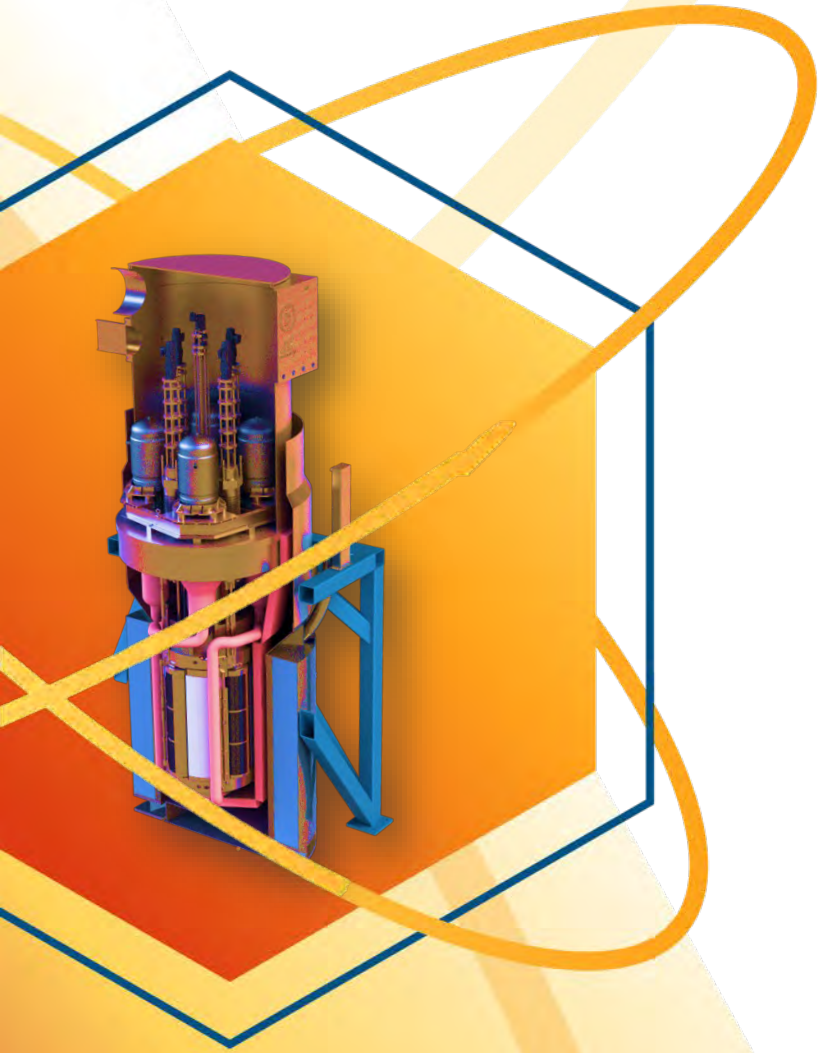
(Microreactor Applications Research, Validation & EvaLuation),



