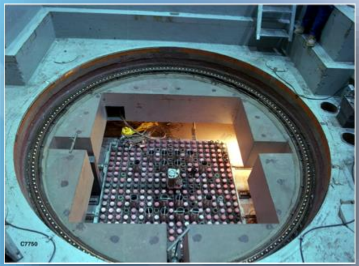


US Transient Testing Program

Dan Wachs
National Technical lead for Transient Testing
Idaho National Laboratory

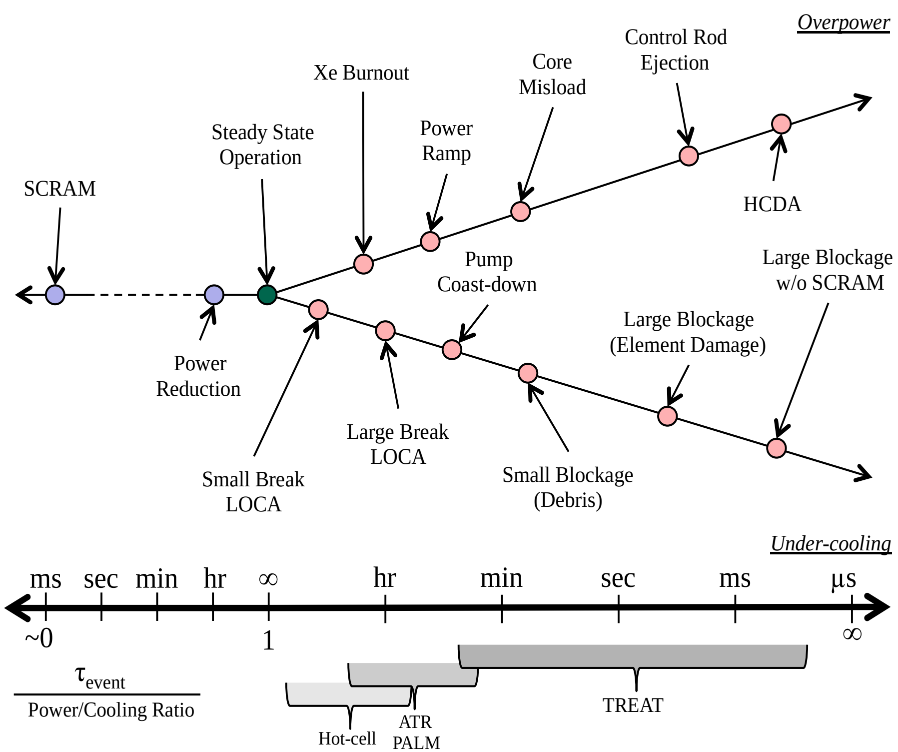
18th IGORR Meeting, Sydney, Australia
December 7, 2017

