Transient Test Reactors

Dr. Daniel M. Wachs
National Technical Lead for Transient Testing
Idaho National Laboratory, USA

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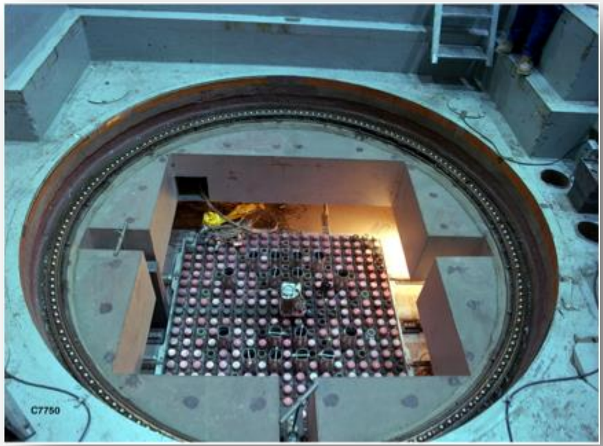

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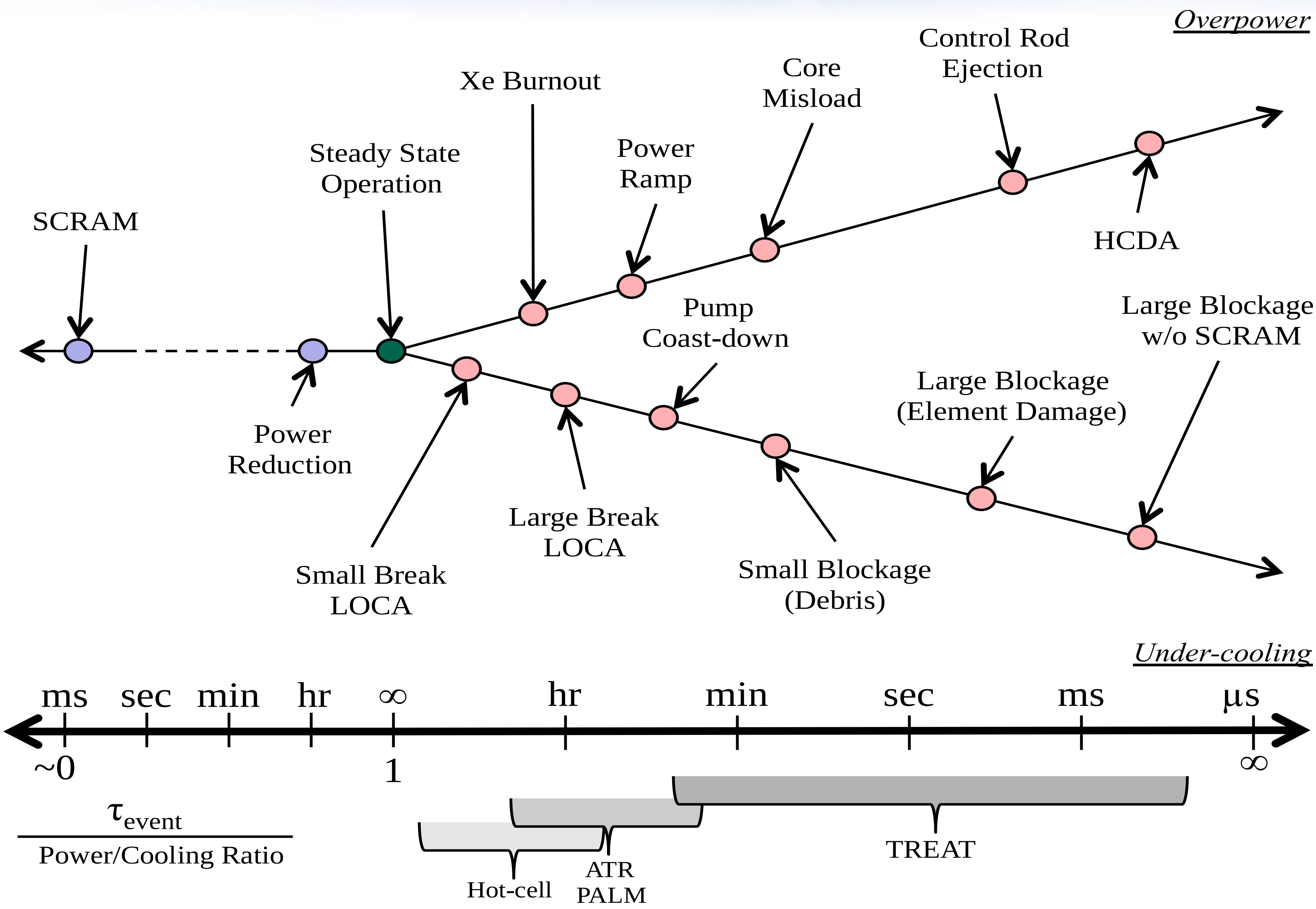
Why do we need Transient Reactors?

