INL/MIS-22-69771-Revision-0

TWIST Mechanical Design Presentation

October 2022

Klint Stephens Anderson, Jason L Schulthess, Justin Des Yarrington, Spencer Hugh Parker

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TWIST Mechanical Design

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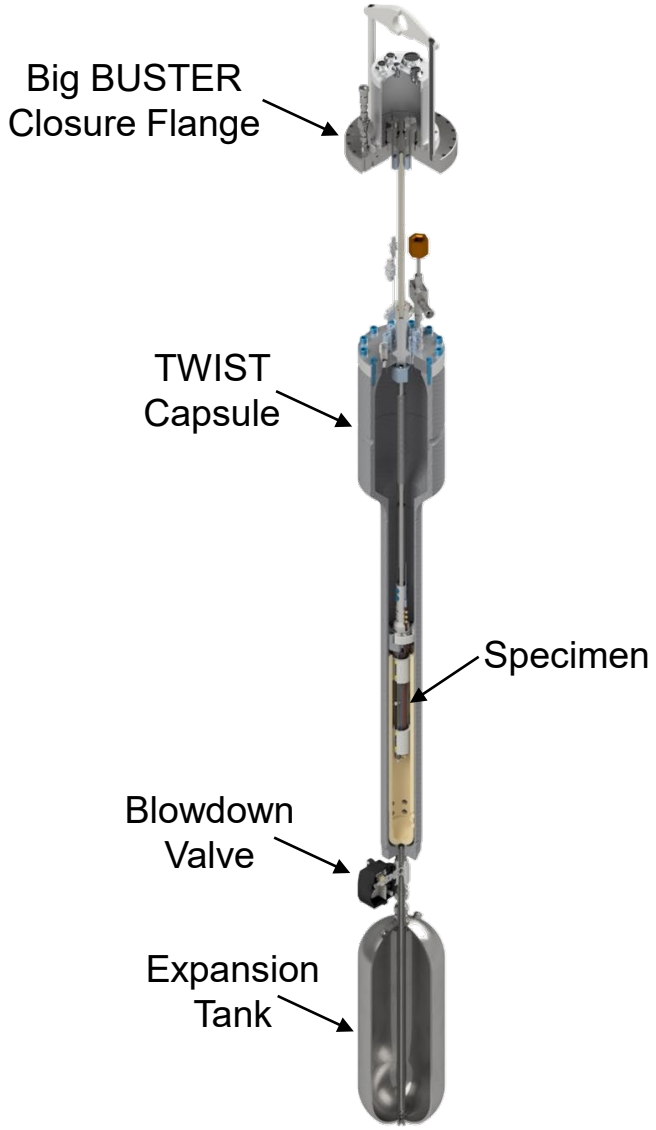
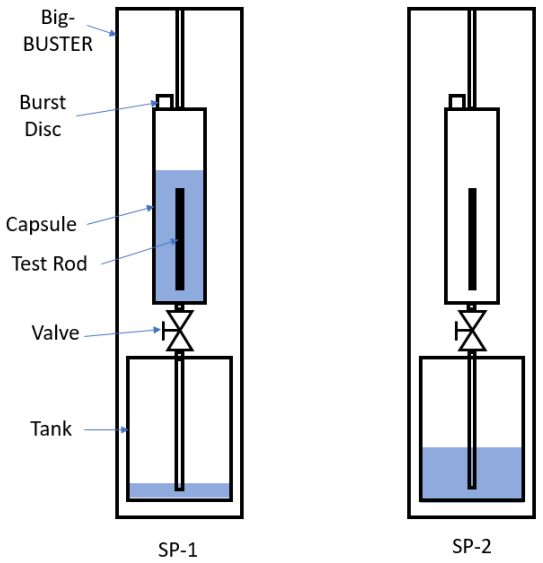
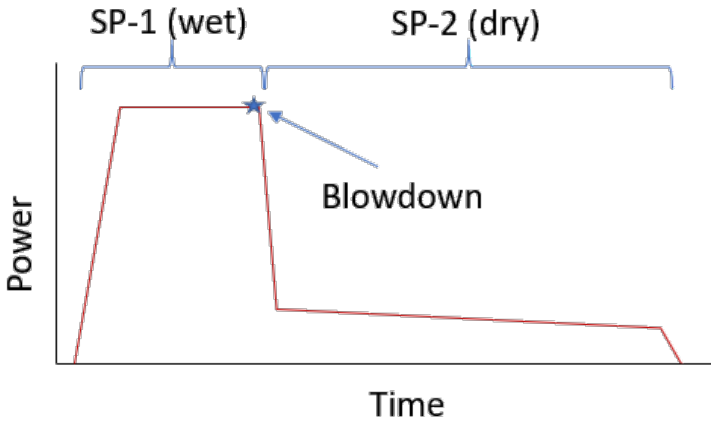
Idaho National Laboratory

Transient Water Irradiation System for TREAT (TWIST)

- Simulates LWR Loss of Coolant Accidents (LOCA)
- State Point 1 (SP-1)
  - Water in capsule at 20° C and ~ 580 psi
  - ~30 second transient segment ~40MW reactor power
  - Nucleate boiling to achieve LWR fuel temperature state
- State Point 2 (SP-2)
  - Valve opens, water drains in ~2-3 seconds
  - ~100 second transient segment ~5 MW reactor power
  - LOCA “prototypic” specimen temperature rise

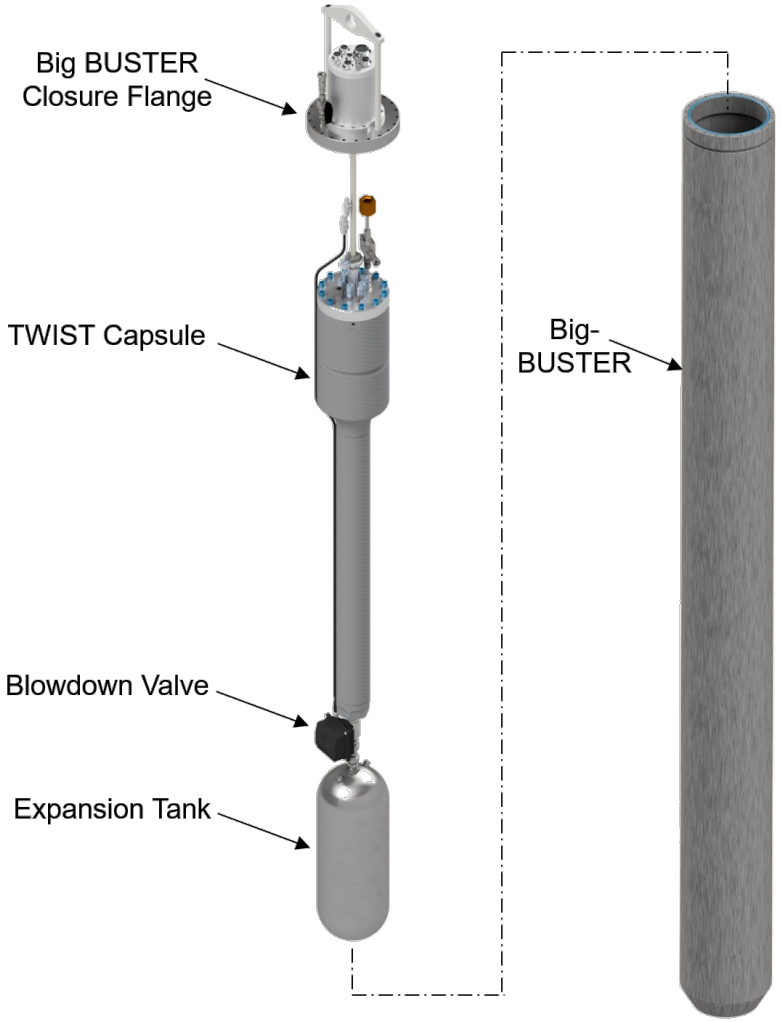




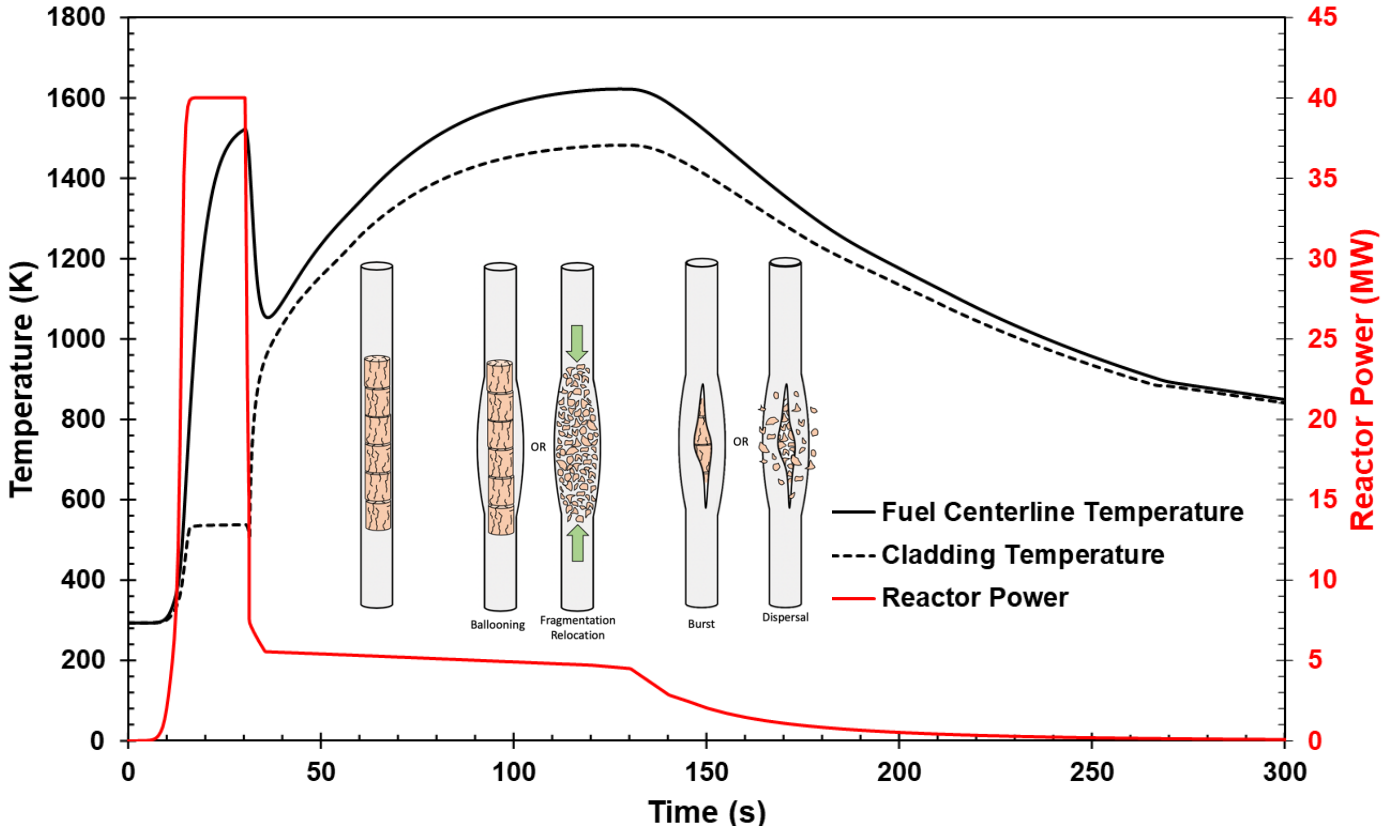


Transient Water Irradiation System for TREAT (TWIST)

