(Microreactor Applications Research, Validation & EvaLuation),

MARVEL Technology Review

10/19/2022- 10/20/2022

Reactor Design Overview

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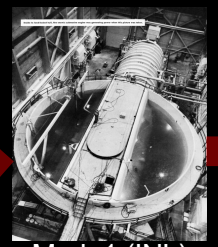
Technical Area Lead, DOE Microreactor Program

Microreactor Technical Lead, Nuclear Science & Technology, Idaho National Laboratory


welcome
– THANK YOU FOR JOINING US –

EBR-I (INL)

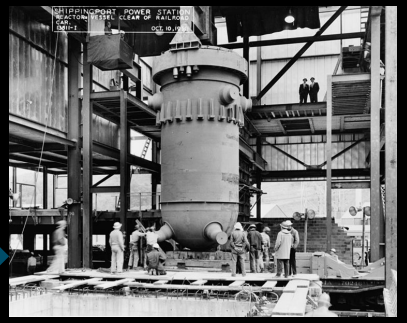


Mark 1 (INL)

Defense

USS Nautilus

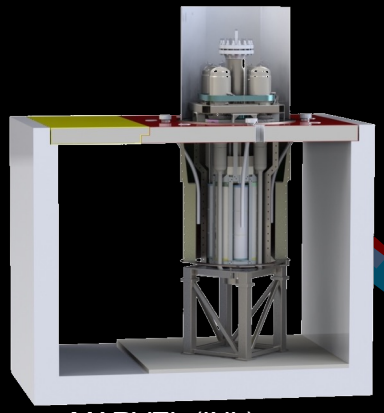
Commercial



Commercial Demo

Commercial LWR

LWR 1951 1953 1954 1957 1960

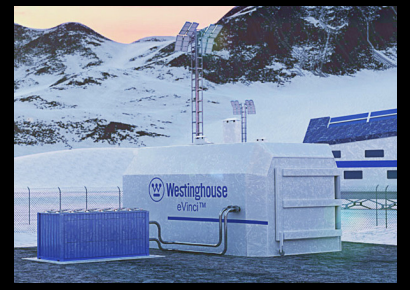


MARVEL (INL)

PELE (INL)

Defense

Commercial



Commercial Microreactors

Microreactor 2023 2024 2025 2025+

Multiple Microreactor Developers

MARVEL Project Goals and Objectives

Project Goals: Accelerate demonstration of a small-scale microreactor test system:

- Engage future microreactor end-consumers → Empower remote/isolated energy users
- Engage developers to demo next-generation technologies → Reduce risks- share Lessons learned and technologies
- Engage next-generation researchers → Innovate, test next generation technologies

Primary Objectives:

Sponsor, Regulator & Team:

U.S. DEPARTMENT OF ENERGY
Nuclear Energy

Sponsor

U.S. DEPARTMENT OF ENERGY
Idaho Operations Office

Regulator

INL
Idaho National Laboratory

WALSH ENGINEERING SERVICES

Qnergy
Reliable Remote Power

Creative Engineers, Inc.
UNITED STATES | CANADA | INTERNATIONAL

Los Alamos NATIONAL LABORATORY EST. 1943

Argonne NATIONAL LABORATORY

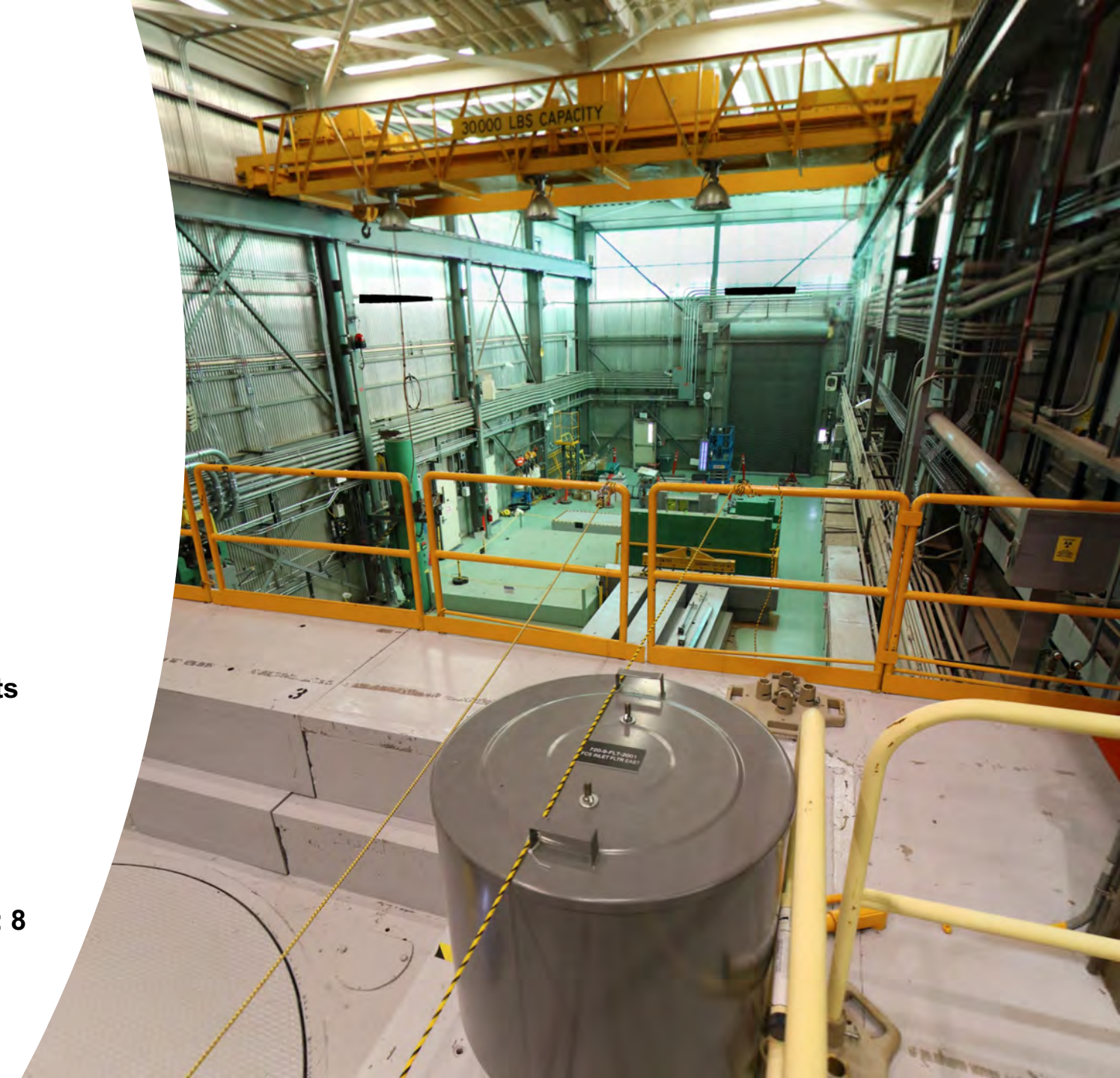
NC STATE UNIVERSITY

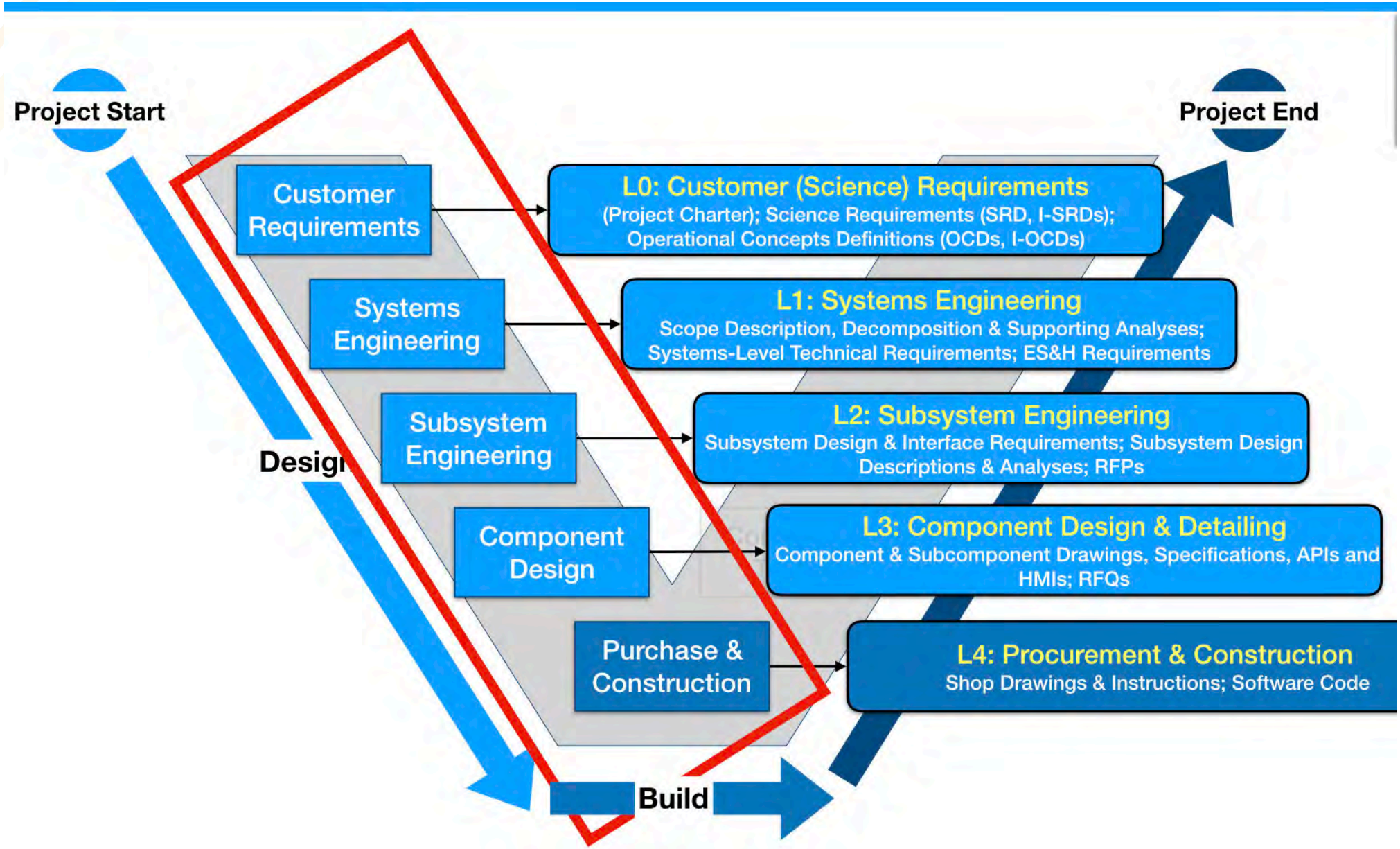
Idaho State University

MRP Microreactor Program

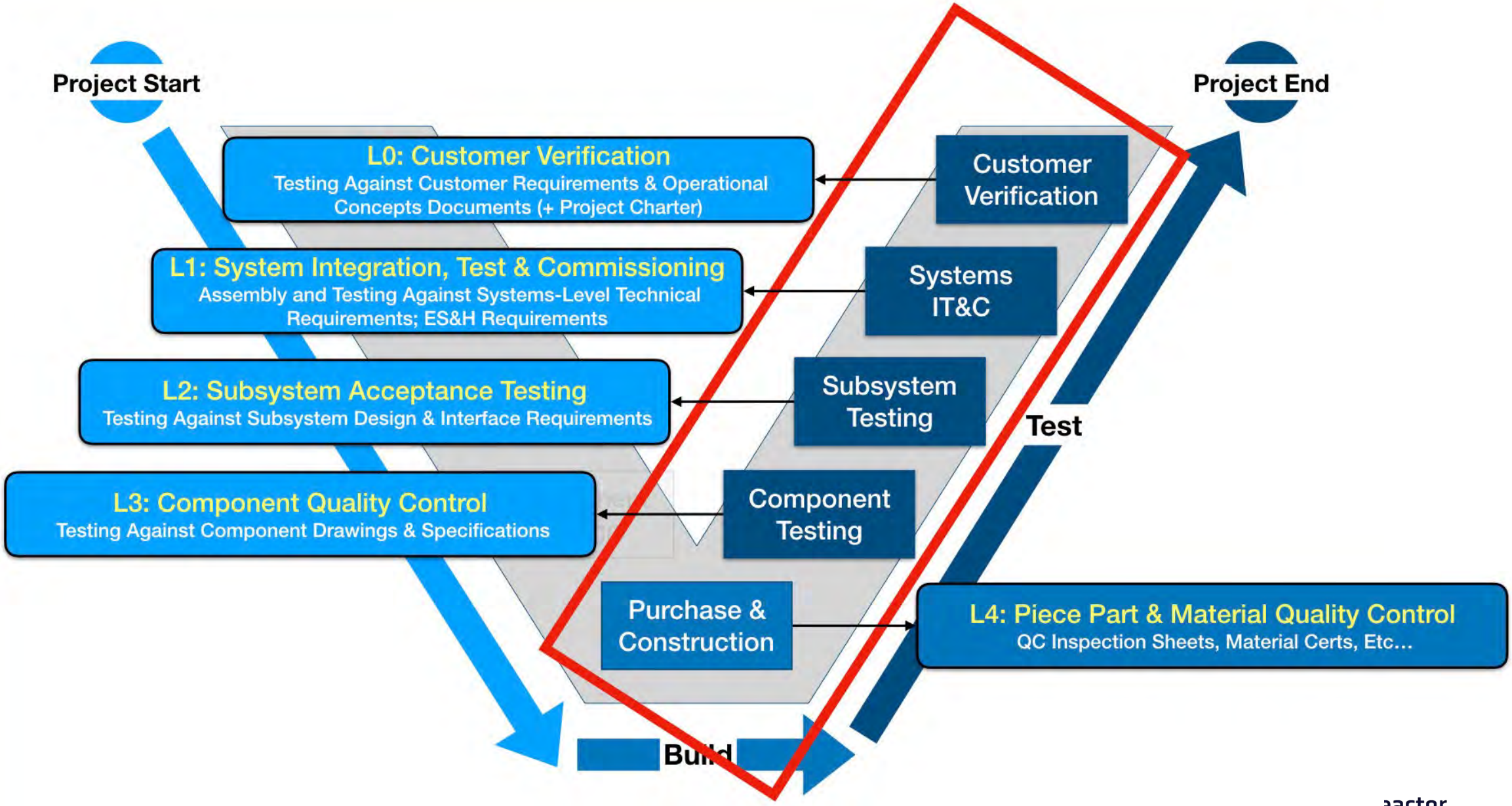
Level 1 Requirements

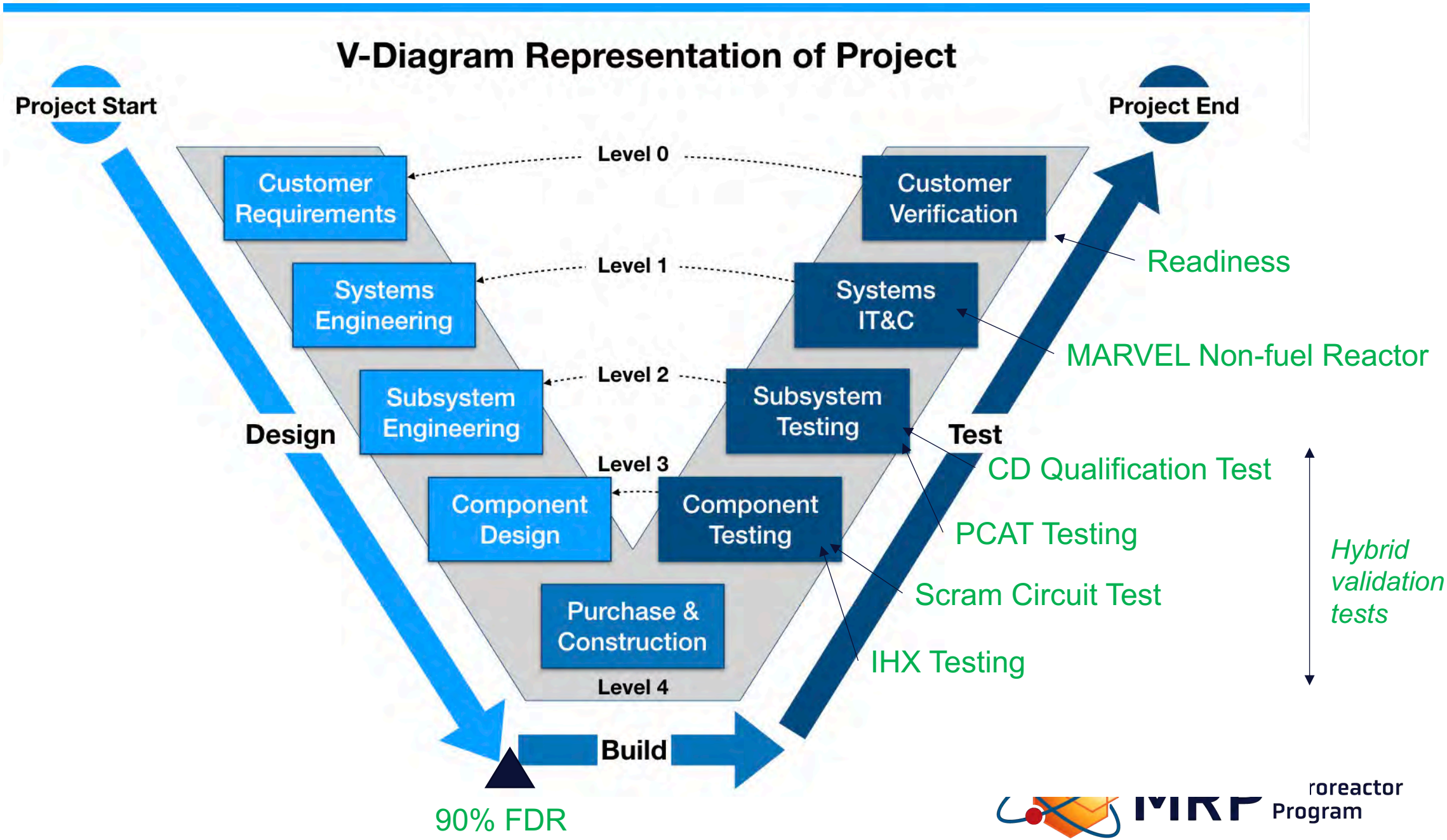
- **KEY PERFORMANCE PARAMETERS (KPPs) :13 requirements**
  - MARVEL Reactor Design
  - Reactor Design Constraints
  - Regulatory Requirements
  - TREAT Infrastructure Interface
  - TREAT Operational Interface
- **KEY SYSTEM ATTRIBUTES (KSAs): 36 Requirements**
  - Reactor Design
  - Regulatory requirements
  - INL/TREAT Process
  - TREAT Infrastructure Interphase
  - TREAT Operational Interface
- **ADDITIONAL PERFORMANCE ATTRIBUTES (APAs): 8 requirements**
  - INL/TREAT Interface





