NASA's Fission Surface Power (FSP) Project

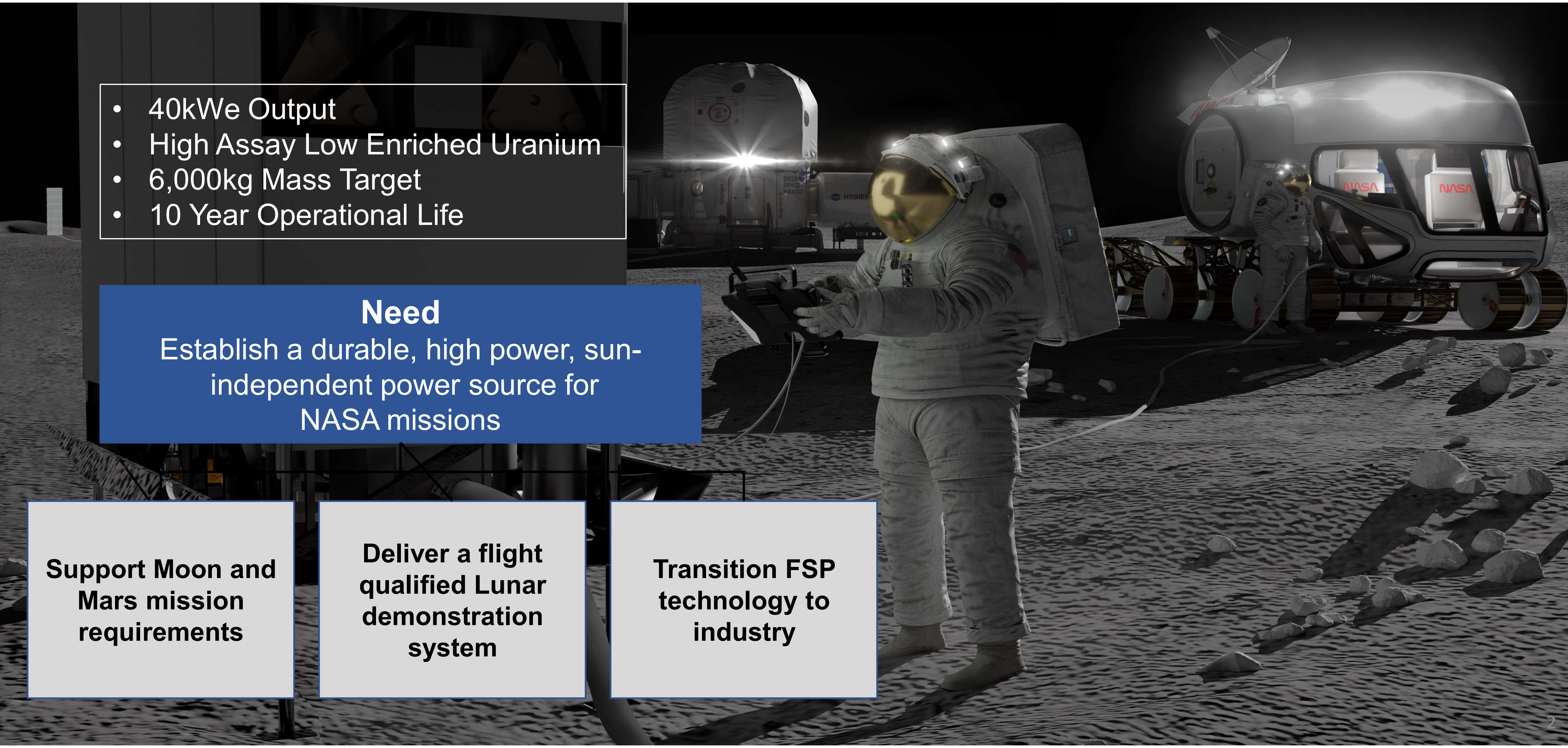
NASA Glenn Research Center

Project Manager: Lindsay Kaldon

NASA Advisory Council (NAC)

5 Sept 2024

FSP Goals/Objectives



- 40kWe Output
- High Assay Low Enriched Uranium
- 6,000kg Mass Target
- 10 Year Operational Life