- Utilizes the Big-BUSTER irradiation device as the experiment containment



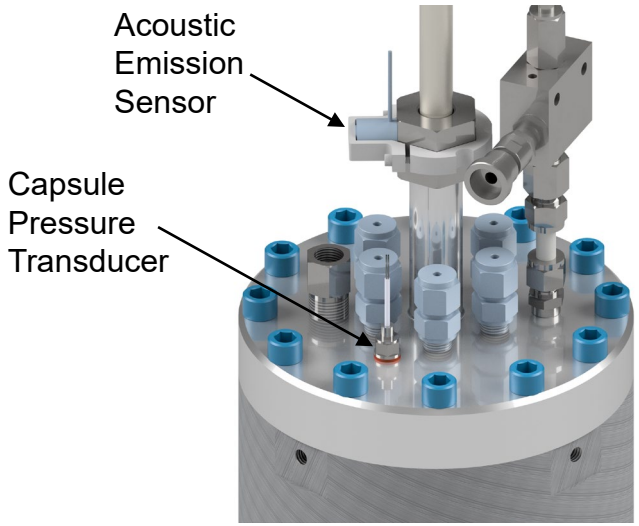
Example Transient Design

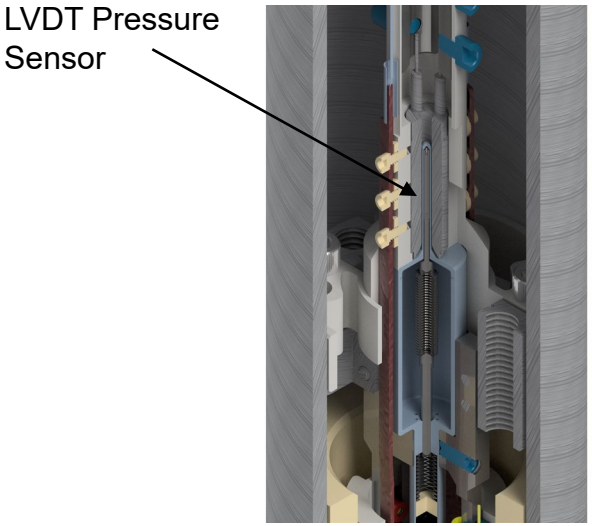


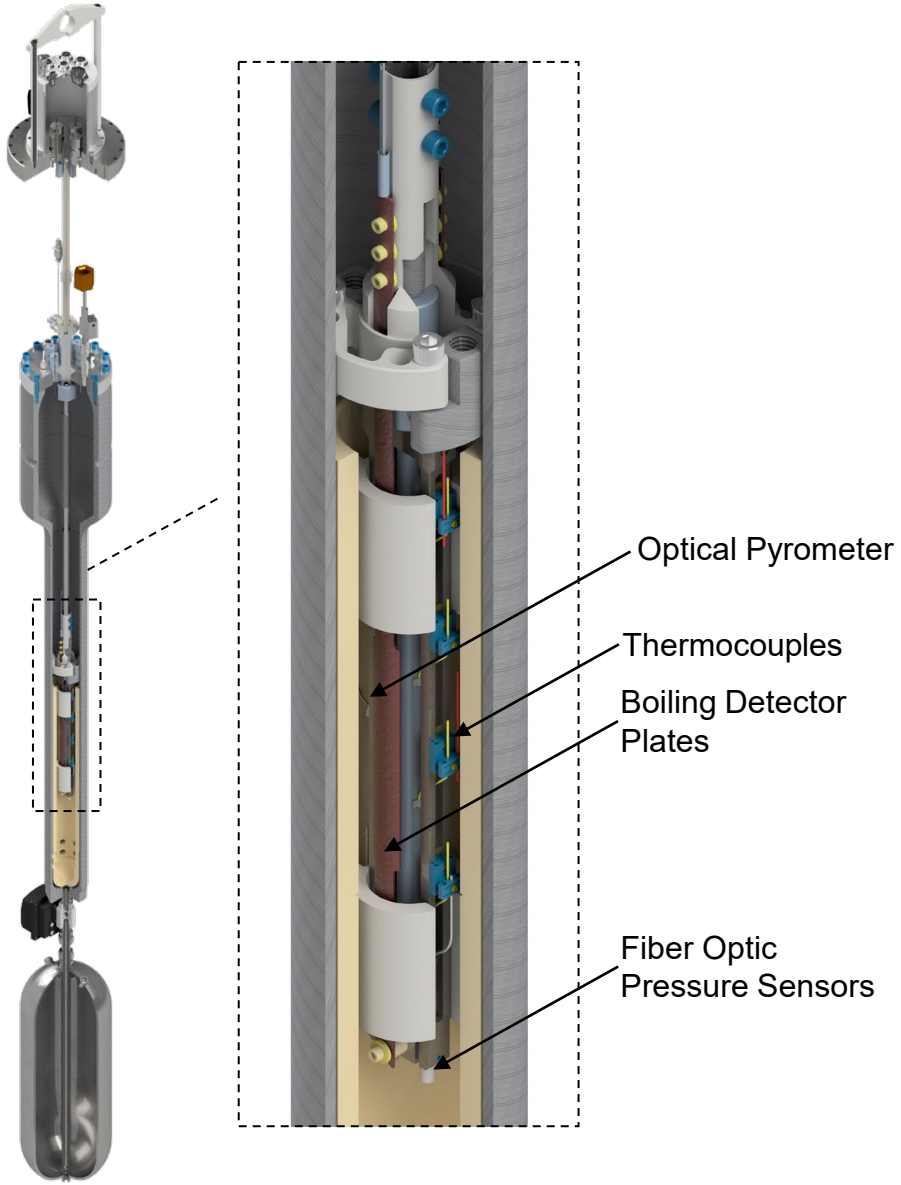
Extreme case calculated (RELAP) for HBU fuel to determine TREAT capability, lower power/temperature transients to be used for typical UO_2-Zry fuel rod testing

TWIST Instrumentation

- Instrumentation Package Includes
  - 6-10 thermocouples measure cladding and water temperature at various axial elevations
  - Thermocouple for centerline fuel temperature or LVDT for rodlet pressure measurements
  - Pressure Transducer for capsule pressure
  - Optical Pyrometer for cladding temperature
  - Fiber Optic Pressure Sensors located inside the capsule
  - Boiling Detector Plates to measure phase change events
  - Acoustic Emission Sensor for cladding rupture detection

