Reactor 90% Final Design & FY2024 Progress

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M.W. Patterson
MARVEL Sr. Project/Program Manager
Idaho National Laboratory, USA
MARVEL Summary at 90%
Final Design

Project Goal: Build a Test Microreactor ASAP

<table>
<thead>
<tr>
<th>Key Design Features</th>
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<tbody>
<tr>
<td>Reactor Type</td>
<td>Liquid Metal Thermal Reactor</td>
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<tr>
<td>Thermal Power</td>
<td>85 kW-th</td>
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<tr>
<td>Electrical Power</td>
<td>~20 kW-e</td>
</tr>
<tr>
<td>Coolant Drive</td>
<td>Natural Circulation</td>
</tr>
<tr>
<td>System Life</td>
<td>2 years</td>
</tr>
<tr>
<td>Fuel</td>
<td>TRIGA Fuel</td>
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<tr>
<td>Weight</td>
<td>7.5 metric ton</td>
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<tr>
<td>height</td>
<td>&lt;15 feet</td>
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</table>
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, and
  - 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
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)
**TREAT- Reactor Experiment Cell (TREX-C)**

*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**
MARVEL Safety Modeling
Postulated Severe Accident Models (no scram) –

- Reactivity
- Temperature
- Safety
- Margins

No safety concerns identified
**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.

- 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)
  - Incorporation in PDSA for DOE review & authorization
  - Triggers cost estimate update(s)
  - Enables start of procurement for construction

### Open Design Item and Qualification Testing after 90% Final Design

<table>
<thead>
<tr>
<th>Open Design Item</th>
<th>Discussion</th>
<th>Systems</th>
<th>EC</th>
<th>Needed for:</th>
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</thead>
<tbody>
<tr>
<td>Detailed ASME Section III Analysis**</td>
<td>Completion of detailed ASME Section III analyses and simulation is required, as well as update of MARVEL’s ASME specification</td>
<td>PCS</td>
<td>1755</td>
<td>PDSA Submittal</td>
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<tr>
<td>Qualification Testing</td>
<td></td>
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<tr>
<td>RCS Qualification Testing</td>
<td>Qualification testing of the Reactivity Control System</td>
<td>RCS</td>
<td>1756</td>
<td>Assembly in Cell</td>
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<tr>
<td>Stirling Engine Prototype Test</td>
<td>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)</td>
<td>PGS, RCS</td>
<td>1755, 1757</td>
<td>1) PDSA submittal 2) Assembly in Cell</td>
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<tr>
<td>PCAT Testing</td>
<td>Completion of PCAT testing is required to validate thermo-hydraulic analysis suitability</td>
<td>PCS</td>
<td>1755</td>
<td>PDSA Submittal</td>
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</table>

**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.
MARVEL Progress in FY 2024

• Long Lead Procurement
  o Material procurement & fabrication of 316H SS structures, systems, and components
    - Switching fabrication subcontractors
    - Guard Vessel fabrication underway
  o 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
MARVEL Progress in FY 2024 - continued

- Long Lead Procurement - continued
  - Beryllium metal reflectors and dowels - RFP prepared, procurement on hold for funding (BeO reflectors ordered by T-REXC Project)
  - 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

- Primary Coolant Apparatus Test (PCAT)
  - Fabrication, calibrations, programming complete
  - System certification in March 2024
  - Qualification testing in April 2024

- Independent Project Review - Complete
## Level 2 Milestones for FY2024

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<tr>
<th>Level</th>
<th>WBS</th>
<th>WP Title</th>
<th>Milestone ID Number</th>
<th>Milestone Title</th>
<th>Estimated Finish</th>
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<td>M2</td>
<td>2.04.08.05.03</td>
<td>MARVEL Engineering - INL</td>
<td>M2AT-24IN0805032</td>
<td>Complete development of Long Lead Procurement (LLP) #3 request and submit for approval to DOE-ID</td>
<td>11/30/2023</td>
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<td>M2</td>
<td>2.04.08.05.06</td>
<td>Fuel Production &amp; Procurement - INL</td>
<td>M2AT-24IN0805062</td>
<td>Award MARVEL Fuel Fabrication Contract</td>
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<td>Fuel Production &amp; Procurement - INL</td>
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<td>Start of production for MARVEL fuel elements at TRIGA International (TI)</td>
<td>2/29/2024</td>
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<td>M2</td>
<td>2.04.08.05.07</td>
<td>TREAT SAR Addendum - INL</td>
<td>M2AT-24IN0805076</td>
<td>Complete Primary Coolant Apparatus Test (PCAT) Thermohydraulic Testing</td>
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<td>MARVEL Readiness - INL</td>
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<td>Submit MARVEL Plan of Action (POA) to DOE-ID</td>
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<td>M2</td>
<td>2.04.08.05.02</td>
<td>MARVEL Leadership - INL</td>
<td>M2AT-24IN0805023</td>
<td>Complete MARVEL program plan for Phase 2- Operations</td>
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<td>2.04.08.05.07</td>
<td>TREAT SAR Addendum - INL</td>
<td>M2AT-24IN0805072</td>
<td>Complete and submit MARVEL Preliminary Documented Safety Analysis (PDSA) to DOE-ID for review</td>
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<td>MARVEL Fabrication - INL</td>
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<td>Complete fabrication of the MARVEL reactivity control system</td>
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Thank-you

