Technology Maturation Conclusions

- As vendors are interested in small reactors for a variety of purposes and nuclear energy becomes a larger portion of the overall energy portfolio in the US as stated by the new Secretary of Energy, Microreactor technology will become increasingly valuable to develop.
- In parallel to building a Microreactor demonstration, other non-nuclear demonstrations, fabrication capabilities, and critical experiments can offer a wealth of knowledge.
- Other technology that needs to be developed includes:
  - fuels (through other programs),
  - safeguards and security,
  - shielding,
  - reflector,
  - control mechanisms,
  - electronics/detectors,
  - power conversion units,
  - thermal energy usage,
  - More.

MRP Microreactor Program

Lunchtime talk: Reactor-related critical experiments at LANL

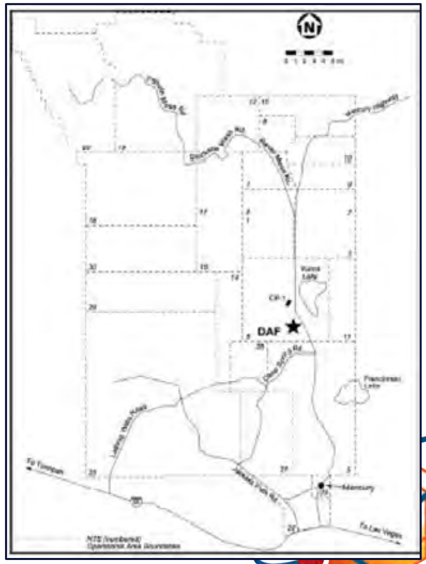
- Hypatia – YH_2 reactivity temperature coefficients
- Deimos – high assay low enriched uranium test bed

MRP Microreactor Program

NCERC is our nation's only general-purpose critical experiments facility and is one of only a few that remain operational throughout the world

- Location: Device Assembly Facility (DAF) at the Nevada Nuclear Security Site (NNSS)
- Operated by: Los Alamos National Laboratory
- NCERC Mission Statement:

  The mission of the National Criticality Experiments Research Center (NCERC) is to conduct experiments and training with critical assemblies and fissionable material at or near criticality in order to explore reactivity phenomena, and to operate the assemblies in the regions from subcritical through delayed critical. One critical assembly, Godiva-IV, is designed to operate above prompt critical.

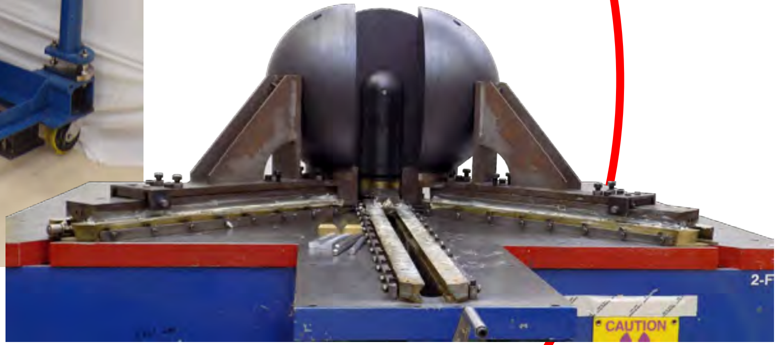


Los Alamos NATIONAL LABORATORY

MRP Microreactor Program

There are four critical assembly machines located in two assembly cell buildings.

Planet



Flat-Top

- Comet

Godiva IV

Can only operate one per building at a time.

MRP Microreactor Program

Planet

- A general-purpose, light-duty vertical-lift assembly designed for flexibility in conducting critical experiments.

