

Office of **NUCLEAR ENERGY** 



Advanced Sensors and Instrumentation

# Advanced Sensors and Instrumentation (ASI) Program Overview

Advanced Sensors and Instrumentation (ASI) Annual Program Webinar Oct. 30 – Nov. 2, 2023

Federal Program Manager: Daniel Nichols, PhD

U.S. Department of Energy, Office of Nuclear Energy

#### Administrative Items

The FY23 Advanced Sensors and Instrumentation (ASI) annual program review webinar will run from Oct. 30<sup>th</sup> – Nov. 2<sup>nd</sup>.

The program review contains presentations in the following categories:

- 18 Directed Research Projects
- 5 CINR Awards

5 NSUF Awards

12 SBIR/STTR Awards

1 Industry-FOA Project

#### Goals:

Complete Annual Review of all ASI program projects

Provide broad programmatic information for stakeholders throughout NE industry Provide detailed project status presentations to inform NE community of progress

#### **Expected Outcomes:**

Allow for productive dialogue about ongoing work

Ongoing projects gain visibility with NE industry stakeholders

Receive feedback from NE community on the ASI program and projects

For webinar-related technical support, please contact Eric Schuster:

hyrum.wray@inl.gov	-or-	(208) 715-1449
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>	Advanced Sensors and Instrumentation	MEETING AGENICA Advanced Sensors and Instrumentation (ASI)		
2VD	1104 (mm)05205 100 1	FY23 Annual Program Review meeting		
Ionday, Oct	ober 30, 2023			
ession 1: Int	roduction Ma	derators: Daniel Nichols (DOE)/Pattrick Calderoni (INL)		
10:00 am	Welcome, Opening Remarks, and ASI Program	n Overview Suibel Schuppner/Daniel Nichols, DOE		
10:40 am	ASI Program Roadmap	Pattrick Calderoni, INL		
11:00 am	NRC Research Status Update	Chris Cook, NRC		
ession 2 (par	t 1): Sensors for Advanced Reactors	Moderator: Chris Petrie, ORNL		
11:20 am	Neutron Flux - INL	Kevin Tsai, INI		
11:40 am	Neutron Flux - ORNL	Tony Biri/Pat Mulligan, ORNL		
12:00 pm	n [SBIR] Commercialization of the Micro Pocket Fission Detector (MPFD) Taylor Ochs, Radiation Detection Technologies, Inc.			
12:20 pm	BreakBreakBreak			
12:50 pm	Optical Fiber – INL	Austin Fleming, INI		
1:10 pm	Optical Fiber - ORNL	Chris Petrie, ORNI		
1:30 pm	Non-Contact Strain and Displacement Monitoring via Single Crystal Sapphire Based Interferometry Daniel Homa, Virgina Tech			
1:50 pm	[NSUF] Irradiation of Optical Components of In-Situ Laser Spectroscopic Sensors Igor Jovanovic, University of Michigan			
2:10 pm	Lunch			
2:40 pm	[NSUF] High Fluence Active Irradiation and Combined Effects Testing of Sapphire Optical Fiber Distributed Temperature Sensors Kelly McCary/Josh Daw, INL			
3:00 pm	[SBIR] Fiber-optic Sensor System for Multi-Point Pressure and Temperature Measurement Qiwen Sheng, Nusenics, LLC			
3:10 pm	[SBIR] Scaled Reduced Mode Sapphire Fiber Production Towards High Temperature Radiation Resilient Sensors Derek Rountree, Luna Innovations, Inc.			
3:30 pm	[SBIR] Fiber-Embedded Wireless Sensors	Joseph Pegna, Free Form Fibers		
3:40 pm	[SBIR] Optical Fiber Based Distributed Radiat	ion Detection Chris Westcott, Luna Innovations, Inc		
3:50 pm	[SBIR] Fiber-Optic Multifunctional Sensor for	Crack Monitoring in Harsh Environments George Boggs, Luna Innovations, Inc		
4:10 pm		Wrap Up		

#### Structure of the Office of Nuclear Energy



#### Advanced Sensors and Instrumentation Leadership



Federal Program Manager: Daniel Nichols daniel.nichols@nuclear.energy.gov National Technical Director: Pattrick Calderoni pattrick.calderoni@inl.gov

