



Team Approach Overcoming Unique Challenges in the Return to Service of NIST NBSR

TRTR 2024

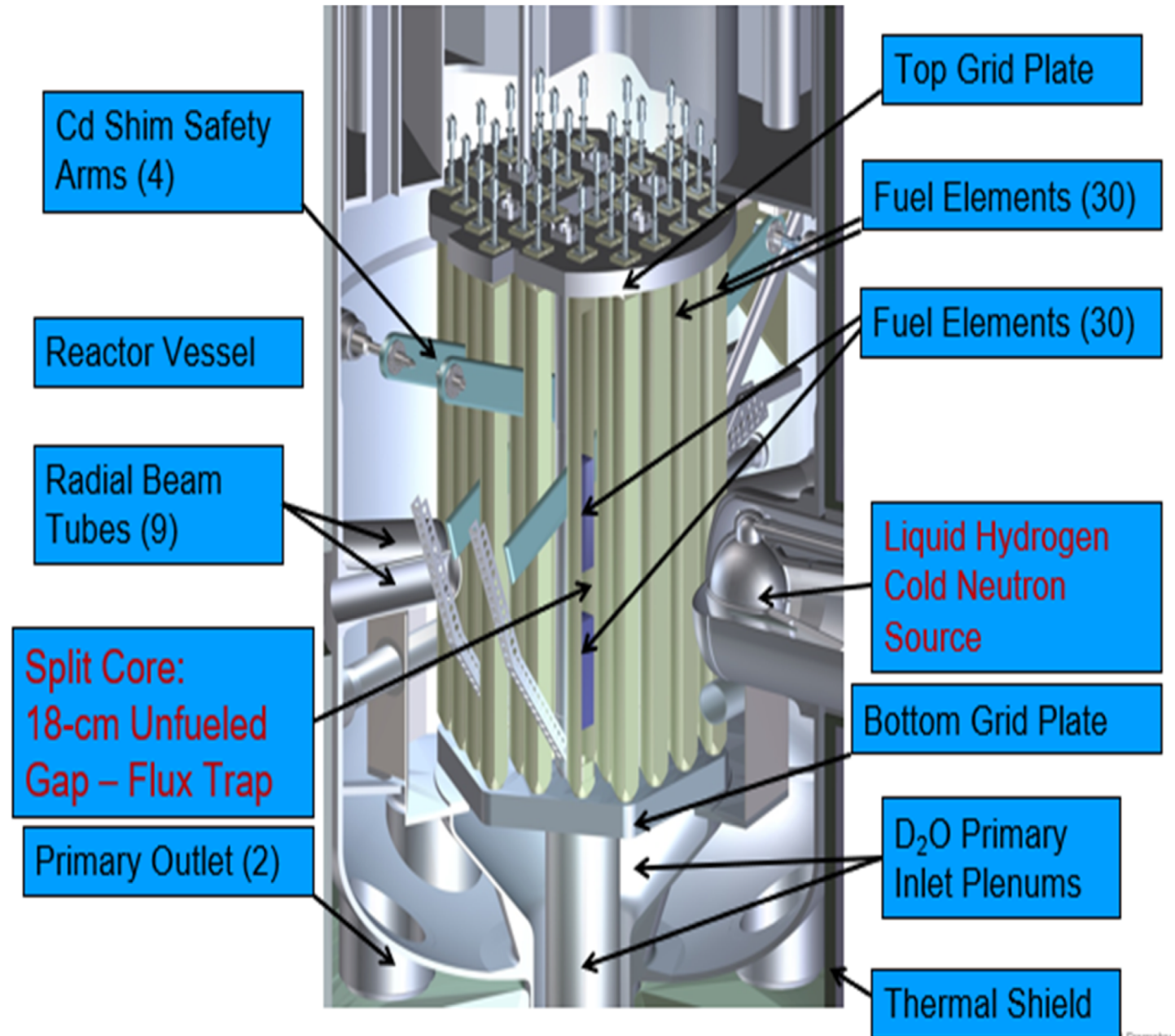


NIST Center For Neutron Research

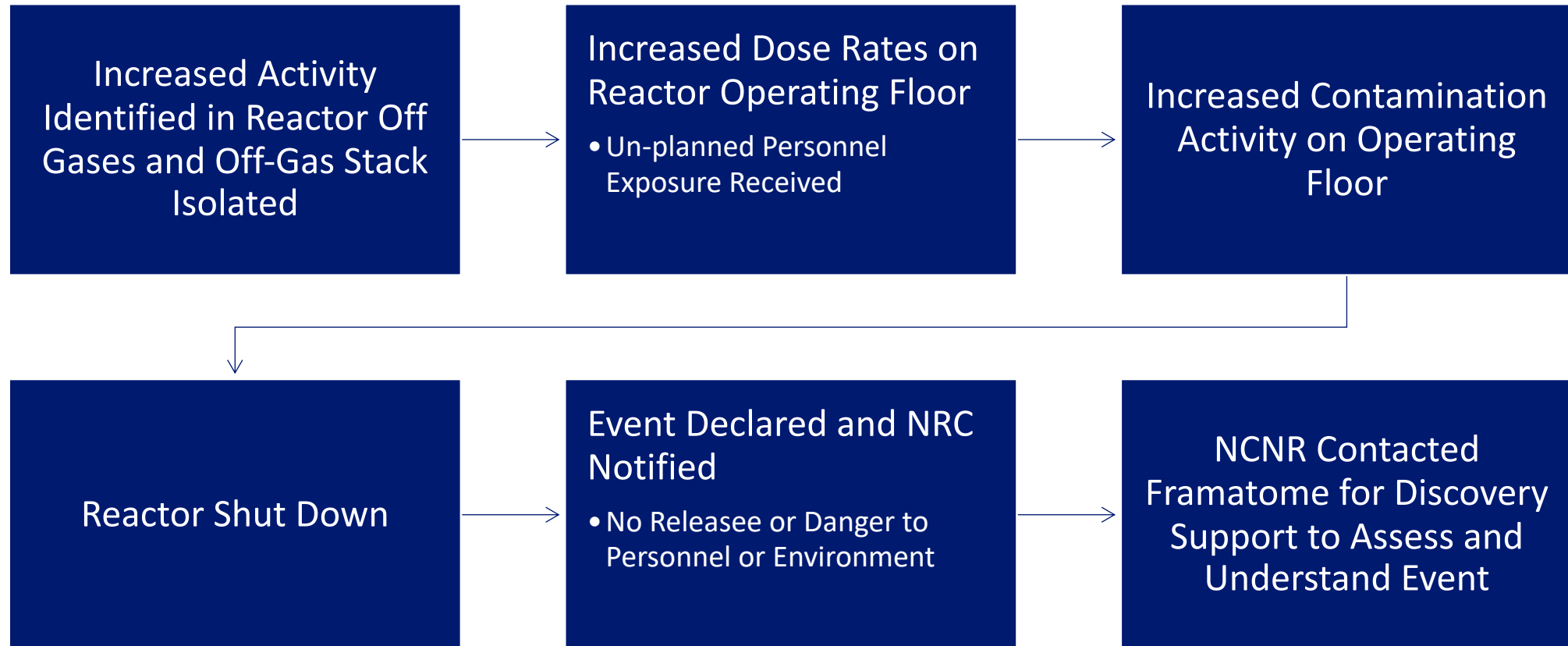
- One of three major neutron Science Centers in the US
- Supports > 3000 research participants annually
- Neutrons supplied by 20 MW reactor, the NBSR
- Reactor operates on a 38-day fuel cycle



Cut-Away View of the NBSR Core



NCNR February 3, 2021 Event



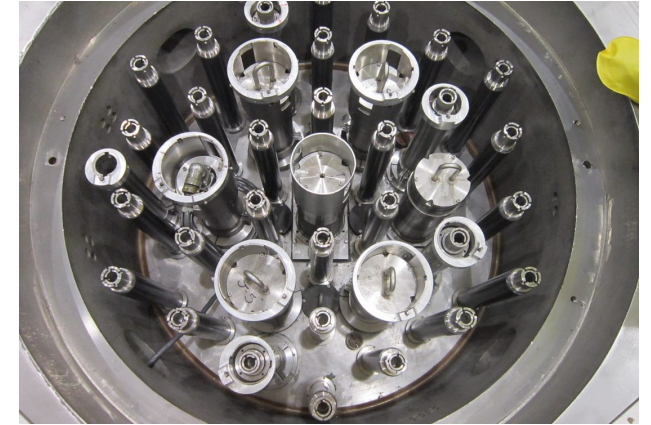
Initial Discovery Support

- **Challenge:**

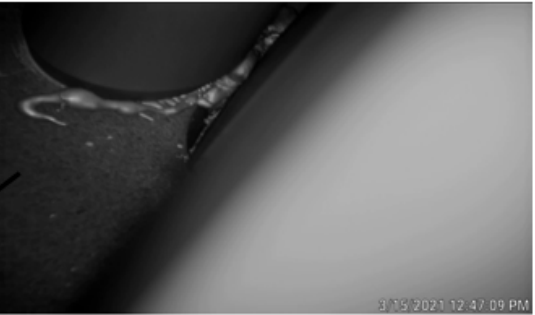
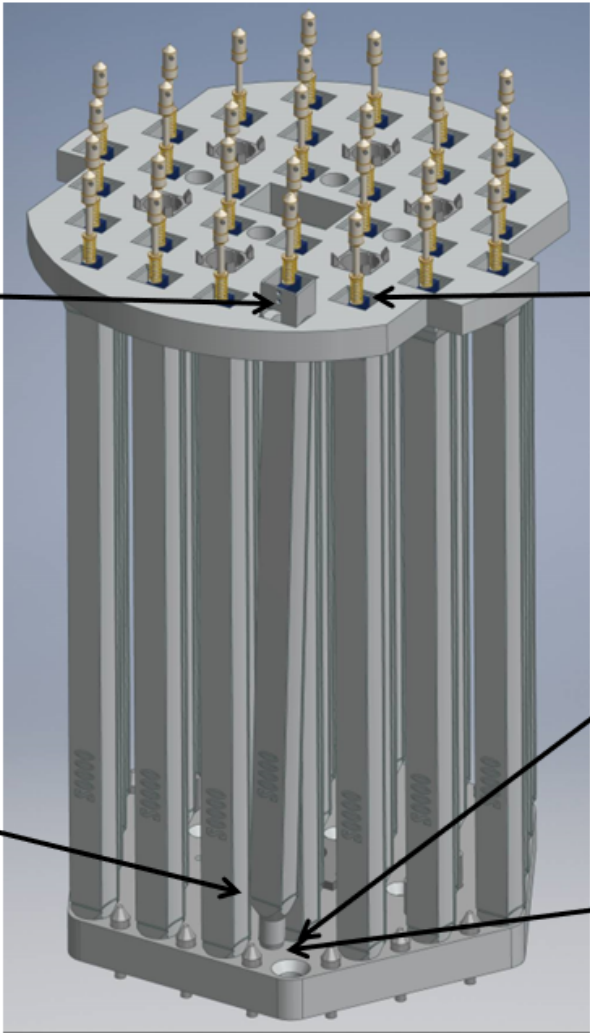
- High Radiation Fields within the Reactor Core
- Unknown Condition of Core Components
- Access to the Reactor Core Thru 2.25 inch Refueling Tool Port