# Reactor 90% Final Design & FY2024 Progress

March 7, 2024

M.W. Patterson

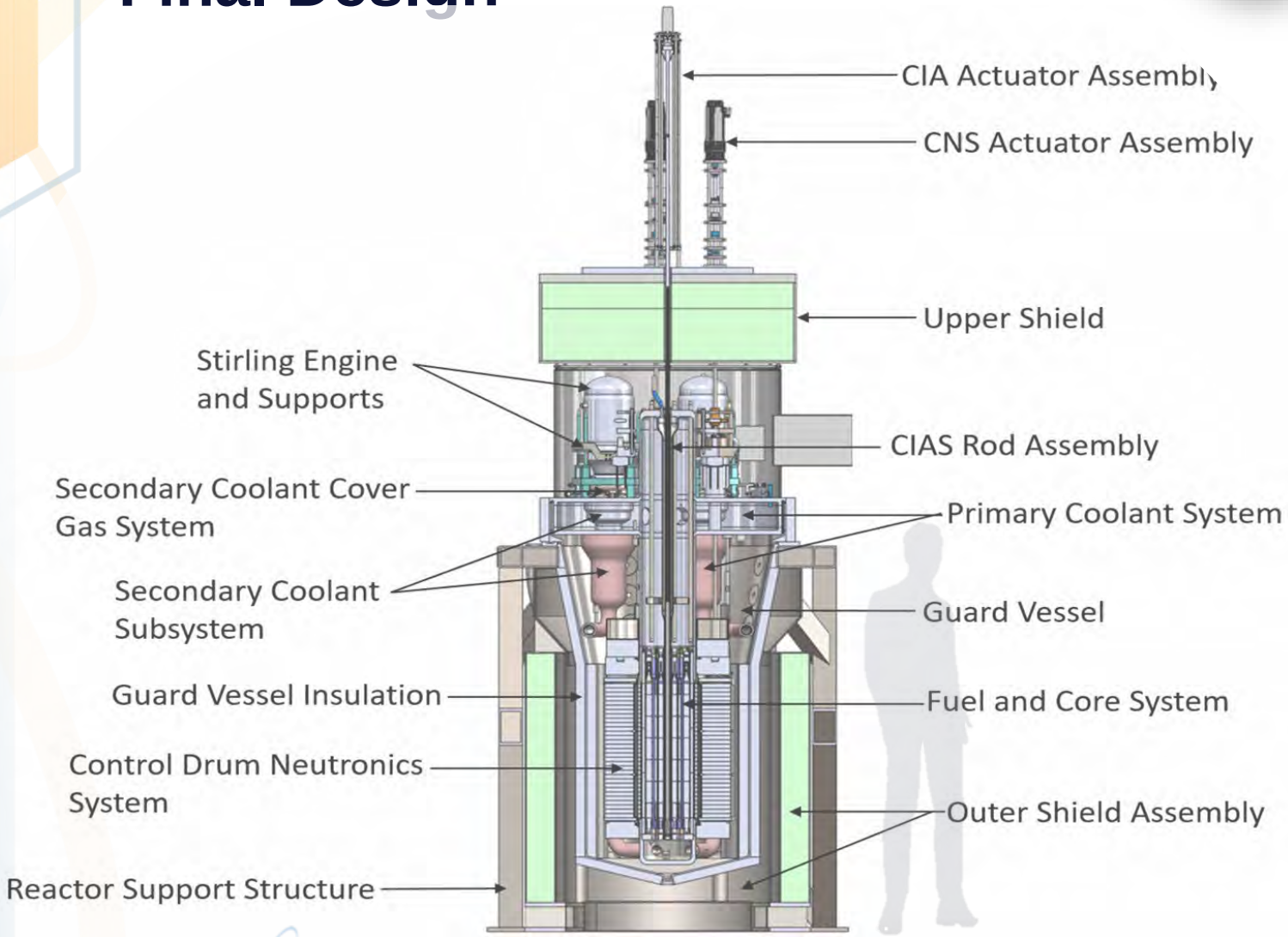
MARVEL Sr. Project/Program Manager

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 |

Los Alamos NATIONAL LABORATORY · Argonne NATIONAL LABORATORY · WALSH ENGINEERING SERVICES · Qnergy Reliable Remote Power · Creative Engineers, Inc. · INL Idaho National Laboratory · MRP Microreactor Program

# 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

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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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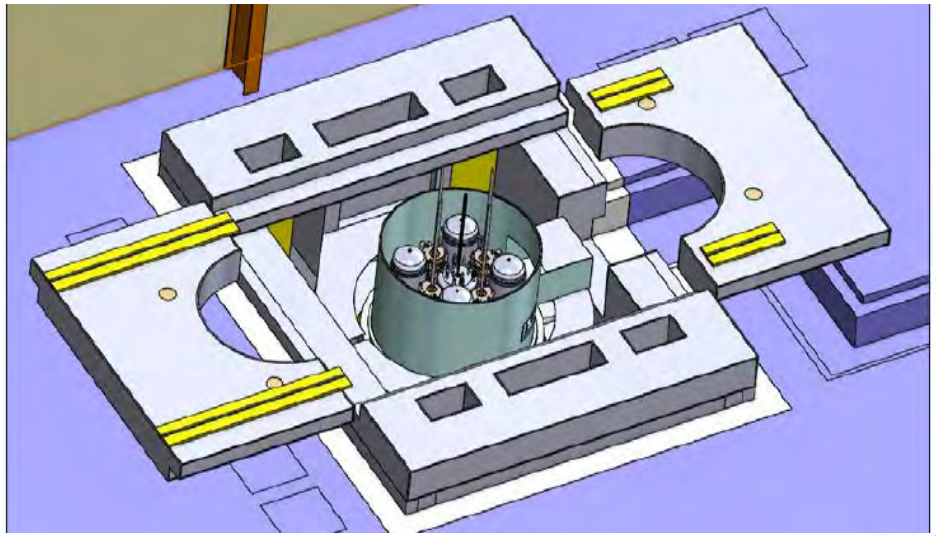
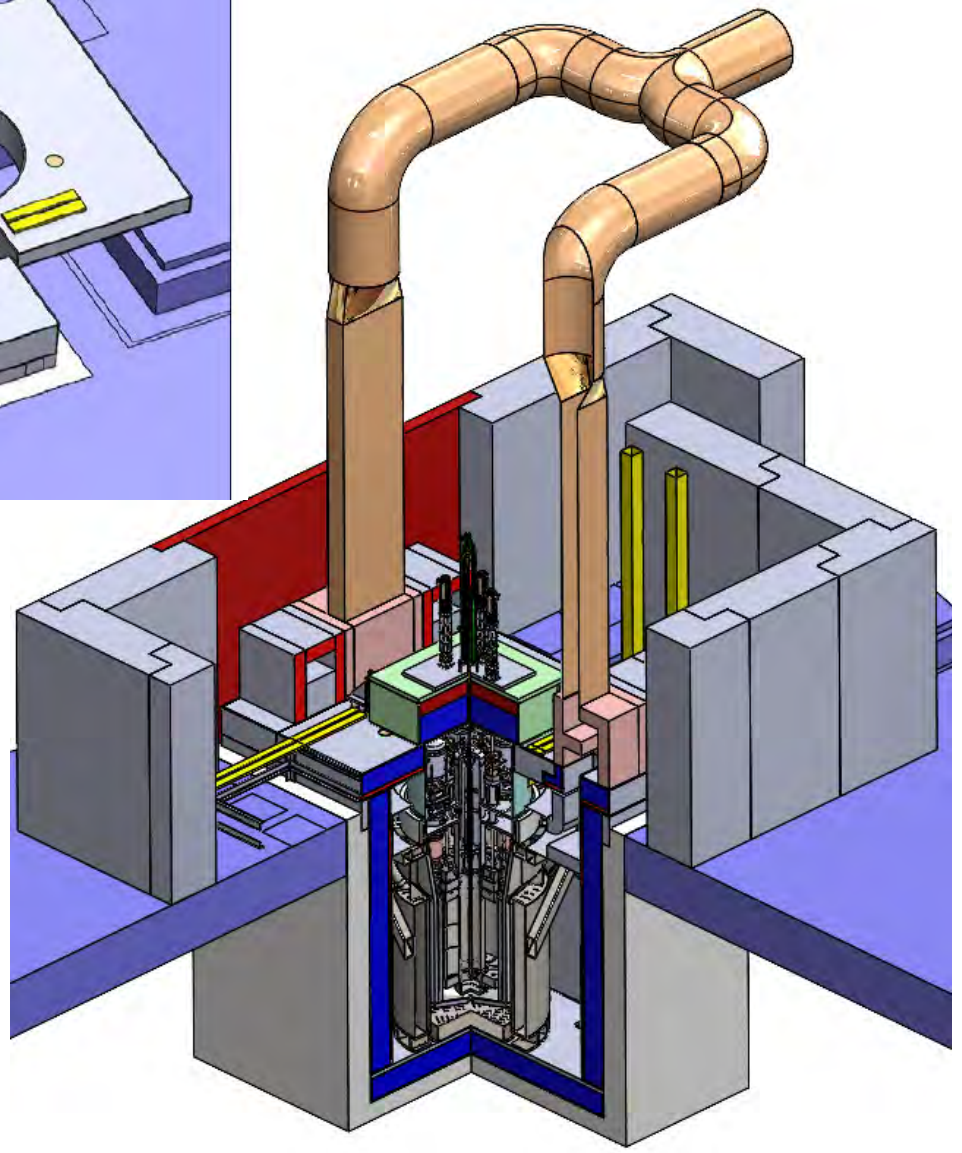
# TREAT- Reactor Experiment Cell (TREX-C)

