(Microreactor Applications Research, Validation & EvaLuation),
2024

MARVEL Technology Review

Fuel and Core System

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Presentation Overview

- Reactor Model Overview
- Fuel and Core System Overview
- Safety Classifications
- Major neutronic analyses or evaluations
- MCNP 6.2 V&V
- Final Design Verification
- Questions

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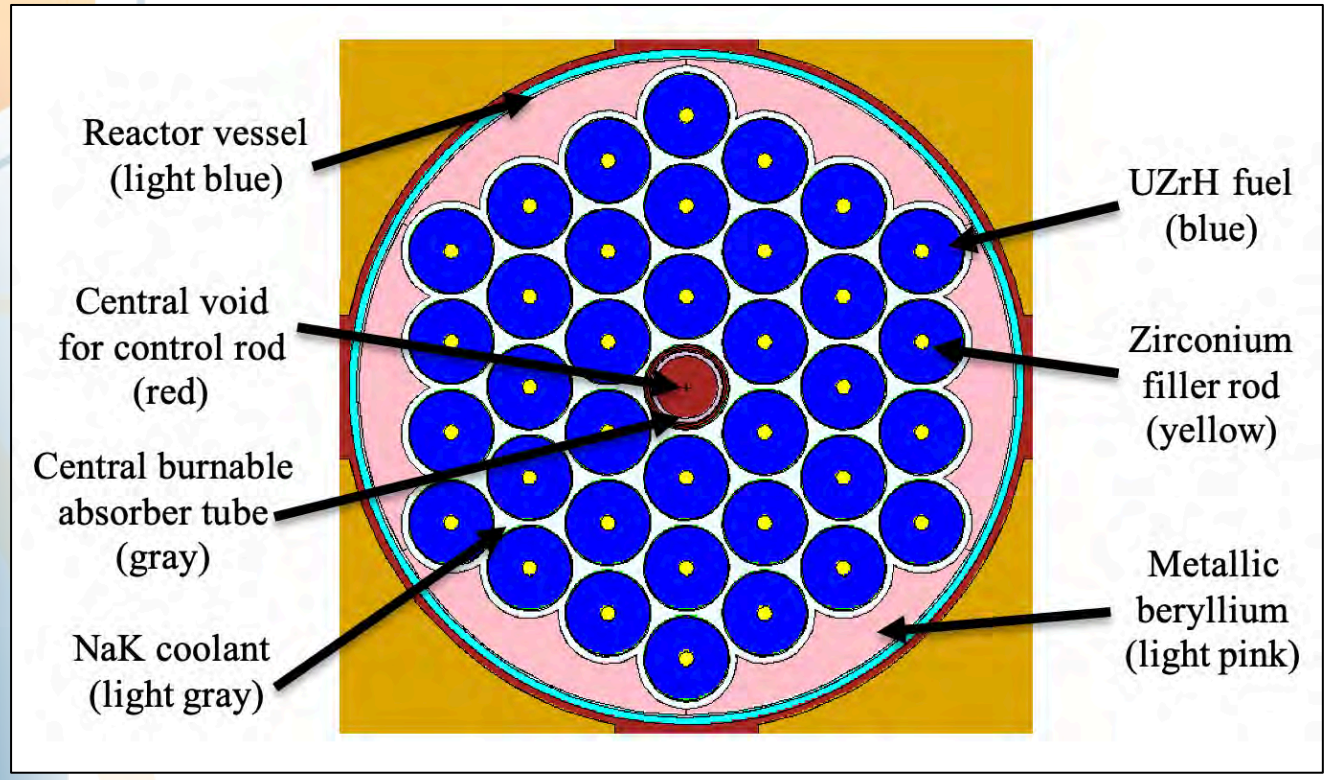
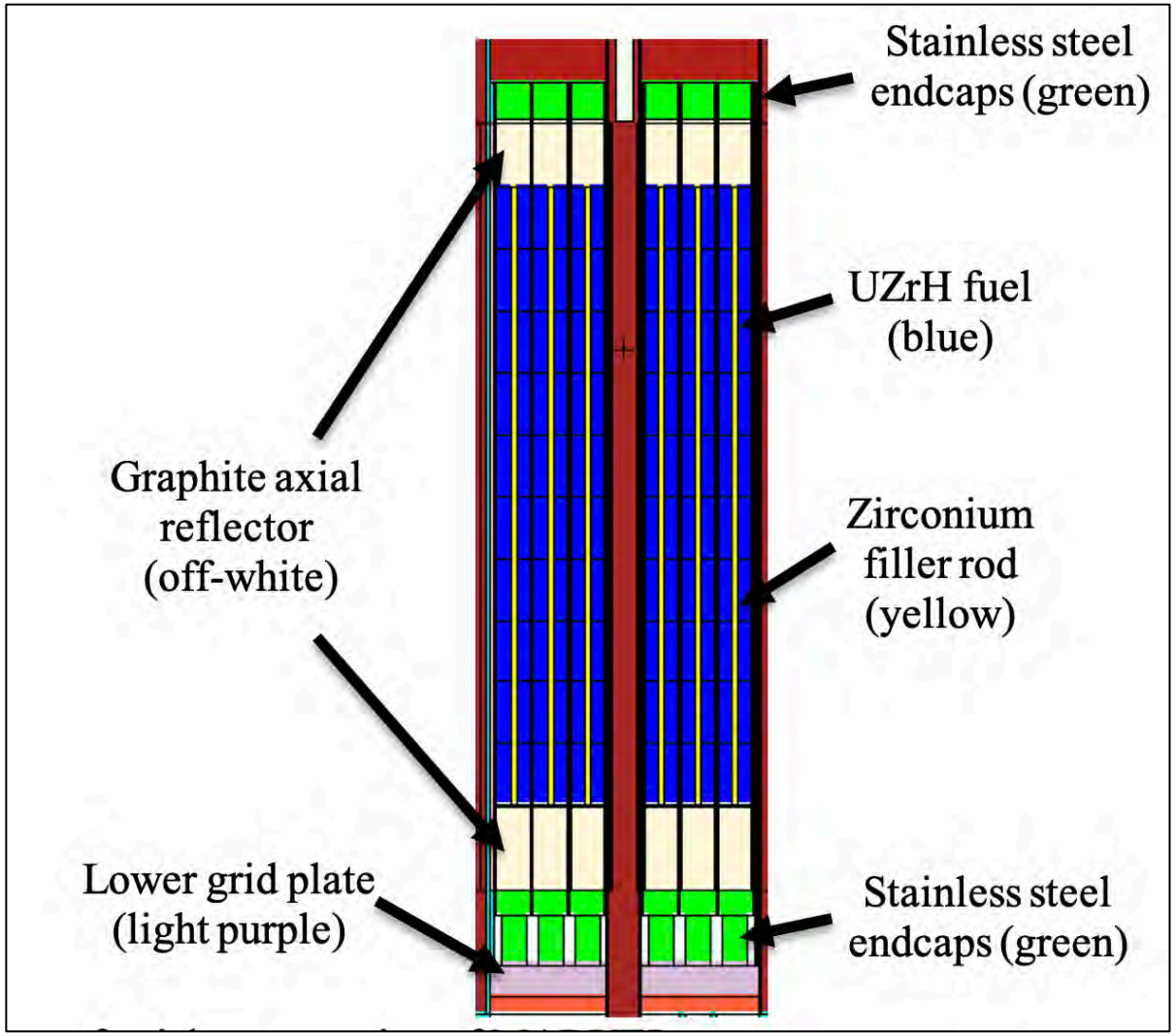
MARVEL MCNP Model