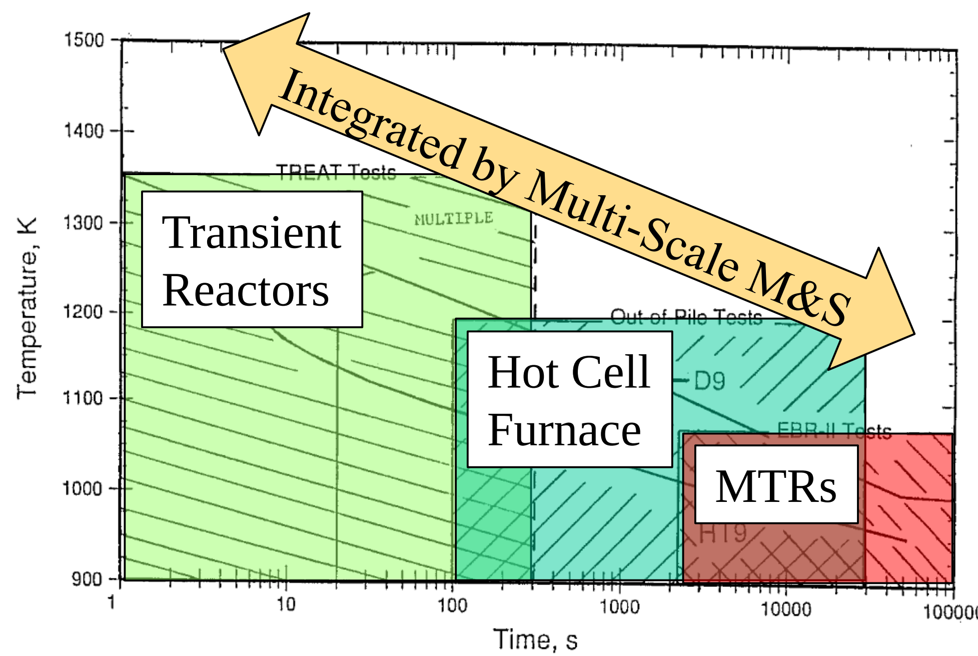
www.inl.gov

Idaho National Laboratory

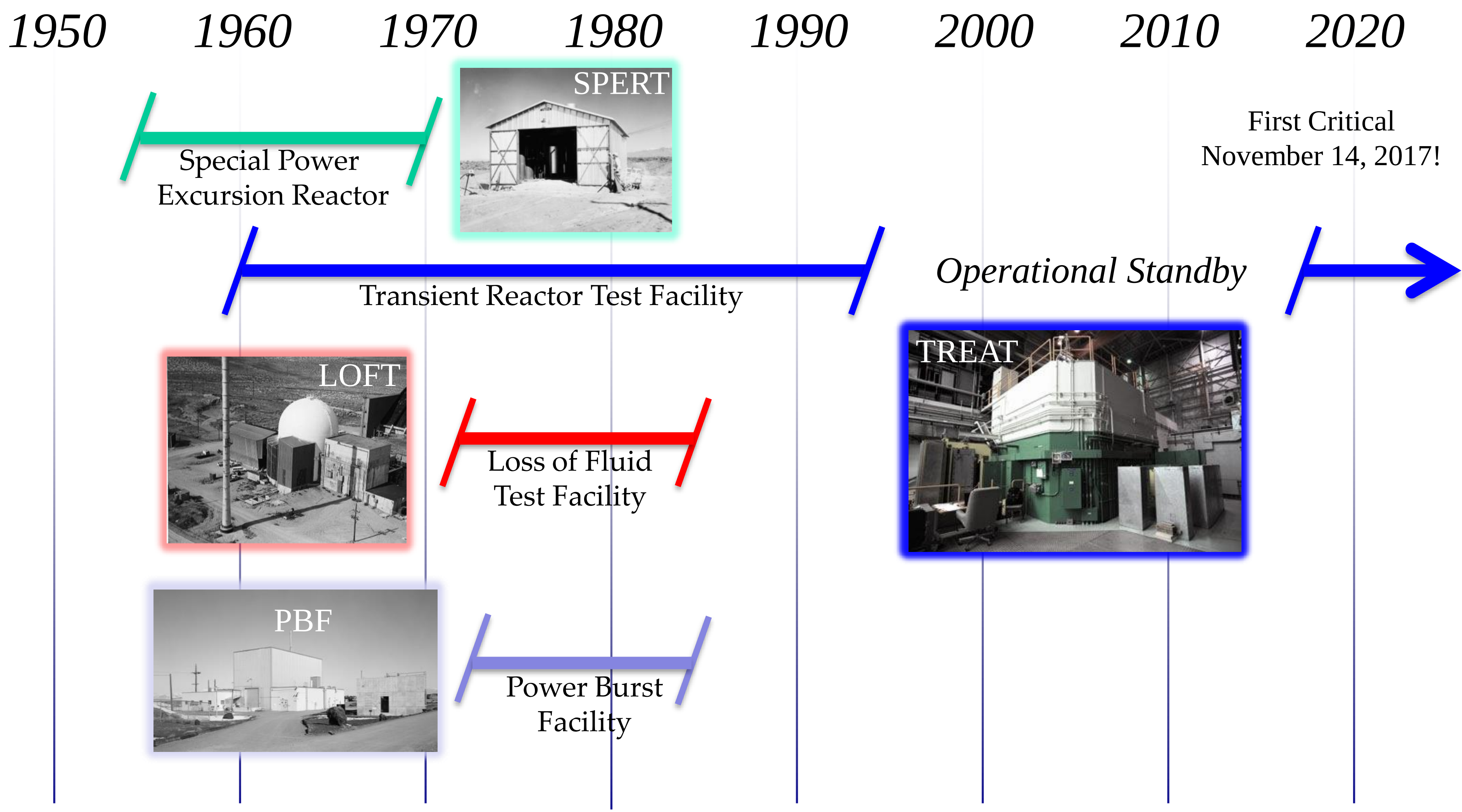
Fuel Safety Research

- **Objective:**
  Conduct the experimental activities required to help the industry describe how fuel systems respond to relevant transients (both operational and off-normal)