- Nuclear reactors are a complex multi-physics problem
  - Nuclear feedback mechanisms (coupled to thermal and mechanical response) are critical to enable reactor control and to maintain safe operations
  - All analysis codes must be benchmarked against representative experimental data
- The performance limits of engineered reactor systems must be demonstrated to receive an operating license
  - Used extensively to qualify current LWR systems (and ongoing optimization)
  - Research and development of advanced systems

Transient Nuclear Physics

- **Annular Core Research Reactor (ACRR)** at Sandia National Laboratory
  - https://www.youtube.com/watch?v=pa0Fmcv83nw
  - Transient response
    - Large reactivity insertion (rod ejection)
    - **Very** strong negative temperature feedback coefficient that rapidly reduces reactor power
    - Short power pulse (~10's of ms)
- **Special Purpose Experimental Reactor Test (SPERT)** at Idaho National Laboratory
  - https://www.youtube.com/watch?v=0FIhafVX_6I
  - Transient response
    - Large reactivity insertion (rod ejection)
    - **Fairly** strong negative temperature feedback coefficient that rapidly reduces reactor power (just not fast enough)
    - Short power pulse (~10's of ms)

Fuel Performance and Safety Limits



Fuel Safety Research

- To receive a design or operating license for a nuclear reactor the licensee must describe the off-normal performance of the system to define
  - Operating limits
  - Risk to the public
- For design basis accidents including both overpower (reactivity initiated accident) and undercooling (loss of coolant accident)
  - Maintain coolable geometry (prevent propagation of failure)
  - Establish the related source term (and confirm its within regulatory limits)
    - Fraction of fuel failed (threshold for cladding rupture)
    - Radionuclide release (fraction of fission product retained)

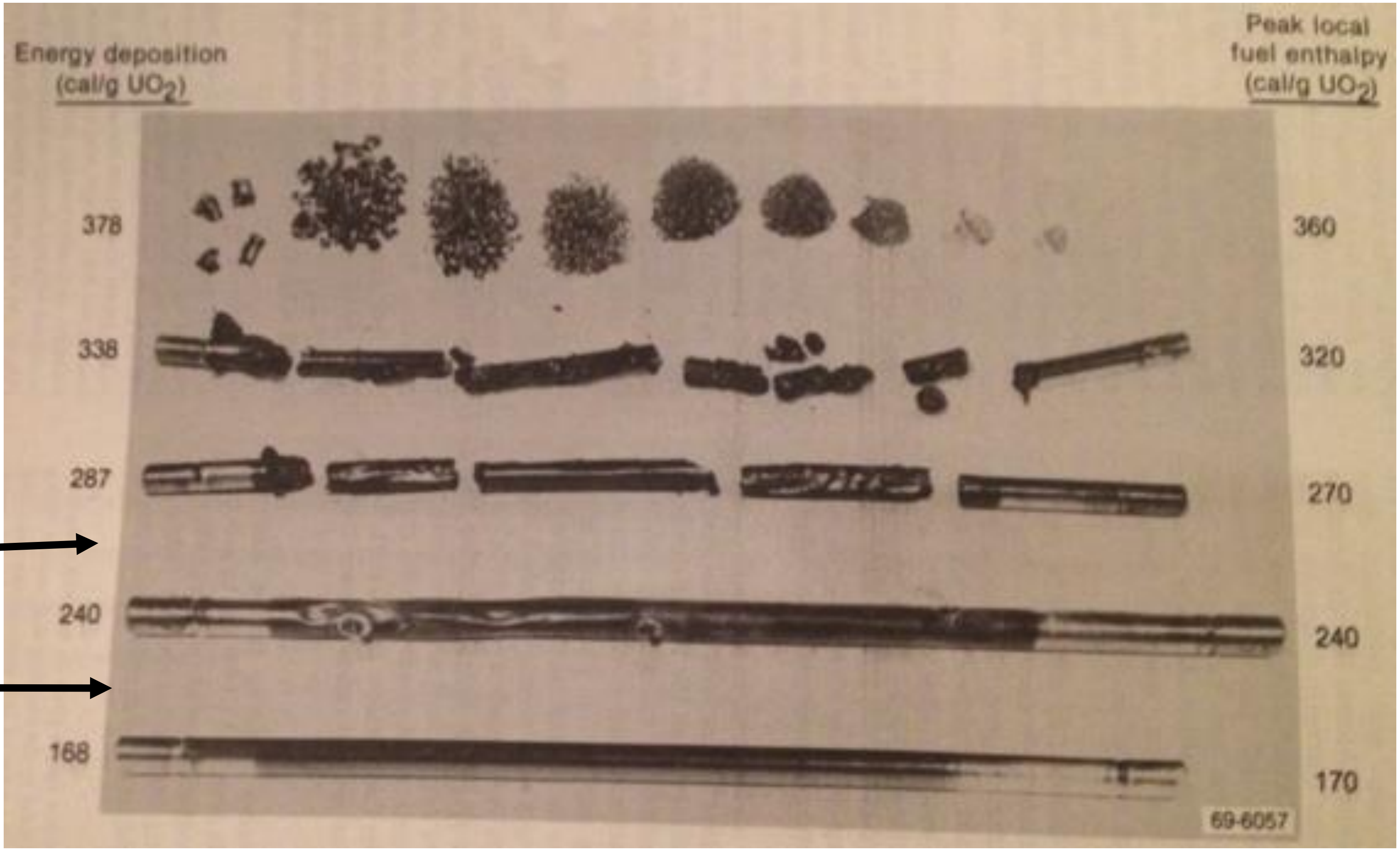
Visualization of Fuel Behavior During RIA