### ASI Program Focus

#### Mission

Develop <u>advanced sensors and I&C</u> that address critical technology gaps for monitoring and controlling existing and advanced reactors and supporting fuel cycle development

### Vision

NEET ASI Research results in advanced sensors and I&C technologies that are <u>qualified</u>, <u>validated</u>, <u>and ready to be</u> <u>adopted</u> by the nuclear industry



#### ASI R&D Components



#### Methods and Metrics of ASI Research



## Program-related Funding Opportunities

Consolidated Innovative Nuclear Research (CINR)

#### Universities

Principal Investigator/Sub-awardee for:

- Integrated Research Projects (IRP)
- Research & Development (R&D)
- Nuclear Science User Facility (NSUF) access only



Principal Investigator/Sub-awardee for:

 Nuclear Science User Facility (NSUF) access only

Sub-awardee for:

- Integrated Research Projects (IRP)
- Research & Development (R&D)

Engage and collaborate with a small business to commercialize the technology

Lead R&D efforts as the Principal Investigator



Industry

Principal Investigator/Sub-awardee for:

Nuclear Science User Facility (NSUF) access only

Sub-awardee for:

- Integrated Research Projects (IRP)
- Research & Development (R&D)

Lead the commercialization effort as the Principal Investigator

Collaborate with National Laboratory as a subcontractor

Small Business Innovation Research (SBIR) & Small Business Technology Transfer (STTR) programs Engage and collaborate with a small business to commercialize the technology

**Directed Research** 

Collaborate with National Laboratory as a subcontractor

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### Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR)



SBIR and STTR focus on industry-led projects with the intent to advance technologies to commercialization

Key Upcoming Dates:

Topic Issues	Nov. 6, 2023
Topic Webinar	Nov. 13, 2023 (tent.)
FOA issued	Dec. 11, 2023
FOA Webinar	Dec. 15, 2023 (tent.)
Letters of Intent	Jan. 3, 2024
Full Applications	Fed. 21, 2024

For more information about the DOE SBIR/STTR FOA, visit: <u>https://science.osti.gov/sbir/Funding-Opportunities</u> For more general SBIR/STTR information, visit: <u>https://www.sbir.gov/</u>



## FY23 SBIR/STTR Recipients (ASI related work)

				Concluding		
Subtopic	Phase	Insitution	Location	<b>Fiscal Year</b>	PI	Title
40w	I	NUSENICS, LLC	Okemos, MI	2024	Sheng, Qiwen	High Penetration Wireless Networking for Nuclear Power Plant Sensing
40w	I	Luna Innovations Incorporated	Roanoke, VA	2023	Wescott, Christopher	Ultrasonic Multipoint Temperature Sensor for Nuclear Reactor Applications
40w	I	Free Form Fibers	Saratoga Springs, NY	2023	Pegna, Jospeh	Printed Sensors for Monitoring Reactor Health
225		Alphacorollac	Tompo A7	2022	Salcin Econ	Advanced Process Instrumentation System for Next-Generation Nuclear
55d	ПВ	Alphacore inc	iempe, Az	2025	Salcin, Esen	Reactors
202		Operant Networks Corporation	Santa Posa CA	2022	King Pandall	Three-Dimensional, Ultra-Radiation-Hardened Video System for Nuclear Power
598		Operant Networks Corporation	Janua Rusa, CA	2025	Killg, Kalluali	Plant Inspection

#### Other Industry-relevant FOAs



Gateway for Accelerated Innovation in Nuclear (GAIN) Vouchers for FY2024:

Round 1 – Applications due Oct. 31, 2023 (5:00pm EDT) Round 2 – Applications due Jan. 31, 2024 (5:00pm EST) Round 3 – Applications due Apr. 30, 2024 (5:00pm EDT) Round 4 – Applications due Jul. 31, 2024 (5:00pm EDT)

More information about both FOAs can be found of the GAIN website: gain.inl.gov

#GAINAccess 💻

The U.S. Department of Energy's Office of Nuclear Energy established the GAIN initiative to provide the nuclear community with access to the technical, regulatory, and financial support necessary to move innovative technologies toward commercialization.

The NE Voucher Program is one way to provide industry with access to the unique research capabilities and expertise at DOE's national labs.

