



# Fundamentals of Safety Testing

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**Colby Jensen**

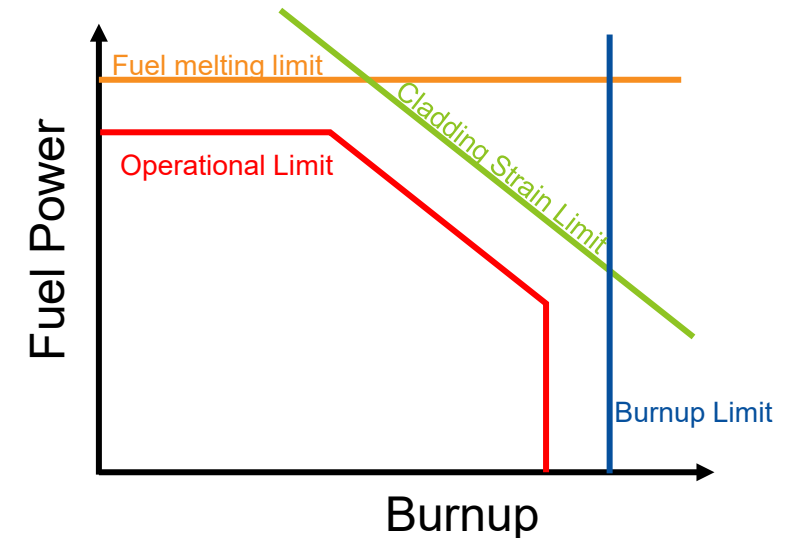
*National Technical Lead for Transient Testing*



Idaho National Laboratory

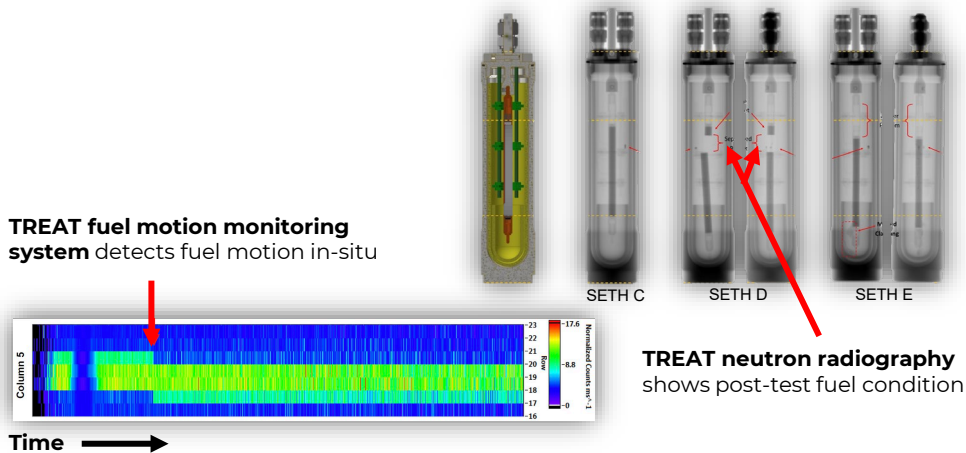
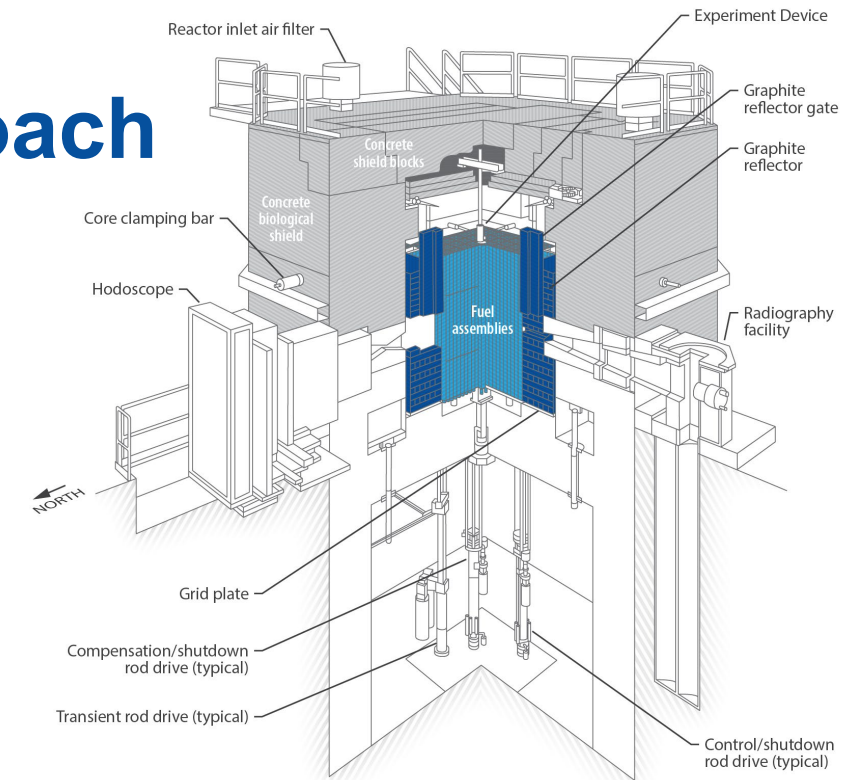
# Why Transient Test Nuclear Fuels & Materials?

