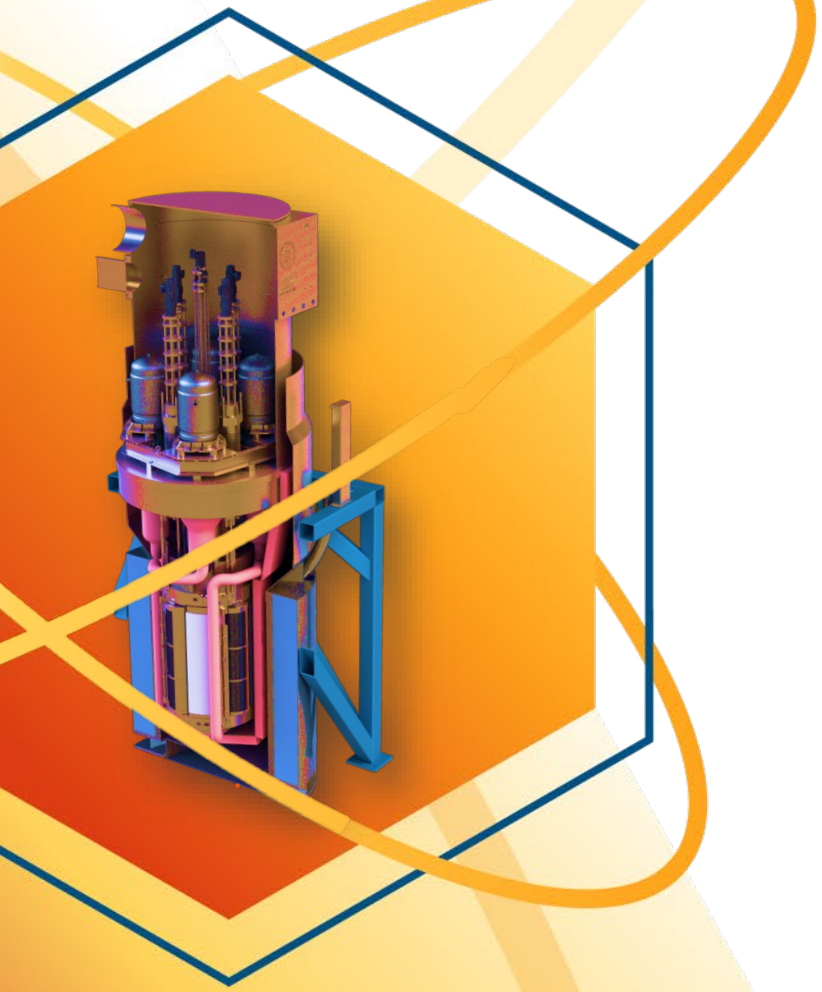
INL/MIS-26-90516

(Microreactor Applications Research, Validation & EvaLuation),



MARVEL Overview and Mission

Microreactor Program Review
March 2026

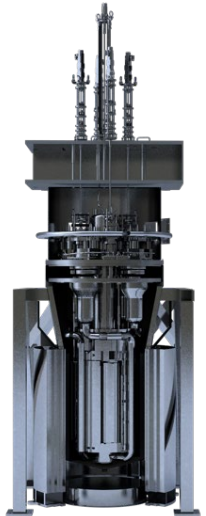
A. Abou-Jaoude

MARVEL Can Enable a New Class of Nuclear Reactors

(Microreactor Applications Research, Validation & EvaLuation)

Primary Goals:

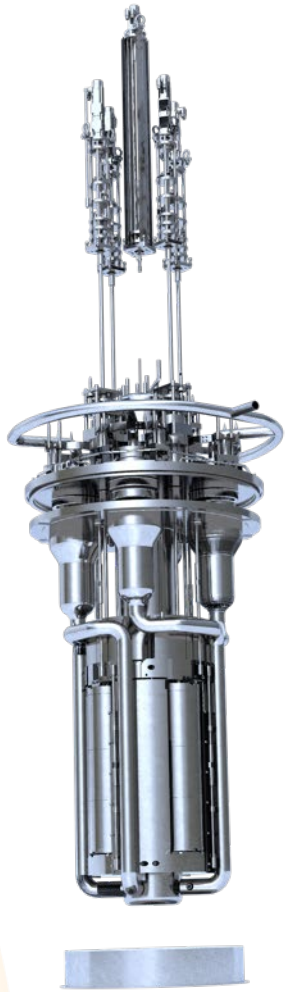
- MARVEL as a ***Pathfinder***
  - Exercising DOE processes, kickstarting supply chain, sharing lesson learned, providing template for private sector
- MARVEL as a ***Testbed***
  - Platform to demonstrates novel nuclear applications (microgrids, heat, etc.) and novel technology (autonomous controls, novel sensors, etc.)
- MARVEL as an R&D ***Use case***
  - Open design that can be used for AI training, code V&V