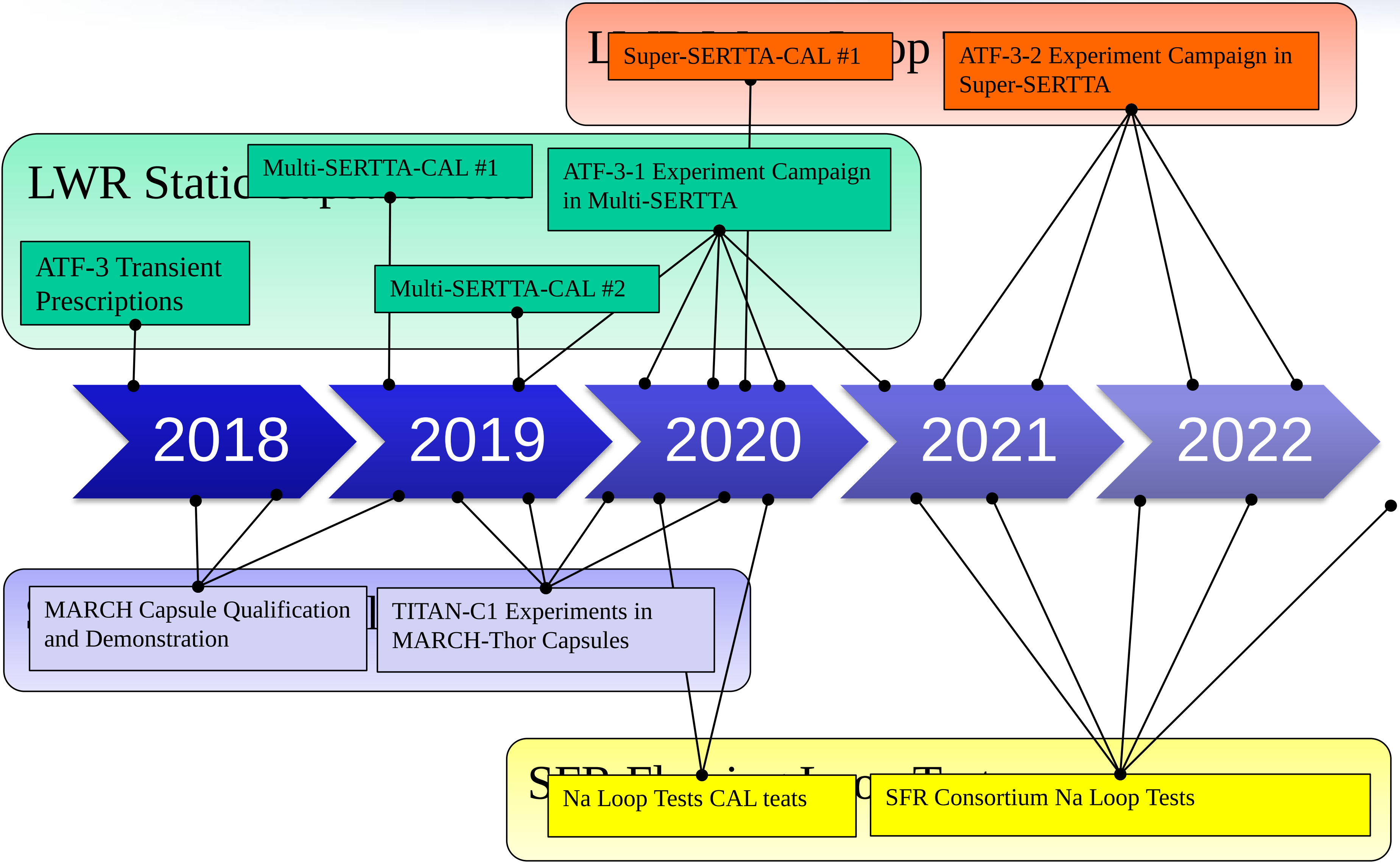




History of Fuel Safety Research at INL

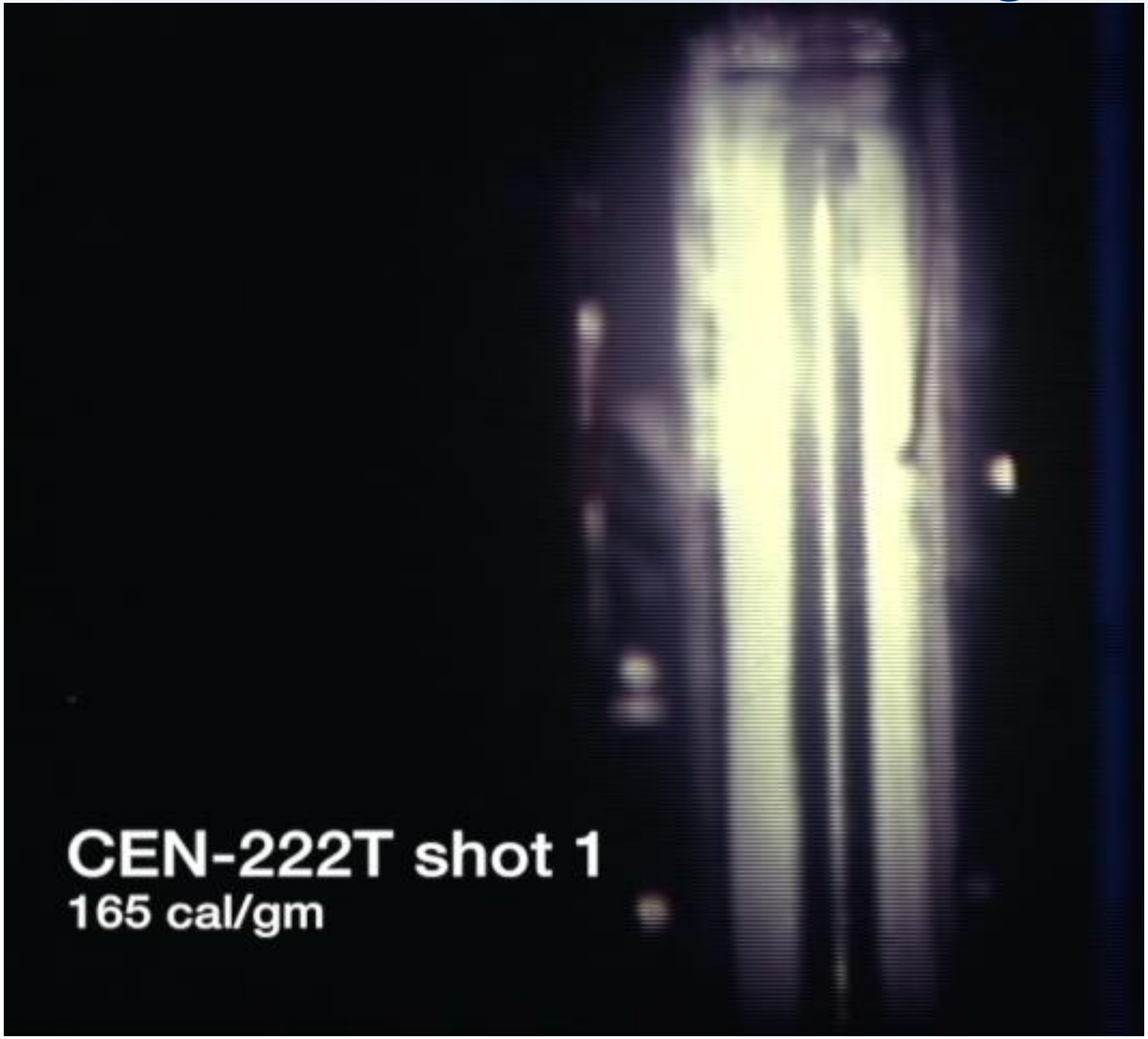


Transient Testing Phase 1 Timeline



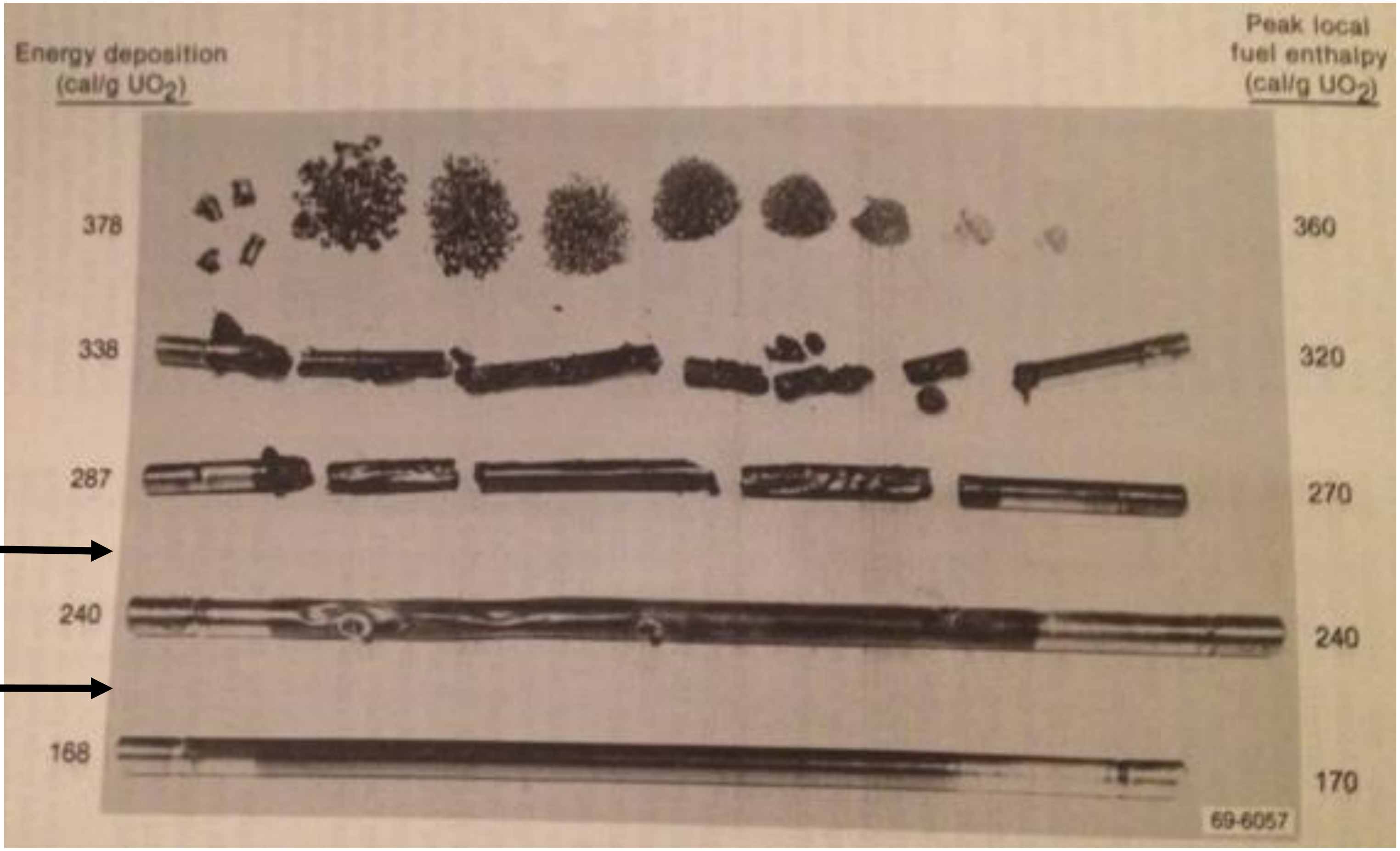
+ support of emerging programs (NSUF, NASA, NHS, …)