***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***

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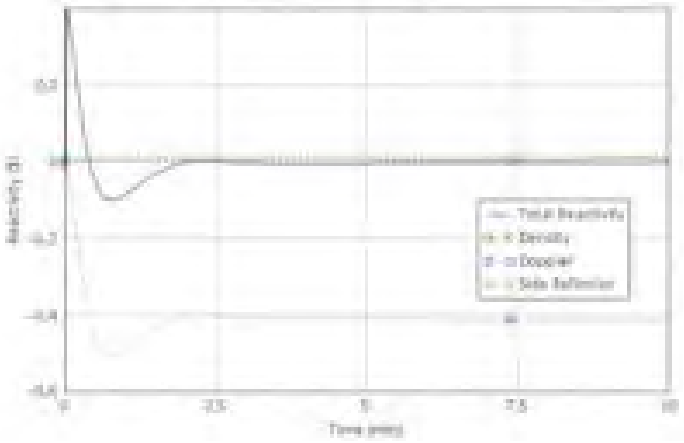
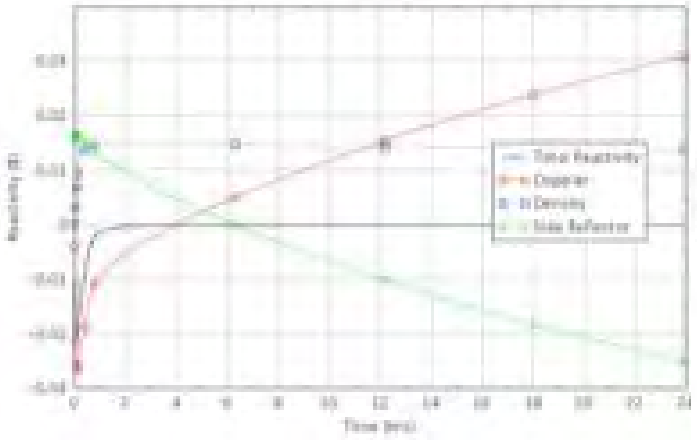
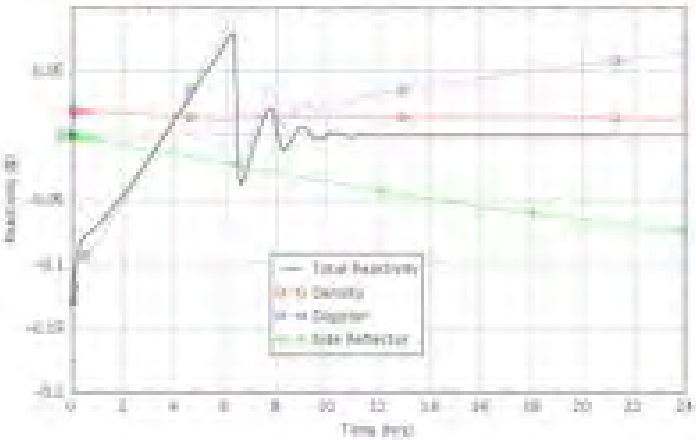
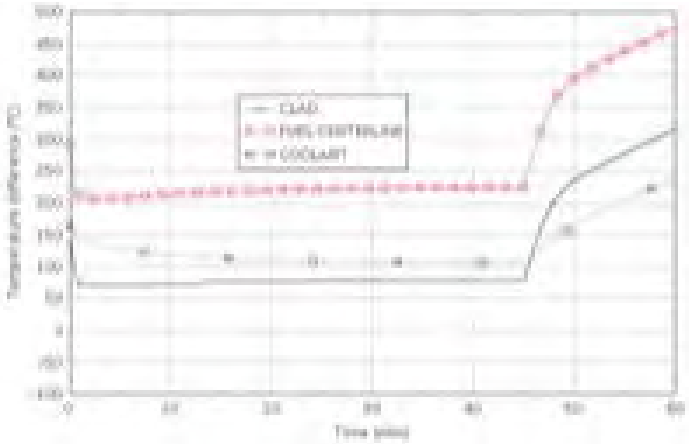
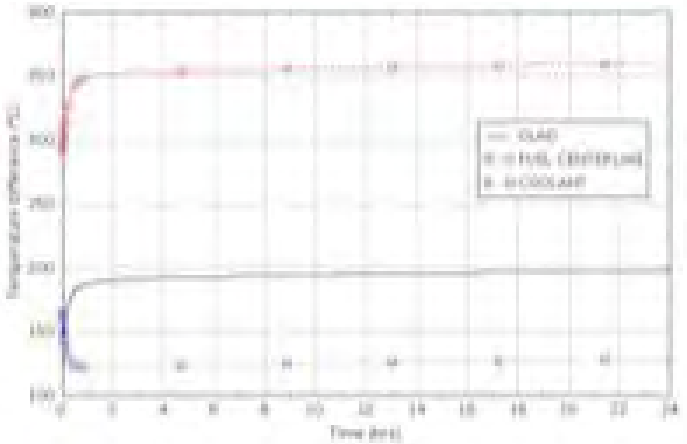
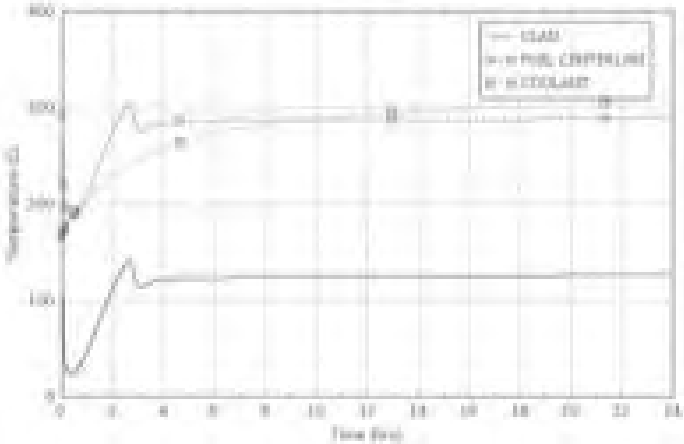
# MARVEL Safety Modeling