Specs:

85 kW-thermal, <20 kW-electric
> 300 C salt for heat applications
~15 feet tall, <10 tons
NaK primary coolant, natural circulation
TRIGA fuel
Radial control drums
Graphite, Be and BeO reflector
2 operators
Self-regulating

How MARVEL is Helping Unleash Advanced Nuclear Energy



Environmental Assessment

First EA for an advanced reactor in history
Pathfinder for streamlined NEPA approvals and training staff on submission process
Process being leveraged by DOME, MCRE, VALKRE

01

Design Analysis

Trained INL staff to perform key safety analyses (e.g., structural analysis, transient simulations)
Benefiting Pele, MCRE, VALKRE and Westinghouse + Radiant demonstrations

02

Safety Review

First new reactor PDSA submission to DOE in history
Novel approach using risk-informed methodology for reactor safety
Submittal paved the path for other DOE-authorized reactors (e.g., Pele, MCRE, eVinci)

03

Guard Vessel Fabrication

First time in history that a nuclear vessel manufactured by a non-'N' stamp supplier
Broadening supply chain by enabling non-nuclear vendors to compete
Helped identify errors in ASME code that will accelerate future advance reactor manufacturing

04

Reactivity Control System

Established a complete design/fabrication package for microreactor control systems
Being directly leveraged by VALKRE - under evaluation by commercial vendors (e.g., Antares)

05

2025 Executive Orders

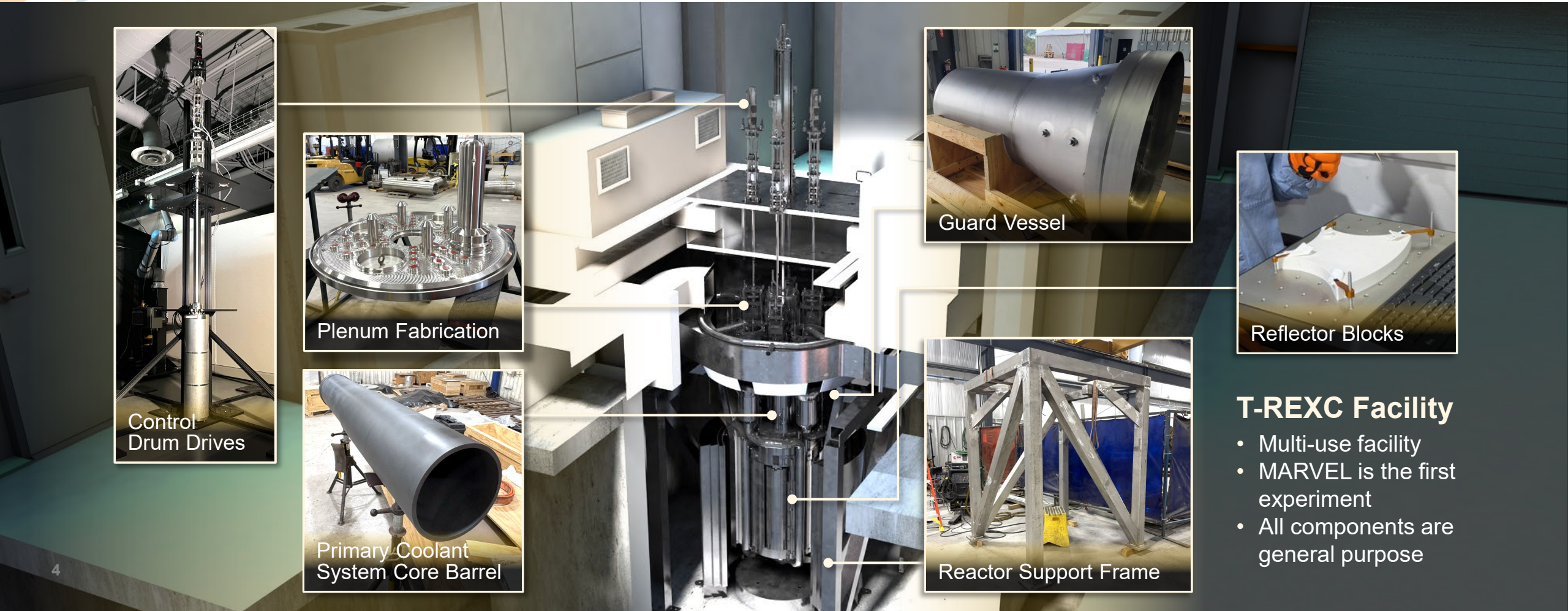
Using regulatory pathways laid out by MARVEL and Pele to support responses to Executive Orders for expediting the review, approval, and deployment of advanced reactor