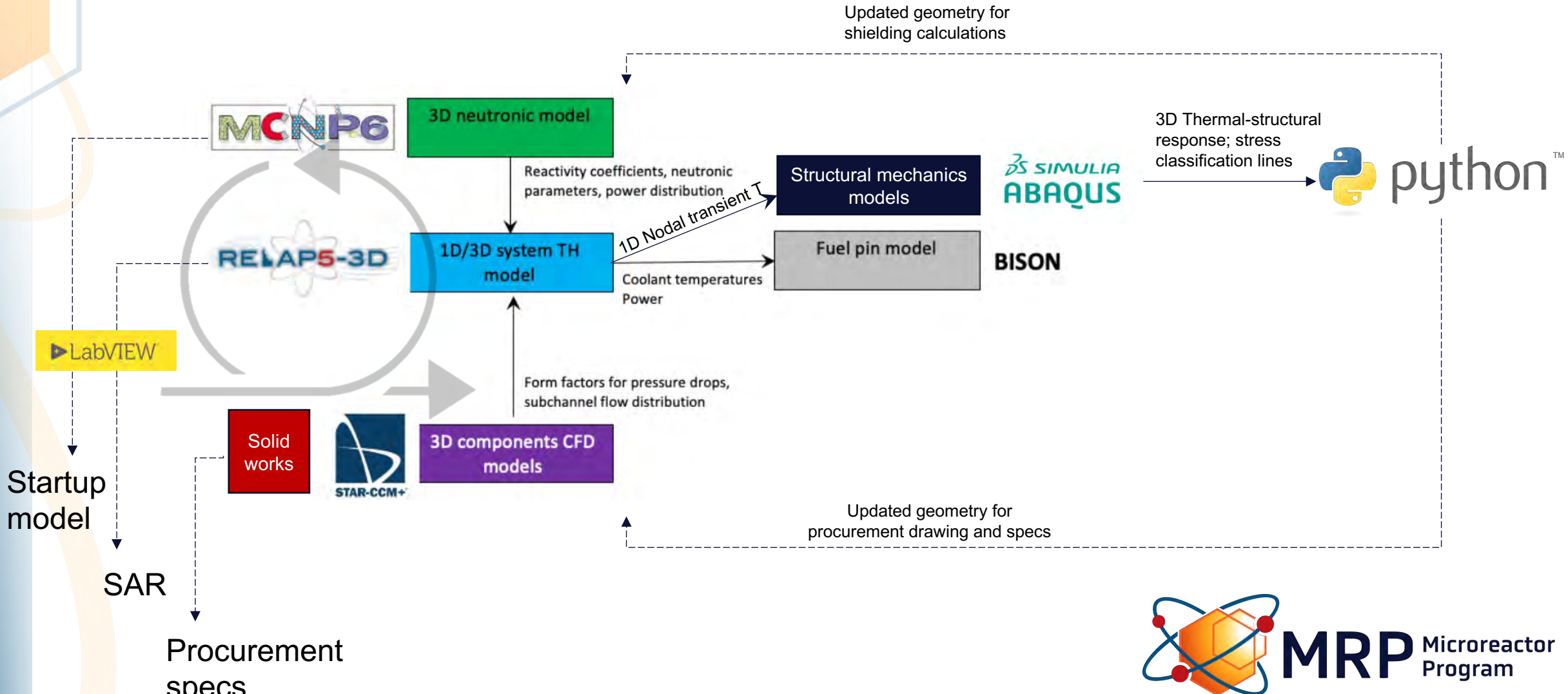
MRP Microreactor Program


Project Start
Project End
L0: Customer Verification
Testing Against Customer Requirements & Operational Concepts Documents (+ Project Charter)
Customer Verification
L1: System Integration, Test & Commissioning
Assembly and Testing Against Systems-Level Technical Requirements; ES&H Requirements
Systems IT&C
L2: Subsystem Acceptance Testing
Testing Against Subsystem Design & Interface Requirements
Subsystem Testing
L3: Component Quality Control
Testing Against Component Drawings & Specifications
Component Testing
Purchase & Construction
L4: Piece Part & Material Quality Control
QC Inspection Sheets, Material Certs, Etc...
Test
Build