- **Solution:**

- Deployment of Experienced Investigative Team with High Radiation Tolerant Camera and In-Core Camera Handling Experience
- Delivered/Positioned Camera and Lighting into Reactor Core thru 2.25" Refueling Tool Port
- Provided Camera Views to Identify and Characterize Event Issue



Initial Discovery Support (Cont'd)



Single Award Task Order Contract (SATOC)

- **NCNR Procurement Team received U.S. Department of Commerce Acquisition Excellence Award**
- **Original SATOC Award identified 10 Tasks**
- **Currently Completed/Executing/Planning 25 Tasks**
 - Task 1: Gamma Imaging of Hot Spots
 - Task 2: Bulk Debris Removal from Reactor Vessel Internal
 - Task 3: Inspect and Clean Irradiated Fuel Elements
 - Task 4: Ultrasonic Cleaning/Hot Spot Mitigation
 - Task 5: Cleaning Primary D₂O Storage Tank
 - Task 6: Cleaning Drop Out Transfer Chute
 - Task 7: Fabrication of Replacement Hold Down Sleeve
 - Task 8: Hood/Air System and Filters; Removal of Radioactive Sources
 - Task 9: Removal of Hot Spot and Modification of HE-1C Flanges
 - Task 10: Repair Main Primary Coolant Pumps
 - Task 11: Design/Fabricate/Install HE-1C Flange Drain Down Filtration System
 - Task 12: Removal/Packaging/Disposal of Ion Exchange Vessel/System
 - Task 13: Design/Fabricate/Install Reactor Top Absorber
 - Task 14: Sealing B1 Level HEPA Duct Work
 - Task 15: Design/Fabricate/Install Reactor Replacement Shield Plugs
 - Task 16: Modification of B1 Level Duct Work
 - Task 17: Removal/Packaging/Disposal original Poison Hold Down Sleeve
 - Task 18: Removal/Packaging/Disposal 30 Fuel element filters
 - Task 19: Removal/Packaging/Disposal Capping Tool
 - Task 20: Removal/Packaging/Disposal Two Trash containers
 - Task 21: Removal/Packaging/Disposal damaged fuel element 1175
 - Task 22: Post Operational Debris Removal
 - Task 23: Phase 3 of Tasks 9 & 11
 - Task 24: Characterization of Spent Fuel Pool Components
 - Task 25: Refurbish Confinement Ventilation Automatic Control Valves

SATOC Execution

- Teamwork essential in Task development, planning, preparation, training and execution



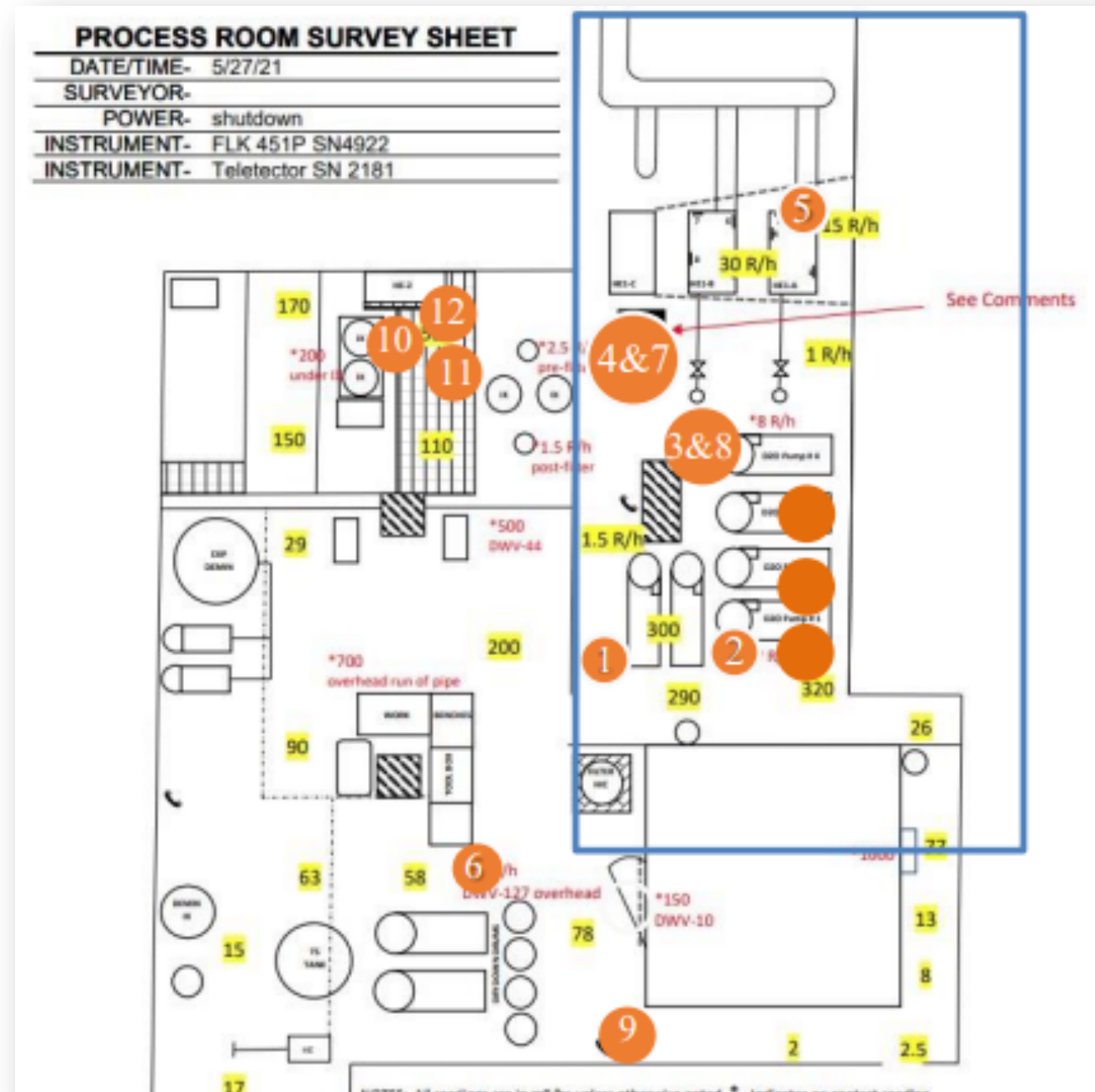
Task 1: Gamma Spectrometry

- **Challenge:**

- Highly Radioactive Material Deposited Throughout Reactor Coolant System Process Piping
- Identified Twelve (12) Major Hot Spots that Impact Execution of Normal Work Activities
- Hot Spots in close proximity to each other; difficult to identify the individual source/contribution

- **Solution:**

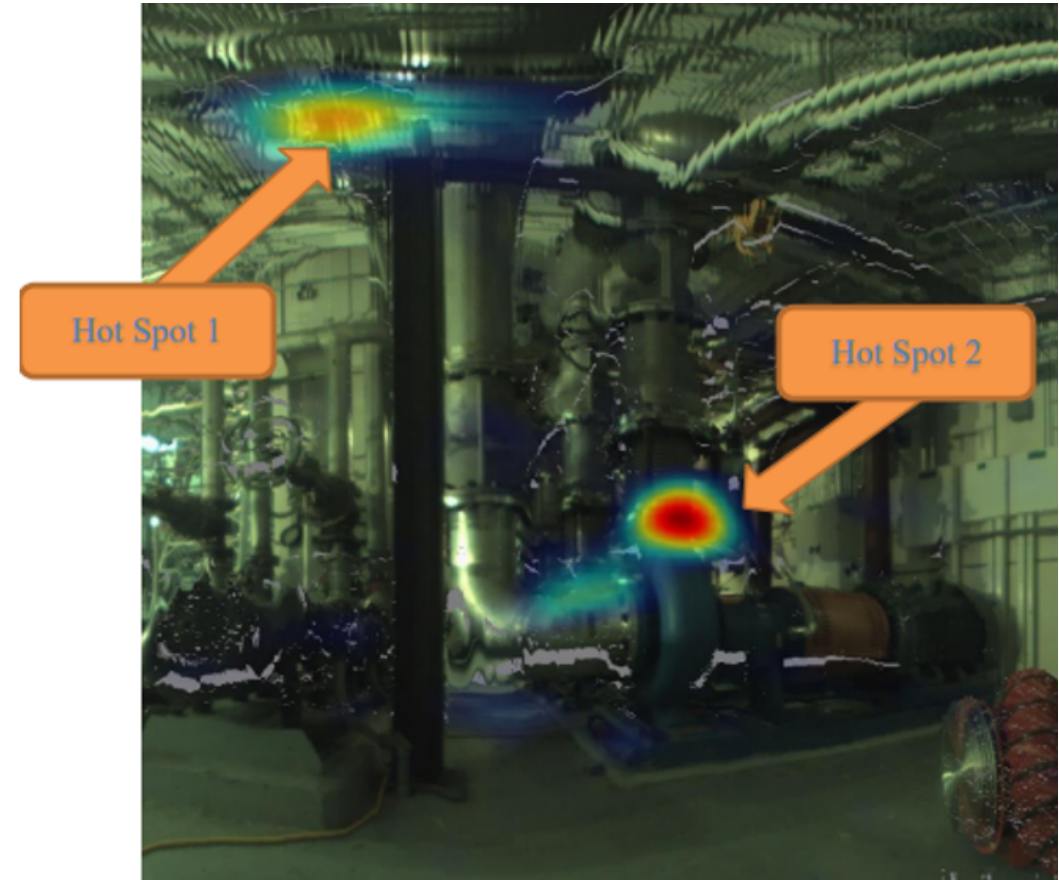
- Deployment of Gamma Spectrometry and Lidar Systems Data Collection Systems
- Utilize RadVision Software (Transco Products Inc.) to Analyze Data for Energy Spectrums
- Characterization of Each Individual Hot Spot to support Remediation Actions



Task 1: Gamma Spectrometry (Cont'd)