- Transient testing is like car crash testing for nuclear fuels
- Licensing a fuel system *requires* (see NUREG-0800):
  - identification of all **degradation mechanisms and failure modes**
  - definition of **failure thresholds** corresponding to each degradation mechanism
  - applies to **normal operations, anticipated operational occurrences and design basis accidents**
- Many operational limits are dependent on degradation and failure thresholds
- Enables economic reactor operations via improved fuel design and performance understanding



# TREAT Design & Experimental Approach

- The Transient Reactor Test Facility (TREAT) operated from 1959-1994 and resumed operations 2017 to support fuel safety testing and other transient science
- Zircaloy-clad graphite/fuel blocks comprise core, cooled by air blowers
  - Virtually any power history possible within 2500 MJ max core transient energy
  - No reactor pressure vessel/containment, facilitates access for in-core instrumentation
  - 4 slots view core center, 2 in use for fuel motion monitoring system & neutron radiography



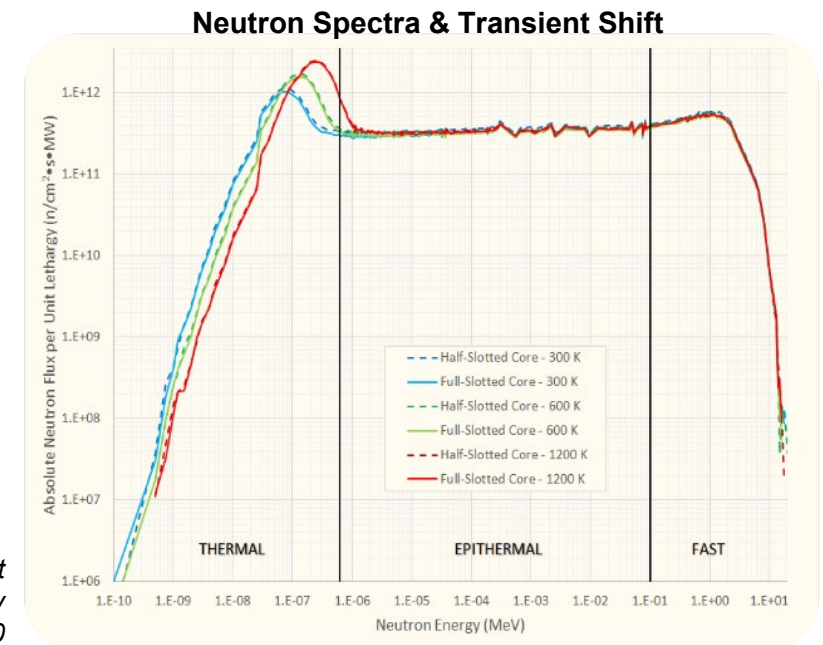
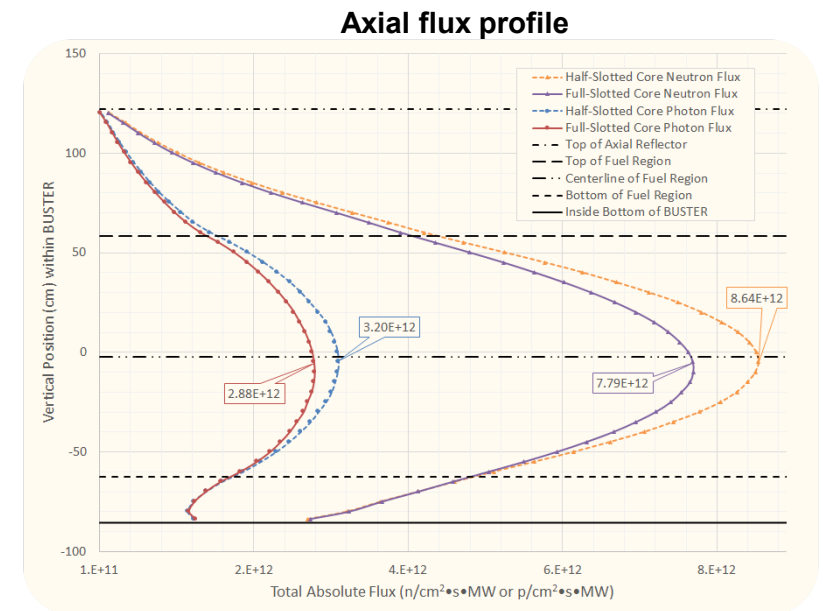
- Reactor provides brief (and typically extreme, up to  $10^{17}$  n·cm<sup>-2</sup>·s<sup>-1</sup>) shaped neutron flux histories to test specimens
- Experiment vehicle does everything else
  - Safety containment, specimen environment, and instrumentation
- Diversity of TREAT's experiment history and foreseen community science needs and unique capability
  - Emphasized need for modern and multipurpose experimental tools

Virtual facility tour: <https://inlgov360.b-cdn.net/TREAT/tour.html>

# TREAT Experimental Approach

- Typical residence time in the TREAT core for a given experiment is a few days
  - Of which only a few milliseconds to minutes is the transient
  - Even with multiple transients on the same specimen, fluence is extremely low (dpa is effectively zero)
- TREAT is best suited for testing fuels, and materials that could interact with fuels (e.g. cladding, ducts), under extreme conditions for nuclear heated safety research
  - If significant structural burnup or material fluence is needed before transient testing, its better accomplished in another reactor first (e.g. ATR, HFIR)

