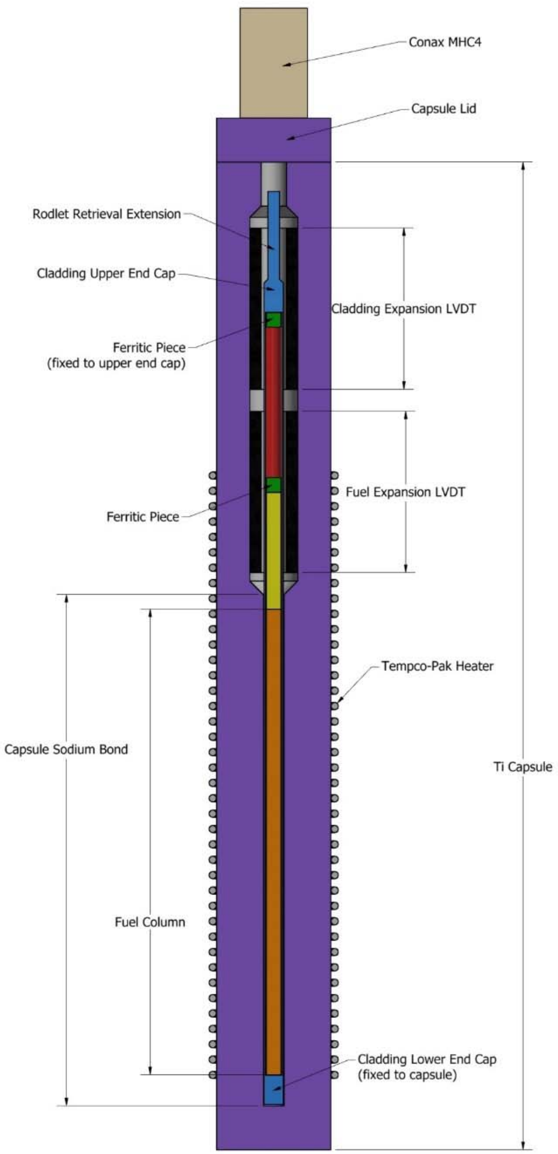
CINDI Module

- Characterization-scale Instrumented Neutron Dose Irradiation module (CINDI)
- 3X Swagelok capsules per train in heater module, designed for Pu-bearing fuels
- Enables high temperature irradiation of 5mm diameter disc-like samples
- Supports pre and post characterization for lower length scale model development
- First irradiations planned in late FY18
- **Don't miss the most-recent CINR call (NEAMS-2)**