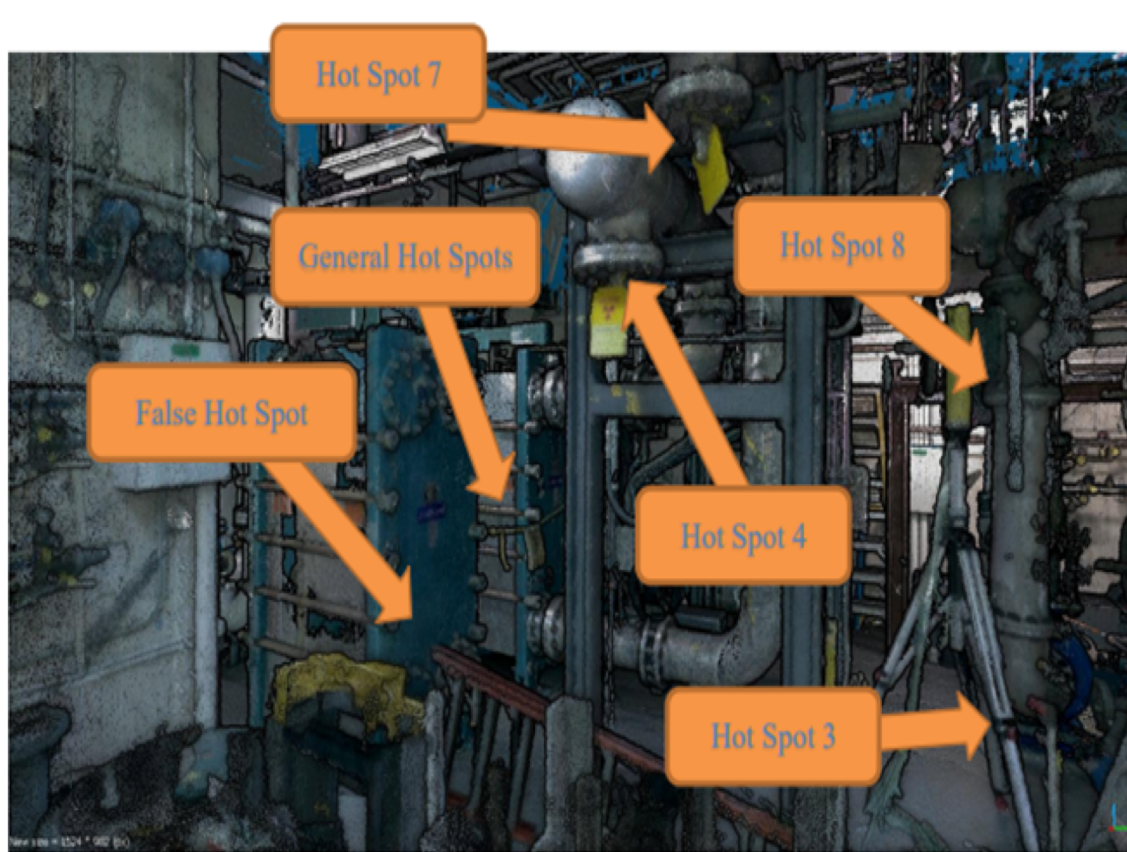


Lidar Mapping Hot Spots

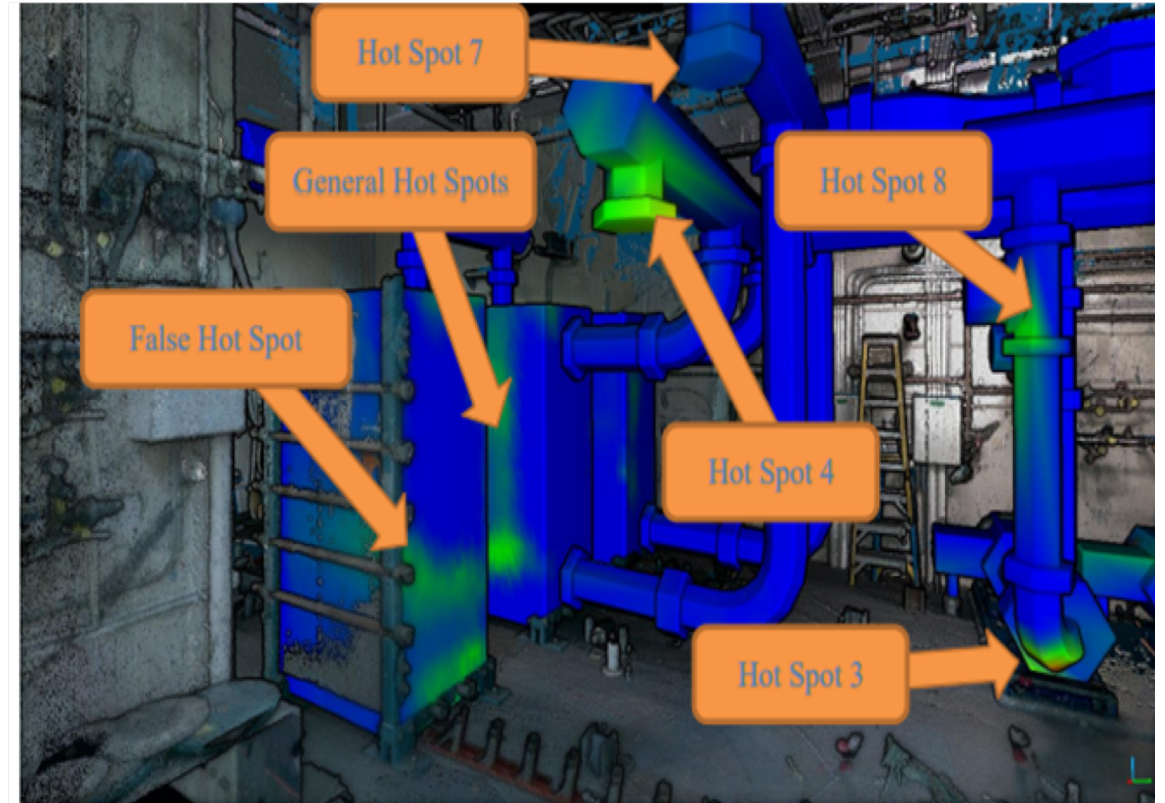


RadVision Data Overlay

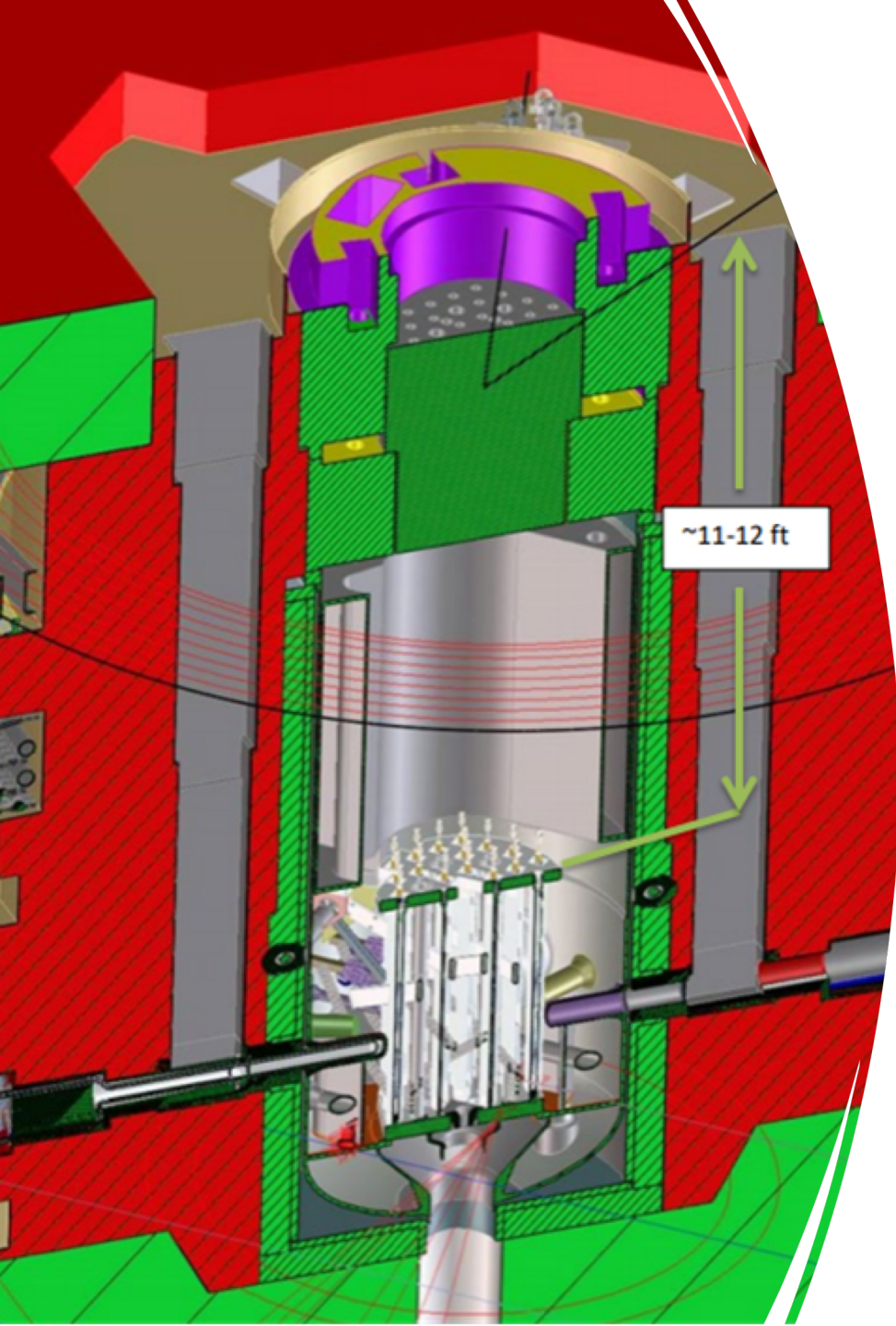
Task 1: Gamma Spectrometry (Cont'd)



Lidar Mapping Hot Spots



RadVision Data Overlay



Task 2: Reactor Vessel & Internals Debris Removal

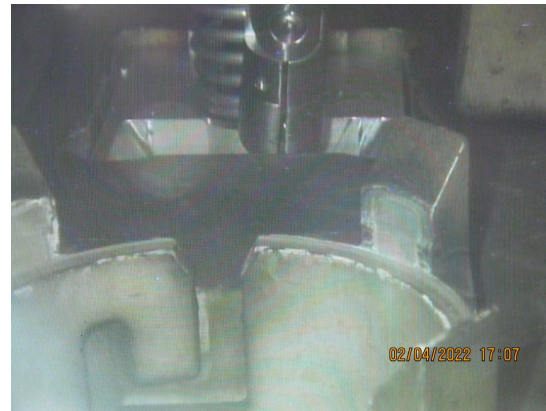
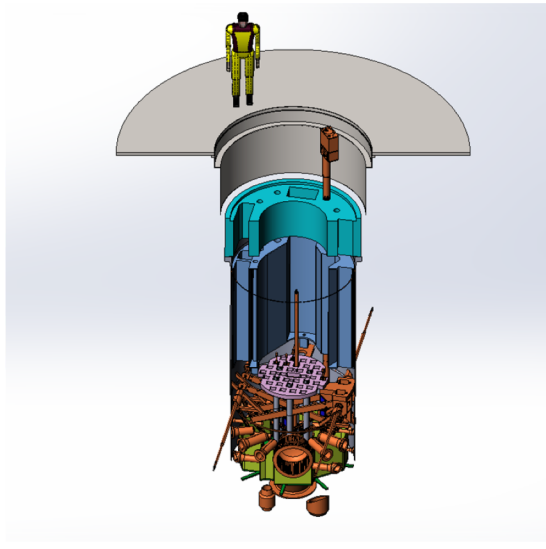
- **Challenge:**

- Three Irradiated Fuel Element Remain in Core
- Execute operations through the Refuel Plug 30 Refuel Ports and Fuel Loading Chute
 - Distance to Top Grid Plate ~12ft
 - Distance to Bottom Grid Plate ~18ft
- Configuration of Reactor Vessel Internal Components
 - Access for Tooling
- Collection of High Dose Rate Fuel Material and Packaging for Disposal
- Maintain D₂O Integrity
- Tritium Dose Rates to Personnel