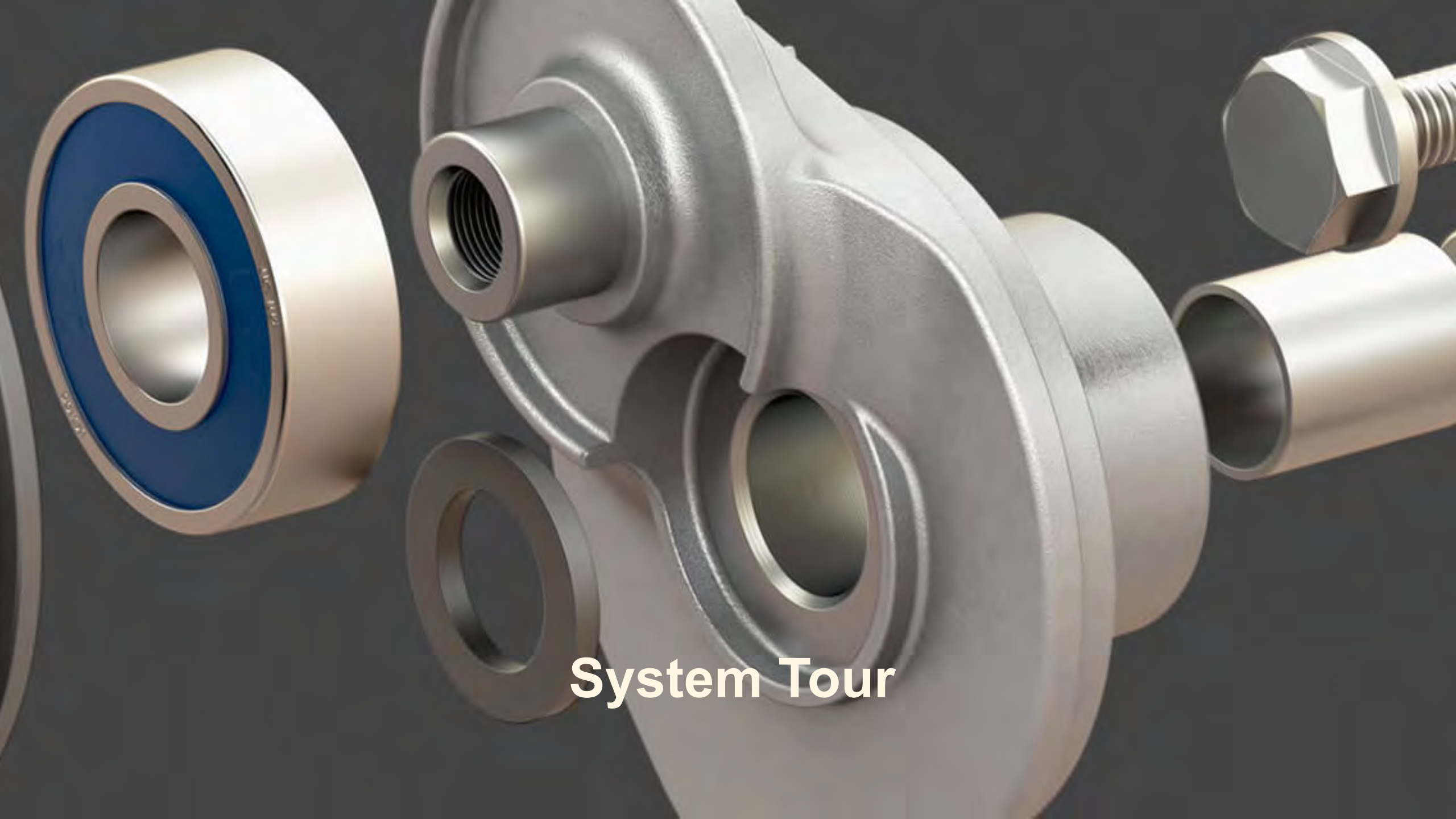


roreactor Program

Key Modeling Simulation Tools Used in MARVEL Project



MRP Microreactor Program



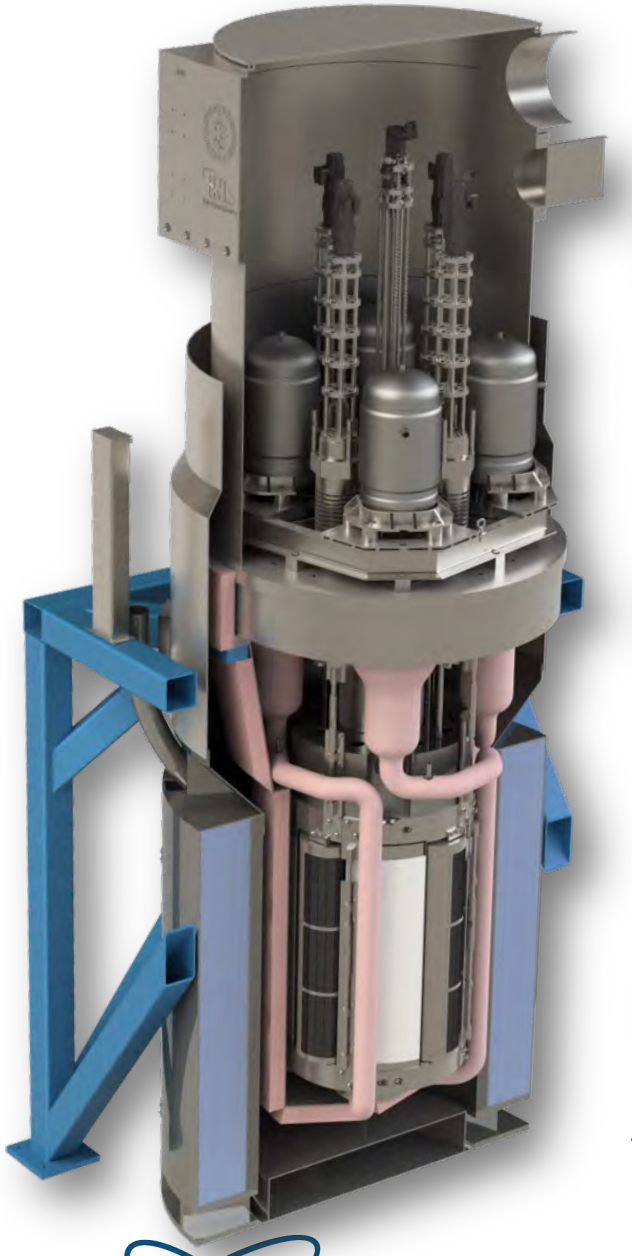
System Tour

MARVEL - Test Microreactor

Microreactor Application Research, Validation and EvaLuation Project

Key Design Features	
Thermal Power	100 KW_{th} (85 kW_{th} nominal)
Electrical Power	20 kW_e (QB80 Stirling Engines)
Heat Extraction	40 kW_{th} (450°C), 60kW_{th} (60°C)
Weight	~11 metric ton (12 US ton)
Primary Coolant	Sodium-Potassium eutectic
Intermediate Coolant	Molten Lead
Coolant Driver	Natural Convection, single phase
Fuel	HALE(UZrH), 304SS clad, end caps
Moderator	Hydrogen
Neutron Reflector	Graphite, Beryllium (S200), Beryllium oxide
Reactivity Control	Radial Control Drums, Central Absorber
Primary Coolant Boundary	SS316H

Innovation- MARVEL used an inherently safe research reactor fuel and design a high-temperature advanced reactor

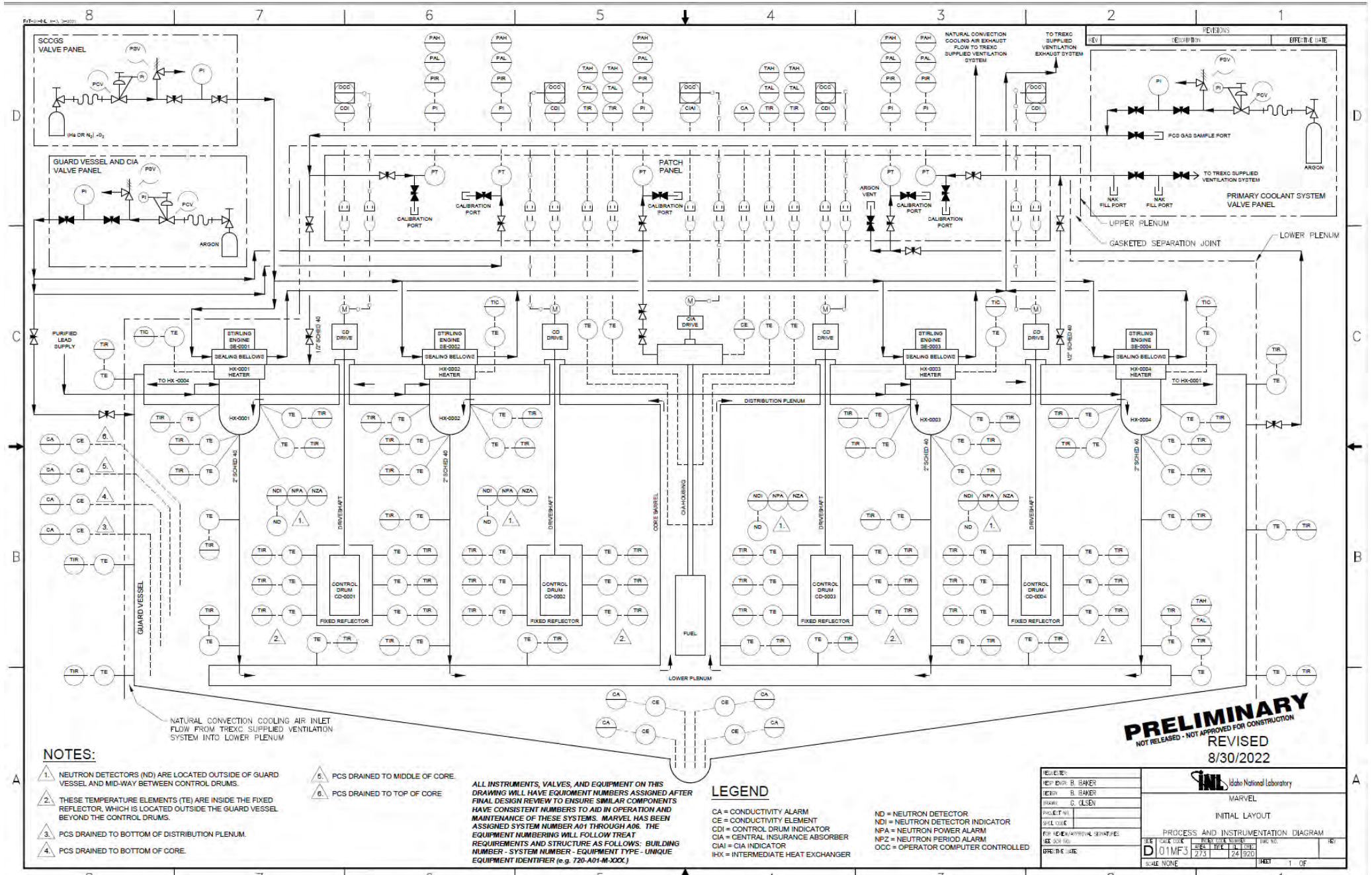


Factory Fabricated

transportable

Self-regulating

MRP Microreactor Program



PRELIMINARY
NOT RELEASED - NOT APPROVED FOR CONSTRUCTION
REVISED
8/30/2022

NOTES:

1. NEUTRON DETECTORS (ND) ARE LOCATED OUTSIDE OF GUARD VESSEL AND MID-WAY BETWEEN CONTROL DRUMS.
2. THESE TEMPERATURE ELEMENTS (TE) ARE INSIDE THE FIXED REFLECTOR, WHICH IS LOCATED OUTSIDE THE GUARD VESSEL BEYOND THE CONTROL DRUMS.
3. PCS DRAINED TO BOTTOM OF DISTRIBUTION PLENUM.
4. PCS DRAINED TO BOTTOM OF CORE.
5. PCS DRAINED TO MIDDLE OF CORE.
6. PCS DRAINED TO TOP OF CORE.

