Microreactor Program FY2024

Winter Program Review – March 5-6th, 2024

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National Technical Director

Meeting Logistics and Objectives

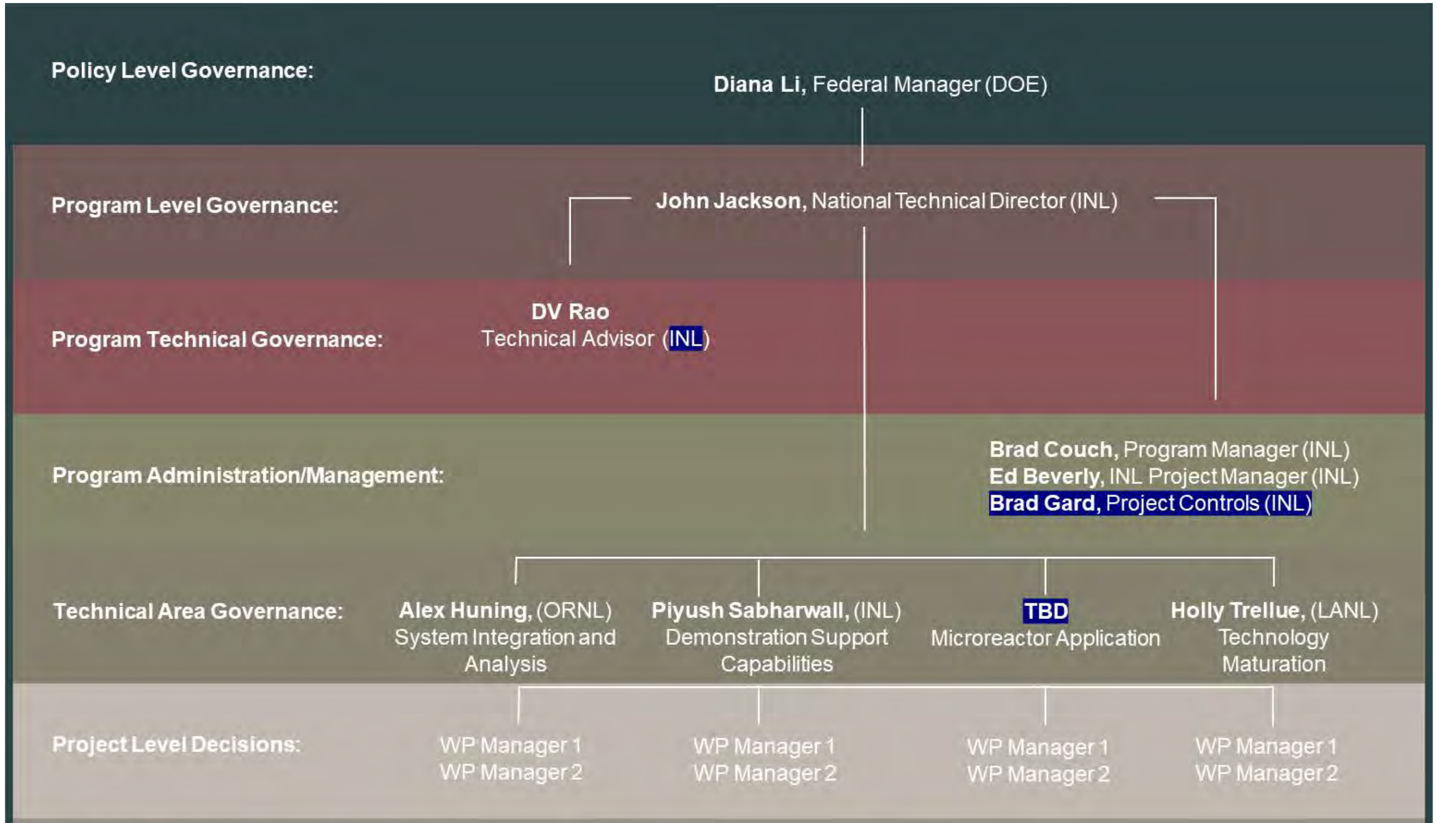
- Please mute your microphone and turn your camera off
  - Ask questions during Q&A by raising your hand or using chat during the discussion
  - Speakers will turn on their cameras
- Primary purpose for the meeting is to review mid-year progress and focus on known and potential issues for FY24
- Introduce changes to the program
- Share with developers and other stakeholders
- This is a self assessment so it’s “open season” for any suggested changes/updates