Visualization of Fuel Behavior During RIA



https://www.youtube.com/watch?v=h0o4P_F4s9s

Transient Test Results



Fragmentation Threshold

Failure Threshold

Traditional Nuclear Technology Development

	$/test	*time*	# tests
Integral Irradiation Testing • Event simulations conducted in prototypic environments and configurations	$$$$	yrs	####
Semi-integral Testing • Partial event simulations in simplified environments that engage multiple relevant phenomena. • Tests can be used to validate integral M&S tools	$$$	~yr	###
Phenomenological Tests • Separate effects studies conducted to understand and describe individual physical phenomena • Analytical models developed for use in future integral testing	$$	mths	##
Material Properties • Definition of thermal physical and mechanical properties of materials and components used in fuel system.	$	wks	#

R&D is specific to a single fuel design.
Effort is expensive and takes a long time

Idaho National Laboratory

Modern Multi-Scale, Multi-Physics Development

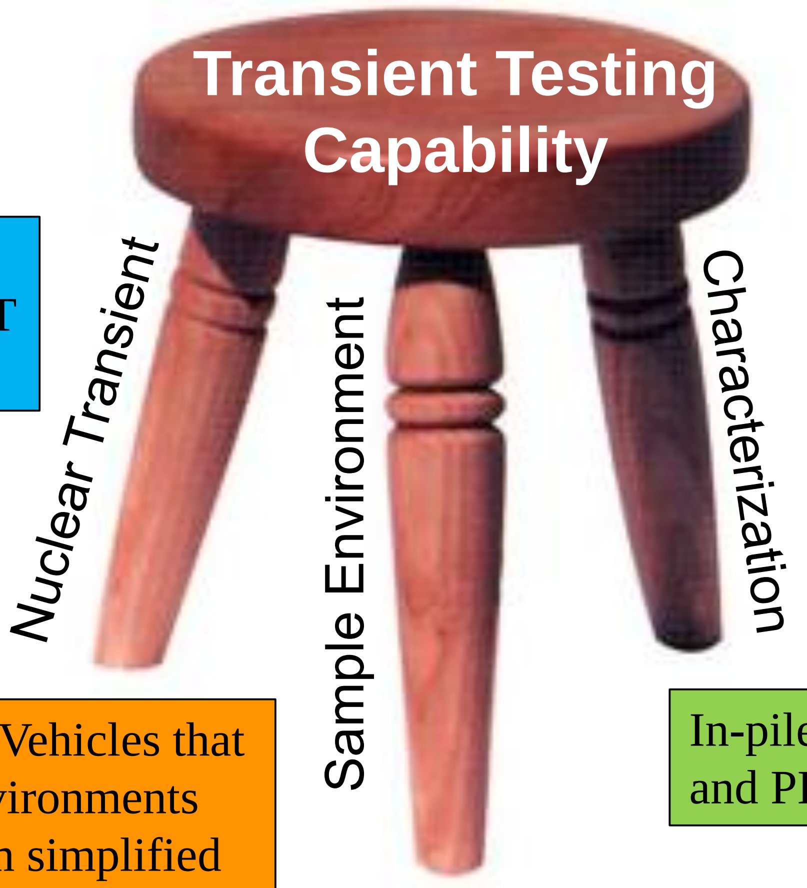
R&D Integrated through M&S

Testing level	$/test	*time*	# tests
Integral Irradiation Testing • Event simulations conducted in prototypic environments and configurations	$$$$	yrs	#
Semi-integral Testing • Partial event simulations in simplified environments that engage multiple relevant phenomena. • Tests can be used to validate integral M&S tools	$$$	~yr	##
Phenomenological Tests • Separate effects studies conducted to understand and describe individual physical phenomena • Analytical models developed for use in future integral testing	$$	mths	###
Material Properties • Definition of thermal physical and mechanical properties of materials and components used in fuel system.	$	wks	####

R&D is relevant to many fuel designs.
Effort is still expensive and takes a long time