## 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)***

- Incorporated in PDSA for DOE review & authorization
- Triggers cost estimate update(s)
- Enables start of procurement 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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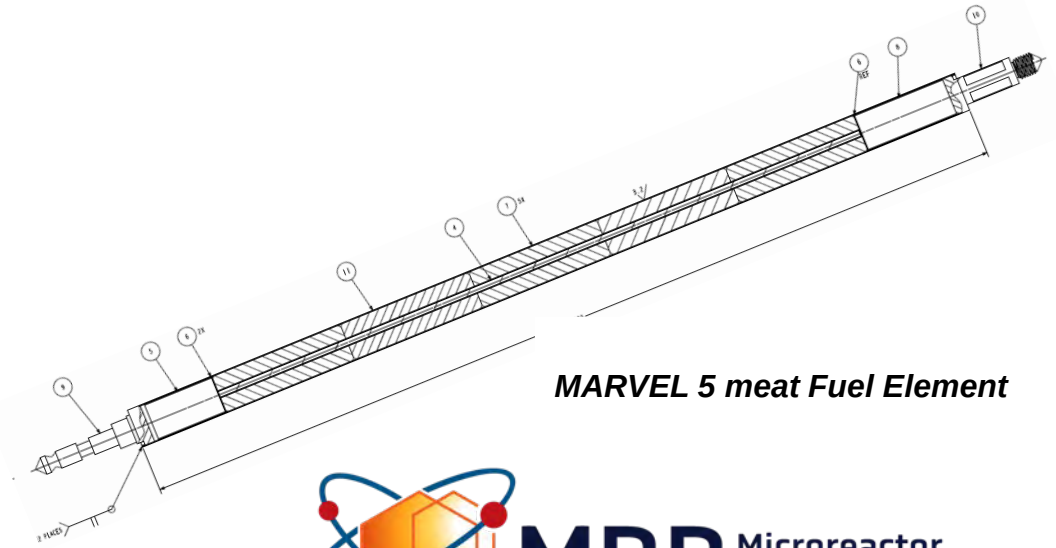
# MARVEL Progress in FY 2024

- 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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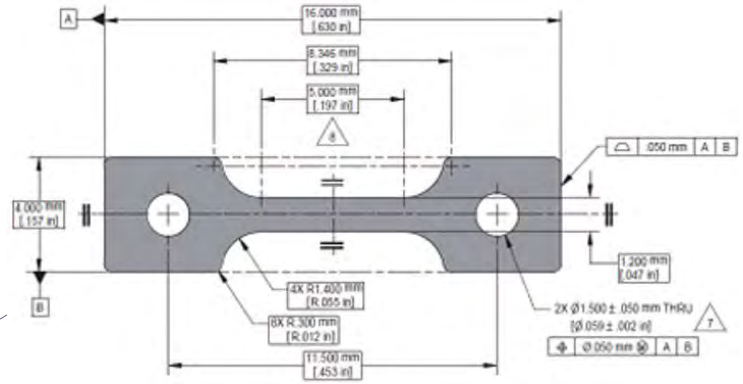
# MARVEL Progress in FY 2024 - continued