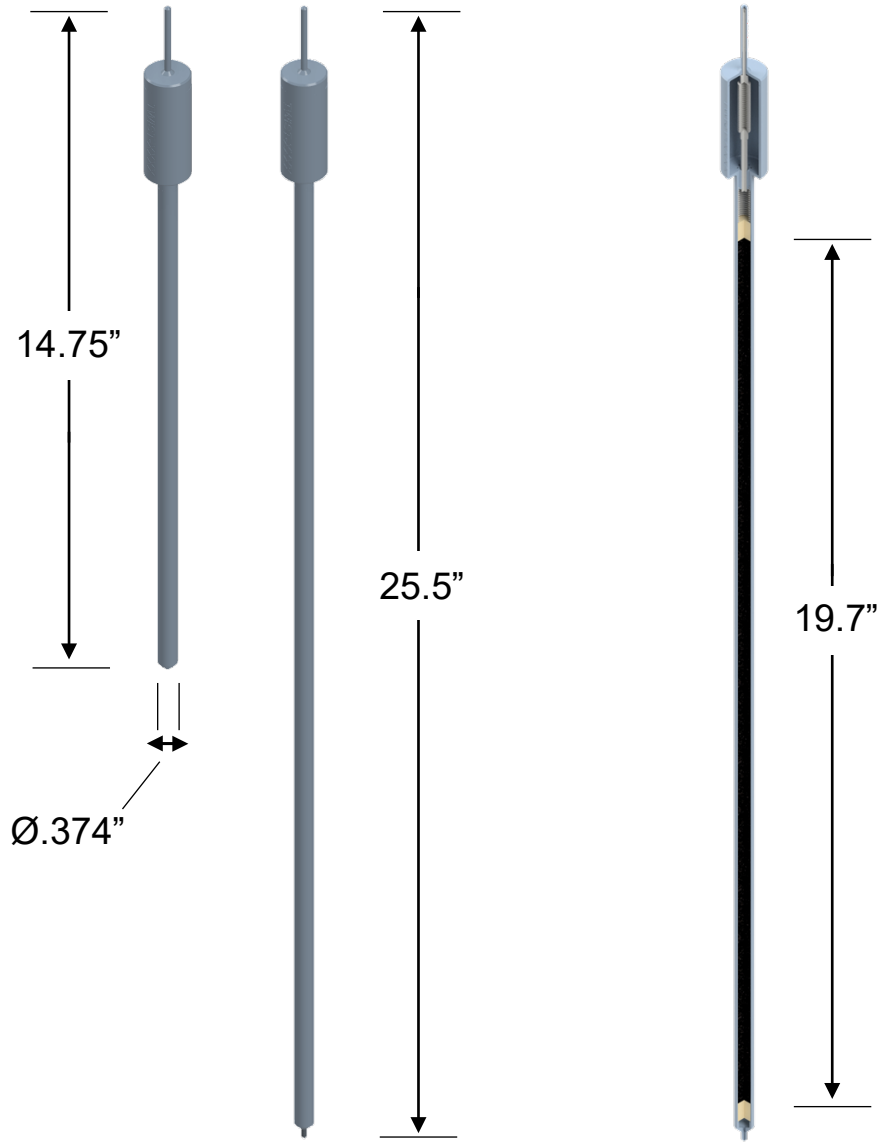






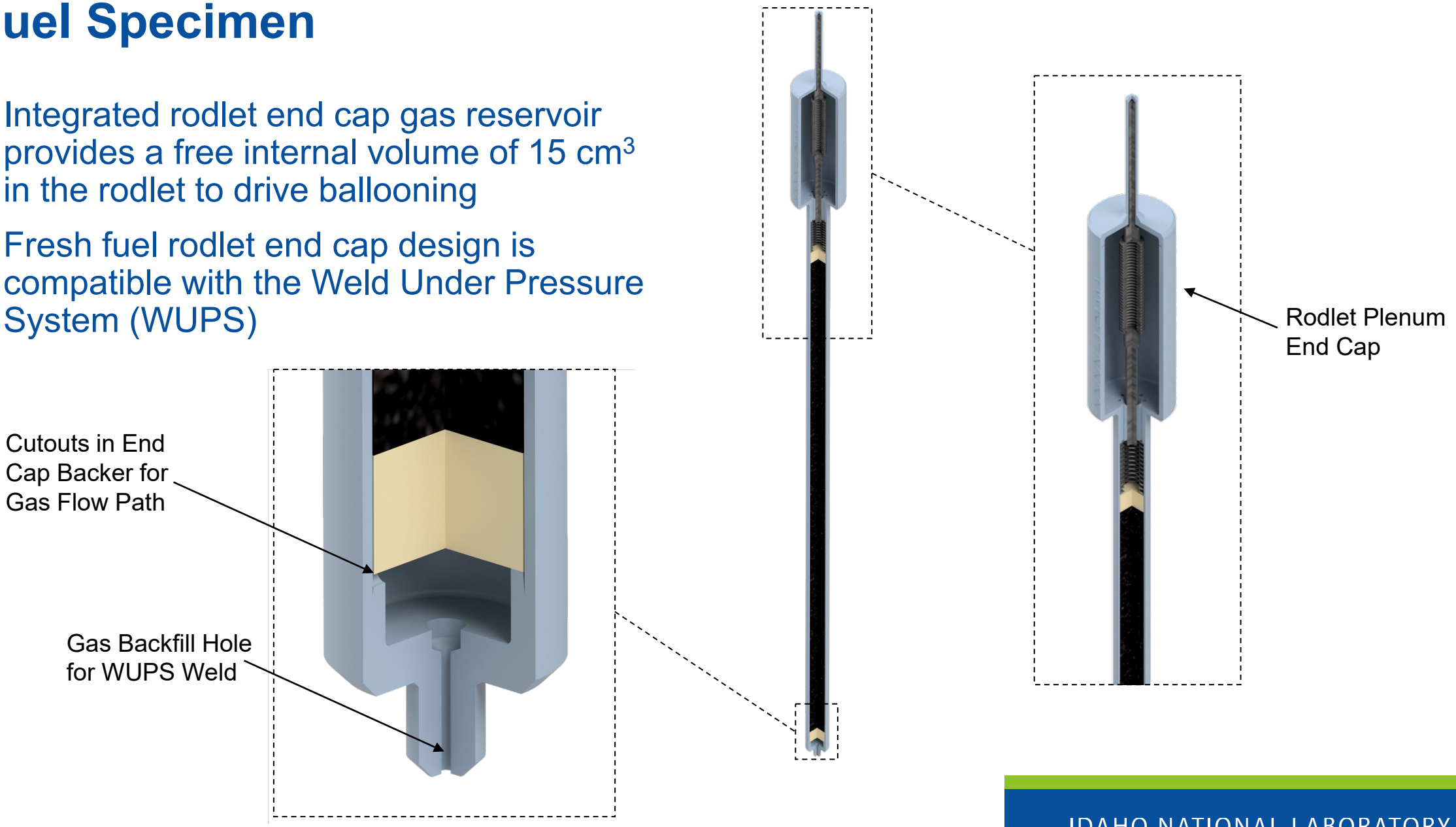
Fuel Specimen

- The TWIST capsule accommodates a single rodlet of up to 50 cm fueled length
- Two different fresh fuel specimen lengths will be tested as part of the commissioning series
- Specimens are typical of pressurized water reactors and contain UO_2 fuel encompassed in zirconium alloy cladding with an outside diameter of .374 inches



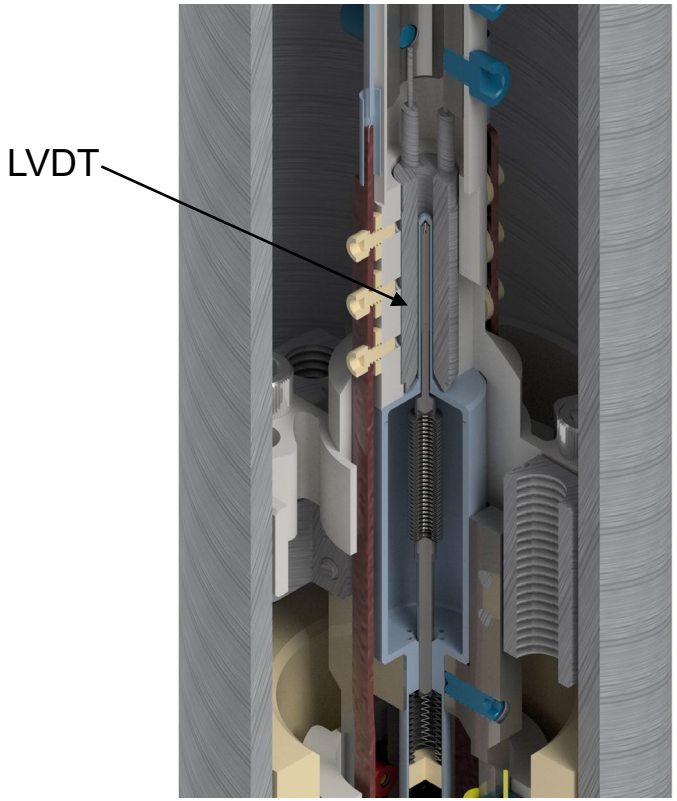
Fuel Specimen

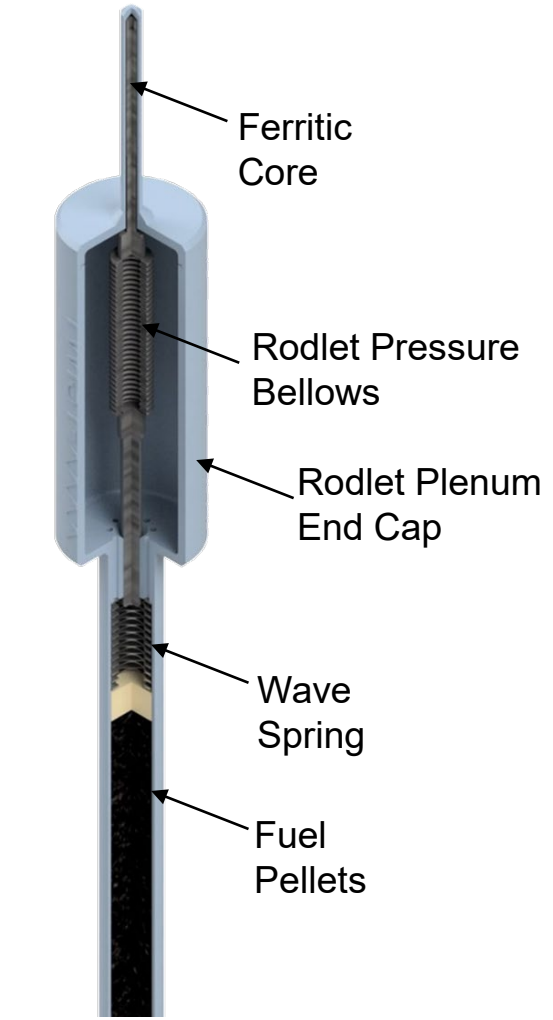
- Integrated rodlet end cap gas reservoir provides a free internal volume of 15 cm^3 in the rodlet to drive ballooning
- Fresh fuel rodlet end cap design is compatible with the Weld Under Pressure System (WUPS)



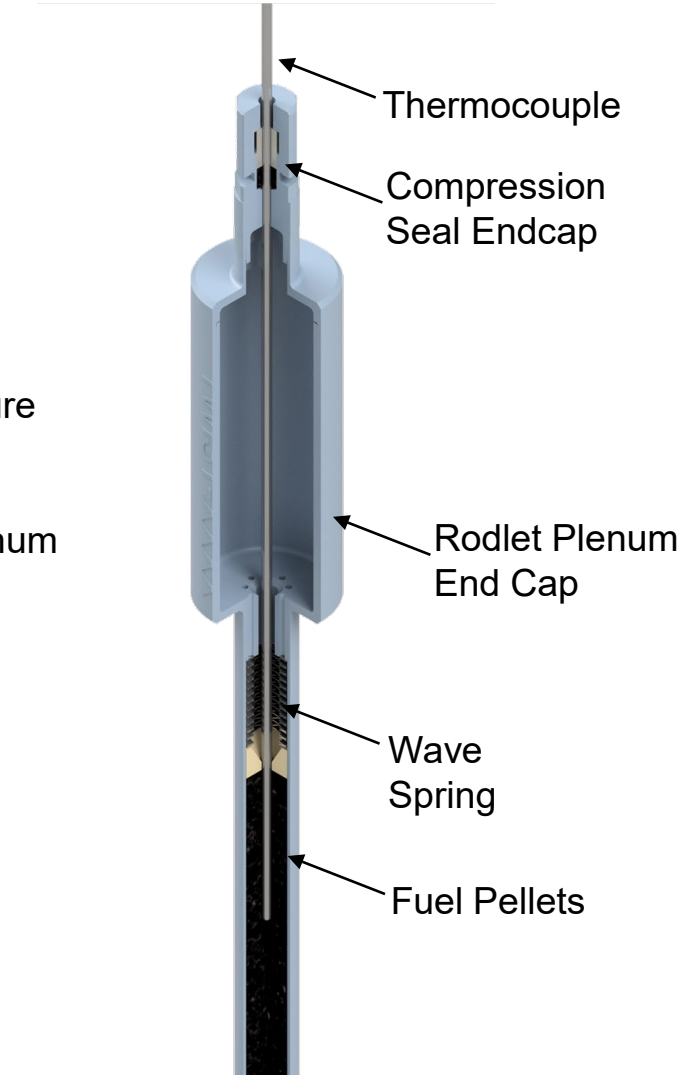
Fuel Specimen

- Two upper end cap designs enable measurements of rodlet upper plenum internal pressure and fuel centerline temperature



