NSUF1.1: TESTING OF ADVANCED MATERIALS OR ADVANCED SENSORS FOR NUCLEAR APPLICATIONS

Pattrick Calderoni
HTTL Group lead

Fusion, Hydrogen and Measurement Sciences
Nuclear Science and Technology

#INLCINRWorkshop

CINR Workscope

NSUF 1.1: TESTING OF ADVANCED MATERIALS OR ADVANCED SENSORS FOR NUCLEAR APPLICATIONS

(FEDERAL POC: SUIBEL SCHUPPNER & TECHNICAL POC: BRENDEN HEIDRICH)
(ELIGIBLE TO LEAD: UNIVERSITY, NATIONAL LABORATORY, OR INDUSTRY)
(UP TO 3 YEARS AND $500,000)

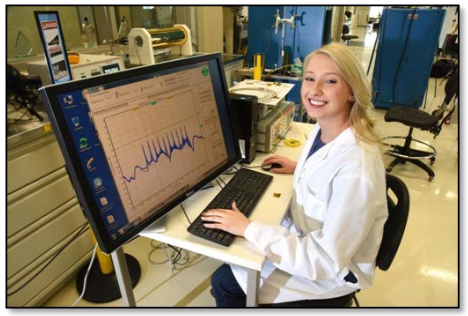
Proposals are sought for irradiation testing and post-irradiation examinations that support the development of advanced materials for sensors, and development of advanced sensors themselves to support NE's mission to enhance the long term viability and competitiveness of the existing fleet, to develop an advanced reactor pipeline, and to implement and maintain national strategic fuel cycle and supply chain infrastructure. **This funding does not support research and development activities to develop materials or sensors, but rather the irradiation of sensors and materials as described below.**

1) Advanced Materials for Sensors: Successful irradiation testing and post irradiation examination of candidate materials proposed for advanced sensors applications will include: a description of the materials; irradiation and post irradiation examination needs; the role of the materials in new sensors, controls, communications or associated applications.

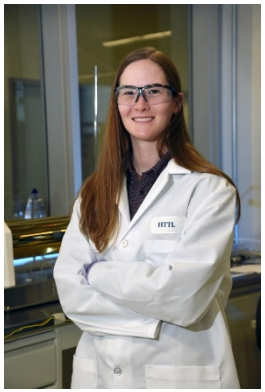
2) Advanced Sensors: Successful irradiation and post irradiation examination of sensors and associated instrumentation will include: a description of the sensor and associated instrumentation and materials requiring irradiation and post irradiation examination; irradiation and post irradiation examination needs; and the purpose and application of the developed sensor in nuclear energy systems.

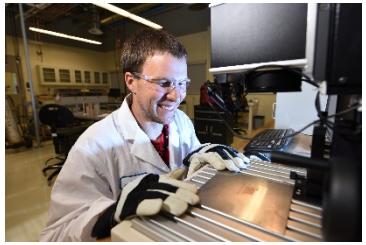
HTTL capabilities in support of the development of advanced nuclear instrumentation at INL

INL researchers and international collaborations



University fellowship and internship programs





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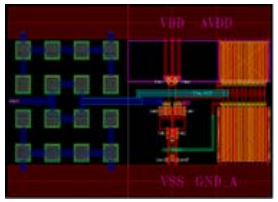
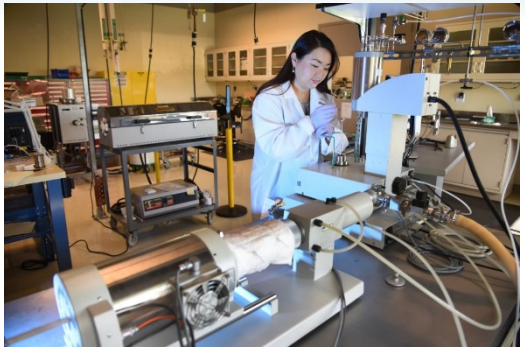
Neutron flux detectors

Averaged data from reactor operation + flux wires



Radiation Hardened amplifier for MPFD developed in collaboration with KAERI

Passive neutron dosimeters (flux foils) fabricated by advanced manufacturing



Intern from BSU working on the characterization of AM prototypes in the HTTL Differential Scanning Calorimeter (DCS)

