INL/CON-24-76596-Revision-0

Reactor 90 percent Final Design & FY2024 Progress (presentation)

March 2024

MW (Mike) Patterson

Changing the World's Energy Future

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March 2024

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Prepared for the
U.S. Department of Energy
Under DOE Idaho Operations Office
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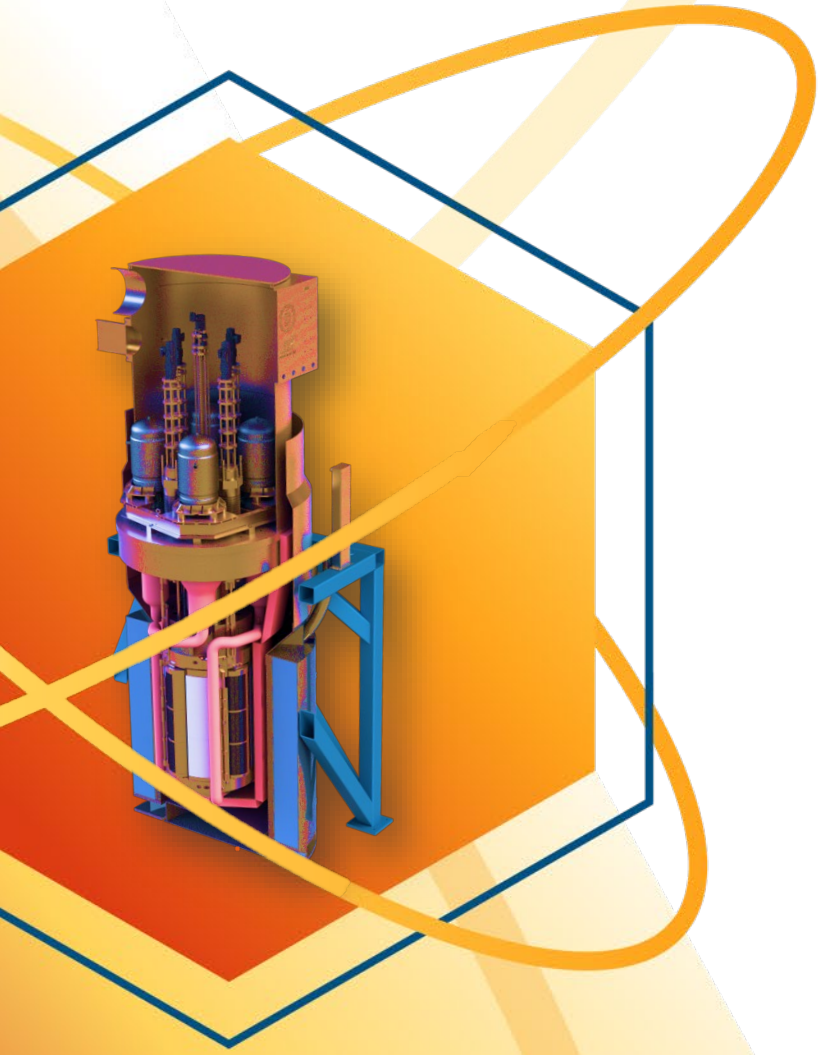
(Microreactor Applications Research, Validation & EvaLuation),