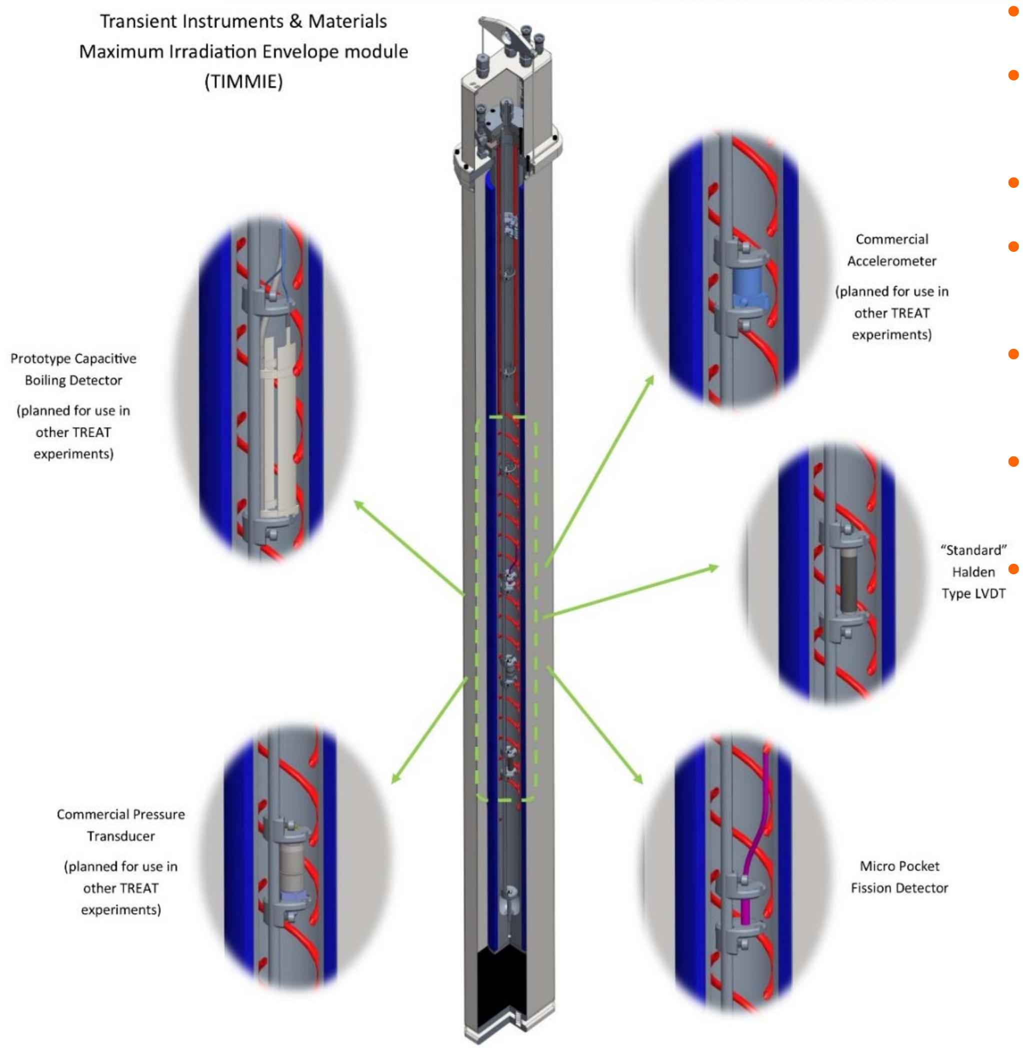


THOR Module

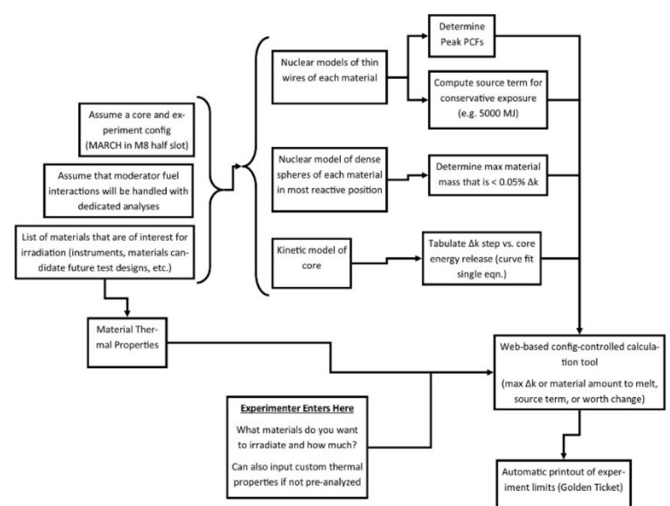


- Temperature Heat-sink Overpower Response module (THOR)
- Thick-walled capsule absorbs energy in longer transients
- Liquid metal bond to specimen
- Doesn’t fit in heater module, but small cable heater melts metal bond and elevates pre-transient temperature (~100-400°C)
- Simulates fuel temperature response during early stages of overpower transients
- Larger specimen and longer exposure, more radioactive than most MARCH modules, designed for disassembly in small INL hot cell

