

WELCOME

Fission Surface Power (FSP)

INDUSTRY DAY
August 20, 2020

FSP Industry Day Agenda

Agenda:

- 11:00 –11:10 Virtual Platform Ground Rules, Introductions and Agenda (**Aaron Weston, INL**)
- 11:10-11:25 Space Fission Power Systems Vision (**James Reuter, NASA / Dr. Rita Baranwal, DOE**)
- 11:25 –11:35 Nuclear Space Policy (**Aaron Miles, OSTP / Ryan Whitley, National Space Council**)
- 11:35 – 11:55 Surface Power Enabling Technology (**Anthony Calomino, NASA / Tracey Bishop, DOE**)
- 11:55 –12:40 NASA Fission Surface Power – (**Todd Tofil, NASA / Bradley Gravatt, INL**)
- 12:40-1:00 Break
- 1:15-1:55 Discussion: Q&A Industry (**Anthony Calomino, NASA / Bradley Gravatt, INL**)
- 2:00 – 5:30 One-on-One Industry /Government Sessions

Meeting Goals:

- Share NASA's vision and needs for surface fission power
- Detail the RFI & RFP processes and purpose
- Update government on industry capabilities, readiness, and interest

Video-Conference Ground Rules

- Thank-you for joining Industry Day
- If you have technical problems, please submit them through the “Chat” option on the GoToWebinar control panel
- Participants’ connection will be in listen mode, use “Chat” to write a question
- Please enter all questions for speakers using the “Questions” option on the GoToWebinar control panel. Please write questions as we go, there’s also a separate Q&A section
- We will address questions after each set of speakers, followed by a general discussion session at the end of the webinar
- Comments after the video-conference concludes must be submitted in writing to the CO
- The presentation sections are open; however, media will be asked to leave at the break before the question and answer period
- All information being provided in relation to the potential follow-on procurement is based on current information and is subject to change

Industry Day Key People

- James Reuter Associate Administrator for the Space Technology Mission Directorate (STMD) at NASA Headquarters
- Dr. Rita Baranwal Assistant Secretary for the Office of Nuclear Energy in the U.S. Department of Energy (DOE)
- Aaron Miles Office of Science and Technology Policy, Principal Assistant Director for National Security and International Affairs
- Ryan Whitley Director of Civil Space Policy for the National Space Council
- Dr. Anthony Calomino Space Nuclear Portfolio Manager in STMD
- Tracey Bishop Deputy Assistant Secretary for Nuclear Infrastructure Programs at DOE
- Todd Tofil FSP Project Manager at the NASA Glenn Research Center
- Aaron Weston FSP Manager at the Idaho National Laboratory
- Bradley Gravatt FSP Contract Specialist at the Idaho National Laboratory

Space Fission Power Systems

NASA/DOE Space Nuclear Technology, August 20, 2020

James Reuter

Associate Administrator, Space Technology Mission Directorate



Space Fission Power Systems

NASA/DOE Space Nuclear Technology Industry Day

Dr. Rita Baranwal

Assistant Secretary for the Office of Nuclear Energy



Nuclear Space Policy

NASA/DOE Space Nuclear Technology Industry Day

Aaron Miles

Office of Science and Technology Policy, Principal Assistant
Director for National Security and International Affairs

Ryan Whitley

Director of Civil Space Policy for the National Space Council



Space Nuclear Power and Propulsion

NASA/DOE Space Nuclear Technology, August 20, 2020

Dr. Anthony Calomino | STMD Nuclear Technologies Portfolio Manager
Tracey Bishop | DOE Nuclear Energy



Fission Surface Power (FSP)

“The United States will...**establish a sustainable human presence on the Moon by the end of the decade, and chart a future path for Mars exploration.**”

White House Fact Sheet, 26 Mar 2019

NASA and DOE are collaborating on the development of a 10 kWe-class fission power system for a flight demonstration to the Moon by 2027, with extensibility to human Mars missions.



Fission surface power is the Agency's top nuclear fission priority

- Enabling capability for lunar sustainable presence and crewed Mars exploration
- Provides a near-term opportunity for fabrication, testing, and flight of a space fission system
- Will serve as a pathfinder for launching and operating other space fission systems
- DOE identified moderated HALEU FSP reactors and recently released an RFI for Industry Designs

Space Nuclear Technology Overview

- The Space Nuclear Technology portfolio, as part of the NASA STMD Technology Demonstration Mission program, will advance and demonstrate the nuclear fission technologies and capabilities needed to meet NASA exploration missions

Fission Surface Power (FSP)

- Lunar surface capabilities that:
 - Enable a long-duration Moon (Mars operation analog)
 - Support the first mission to Mars