Instructions for Presentations

- Each Technical Area (TA) is provided time on agenda for discussion at the TA level and work package level
- Discussion should be focused on:
  - Progress made so far (Fiscal Year 2024)
  - Major FY24 milestones should be discussed with emphasis on any that may be facing issues or delayed
  - Connectivity with FY2025
- Each Technical Area Lead (TAL) will lead a session focused on their TA and related NEUP projects
- Presenters will adhere to their time slot

MRP Microreactor Program

Current Microreactor Program Org Chart



Key program roles and responsibilities shown in the organization structure are defined below:

DOE Federal Manager – Provides program direction, guidance, and priorities through coordination with NE senior leadership, Congressional direction, other federal program managers, other relevant federal agencies, and program NTD.

National Technical Director (NTD) – Provides overall technical leadership of the program by performing program planning, directing technical work through the Technical Area Leads, reviewing work performed, and communicating with key stakeholders and other program directors.

Technical Area Leads (TALs) – Provides leadership over a specific technical program scope area (see Program Scope section), supports program planning, provides technical direction and oversight to work package managers in their technical area, and reviews work performed.

Work Package Managers (WPM) – Leads and performs a specific technical work scope in support of program milestones and objectives. Provides oversight on work being performed within their work package and is responsible for delivery of assigned milestones within their work scope.

MRP Microreactor Program

DOE Microreactor Program

Program Vision

Through cross-cutting research and development and technology demonstration support, the Microreactor Program will enable broad deployment of microreactor technology by:

- Achieving technological breakthroughs for key features of microreactors
- Identifying and addressing technology solutions to improve the economic viability and licensing readiness of microreactors.
- Enabling successful demonstrations of multiple domestic commercial microreactors.

Program Objectives

- Address critical cross-cutting R&D needs that require unique laboratory/university capability or expertise
- Develop R&D infrastructure to support design, demonstration, regulatory issue resolution, and M&S code validation
- Develop advanced technologies that enable improvements in microreactor viability

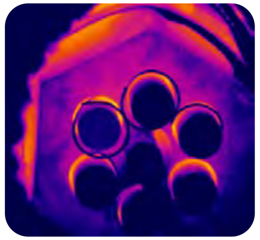
Technology Readiness Level

Microreactor Application

- Integrated Nuclear Testing
- Applied R&D

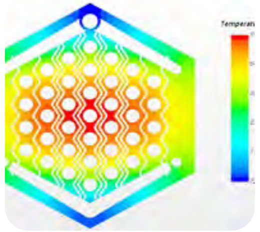
Demonstration Support Capabilities

- Non-nuclear Testing
- Test-beds for developers/regulators



Technology Maturation

- Matures fundamental microreactor enabling technologies and capabilities



System Integration & Analyses

- Identification of technology and regulatory gaps for Microreactors

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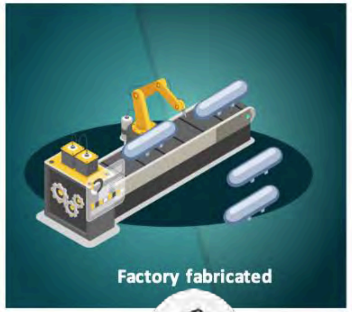
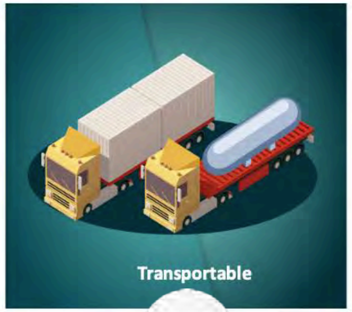
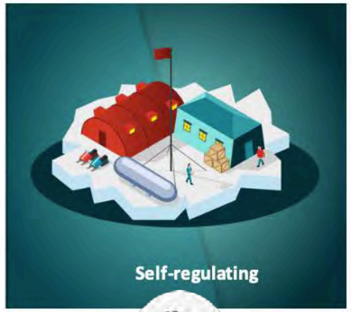
Microreactors
Megawatt-scale Advanced Nuclear Reactors