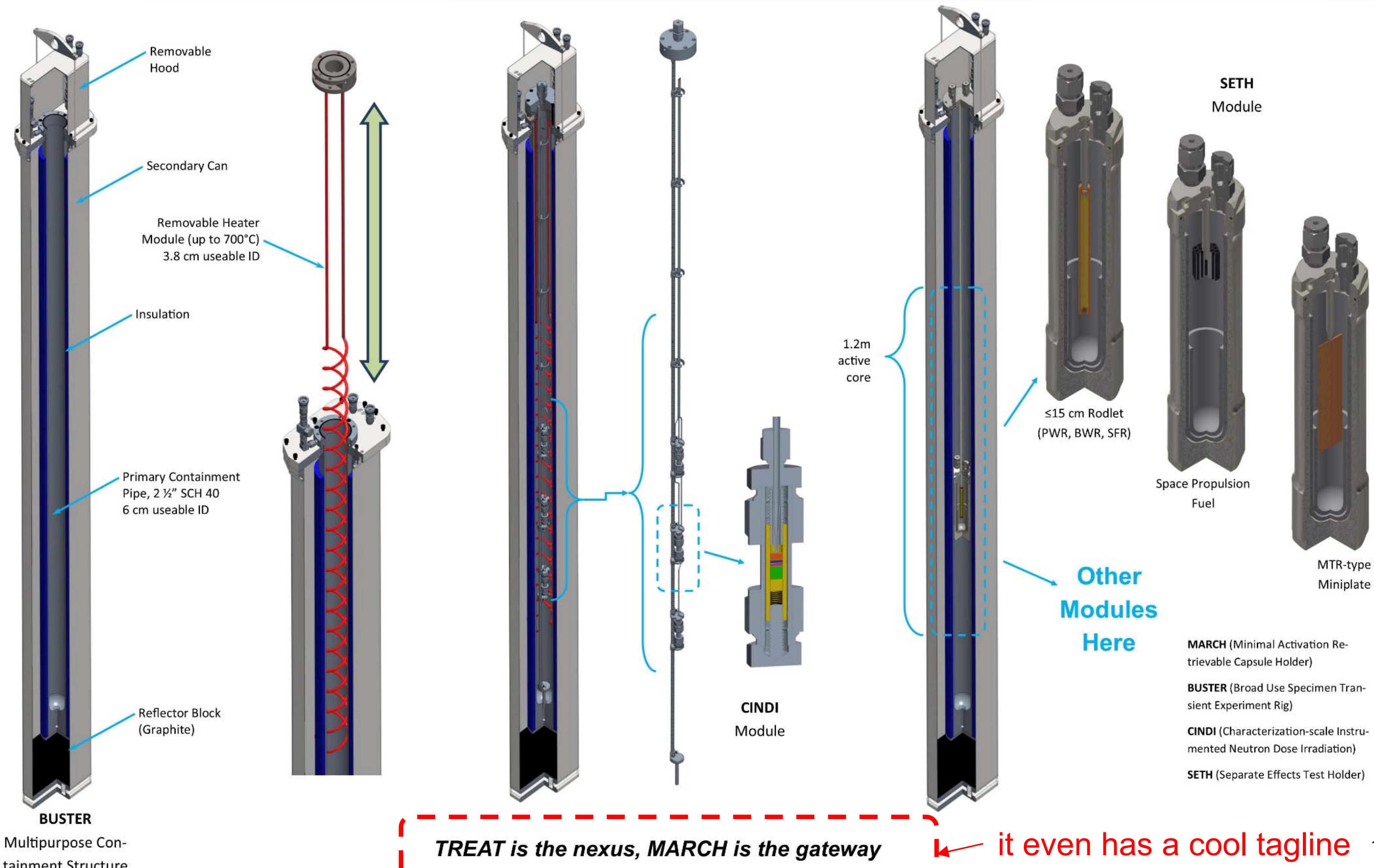
TIMMIE Module



- Adjustable instrument/material holding rack
- Fits in heater module for high temperature irradiation
- Wire management and penetration features
- Debris/melt catcher features permit instrument destruction
- Paired with enveloping analysis tool for cheap & easy safety permission
- Targeted for NEET instrument in-pile instrument program irradiations in early FY19
- **Don't miss the most-recent CINR call (NSUF-1.1, 1.2)**



The MARCH System



MARCH (Minimal Activation Retrievable Capsule Holder)

BUSTER (Broad Use Specimen Transient Experiment Rig)

CINDI (Characterization-scale Instrumented Neutron Dose Irradiation)

SETH (Separate Effects Test Holder)