06

MRP Microreactor Program

Moving from Paper to Real Reactor

Hardware actively being manufactured and procured:

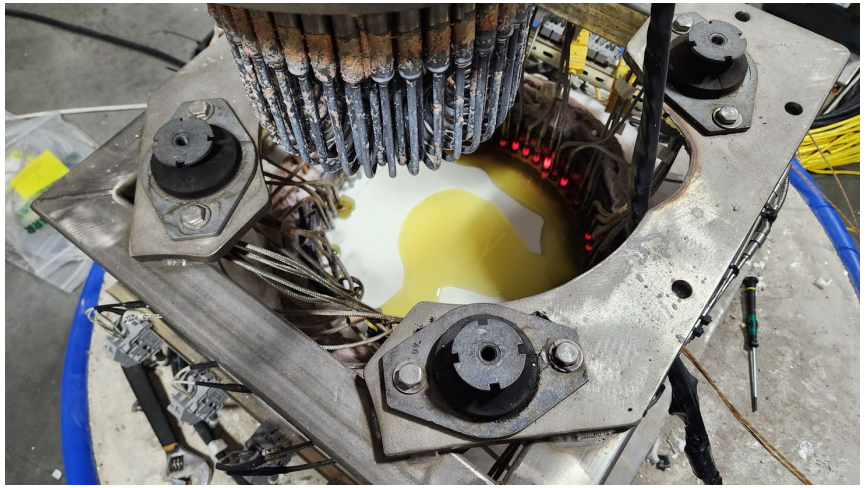


T-REXC Facility

- Multi-use facility
- MARVEL is the first experiment
- All components are general purpose