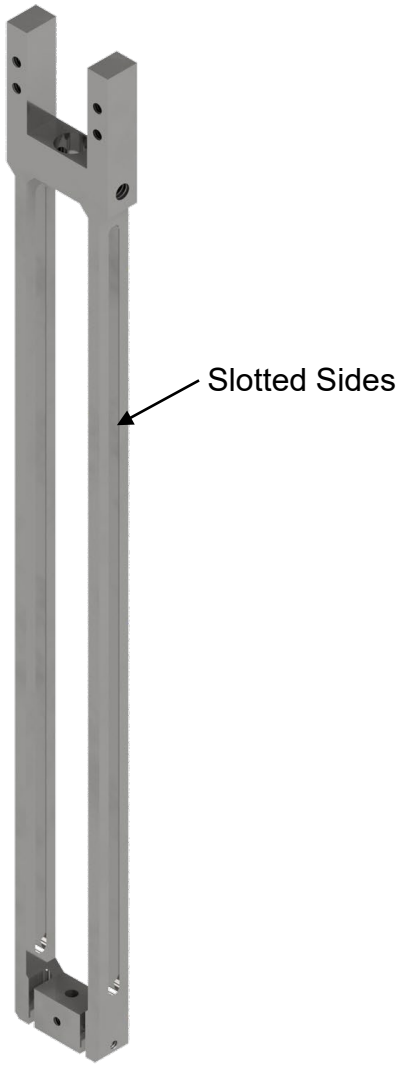


Bellows Pressure Measurement Endcap

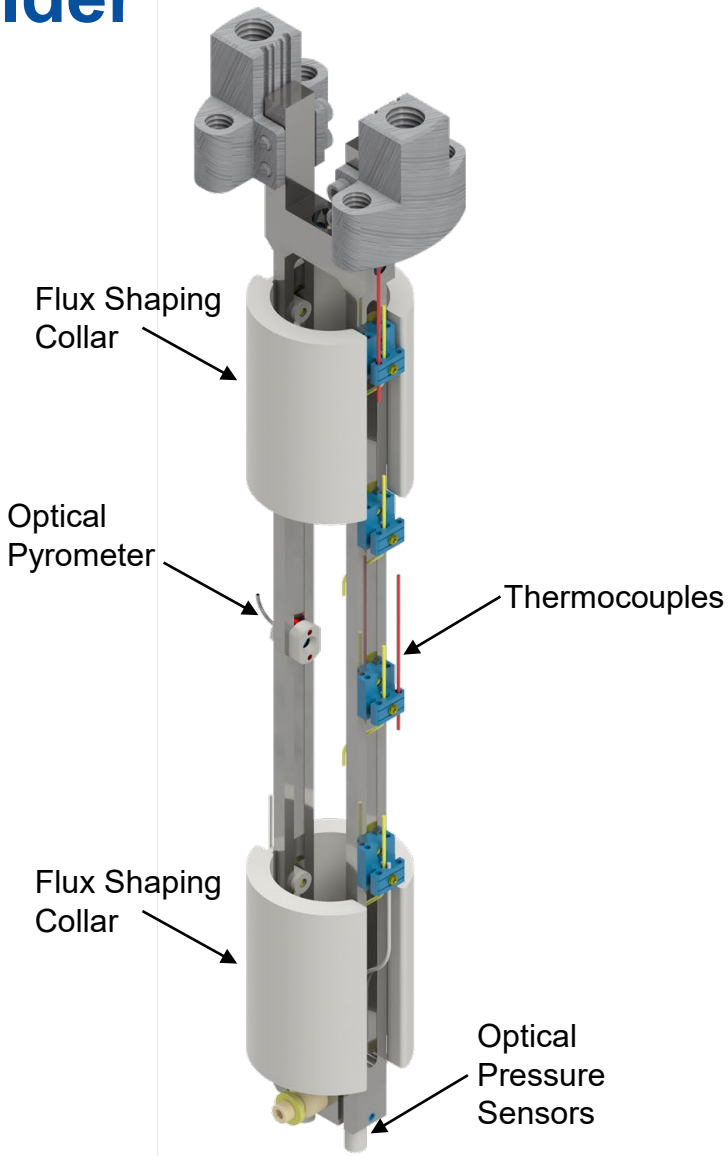


Fuel Centerline Temperature Endcap

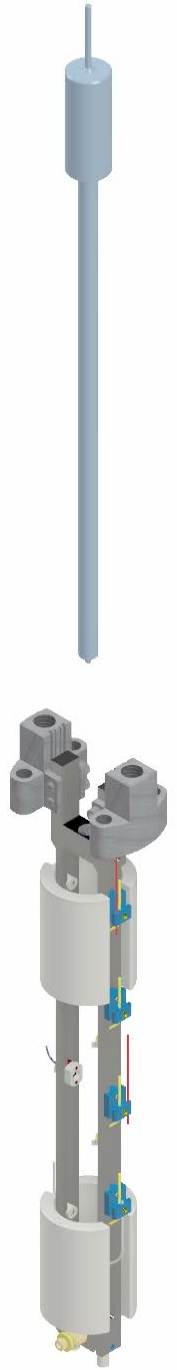
Specimen Holder

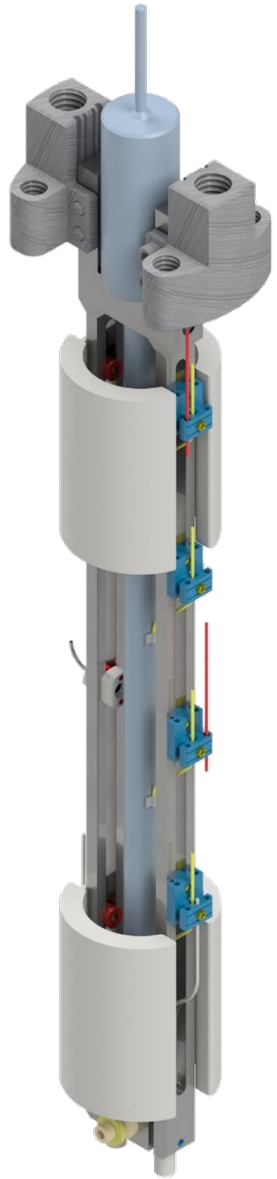


Specimen Holder



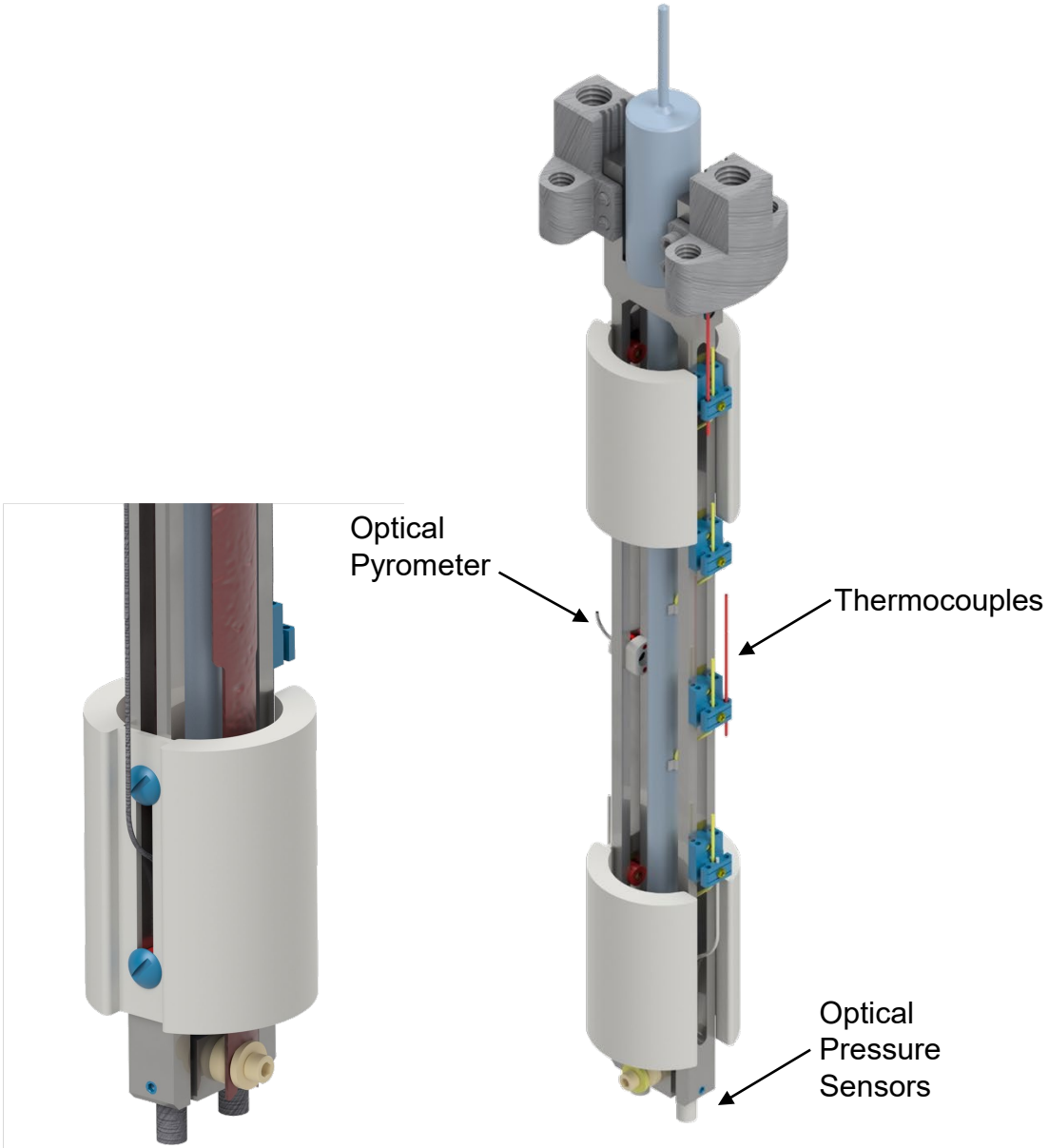
Instrumented Holder



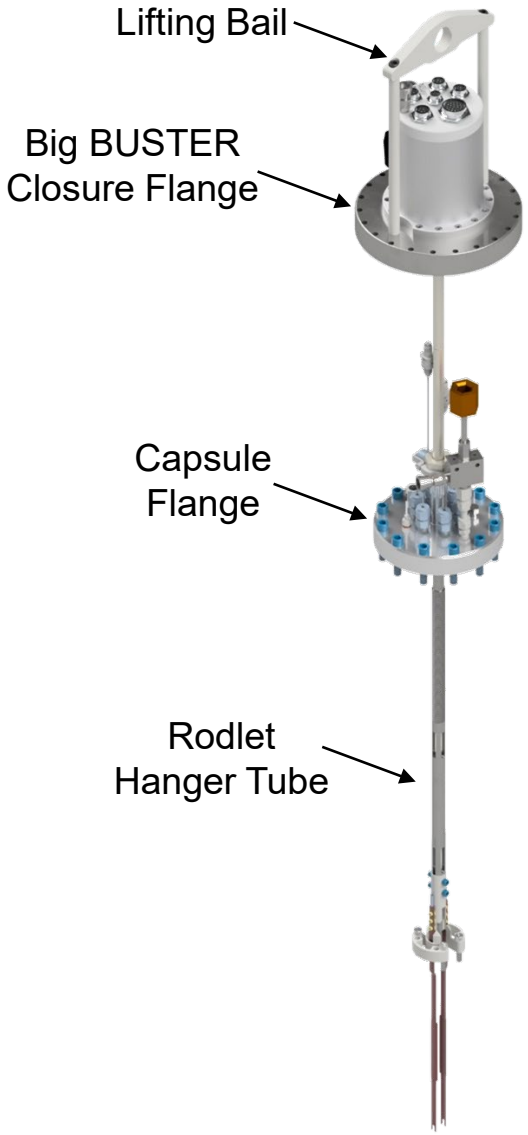


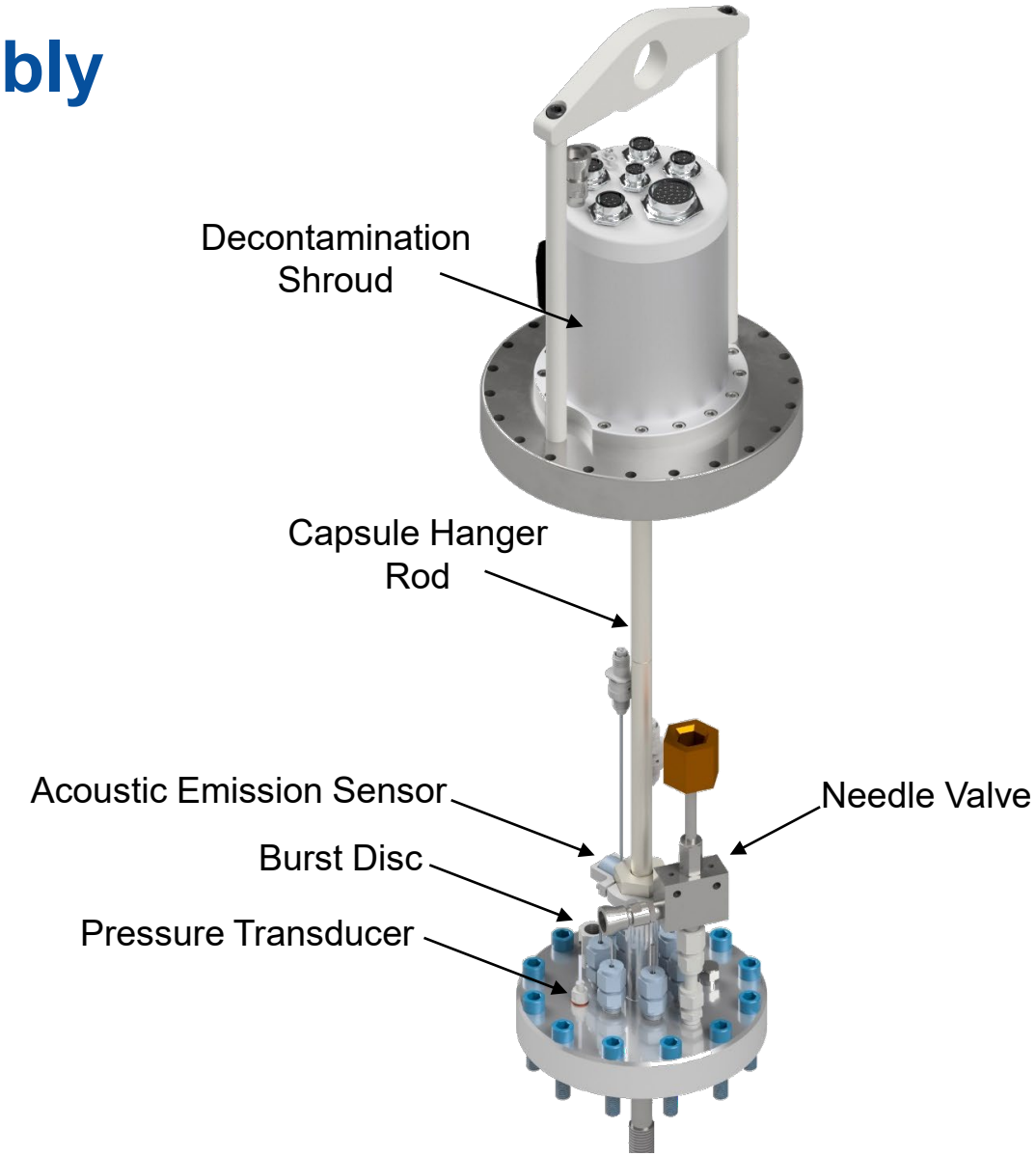
Specimen Holder

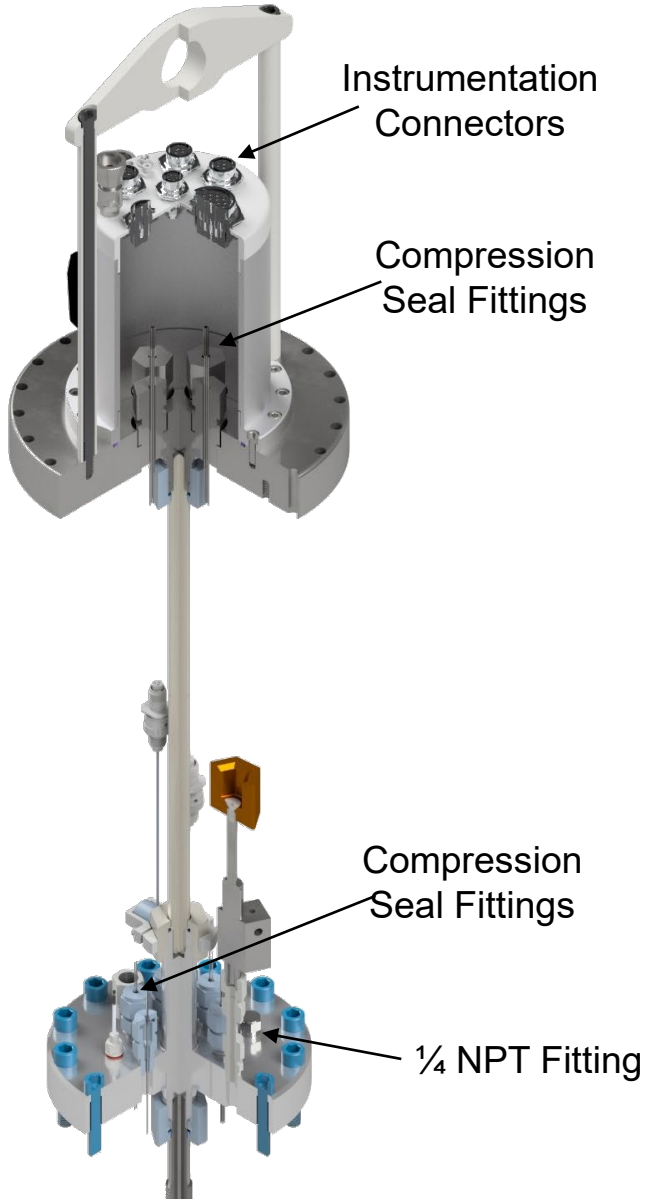
- Thermocouples attached to the cladding and an optical pyrometer attached to the specimen holder measure the specimen cladding surface temperature response
- Thermocouples are also placed in close proximity to the specimen to measure the temperature of the water/steam environment