- Long Lead Procurement - continued
  - Beryllium metal reflectors and dowels - RFP prepared, procurement on hold 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



***SSJ-3 Mini-Tensile Testing Dog Bone Coupon***

***PCAT in Stand prior to Insulating***

# 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 |
| M2 | 2.04.08.05.06 | Fuel Production & Procurement - INL | M2AT-24IN0805062 | Award MARVEL Fuel Fabrication Contract | 11/30/2023 |
| 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 |
| M2 | 2.04.08.05.07 | TREAT SAR Addendum - INL | M2AT-24IN0805076 | Complete Primary Coolant Apparatus Test (PCAT) Thermohydraulic Testing | 4/30/2024 |
| M2 | 2.04.08.05.08 | MARVEL Readiness - INL | M2AT-24IN0805086 | Submit MARVEL Plan of Action (POA) to DOE-ID | 5/20/2024 |
| M2 | 2.04.08.05.02 | MARVEL Leadership - INL | M2AT-24IN0805023 | Complete MARVEL program plan for Phase 2- Operations | 5/30/2024 |
| 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 |
| M2 | 2.04.08.05.04 | MARVEL Fabrication - INL | M2AT-24IN0805047 | Complete fabrication of the MARVEL reactivity control system | 9/5/2024 |

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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

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# 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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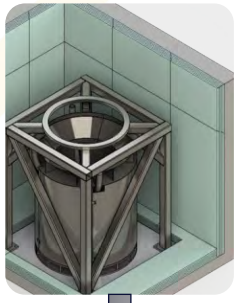
# Software Quality Assurance

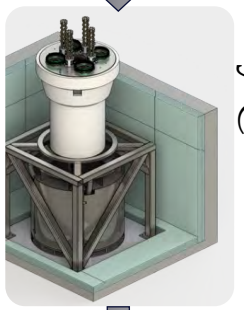
## Microreactor Application Research Validation and Evaluation (MARVEL) Project Software Quality Assurance Plan (SQAP), PLN-6908, Rev 0

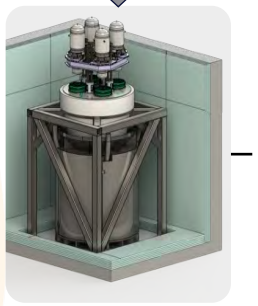
- STANDARDS, PRACTICES, CONVENTIONS, AND METRICS
- SOFTWARE REVIEWS
- TESTING
- ERROR REPORTING AND CORRECTIVE ACTION
- CONFIGURATION MANAGEMENT
- RECORDS COLLECTION, MAINTENANCE, AND RETENTION
- TRAINING
- RISK MANAGEMENT
- PLAN MAINTENANCE

| Document | Record Location | Software Name/ Version No. | Assigned Control No. |
|---|---|---|---|
| **Safety Software Determination (SSD)** | INL Intranet<br><br>Interactive Form 562.37 | ABAQUS v. 2021hf6 | SSD-000260 |
| | | MCNP v.6.2 | SSD-000852 |
| | | MOOSE/BlackBear Build 08.01.2023 | SSD-000853 |
| | | RELAP5-3D v. 4.4.2 | SSD-000854 |
| | | STAR CCM+ v. 2210.0001 | SSD-000260 |
| **Quality Level Determination (QLD)** | INL Intranet<br><br>Interactive Form 414.A91 | ABAQUS v. 2021hf6 | MSA-000200 |
| | | MCNP v.6.2 | * |
| | | MOOSE/BlackBear Build 08.01.2023 | * |
| | | RELAP5-3D v. 4.4.2 | * |
| | | STAR CCM+ v. 2210.0001 | MSA-000200 |
| **IT Asset Management Plan/Configuration Management Plan** | EDMS | ABAQUS v. 2021hf6 | PLN-3597 |
| | | MCNP v.6.2 | PLN-6908 |
| | | MOOSE/BlackBear Build 08.01.2023 | PLN-4005 |
| | | RELAP5-3D v. 4.4.2 | PLN-3397 |
| | | STAR CCM+ v. 2210.0001 | PLN-3597 |
| **Commercial Grade Dedication** | EDMS | ABAQUS v. 2021hf6 | CGI-1305 |
| | | MCNP v.6.2 | CGI-1310 |
| | | MOOSE/BlackBear Build 08.01.2023 | CGI-1306 |
| | | RELAP5-3D v. 4.4.2 | CGI-1309 |
| | | STAR CCM+ v. 2210.0001 | CGI-1307 |
| **Software Validation Plan and Report** | EDMS | ABAQUS v. 2021hf6 | ECAR-5544 |
| | EDMS | MCNP v.6.2 | ECAR-7300 |
| | EDMS | MOOSE/BlackBear Build 08.01.2023 | * |
| | EDMS | RELAP5-3D v. 4.4.2 | ECAR-6654 |
| | EDMS | STAR CCM+ v. 2210.0001 | Test Plan: ECAR-3020, Test Report:* |
| **User Documentation** | Not maintained by INL. Available online | ABAQUS v. 2021hf6 | N/A, not available in a downloadable format |
| | EDMS | MCNP v.6.2 | RPT-14139 |
| | EDMS | MOOSE/BlackBear Build 08.01.2023 | GDE-587 |
| | INL Intranet | RELAP5-3D v. 4.4.2 | Various |
| | EDMS | STAR CCM+ v. 2210.0001 | RPT-14140 |