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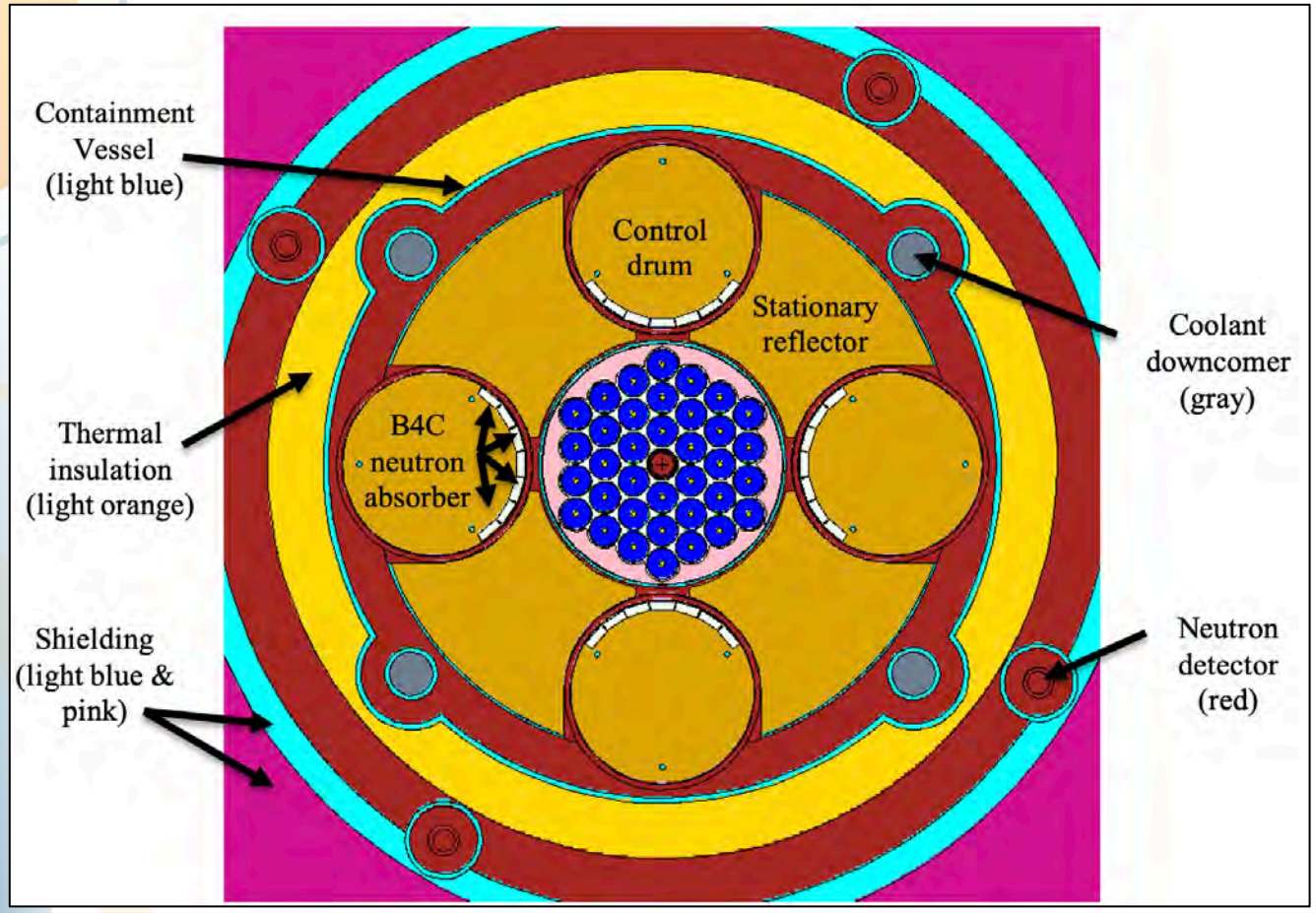
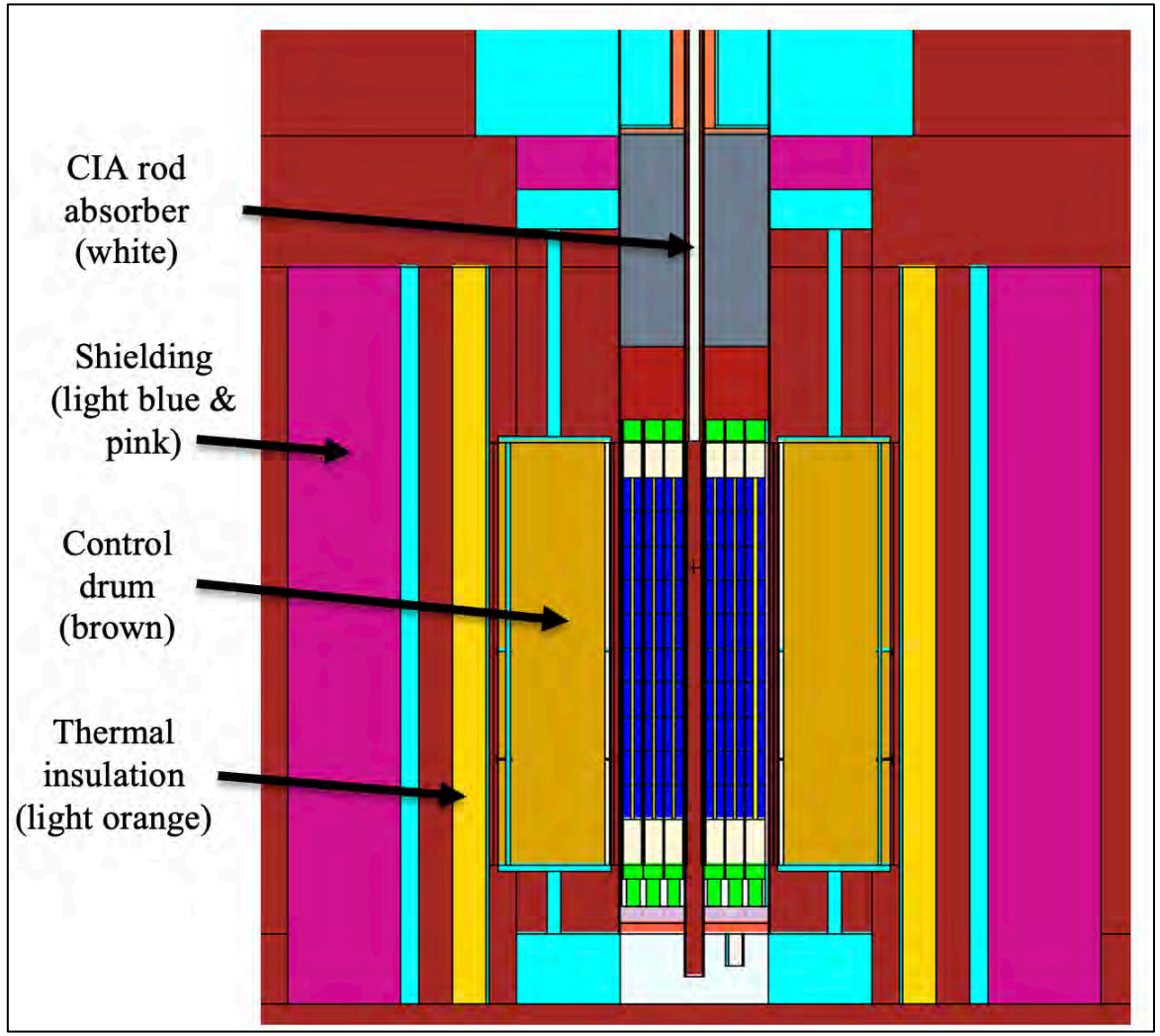
MARVEL MCNP Model