Real-time, miniaturized flux detectors

Nano-structured materials for solid-state neutron detectors

X-ray 3-D scan of the AGR5/6/7 MPFD at HTTL to validate fabrication process

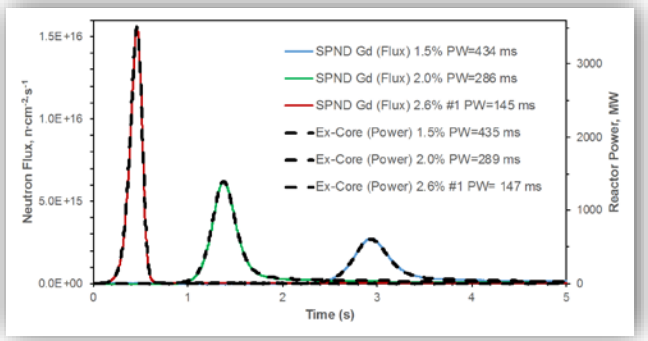
Neutron flux instrumentation for real time, local in-pile measurement with validated performance

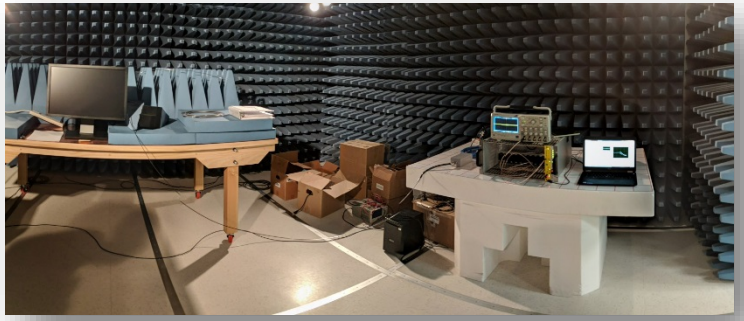
FY18 activities: SPND

Troy Unruh, R Fronk, K Tsai, D Chichester, A Al Rashdan

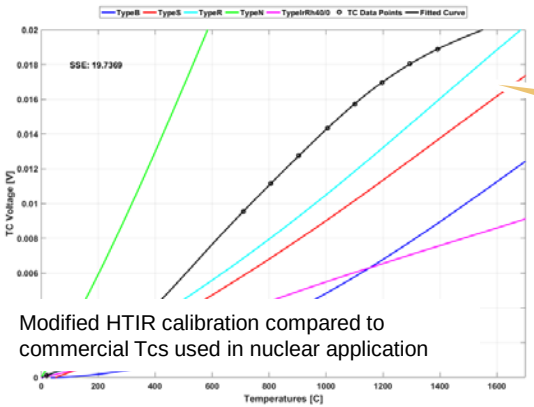
Development of Self Power Nuclear Detectors (SPND) – demonstrate performance and reliability to allow direct integration in irradiation test design

- Design optimization (sensor/counting electronics) for a wide range of conditions (high/low flux, steady-state or transient)
- Fabrication
- Out of pile characterization (thermal cycles, electronics calibration, materials)
- Demonstrate performance in-pile - compare with miniaturized Fission Chambers (CEA), micro-pocket fission detectors (MPFD) and Advanced Manufactured dosimeters
- Signal transmission – noise optimization



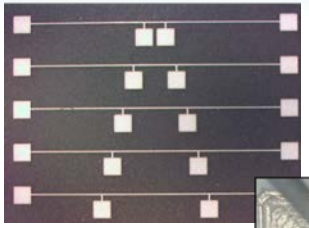


Temperature

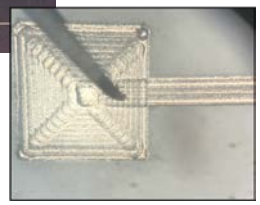


Modified HTIR calibration compared to commercial Tcs used in nuclear application

Tc + melt wires



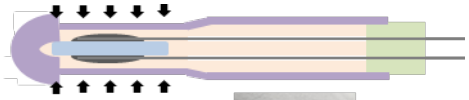
Printed melt wire array prototype with 50 µm silver lines over sapphire substrate