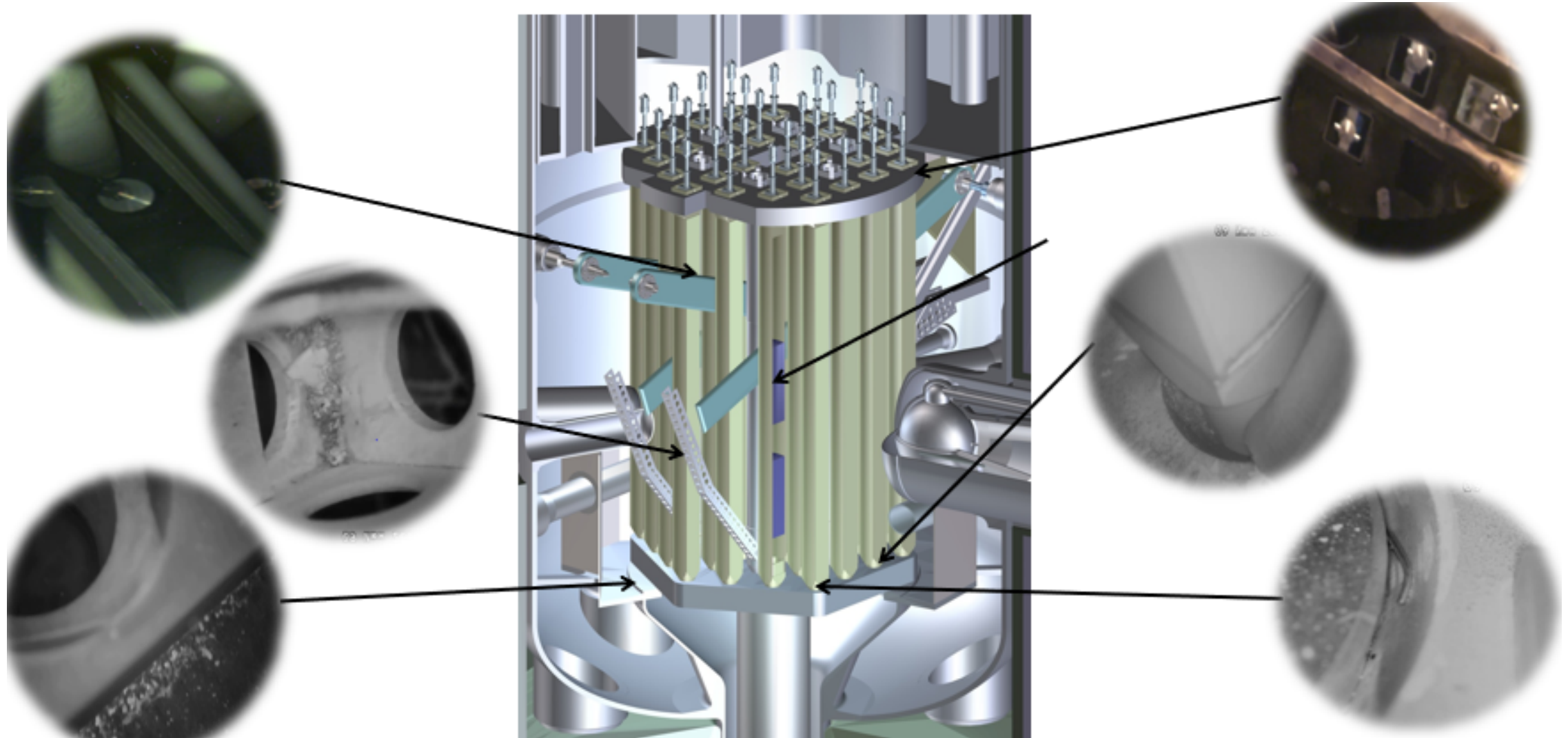
- **Solution:**

- Removal of Refuel Plug for Full Access to Reactor Internals
- Development of s Maintain D₂O Integrity and Mitigate Tritium Dose to Personnel
- Development of Tooling Delivered by Long Handled Poles
- Development of Shielded Work Platform
- Development of Vacuum Collection System

Task 2: Reactor Vessel & Internals Debris Removal



Task 2: Reactor Vessel/Internals Debris Removal



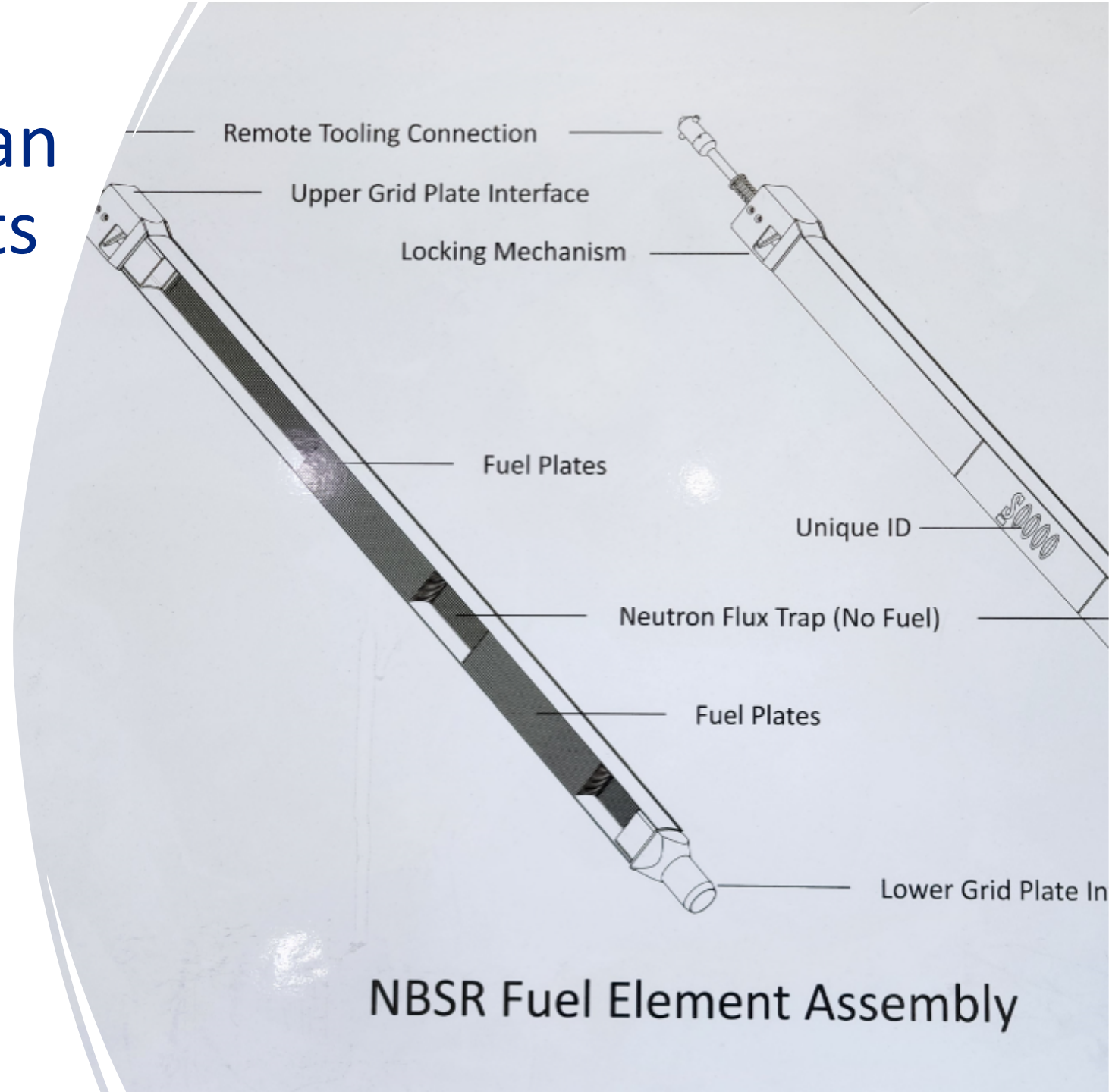
Task 3: Inspect and Clean Irradiated Fuel Elements

- **Challenge:**

- Inspection of Irradiated Fuel Elements Located in Core During Event
- Removal of Debris for Irradiated Fuel Elements
 - Capturing of removed debris for disposal
- Positioning of Fuel Irradiated Fuel Elements for Inspection and Cleaning
- Spatial Envelope for Equipment Operation and Fuel Element Movement within Spent Fuel Pool Fuel
- Spatial Access for Camera Inspection

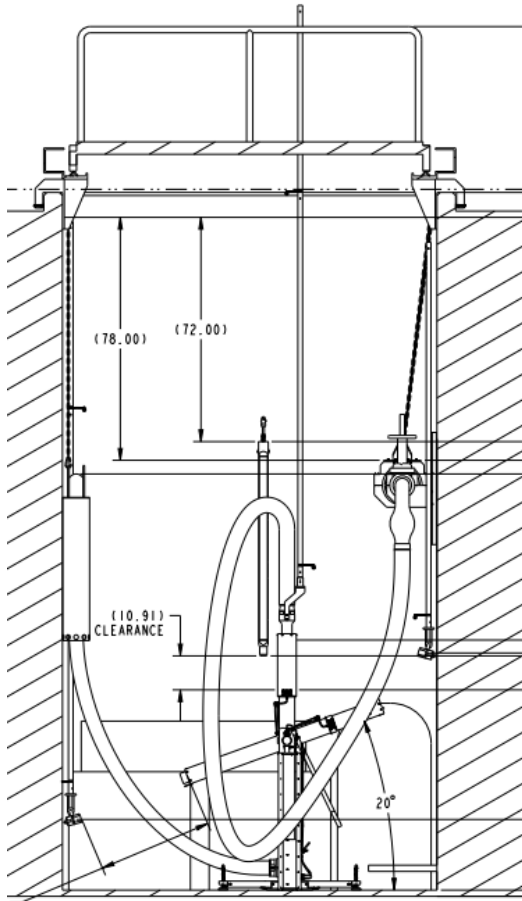
- **Solution:**

- Use of High Radiation Tolerant Camera
- Design/Fabrication of Fuel Element Handling/Positioning Fixture
- Design/Fabrication of Back Flushing and Radioactive Waste Collection Systems



NBSR Fuel Element Assembly

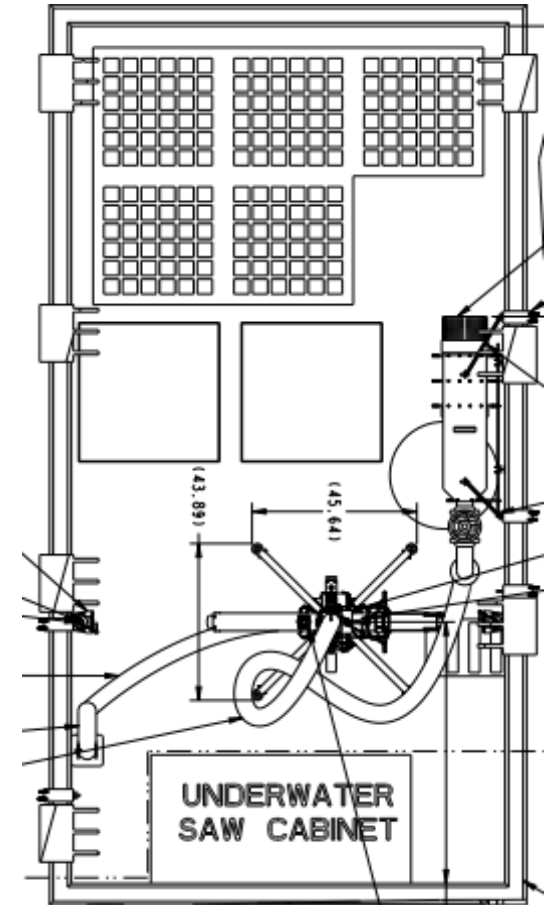
Task 3: Inspect and Clean Irradiated Fuel Elements (Cont'd)