Experimental Capability Development

Demonstrated range of shaped transients TREAT can deliver

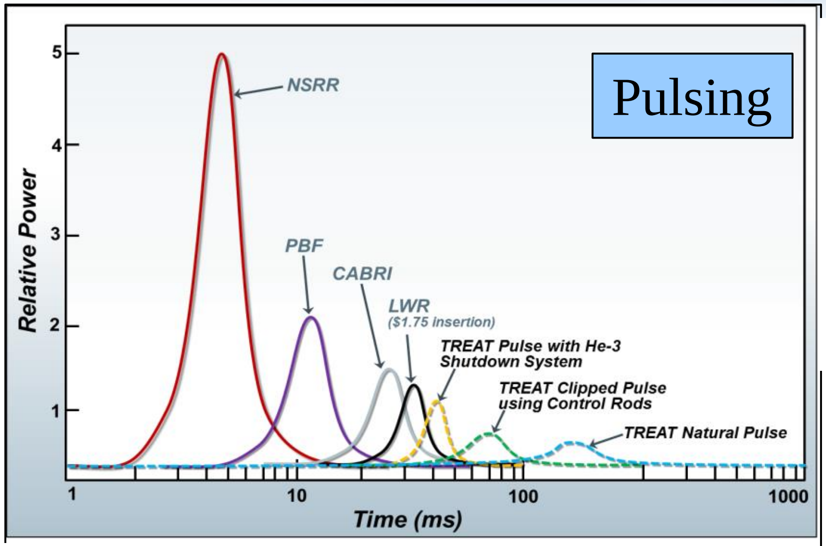


Experiment Vehicles that simulate environments ranging from simplified to prototypic

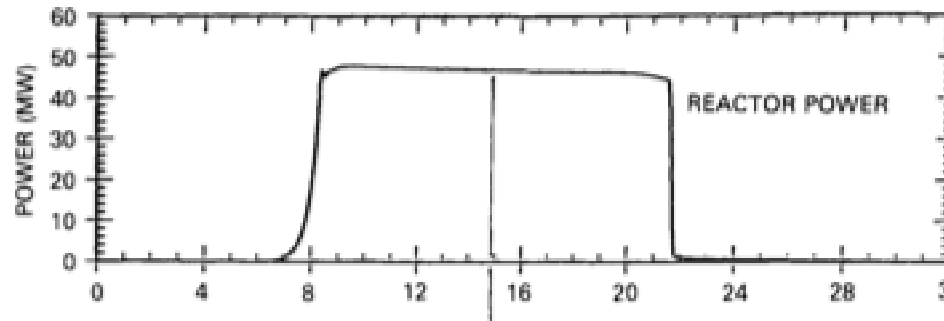
In-pile instrumentation and PIE capabilities

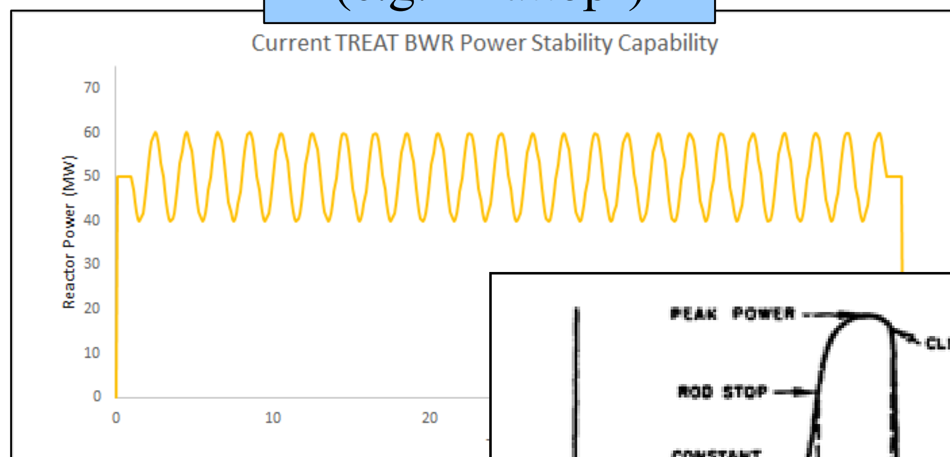
TREAT Transients

Pulsing

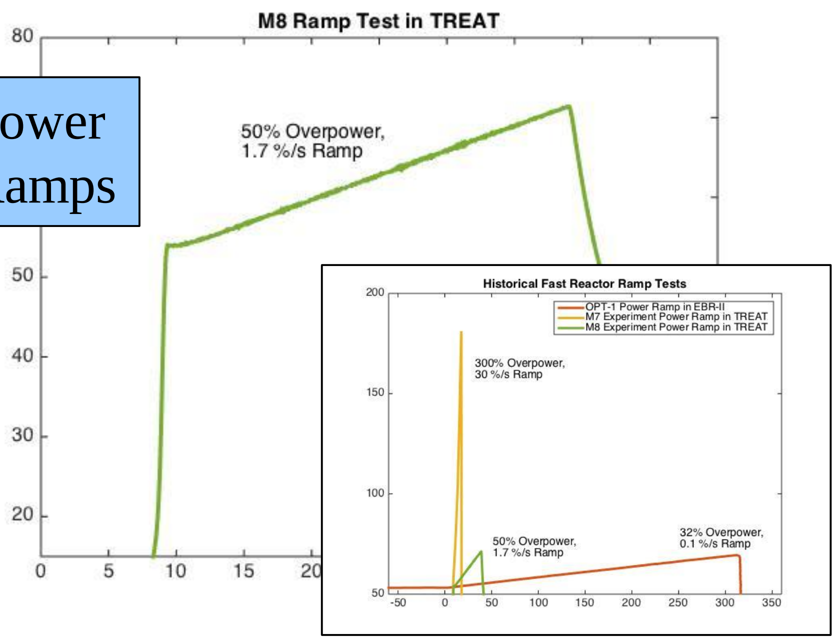


Continuous Power (e.g. 'Flattop')