Reactor 90% Final Design & FY2024 Progress

March 7, 2024

M.W. Patterson

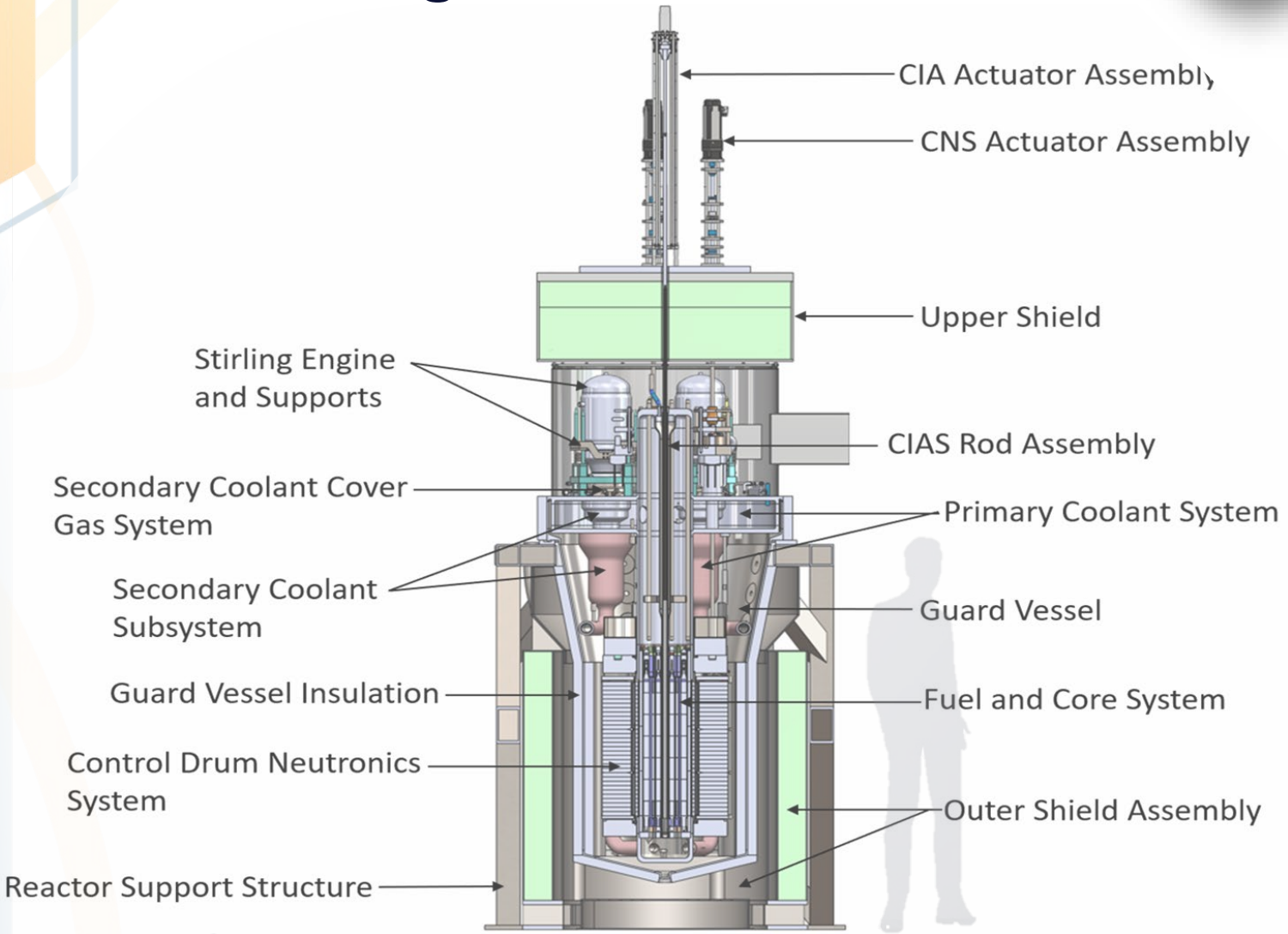
MARVEL Sr. Project/Program Manager

Idaho National Laboratory, USA

MARVEL Summary at 90% Final Design

Office of NUCLEAR ENERGY

DOE Idaho Operations Office



Project Goal: Build a Test Microreactor ASAP

Key Design Features	
Reactor Type	Liquid Metal Thermal Reactor
Thermal Power	85 kW-th
Electrical Power	~20 kW-e
Coolant Drive	Natural Circulation
System Life	2 years
Fuel	TRIGA Fuel
Weight	7.5 metric ton
height	<15 feet

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Scope of 90% Final Design

- **Guidance:** MARVEL project's 90% Final Design, as required by U.S. Department of Energy (DOE) Standard-1189, "Integration of Safety into the Design Process
- **Goal**: 90% Final Design documentation focuses on design completion at a level capable of supporting procurement, construction, testing, and operation
- **Scope:** 90% final design includes the complete reactor, including the design, operability and maintainability of the five major reactor systems + Auxiliary systems (~250 documents):
  - Fuel and Core System.
  - Reactivity Control System.
  - MARVEL Reactor Structure.
  - Instrumentation & Control System.
  - Power Generation System.
  - The scope of this design also includes the primary and secondary coolant loading system (vendor system).