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

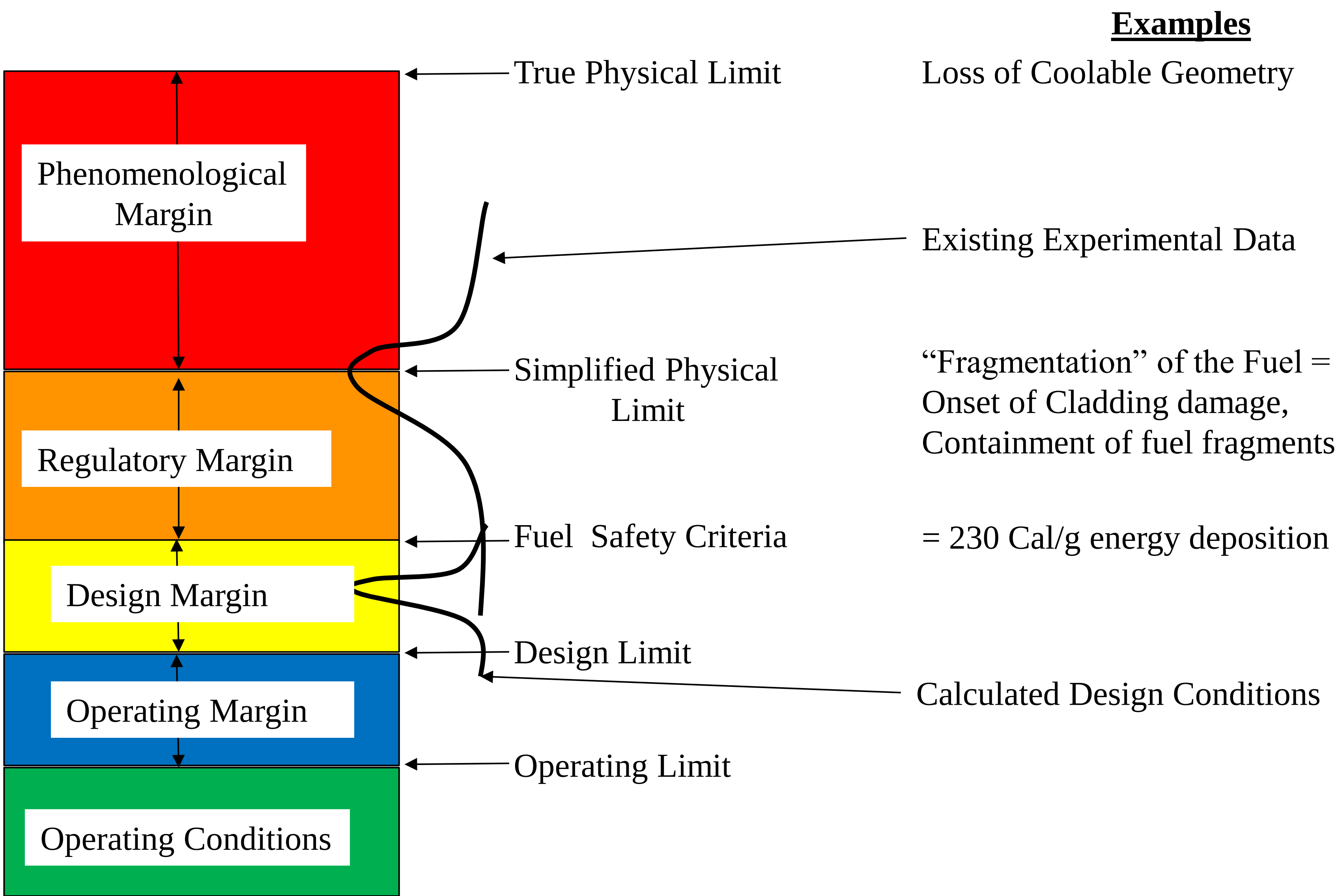
Transient Test Results

Fragmentation Threshold

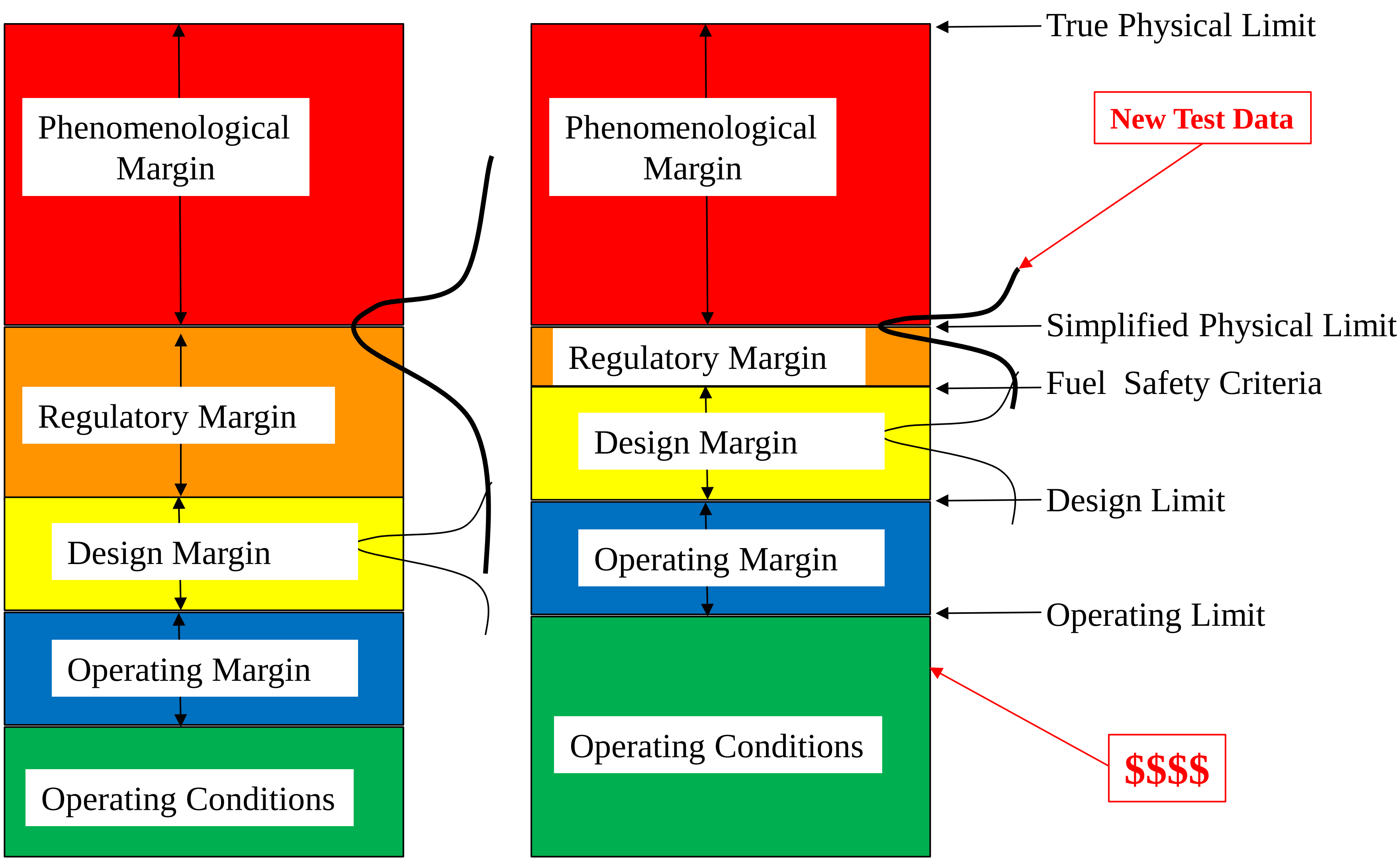
Failure Threshold



Fuel Safety Research Objectives



Fuel Safety Science Objectives



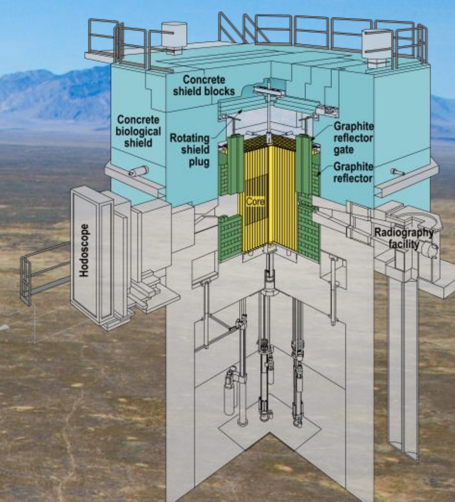
Transient Neutron Sources

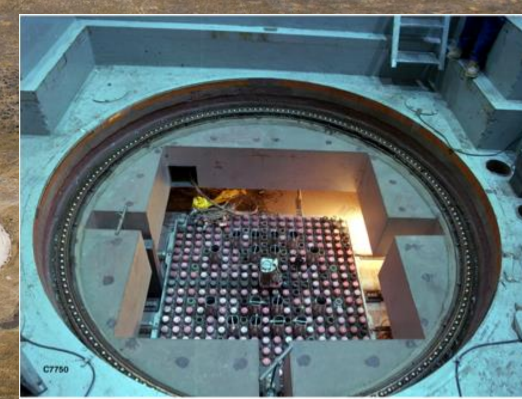
- Specialized reactors are required to deliver shaped neutron pulses to
  - Simulate off-normal conditions ranging from
    - Operational transients
    - Design basis accidents
    - Beyond design basis (severe) accidents
  - All without destroying the reactor!