# MARVEL Readiness Activities







Non-Fuel Assembly @TREAT

DOE Approval of SAR Addendum

MSA #1

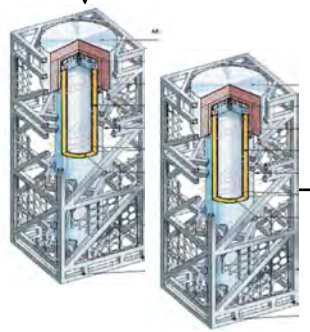
MSA #2

CRA

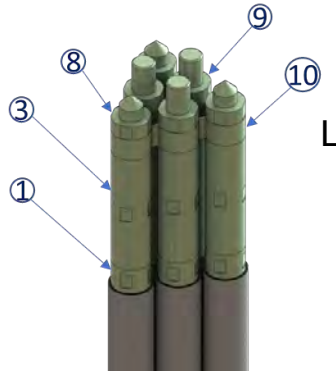
DOE-RA

Approval to Complete Fuel Assembly & Core Load

Fuel Receipt at INL in TNBGC Casks



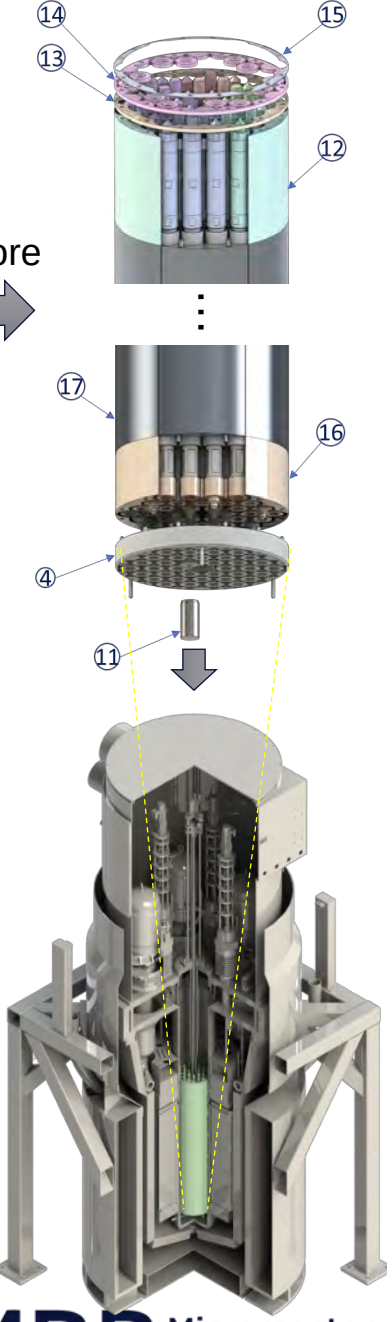
TREAT Limit = 8 pins
2 x TNBGCs = 6 fuel pins




1 subassembly = 6 fuel pins

6 subassemblies total with associated grid plates and reflectors

Load in core

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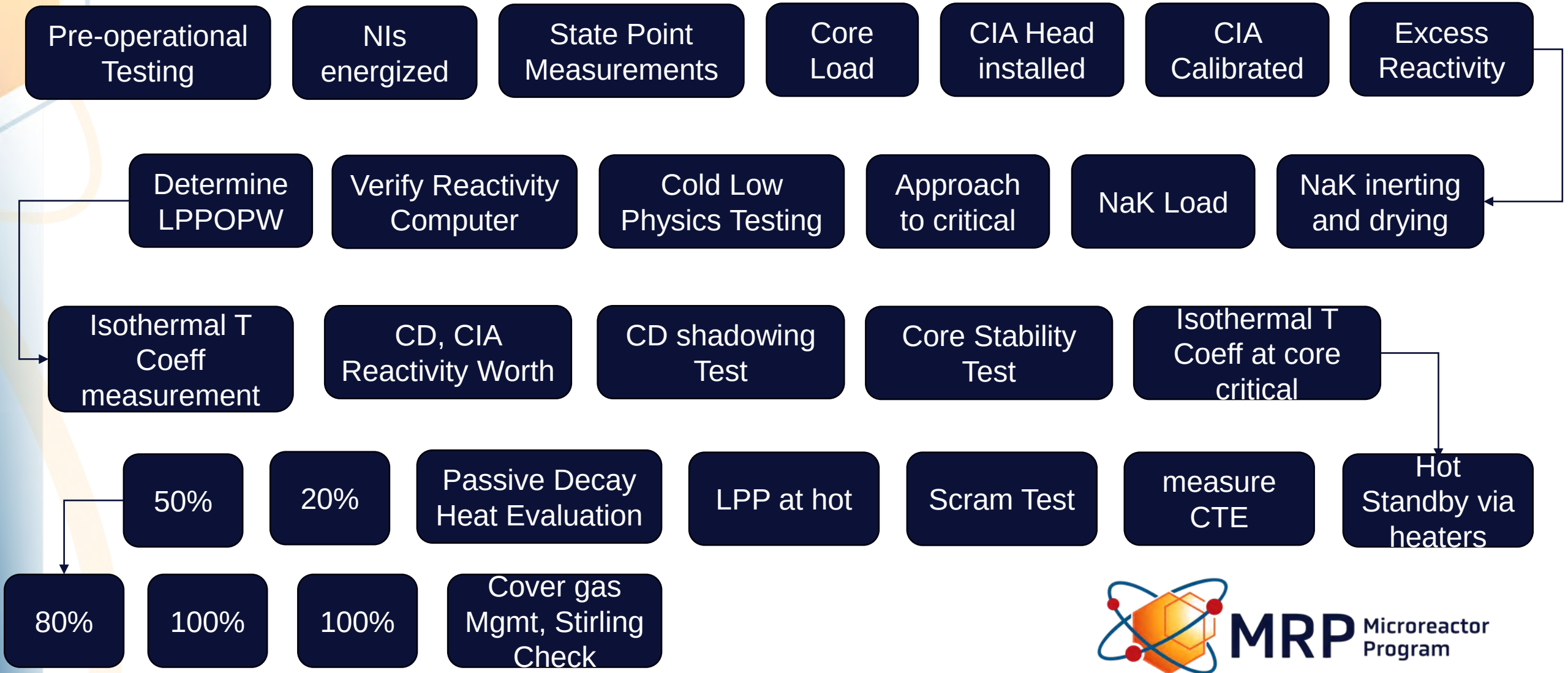
# MARVEL Startup Plan (PLN-6816)