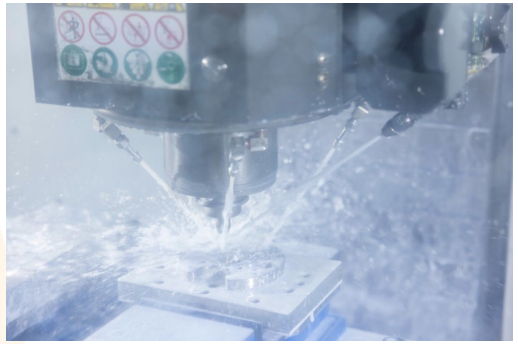
Hardware Getting Built and Tested

Reactor upper plenum and core barrel getting welded



Testing Stirling Engines in Hitec Salt

Finished downcomer and shield support structure

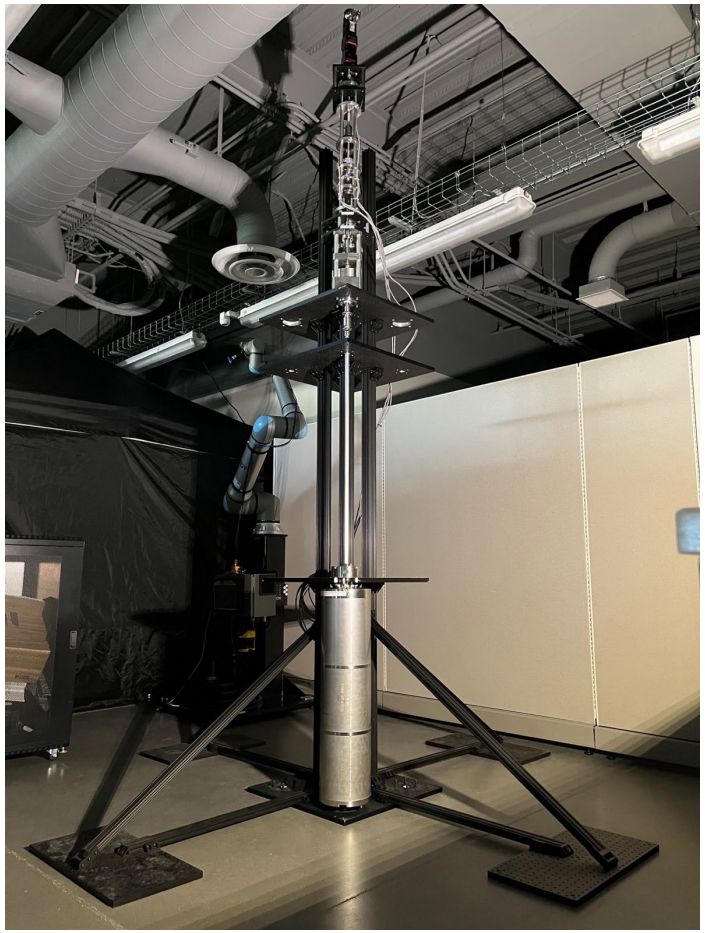


Parts for Reactivity control system

MRP Microreactor Program

Hardware Showcase at INL: Reactivity Control System

Final fabricated parts for the MARVEL RCS



Start of RCS assembly in qualification stand at ESRL

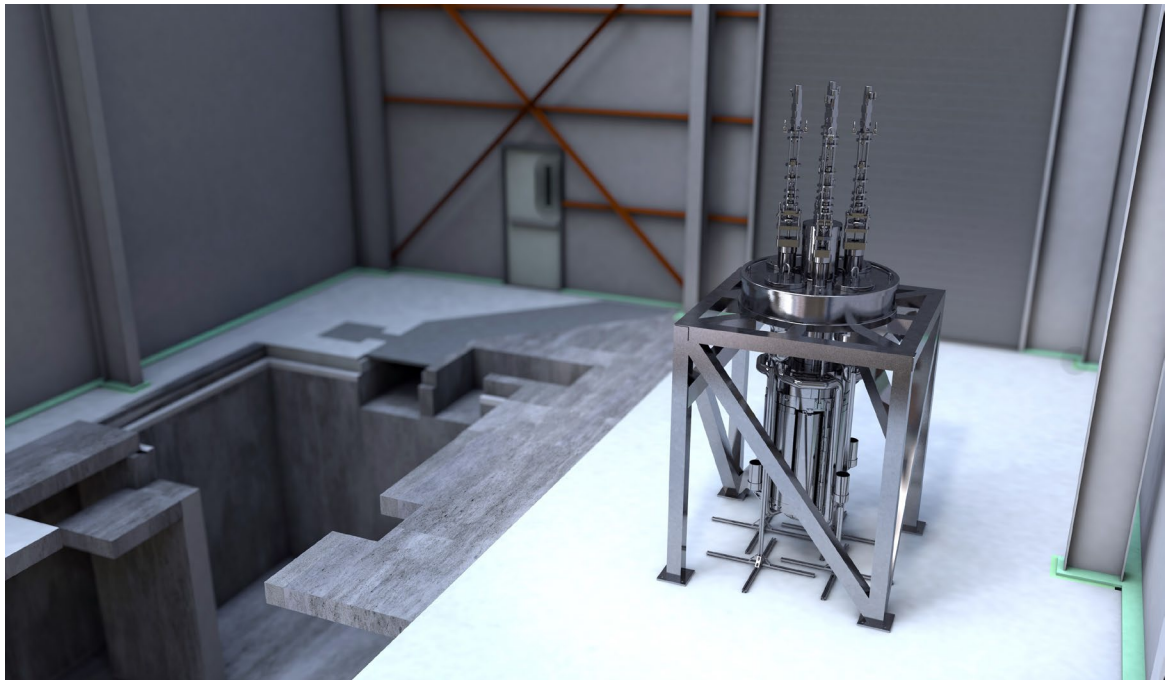
First Microreactor-Dedicated Control System in a Generation!