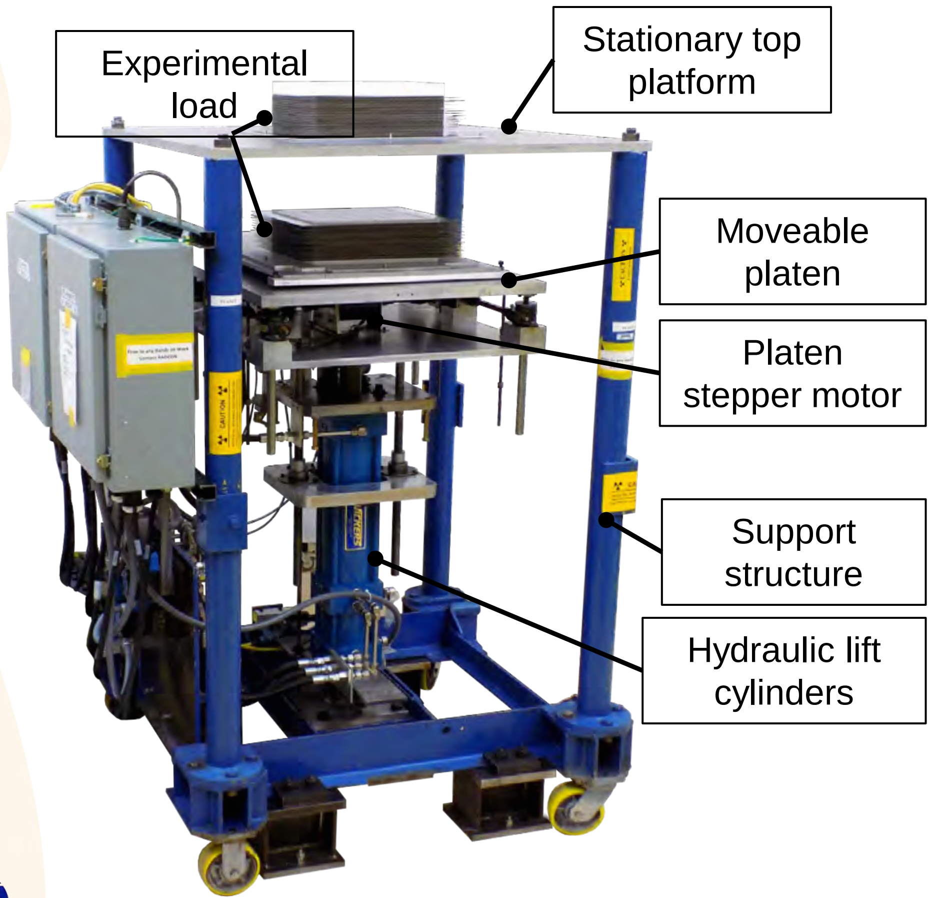
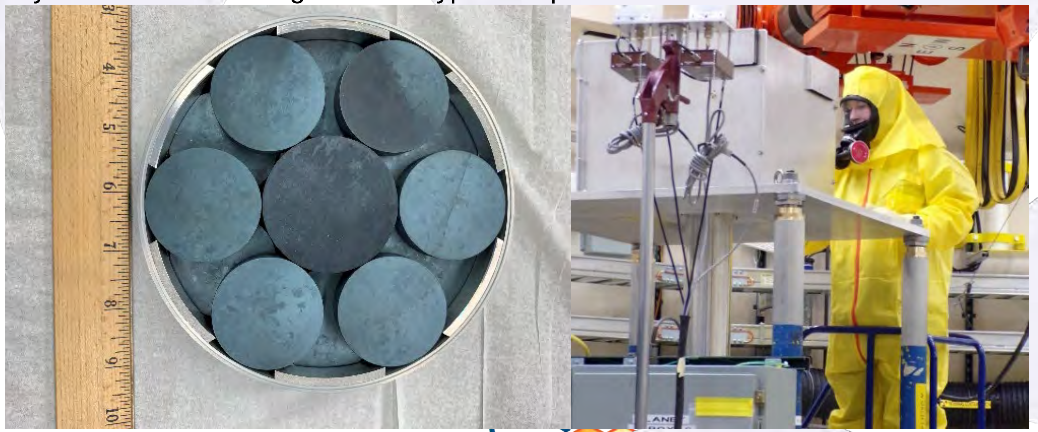


Image editing courtesy of Eloura Phelps, NCERC-FO

- Criticality Safety Training
- International Criticality Experiments Benchmark Evaluation Project

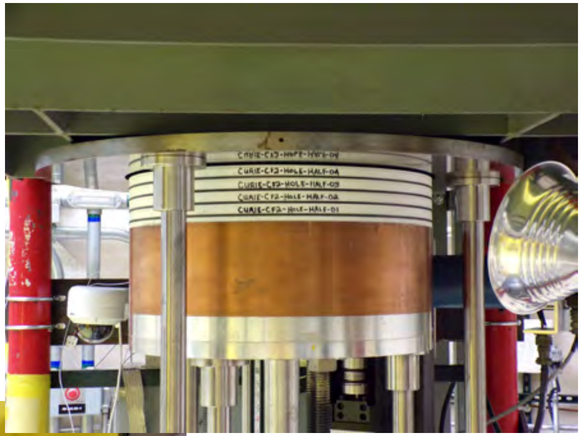
Yttrium Hydride before canning and the Hypatia experiment on Planet for DOE-NE.



MRP Microreactor Program

Comet

- A general-purpose, *heavy-duty* vertical lift assembly designed for flexibility in conducting critical experiments.

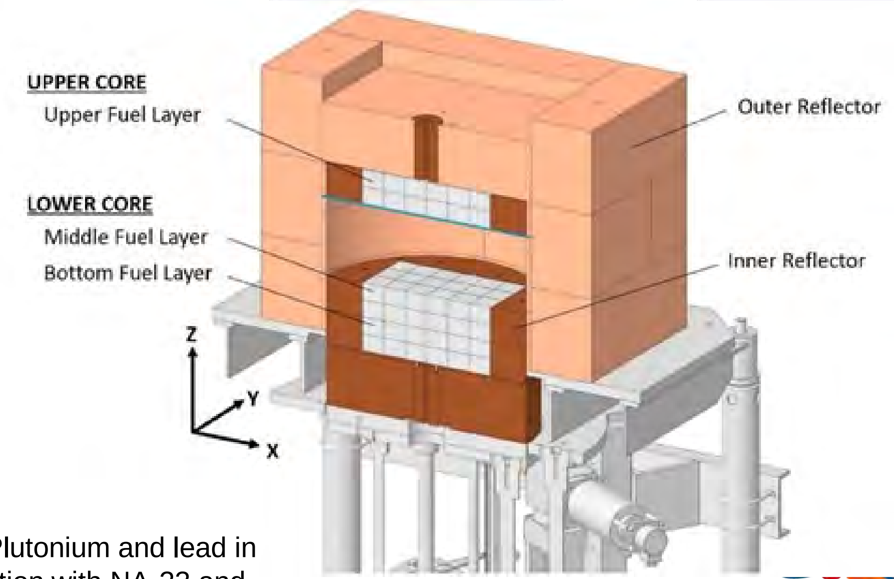


CURIE: Uranium and Teflon to test unresolved resonance region.

- JAEA U-Lead and Pu-Lead
- NASA KRUSTY/Kilopower
- NTNF foil irradiations
- ICSBEP Benchmark Evaluations

KRUSTY collaboration with NASA

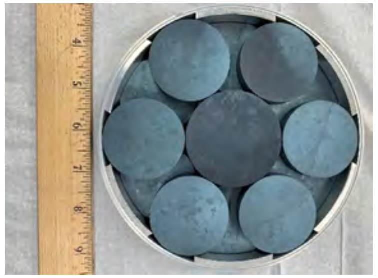
TEX-HEU: Uranium and poly, designed to add Hafnium.



