USNC-Tech

Overview of USNC-Tech LEU Fission Power Systems for Space Applications

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USNC-Tech

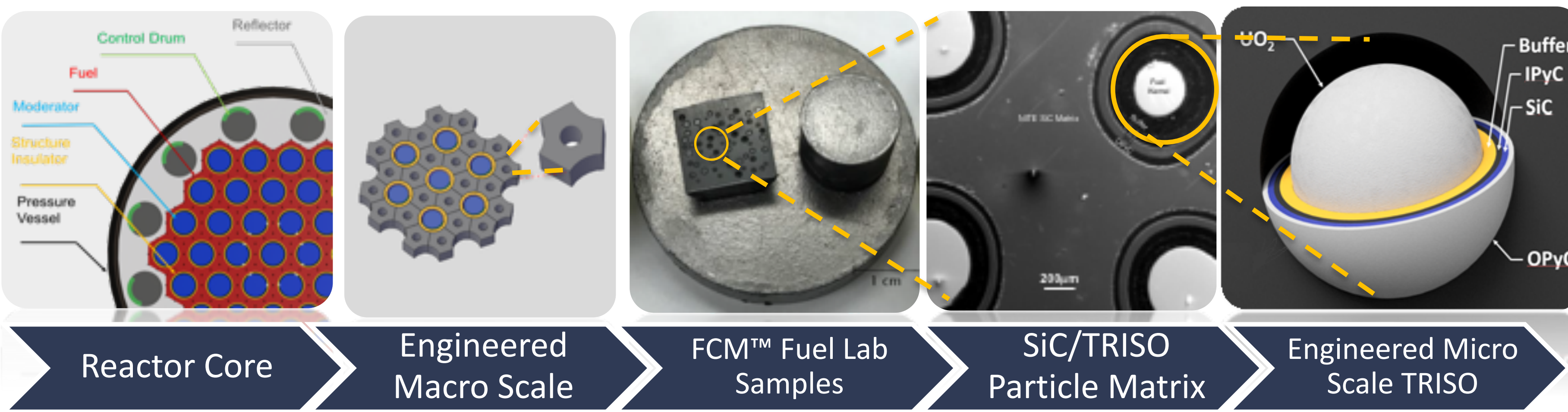
Premier Commercial Space Nuclear Design and Analysis Group in the USA

- First to demonstrate the applicability of Low-Enriched Uranium (LEU) fuel for nuclear thermal propulsion
- Reactor design team responsible for the majority of LEU-NTP concept designs produced for the NASA LEU-NTP program
    - Center for Space Nuclear Research – Research Fellows
    - Aerojet Rocketdyne – Contracted Design Team
    - BWXT – Previously Contracted Design Team
- Conducted criticality experiments and hot hydrogen tests, purchased LEU, and currently producing surrogate fuel samples
- More than 60 space nuclear publications
- Large research collaborator network to address any nuclear development need including fuel, material, hot hydrogen testing, nuclear testing, flow tests, fluid-hydraulics CFD and experiments, and mission analysis