- Summarized in MARVEL 90% Final Design Report - INL/RPT-23-74280

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90% Final Design Deliverables

~250 Total Documents

- Safety Design Strategy (1)
- Hazard Analysis (1)
- Requirements (7)
- Code of Record (1)
- Specifications (17)
- Commercial Grade Dedication Plans (22)
- Engineering Calculation and Analysis Reports (33)
- Risk & Opportunity Matrix (1)
- Current Cost Estimate (1)
- Current Construction Schedule (1)
- Project Execution Plan (1)
- Security & Vulnerability Assessment (1)
- Software Quality Assurance Plan (1)
- Test Plans (3)
- Engineering Change Forms (5)
- Final Design Review Comments and Resolutions (1)
- Engineering Verification Matrix (1)
- Drawings (152)

Does not include:

- High-grade heat extraction system (HGHES)
- Interfacing systems in TREAT facility (provided by TREAT Micro-Reactor Experiment Cell (T-REXC) project)

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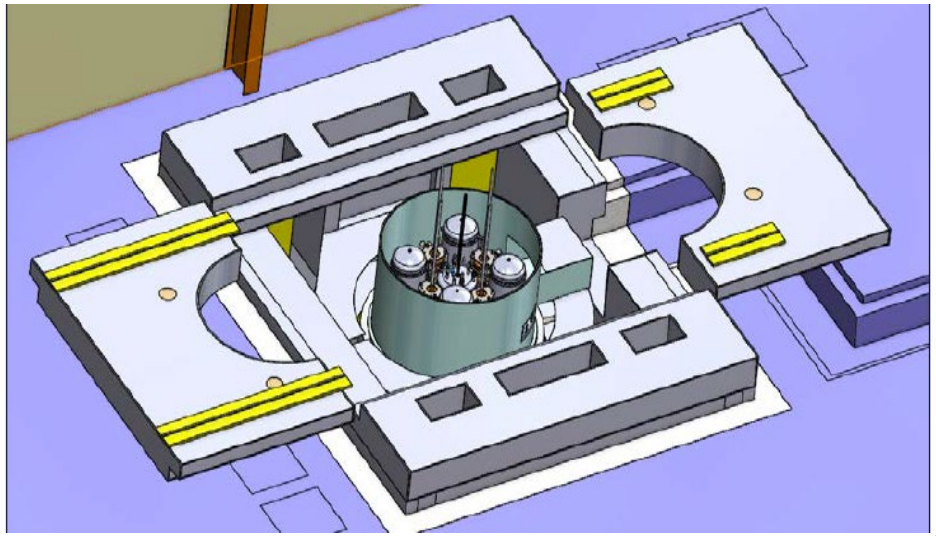
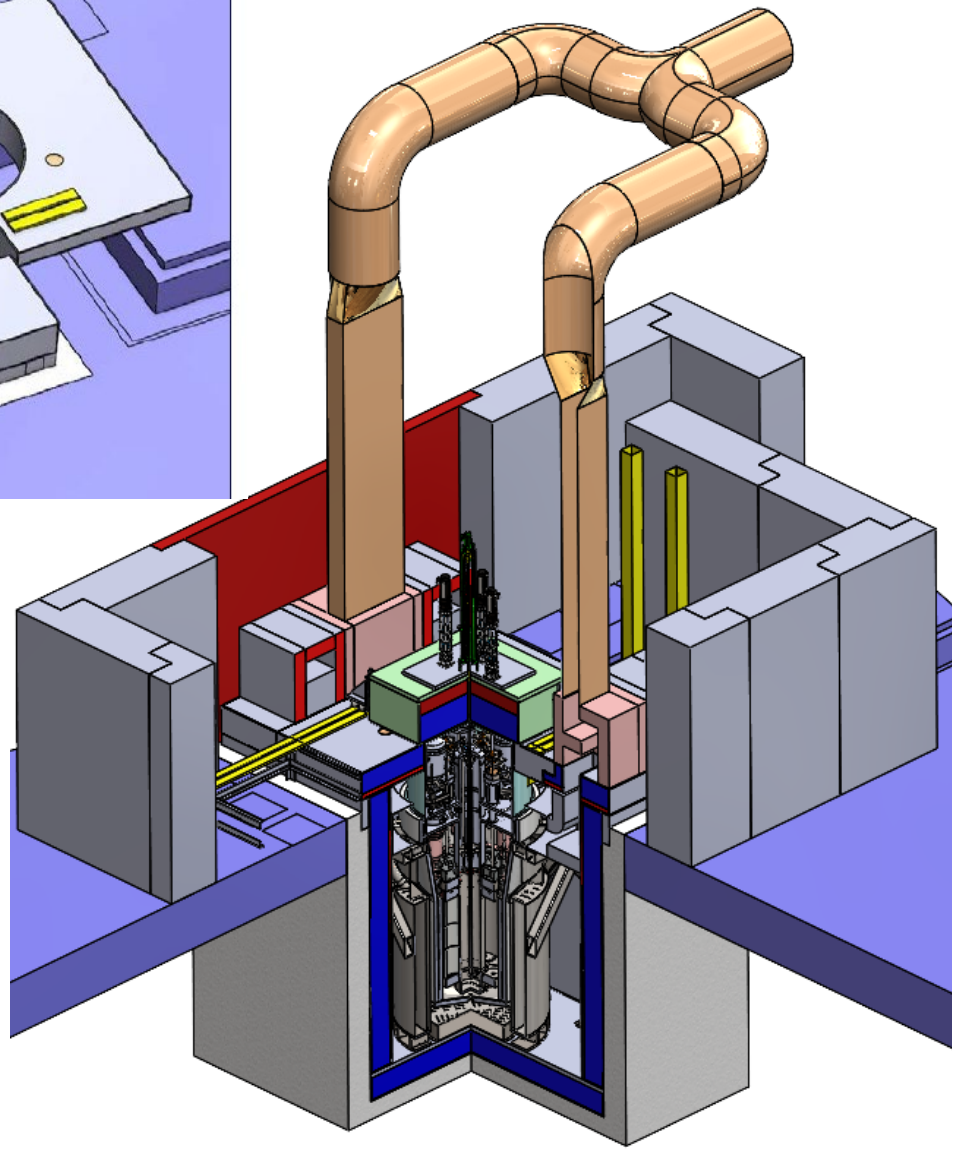
TREX-C Project