Jupiter: Plutonium and lead in collaboration with NA-23 and JAEA.

Hypatia- $YH_{1.9}$ Integral Experiment

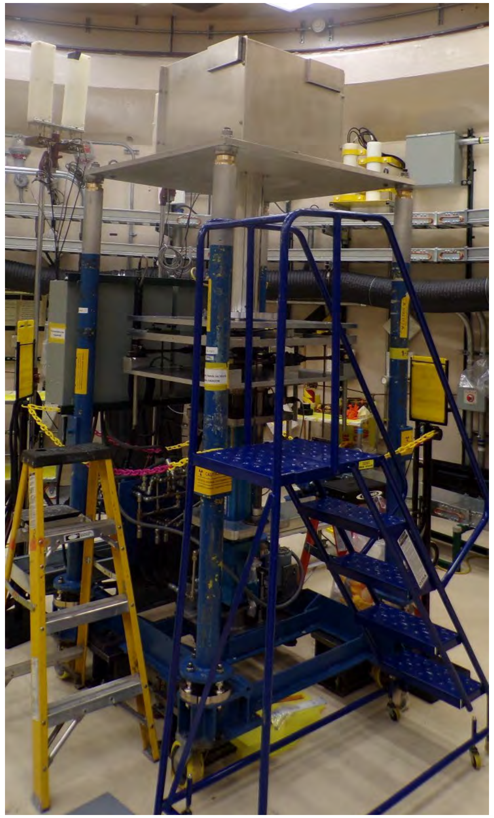
- Conducted at NCERC Jan 11-21, 2021
- Purpose: validate temperature dependent feedback in YH_2 in a critical experiment on Planet
- Use electric heating (no nuclear heating)
- 15 unique measurements, based on two different core column configurations (two and four cans of $YH_{1.9}$)
  - Includes 3 sets of dynamic measurements, which include heating the reflector and instantaneous reactivity feedback.
  - Temperatures at 7 points along the core column via RTDS.



$YH_{1.9}$ discs inside moly can (without welded lid)

Center portion for config 2

LDRD



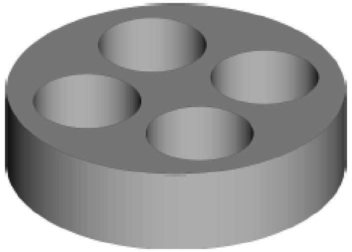
MRP Microreactor Program

Overview

- **Primarily Funded by DOE NE Microreactor Program**
  - Lots of current work on material properties
    - Effects of impurities
    - Hydrogen distribution
    - Fabrication Methods and capabilities
  - Recent Thermal Scattering Law for H-YH_2 in ENDF/B-VIII.0
  - Capability to reduce fuel mass while retaining hydrogen up to ~800 C
- Why
  - No critical experiments for validation
  - Ongoing differential measurements need validation
  - Simulation capabilities for heat testing insufficient
  - Expect Positive Temperature Coefficient
- Demonstrate renewed capability to do electrically heated test at NCERC
- Materials
  - HEU (C-discs)
  - $YH_{1.9}$ canned in molybdenum
    - 2 layers
  - Alumina Heaters and Spacers
  - Beryllium radial reflector

HEU C-disc (before and after)

YH_2 discs pre-canning

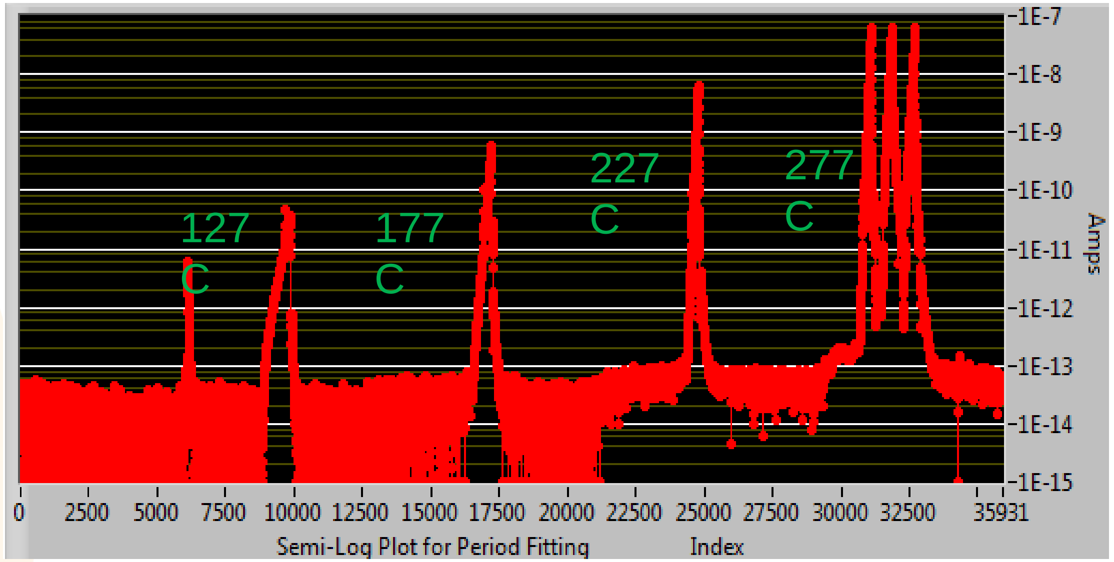


Alumina Spacer

Program

Hypatia Core Column 1 Static Results

Experiment Heater Temp (°C)	Inferred $YH_{1.9}$ Temp (°C)	Measured Reactivity Change from R.T. (cents)	Predicted Reactivity Change from R.T. (cents)
13.0	-	0.00	
85.0	77	3.2	2.9
140.5	127	6.7	7.1
200.0	177	11.4	11.1
260.0	227	13.1	16.0
310.0	277	18.4	18.1