- Currently available test facilities include
  - CABRI (France) – recently refurbished
  - TREAT (USA) – to resume operations next week
  - NSRR (Japan)
  - IGR (Kazakhstan)

Transient Reactor Test (TREAT) Facility

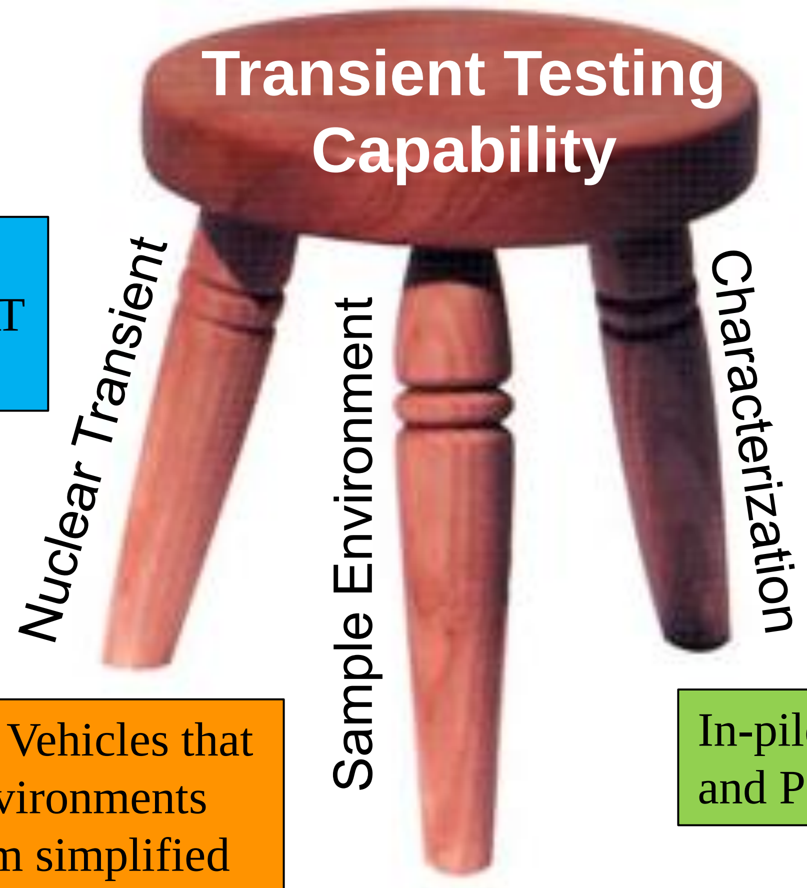
- TREAT's unique design delivers the nuclear environment required to meet fuel safety research needs
  - 19 GW Peak Transient Power (with 100 kW Steady-state power option)
  - Core: ~1.2 m high x 2 m. dia19 x 19 array of 10 x 10-cm. fuel and reflector assemblies
  - Instantaneous, large negative temperature coefficient (self protecting driver core)
- Resumption of Operations
  - *'Mission Need Statement for Resumption of Transient Testing'* issued by DOE in January 2010
  - TREAT Selected as '*preferred option'* in February 2014 and restart activities were initiated at the beginning of FY15
  - **Authorization to restart received in Sept 2017, First critical expected next week!**





Transient Testing Capability

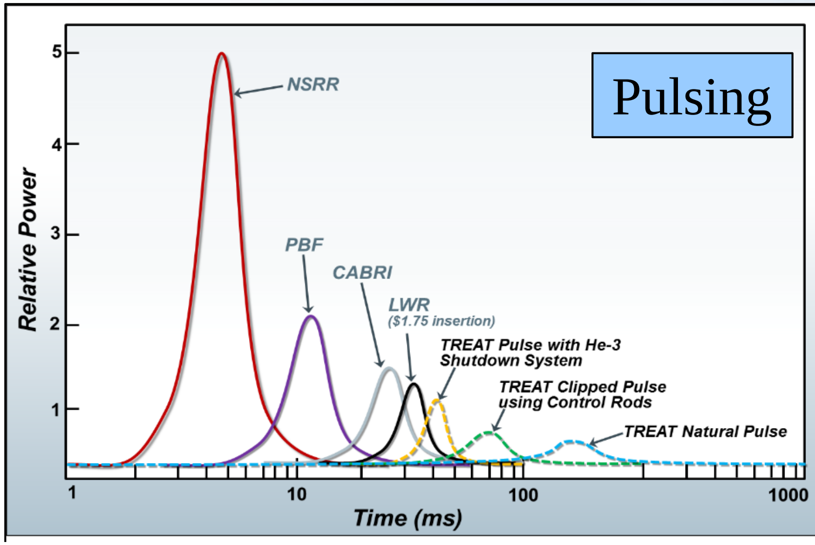
Demonstrated range of shaped transients TREAT can deliver



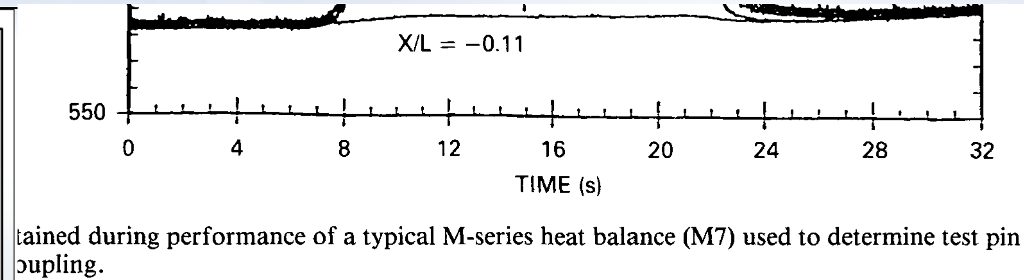
Experiment Vehicles that simulate environments ranging from simplified to prototypic