### Consolidated Innovative Nuclear Research (CINR)



# Consolidated Innovative Nuclear Research (CINR) holds various opportunities:

 U.S. University-led R&D Projects
U.S. University-led Integrated Research Projects (IRPs)
U.S. University-, National Laboratory-, or Industry-led Nuclear Science User Facilities (NSUF) Access Only Projects

Key Upcoming Dates:

NSUF Final Statement of Work Due Date: December 6, 2023, at 5:00 p.m. ET

Full R&D/NSUF and IRP Applications Due Date: December 20, 2023, at 5:00 p.m. ET

NOTE: Deadlines are the dates/times by which DOE must receive the specified submittal.

For more information visit the NEUP website:

neup.inl.gov

#### FINANCIAL ASSISTANCE FUNDING OPPORTUNITY ANNOUNCEMENT



U. S. Department of Energy

**Idaho Operations Office** 

Fiscal Year 2024 Consolidated Innovative Nuclear Research

Funding Opportunity Announcement: DE-FOA-0003038

Announcement Type: Initial – June 22, 2023 Amendment 001: August 31, 2023 Assistance Listings Number: 81.121

Informational Webinar: May 31, 2023 (Video links and presentations are available at <u>www.NEUP.gov</u>)

Issue Date: June 22, 2023

DOE Topic Area Office Hours: July 10-14, 2023 (Video links and presentations are available at <u>www.NEUP.gov</u>)

Letter of Intent (Mandatory only for NSUF-1 and NSUF-2 Applications) Due Date: July 12, 2023, at 5 p.m. ET

R&D/NSUF Pre-Applications (Mandatory except for IRPs) Due Date: July 26, 2023, at 5:00 p.m. ET

NSUF Preliminary Statement of Work Due Date: August 31, 2023, at 5:00 p.m. ET

NSUF Final Statement of Work Due Date: December 6, 2023, at 5:00 p.m. ET

Full R&D/NSUF and IRP Applications Due Date: December 20, 2023, at 5:00 p.m. ET

NOTE: Deadlines are the dates/times by which DOE must receive the specified submittal

#### FY23 CINR Recipient for Workscope IC-1

Project Title: Integrated Stand-Off Optical Sensors for Molten Salt Reactor Monitoring

Principal Investigator: Dr. Kevin Chen (University of Pittsburgh)

**Summary:** Molten salts at high temperatures are highly corrosive coolants. To ensure safe and efficient operation of MSRs, robust sensors are needed to monitor both physical and chemical properties of molten salts at high temperatures in harsh radioactive environments. Most of electronic sensors cannot survive in these harsh environments. To address these challenges, this project will develop stand-off optical sensors that does not require physical contacts with liquid coolants to perform measurements. Using a single radiation harden fused silica rod as the optical port to remotely access reactor cores or flow loops, this project will develop integrated stand-off optical sensors to perform coolant levels, flow rate, and metal impurity characterization in real-time to ensure safe and efficient operation of MSRs. Through optical frequency domain reflectometry and intracavity self-mixing effects, physical parameters of molten salts can be accurately measured in both reactor vessel and flow loops using low-cost diode lasers from telecom and virtual reality industries. Using advanced dual-pulse laser induced breakdown spectroscopy (LIBS), this project will develop a stand-off laser chemical sensor with detection sensitivity better than 10 ppm to measure dissolved metal such as Ni, Cr, and Mn which are directly connected to molten-salt induced corrosion of pressure vessels.





**Project Period:** 10/1/2023 – 09/30/2026

#### FY23 CINR Recipient for Workscope IC-1

Project Title: Optical Sensors for Impurity Measurement in Liquid Metal-cooled Fast Reactors

Principal Investigator: Dr. Milos Burger (University of Michigan)