Figures from: Bess et al., Ann. Nucl. Energy 124 (2019) 270

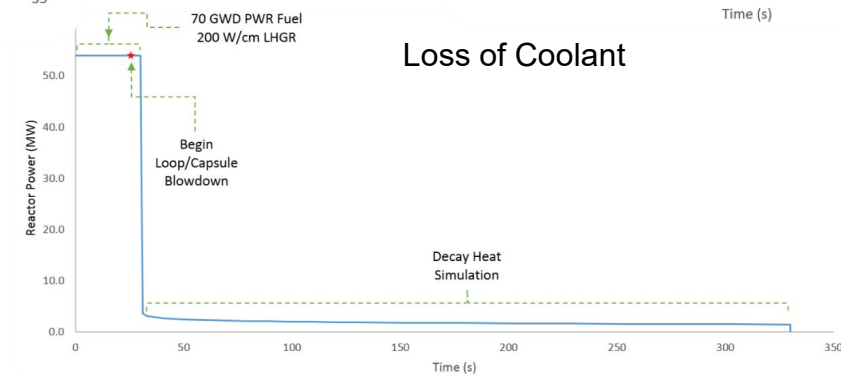
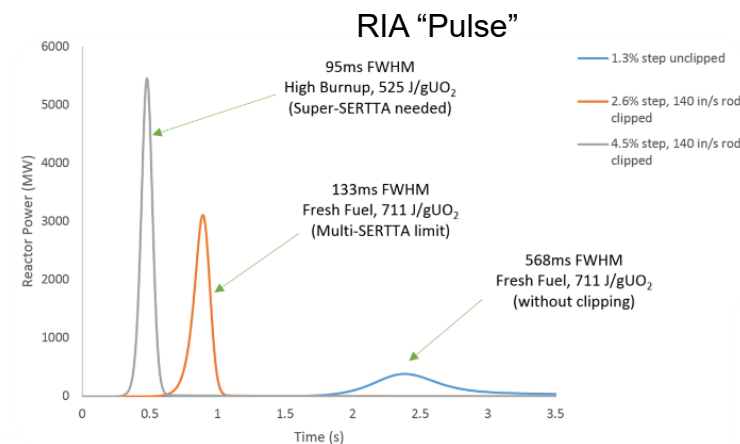
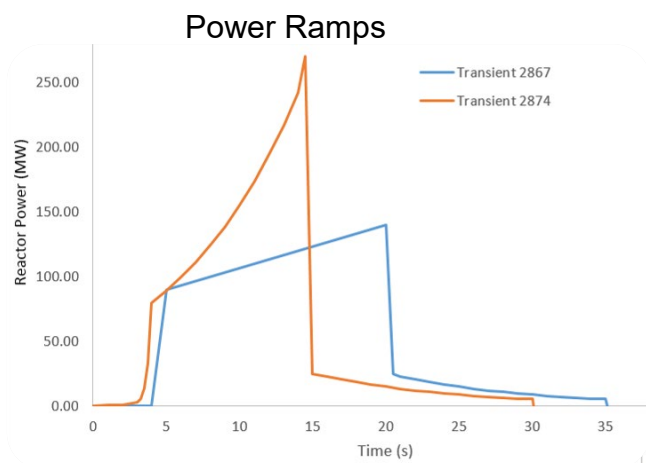


# Reactor Power Control

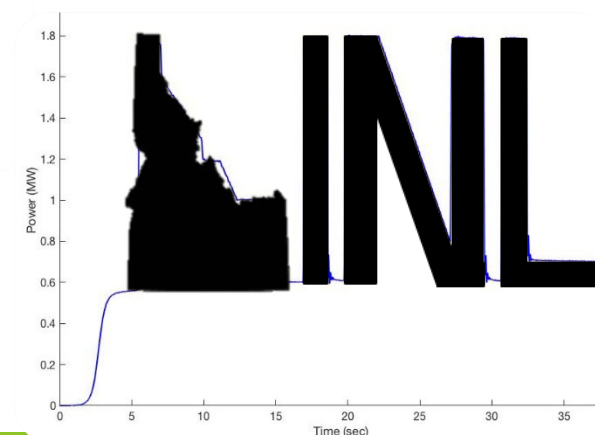
- TREAT is a transient reactor, not only a pulse reactor – “windowed” power histories