In-pile instrumentation and PIE capabilities

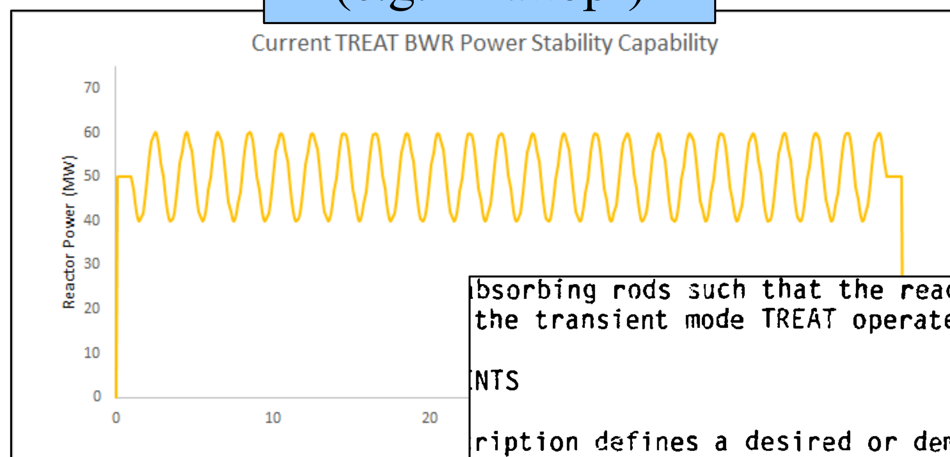
TREAT Transients



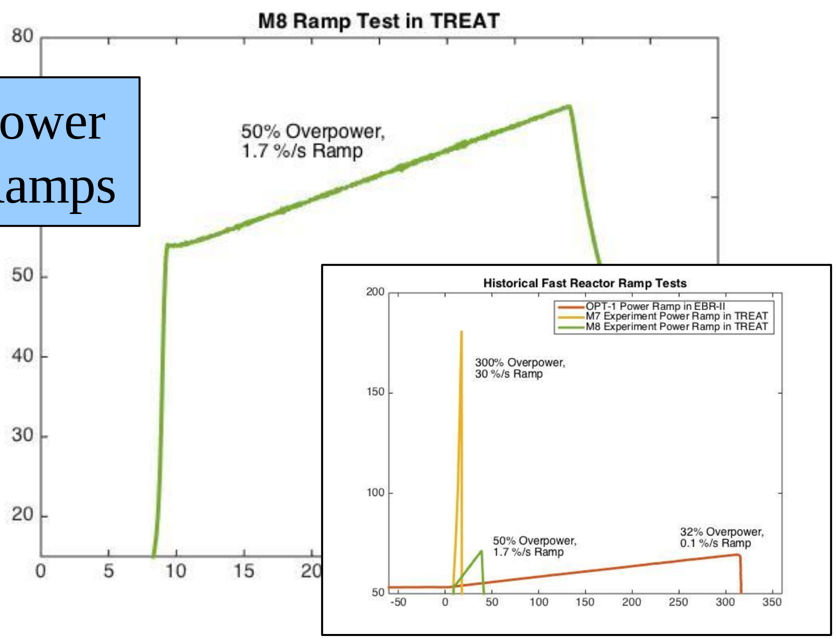
Pulsing



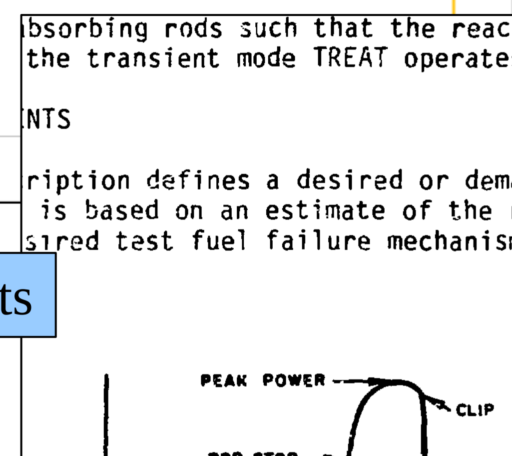
Continuous Power (e.g. 'Flattop')