**Summary:** One of the major challenges in Sodium-cooled Fast Reactor design at ANL's Mechanisms Engineering Test Loop relate to the control of impurities in the sodium coolant. For example, the high concentration of impurities such as oxygen can accelerate the corrosion process and cause unwanted plugging in the cooling system, and the presence of hydrogen in sodium is indicative of a leak. The existing technology (plugging meter) has several disadvantages, the main of which is its inability to discriminate among different types of impurities. Any impurity in the system could result in plug restriction, and an assumption must be made concerning the impurity type to infer its concentration. As a result, the plugging meter could not determine whether a corrosion concern exists due to high oxygen concentration, or a leak has developed as indicated by high hydrogen concentration, for instance. Combining two versatile optical techniques such as laser-induced breakdown spectroscopy (LIBS) and two-photon absorption laser-induced fluorescence (TALIF) aims to provide a sensitive, robust, and convenient method for in-situ, real-time detection of trace impurities in liquid sodium coolant. The resulting microplasma emits characteristic radiation, enabling the spectral detection of all analyte constituents via LIBS. Excited states of oxygen and hydrogen produced in laser ablation can be further resonantly pumped using TALIF to enhance the detection sensitivity.







#### **ASI Program Resources**

#### Visit the DOE-NE website:

https://www.energy.gov/ne/nuclear-energy-enablingtechnologies/advanced-sensors-and-instrumentation

Checkout the new ASI website: <u>asi.inl.gov</u>

Visit the Nuclear Energy Sensor Database: <u>https://nes.energy.gov</u>



### **Concluding Remarks**

- Improvements and advancements in ASI technologies will
  - enable advances in nuclear reactor and fuel cycle system development
  - enhance economic competitiveness for nuclear power plants, and
  - promote a high level of nuclear safety
- NEET-ASI research produces concepts, techniques, capabilities, and equipment that are or can be demonstrated in simulated or laboratory test bed environments representative of nuclear plant systems or fuel cycle systems
- Innovative and crosscutting research is funded through competitive, peer-reviewed, solicitations and directed work

#### Daniel M. Nichols, PhD

Federal Program Manager | Advanced Sensors and Instrumentation [NE - 51] United States Department of Energy | Office of Nuclear Energy Email: <u>daniel.nichols@nuclear.energy.gov</u> Time Zone: EDT (UTC - 04:00) Advanced I&C technologies are an integral component for advanced reactors to provide safe, clean, and reliable power



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Advanced Sensors and Instrumentation

# **Thank You**



### Consolidated Innovative Nuclear Research (CINR)

FY	Project Title	Principal Investigator / Location
2023	Integrated Stand-Off Optical Sensors for Molten Salt Reactor Monitoring	Kevin Chen / University of Pittsburgh
2023	Optical Sensors for Impurity Measurement in Liquid Metal-cooled Fast Reactors	Milos Burger / University of Michigan
2022	An Innovative Monitoring Technology for the Reactor Vessel of Micro-HTGR	Lesley Wright / Texas A & M University
2021	Gallium Nitride-based 100-Mrad Electronics Technology for Advanced Nuclear Reactor Wireless Communications	Milton Ericson / Oak Ridge National Laboratory
2020	Development of Sensor Performance Model of Microwave Cavity Flow Meter for Advanced Reactor High Temperature Fluids	Alexander Heifetz / Argonne National Laboratory
2020	Design and Prototyping of Advanced Control Systems for Advanced Reactors Operating in the Future Electric Grid	Roberto Ponciroli / Argonne National Laboratory
2019	Acousto-optic Smart Multimodal Sensors for Advanced Reactor Monitoring and Control	Michael Larche / Pacific Northwestern National Laboratory
2019	Design of risk informed autonomous operation for advanced reactor	Michael Golay / Massachusetts Institute of Technology
2019	Cost-Benefit Analyses through Integrated Online Monitoring and Diagnostics	David Grabaskas / Argonne National Laboratory
2019	Advanced Online Monitoring and Diagnostic Technologies for Nuclear Plant Management, Operation, and Maintenance	Daniel Cole / University of Pittsburgh
2019	Context-Aware Safety Information Display for Nuclear Field Workers	George Gibson / Arizona State University
2018	Development of optical fiber-based gamma thermometer	Thomas Blue / The Ohio State University
2018	Analytics-at-scale of Sensor Data for Digital Monitoring in Nuclear Plants - INL	Vivek Agarwal / Idaho National Laboratory
2018	Process-Constrained Data Analytics for Sensor Assignment and Calibration	Richard Vilim / Argonne National Laboratory
2017	Integrated silicon/chalcogenide glass hybrid plasmonic sensor for monitoring of temperature in nuclear facilities	Maria Mitkova / Boise State University
2017	High temperature embedded/integrated sensors (HiTEIS) for remote monitoring of reactor and fuel cycle systems	Xiaoning Jiang / North Carolina State University
2017	3-D Chemo-Mechanical Degradation State Monitoring, Diagnostics and Prognostics of Corrosion Processes in Nuclear Power Plant Secondary Piping Structures	Douglas Adams / Vanderbilt University
2017	Versatile Acoustic and Optical Sensing Platforms for Passive Structural System Monitoring	Gary Pickrell / Virginia Tech
2017	Ultrasonic Sensors for TREAT Fuel Condition Measurement and Monitoring	Andrew Casella / Pacific Northwestern National Laboratory