TREAT is the nexus, MARCH is the gateway

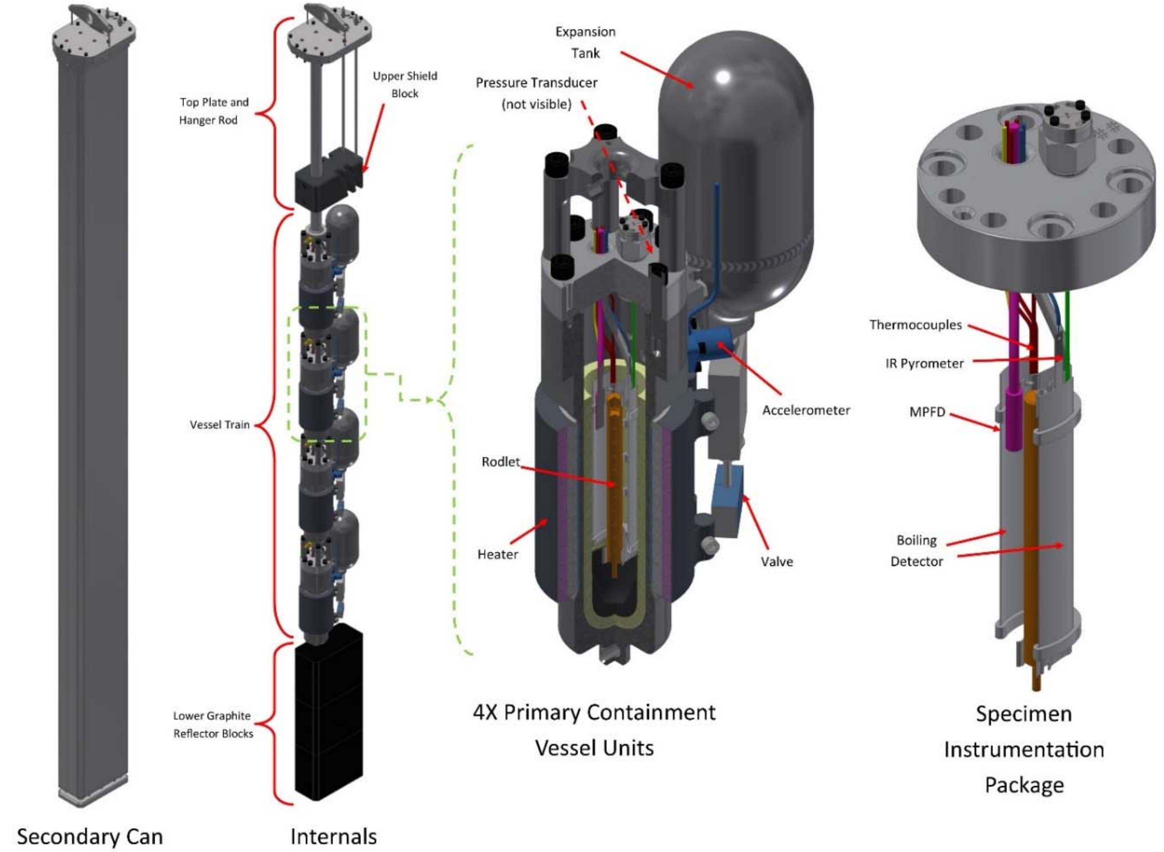
it even has a cool tagline

Multi-SERTTA

- Impressive instrument array (including fast-response temperature and boiling detection)
- 4X vessels filled with one 10-pellet PWR rodlet each
- Filled with static PWR-condition water (280C, 16MPa)

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

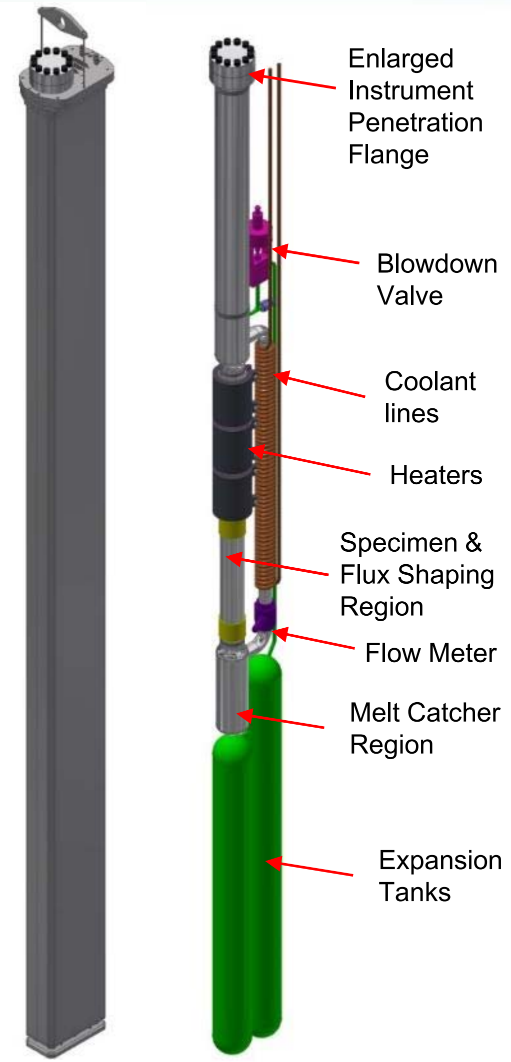
Crane-Suspended Handling Mockup in Front of Reactor