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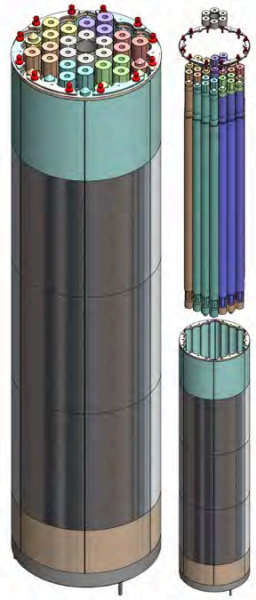
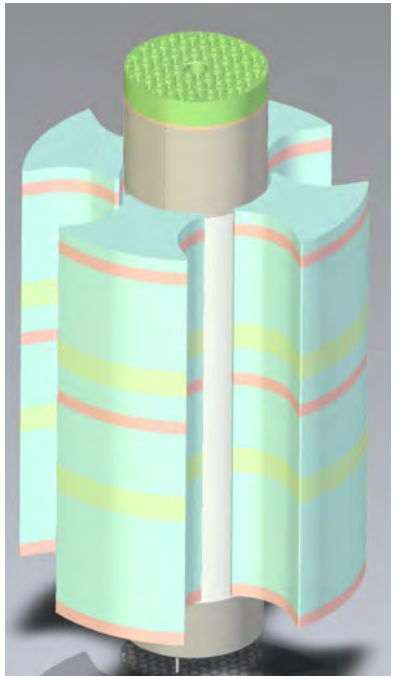
Overview of Fuel and Core System (FCS)