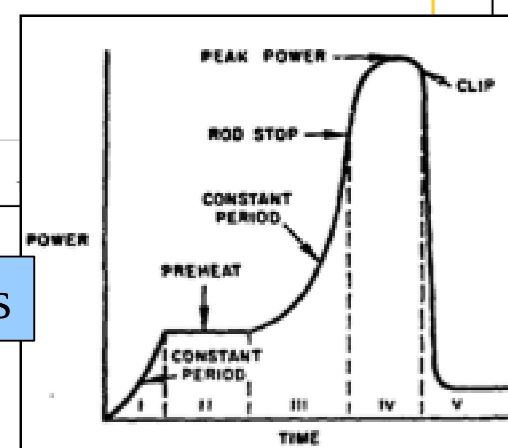




Power Ramps



Complex Transients

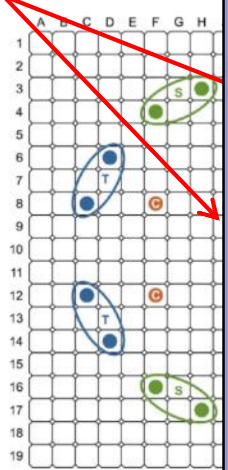


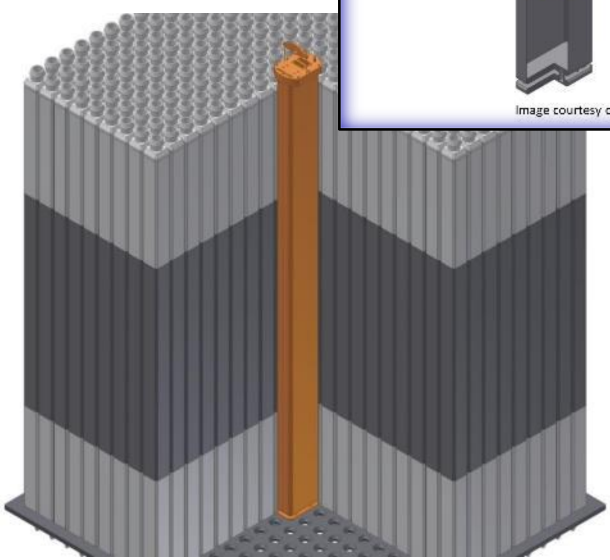
Sample Environment

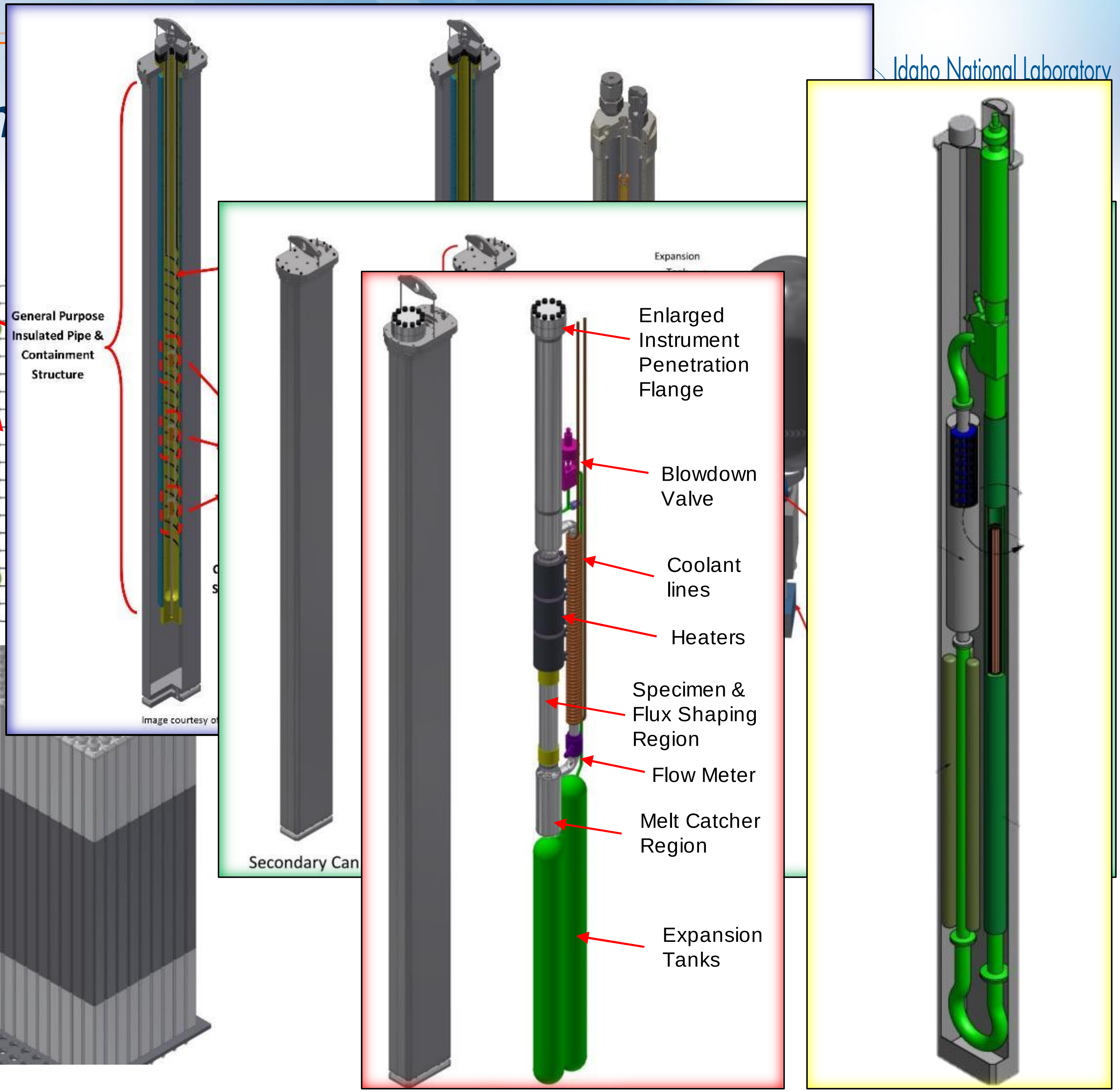
- The irradiation test vehicle used in TREAT are cartridge type devices operated independently of the reactor.
- These devices deliver the experiment specific thermal-hydraulic environment. Systems can be developed to deliver a wide range of conditions
  - Prototypic pressure/temperature/flow for LWR, SFR, LFR, GR or MSR applications
  - Specialized or simplified environments for separate effects studies
- Program strategy will focus on development of modular devices that can be adapted for various user applications with minimal cost and schedule