- Parts fabrication completed 9/11/2025
  - Total of ~600 finished part
  - Many first articles and test part
  - ~12000** man hours by the team @ INL
  - Walsh providing support for drawing revisions.
- Assembly on test stand completed on Feb 12

MRP Microreactor Program

Moving Towards Dry Criticality for MARVEL

- MARVEL dry criticality experiment targeting end of 2026.
- Dry criticality PDSA submitted to DOE-ID on 09/25/2025
- Drawings, ECs, and ECAR all finalized
- Assembly plan sequence in progress
- Purpose:
  - De-risking of key characteristics of MARVEL design
  - Increased confidence in reactor performance by validating reactor physics models and fuel reactivity worth
  - A neutronic benchmark for industry designers of microreactors.



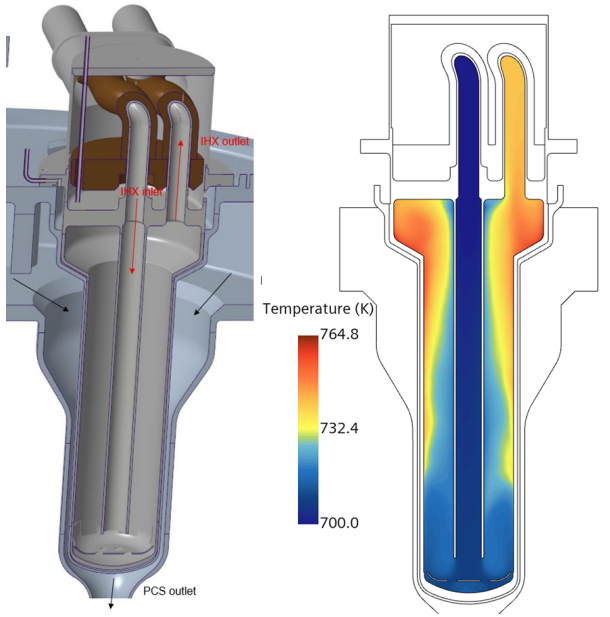
Balance of Plant Design & Testing

Heat Extraction System:

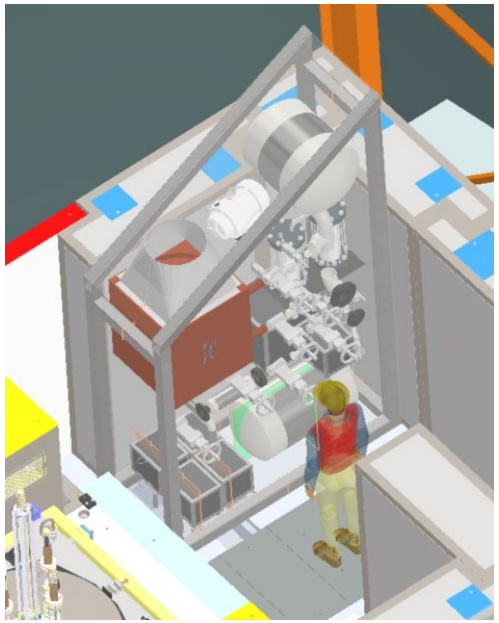
- Component skid prelim design completed 11/17/2025. Final design for ski planned for March-April timeframe.
- IHX design completed, sent to drafting
- Mockup for testing IHX thermal paste being prepared.
- Piping and IHX PV design ECARs in progress.
- Thermal analyses for IHX and Reactor in progress, iterating with RELAP and CFD to final anticipated conditions (including transients)
- Drafting nearly complete for T-REXC modifications.