- Includes fuel subsystem (FS), core support structures subsystem (CSS), and stationary core reflectors subsystem (SCR)

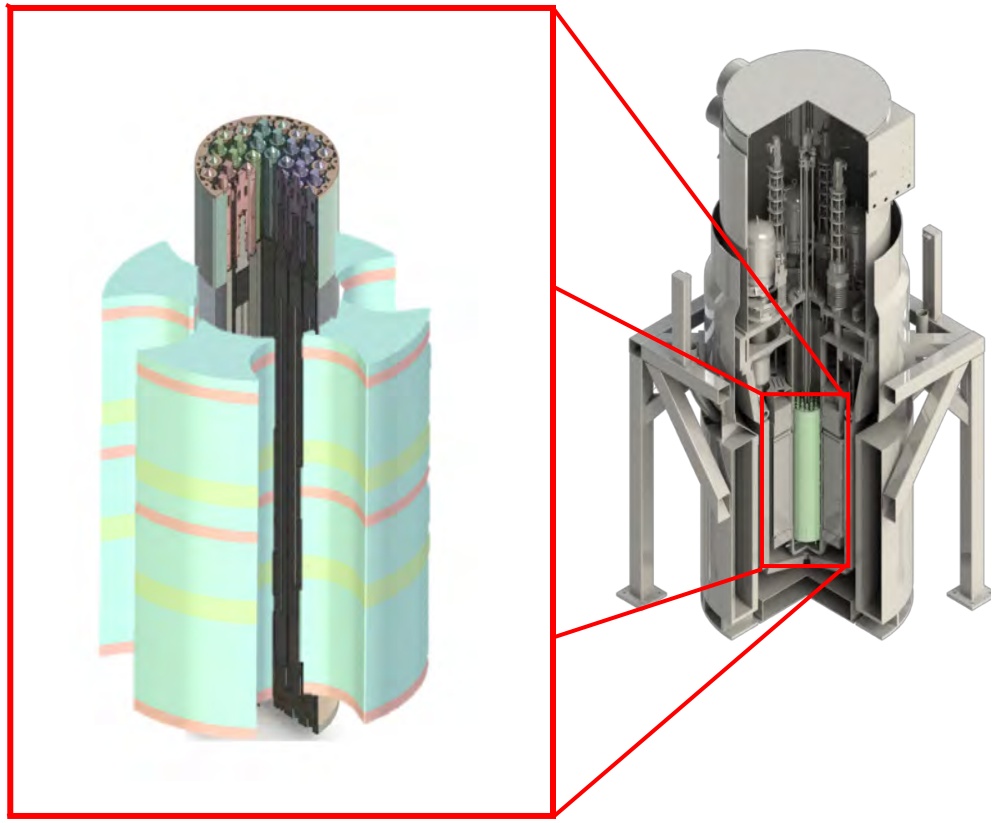
Fuel subsystem



Core support structures



Stationary core reflectors



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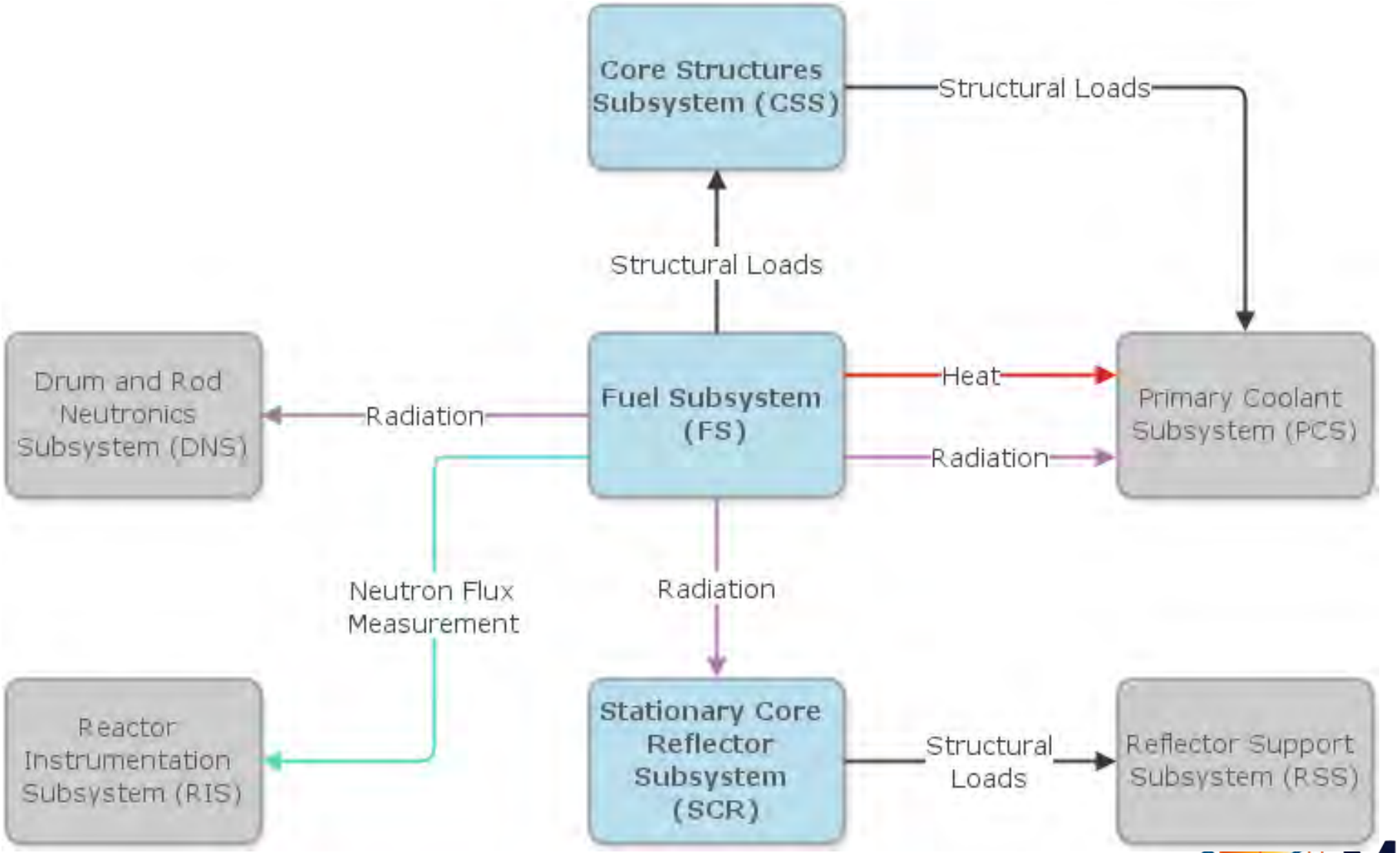
FCS Interfaces



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Safety Significant Component Classification

- **Safety Related (SR)**
  - Fuel subsystem
  - core support structure subsystem
