# In-Pile Instrumentation for Fuel Safety Testing

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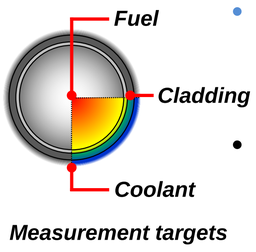
## Overview

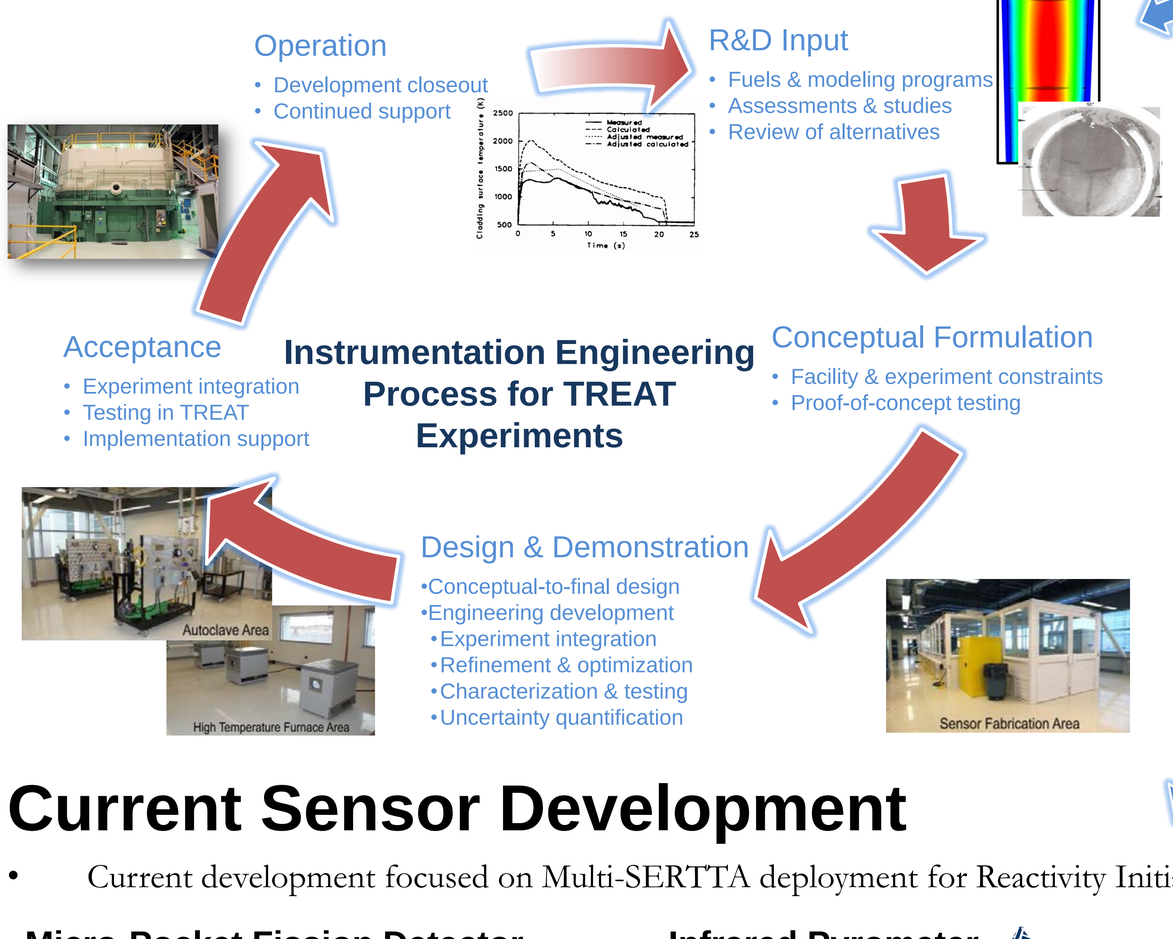
- Goal: Measure critical fuel performance parameters with quantified uncertainty
- Advanced instrumentation is key to unraveling the complex multiphysics involved during transient irradiation experiments including development and validation of modern modeling and simulation tools.



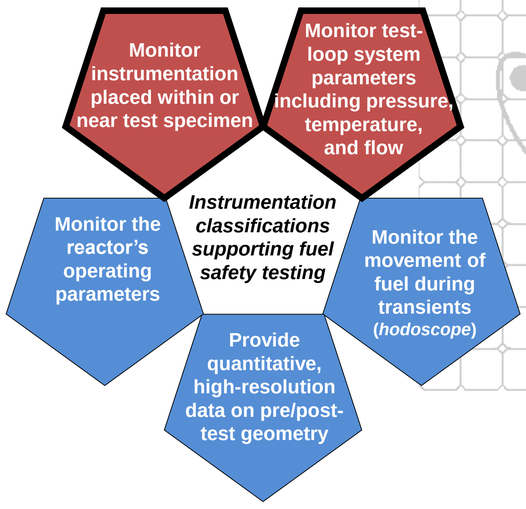

- A science-based, engineering focus for nuclear fuels and materials development requires access to data streams beyond those historically available
- The success of advanced fuels and materials development programs hinge on well-coordinated and innovative instrument R&D covering full range of technical readiness levels