- Graphite heat sink, nimble control rod system → flexible power maneuvers
- Rod control system can accept feedback from experiment instrumentation



TREAT subpile room



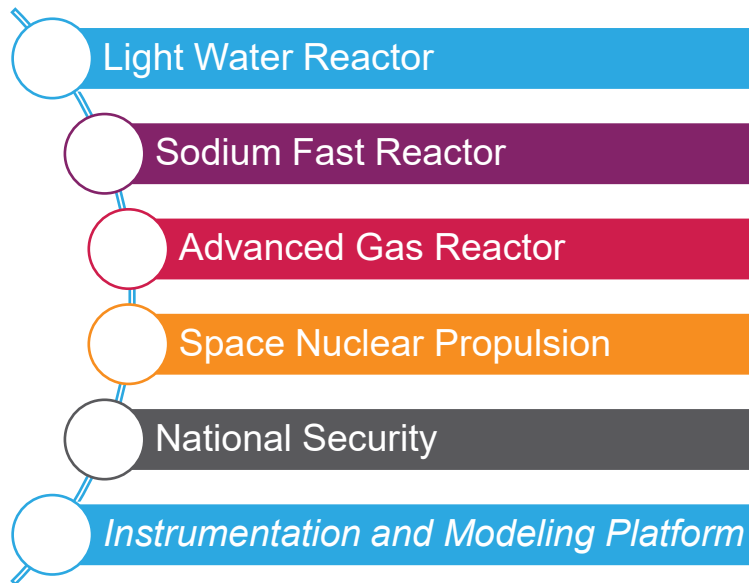
Complex Shaped Transient  
and so on...