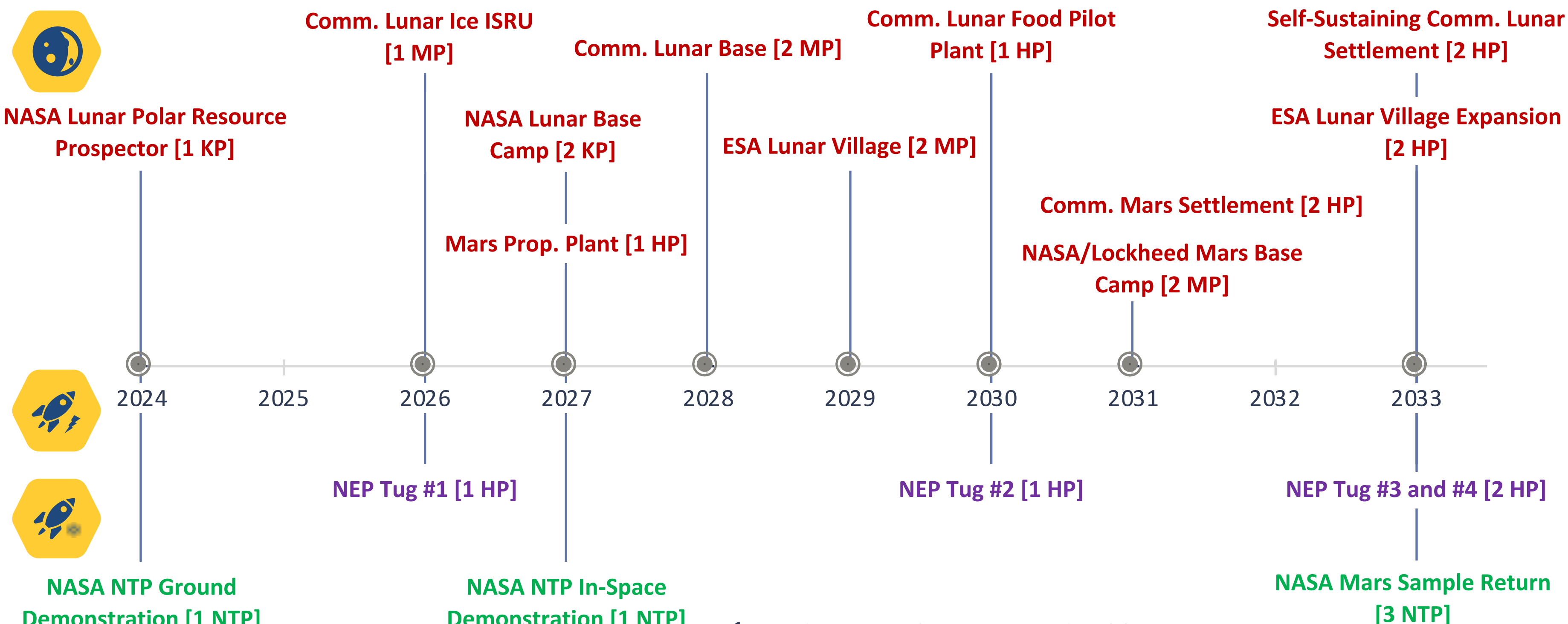
Key Technology/Competitive Advantage – **FCM™ Nuclear Fuel**

Nuclear Fuel is Foundation of The Nuclear System

Fully-encapsulated Ceramic Matrix **(FCM™)** fuel has over 30 million dollars in R&D from the DoE Accident Tolerant Fuels Program. It is **radiation resistant, chemically non-reactive, fully encapsulates fission products, and capable of extremely high temperatures.** FCM™ is a highly engineered fuel built to ensure no release of radioactive material even under accident scenarios. Current SiC FCM™ is capable of operation at temperatures above 1600 K.



Missions Need Nuclear Power and Propulsion Today



[1]Based on open literature and public announcements

USNC-Tech Designs, Develops, and Plans to Build Nuclear Reactors for Commercial Markets and Government Customers

Surface fission power reactor for Earth

Permanent power, mobile power, and industrial heat

MMR™ team is currently licensing first-of-a-kind in Canada

Surface fission power reactor for Space

Power for ISRU, life-support, mining, reprocessing of materials

Nuclear Thermal Propulsion (NTP) reactor

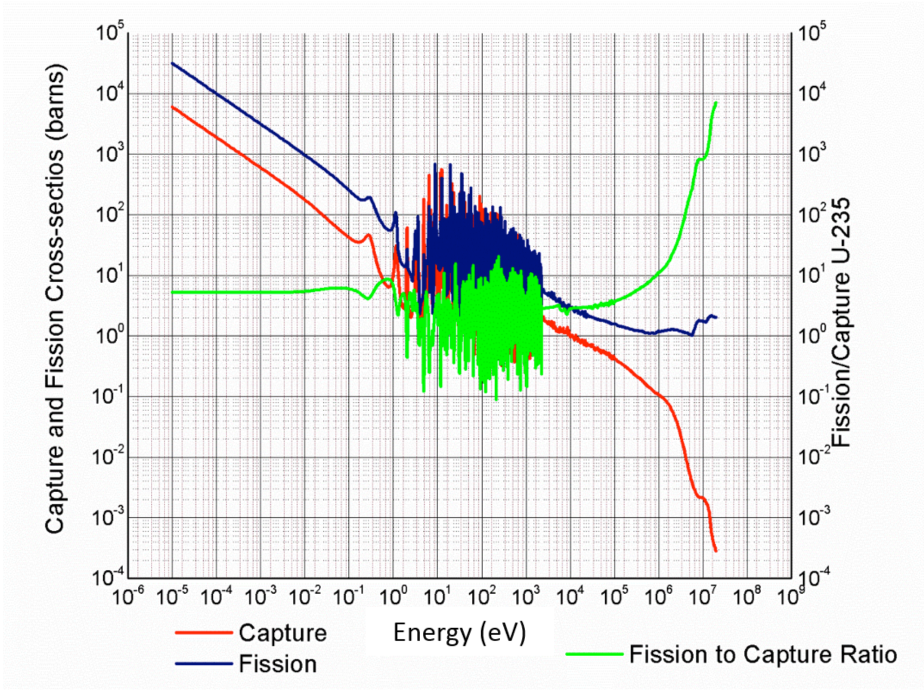
Capable of specific impulse (I_{sp}) of 750 s with growth path to > 900 s