Inspection/Flushing System Side View (West)

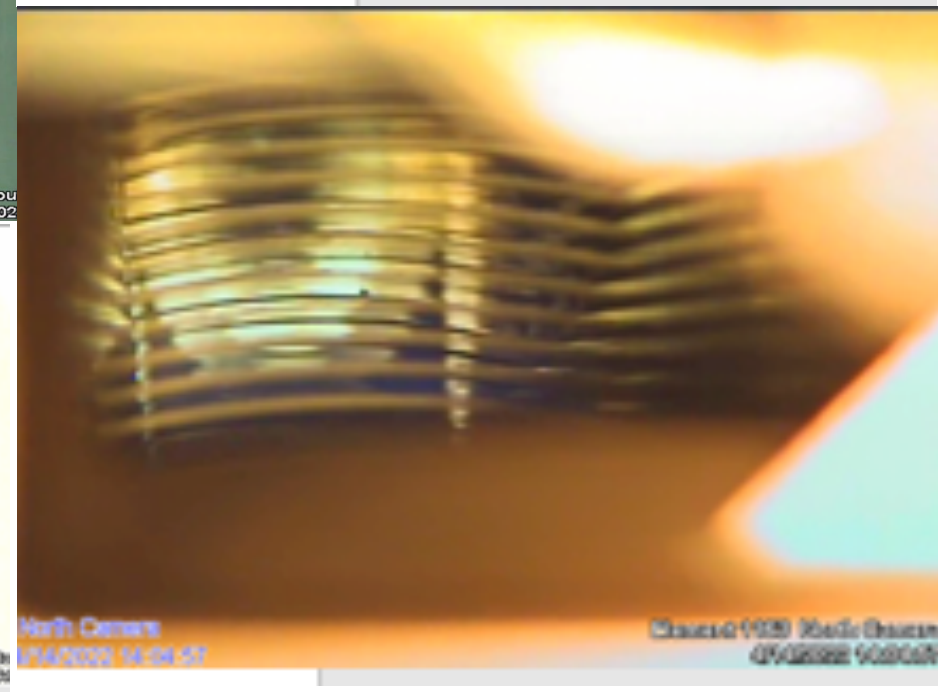
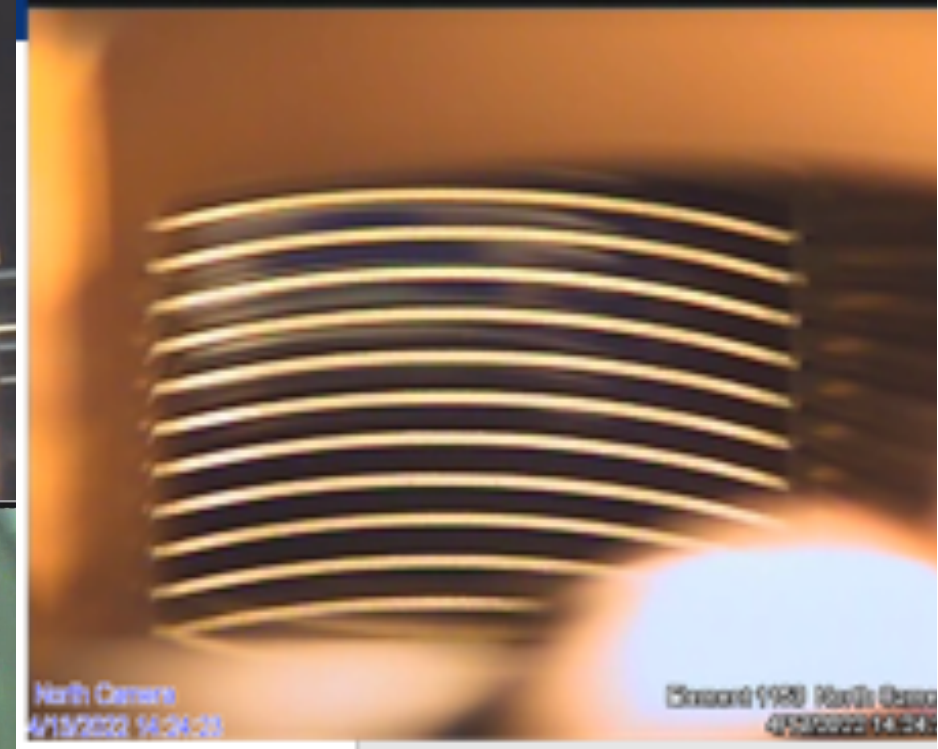
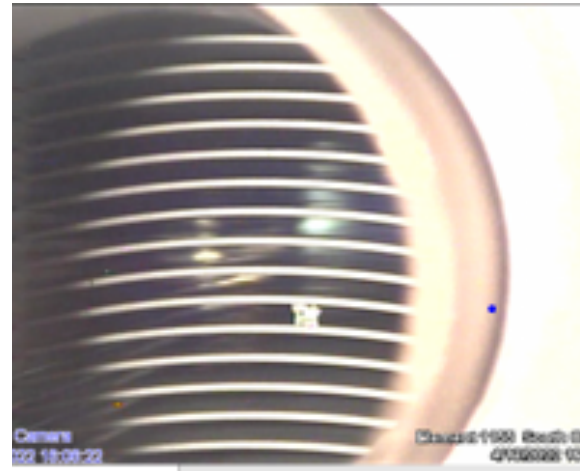
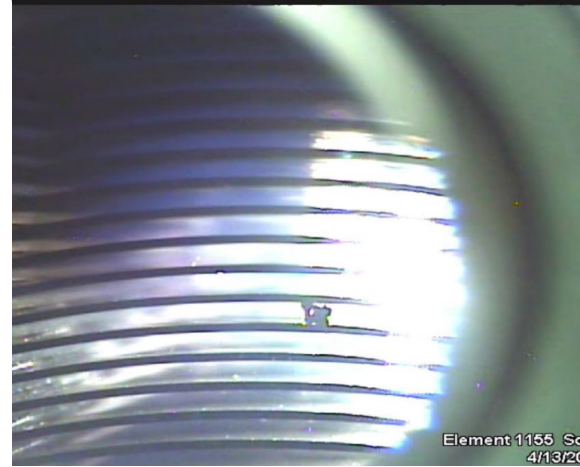
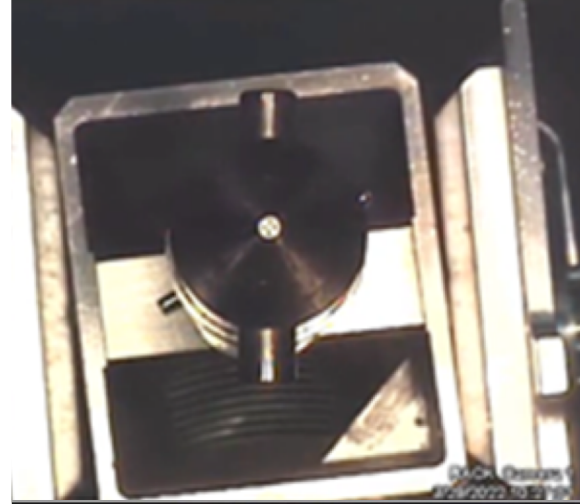


Fuel Element Handling and Positioning System



Inspection/Flushing System Top View

Task 3: Inspect and Clean Irradiated Fuel Elements (Cont'd)



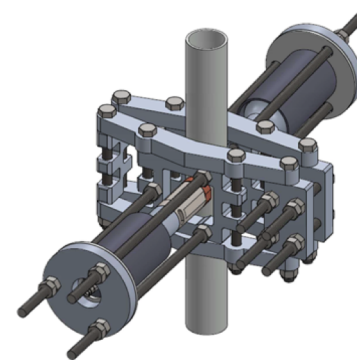
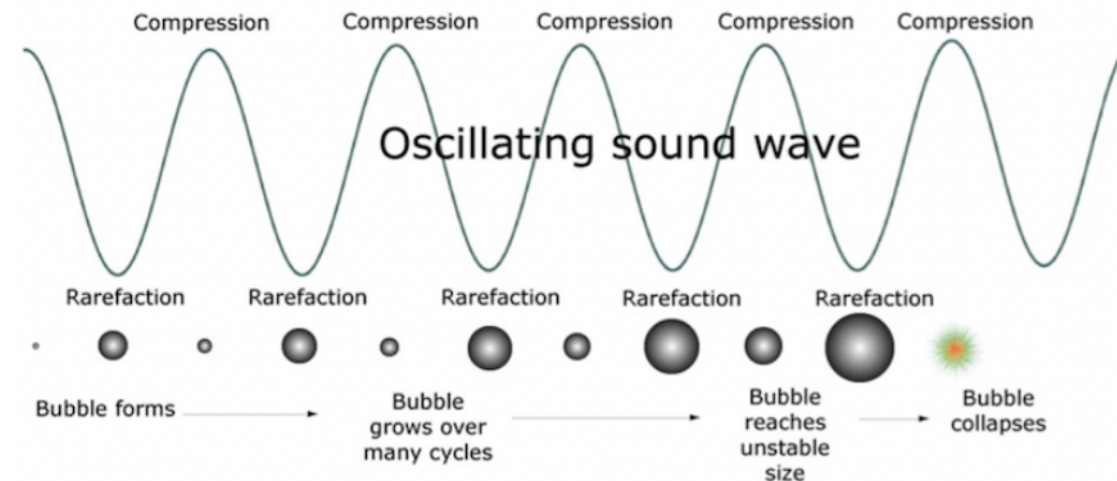
Task 4: Ultrasonic Cleaning/Hot Spot Mitigation

- **Challenges:**

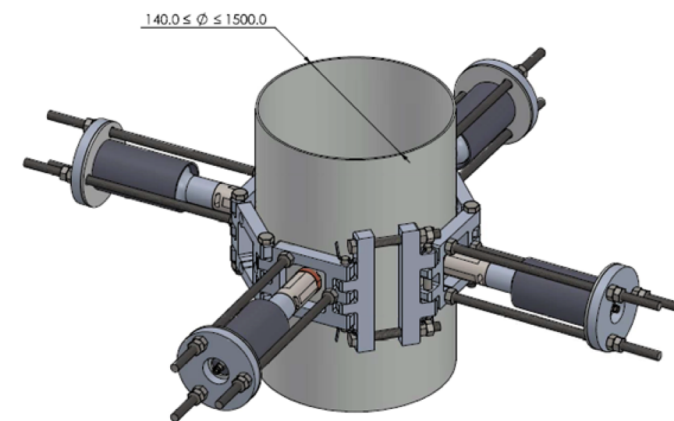
- High Dose Rates Restricting Access for Return to Service Activities
- Normal Plant Operations Unable to Flush Out/Mitigate the Hot Spot
- Concerns Breaching D₂O Coolant System

- **Solution:**

- Application of Ultrasonic Cleaning System (Altum Technologies) to Mobilize Radioactive Material
- Modified Clamping Systems to support ALARA