ALL INSTRUMENTS, VALVES, AND EQUIPMENT ON THIS DRAWING WILL HAVE EQUIOMENT NUMBERS ASSIGNED AFTER FINAL DESIGN REVIEW TO ENSURE SIMILAR COMPONENTS HAVE CONSISTENT NUMBERS TO AID IN OPERATION AND MAINTENANCE OF THESE SYSTEMS. MARVEL HAS BEEN ASSIGNED SYSTEM NUMBER A01 THROUGH A06. THE EQUIPMENT NUMBERING WILL FOLLOW TREAT REQUIREMENTS AND STRUCTURE AS FOLLOWS: BUILDING NUMBER - SYSTEM NUMBER - EQUIPMENT TYPE - UNIQUE EQUIPMENT IDENTIFIER (e.g. 720-A01-M-XXX.)

LEGEND

CA = CONDUCTIVITY ALARM
CE = CONDUCTIVITY ELEMENT
CDI = CONTROL DRUM INDICATOR
CIA = CENTRAL INSURANCE ABSORBER
CIAI = CIA INDICATOR
IHX = INTERMEDIATE HEAT EXCHANGER
ND = NEUTRON DETECTOR
NDI = NEUTRON DETECTOR INDICATOR
NPA = NEUTRON POWER ALARM
NPZ = NEUTRON PERIOD ALARM
OCC = OPERATOR COMPUTER CONTROLLED

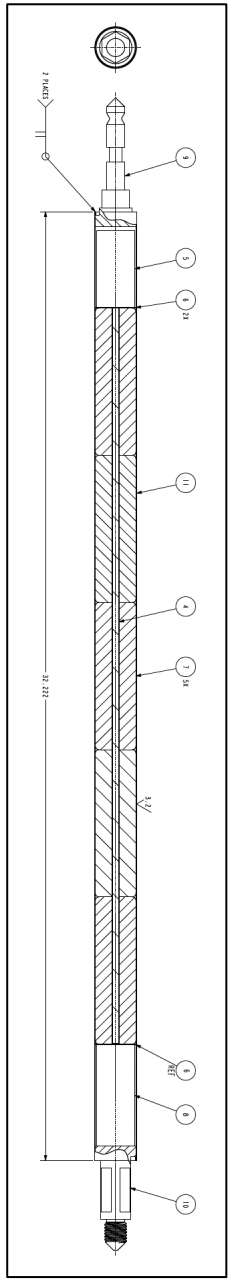
REVIEWER:	
REVIEWER:	B. BAKER
DESIGN:	B. BAKER
DRAWN:	C. OLSEN
PROJECT NO:	
SPEC CODE:	
FOR REVIEW/APPROVAL SIGNATURES	
SEE BOX NO.	
EFFECTIVE DATE:	

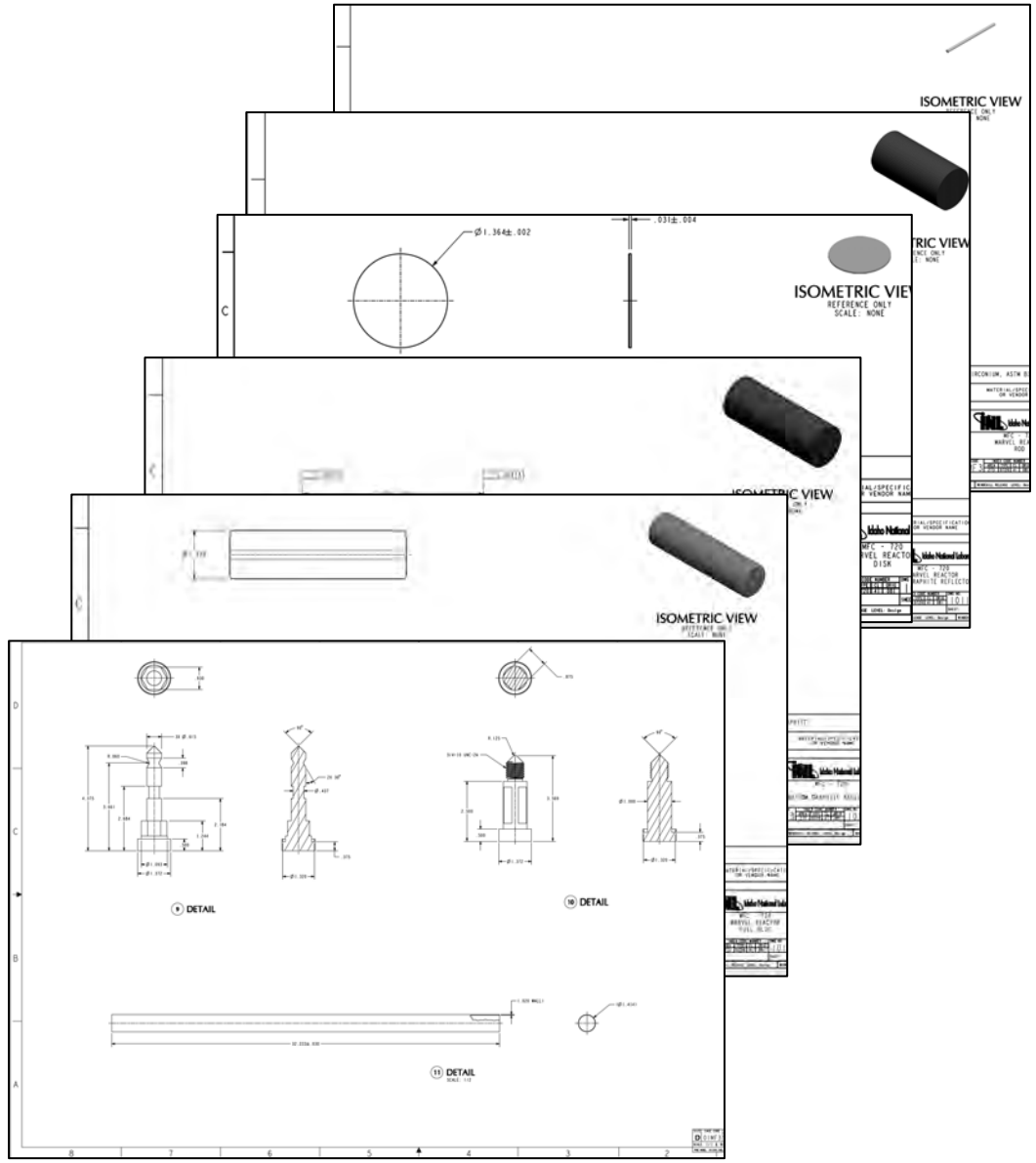
Idaho National Laboratory
MARVEL
INITIAL LAYOUT
PROCESS AND INSTRUMENTATION DIAGRAM
SIZE D | SCALE CODE 01MF3 | PROJECT CODE AREA 273 TYPE 24 | DWG NO. 920 | REV
SCALE: NONE
SHEET 1 OF

Fuel Subsystem Description

- Fuel purchased by external supplier: TRIGA International
  - GA and CERCA in France
- MARVEL fuel is modified “off the shelf”
  - Catalog item 419 (with 5 fuel pellets instead of 3)

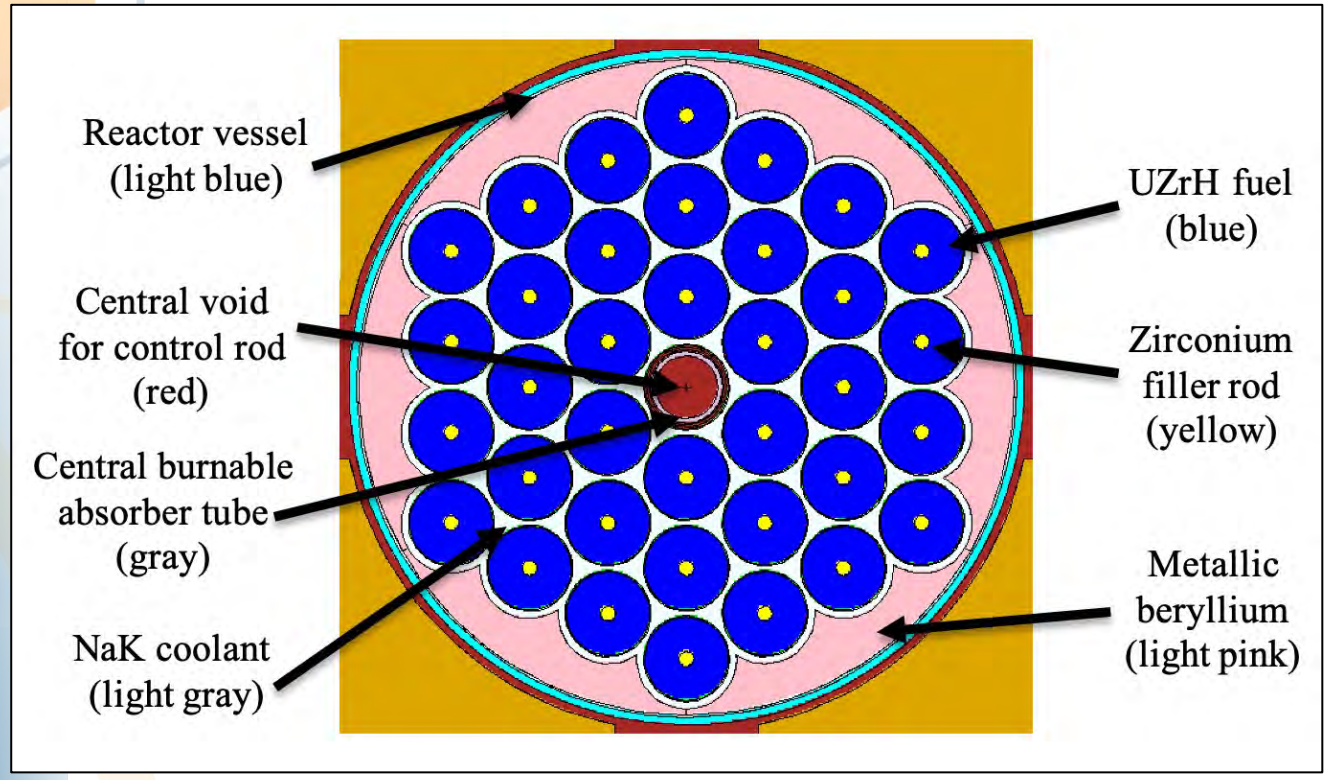
Fuel Element Design Data	Specification
Number of fuel elements	36
Fuel type	U-$ZrH_{1.6}$
Zirconium rod diameter, in.	0.225
Fuel meat outer diameter, in.	1.370
Fuel meat length, in.	25.0
Clad thickness, in.	0.020
Clad material	304 SS
Total uranium, wt%	30.0
Uranium density, g/cm^3	2.14
Weight of U-235 per rod, g	246.85
Uranium enrichment, %	19.75
Nominal hydrogen/zirconium ratio	1.6