Institutionally-funded project to prepare TREAT to host multiple demonstrations (MARVEL will be the first)





T-REXC Scope: (SPC-70454 T-REXC Interface Specification)

- Pit shield structures (to prevent neutron activation of the concrete)
- Pit lid, with integrated top shielding
- I&C infrastructure facility data and demonstrator data displays)
- Electrical power infrastructure – interface panel, standby generator
- Signal/data transfer between MFC-720 & MFC-724 Control Room
- Ventilation, including HEPA filter and exhaust monitoring
- Fire detection, including Na and NaK fires
- Fire mitigation systems, per TREAT fire hazards analysis
- Neutron source for startup
- Radial static neutron reflectors
- Beryllium oxide (BeO) control drums for neutron population control
- A system to preclude water intrusion into the pit
- Radiation monitoring.

T-REXC safety-related SSC design will be incorporated in MARVEL PDSA

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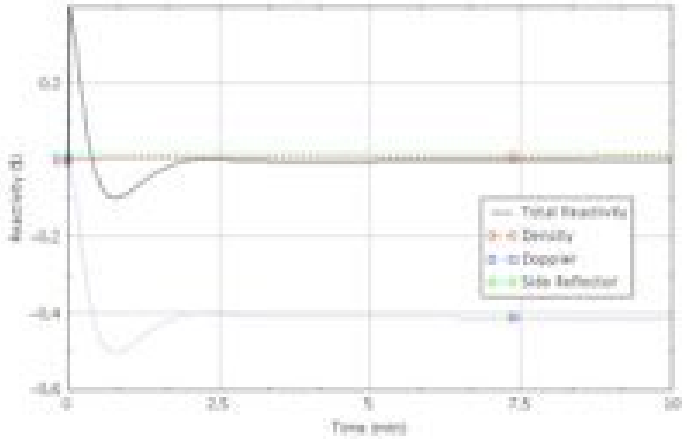
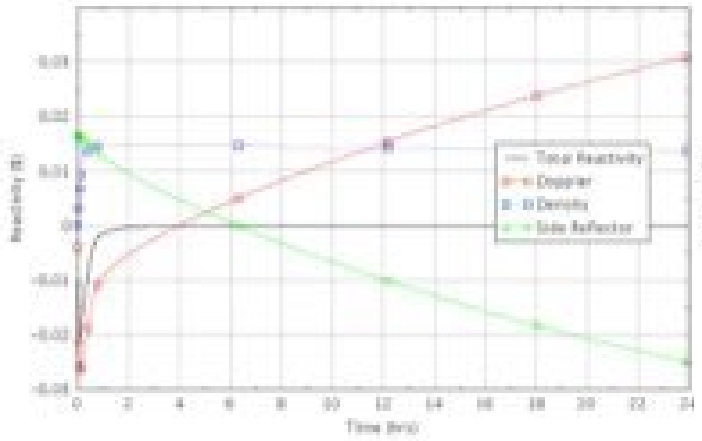
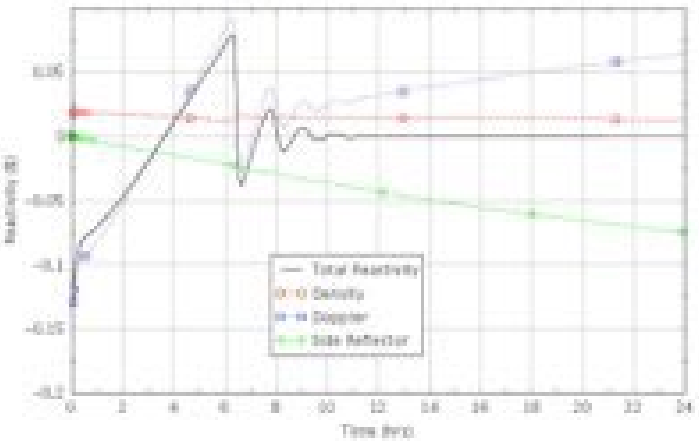
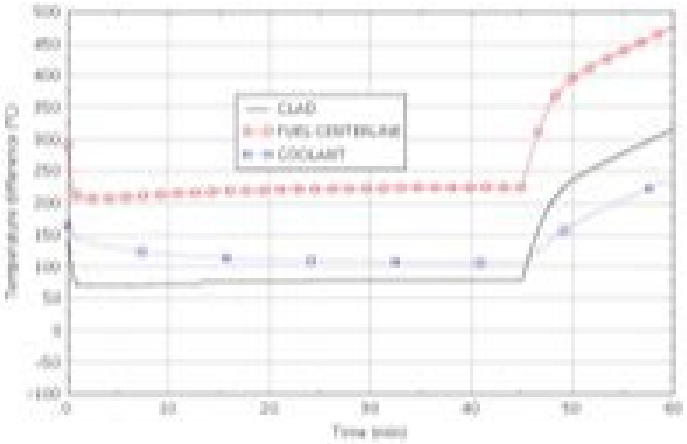
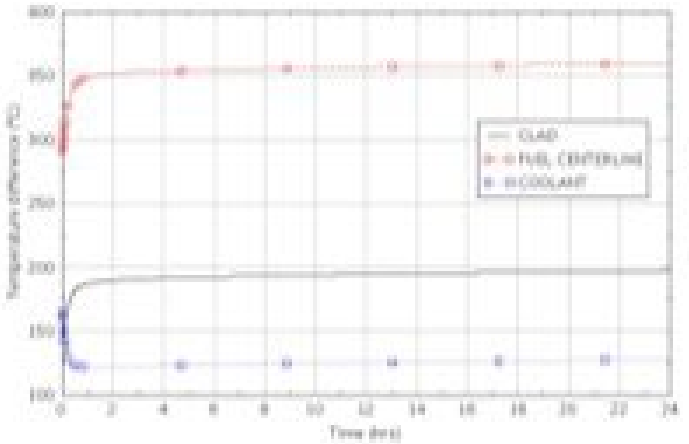
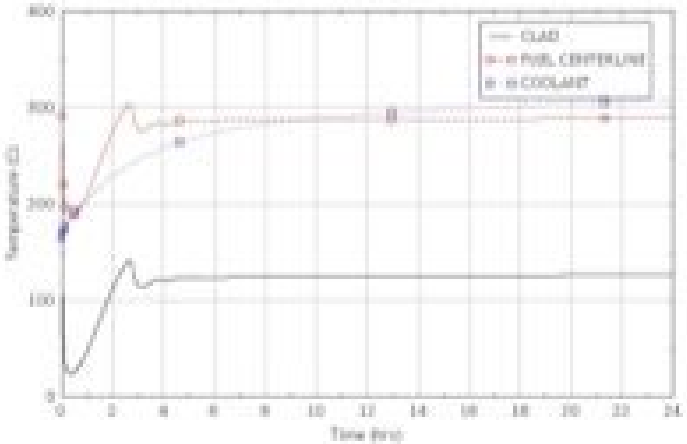
MARVEL Safety Modeling