# Transient Testing Testbeds and Infrastructure

- TREAT programs fall within 5 product lines, each of which is supported by its own test bed infrastructure

- Each testbed naturally divides in two size scales also distinguished by passive and active cooling
- Most R&D plans include tests from both size scales



“Capsule-scale”  
More affordable  
static environment  
devices



Cartridge-in-console  
architecture used  
whenever possible for  
general infrastructure

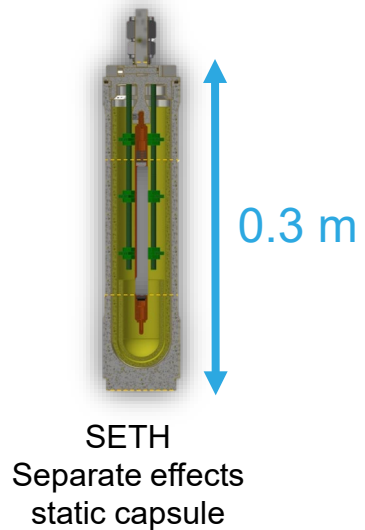
~ 3.5 m

“Loop-scale”  
Devices with active  
thermal-hydraulic  
manipulation

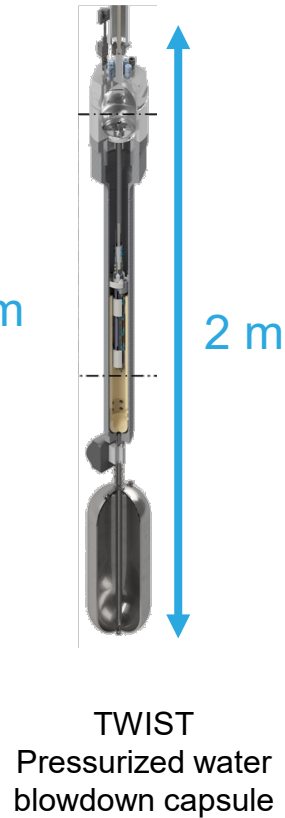
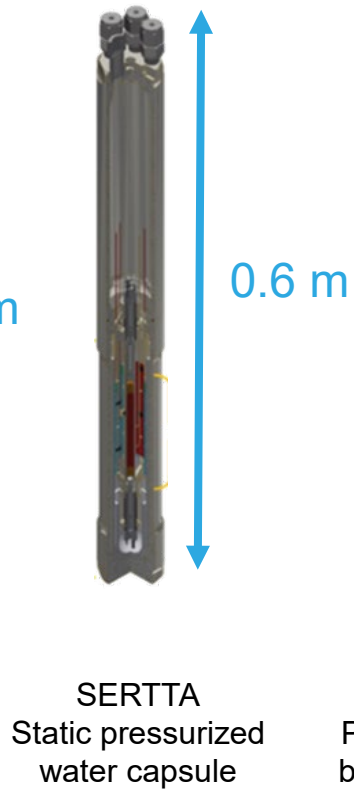
# TREAT Experimental Testbeds