Test Veh

Insert Experiment Here



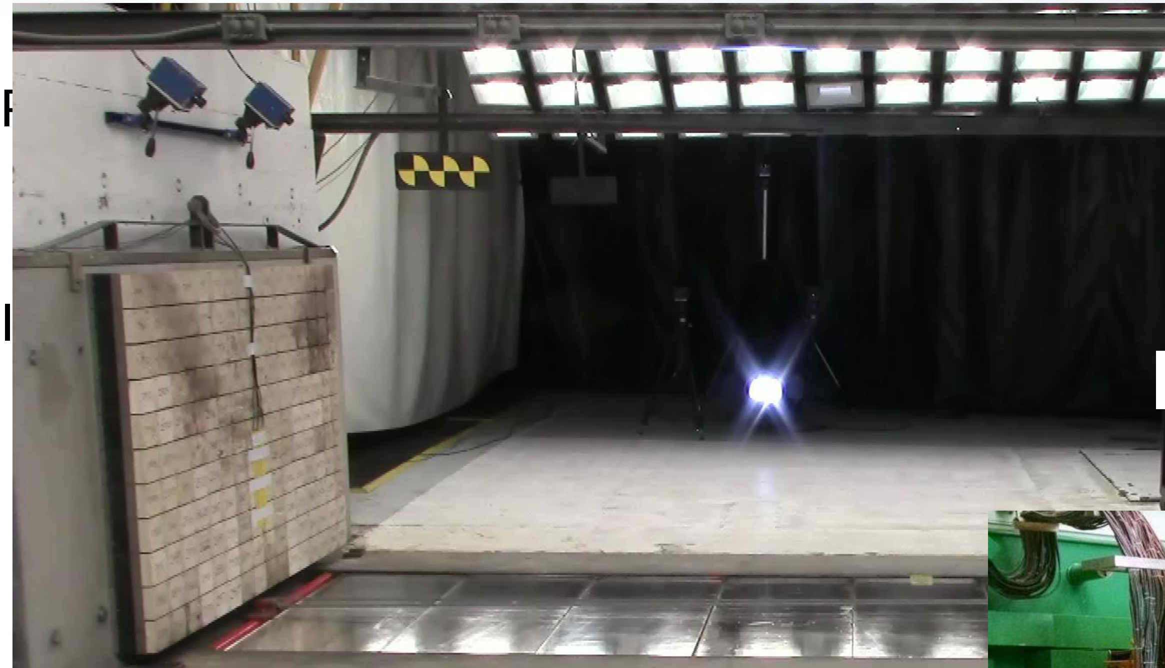




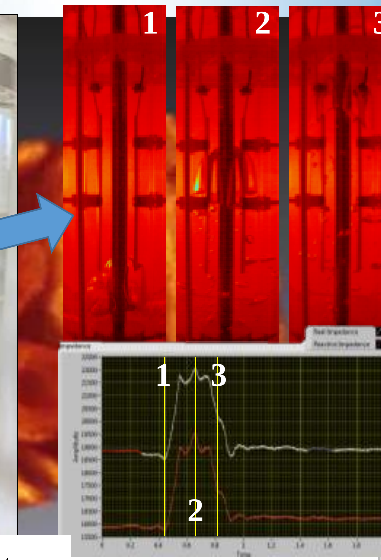
Irradiation Testing Rig Design Workshops

- Irradiation test rig design is a unique area of engineering specialists that are not adequately supported by existing international communities
- Goal is to develop technical relationships between specialists that may
  - Lead to stronger engineering collaborations across institutes
  - Overall enhancement of irradiation testing services (reduction in irradiation test cost and improved products)
- 1st workshop held at SCK-CEN with participation from ~10 test reactors and institutes
- **2nd workshop to be held at INL in July 2018**
- 3rd workshop under partnership with IGORR meeting in 2019

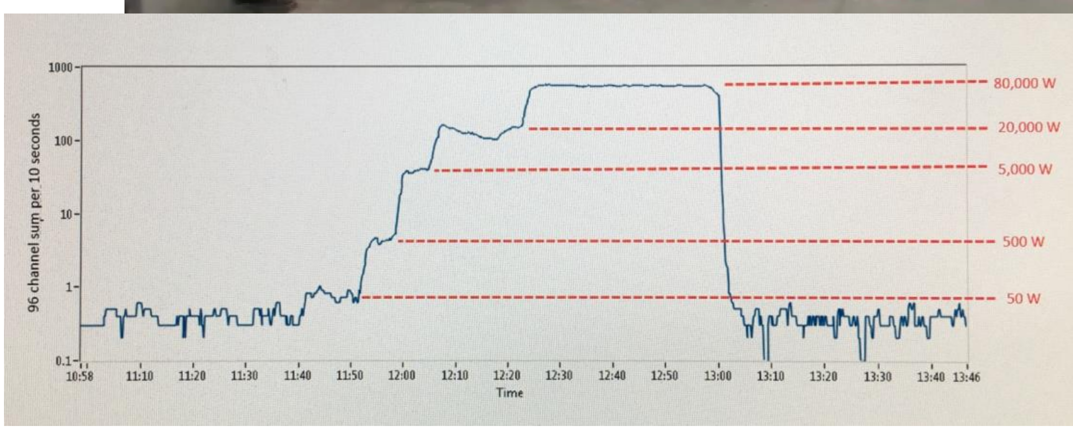
Sample Characterization



Boiling Detector



7-pin TREAT Test



Sum of all 96 hodoscope channels during power ramp to 80 kW

TREAT Fast Neutron Hodoscope

Summary

- The US is in the progress of re-establishing the capability to conduct transient testing in support of fuel safety research for advanced nuclear fuel systems
- Testing and research programs are built around the modern methods that integrate multi-physics, multi-scale behaviors using modern M&S **and** experimental techniques
- Testing capability centers around three pillars
  - Nuclear transient simulation (TREAT restart)
  - Irradiation test device design (for multiple reactor system types)
  - Advanced instrumentation (for in-situ behavior monitoring)