Power Ramps



Complex Transients

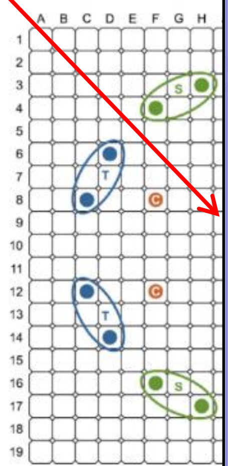


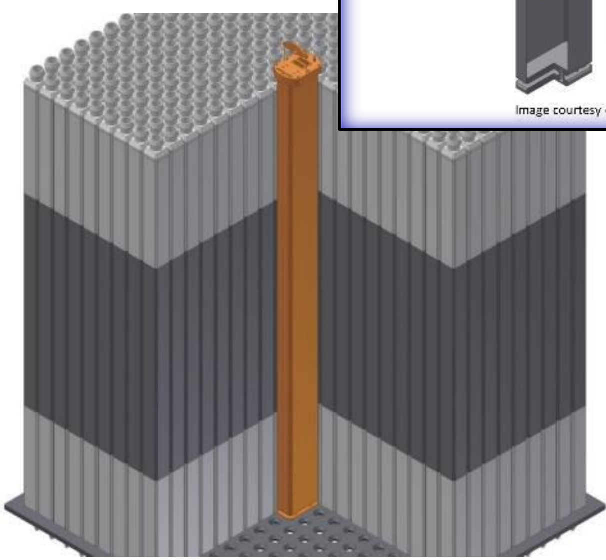
Sample Environment

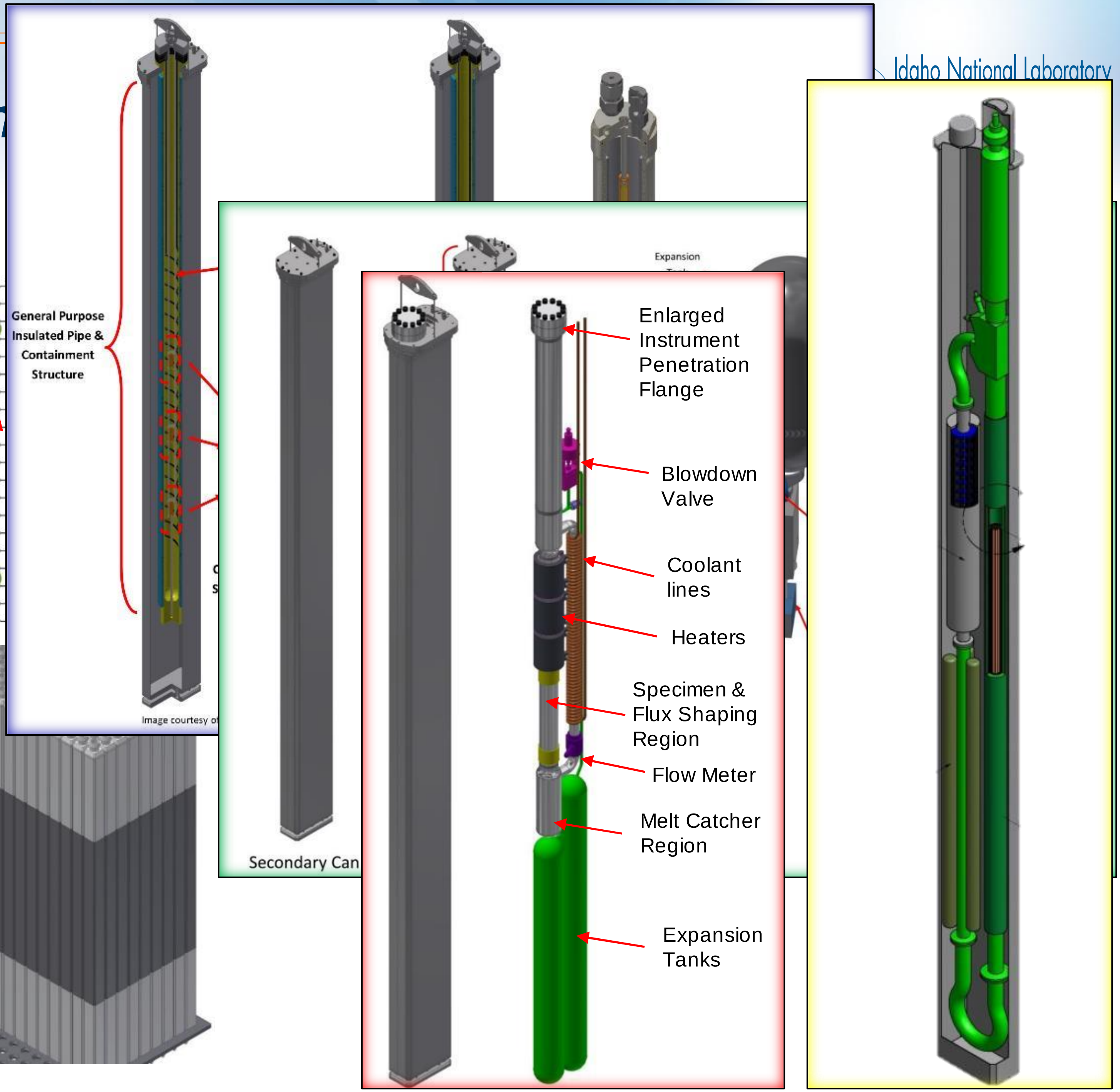
- The irradiation test vehicle used in TREAT are cartridge type devices operated independently of the reactor.
- These devices deliver the experiment specific thermal-hydraulic environment. Systems can be developed to deliver a wide range of conditions
  - Prototypic pressure/temperature/flow for LWR, 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