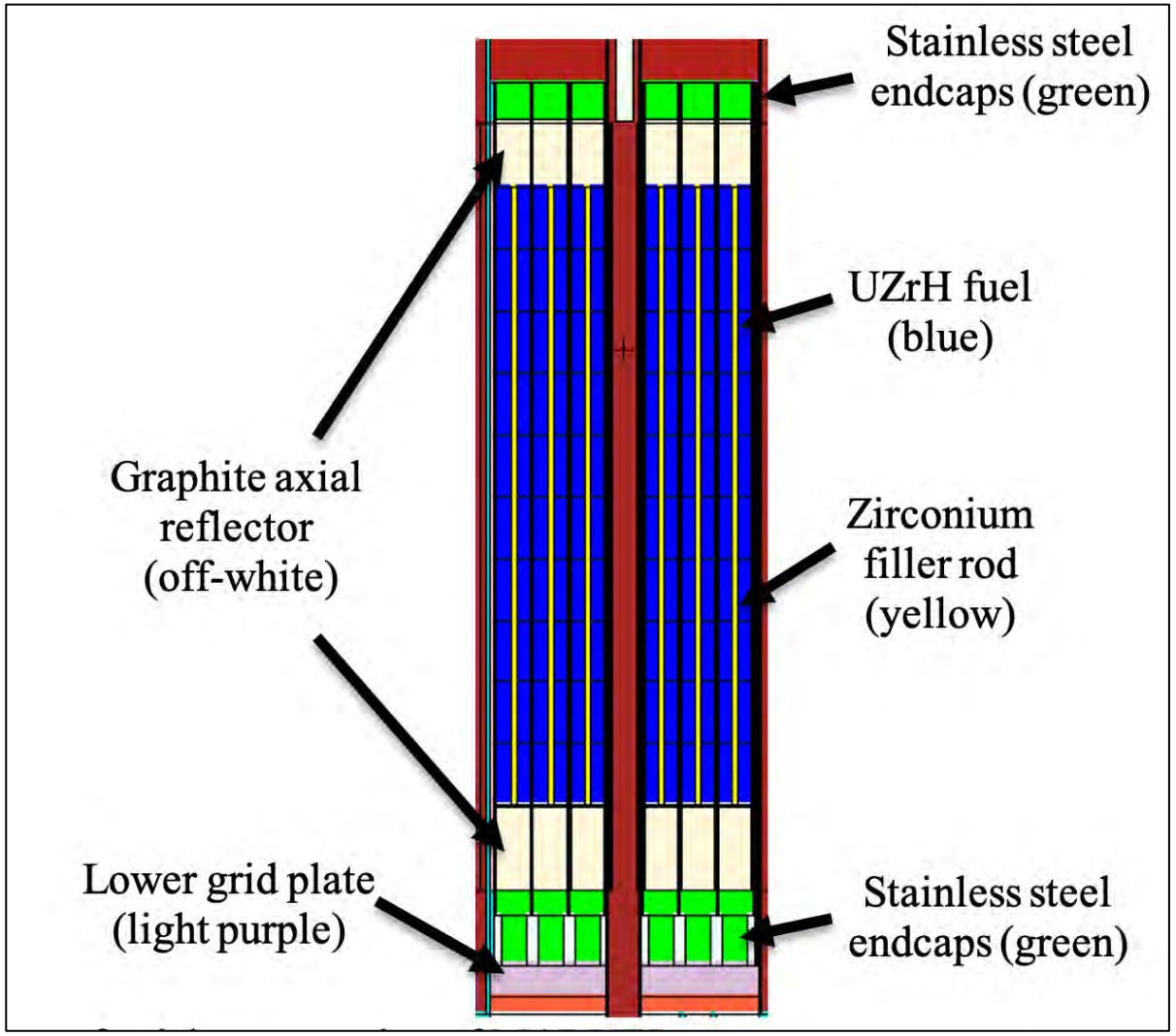




MRP Microreactor Program

MARVEL Core



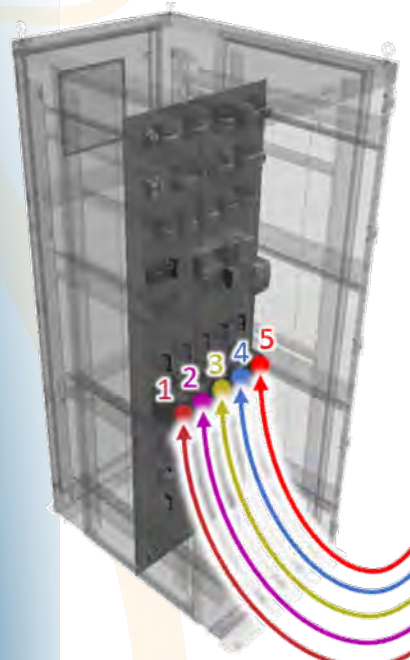


MRP Microreactor Program

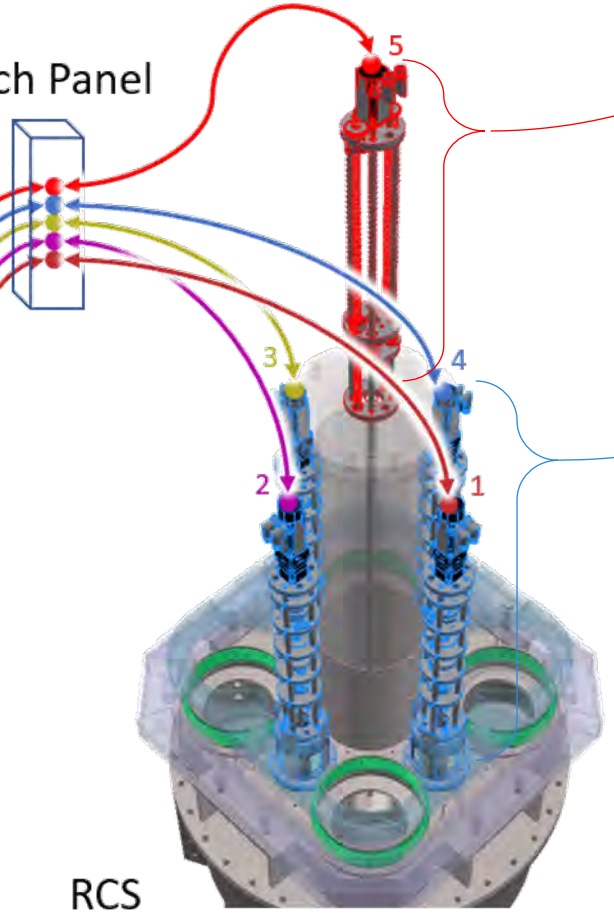
Reactivity Control Overview

- Four drums, one absorber, and associated drivers in control cabinet used to control reactor reactivity

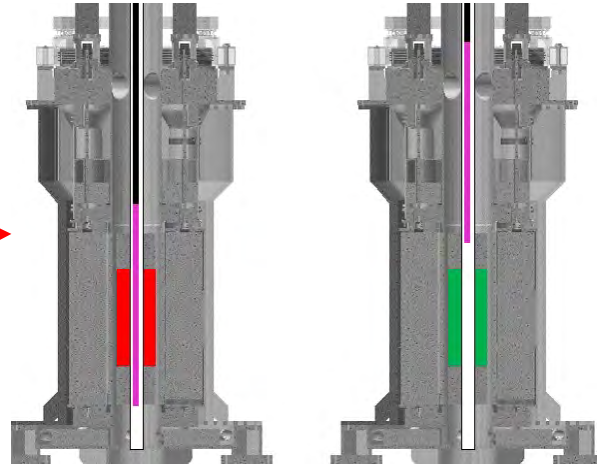
RCS Drive Connections in RCS/RPS/Interlock Cabinet