  - stationary core reflector subsystem
- **Common safety functions**
  - Reactivity Control – Passive IRF
  - Heat Removal - Passive heat rejection
  - Core Flow – Natural circulation and coolable geometry
  - Confinement of Radioactive and Hazardous Material Release - Fission product barriers including fuel matrix and Cladding
  - Reactivity Control – CD Insertion

- This determines the level of safety related calculations and required V&V

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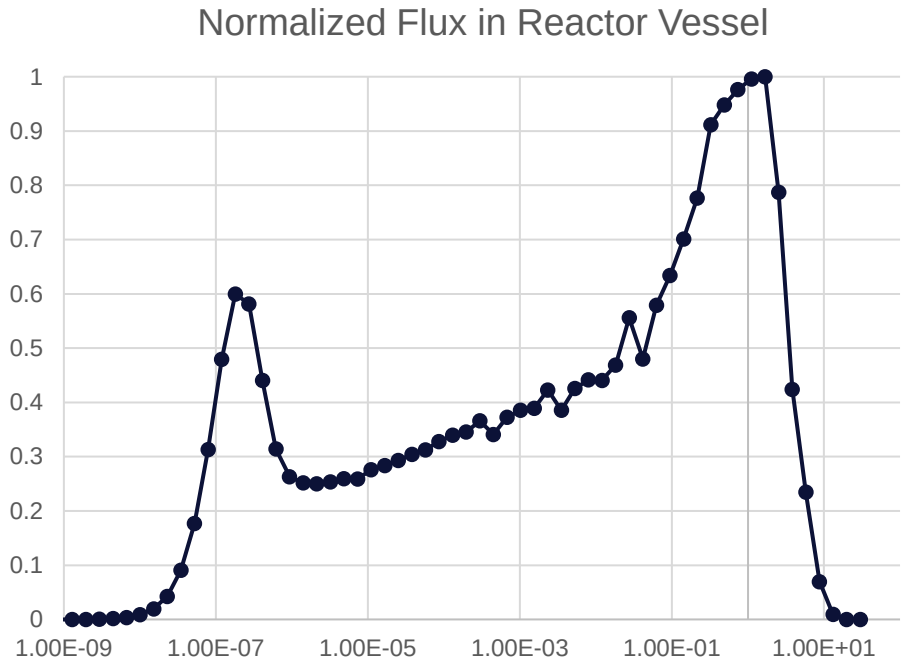
Neutron Flux Spectrum