Power Generation System (PGS):

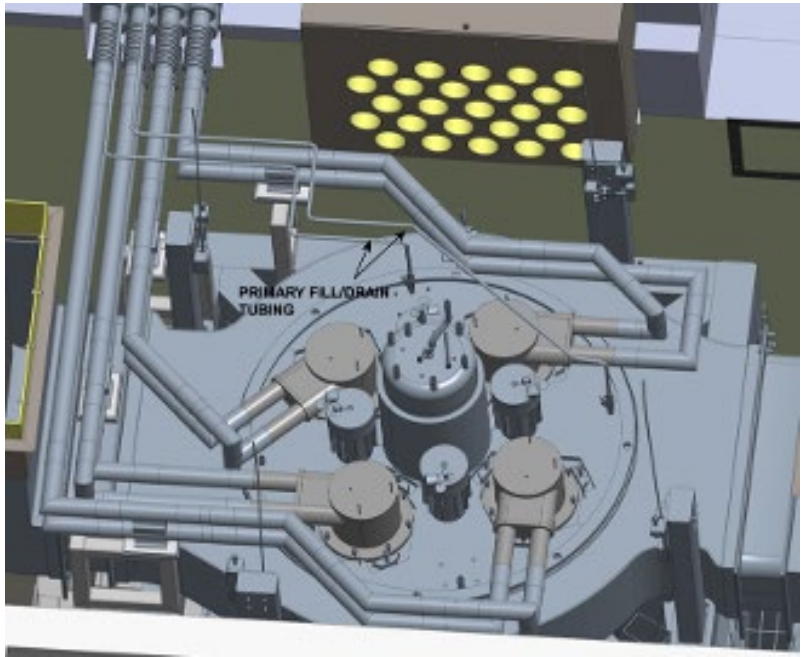
- Stirling Engine testing complete
- Evaluating siting location
  - Inside/Outside T-REXC
  - Single Engine/Multi Engine Deployments