Postulated Severe Accident Models (no scram) –

	Unprotected Transient Overpower	Unprotected Loss of Heat Sink	Unprotected Loss of Flow
Reactivity			
Temperature Safety Margins			

No safety concerns identified

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90% Final Design Summary

Completion of 90% Final Design per DOE-STD-1189 indicates project design can support testing, procurement, construction, & operations (Office of Nuclear Safety (AU-30), 2016)

- Incorporate in PDSA for DOE review/authorization
- Triggers cost estimate update(s)
- Enables procurement preps for construction

Open Design Item	Discussion	Systems	EC	Needed for:
Detailed ASME Section III Analysis**	Completion of detailed ASME Section III analyses and simulation is required, as well as update of MARVEL's ASME specification	PCS	1755	PDSA Submittal
Qualification Testing	**Discussion**	**Systems**	**EC**	**Needed for**
RCS Qualification Testing	Qualification testing of the Reactivity Control System	RCS	1756	Assembly in Cell
Stirling Engine Prototype Test	Prototype testing of the Stirling Engine and IHX Liner system in GaInSn. Two parts: 1) corrosion testing (in PICS) 2) Stirling engine testing (working alternatives analysis)	PGS, RCS	1755, 1757	1) PDSA submittal 2) Assembly in Cell
PCAT Testing	Completion of PCAT testing is required to validate thermo-hydraulic analysis suitability	PCS	1755	PDSA Submittal

Open Design Item and Qualification Testing after 90% Final Design

** *ASME Section III Analysis: identified in CCN 254615 as an open design item and now controlled per ASME NQA-1-2008 Part 1, Requirement 3 "Design Control" Para 500 (b) and DOE STD-1189*

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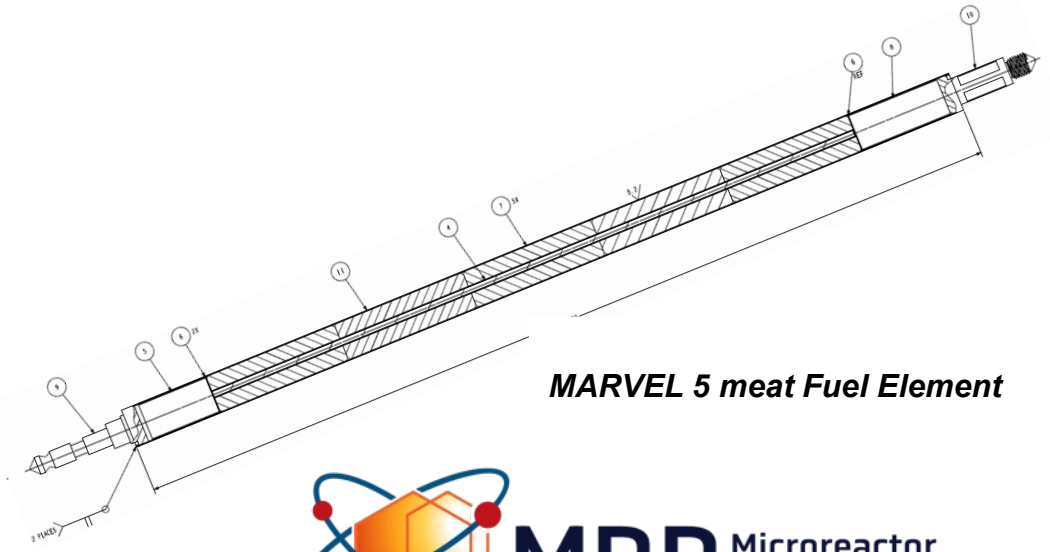
MARVEL Progress in FY 2024

- Long Lead Procurement
  - Material procurement & fabrication of 316H SS structures, systems, and components
    - Switching fabrication subcontractors
    - Guard Vessel fabrication underway
  - MARVEL Fuel
    - HALEU feedstock procured/shipped to France (June 2023)
    - Fabrication contract placed November 2023
    - Fuel element fabrication
      - Prepping molds, batching plans etc.
      - Casting start – ~April 2024 (pending UFS Release 2 fusion/refusion completion
      - Finish – Fall 2024
    - Shipping container recertification – under review by French regulator