- Pressure sensors placed at the bottom of the specimen holder measure pressure of the system surrounding the specimen throughout the experiment
- Flux collars surrounding the specimen are doubly attached to the specimen holder and are placed at the top and bottom of the fuel stack



Flange Assembly

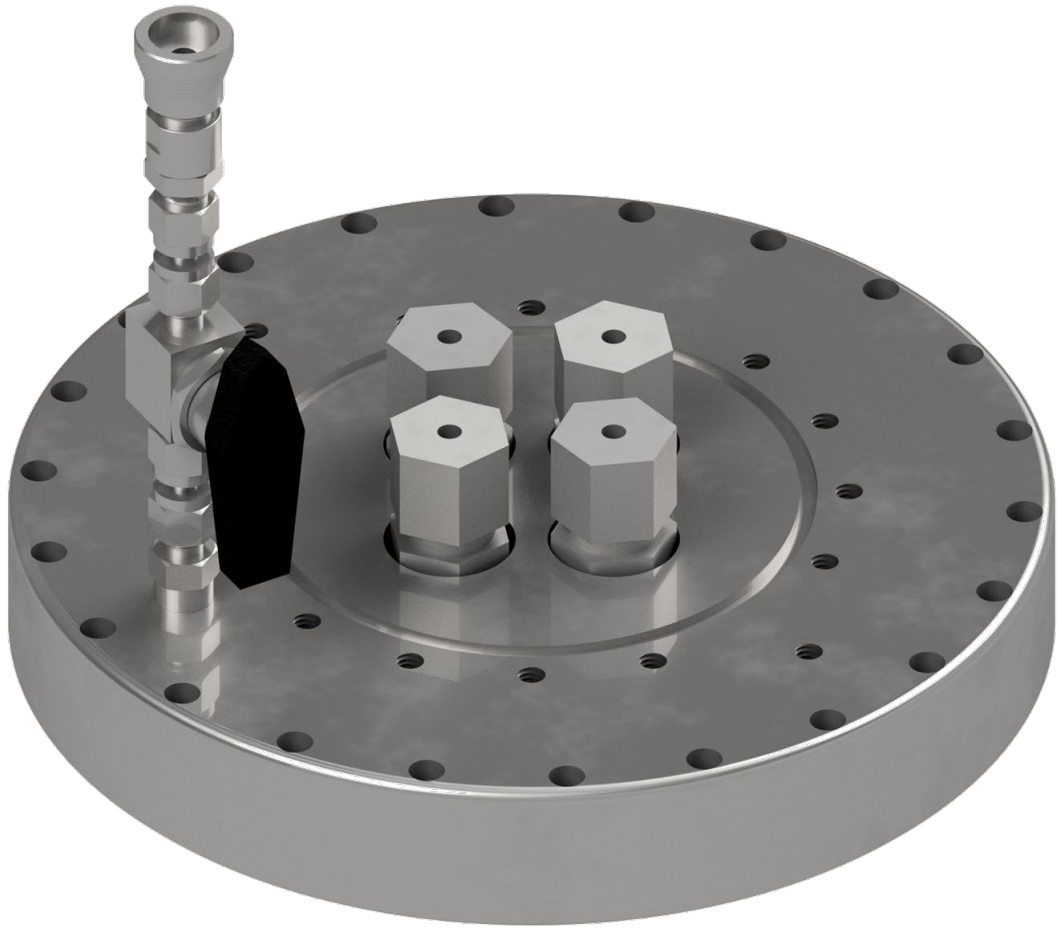






Big-BUSTER Closure Flange

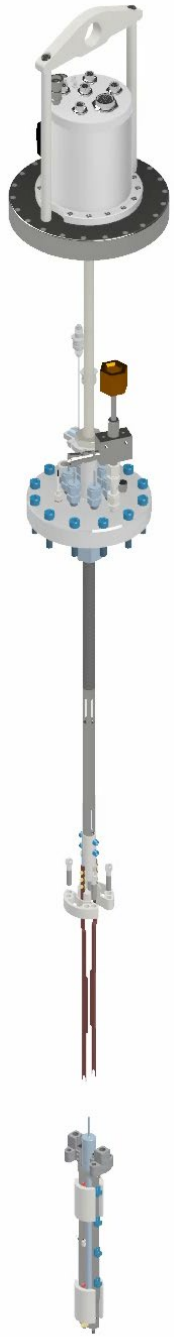
- The Big-BUSTER closure flange is designed and will be fabricated per ASME BPVC Section III, Class 1 requirements
- This flange is assembled to the top of the TWIST module and mates with Big-BUSTER to form the experiment containment