- Reactor and hot cell facility integration

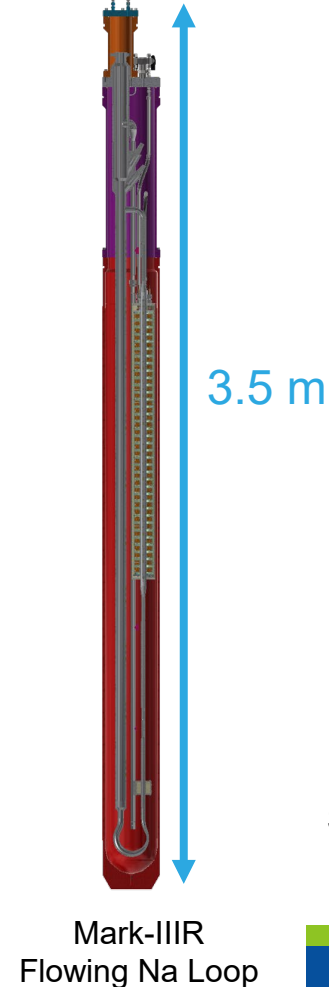
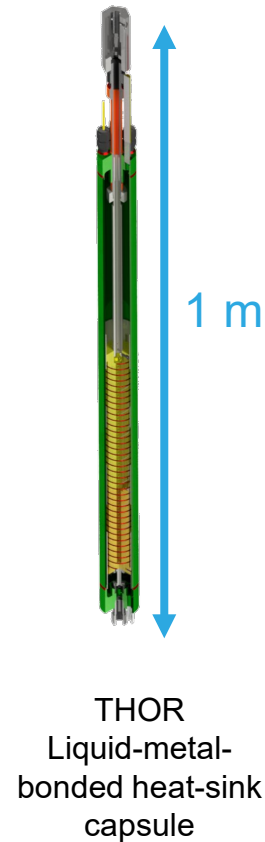
General purpose



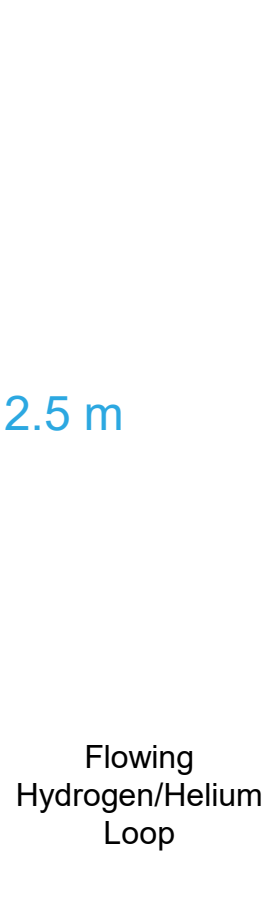
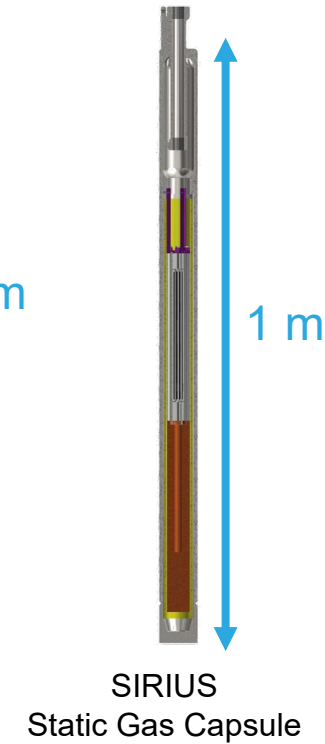
Water testbed



