The DOE Microreactor Program
MARVEL Microreactor

2024 MARVEL Technology Review
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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
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)

<table>
<thead>
<tr>
<th>Developer</th>
<th>Name</th>
<th>Type</th>
<th>Power Output (MWe/MWth)</th>
<th>Fuel</th>
<th>Coolant</th>
<th>moderator</th>
<th>refueling interval</th>
<th>PCU</th>
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<tbody>
<tr>
<td>Aalo Atomics</td>
<td>Aalo One</td>
<td>STR</td>
<td>7 MWe/20MWth</td>
<td>U-Zr-H</td>
<td>Sodium</td>
<td>H</td>
<td>3-5 years</td>
<td>Steam Rankine</td>
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<td>Alpha Tech Research Corp</td>
<td>ARC Nuclear Generator</td>
<td>MSR</td>
<td>12 MWe/30 MWth</td>
<td>LEU</td>
<td>Flouride salt</td>
<td>intermittent</td>
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<tr>
<td>Antares Industries</td>
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<td></td>
<td>1.2 MWth</td>
<td>sodium</td>
<td>graphite</td>
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<td>BWXT</td>
<td>BANR</td>
<td>HTGR</td>
<td>17 MWe/50 MWth</td>
<td>TRISO</td>
<td>Helium</td>
<td>graphite</td>
<td>5 years</td>
<td>Brayton Cycle</td>
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<td>GA Micro</td>
<td>HTGR</td>
<td>1-10 MWe</td>
<td>gas</td>
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<td>HolosQuad</td>
<td>HTGR</td>
<td>13 MWe</td>
<td>TRISO</td>
<td>Helium/CO2</td>
<td>10 years</td>
<td>Brayton Cycle</td>
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<td>Micro Scale Nuclear Battery</td>
<td>MSR/heat pipe</td>
<td>10 MWe</td>
<td>UF4</td>
<td>FLBe</td>
<td>YH</td>
<td>10 years</td>
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<td>HTGR/MSR</td>
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<td>UO2</td>
<td>Helium</td>
<td></td>
<td>Integral direct cycle</td>
<td>Brayton Cycle</td>
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<td>NuGen, LLC</td>
<td>NuGen Engine</td>
<td>HTGR</td>
<td>2-4 MWt</td>
<td>TRISO</td>
<td>Helium</td>
<td></td>
<td>Integral direct cycle</td>
<td></td>
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<td>NuScale Power</td>
<td>NuScale Microreactor</td>
<td>LMTM/heat pipe</td>
<td>&lt;10 MWe</td>
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<td>Liquid Metal</td>
<td>Liquid Metal</td>
<td>10 years</td>
<td>TPV</td>
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<td>Oklo</td>
<td>Aurora</td>
<td>SFR</td>
<td>15 MWe</td>
<td>metallic (U-Zr)</td>
<td>Sodium</td>
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<td>10+ years</td>
<td>Steam Rankine</td>
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<td>Radiant Nuclear</td>
<td>Kaleidos Battery</td>
<td>HTGR</td>
<td>1.2 MWe</td>
<td>TRISO</td>
<td>Helium</td>
<td>graphite</td>
<td>4-6 years</td>
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<td>Ultra Safe Nuclear</td>
<td>MicroModular Reactor</td>
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<td>5 MWe/15 MWth</td>
<td>TRISO</td>
<td>Helium</td>
<td>graphite</td>
<td>20 years</td>
<td>Rankine</td>
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<td>Westinghouse</td>
<td>eVINCI</td>
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<td>5 MWe/15 MWth</td>
<td>TRISO</td>
<td>Sodium</td>
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<td>8 years</td>
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<td>XE-MOBILE</td>
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<td>5 MWe/10 MWth</td>
<td>TRISO</td>
<td>Helium</td>
<td>graphite</td>
<td>3+ years</td>
<td>Open air Brayton Cycle</td>
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Demonstration Support - SPHERE and MAGNET testbeds

**SPHERE - Single Primary Heat Extraction and Removal Emulator**
- Single heat pipe coupled to forced convection cooling, surrounded by 6 electrical heaters
- Designed to quantify operational temperatures and heat rejection from of a single heat pipe
- Highly instrumented to measure temperature and strain distributions in a miniature monolithic core block

**MAGNET – Microreactor AGile Non-nuclear Experimental Test Bed**
- Engineering scale test bed for testing large sections of a monolithic core block with an array (e.g., 37) of heat pipes and electrical heaters
- Capable of testing advanced heat rejection systems or integral effects such as the potential for cascading failures of multiple heat pipes
- Helium component testing

Increasing complexity
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:
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
MARVEL Thermal Hydraulic Prototype

- Thermophysical twin of MARVEL
- Full-scale, electrically heated
- Data used to validate models, per NQA-1
- Initial startup on September 19th, 2023 with demonstration of natural circulation and power generation

NaK flow measurements through 4 loops
Initiation of MARVEL Fabrication Phase

- Final Design Review (completed)
  - Live Review- Sept 2022
  - 440+ comments received
  - Final comments resolution meeting, Aug 2023
  - 90% Design Completion, per DOE-STD-1189 September 29, 2023!
  - Release of 260+ documents
- MARVEL officially in fabrication phase
  - Purchased materials, Long Lead Procurement #1 (completed)
  - Fabrication, LLP#2 (initiated)
  - RCS, LLP#3 (initiated)
MARVEL Value Statement for Public/End Users

• Nuclear Energy is new to microreactor entry market
  – Operation complexity
  – Fear of colocation
  – Training needs
  – Reliability

• Customers reluctant to adopt microreactor technology unless they “see one” first (not willing to be the first in their backyard)

• Having no real test reactor is a barrier to market entry
  – End users deem it necessary to “interact” with a microreactor prior to providing customer requirements
  – End users unsure of technology potential prior to interaction

MARVEL will be the first microreactor to achieve criticality to demonstrate end user applications
“With many companies working on microreactor concepts behind closed doors, I see unique value in having a system that can be shared and discussed across teams”
Questions?

https://gain.inl.gov/SitePages/MicroreactorProgram.aspx