## Development and Qualification

- The High Temperature Test Laboratory at INL is development hub
- Primary challenge is the integration of instruments into the test device and demonstration of interfaces and instrument performance under experiment conditions

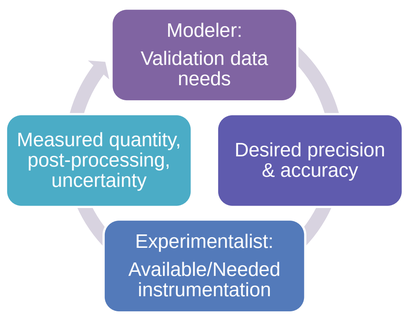



## Instrumentation for Transient Testing




Instrumentation used in in-pile transient testing:

- Thermocouples
- Ultrasonic thermometers
- Pressure transducers
- Linear Voltage Differential Transducer
- Strain gage
- Dosimetry – wires, foils, etc.
- Self-Powered Neutron Detector (SPND)
- Acoustic sensors
- Void sensors
- Coolant column velocity
- Flow meters
- High-speed video
- Hodoscope

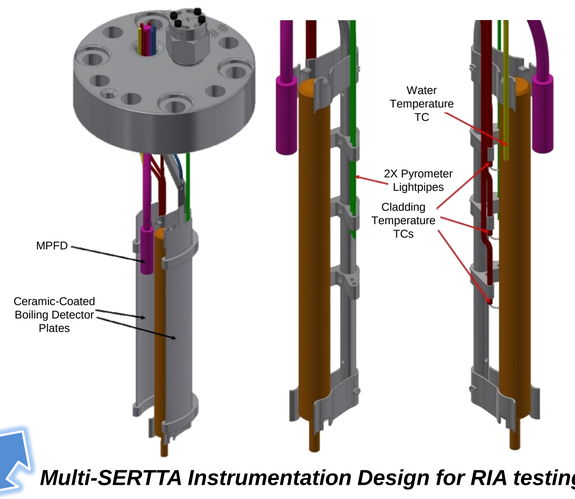



*"Ideal" Experiment Cycle*

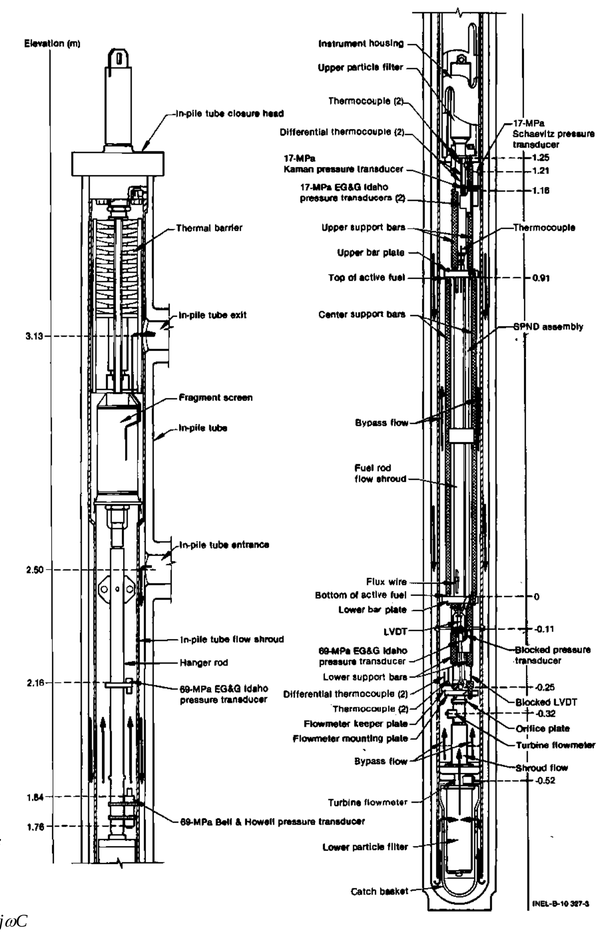
Challenges and Opportunities

- Visualization:
  - visible, IR, advanced hodoscope, ultrasonics
- Miniaturization
  - less obtrusive, increased resolution/quantity
- In-core electronics
  - signal conditioning, A/D conversion
- Enabling technologies
  - feedthroughs, hot-cell implementation, etc.