Guard Vessel Tapered Wall



MARVEL 5 meat Fuel Element

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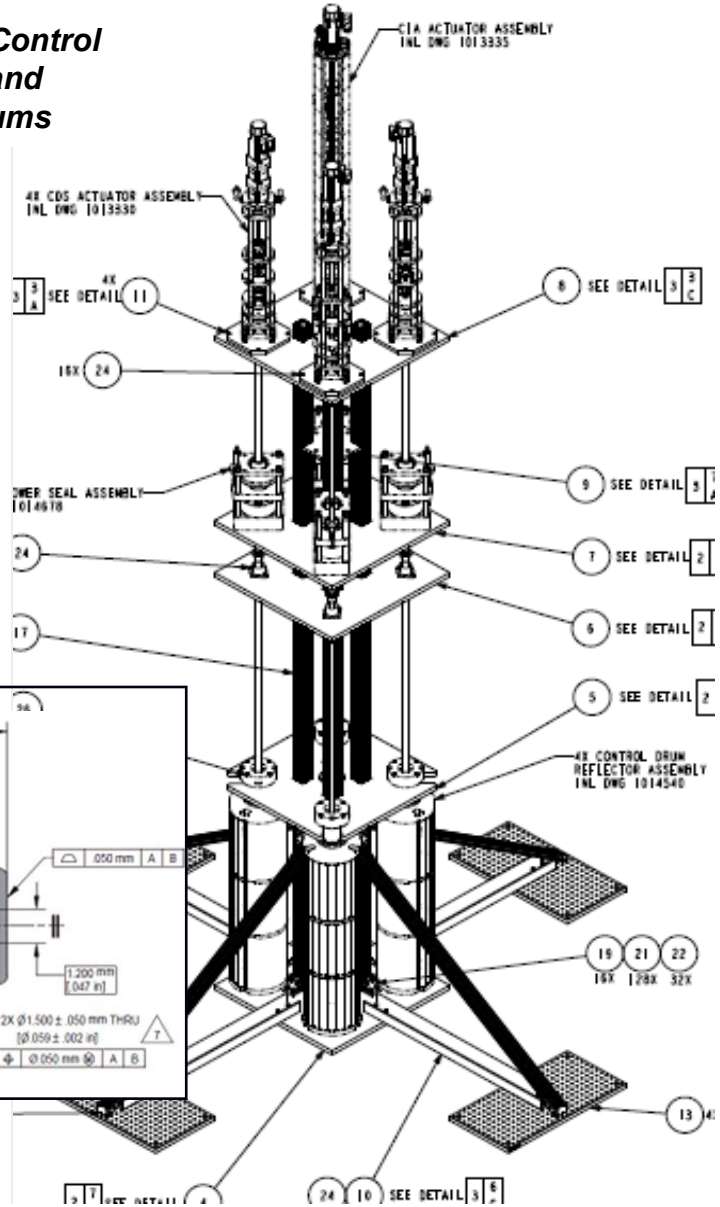
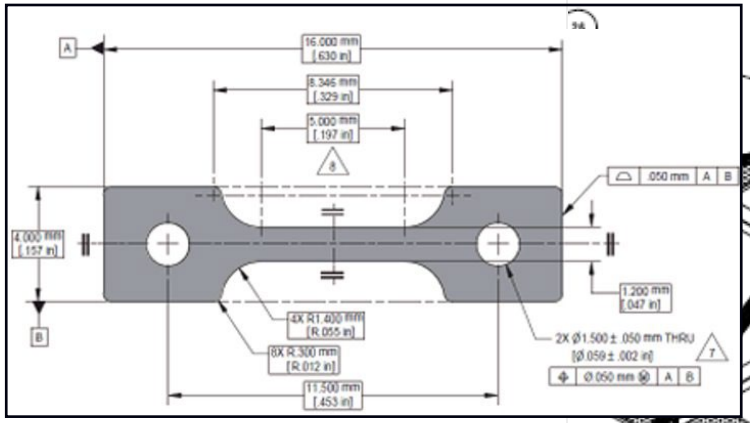
MARVEL Progress in FY 2024 - continued