- Hardened thermal spectrum (or epithermal)
- Fission breakdown by energy
  - 70% from thermal (E<0.625 eV)
  - 26% from epithermal (0.625 eV < E < 100 KeV)
  - 4% from fast (E>100 KeV)



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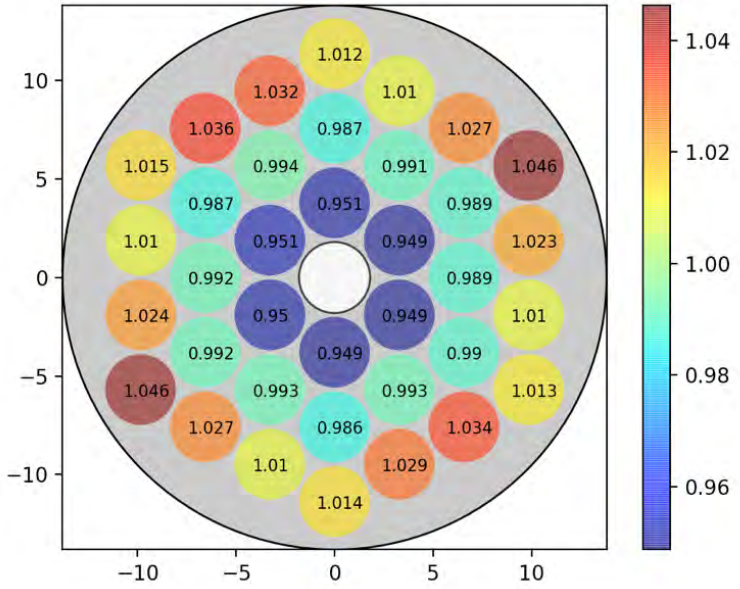
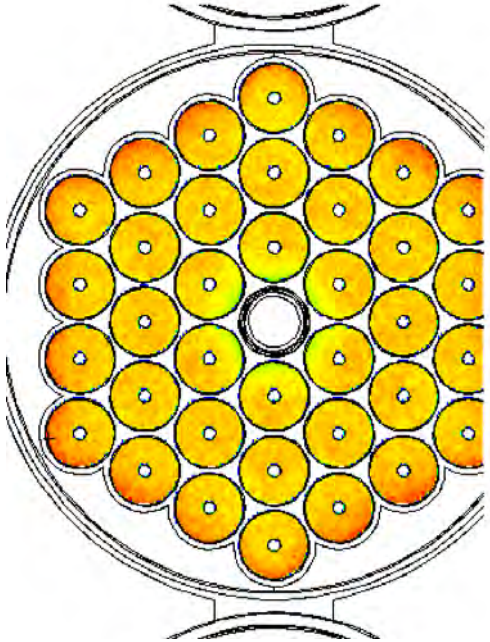
Major Neutronic Analyses

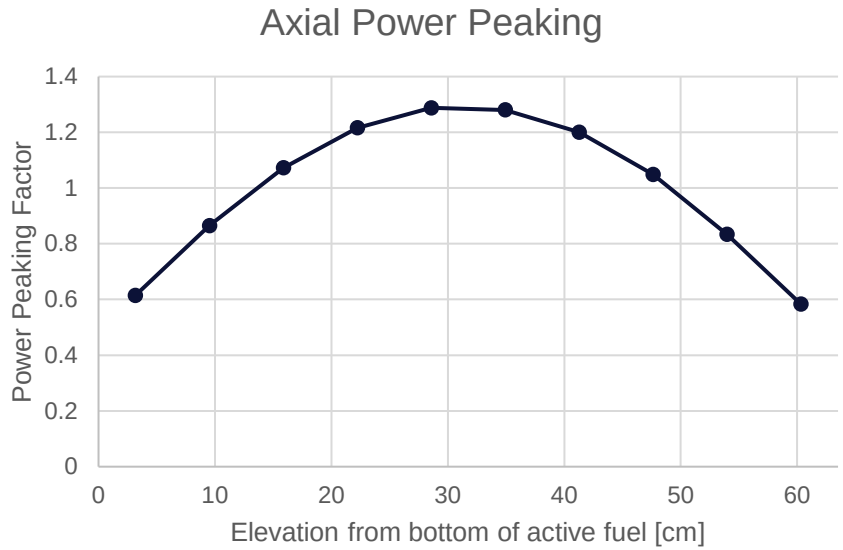
- **2D and 3D rod power peaking factors**
  - Radial: 1.046, Axial: 1.29, 3D: 1.64
- **Temperature reactivity coefficients**
  - Net coefficient: -3.9 pcm/K