- Current efforts to prepare for construction and irradiation of a water-filled nuclear mockup in 2019

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
  - Blowdown capability for LOCA simulation
- Enhanced natural circulation pre-transient
  - Enables heat balance power calibration
  - Not full forced convection, but more stable boundary condition for steady state heat generation
  - Stepping stone to forced-convection loop, but enables form factor of historic loops
    - *Facilitates timely deployment by using existing infrastructure/hardware*
- Conceptual design in FY18

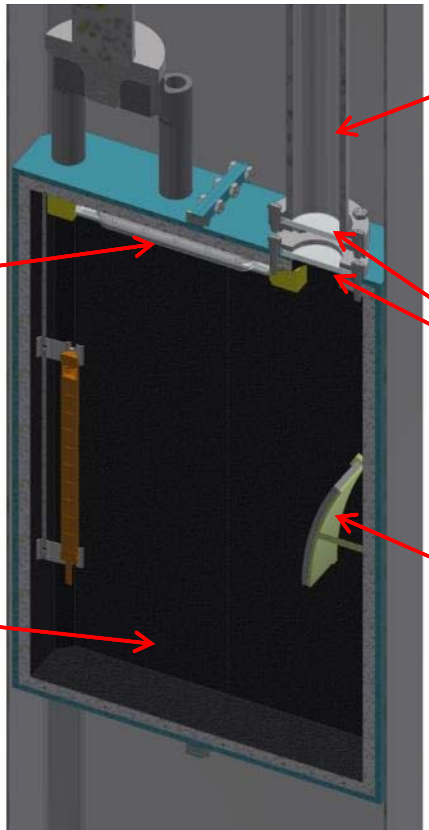


Super-SERTTA (concept only)

RETINA

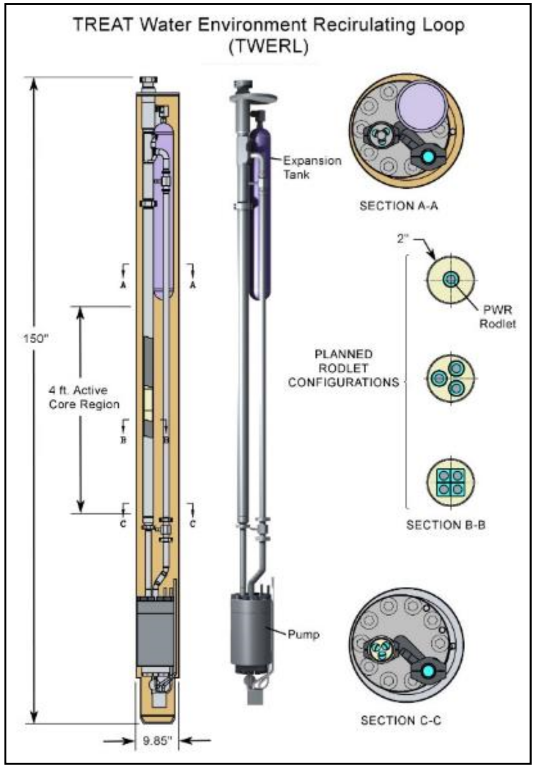
- Reactor Experiment for Transient Imaging of simulated Nuclear Accidents (RETINA)
  - High-speed video for real-time imaging of fuel performance during transients
  - Also facilitates access for optical fiber-based measurements
- Potential capabilities:
  - Transient boiling visualization
  - High speed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

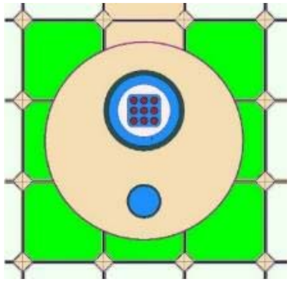
RETINA (concept only)