Patch Panel

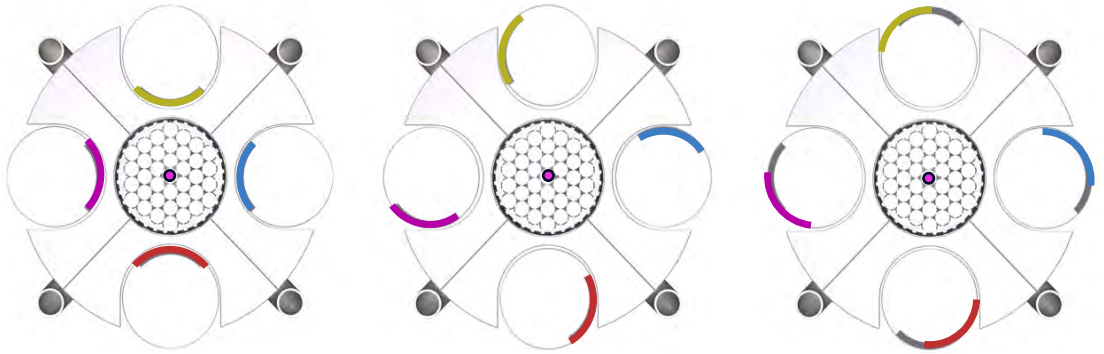


RCS
- 4 CDs (Blue)
- 1 CIA (Red)



CIA In

Criticality Enabled



Full-in: Shutdown

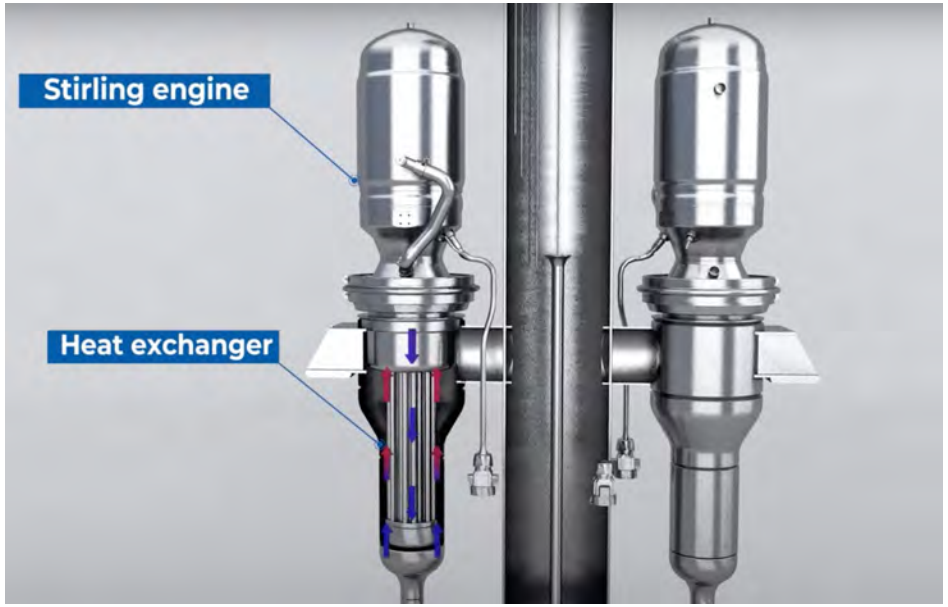
Partial Out: Initial Criticality

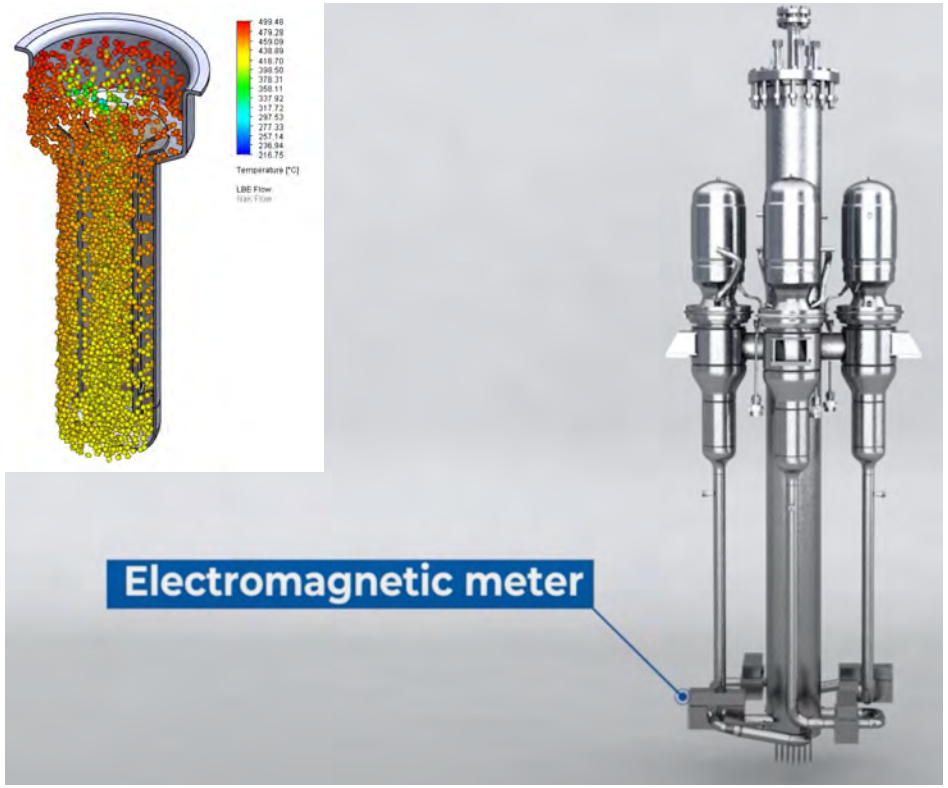
Full Out: Maximum Reactivity*

*Will be set <u>below</u> full out (180 degree) using a tuned hard stop

MRP Microreactor Program

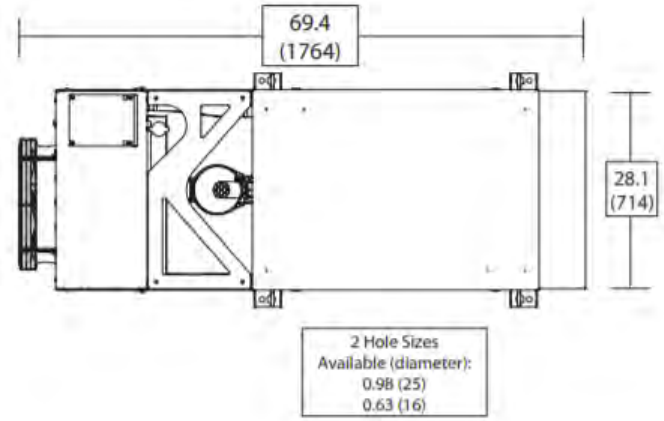

Convection loop

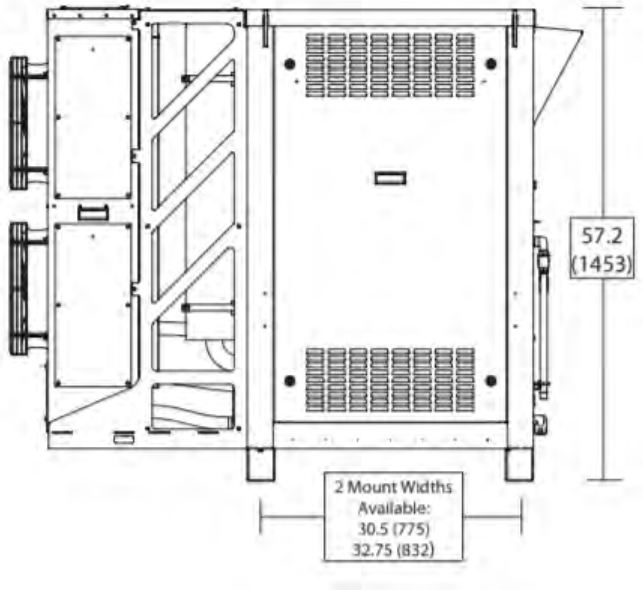

Stirling engine
Heat exchanger

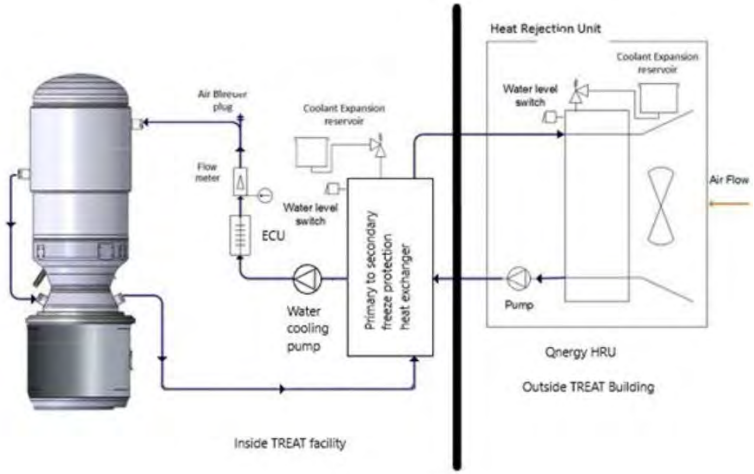

499.48
479.28
459.09
438.89
418.70
398.50
378.31
358.11
337.92
317.72
297.53
277.33
257.14
236.94
216.75
Temperature [°C]
LBE Flow
Main Flow
Electromagnetic meter

Power Generation Systtem

- Heat Rejection Units remove low-grade heat for effective operation of PCKs.
- Heat rejection provided by finned-tube heat exchanger and fans.