## Experiment Integration




*Multi-SERTTA Instrumentation Design for RIA testing*




*Example of historical RIA test train for the Power Burst Facility*

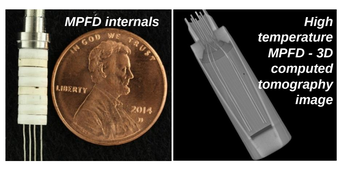
## Current Sensor Development

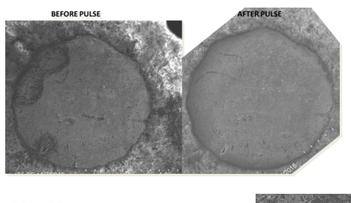
- Current development focused on Multi-SERTTA deployment for Reactivity Initiated Accident (RIA) up to PWR conditions

### Micro-Pocket Fission Detector

Kansas State University

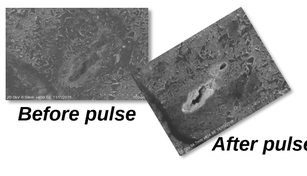
- Goal: Measure real-time neutron flux near test specimen
- State-of-the-art: SPND
- Requirements: compact, wide flux range, high temperature and pressure, ~ms response
- Approach: Adapt MPFD for TREAT application using pulse and current mode - R&D on sensor response to pulsed, high power flux




*MPFD coating pre/post TRIGA pulse images*

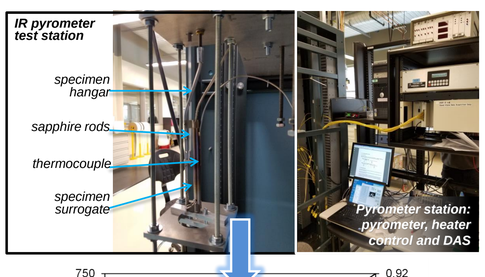
M.J. Harrison, M.A. Reichenberger, D.M. Nichols, D.S. McGregor, J.A. Roberts. "Preliminary Analysis of Damage to MPFDs Caused by Reactor Pulses." Trans. Amer. Nucl. Soc. **116**. (2017)

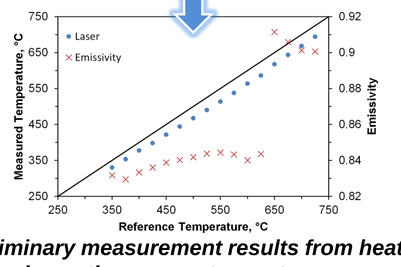




### Infrared Pyrometer

UtahState University

- Goal: Measure cladding temperature with fast response and minimal impact on cladding (non-contact)
- State-of-the-art: Thermocouple
- Requirements: ~ms response time, non-contact, use in gas, water, steam
- Approach: R&D for commercial technologies and complete custom approach – R&D of effects of design and environment



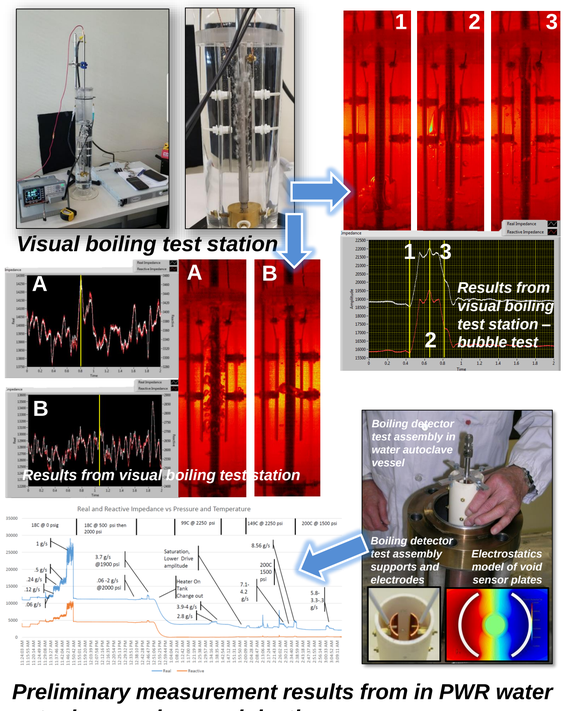




*Preliminary measurement results from heated rod using active pyrometer system*

### Capacitive Void Sensor

UNM
UtahState University

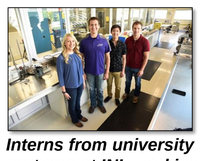
- Goal: Detect departure from nucleate boiling (DNB) and void fraction
- State-of-the-art: Ultrasonics, temperature/pressure sensors
- Requirements: ~ms response, sensitivity to DNB/void fraction
- Approach: capacitance sensor


*Preliminary measurement results from in PWR water autoclaves using gas injection*

## Collaborations

- NEUP Projects
  - Advanced Instrumentation for Transient Reactor Testing IRP – Advanced hodoscope, diamond thermistor, distributed temperature fiber, HTIR, ultrasonic thermometer, needle probe, in-pile testing
    The Ohio State University · Wisconsin · Kansas State University · Idaho State University · INL
  - Benchmarking for Transient Fuel Testing IRP – in-pile instrument testing at MITR and TREAT
    Oregon State OSU · University of Michigan · MIT · INL
  - A Transient Reactor Physics Experiment with High Fidelity 3-D Flux Measurements for Verification and Validation
    Kansas State University
- International collaborations
  - **IRSN** (France), **CEA** (France), **Halden** (Norway), **NNC** (Kazakhstan), **KAERI** (Korea)



*Interns from university partners at INL working on instrumentation*

*Acknowledgments: HTTL Laboratory Staff*