	REACTIVITY COEFFICIENT [PCM/K]	1-SIGMA
UZRH FUEL	-5.28	0.15
BERYLLIUM OXIDE	1.26	0.09
METALLIC BERYLLIUM	0.30	0.06
NAK DENSITY	0.16	0.08
PIN PITCH THERMAL EXPANSION	-0.34	0.04

Averaged over 293 K to 1200 K







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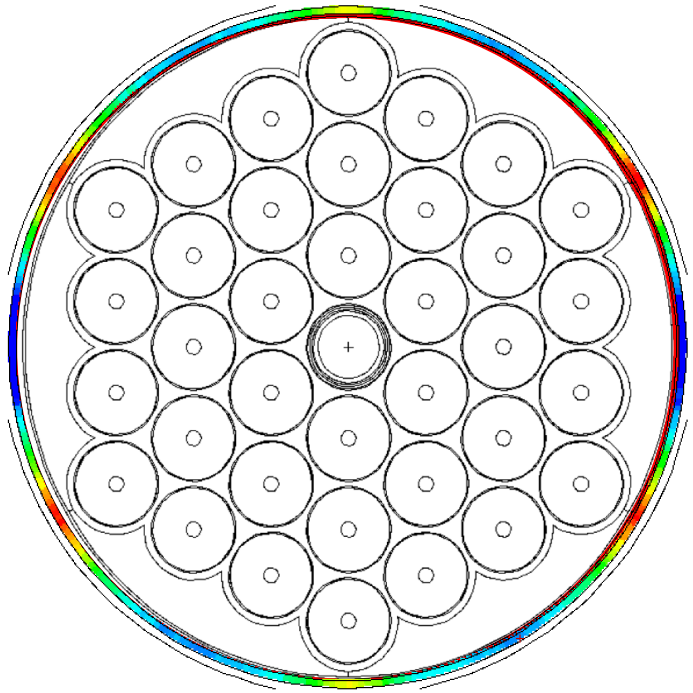
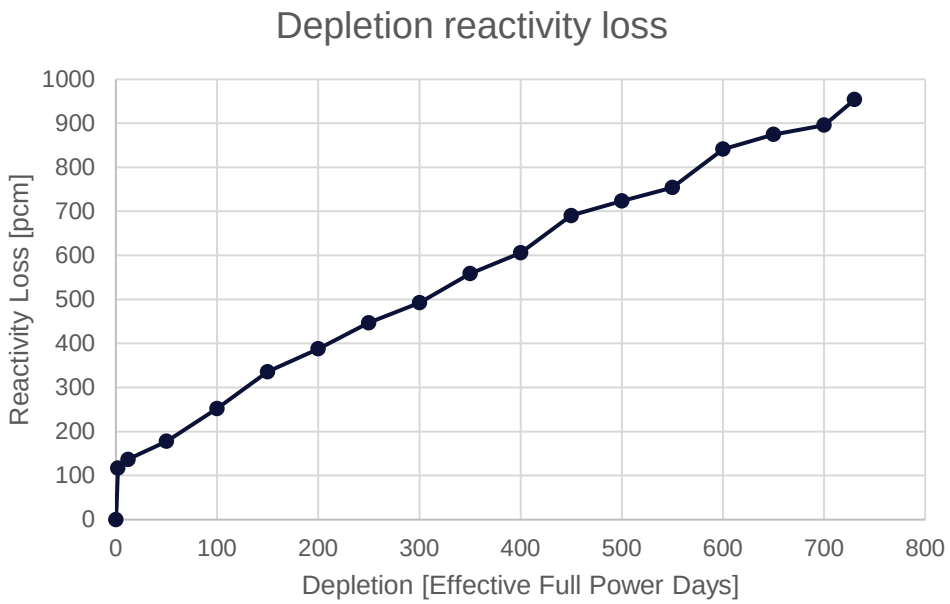
Major Neutronic Analyses Cont.