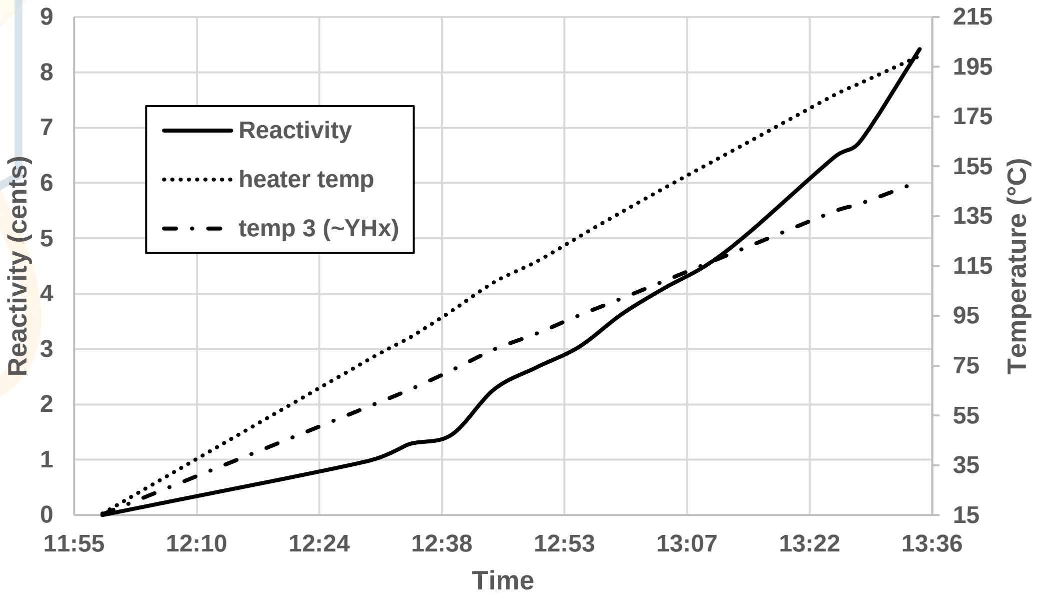
$YH_{1.9}$

106-02 (0.92" DU)	
Graphite (1.6")	
105-2 (0.92" Be)	
Graphite (0.39")	RTD #1
C-28 (0.47" HEU)	
YH2-2 (1.0")	
C-27 (0.47" HEU)	
Graphite (0.39")	RTD #2
Spacer (1.25")	
Heater 2 (0.5")	RTD #Ambient
C-26 (0.47" HEU)	
YH2-4 (1.0")	
YH2-3 (1.0")	
C-25 (0.47" HEU)	
Heater 3 (0.5")	Controller
Spacer (1.00")	
Graphite (0.39")	RTD #3
C-24 (0.47" HEU)	
YH2-1 (1.0")	
C-23 (0.47" HEU)	
Graphite (0.39")	RTD #4
105-1 (0.92" Be)	
Graphite (1.6")	RTD #5
106-01 (0.92" DU)	