Need

Establish a durable, high power, sun-independent power source for NASA missions

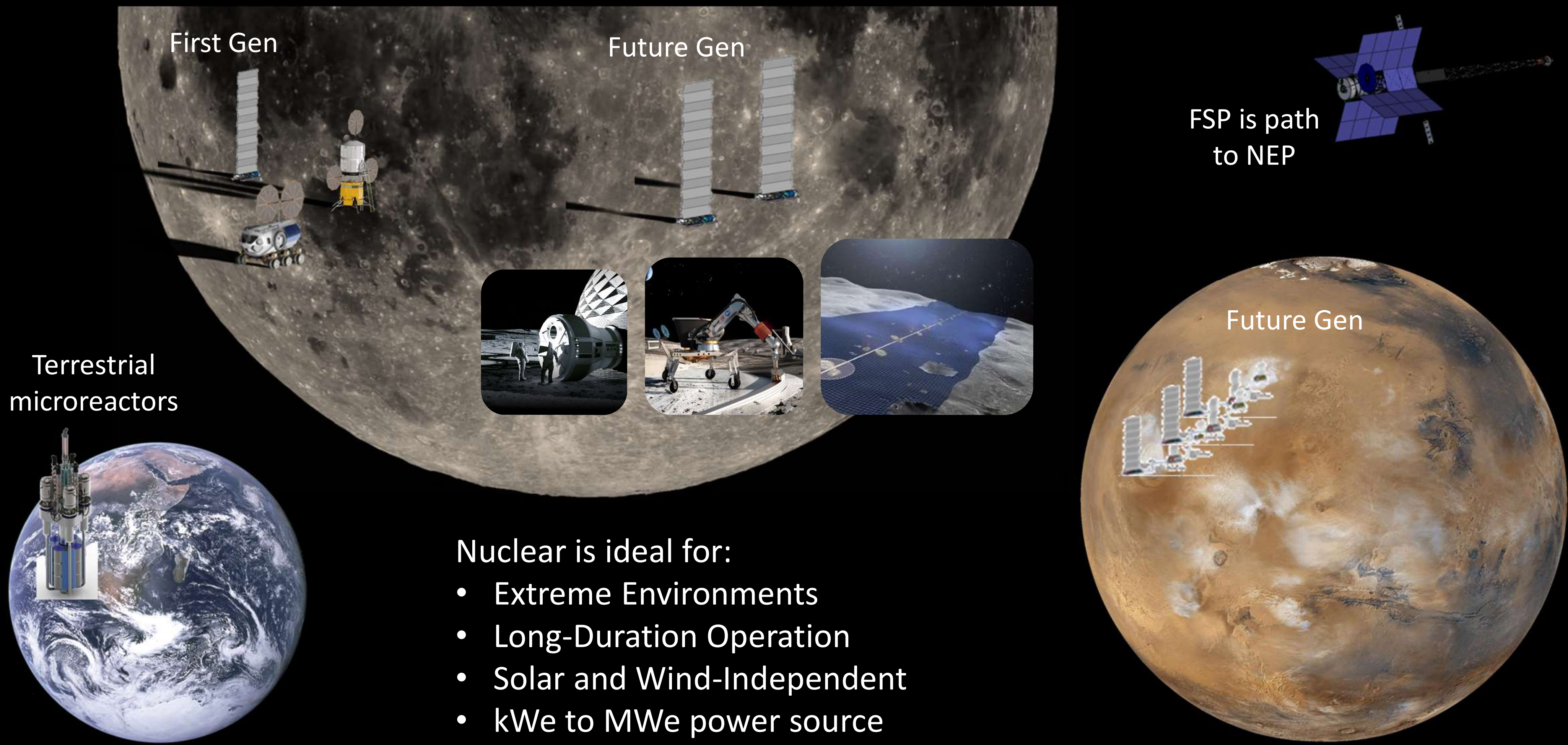
Support Moon and Mars mission requirements

Deliver a flight qualified Lunar demonstration system

Transition FSP technology to industry

Fission Surface Power

The key commodity needed to utilize the Lunar and Martian surface



Nuclear is ideal for:

- Extreme Environments
- Long-Duration Operation
- Solar and Wind-Independent
- kWe to MWe power source

FSP Execution: Two Phases

Phase 1: Completed Sept 2023

- Three contractor teams recently completed 1-year, $5M contracts for FSP design concepts, schedule, and cost estimates
- Requirements and design goals from the Phase 1 RFP:

Westinghouse / Aerojet Rocketdyne; Intuitive Machines / X-energy; Lockheed Martin / BWXT

DR-#	Title	Requirement Details
DR-1	Power	The FSP shall be designed to operate at a minimum end-of-life 40 kW_E continuous power output for at least 10 years in the lunar environment as detailed in Attachment A. Higher power ratings are desirable provided remaining DRs are satisfied.
DR-2	Launch and Landing Loads	The FSP shall be designed to withstand structural loads as detailed in Attachment B.
DR-3	Radiation Protection	The FSP shall be designed to limit radiation exposure at a user interface location 1 km away to a baseline value of 5 rem per year above lunar background.