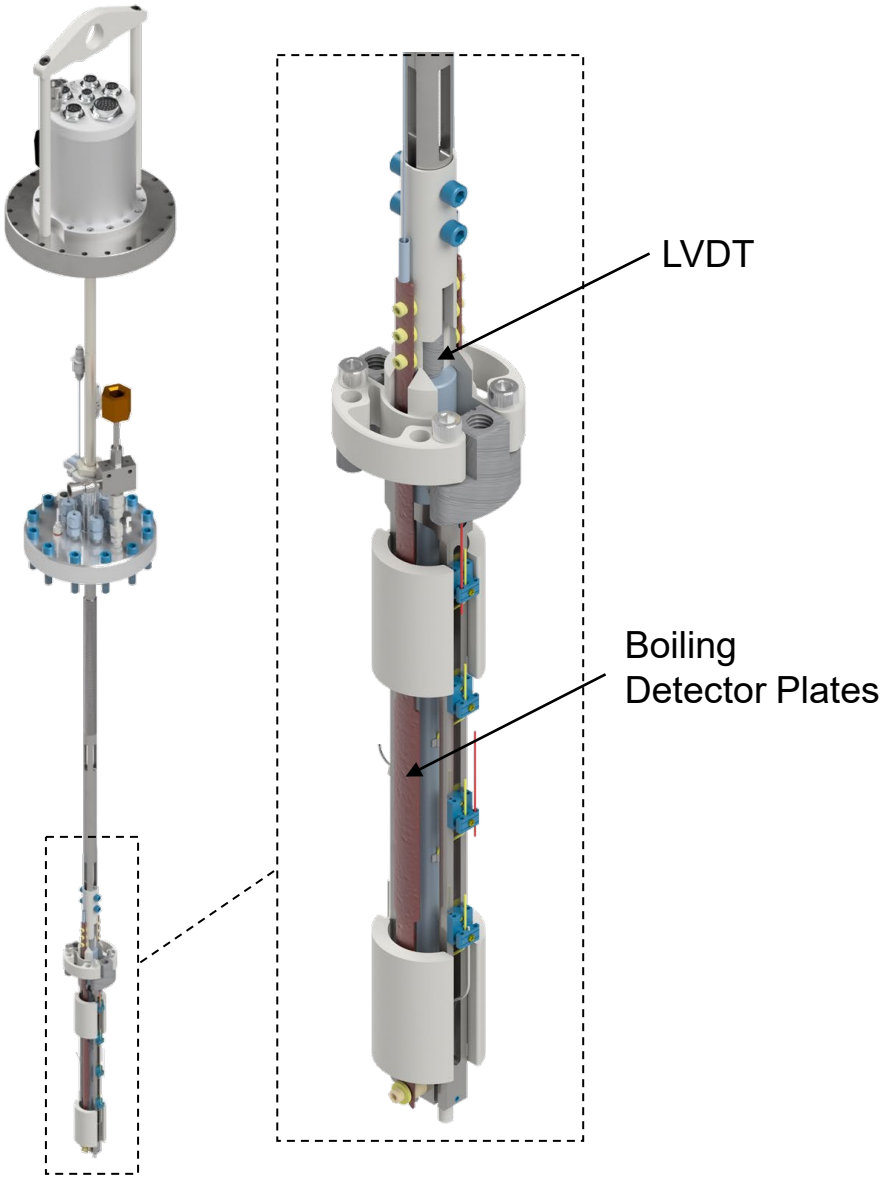


TWIST Big-BUSTER Closure Flange

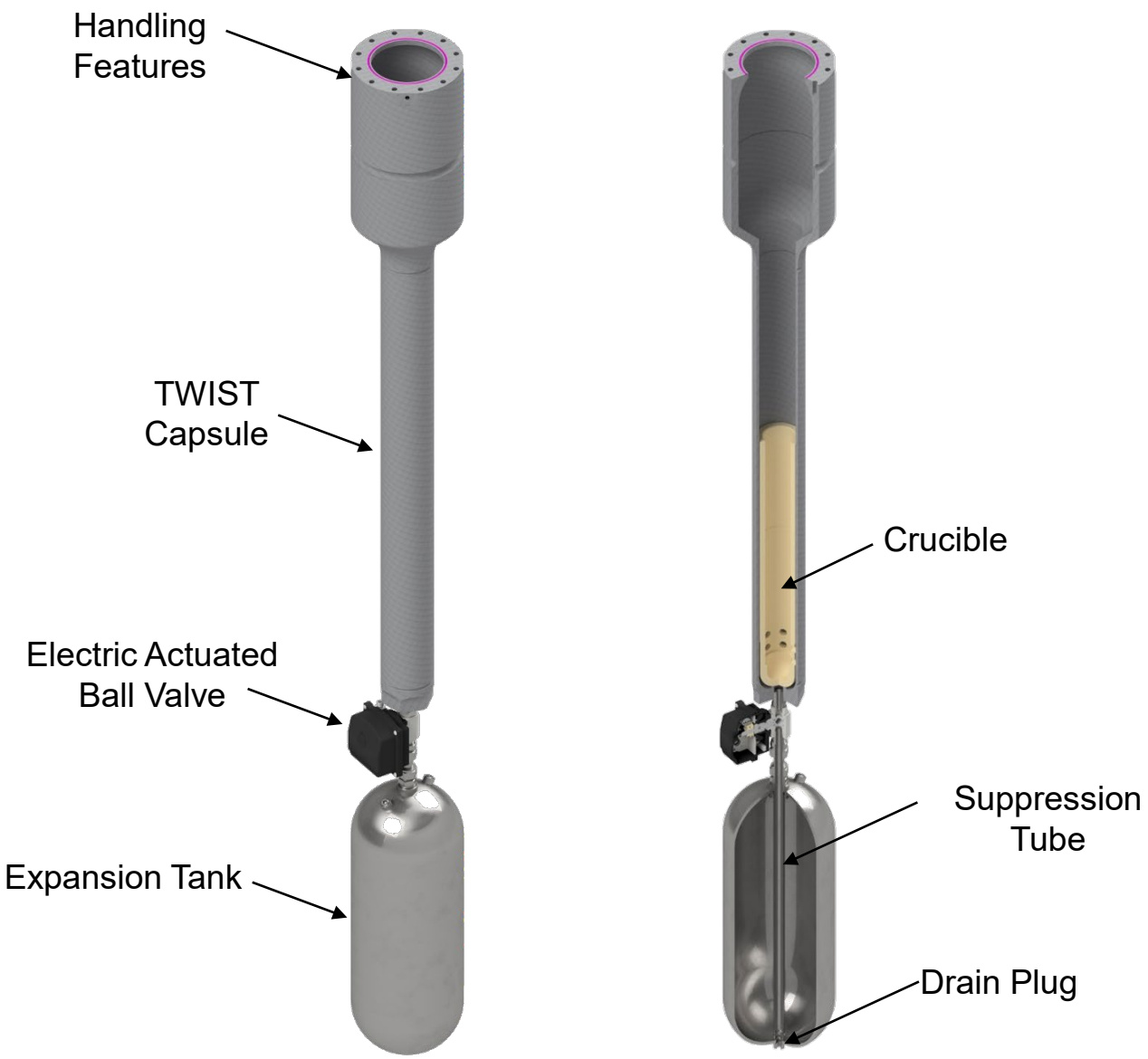
Specimen/Flange Assembly

- Boiling detector plates measure time-resolved data of significant phase change events in the water surrounding the specimen prior to blowdown
- The same boiling detector plates measure significant cladding radial distension after blowdown