Small Bore Pipe Clamp

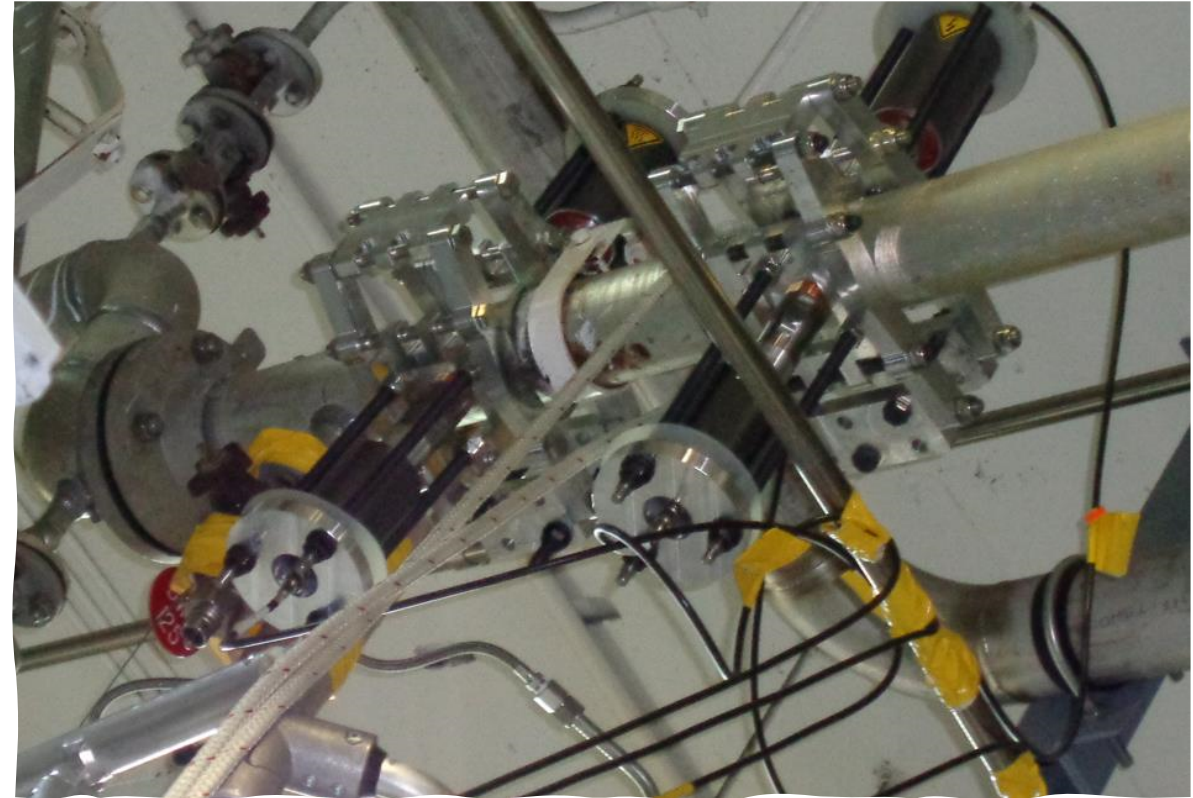


Large Bore Pipe Clamp

Task 4: Ultrasonic Cleaning/Hot Spot Mitigation (Cont'd)



Hot Spot 10: 73% Dose Reduction



Hot Spot 13: 67% Dose Reduction

Task 5: Cleaning Primary D₂O Storage Tank

- **Challenge:**

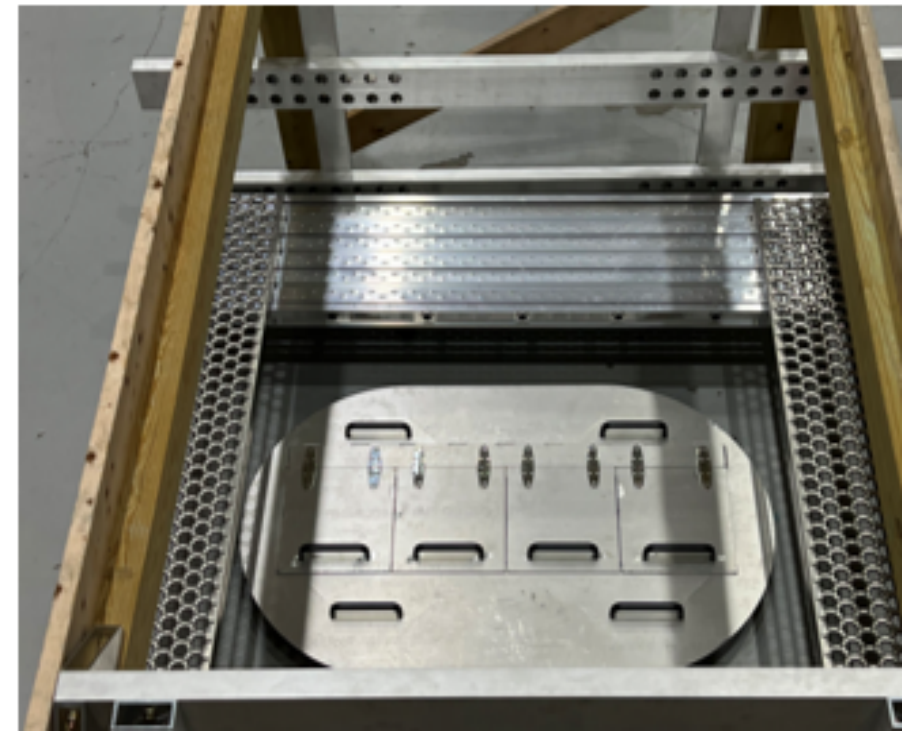
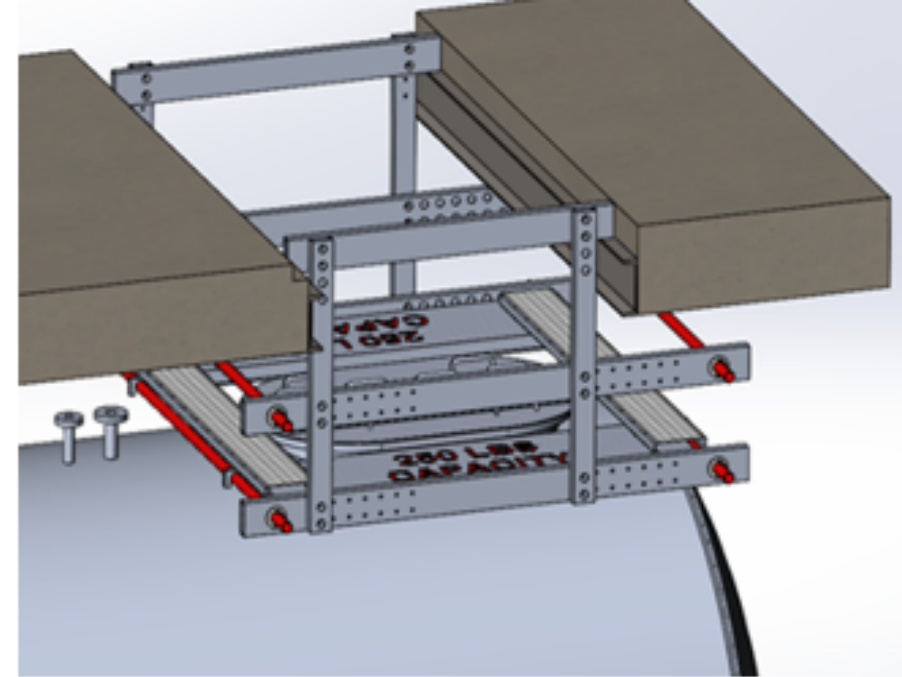
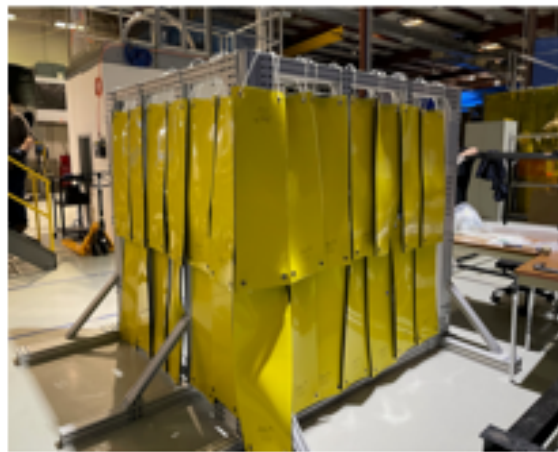
- Lowest Point In Primary Coolant System
- Unknown Material/Sediment in Tank
 - Dose Rates to Be Determined upon Manway Removal
- Tank Access Location in High Radiation Dose Rate Area
- Spatial Access to Tank Manway for Work Execution
 - ~5ft below floor grating
- D₂O Cross Contamination Concerns with Spent Fuel Pool

- **Solution:**

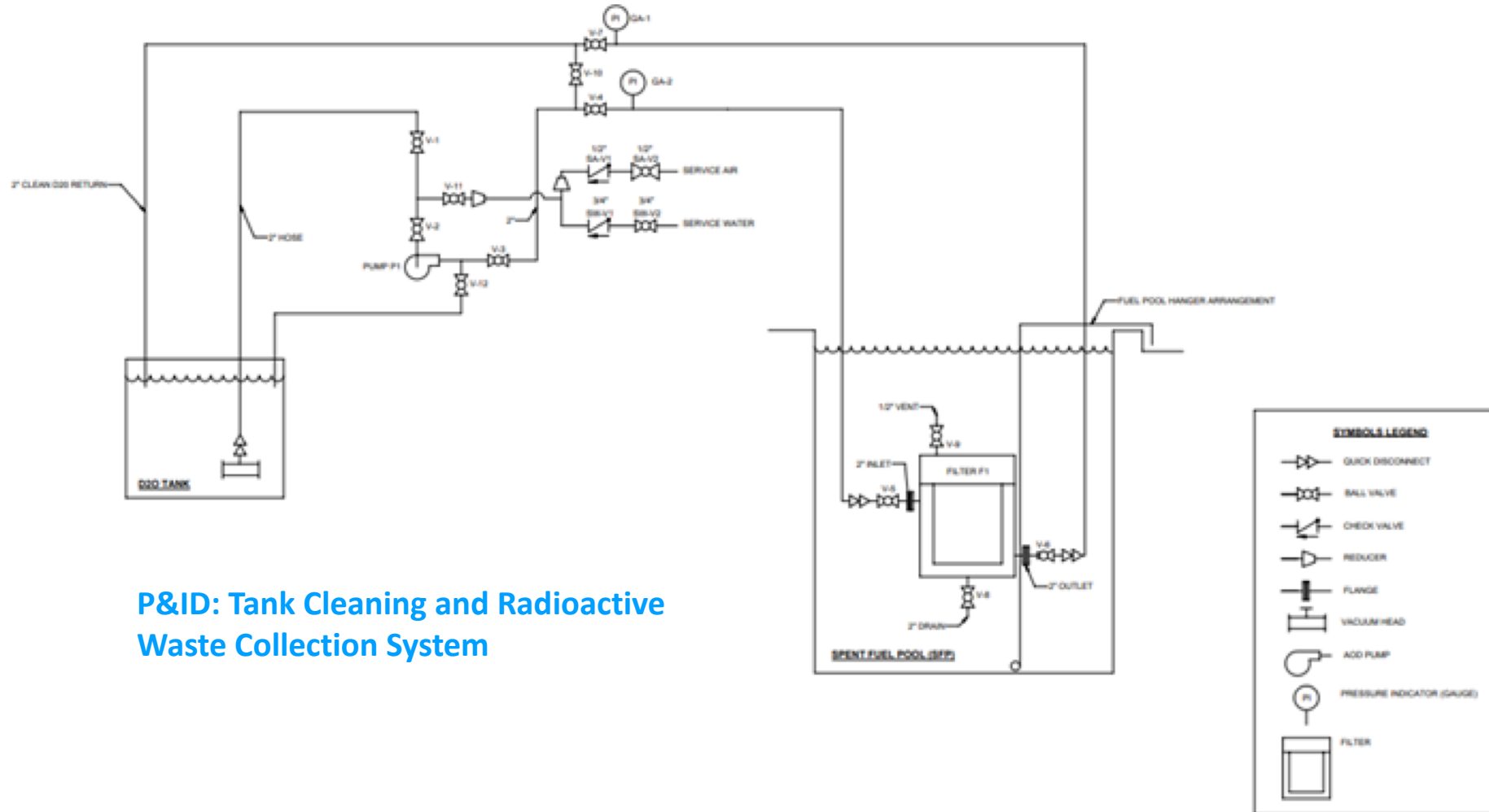
- Development of Tank Cleaning System for Capture & Disposal of Radioactive Waste
- Design General Area Radiation Shielding
- Development of Safety Approved Shielded FME Manway Cover and Access Work Platform