Questions?
Quality Assurance

- **INL QA Program**: PDD-13000, “Quality Assurance Program Description”
  - 10 CFR 830, Subpart A ‘Quality Assurance Requirements’
  - DOE 414.1D, “Quality Assurance.”

- **Code of Construction**: ASME NQA-1, “Quality Assurance Requirements for Nuclear Facility Applications”
  - appropriate guidance on how MARVEL is designed, procured, manufactured, and tested

- **Design**: Design activities are performed by qualified personnel and verified via an independent peer review and/or software validation.
  - INL’s Quality Assurance Program (PDD-13000)
  - Conduct of Engineering (PDD-10000)
  - Applicable Codes and Standards are recorded in MARVEL Code of Record, COR-0011, Rev 0
Quality Assurance (cont’d)

- **Supplier Oversight:** Full-time INL Quality Engineer assigned, who shall be resident at the manufacturer’s facility during the fabrication and testing
  - work independent of cost, schedule, or the direction of work and shall serve in a supplier oversight capacity
  - verify that MARVEL is manufactured in accordance with the design drawings, specifications, and the code references therein
  - signatory to any contractual change requests that may be flowed down to the supplier.
  - QE role and responsibilities have been written into the contract specification
    - verification that materials of construction are in accordance with design and PO requirements,
    - witness and validate dimensional inspection(s),
    - validate calibration of M&TE,
    - witness weld activities,
    - verify that welding is performed within the parameters defined on the Weld Procedure Specification,
    - verify that the supplier is maintaining configuration management and control of documents, and
    - witnessing of test activities.

- **Inspection and Testing:** ASME Boiler and Pressure Vessel Code, Section III, Division 5, criterion listed in Article NCD-5300 of ASME Boiler and Pressure Vessel Code III.1.NCD-2021
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<th>Document</th>
<th>Record Location</th>
<th>Software Name/ Version No.</th>
<th>Assigned Control No.</th>
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<td>Safety Software Determination (SSD)</td>
<td>INL Intranet Interactive Form 562.37</td>
<td>ABAQUS v. 2021hf6</td>
<td>SSD-000260</td>
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<td>MCNP v.6.2</td>
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<td>IT Asset Management Plan/Configuration Management Plan</td>
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<td>ABAQUS v. 2021hf6</td>
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<td>User Documentation</td>
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MSA #1

Fuel Receipt at INL in TNBGC Casks

CRA

DOE-RA

MSA #2

DOE Approval of SAR Addendum

Non-Fuel Assembly @TREAT

Approval to Complete Fuel Assembly & Core Load

TREAT Limit = 8 pins
2 x TNBGCs = 6 fuel pins

1 subassembly = 6 fuel pins
6 subassemblies total with associated grid plates and reflectors

Load in core
MARVEL Startup Plan (PLN-6816)

Pre-operational Testing
- NIs energized
- State Point Measurements
- Core Load
- CIA Head installed
- CIA Calibrated
- Excess Reactivity

Determine LPPOPW
- Verify Reactivity Computer
- Cold Low Physics Testing
- Approach to critical
- NaK Load
- NaK inerting and drying

Isothermal T Coeff measurement
- CD, CIA Reactivity Worth
- CD shadowing Test
- Core Stability Test
- Isothermal T Coeff at core critical

50%
- Passive Decay Heat Evaluation
- LPP at hot
- Scram Test
- measure CTE
- Hot Standby via heaters

20%
- Cover gas Mgmt, Stirling Check

100%

80%
100%
Major Maintenance: Stirling Replacement
“Original Investigation undertaken in order to acquire new knowledge directed towards a practical implementation of MRs”