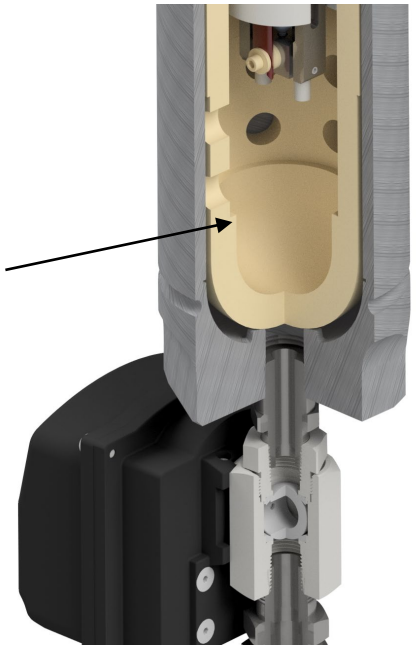


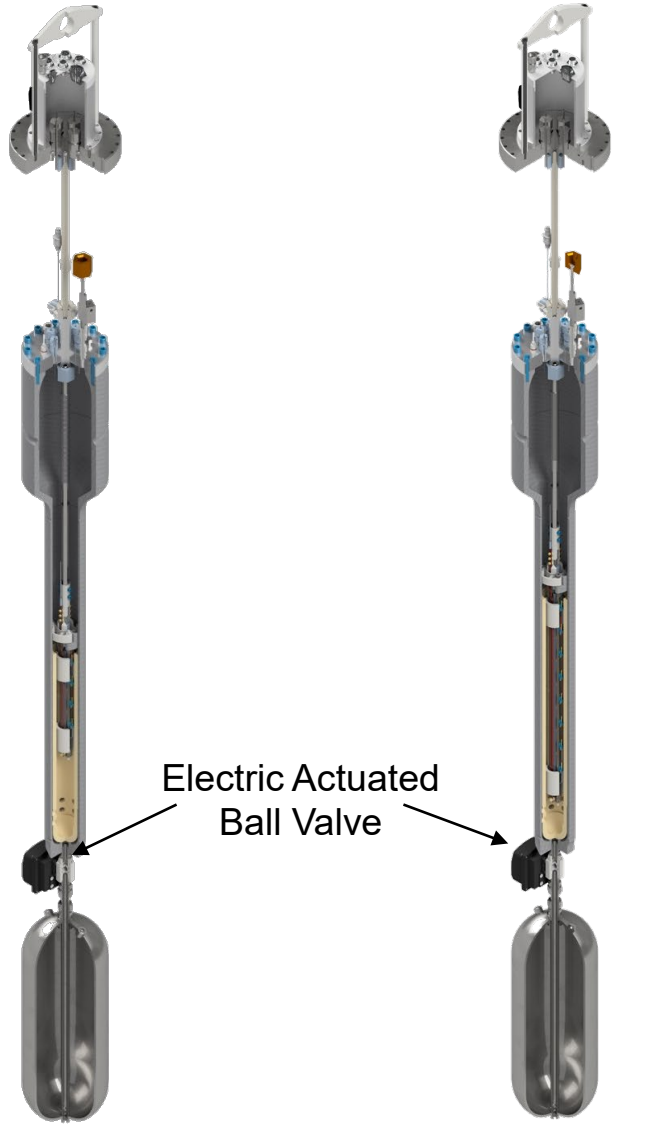
Capsule Assembly



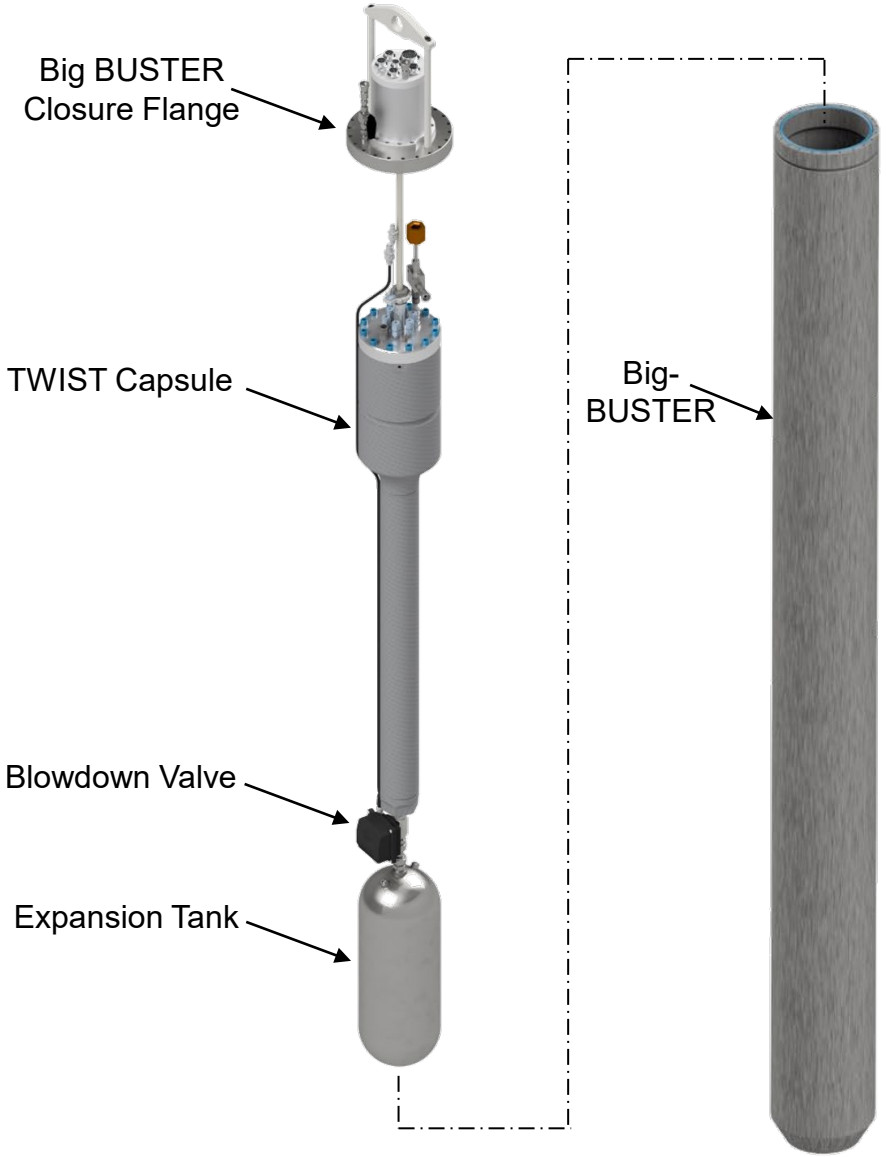
Module Assembly

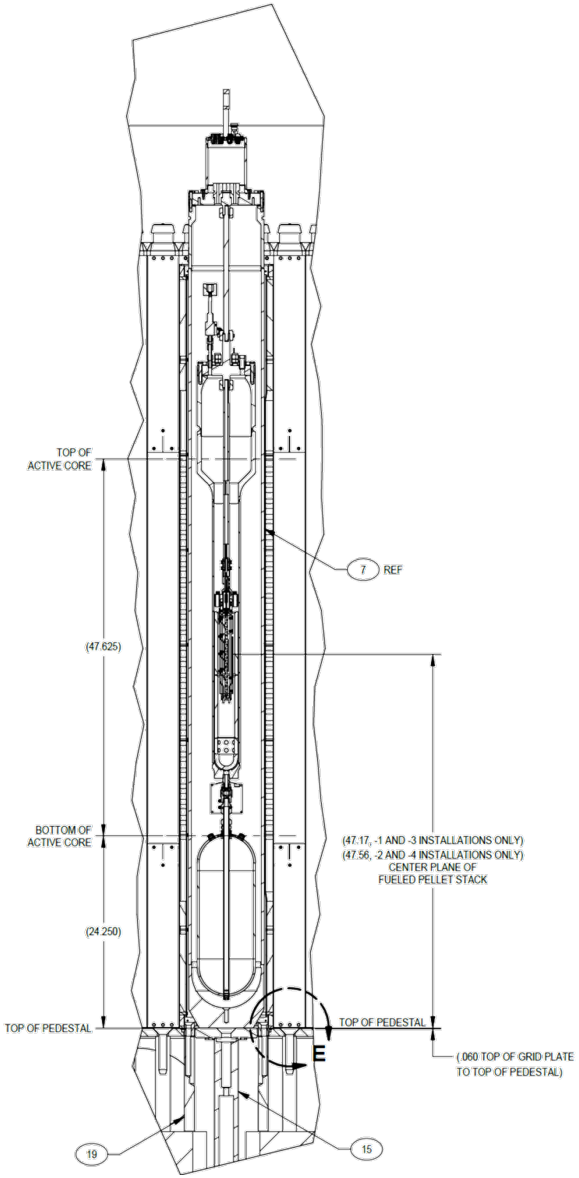
- The capsule provides a specimen pre-transient environment of water submerging the specimen
- The electric actuated ball valve and expansion tank directly below the capsule provide a controllable and rapid release of pressure from the primary capsule (blowdown)
- A lower catch crucible sits directly below the specimen and is designed with sufficient volume to retain a hypothetical fuel melt pool





Big-BUSTER Assembly

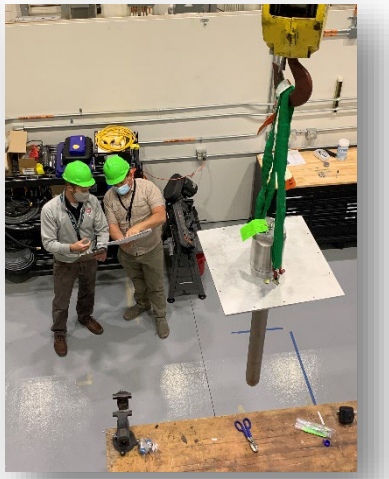


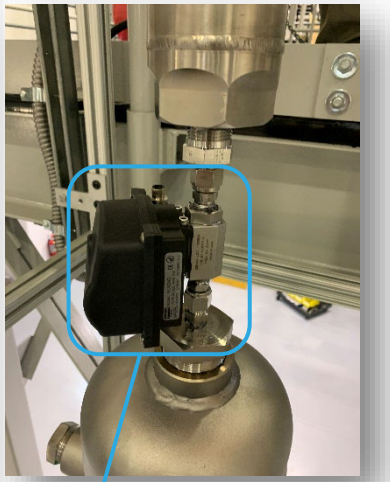


TWIST Assembly in TREAT

Full Scale Prototype

- Full-size TWIST non-nuclear out-of-pile prototype has been constructed
  - Testbed for thermal hydraulic characterization (blowdown rate)
  - Instrumentation testing platform using electrically heated fuel rod simulator
- Testing to commence shortly
  - Data to be used to fine tune experiment models for enhanced transient design
  - First step in model-based interpretation of eventual in-reactor test results
- Assembly has informed mechanical design and helped guide design direction



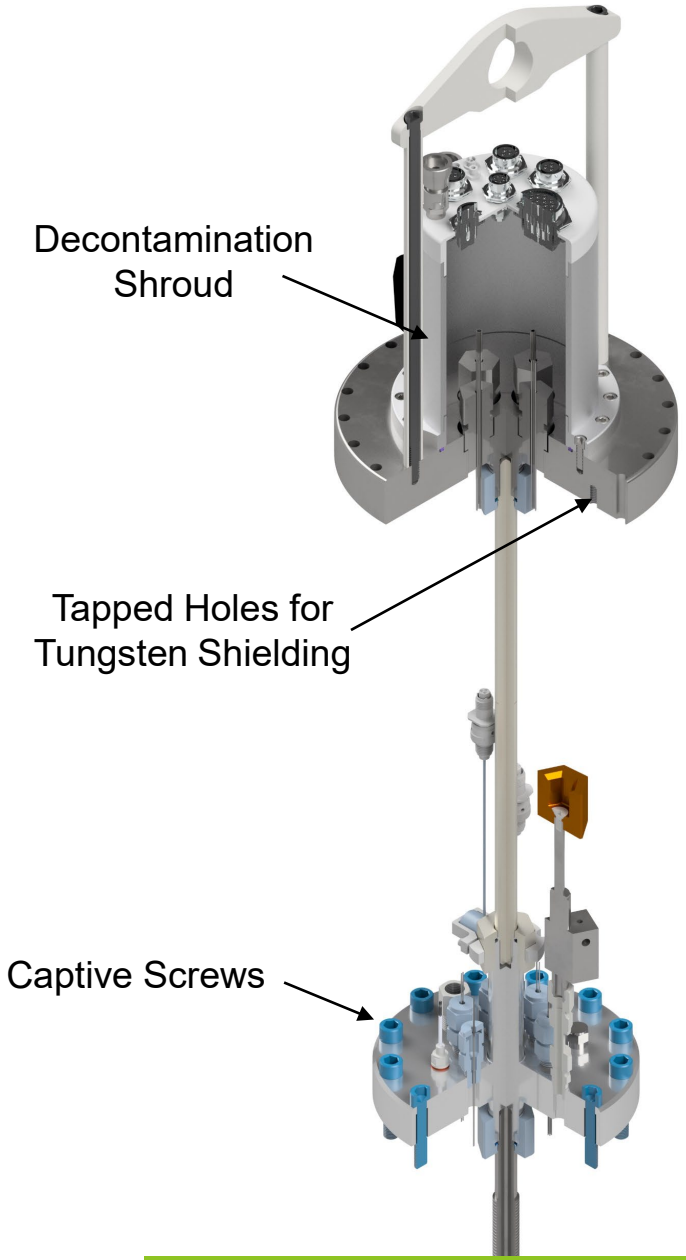


Experiment Assembly and Handling

- Designed with hot cell assembly in mind
- Removable lifting bail attaches to the Big-BUSTER top flange for handling