ENABLING TECHNOLOGIES

Fuel & Moderator

- Small Core,
- Long life,
- HALEU
- High-T Moderator

Reactor Controls

- Automation
- Compact, in-core sensors
- AI/ ML
- Remote Control

Power Conversion

- Skid mounted
- High Temp.
- Robust
- Flexible operation

Structural Material

- Creep resistance
- ASME Sec III, Div. 5 compliant
- NQA-1 supply chain

Neutron Reflector

- Low cost
- Manufacturability
- High moderating ratio
- High temperature

Transport & Siting

- NEPA
- Vibration isolation
- Transport shielding
- Licensing modernization

Microreactor Concepts Under Development in the U.S. (that we're aware of)

Developer	Name	Type	Power Output (MWe/MWth)	Fuel	Coolant	moderator	refueling interval	PCU
Aalo Atomics	Aalo One	STR	7 MWe/20MWth	U-Zr-H	Sodium	H	3-5 years	Steam Rankine
Alpha Tech Research Corp	ARC Nuclear Generator	MSR	12 Mwe/30 MWth	LEU	Flouride salt		intermittent	
Antares Industries		Heat Pipe	1.2 MWth		sodium	graphite		Brayton Cycle
BWXT	BANR	HTGR	17 MWe/50 MWth	TRISO	Helium	graphite	5 years	Brayton Cycle
General Atomics	GA Micro	HTGR	1-10 MWe		gas			?
HolosGen	HolosQuad	HTGR	13 MWe	TRISO	Helium/CO2		10 years	Brayton Cycle
Micro Nuclear, LLC	Micro Scale Nuclear Battery	MSR/heat pipe	10 MWe	UF4	FLiBe	YH	10 years	
Nano Nuclear	Zeus/Odin	HTGR/MSR	1.0 MWe/2.5 MWth	UO2	Helium			Brayton Cycle
NuGen, LLC	NuGen Engine	HTGR	2-4 MWe	TRISO	Helium			Integral direct cycle
NuScale Power	NuScale Microreactor	LMTM/heat pipe	<10 MWe	metallic	Liquid Metal	Liquid Metal	10 years	TPV
Oklo	Aurora	SFR	15 MWe	metallic (U-Zr)	Sodium		10+ years	Steam Rankine
Radiant Nuclear	Kaleidos Battery	HTGR	1.2 MWe	TRISO	Helium	graphite	4-6 years	
Ultra Safe Nuclear	MicroModular Reactor	HTGR	5 MWe/15 MWth	TRISO	Helium	graphite	20 years	Rankine
Westinghouse	eVINCI	heat pipe	5 MWe/15 MWth	TRISO	Sodium	graphite	8 years	Brayton Cycle
X-Energy	XE-MOBILE	HTGR	5 MWe/10 MWth	TRISO	Helium	graphite	3+ years	Open air Brayton Cycle

Nuclear Energy University Program (NEUP)

- (Project 19-16802) Evaluation of Semi-Autonomous Passive Control Systems for HTGR Type Special Purpose Reactors – U of Michigan
- (Project 19-17416) Experiments and computations to address the safety case of heat pipe failures in Special Purpose Reactors – U of Michigan
- (Project 20-19693) Evaluation of micro-reactor requirements and performance in an existing well-characterized micro-grid – UIUC
- (Project 20-19735) Experiments for Modeling and Validation of Liquid-Metal Heat Pipe Simulation Tools for Micro-Reactor – Texas A&M
- (Project 21-24152) Direct heating of chemical catalysts for hydrogen and fertilizer production using Microreactors – Kansas State
- (Project 21-24226) Cost Reduction of Advanced Integration Heat Exchanger Technology for Micro-Reactors – U of Wisconsin
- (Project 22-26910) Demonstrating Autonomous Control, Remote Operation, and Human Factors for Microreactors Under Prototypic Conditions in PUR-1 – Purdue
- (Project 22-27123) Development of Hydrogen Transport Models for High Temperature Metal Hydride Moderators – CSM
- Project 23-29622) Development of the Technical Bases to Support Flexible Siting of Microreactors based on Right-Sized Emergency Planning – Penn State
- (Project 23-29834) Transforming Microreactor Economics Through Hydride Moderator Enabled Neutron Economy – Stonybrook
- (Project 23-29784) Deciphering Irradiation Effects of YHx through In-situ Evaluation and Micromechanics for Microreactor Applications - UNM