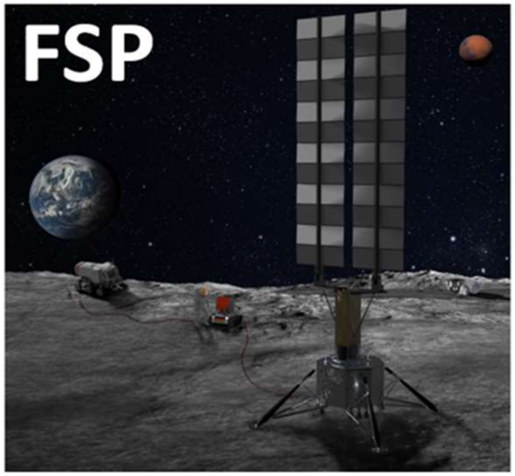
DG-#	Title	Goal Details
DG-1	Volume	The FSP should fit within a 4 m diameter cylinder, 6 m in length in the stowed launch configuration.
DG-2	Mass	The total mass of the FSP should not exceed 6,000 kg which includes mass growth allowance and margin.
DG-3	Power Cycles	As a safety feature, the FSP should be capable of multiple commanded and autonomous on/off power cycling.
DG-4	User Load	The FSP should be capable of supporting user loads from zero to 100% power at the user interface
DG-5	Fault Detection & Tolerance	The FSP should minimize single-point failure modes, should be capable of detecting and responding to system faults, and have the capability to continue providing no less than 5 kW_E under faulted conditions.
DG-6	System Transportability	The FSP should be capable of operating from the deck of a lunar lander or be removed from the lander and placed on a separately provided mobile system and transported to another lunar site for operation.

- Phase 1A Extension Contracts: further reduce risks identified in Phase 1

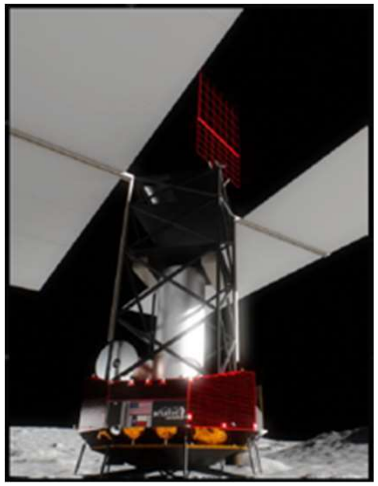
Phase 2

- Planned to be a separate, open and competitive procurement (pending budget received)
- Deliverables planned to include an engineering unit and flight unit

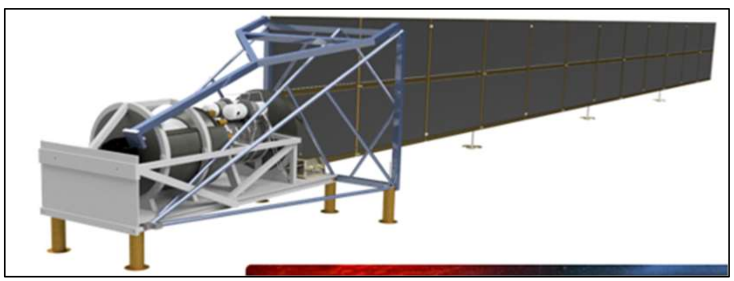
Phase 1 Concepts



Source: Lockheed Martin/BWXT

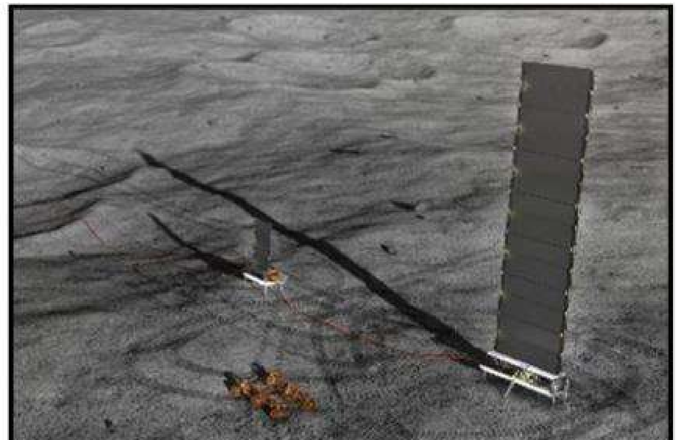


Source: Intuitive Machines/X-Energy



Source: Westinghouse/Aerojet Rocketdyne

Government Reference Design (GRD)