Nuclear Electric Propulsion (NEP) reactor

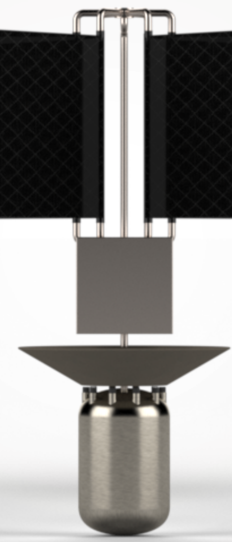
Capable of power density (α) < 20 kg/kW with growth path to < 10 kg/kW

LEU Fuel in Space Nuclear Fission Power Systems

- Increase Uranium Utilization
  - Moderated Spectrums - compensate for lower fissile content, typically rely on high-performance neutron moderators to increase the fission cross-section
- Reduce Parasitic Absorption
  - Use in-core materials that have relatively low neutron absorption cross-sections to prevent neutron absorption in non-fuel materials
- Reduce Neutron Leakage
  - Combination of larger cores with lower volume to surface area ratios and thicker neutron reflectors to prevent neutrons from leaving the system



The Pylon: Surface Fission Power by and for Commercial Space



Near-Term Deployment

- LEU fuel enables commercial product
- Operates at conservative operating temperatures
- Uses existing and well-known materials
- Maximizes ability to use off-the-shelf-components

Designed for Near-Term Space Markets and Applications

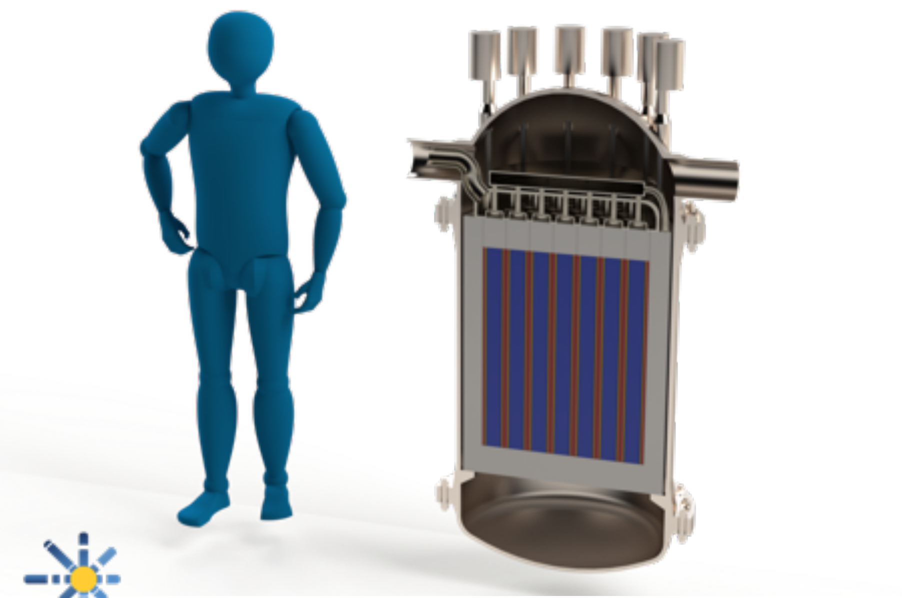
- Scalable design from kW_e to MW_e
- Reactor and system mass viable for near-term lunar landers
  - 150 kWe – 4.5 tons with 30% margin
- Applicable to:
  - ISRU
  - Electrical power
  - Industrial processes

USNC-Tech Pylon Reactor

Conceptual reactors designed with conservative performance and scalable to multiple power levels

Reactor	Reactor Mass (CBE) (kg)	Power level (kWe)	Power per Reactor Mass (We/kg)
PYLON-10	950	10	10
PYLON-150	1,500	150	100
PYLON-1000	3,000	1,000	333