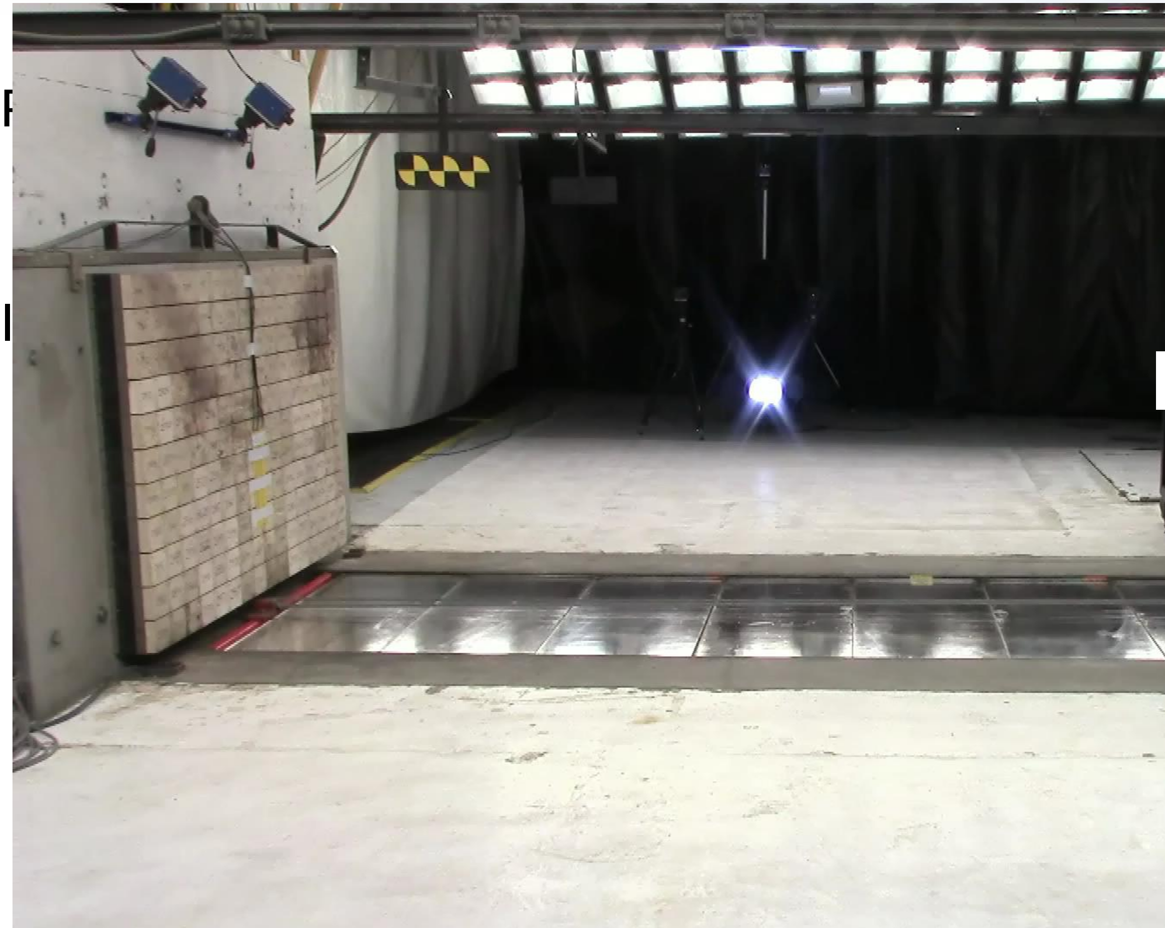


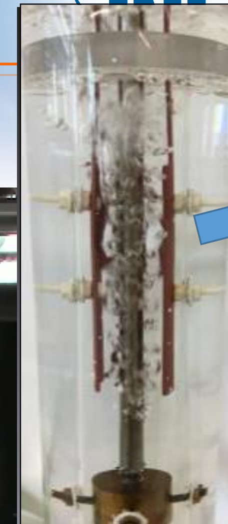




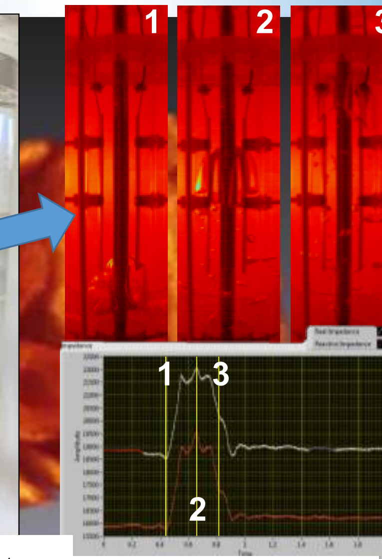
Sample Characterization

- F
- I





Boiling Detector



7-pin TREAT Test

TREAT Fast Neutron Hodoscope

How to access these facilities?

- Joint International Projects
  - Fuel safety research is typically cross-cutting and of universal interest
    - Data shared between reactor designers, fuel vendors, utilities, and regulators (incentive to work together)
  - Limited number of transient test facilities (most nations don't operate their own)
  - Examples include the
    - CABRI International Project (OECD NEA)
    - Halden Reactor Project (OECD NEA)
    - US Nuclear Science User Facility program (US Dept. of Energy)
- Bilateral agreements between individual nations

Questions?