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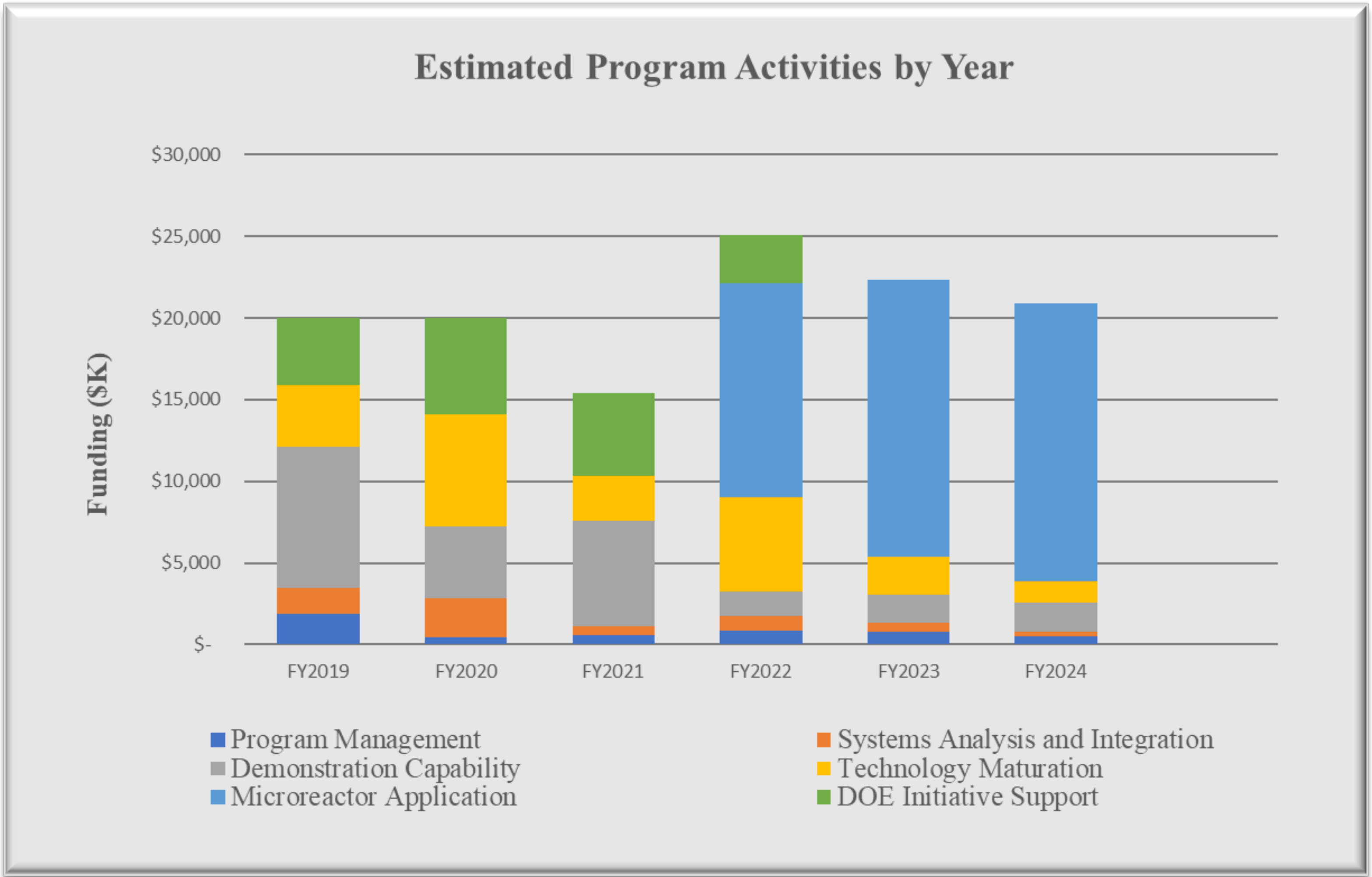
Input from microreactor developers (Westinghouse example)