Fuel column without guide tube or RTDs

MRP Microreactor Program

Hypatia Core Column 1 Transient Preliminary Results



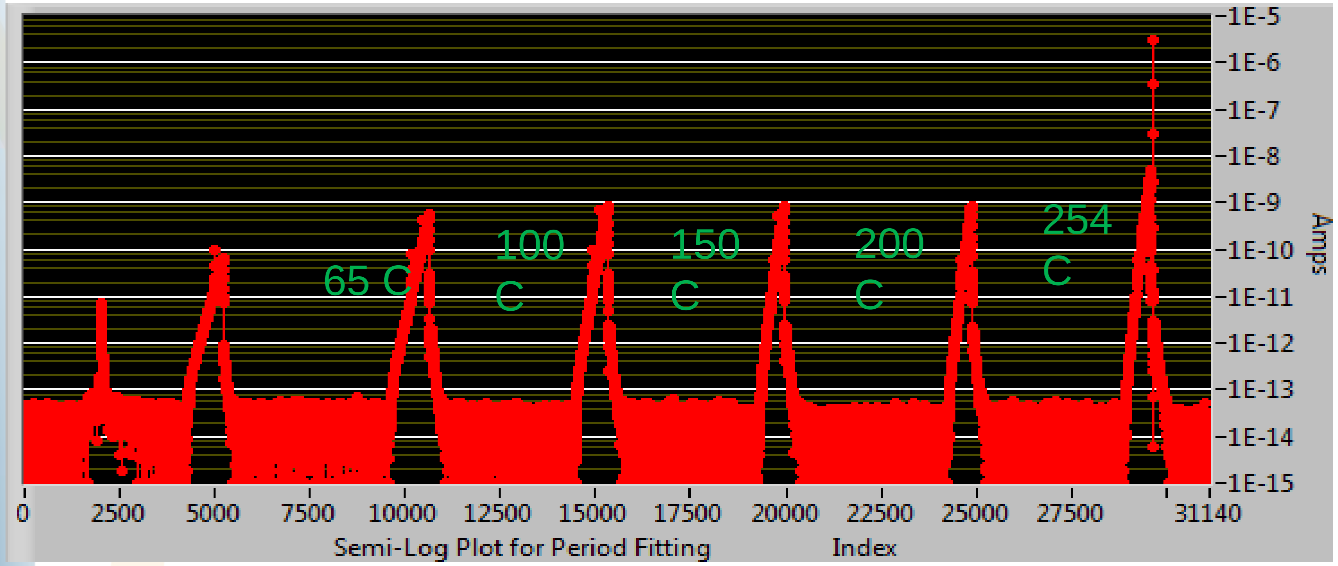
Fuel column guide tube and RTDs

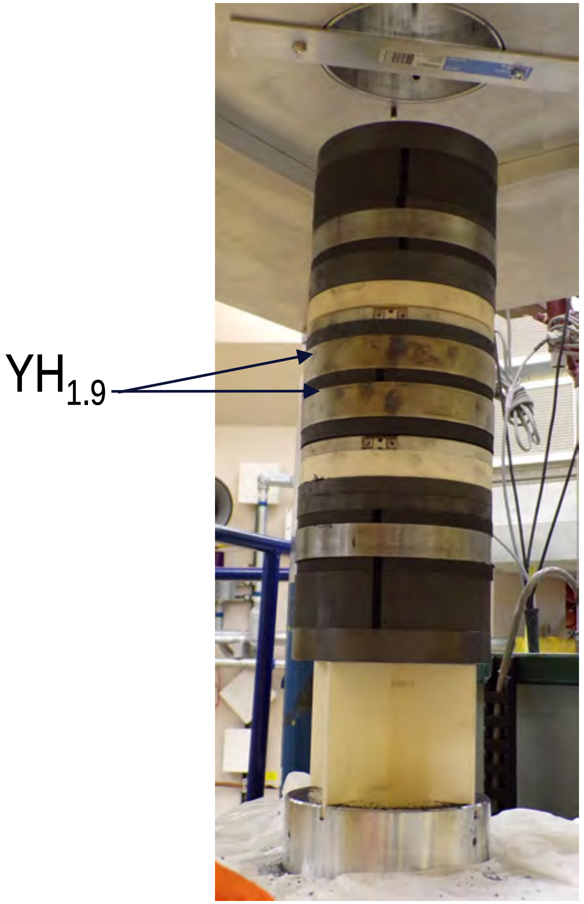
106-02 (0.92" DU)	
Graphite (1.6")	
105-2 (0.92" Be)	
Graphite (0.39")	RTD #1
C-28 (0.47" HEU)	
YH2-2 (1.0")	
C-27 (0.47" HEU)	
Graphite (0.39")	RTD #2
Spacer (1.25")	
Heater 2 (0.5")	RTD #Ambient
C-26 (0.47" HEU)	
YH2-4 (1.0")	
YH2-3 (1.0")	
C-25 (0.47" HEU)	
Heater 3 (0.5")	Controller
Spacer (1.00")	
Graphite (0.39")	RTD #3
C-24 (0.47" HEU)	
YH2-1 (1.0")	
C-23 (0.47" HEU)	
Graphite (0.39")	
105-1 (0.92" Be)	
Graphite (1.6")	RTD #5
106-01 (0.92" DU)	

MRP Microreactor Program

Hypatia Core Column 2 Results

Experiment Heater Temp (°C)	Inferred $YH_{1.9}$ Temp (°C)	Measured Reactivity Change from R.T. (cents)	Predicted Reactivity Change from R.T. (cents)
13.0	-	0.00	-
85	65	1.5	2.1
137	100	3.5	3.7
187	150	5.2	4.9
242	200	6.5	6.3
295	254	7.5	7.4