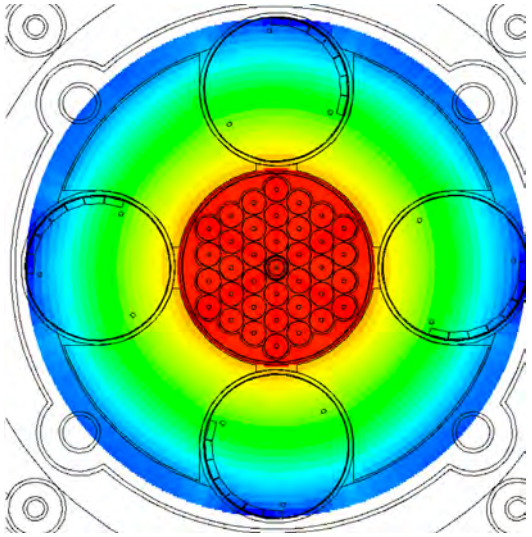
- **Control drum and CIA reactivity worths**
  - ~$4.58 per drum ($18.30 total)(13,727 pcm total)
  - $3.05 (2286 pcm) for the CIA rod
- **Irradiation damage dose**
  - 0.098 DPA peak cladding damage
  - 0.063 DPA peak vessel damage (0.0519 DPA average)
- **Fuel Depletion**
  - Loss of 954 pcm ($1.28) over 2 EFPY
  - Xenon defect of 117 pcm (16¢)
  - Average burnup of 1.47 GWD/MTU
  - Predicted burnup-limited core lifetime: 7.6 EFPY

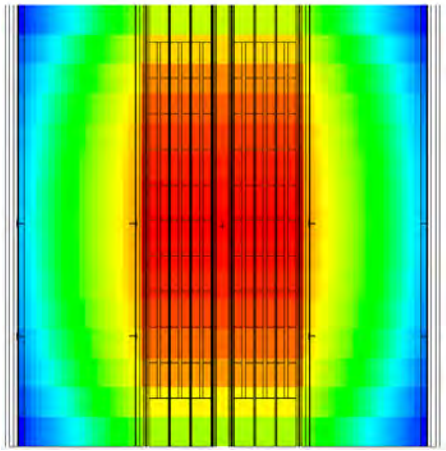


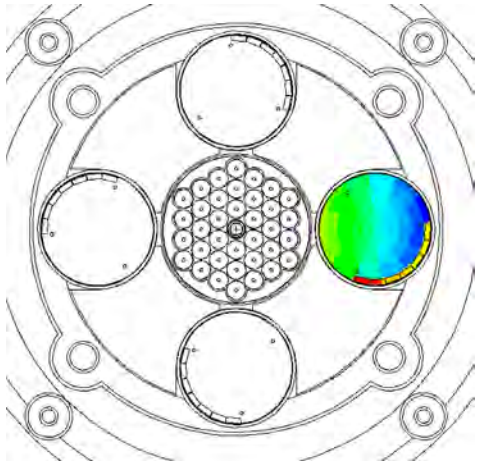


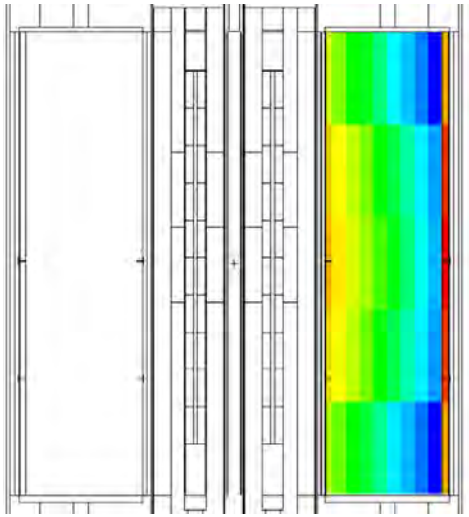
BeO irradiation and neutron+gamma heating

- **BeO irradiation damage**
  - Lifetime fast fluence limit of 2.0×10^{20} nvt from literature
  - Peak lifetime fluence of 6.25×10^{19} nvt
  - Limits swelling to 0.19% and no significant cracking
- **BeO neutron and photon heating**
  - 295 Watts of heating per drum
  - 2400 Watts of heating for all BeO









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MCNP 6.2 V&V on Sawtooth

- **ECAR-7300**
  - Verification and Validation of MCNP 6.2 for MARVEL Neutronic Analysis
- **Safety functions**
  - *Criticality*
    - Verification: 75 benchmarks with analytical solutions
    - Validation: 150 ICSBEP benchmarks, 5 SNAP-10A benchmarks
      - UZrH, Be and BeO reflected, HALEU, Sodium coolant
  - *Shielding*
    - Material cases: Pb, H2O, Poly, Concrete, Steel, W, Zr, Carbon
    - Verification: 78 cases for by code-to-code
    - Validation: 18 benchmark cases – 11 Livermore pulsed spheres

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Final FCS Design Verification

- **Ongoing as-built data to reduce uncertainties as materials are manufactured**
  - U-235 enrichment, uranium loading, H/Zr ratios, BeO densities, etc.
- **As-built data from suppliers**
  - Commercial grade dedication process requires validation and reports of “critical characteristics” from suppliers
    - Material density, impurities, isotopics, geometric dimensions, ASTM standards, etc.
  - To be modeled in MCNP for documented safety analysis
- **Startup testing and zero power physics tests**
  - PLN-6816 “MARVEL Startup Plan"

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FCS Summary

- SSCs and safety functions defined
  - Determines which analyses are safety related and required V&V
- FCS design is stable and evaluated for neutronic safety analysis
- Long lead procurement requests have been submitted for majority of FCS

- Next Steps
  - Finalize PDSA analyses/documentation
  - Incorporate as-built data for DSA as it comes in

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Thank You
Questions?

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