Task 5: Cleaning Primary D₂O Storage Tank (Cont'd)



Task 5: Cleaning Primary D₂O Storage Tank (Cont'd)



P&ID: Tank Cleaning and Radioactive Waste Collection System

Task 9: Removal of Hot Spot and Modification of HE-1C Flanges

- **Challenge:**

- Piping Dead Leg in Primary Coolant System Inlet/Outlet Creates chronic “Crud Trap”
- High Dose Rate 7-10 R/hr
- D₂O Containment
- Spatial Access for Equipment

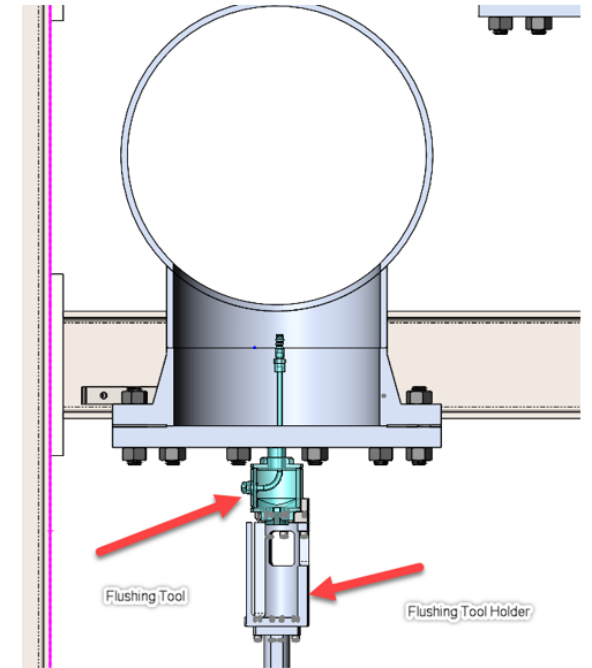
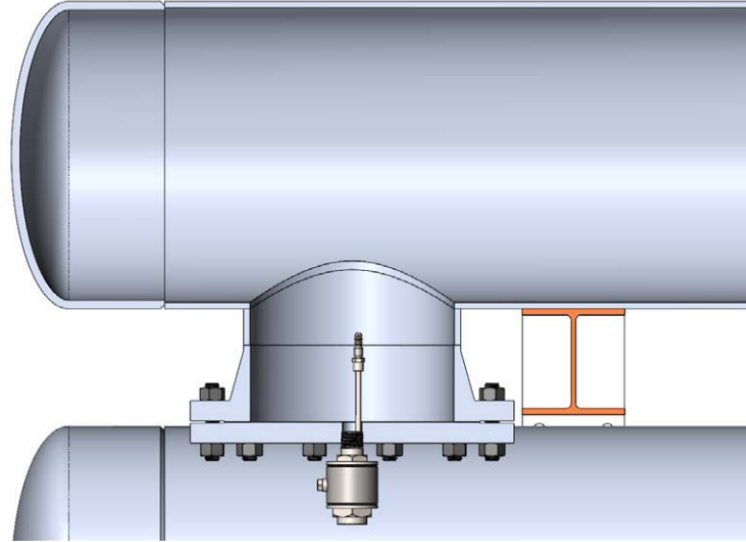
- **Solution:**

- Development of Integral Hydrolase & Drain System
- Development of Remote Positioned Flange Removal/Lowering System
- Replace Blind Flange with Reducing Flange
 - Task 11 Drain Filtration System

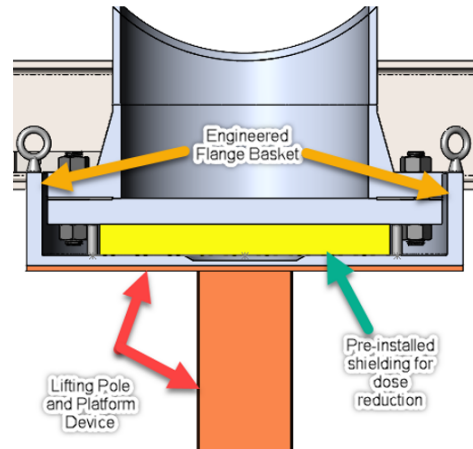


Task 9: Removal of Hot Spot and Modification of HE-1C Flanges

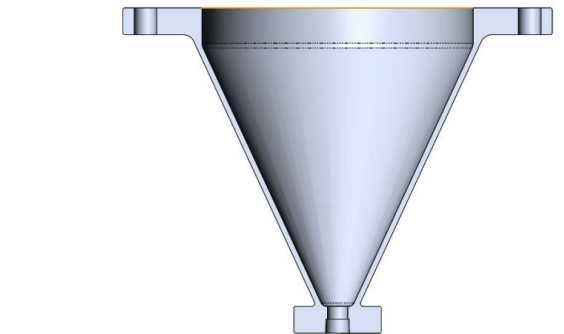
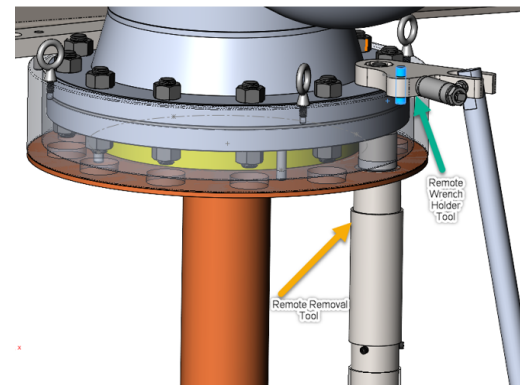
Combined Flushing/Drain System



Flange Removal Tooling



Integrated Design Hydrolase Nozzle & Drain Fitting



Special Fabricated Reducing Flange

Task 14: Sealing B1 Level HEPA Duct Work

- **Challenge:**
 - Leaking HEPA Ventilation EF-3 and EF-4 Ductwork
 - Releasing Radioactive Contamination into B1 Level
 - Causing Personnel Contaminations
 - Ventilation System Ductwork Age
 - Numerous Previous Repairs Processes Applied
- **Solution:**
 - Removal of Previous Repairs
 - Application Framatome-NuKote ST Sealant



EF-3 Duct East



Task 14: Sealing B1 Level HEPA Duct Work (Cont'd)

EF-3 Duct Top



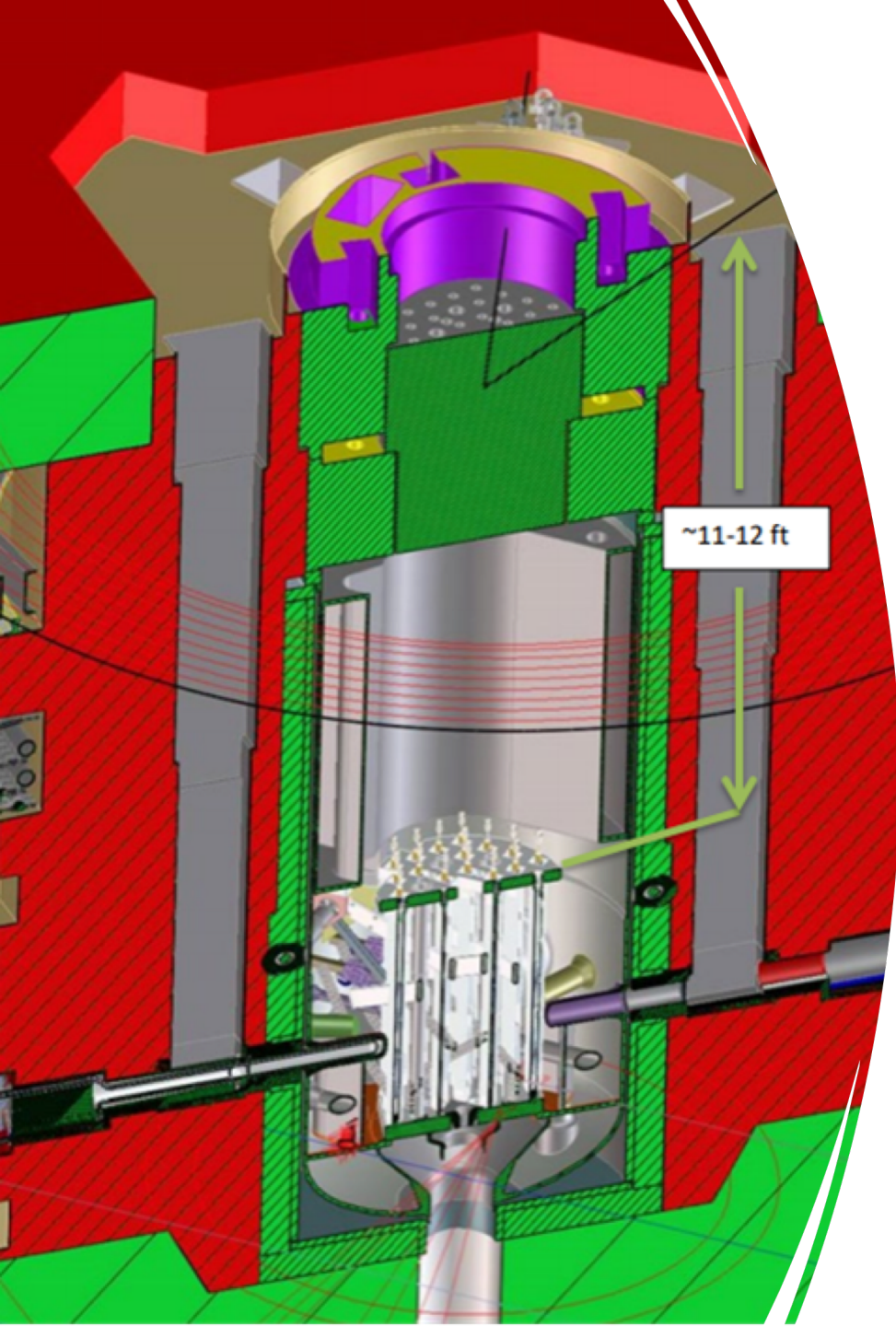
EF-4 Duct North



Task 14: Sealing B1 Level HEPA Duct Work (Cont'd)