- Long Lead Procurement - continued
  - Beryllium metal reflectors and dowels
    - RFP prepared
    - Procurement on hold – funding
    - BeO reflectors ordered by T-REXC
  - Procurement and Fabrication of the Reactivity Control System
    - Parts ordered
    - Early testing underway
  - Stirling Engines and Controls
    - Focus on corrosion testing
    - First test complete early March
- Independent Project Review - Complete

Reactivity Control Actuators and Control Drums





SSJ-3 Mini-Tensile Testing Dog Bone Coupon for Corrosion Testing in eGaInSn

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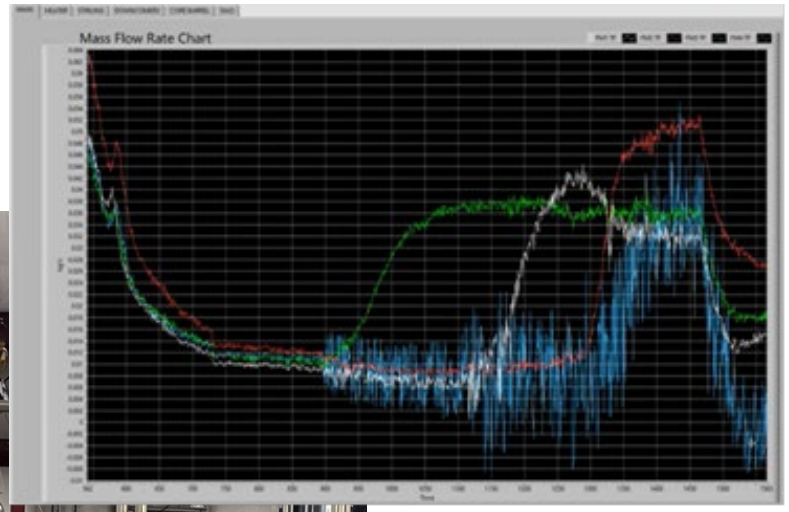
Thermal Hydraulic Prototype – Primary Coolant Apparatus Test (PCAT)

Thermal Hydraulic Prototype

- Started up – 9/19/2023
  - Achieved natural circulation
  - Measurable power output
- Experiment paused after initial start-up to verify glycol mix to cool Stirling engines

FY24 progress/next steps

- Fabrication, calibrations, programming, & NaK fill - complete
- System certification in March 2024
- Qualification testing in April 2024



Trace shows mass flow through each Stirling engine mounted on PCAT as heaters are energized and then de-energized.

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Level 2 Milestones for FY2024

Level	WBS	WP Title	Milestone ID Number	Milestone Title	Estimated Finish
M2	2.04.08.05.03	MARVEL Engineering - INL	M2AT-24IN0805032	Complete development of Long Lead Procurement (LLP) #3 request and submit for approval to DOE-ID	11/30/2023 Complete
M2	2.04.08.05.06	Fuel Production & Procurement - INL	M2AT-24IN0805062	Award MARVEL Fuel Fabrication Contract	11/30/2023 Complete
M2	2.04.08.05.06	Fuel Production & Procurement - INL	M2AT-24IN0805063	Start of production for MARVEL fuel elements at TRIGA International (TI)	2/29/2024 Start dependent on UFS fusion/refusion
M2	2.04.08.05.07	TREAT SAR Addendum - INL	M2AT-24IN0805076	Complete Primary Coolant Apparatus Test (PCAT) Thermohydraulic Testing	4/30/2024 On track
M2	2.04.08.05.08	MARVEL Readiness - INL	M2AT-24IN0805086	Submit MARVEL Plan of Action (POA) to DOE-ID	5/20/2024 Defer - funding
M2	2.04.08.05.02	MARVEL Leadership - INL	M2AT-24IN0805023	Complete MARVEL program plan for Phase 2- Operations	5/30/2024 On track
M2	2.04.08.05.07	TREAT SAR Addendum - INL	M2AT-24IN0805072	Complete and submit MARVEL Preliminary Documented Safety Analysis (PDSA) to DOE-ID for review	7/31/2024 On track
M2	2.04.08.05.04	MARVEL Fabrication - INL	M2AT-24IN0805047	Complete fabrication of the MARVEL reactivity control system	9/5/2024 On track

- Fuel Receipt – FY 2025
- Fuel Loading - FY 2026
- Initial criticality - FY2026
- Unrestricted Ops – FY 2027

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Thank-you

Questions?