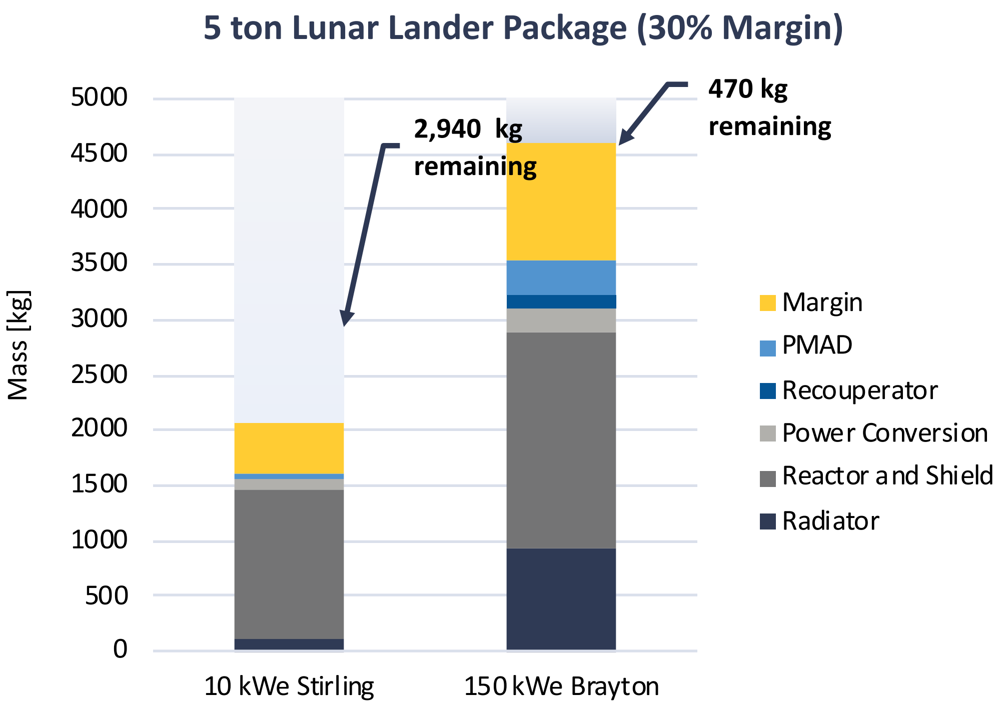
Parameter	Value
Turbine Inlet	1,150 K (875°C)
Life-time	10 years
Uranium Enrichment	19.75 % (LEU)
Fuel Type	FCM™ (coated particle fuel in SiC compact)
Delivery	CLPS Class Lander (Sub-MW)

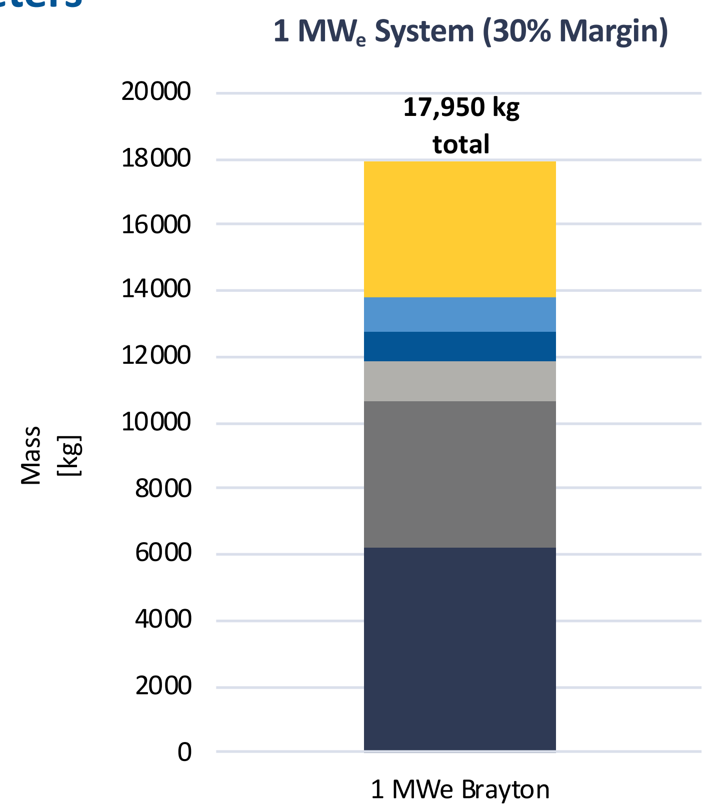


Conceptual design of a 150 kWe Pylon Reactor.