IHX Finished Design



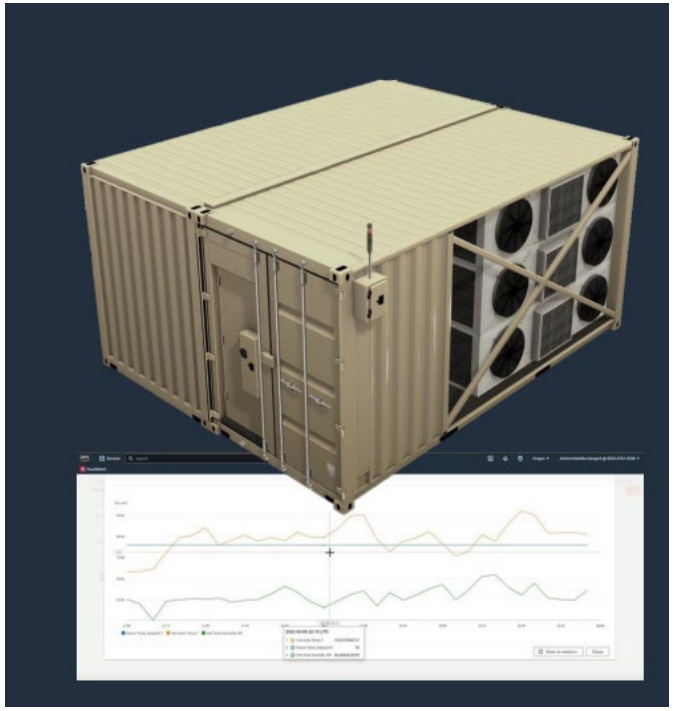
HES Skid



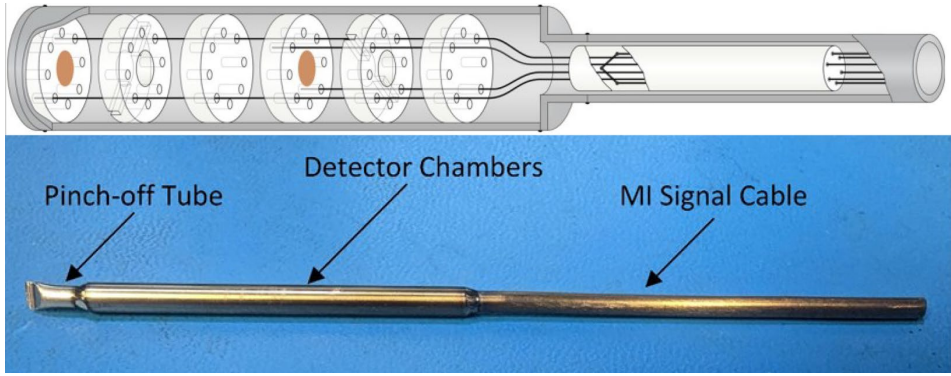
HES interface Design

MARVEL as a Testbed:
First 5 End Users Selected

- The MARVEL team announced the first set of end users to leverage MARVEL as a testbed:
  - **Amazon Web Services (AWS) Inc.** proposes coupling the MARVEL reactor with a modular data center, a new service that makes it simple and cost-effective for defense and government agencies to build data centers anywhere in the world independently of traditional power infrastructure.
  - **DCX USA and Arizona State University** propose to use MARVEL to demonstrate the feasibility of a microreactor to power a data center for AI to yield valuable data on how to provide a stable, continuous power supply capable of handling the demands of AI.
  - **General Electric Vernova** proposes to use MARVEL to demonstrate remote and autonomous reactor operations and establish standards for broader application of the technology with commercial reactors.
  - **Radiation Detection Technologies (RDT) Inc.** proposes to use MARVEL to test advanced high-performance sensor technologies that could help monitor the performance of advanced reactors.
  - **Natura, NOV and ConocoPhillips** propose to leverage MARVEL for a pilot-scale desalination project using nuclear-generated process heat to demonstrate how nuclear energy can help address water challenges in oil and gas operations.
- The next step is to develop a detailed implementation plan for their proposal before then proceeding to hardware execution.



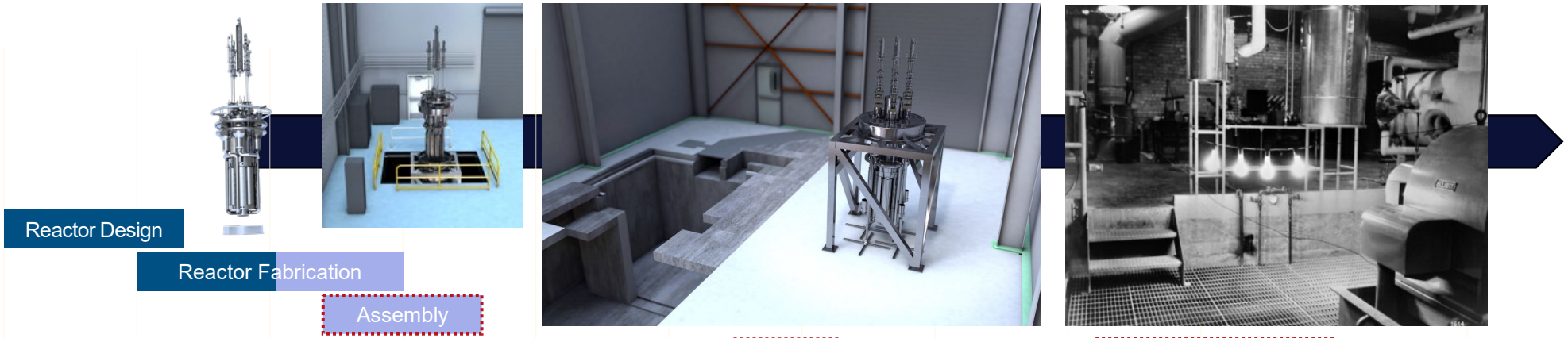
AWS Data Center Module



RDT Micropocket Fission Chamber

MRP Microreactor Program

MARVEL Timeline: *Decoupled*



MRP Microreactor Program

MARVEL as an R&D Platform

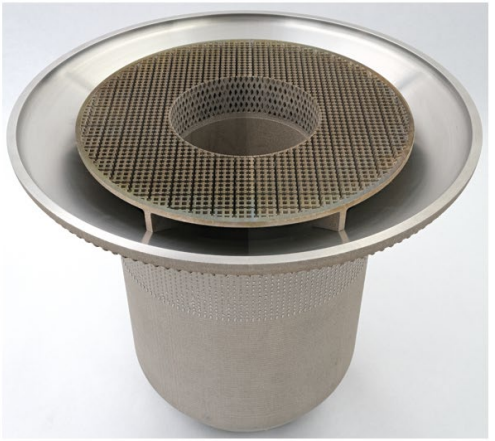
Example Opportunities

- **AI**: train algorithms on 200+ generated ECAR and > 1000 engineering drawings
- **Licensing**: generate template for transitioning from DOE to NRC process
- **Cybersecurity**: demonstrate cybersafe remote operations of nuclear reactors
- **Code V&V**: validate new codes against a real reactor