Power: 40 kWe scalable to higher power
Mobility: Capable of being transported
Mass: less than 6,000 kg
Life: 10 years

Source: NASA

Phase 1 results and GRD show a 40kWe HALEU-fueled reactor is feasible

FSP Meets Multiple Directorate Needs for NASA

FSP enables…

Future Lunar Economy
In-Situ Resource Utilization

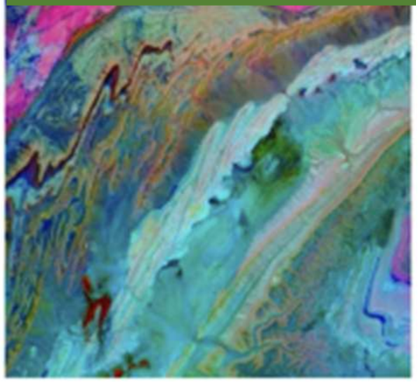
Space Technology Mission Directorate (STMD)

Lunar and Martian Surface Power
Mars Transport Nuclear Electric Propulsion

Exploration Systems Development Mission Directorate (ESDMD)

Deep Space Science Missions
Nuclear Electric Propulsion

Science Mission Directorate (SMD)



40KWe is an ideal starting power level to meet ALL NASA goals

FSP Addresses STMD Civil Space Shortfalls

FSP and its technology investments meet/supports numerous STMD civil space shortfalls:

#1: Survive and operate through the lunar night
#2: High Power Energy Generation on the Moon/Mars
#8: NEP for Human Exploration

And Many More…

Integrated Shortfall Ranking (1-30)

Integrated Rank	Average Integrated Score	Shortfall ID
1	8.1035	1618: Survive and operate through the lunar night
2	7.6118	1596: High Power Energy Generation on Moon and Mars Surfaces
3	7.4345	1554: High Performance Onboard Computing to Enable Increasingly Complex Operations
4	7.3831	1557: Position, Navigation, and Timing (PNT) for In-Orbit and Surface Applications
5	7.2473	1545: Robotic Actuation, Subsystem Components, and System Architectures for Long-Duration and Extreme Environment Operation
6	7.2076	1552: Extreme Environment Avionics
7	7.1961	1519: Environmental Monitoring for Habitation
8	7.1679	709: Nuclear Electric Propulsion for Human Exploration
9	7.1145	1304: Robust, High-Progress-Rate, and Long-Distance Autonomous Surface Mobility
10	7.0946	1520: Fire Safety for Habitation
11	7.0517	1531: Autonomous Guidance and Navigation for Deep Space Missions
12	7.0449	1591: Power Management Systems for Long Duration Lunar and Martian Missions
13	7.0341	702: Nuclear Thermal Propulsion for Human Exploration
14	7.0315	1559: Deep Space Autonomous Navigation
15	6.9684	1527: Radiation Countermeasures (Crew and Habitat)
16	6.9478	1526: Radiation Monitoring and Modeling (Crew and Habitat)
17	6.9465	879: In-space and On-surface, Long-duration Storage of Cryogenic Propellant
18	6.8425	1548: Sensing for Autonomous Robotic Operations in Challenging Environmental Conditions
19	6.8039	1558: High-Rate Communications Across The Lunar Surface
20	6.7919	1626: Advanced Sensor Components: Imaging
21	6.7837	792: In-space and On-surface Transfer of Cryogenic Fluids
22	6.7199	1569: High-Mass Mars Entry and Descent Systems
23	6.7110	1525: Food and Nutrition for Mars and Sustained Lunar
24	6.6953	1571: Navigation Sensors for Precision Landing
25	6.6892	1573: Terrain Mapping Capabilities for Precision Landing and Hazard Avoidance
26	6.6618	1562: Advanced Algorithms and Computing for Precision Landing
27	6.5927	1597: Power for Non-Solar-Illuminated Small Systems
28	6.5922	1568: Entry Modeling and Simulation for EDL Missions
29	6.5842	1516: Water and Dormancy Management for Habitation
30	6.5694	1524: Crew Medical Care for Mars and Sustained Lunar

https://www.nasa.gov/spacetechpriorities/

FSP Technology Maturation Investments

Power Conversion:
- > Advanced Closed Brayton Cycle System (next slide)
- > Repairing the 12 kW Stirling engine from the legacy Technology Demonstration Unit