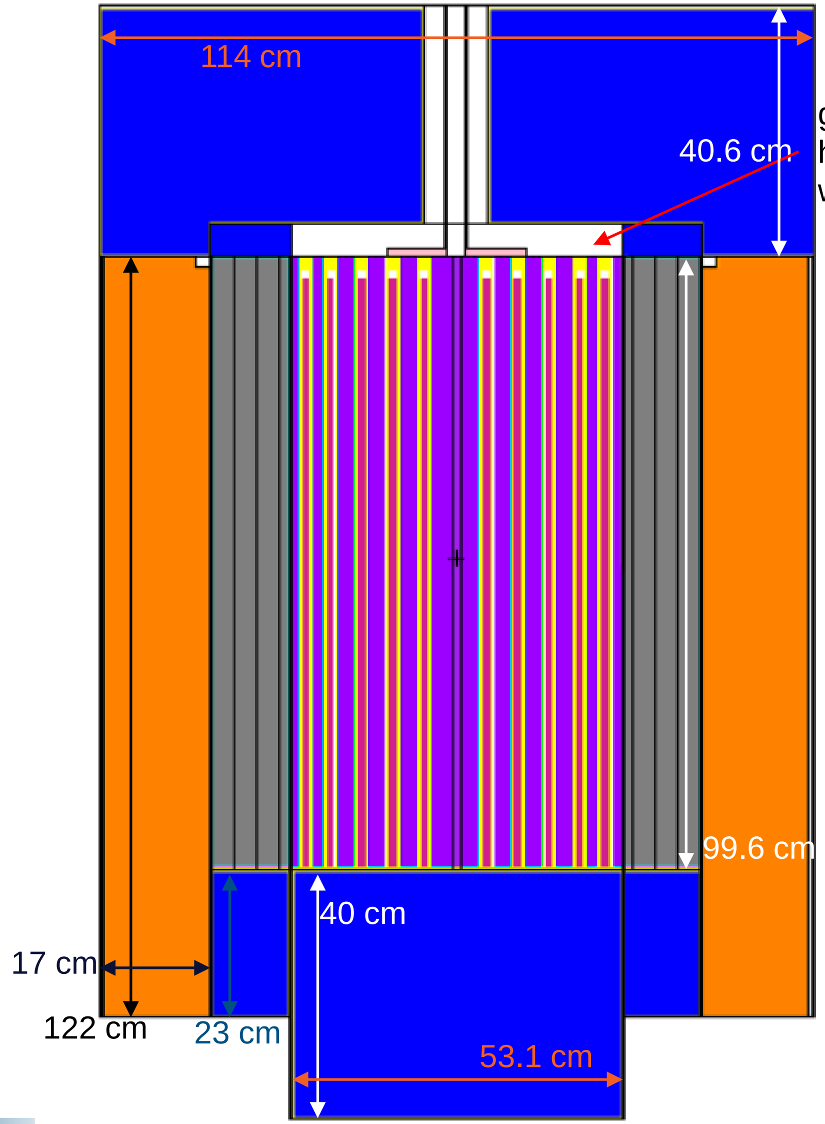


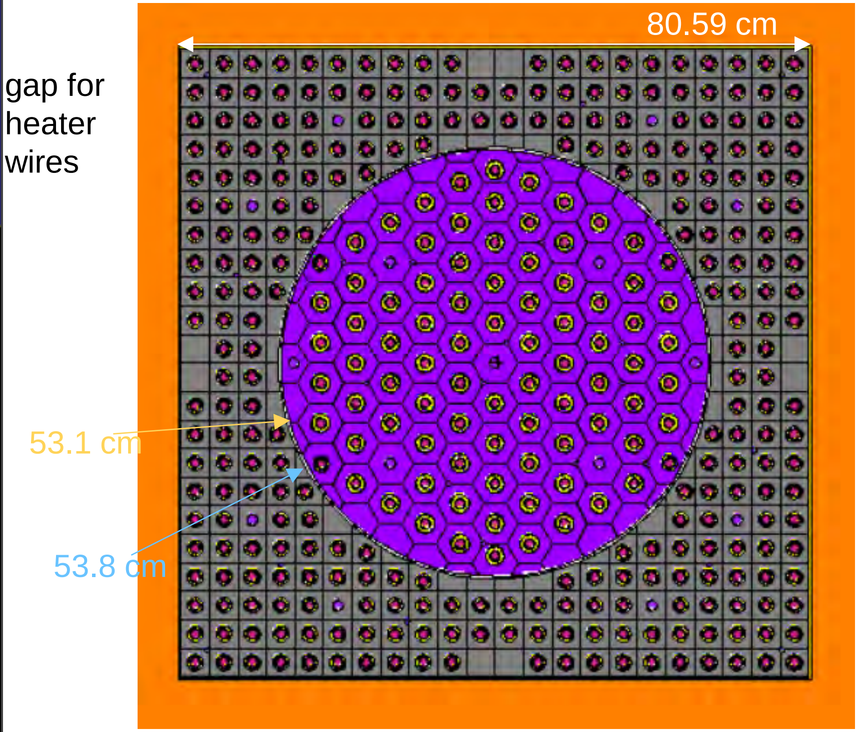


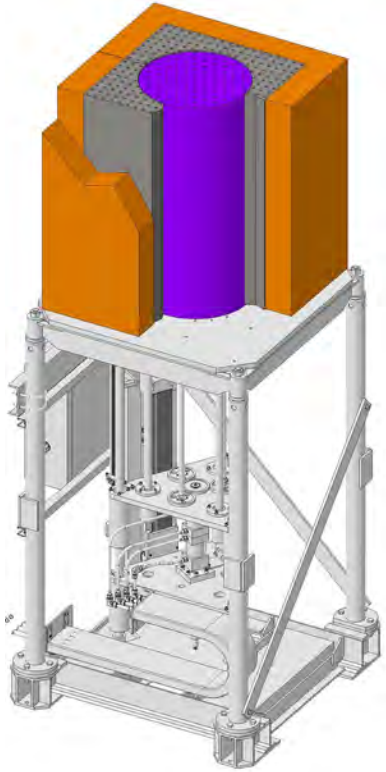
106-02 (0.92" DU)	
Graphite (1.6")	
Graphite (0.39")	RTD #1
105-2 (0.92" Be)	
Graphite (0.39")	RTD #2
C-28 (0.47" HEU)	
C-27 (0.47" HEU)	
Spacer (0.75")	
Heater 2 (0.5")	RTD #Ambient
C-26 (0.47" HEU)	
YH2-4 (1.0")	
Graphite (0.39")	RTD #3
YH2-3 (1.0")	
C-25 (0.47" HEU)	
Heater 3 (0.5")	Controller
Spacer (0.75")	
C-24 (0.47" HEU)	
C-23 (0.47" HEU)	
Graphite (0.39")	RTD #4
105-1 (0.92" Be)	
Graphite (0.39")	
Graphite (1.6")	RTD #5
106-01 (0.92" DU)	

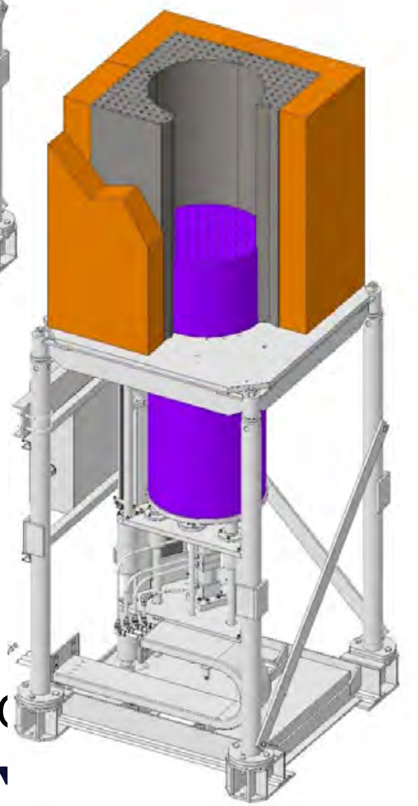
MRP Microreactor Program

Deimos Overall Design – middle purple portion moves up and down for criticality safety with Comet’s vertical lift feature