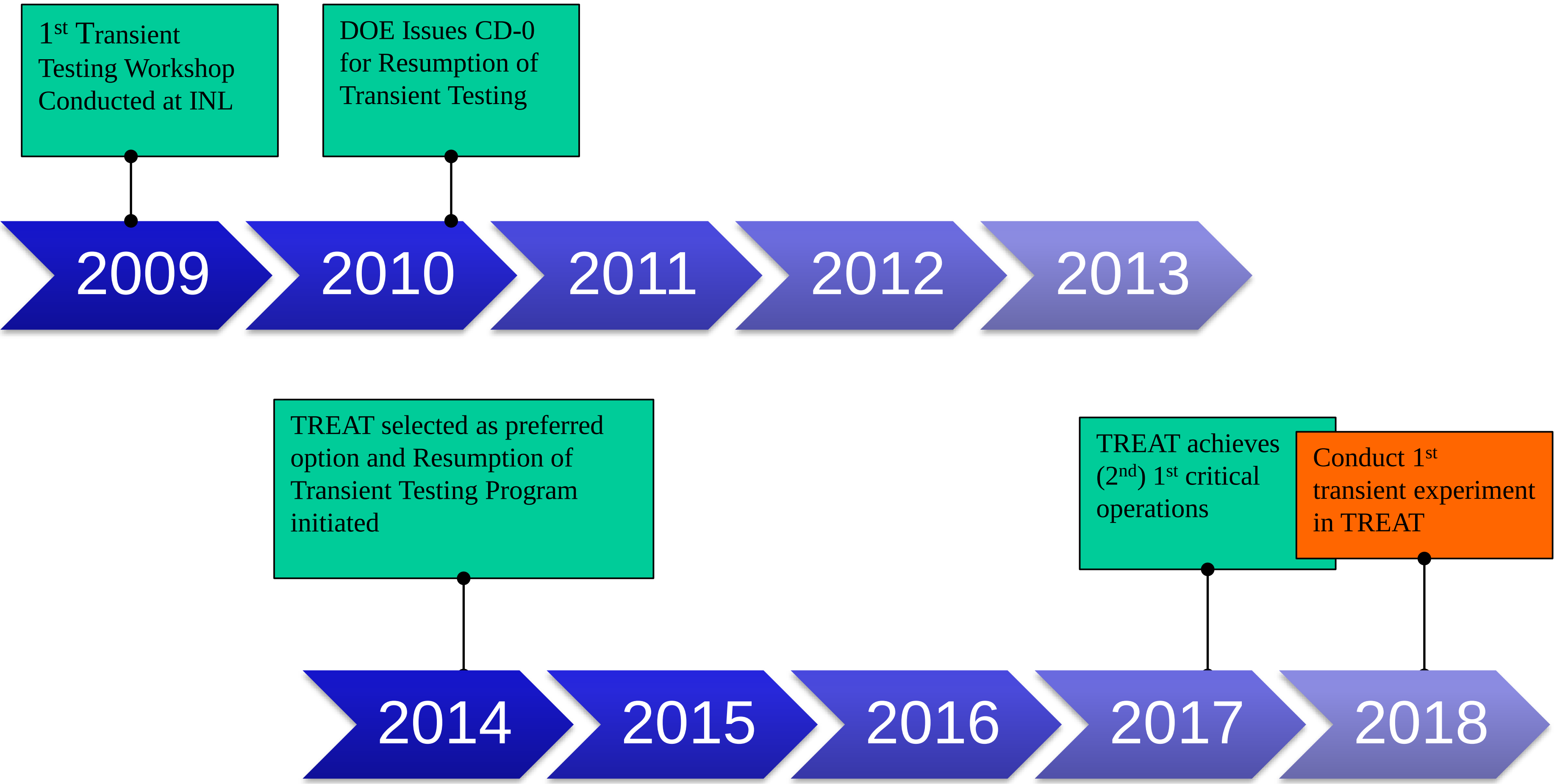
Questions?

10Yr Plan (circa 2014)

Baseline Capability 2014-2018	National-Leading Capability 2018-2022	World-Class Capability 2022-2026	World-Leading Capability 2027-2030
✓ Establish Transient Testing Technical Advisory Board including representatives from key stakeholder communities ✓ Select and develop pilot test program ✓ Develop state-of-the-art reactor testing models to support experiment design and interpretation at all relevant length and time scales (*m to μm, min to ms*) ✓ Re-capture ability to conduct drop-in capsule experiments on irradiated fuel samples including a suite of device designs and remote assembly capability ✓ Implement industry standard instrumentation technologies for experiment monitoring, including reactivation of the fast neutron hodoscope for bulk fuel motion monitoring ✓ Initiate work on new generation of real time fuel motion monitoring instruments, in-pile instruments, and controlled sample environments ✓ Explore development of advanced scientific instruments for in-situ monitoring of nuclear materials behavior	Establish multi-year industry consortium project (comparable to Halden HRP and Studsvik SCIP) Flowing water and Na loops available to support safety testing on prototype scale fuel systems (complemented by a water loop in ATR for pre-irradiation and operational transient testing) Establish capability to remanufacture fuel pins for transient testing Establish remote device assembly and checkout station in HFEF for full length test loops Install advanced fuel motion monitoring capability Establish internationally relevant instrumentation development organization Demonstrate integration of multi-scale modeling and simulation with high fidelity nuclear fuel experimentation (i.e. through MOOSE based applications) Select and install first instrument for in-situ nuclear fuel behavior monitoring	Establish broad user base that includes DOE, industry programs, and university sponsored programs Establish multi-environment platform that offers a broad suite of experiment conditions (coolant, pressure, temperature neutron spectrum, etc.) for experiments Establish capability to internally instrument remanufactured fuel pins for transient testing Establish irradiated materials library to use as source material for experiments (may be a multi-national consortium) Establish capability to transport 'small' experiment samples internationally for collaborative experimenting and PIE	Routinely conduct transient testing in support of safety and performance studies for Industry, NRC, and DOE programs as well as scientific studies for university and DOE programs Establish comprehensive user facility for reactor fuels and material safety testing (ranging from in-pile and out-of-pile capabilities for severe accidents to operational transients) Develop and deploy a set of special-purpose devices and scientific instruments for in-situ monitoring of nuclear phenomena occurring over a wide range of length and time scales (m to nm, min to ms) Routine use of goal-oriented, science-based experimentation to develop and qualify modern modeling and simulation tools for nuclear fuel and materials applications
20 years to qualify incremental changes in nuclear fuel designs	*20 years to qualify new nuclear fuel designs*	*12 years to qualify new nuclear fuel designs*	*7 years to qualify new nuclear fuel designs*

INL/LTD-14-33324

TREAT Restart Timeline



But what come's next?