EF-4 Duct South





Task 22: Post Operational Debris Removal

- **Challenge:**

- Recovery of estimated remaining 10% of fuel debris
- Access 100% of the Reactor Vessel Internals (RVI) surfaces
- Flush the Reactor Vessel Internals surfaces to dislodge debris material
 - Flushing system must circulate reactor vessel D₂O
- Vacuum up loose debris material using 20 micron to 1 micron filters system
- Collection of High Dose Rate Fuel Material and Packaging for Disposal
- Maintain D₂O Integrity

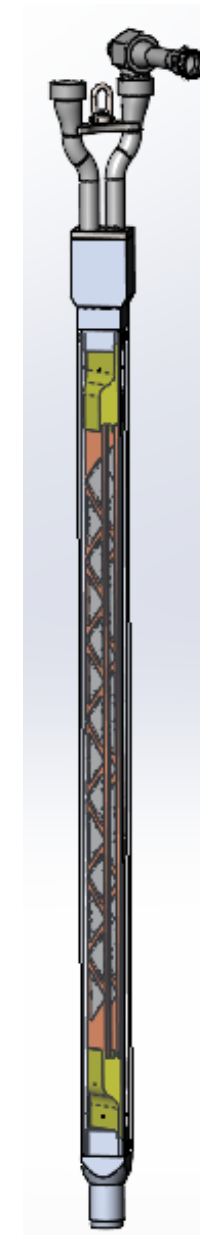
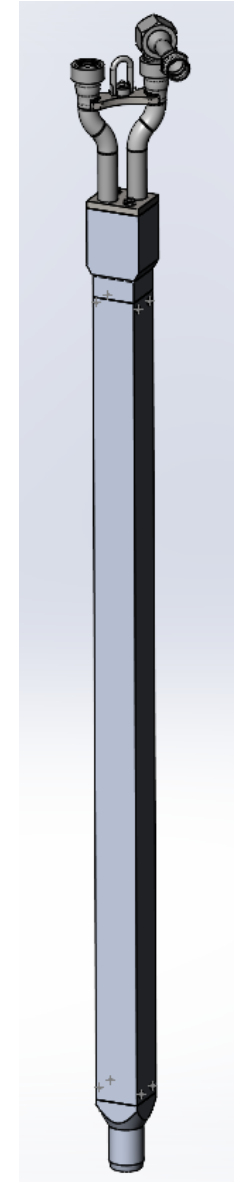
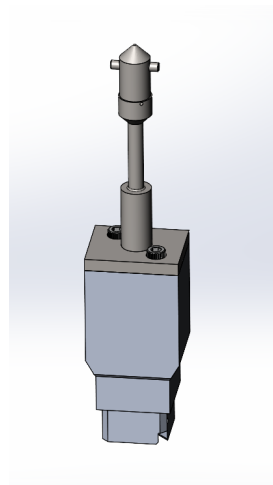
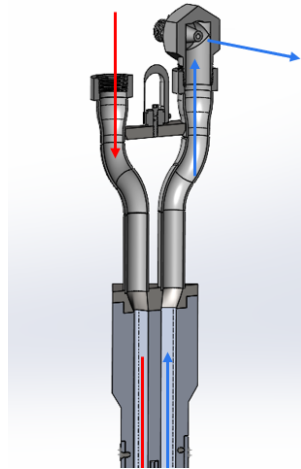
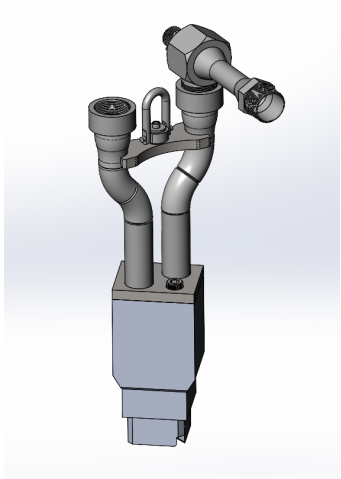
- **Solution:**

- Expand on Lessons Learned and Operating Experience from Task 2 Execution
- Development of tool system delivered by long handled poles to access 100% RVI surfaces
 - Hydro lasing
 - Vacuuming
- Development of Multi-Stage Filtration Vacuum collection system

Task 22: Post Operational Debris Removal (Cont'd)

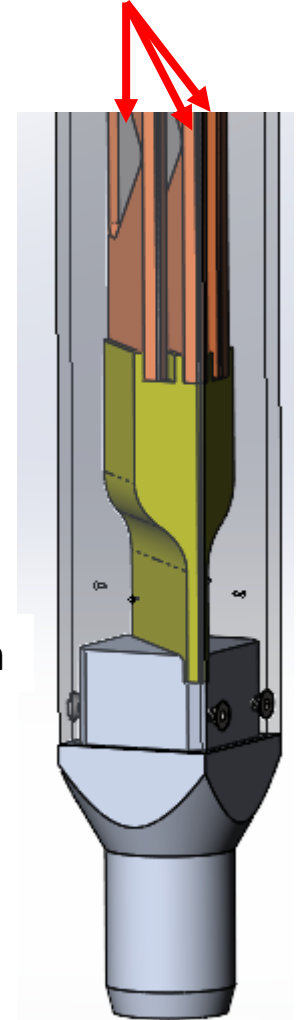
Filtration Concept

- Same concept as Task 2 filter
 - Sized like a fuel assembly
 - Vacuum / Transfer head interchangeable
- 3 Stages of filtration
 - 20 micron, 10 micron, 1 micron



Filter Mesh

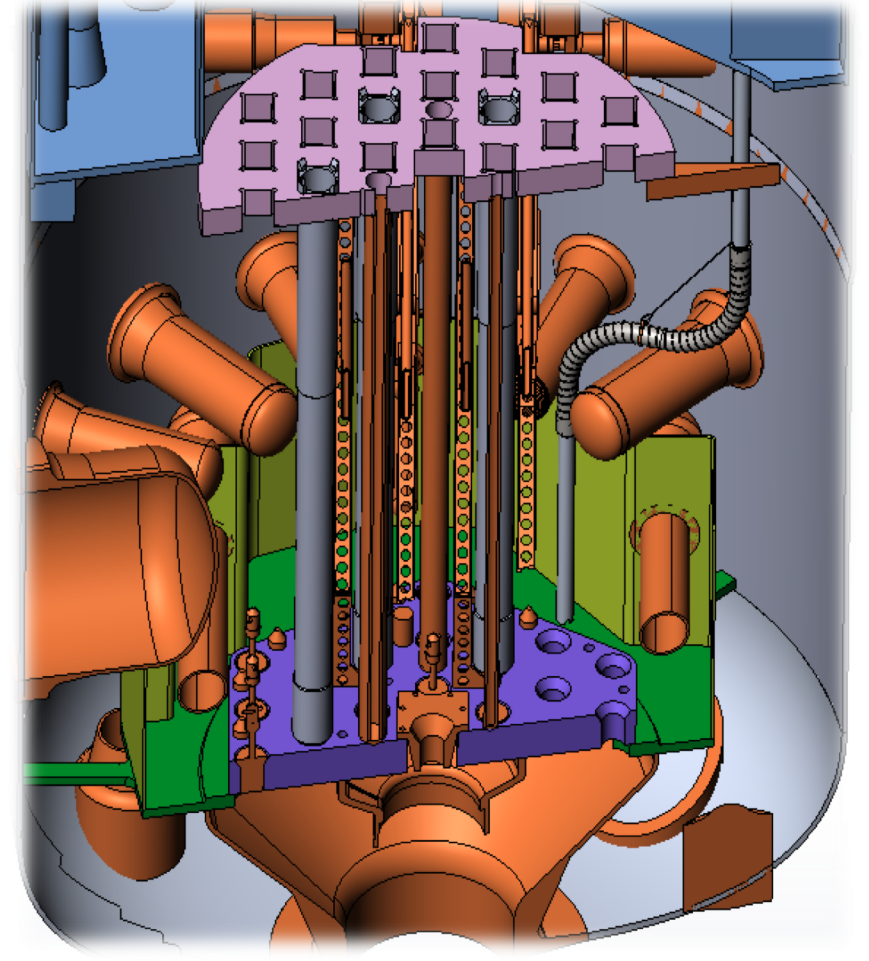
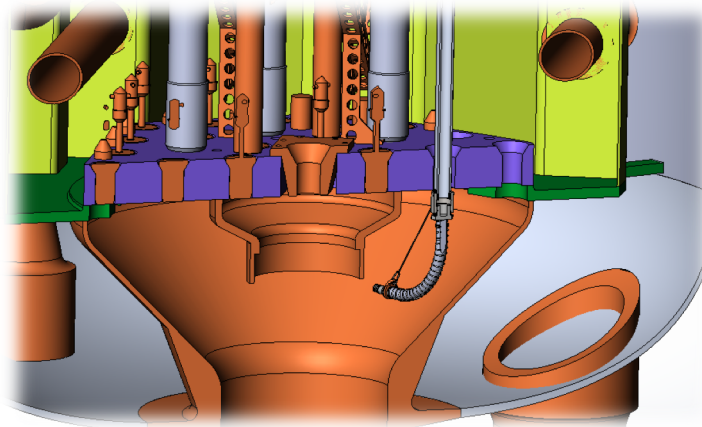
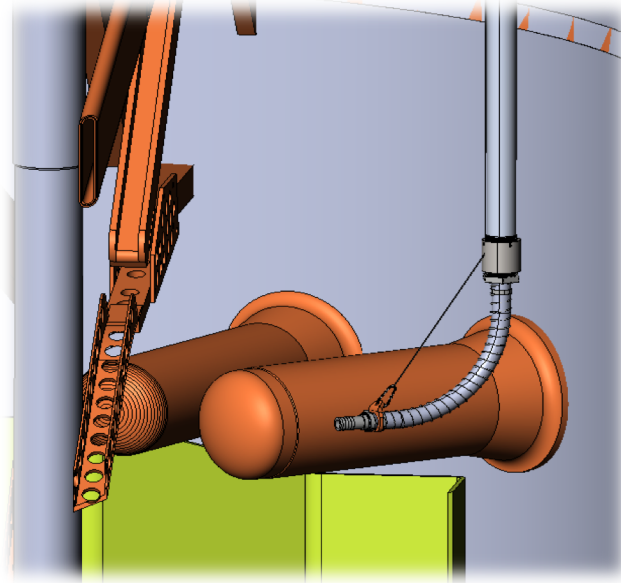
20, 10, 1 μm
filter elements



Task 22: Post Operational Debris Removal (Cont'd)

Vacuuming Concept

- Long handled tools with remote manipulated end effectors



Summary

- **NCNR Event was FOAK for the Test Reactor Facilities**
- **Presented Unique Challenges and Requirements for Recovery and Re-Start**
- **Combined NCNR/Framatome Experience and Knowledge Developed Solutions for the Challenges**
- **Team Utilized Commercially Off the Shelf Equipment/Processes and Integrated into Systems to Successfully Provide Solutions for All the Challenges**
- **On Going Tasks Being Executed for System Improvements and Mitigation**
- **NCNR Reactor Successfully Returned to Service March 10, 2023**
- **Planned Full Operational and Experimental Testing Return to Service October 2025**



Thank you

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