Radiation Tolerance:
- > Evaluating organics in Power Conversion System and heat pipe fluids
- > Electronics Protection

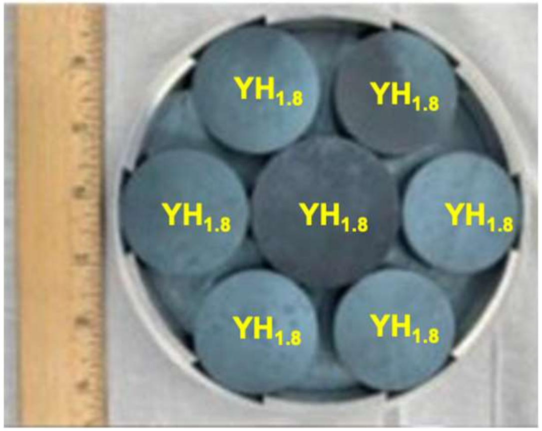
Materials:
- > Developing Advanced Manufactured turbines and heater heads

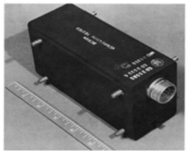
Heat Rejection:
- > Radiator dust tolerance / contamination test in vacuum facility
- > High temperature thermal radiators

Primary Heat Transfer:
- > Heat Pipes (Integrated Heat Pipe-Stirling Test), Liquid Metal Pumps

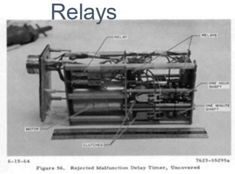
Power Management and Distribution:
- > High Voltage PMAD Demonstration Test

Reactor:
- > Moderator, Metallic Hydrides (YH)
- > Instrumentation and Control
- > Shielding Materials





SNAP-10 Relays

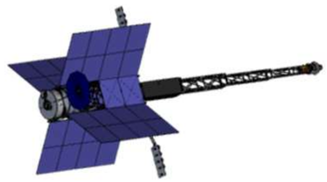


Modern equivalents

Sourcing: Project Funds, Small Business Innovation Research (SBIR), Early Career Initiative (ECI), Center Innovation Funds (CIF)

FSP Commonality with Nuclear Electric Propulsion (NEP)

FSP



NEP

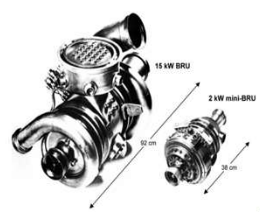
NEP Critical Technology Element (CTE)	FSP
Reactor and Coolant Subsystem (RXS)	✓
Power Conversion System (PCS)	✓
Power Management and Distribution (PMAD)	✓
Electric Propulsion Subsystem (EPS)	*
Primary Heat Rejection Subsystem (PHRS)	✓
Other: Instrumentation & Control	✓

* Currently worked under SEP

Advanced Closed Brayton Cycle Contracts

Three $1M contracts are currently in work under FSP to progress an Advanced Closed Brayton Cycle system design for high temperature operations to address future scaling needs for large (Megawatt-scale) surface power systems with a turbine inlet temperature of 1500-1700 K.

Rolls Royce North American Technologies
Brayton Energy
General Electric (GE)