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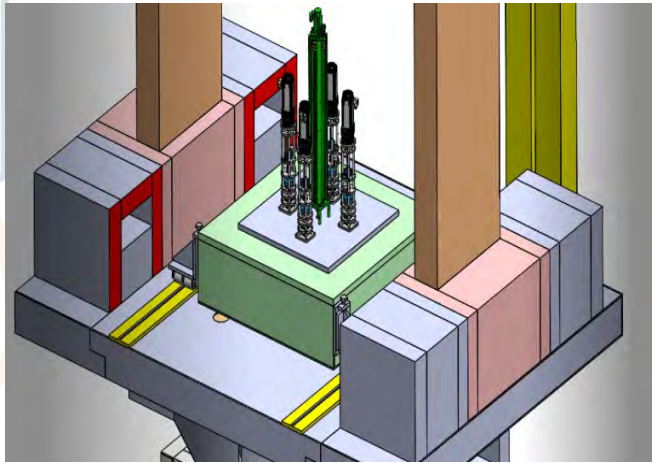
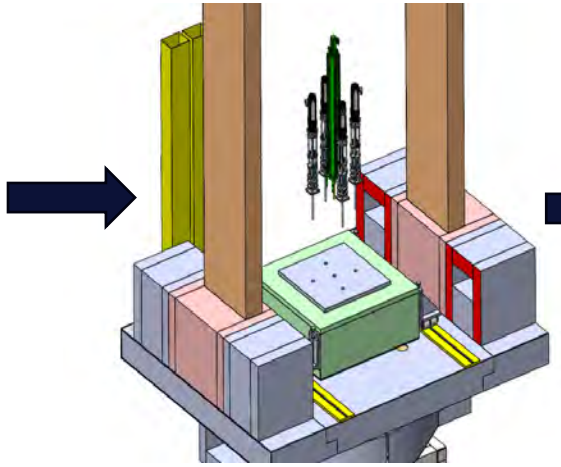
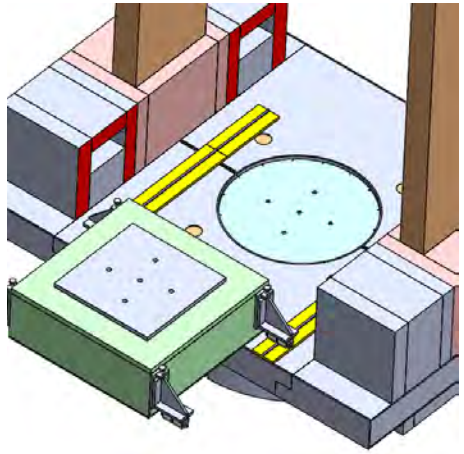
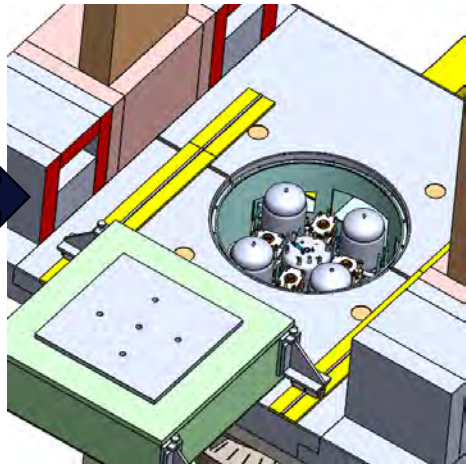
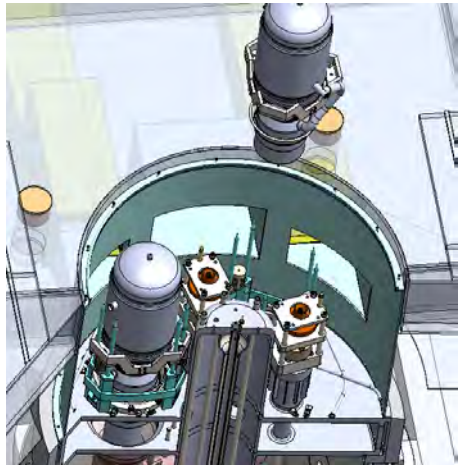
# Major Maintenance: Stirling Replacement