Lunar Pylon System Mass Breakdown

High-performance system with realistic parameters





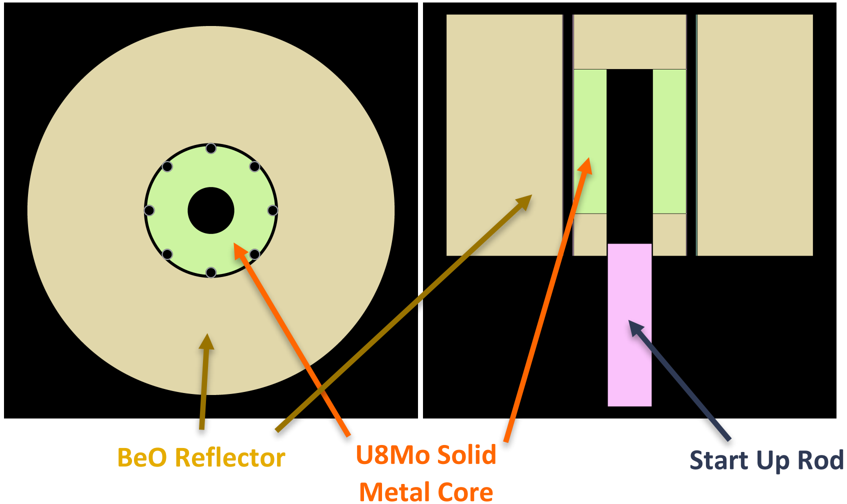
USNC-Tech LEU-FCM™ Fission Power Systems are Competitive

Reactor	Reactor Mass (CBE) (kg)	Power level (kWe)	Power per Reactor Mass (We/kg)	Outlet Temp. (K)	U-235 Enrichment	
PYLON-10	950	10	10	1,150	LEU	USNC
PYLON-150	1,500	150	100	1,150	LEU	
PYLON-1000	3,000	1,000	333	1,150	LEU	
10 kWe KiloPower HEU	235	10	33	~1,000	HEU	DOE and NASA
10kWe KiloPower LEU (U7Mo)	900	10	11	~1000	LEU	
NASA Fission Surface System	439	40	16	850	HEU	
JIMO Reactor	1,060	200	125	1,150	HEU	
KiloPower Derived system	3,000	200	67	~1,000	LEU	
Megapower	22,000	2,000	91	~1,000	LEU	

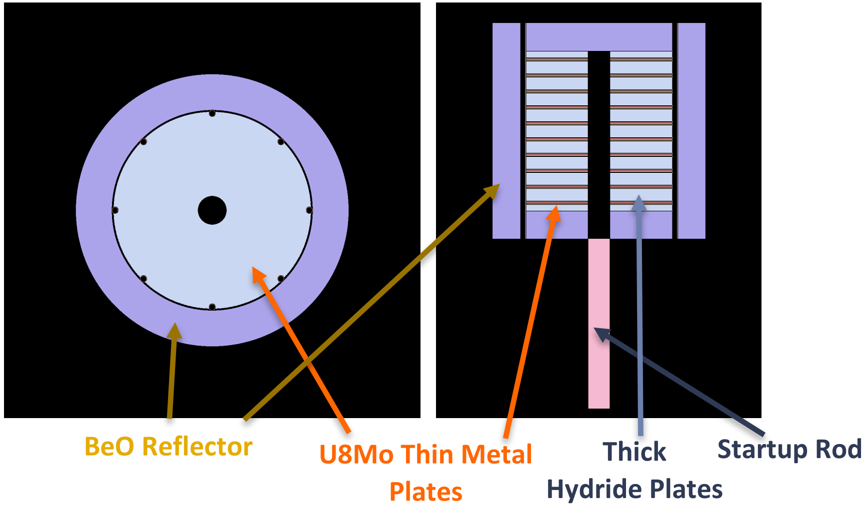
1. David I. Poston, "Reference Reactor Module Design for NASA's Lunar Fission Surface Power System", Proceedings of Nuclear and Emerging Technologies for Space 2009, Atlanta, GA. June 2009
2. National Aeronautics and Space Administration "Prometheus Project final report" 982-R120461
3. Patrick McClure, David Poston "Design and Testing of Small Nuclear Reactors for Defense and Space Applications "Invited Talk to ANS Trinity Section"