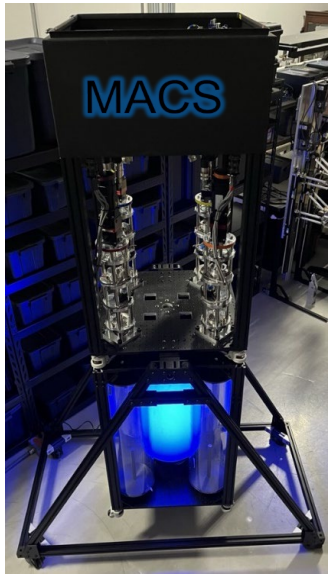
Programs Engaged:

- **DOE-NE**: ASI, ARSS, PROMETHEUS, NEAMS, SA&I, AMMT
- **DOE-OE**: Microgrid program
- **NNSA**: ETI, NA22 DNN

AMMT Program: 3D-printed liner for MARVEL



ASI Program: COMMAND control system deployed on MRP's MACS platform in MARVEL configuration



SA&I Program: Economics of microreactor mass production

Agenda for Today

Topics Covered:

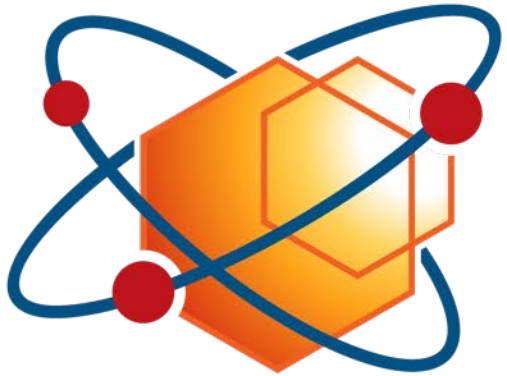
- Overall project status
- Fabrications and assembly of components
- Updated balance of plant design
- Controls interface
- Dry criticality assembly
- End users

8:00	**Welcome.**	**John Jackson**
8:10	**MARVEL Mission and Overview**	**Abdalla Abou-Jaoude**
8:30	**MARVEL Fabrication**	**Reese Gannon**
8:50	**Reactivity Control System Assembly and Qualification**	**Tony Crawford**
9:10	**Heat Extraction System Design**	**Carl Bailey**
9:30	**Instrumentation and Controls**	**Andrew Heim**
10:10	**Break**	**All**
10:30	**Electricity Generation with Stirling Engines**	**Ben Baker**
10:50	**Process Heat Delivery System**	**Rami Saeed**
11:10	**TREAT Reactor Experiment Cell (TREX-C)**	**Vincent Schwartz**
11:30	**MARVEL Dry Criticality Layout and Analysis**	**Travis Lange**
11:50	**MARVEL PDSA and SAR Preparation**	**Doug Gerstner**
12:10	**Working lunch (tentative Virtual tour of NRIC, DOME and LOTUS)**	**All**
1:10	**Assembly Sequence for Dry Criticality**	**Chad Ryan**
1:30	**Readiness and Transition to Operations**	**Travis King**
	MARVEL Demonstrations	
1:50	**Amazon Web Services – Powering a Data Center Module**	**Paolo Venneri**
2:10	**DCX – Powering an AI Computing Pod**	**George Slessman**
2:30	**Natura – Nuclear Heat for Oil & Gas Desalination**	**Nicholas Moriss**
2:50	**Radiation Detection Technologies – Testing Neutron Sensors**	**Taylor Ochs**
3:10	**General Electric Vernova – Remote Operations Testing**	**Faith Beck**
3:30	**Wrap up and adjourn**	**Abdalla Abou-Jaoude/John Jackson**

Questions?

Abdalla.aboujaoude@inl.gov

MRP Microreactor Program



MRP Microreactor Program