Sodium testbed

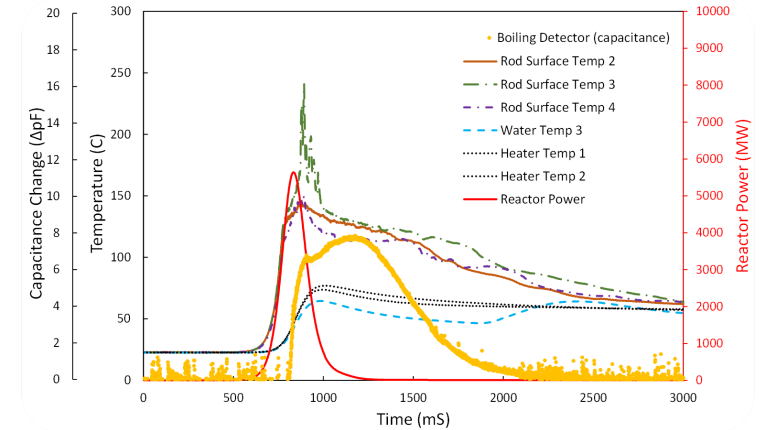


Advanced Gas Reactor &  
Space nuclear testbed

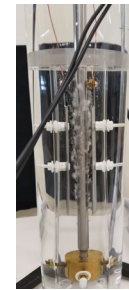
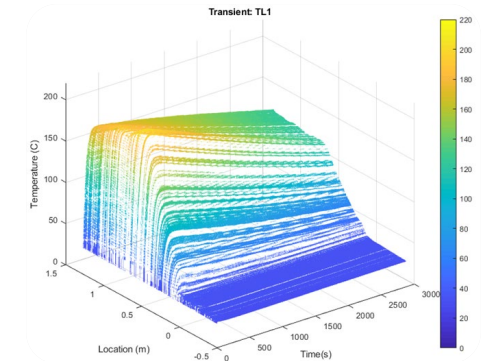


# In-Situ Instrumentation

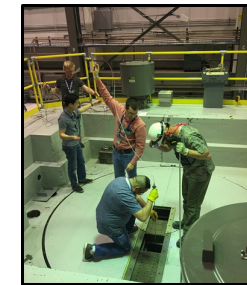
- Extensive in-situ measurements are routine in TREAT
  - Unparalleled core access
- Desired data should be important initial consideration
  - Wide array of options available today
  - Development of custom approaches is expected and welcome
- Laboratories have dedicated facilities and expertise for designing, fabricating, qualifying, and interpreting advanced instrumentation



*In-situ data using advanced instrumentation*



*Out-of-Pile Characterization*



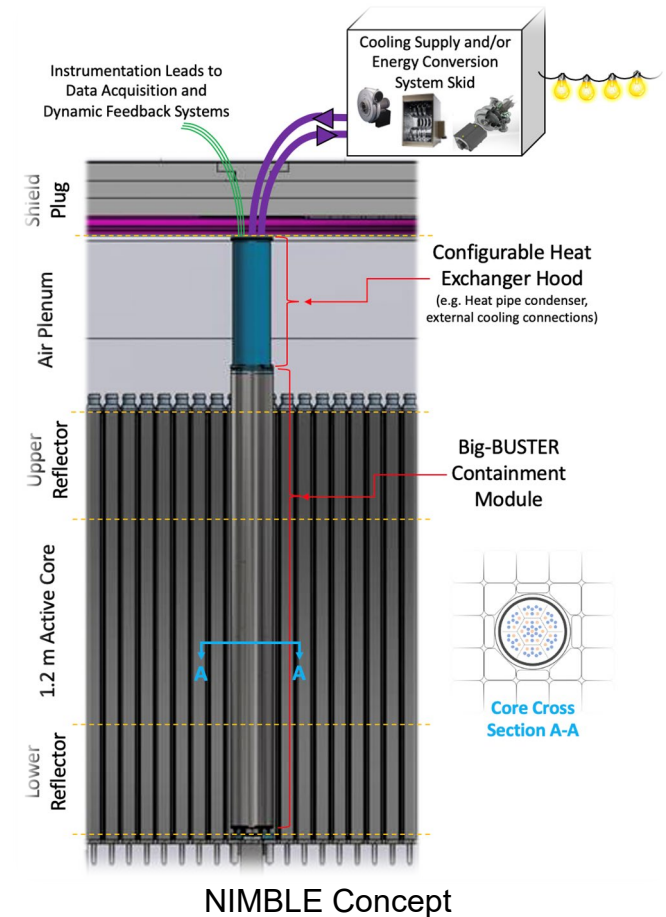
*In-Pile Characterization*



# Non-Traditional Applications of the TREAT Facility

## (Beyond Transient Testing Nuclear Fuels)

- Fission effects on material properties
- Nuclear materials under extreme conditions (very high temperature properties and behaviors)
- Dynamic multiphysics instrumentation testing and model benchmarking
- System-scale core component testbed with nuclear heating
  - Non-safety category automatic reactor control system



Reactor Core Component  
System Testbed

# TREAT User's Guide

- Published reference including facility overview, experimental capabilities
- Experiment information contact:  
colby.jensen@inl.gov, Program Technical Lead  
nicolas.woolstenhulme@inl.gov Experiment capability lead  
todd.pavey@inl.gov, Program Manager