Advanced passive temperature monitors

Advanced thermocouples

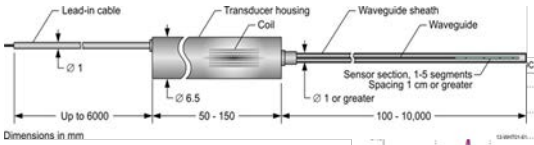
Solid-state thermistors

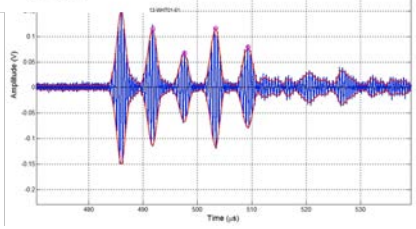


Diamond thermistor

Ultrasound thermometers (UT)

OF sensors





Multi-zone ultrasonic thermometer with High-Frequency Magnetostrictive Transducer

Temperature sensors for real time, distributed in-pile measurement with validated performance

FY18 activities: HTIR

Richard Skifton, K Davis, J Palmer, P Calderoni, L Aagersen

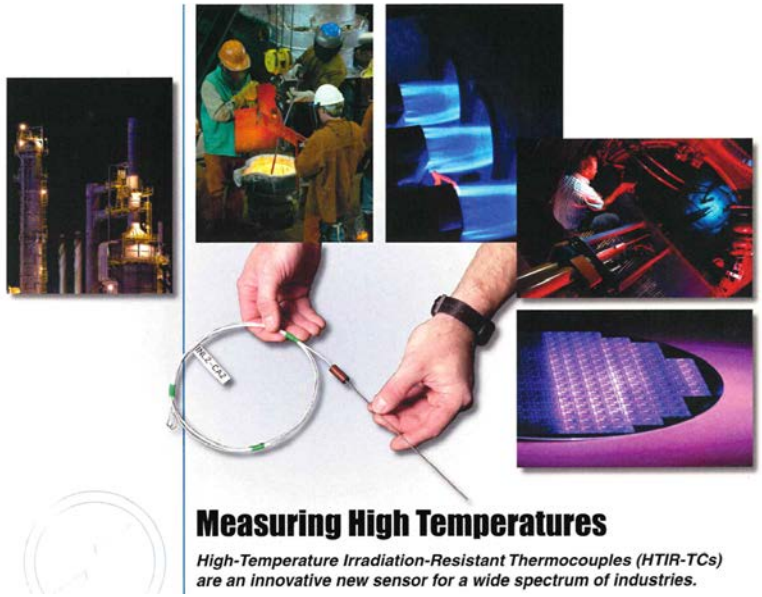
Improve the reliability across a wider range of target operational parameters

- Design optimization
- Fabrication

Electrodes	Insulation	Sheat material
Mo (dopants) / Nb (dopants)	Al_2O_3, MgO, HfO_2	Nb alloy (composition)

- Heat treatment optimization
- Thermo-mechanical test (ASTM)
- Materials characterization

- Modeling

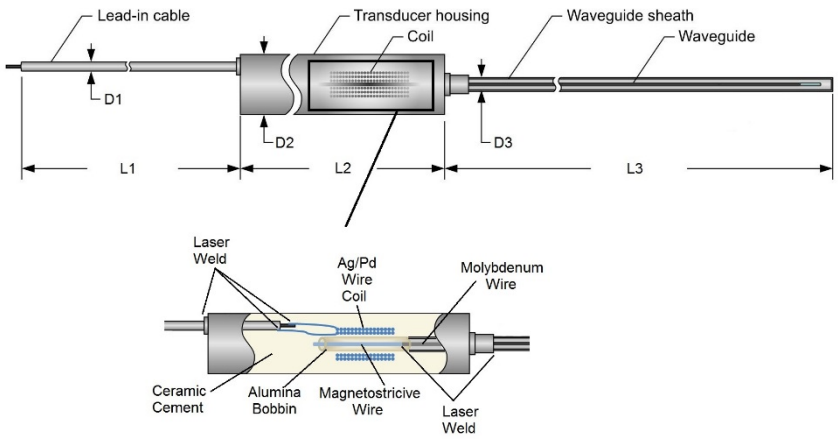


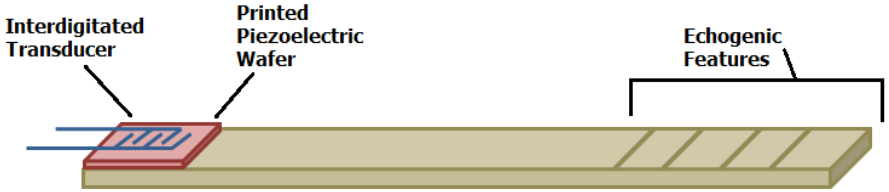
FY18 activities: UT

Josh Daw, L Hone (INL)