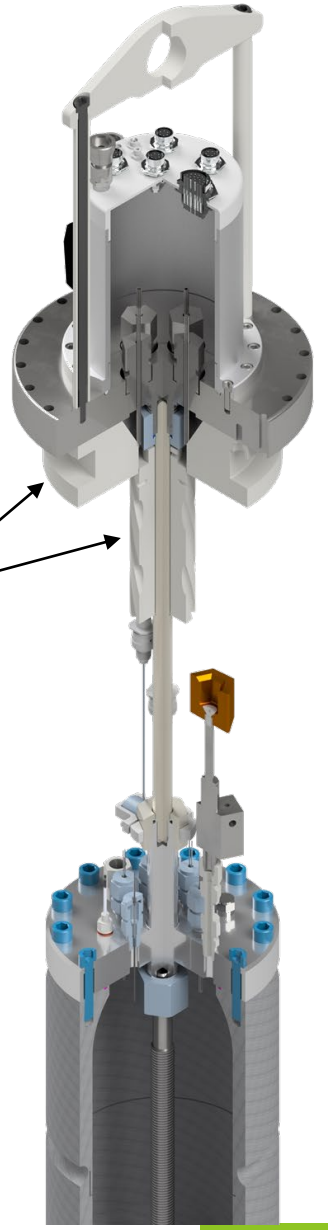
Lifting Bail

Shoulder Screws
Assembled to the Capsule



Pre-Irradiated HERA Testing in TWIST

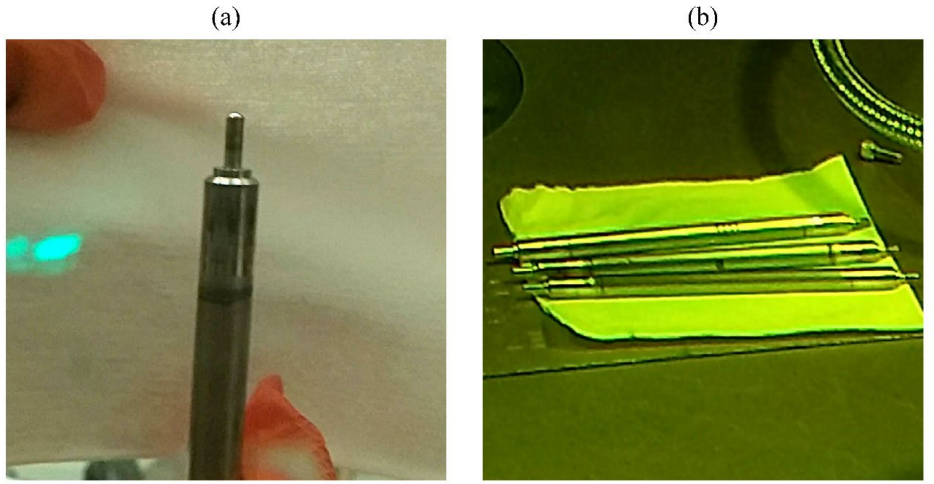
- The first irradiations in TWIST will occur next summer with fresh fuel specimens
- Work is currently underway to develop fixtures and methods for remote handling and assembly
- Integration of HERA into the TWIST capsule provides continuity for hot cell operations



Basic Specimen Refabrication is Currently Available

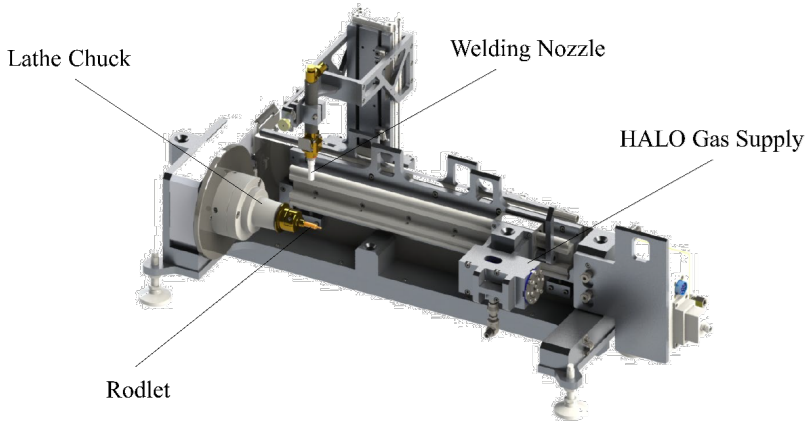
- Fabrication, installation, and demonstration of all the “basic refabrication” equipment was completed last year
- Successfully refabricated 3 irradiated rodlets from the ATF-2 experiment using the INL developed Rodlet End Weld System (REWS), and In-Cell Weld Under Pressure System (ICWUPS)
- ICWUPS capable of 2250 psi

(a) Out of cell demonstration of endcap weld using REWS

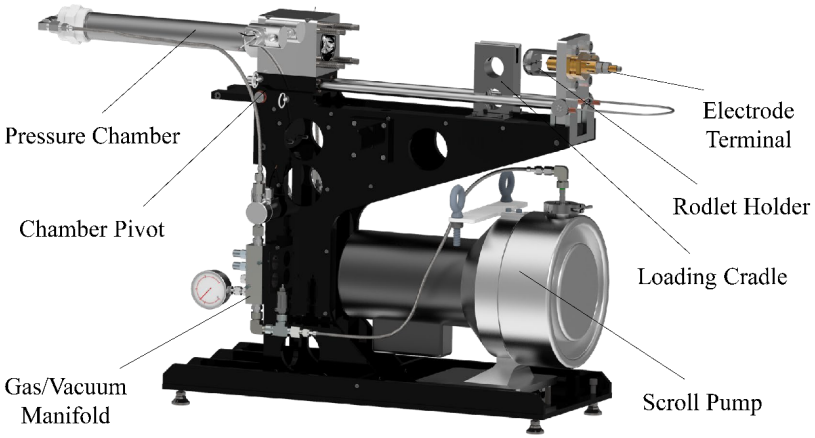


(b) Three rodlets successfully refabricated in HFEF

REWS



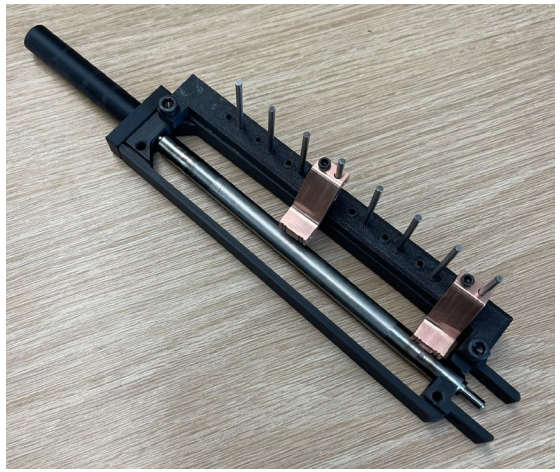
ICWUPS

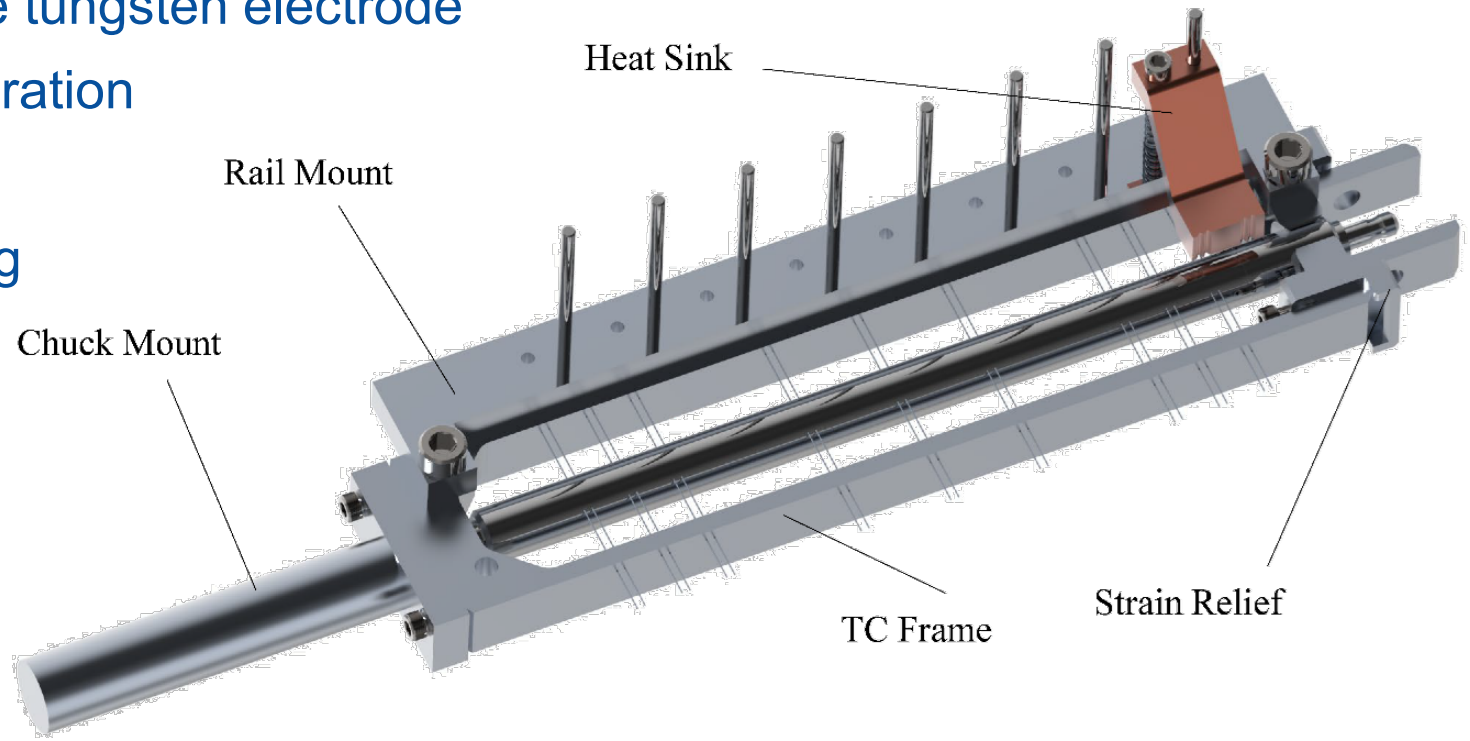


Courtesy of Jason Schulthess, Justin Yarrington, and Spencer Parker

Concept for Remotely Attaching Surface Thermocouples on Previously Irradiated Rodlets

- Focused on compatibility with the TWIST irradiation vehicle (currently no intermediate connectors for instrument leads)
- Utilize Rodlet End Weld System (REWS) to perform weld which enables accurate positioning of the TC wires to the tungsten electrode
- Minimize TC wire handling for remote operation
- Repeatable weld is a high priority
- Currently fabricating a prototype for testing





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