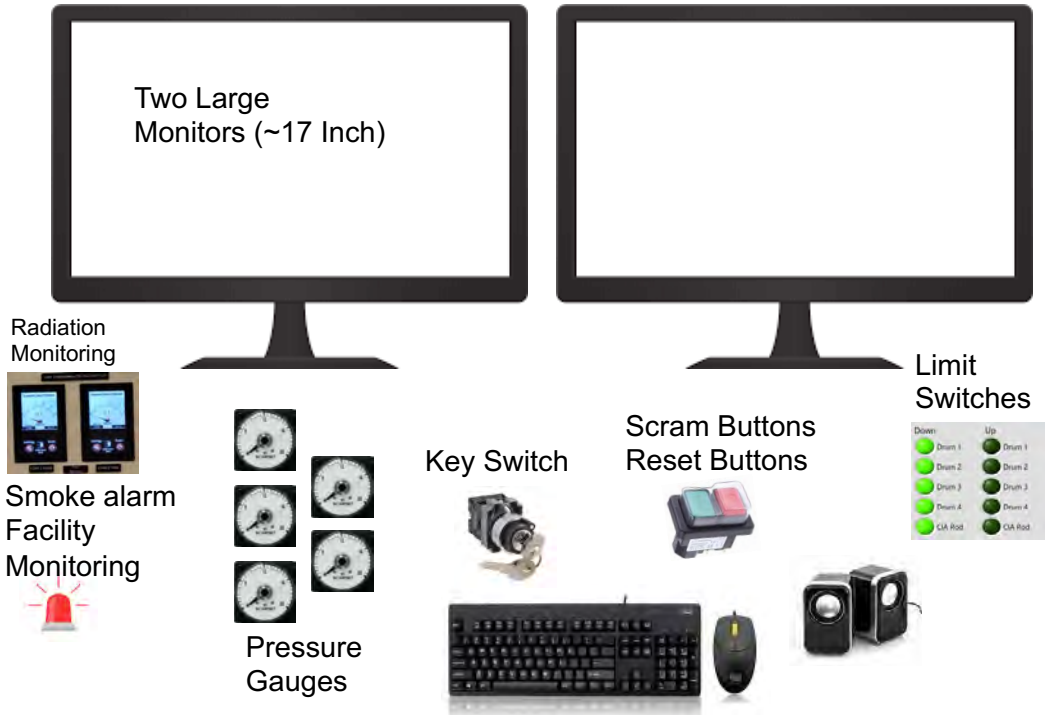






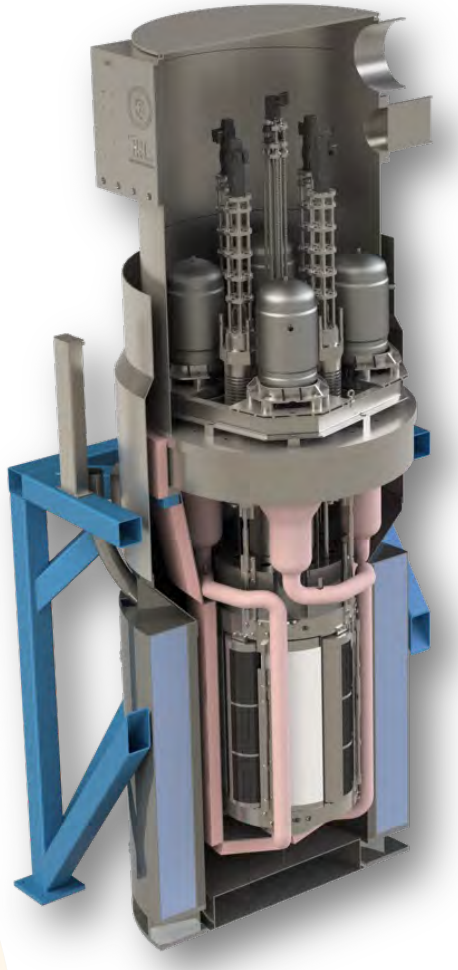
MRP Microreactor Program

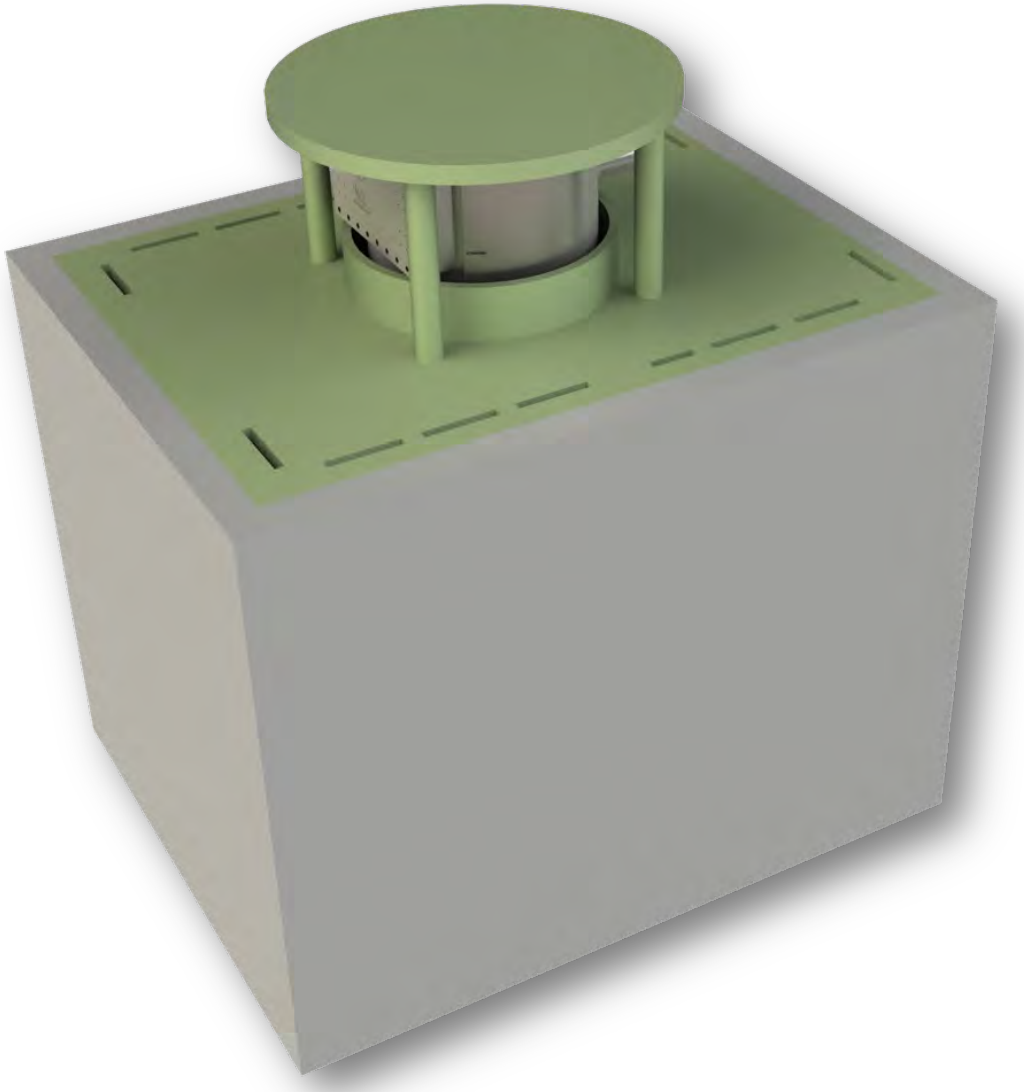
Control Room Layout



MRP Microreactor Program

MARVEL will be complete 90% Construction Summer 2023, and achieve Criticality by Summer 2024





Key Risks:

- **Supply Chain**
- **Fuel Prioritization**
- **Funding Appropriations**

MRP Microreactor Program