Future Engineering-Scale Test Capabilities

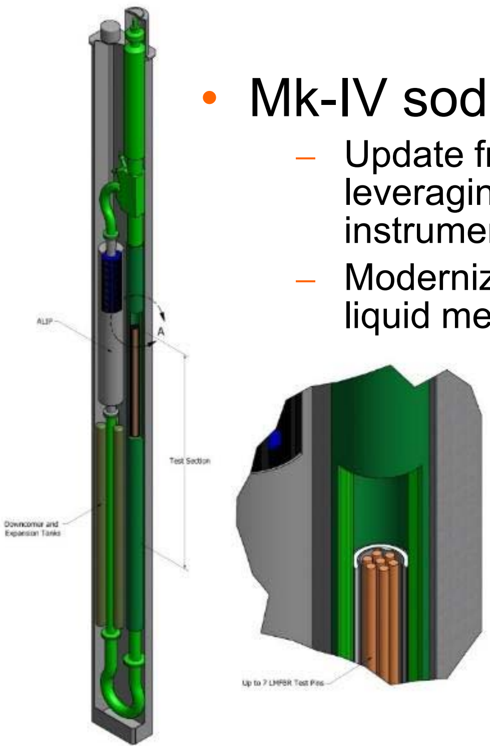
- TREAT Water Environment Recirculating Loop (TWERL)
  - Full forced-convection PWR loop capability to be established
  - Most representative boundary conditions for high-value tests
  - TREAT is capable of driving 9-rod high-burnup bundles to regulatory limits and beyond
  - Crucial for engineering scale licensing tests





MCNP Rendering of 9-rod "Super-TWERL"

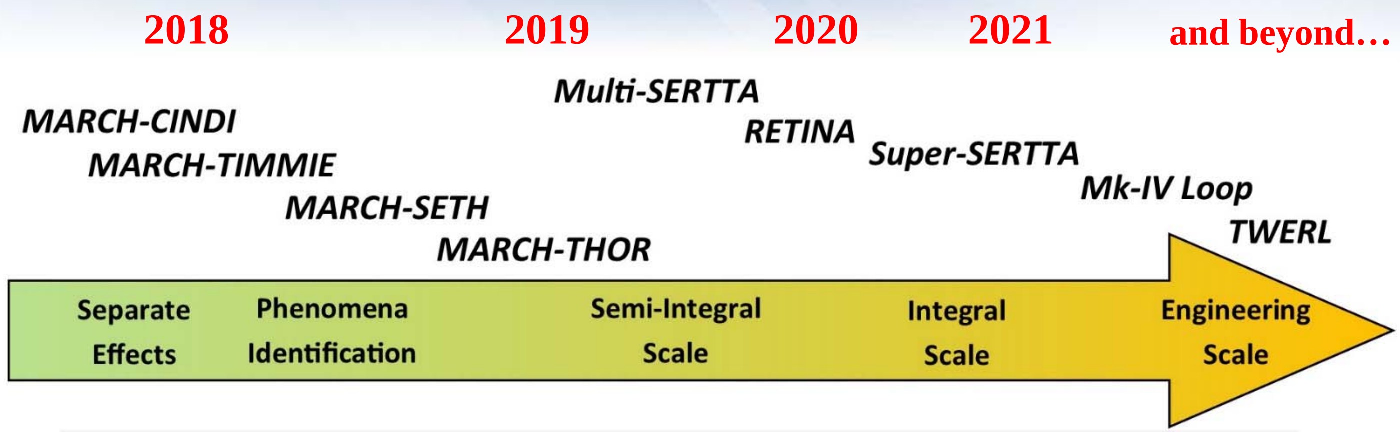
- Mk-IV sodium loop
  - Update from historic designs, leveraging advances in materials, instruments, and modeling
  - Modernized to meet current needs of liquid metal-cooled reactor community



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

- There are also serious conversations about molten salt and high temperature gas capsules/loops…

Summary



Cost to Design, Build, and Irradiate	$	$$	$$$	$$$$
Specimen/Schedule Throughput				
Cost for logistics and PIE	$ (Glovebox)	$$ (Hot cell, disassembly only)		$$$$ (Hot cell, all operations)
Specimen State	Fresh & minimally activated	Fresh, but moderately activated by transient		Pre-irradiated in another reactor
Boundary Condition Capability	Inert, stable, easy to model	Representative (e.g. static coolant or heat sink)		Prototypic (e.g. convective coolant, blowdown, etc.)
In-Situ Data Capability	Adequate Only	State of the Art		Advanced
Specimen Scale	Small and/or separated material	Sub-size fuel system sample (e.g. rodlet)		Fuel system assembly (e.g. bundle)