Improve reliability of ultrasound based temperature measurements through design improvements and new fabrication methods

- Design and fabricate UTs (sensor and electronics) based on solid rod waveguide with focus on near term deployments (DISECT, MITR)
- Design and fabricate UT based on Advanced Manufacturing techniques
- Demonstrate performance and reliability in out of pile test



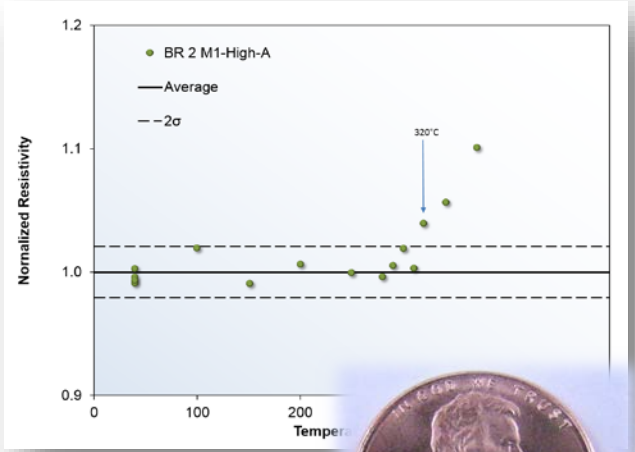


FY18 activities: SiC monitors

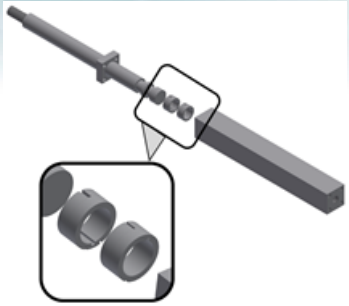
Kurt Davis, Ahmad Al Rashdan

Demonstrate a practical and reliable approach to measure peak irradiation temperature during PIE with SiC passive monitors of different shape

- Isochronal heating process with resistivity measurement demonstrated with BR-II samples (rodlets)
- Develop and demonstrate an automated, continuous heating process based on resistivity measurement (rodlets)
- Optimize the process to accept monitors of different shape, in particular TEM size disc used in nuclear materials test