FSP Technology Investments Directly Contribute to NEP

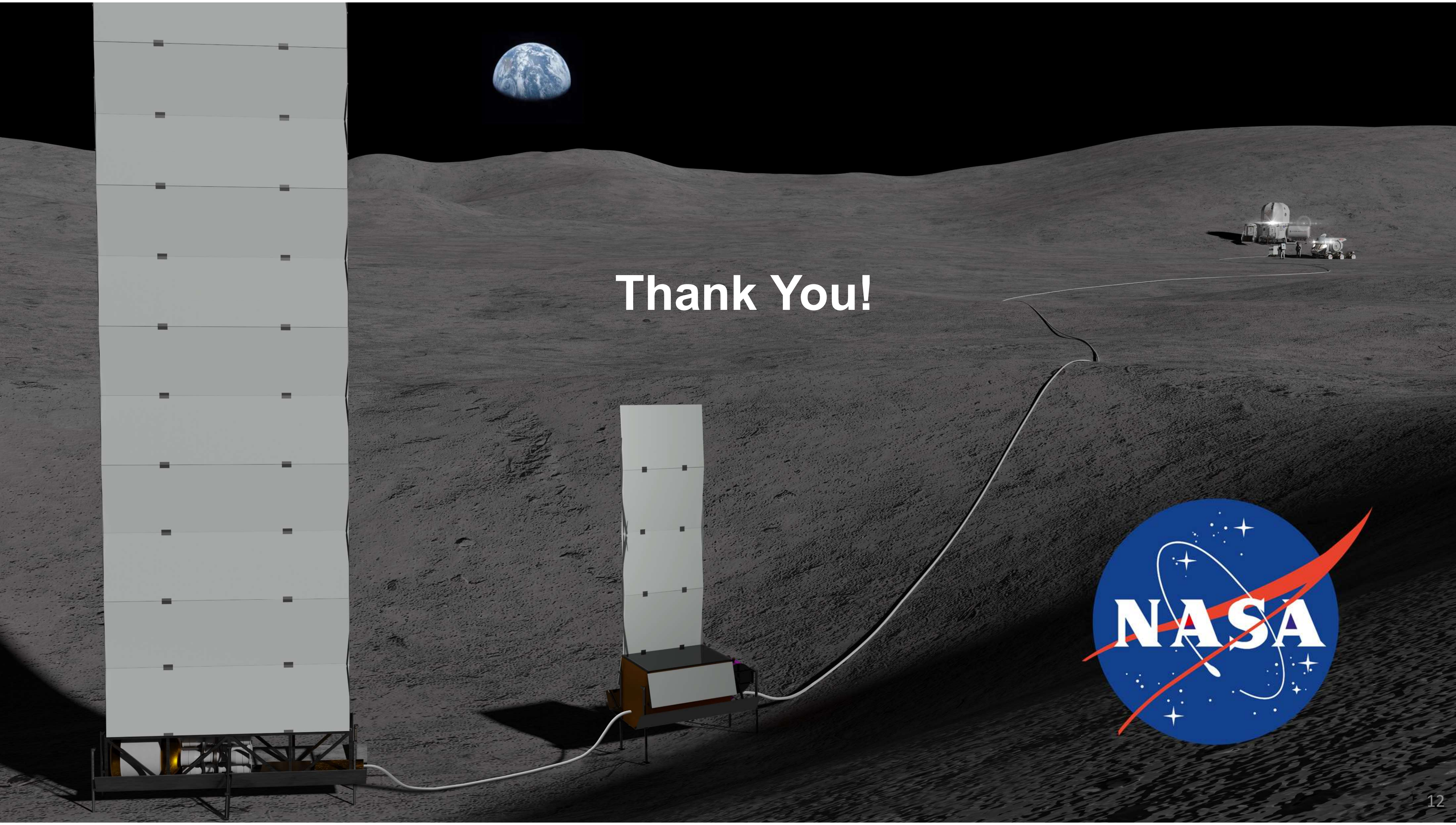
Potential Partnerships/Collaborations

- Department of Defense (Air Force, Space Force, Others)
  - **VALKRE** (Versatile Autonomous Lightweight Kilowatt-Class Reactor Experiment)
    US Marine Corps, OUSD Operational Energy
  - **JETSON** (Joint Emergent Technology Supplying On-Orbit Nuclear)
    Air Force Research Laboratory
- International Space Agencies
- Department of Energy
- National Science Foundation
- Clean Energy Initiatives

https://www.energy.gov/eere/funding/eere-funding-opportunities

Summary

- The broad spectrum of potential benefits of FSP goes beyond NASA missions: Small, portable power reactors designed to operate reliably and autonomously have the potential benefit to provide off-grid power for emergency relief sites, small communities, isolated industrial operations, and remote troop placements
- NASA-GRC technology investments are targeting key non-nuclear systems needs, including power conversion solutions, radiation hardening of electronics, and power distribution capabilities critical to nuclear systems
- Ongoing collaboration with ESDMD to support an Element Initiation for surface power
- NEP will be able to leverage technology investments being made by FSP today
- The project will continue planning for Phase 2 FSP development


Thank You!
NASA