## Nuclear Science User Facility (NSUF) R&D

FY	Project Title	Principal Investigator / Location
2021	Understanding irradiation behaviors of ultrawide bandgap Ga2O3 high temperature sensor materials for advanced nuclear reactor systems	Ge yang / North Carolina State University
2021	Deployment and In-Pile Test of an Instrument for Real-Time Monitoring Thermal Conductivity Evolution of Nuclear Fuels	Zilong Hua / Idaho National Laboratory
2020	Irradiation of Sensors and Adhesive Couplants for Application in LWR Primary Loop Piping and Components	James Wall / Electric Power Research Institute
2019	Irradiation of Optical Components of In-Situ Laser Spectroscopic Sensors for Advanced Nuclear Reactor Systems	Igor Jovanovic / University of Michigan
2019	High Fluence Active Irradiation and Combined Effects Testing of Sapphire Optical Fiber Distributed Temperature Sensors	Joshua Daw / Idaho National Laboratory
2018	Irradiation Behavior of Piezoelectric Materials for Nuclear Reactor Sensors	Marat Khafizov / The Ohio State University
2018	High-performance nanostructured thermoelectric materials and generators for in-pile power harvesting	Yanliang Zhang / University of Notre Dame
2017	Additive manufacturing of thermal sensors for in-pile thermal conductivity measurement	David Estrada / Boise State University
2017	Radiation Effects on Optical Fiber Sensor Fused Smart Alloy Parts with Graded Alloy Composition Manufactured by Additive Manufacturing Processes	Kevin Chen / University of Pittsburgh

#### Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR)

Phase	FY	Project Title	Principal Investigator / Location
1.1		Fiber-optic Sensor System for Multi-point Pressure and Temperature Measurement	Qiwen Sheng / NUSENICS, LLC
1.1	2022	Optical Fiber Based Distributed Radiation Detection	Christopher Wescott / Luna Innovations Incorporated
1.1	2025	Fiber-embedded wireless sensors	Jospeh Pegna / Free Form Fibers
IIB		Video Camera for Harsh Environments in Nuclear	Esen Salcin / Alphacore Inc
11		High Penetration Wireless Networking for Nuclear Power Plant Sensing	Randall King / Operant Networks Corporation
1.1		Scaled Reduced Mode Sapphire Fiber Production Towards High Temperature Radiation Resilient Sensors	Derek Rountree / Luna Innovations Incorporated
1.1		Commercialization of the Micro Pocket Fission Detector (MPFD)	Taylor Ochs / Radiation Detection Technologies, Inc.
1	2022	Ultrasonic Multipoint Temperature Sensor for Nuclear Reactor Applications	Dan Xiang / X-wave Innovations, Inc.
1	2022	Advanced Process Instrumentation System for Next-Generation Nuclear Reactors	Alexander Hashemian / Analysis & Measurement Services Corp.
1		Three-Dimensional, Ultra-Radiation-Hardened Video System for Nuclear Power Plant Inspection	Tony Moretti / Vega Wave Systems
1.1		Fiber-Optic Multifunctional Sensor for Crack Monitoring in Harsh Environments	George Boggs / Luna Innovations Incorporated
1		Printed Sensors for Monitoring Reactor Health	Richard Fink / Applied Nanotech, Inc.
11	2021	Advanced Laser Ultrasonic Sensor for Fuel Rod Characterization	Bobbs Bradly / Intelligent Optical Systems, Inc.
11	2020	Development of Radiation Endurance Ultrasonic Transducer for Nuclear Reactors	Dan Xiang / X-wave Innovations, Inc.