Pressure and strain



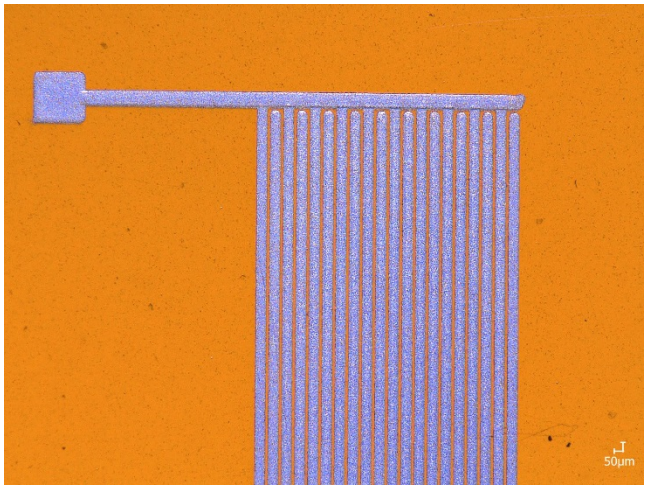
LVDT based Diameter Gauge sensor

LVDT

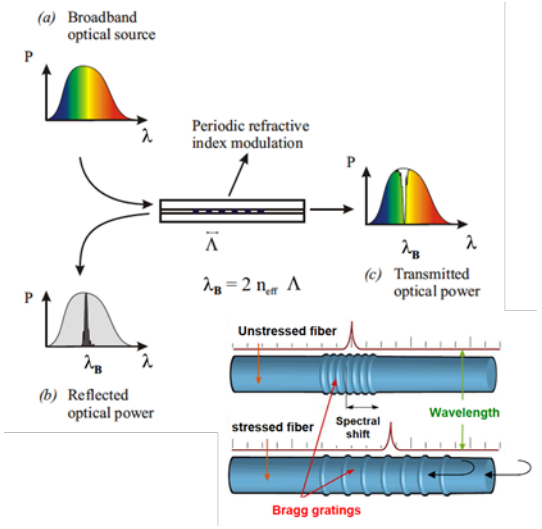
LVDT deployment and miniaturization

Miniaturized strain and pressure gauges

AJP printed strain gauge prototype



OF sensors



Principle of operation of FBGs

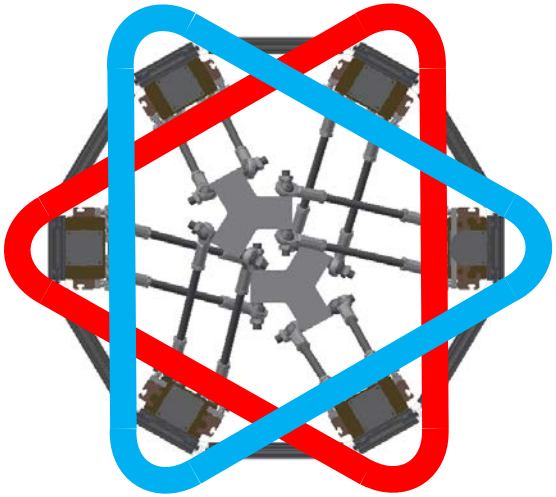
Temperature sensors for real time, distributed in-pile measurement with validated performance

FY18 activities: mechanical sensors

Anthony Crawford, A Fleming, K Davis, R Skifton

Measure the response of material and components to thermo-mechanical solicitations: strain, deformation, force, pressure, acceleration and vibration

- Strain gauges for nuclear fuels and materials experiment
  - Develop Advanced Manufactured strain gauges
  - Characterize strain gauges performance out of pile
- Deformation sensors for nuclear fuels and materials experiment
  - Develop impedance based diameter gauge (fuel pins and graphite components)
  - Compare to LVDTs and F-P interferometer



Enabling technologies

- Goal, and Objectives
  - Enable the deployment of optical fiber based sensor as in-pile instrumentation
  - Develop power harvesting materials to enable self-powered in-pile instrumentation
  - Optimize data transmission and analysis and develop wireless capability for in-pile instrumentation
- Problem Statement / Need Statement

The identified enabling technologies offer the potential of breakthrough innovation for in-pile instrumentation

- Approach

Strategy is based on the development of three classes of innovative materials that can withstand the radiation environment: optical fibers, thermo-electric and piezoelectric materials. Near term activities include:

- **Optical fibers**

Pressure seal for deployment in irradiation facilities / Radiation tolerant optical fiber materials / Photonic Crystal Fibers (PCFs) for in-pile instrumentation

- **Power harvesting**

Apply Integrated High-Throughput Computational Screening (IHTCS) methods to design radiation-resistant Electric Generating Materials (EGM) / Thermoelectric generators (TEGs)

- **Data transmission and analysis**

RF and acoustic transducers for in-pile wireless communication / Electromagnetic interference (noise) control / Data analytic tools

FY18 activities: rad hard fibers

Josh Daw, P Calderoni, A Fleming, J Smith, K McCary

Thermo-mechanical characterization of optical fibers and sensors with potential in-core applications

- Procure samples of silica based, radiation tolerant optical fiber materials and intrinsic sensors (commercial + partners)
- Demonstrate sensor performance out of pile
- Perform thermo-mechanical test (Corning standard)

CINR Workscope(s)

ADVANCED DIGITAL MONITORING AND CONTROL TECHNOLOGY (NEET-2)

NEET-2.3: ADVANCED SENSORS AND COMMUNICATION

(FEDERAL POC – SUIBEL SCHUPPNER & TECHNICAL POC – CRAIG PRIMER)
(ELIGIBLE TO LEAD: UNIVERSITY OR NATIONAL LABORATORY)
(UP TO 3 YEARS AND $1,000,000)

… develop and demonstrate new sensors and instrumentation for advanced plant control, data analytics, and nuclear applications for advanced reactors….

- Develop new radiation resistant sensors not currently under development for measurement of:
  - o Local radiation and temperature (e.g. solid-state detectors, diamond thermistors)
  - o Dimensional changes (specifically diameter and volume) and crack propagation,
  - o Material properties, such as thermal conductivity, mechanical properties, thermal expansion, etc.)
  - o Fission gas release (pressure and composition).
  - o Other in-core parameters important to reactor safety and/or fuel performance.