HEU and LEU Kilopower Reactor Core and Reflector Geometry

Metal HEU Design



Moderated LEU Design



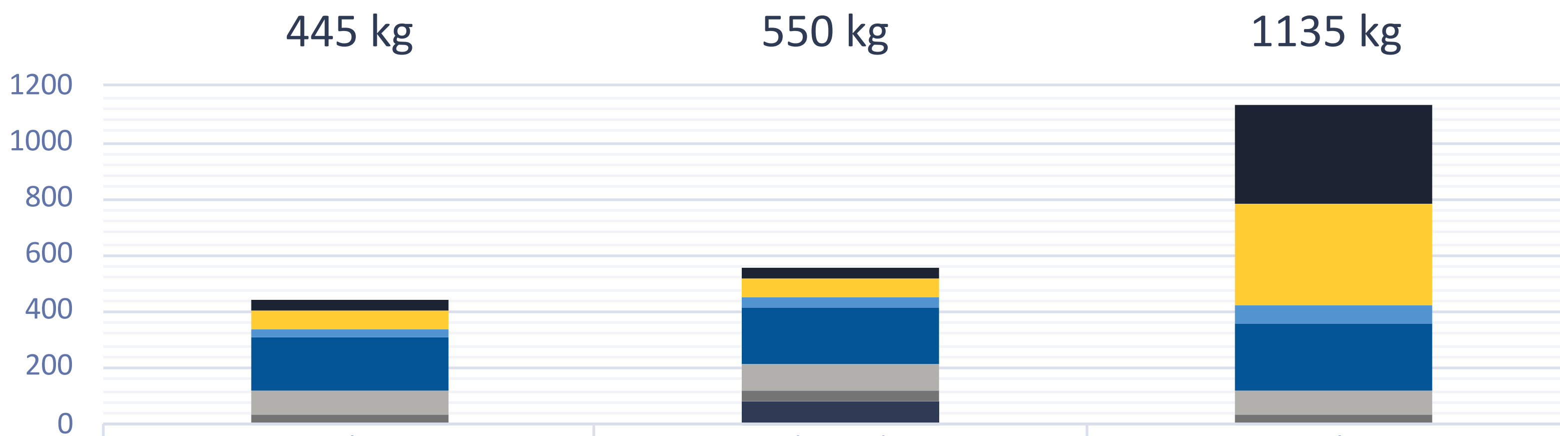
HEU Kilopower Design

- All metal core
- Small core, large reflector
- Relies upon > 90 percent enriched HEU for compact design

LEU Kilopower Design

- Thin Plates of Fuel separated by large plates of metal hydrides
- Large core, smaller reflector
- Relies upon hydrides for compact size

Lunar Configuration Mass Comparison



	Metal HEU	Moderated LEU	Metal LEU
U8Mo Fuel	35	30	350
BeO Reflector	74	74	360
Components	25	35	70
Shielding	185	200	230
Power Conversion	90	90	90
Reflector	35	44	35
Moderator	0	79	0

D. Poston, "Kilopower Reactors for Potential Space Applications," NETS 2019, http://anstd.ans.org/NETS-2019-Papers/Track-4--Space-Reactors/abstract-96-0.pdf

M. Gibson, "Development of NASA's Small Fission Power System for Science and Human Exploration," Tech. Rep. GRC-E-DAA-TN16225, https://ntrs.nasa.gov/search.jsp?R=20140017750

M. Herring, "*Small Modular Fission Reactors for Space Applications,*" NETS 2019, *http://anstd.ans.org/NETS-2019-Papers/Track-4--Space-Reactors/abstract-119-0.pdf*

D. Poston, P. McClure, "Use of LEU for a Space Reactor", Los Alamos National Laboratory LA-UR-17-27226 (2017)

Considerations for Designing Space Fission Power Systems

Performance	Manufacturability	Affordability	Commercialization
- Reliably provide power for desired time period - Meet mass and volume requirements	- Can be made at needed scale and quantities - Reliable supply chain	- Needs to be affordable in terms of money as well as time to implementation	- Private companies need to be able to make a business case

Final Technical Thoughts for Discussion

- Above ~100 kWe, HEU and LEU fission power systems have similar performances characteristics.
  - With some further work, we believe that moderated LEU Kilopower systems can be comparable to HEU Kilopower at lower power levels as well.
- HEU fuel enables fast spectrum systems at lower power levels
- Commercial systems need to be commercially viable and be able to close the business case for their development.
- The reliability of the fuel supply is a key concern for scalable power systems.
- Manufacturability of high-performance moderators (ZrH, Be compounds) are a key development goal to enable LEU systems.

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Thank You

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