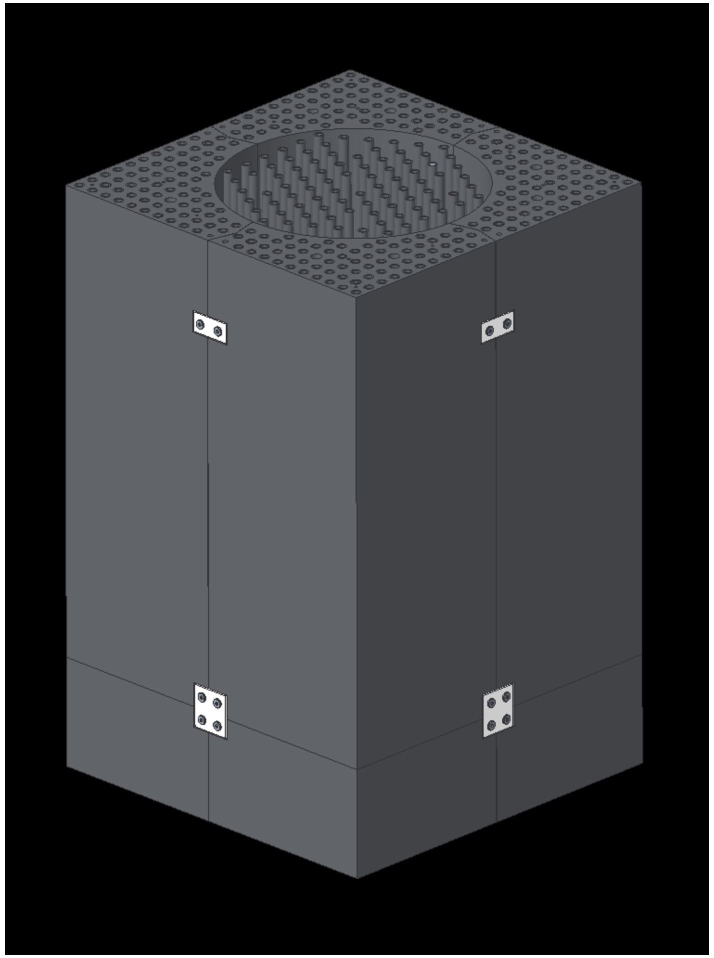


Central portion should be **changeable** for use as testbed **for additional advanced reactor experiments**

Blue – Graphite Axial Reflector; Purple – Center Core Graphite; Gray – Outer Core Graphite; Red – CNPS TRISO fuel in cylindrical cups; Orange – Beryllium Reflector

Deimos Design

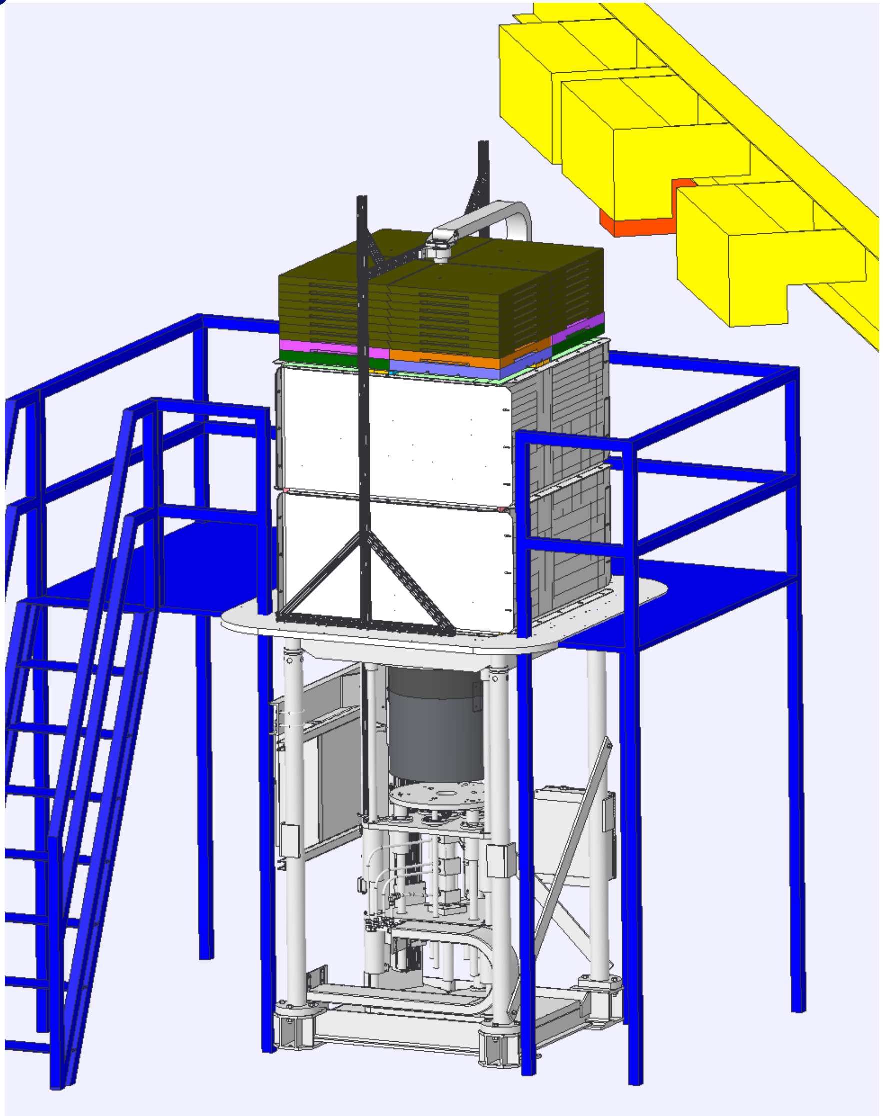
- Graphite monolith reflector in a few primary components
  - Top reflector blocks, four quadrants of radial reflector, bottom axial reflector
  - Tight tolerances on all components
- Radial Reflector components have holes for heaters, fuel, and thermocouples
- Be blocks as radial reflector outside graphite
  - Necessary to achieve a critical configuration
  - Don’t significantly impact neutron spectra
- Central moveable portion is single graphite monolith with holes for heaters, fuel, and thermocouples
- Fuel is CNPS compacts
- Unique design, which has fuel on both the moveable *and* stationary portions