- **MAGNET/SPHERE**
  - Planning and execution of testing (SPHERE and MAGNET) for code validation and electrical demonstrations*
- **High-Temperature Moderator Materials**
  - Beryllium Oxide (BeO) Advanced Manufacturing Techniques for near-net shape consolidation and Improved Economics
  - Extend Yttrium Hydride Moderator Irradiation Testing*
- **Integrated Modeling and Simulation of Microreactors**
  - Transient and Irradiation Testing of TRISO Fuel
  - Neutronics Benchmarking and Criticality Testing*
  - TRISO Pd-SiC Interaction Margin Improvement
  - Microreactor and Heat Pipe Microreactor Startup Modeling
- **Licensing and Regulatory**
  - Safeguards Licensing Development
- **Heat Transfer and Power Conversion**
  - Mechanical Seals for High Temperature Helium Environment*
- **Advanced Structural Material Manufacturing and Testing**
  - Graphite and Carbon-Carbon Composite Thermal Coupling Material

MRP Microreactor Program

Microreactor Program funding



Microreactor Program FY24 Budget scenarios

Microreactor base R&D	FY24 Planned Target	FY24 Over Target
Project Management	$475K	$475K
Directed Research	$3,725K	$5,605K
Total	**$4,200K**	**$6,080K**

MARVEL	FY24 Planned Target	FY24 Over Target
Project Management	$3,150K	$3,150K
Directed Research	$13,850K	$16,850K
Total	**$17,000K**	**$20,000K**

MRP Microreactor Program

FY24 Base Microreactor Program Planned Outcome Highlights

1) Integrate Power Conversion Unit with MAGNET to enable integrated microreactor heat transfer system testing
2) Complete initial MELCOR and BlueCRAB code to code comparison with FATE for a generic heat pipe microreactor
3) Demonstrate decision making by integrated Microreactor Automated Control System (MACS) software using sensors from hardware in the loop
4) Complete and integrate research grade MACS software module
5) Technoeconomic evaluation of a microreactor using detailed bottom-up estimate
6) Investigate emergency planning for transportation of microreactors
7) Heat transfer characterization for a high-performance refractory metal heat pipe
8) Complete final design for high temperature/high pressure helium test loop
9) Progress on structural materials – 316H SS creep fatigue and refractory metal additive manufacturing characterization
10) Refinement of acoustic techniques for detection and characterization of defects (structural health monitoring)
11) Continued development of advanced moderator modules
12) Design and build graphite core block test article

MRP Microreactor Program

MARVEL Can Enable a New Class of Nuclear Reactors

(Microreactor Applications Research, Validation & EvaLuation)

Project Goals:

- Development of a small-scale microreactor that provides a platform to test unique operational aspects and applications of microreactors

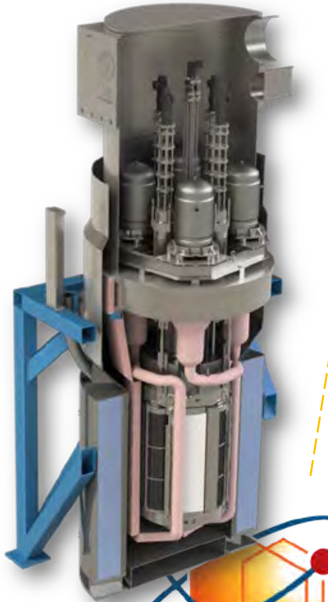
Primary Objectives:

- **Operational** microreactor
- Produce **combined heat and power (CHP)** to a functional **microgrid**
- **Share lessons learned** with commercial developers
- **Train** future operators

U.S. DOE Sponsor Program:

MRP Microreactor Program

Create momentum,
Champion rapid technology maturation to de-risk industry
Collaborate and engage microreactor end-user companies



- 85 kW-thermal
- 20 kW-electric
- ~15 feet tall
- < 12 tons
- 2 operators
- Self-regulating

MRP Microreactor Program

Questions?