MS-FC-1: MAINTAINING AND BUILDING UPON THE HALDEN LEGACY (IN SITU DIAGNOSTICS)

(FEDERAL POC – KEN KELLAR & TECHNICAL POC – COLBY JENSEN)
(ELIGIBLE TO LEAD: UNIVERSITIES ONLY)
(UP TO 3 YEARS AND $400,000)

Real-time in-core diagnostic instrumentation of interest include, but are not limited to: creep, crack propagation, swelling, corrosion/crud build up, temperature, pressure, flux, two-flow phase, and fission product transport. Research that enables in-core application and associated logistics is also encouraged such as focuses on miniaturization, non-contact/non-intrusive as well as innovative data transmission techniques, such as wireless methods is also encouraged.

CINR Workscope(s)

ADVANCED FUELS (FC-2)

FC-2.4: ADVANCED CREEP TESTING OF FERRITIC STEELS FOR REACTOR CLADDING APPLICATIONS

(FEDERAL POC – JANELLE EDDINS & TECHNICAL POC – ANDY NELSON)
(ELIGIBLE TO LEAD: UNIVERSITIES ONLY)
(UP TO 3 YEARS AND $800,000)

Thus, proposals are requested to measure the thermal creep of advanced fuel cladding relevant ferritic steels using methods requiring shorter evaluation times and possibly smaller scale specimens…. It will be advantageous (but not required) if the proposed method(s) used to measure thermal creep can also be applied to measuring irradiation creep in situ.

FC-2.5: SEPARATE EFFECTS TESTING IN TREAT USING STANDARD TEST CAPSULES

(FEDERAL POC: KEN KELLAR & TECHNICAL POC: DAN WACHS)
(ELIGIBLE TO LEAD: UNIVERSITIES ONLY)
(UP TO 3 YEARS AND $500,000)
(NSUF LETTER OF INTENT REQUIRED)

The response of the test sample to the nuclear stimulus while immersed in this carefully controlled environment can be readily monitored using existing qualified or user supplied instruments.

CINR Workscope(s)

SALT BEHAVIOR IN MOLTEN SALT REACTORS (RC-2)

RC-2.2: UNDERSTANDING THE STRUCTURE AND SPECIATION OF MOLTEN SALT AT THE ATOMIC AND MOLECULAR SCALE

(FEDERAL POC – STEPHEN KUNG & TECHNICAL POC – DAVID HOLCOMB)
(ELIGIBLE TO LEAD: UNIVERSITIES ONLY)
(UP TO 3 YEARS AND $800,000)

(2) develop novel electrochemistry and spectroscopy methods for in-situ monitoring and predictive modeling

RC-3: LIQUID METAL-COOLED FAST REACTOR TECHNOLOGY DEVELOPMENT AND DEMONSTRATION TO SUPPORT DEPLOYMENT

(FEDERAL POC – TOM SOWINSKI & TECHNICAL POC – BOB HILL)
(ELIGIBLE TO LEAD: UNIVERSITIES ONLY)
(UP TO 3 YEARS AND $800,000)

Development of sensors and prognostic techniques for deployment that can monitor and quantify materials degradation in liquid metal-cooled fast reactor primary systems…. can be embedded in/on structural materials to enable structural health monitoring

CINR Workscope(s)

RC-7: MOLTEN SALT REACTOR TECHNOLOGIES

RC-7.1: FUEL SALT SAMPLING TECHNOLOGY DEVELOPMENT

(FEDERAL POC – BRIAN ROBINSON & TECHNICAL POC – DAVID HOLCOMB)
(ELIGIBLE TO LEAD: UNIVERSITIES ONLY)
(UP TO 3 YEARS AND $800,000)

A key technology for MSR operations is the ability to sample the hot, highly-radioactive fuel salt and to introduce additional (e.g. fuel or redox control) materials

RC-7.3: RADIATION HARDENED VISION SYSTEMS

(FEDERAL POC – BRIAN ROBINSON & TECHNICAL POC – DAVID HOLCOMB)
(ELIGIBLE TO LEAD: UNIVERSITIES ONLY)
(UP TO 3 YEARS AND $800,000)

Optically based systems remain the most important sensing modality for guiding remote O&M. Relatively recently, the Spallation Neutron Source target handling facilities and ITER have developed radiation hardened remote O&M technology. Demonstration of a multi-camera, radiation hardened 3D vision system to continuously update the in-containment model status is requested. Demonstration of techniques to repair and/or replace vision system components within containment is also requested