MRP Microreactor Program

System Pictures

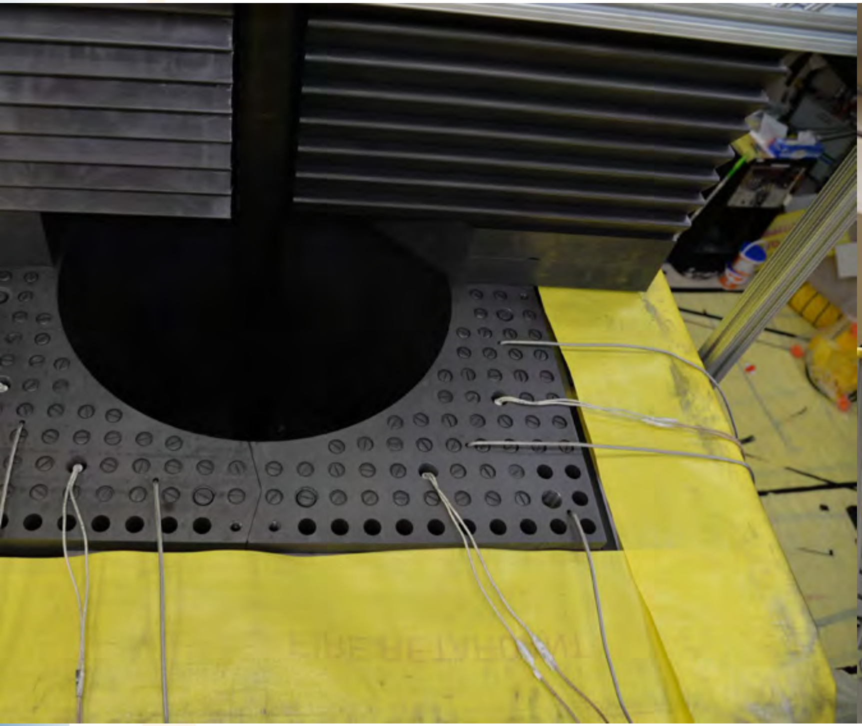
COMET

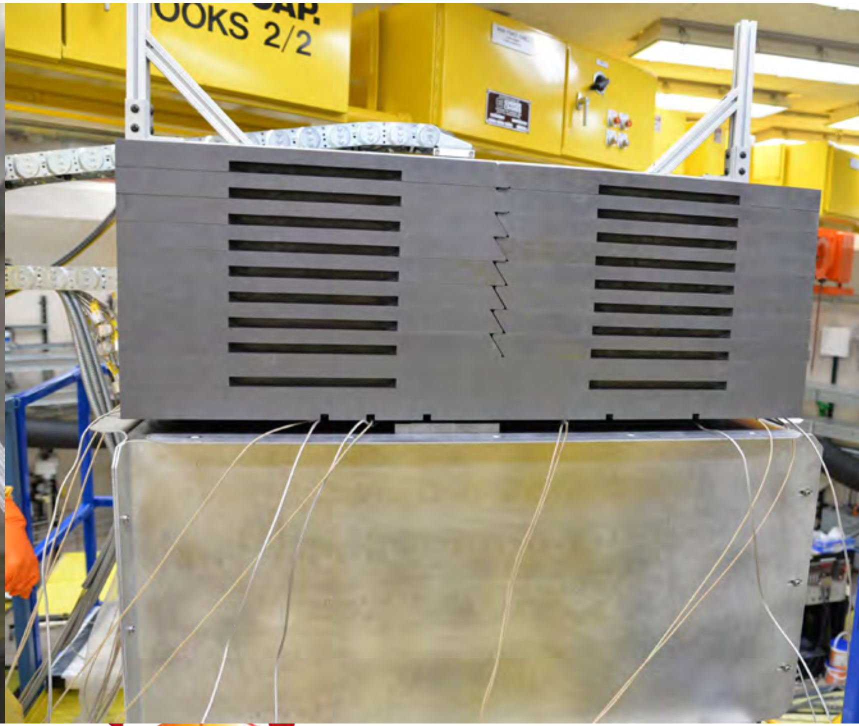


MRP Microreactor Program

Critical Configuration

- 15 Heaters
- 21 Thermocouples
- 298 Fuel Cups





MRP Microreactor Program

Future Work

- Deimos is undergoing benchmarking efforts as part of the DOE/NRC Criticality Safety for Commercial-Scale HALEU (DNCSH) for Fuel Cycle and Transportation project (NE-4)
- More DNCSH Experiments Planned!
  - THETA using Deimos platform
  - eDeimos using Deimos platform with new fuel
  - Terrapower Cl experiment using TEX-U platform

Acknowledgements

- Hypatia was funded by the DOE-NE Microreactor program
- The Deimos experiments are supported by the US Department of Energy through the Los Alamos National Laboratory and the Laboratory Directed Research & Development “Next Generation Small Nuclear Reactors”, 20220084DR.
- NCERC is supported by the DOE Nuclear Criticality Safety Program, funded and managed by the National Nuclear Security Administration for the Department of Energy.