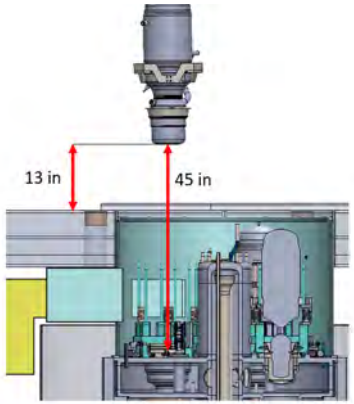


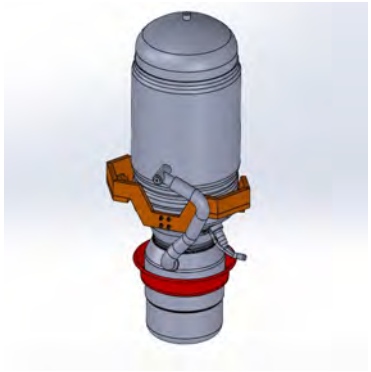










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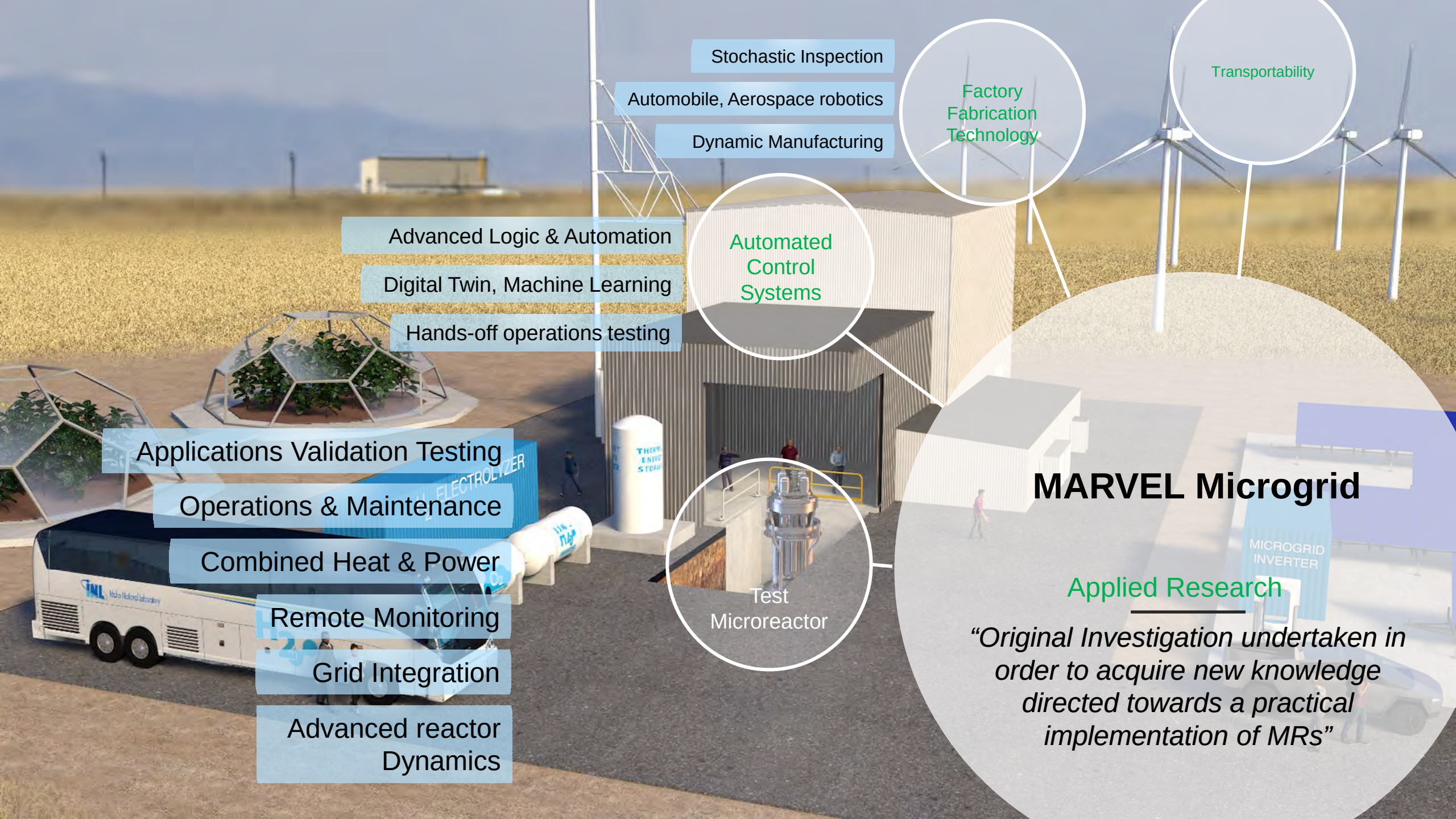
Stochastic Inspection
Automobile, Aerospace robotics
Dynamic Manufacturing
Factory Fabrication Technology
Transportability
Advanced Logic & Automation
Digital Twin, Machine Learning
Hands-off operations testing
Automated Control Systems
Applications Validation Testing
Operations & Maintenance
Combined Heat & Power
Remote Monitoring
Grid Integration
Advanced reactor Dynamics
Test Microreactor
MARVEL Microgrid
Applied Research
"Original Investigation undertaken in order to acquire new knowledge directed towards a practical implementation of MRs"