Space Nuclear Propulsion (SNP) Systems

- Nuclear Thermal Propulsion (NTP) and /or Nuclear Electric Propulsion (NEP)
 - Enable opposition class mission for Mars

Prioritize lunar surface power while continuing to advance nuclear propulsion capabilities to support future human missions to Mars

FSP Integration Story

Lunar Surface Fission Power Demonstration

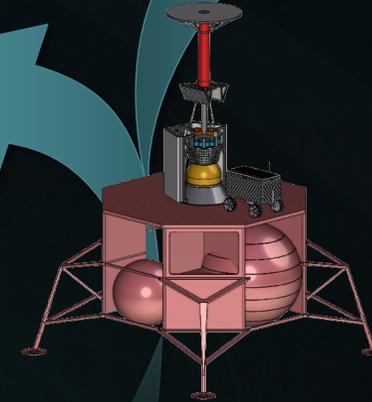
- Design, fabricate and qualify a 10 kWe FSP flight unit by 2027
- FSP hardware includes thermal reactor, power conversion system, heat rejection, power cable, and power connection

Lunar Surface Sustainability

- Solar offers sustained operations desire dissimilar redundancy
- Power needs for foundational habitat met with 10 kWe power
- Concept of operation includes power system, 1 km power cable, cable cart, and deployment rover

Mars Surface Power Needs

- Dust storms make solar power risky with ~40% more mass
- Current Mars surface power needs can be met with 10 kWe
- Operational needs and performance metrics feed forward to lunar demonstration



Fission Power Lunar Demonstration

Fission Surface Power System Design

- Power: 10kWe with design flexibility up to 20 kWe
- Life: 10 year design life
- Modularity: Multi-unit interconnectivity to accommodate higher power
- Distribution: 1km cable cart + conditioning box
- Radiation: ~5 rem/yr @ 1 km (fission source)

Fission Power System Initiative Status

- Request for Information issued on JULY 23rd in partnership with DOE seeking industry designs for a FSP full system
 - Phase 1 RFP planned release in early October 2020
 - Phase 1 PDR level design by December 2021
 - Phase 2 RFP release by January 2022
 - Phase 2 Flight unit design, test and launch ready by 2027

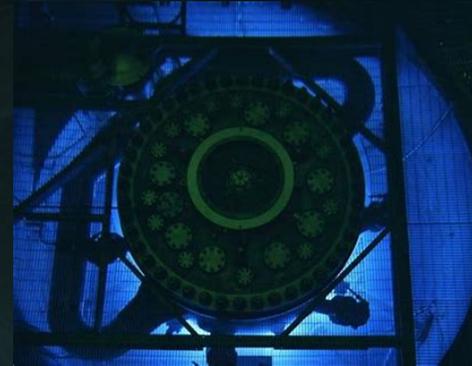


DOE's Contribution to the Space Program

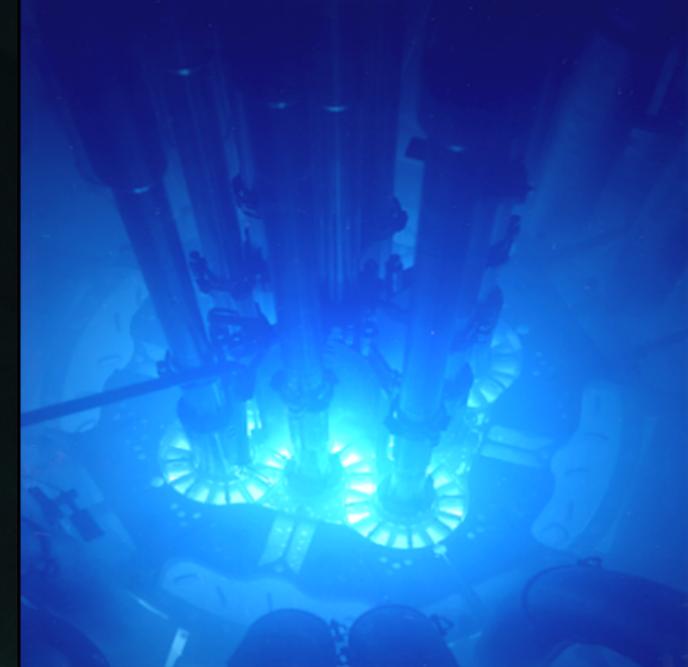
- Nuclear safety framework for NASA and commercial nuclear industry to support technology development and demonstrations that enable nuclear-power exploration missions
- National expertise, laboratory research facilities, and nuclear testing covering a wide array of technical support areas
- Extensive industry, university, and national laboratory engagement and contract mechanisms



Transient Reactor Test Facility - INL



High Flux Isotope Reactor – ORNL

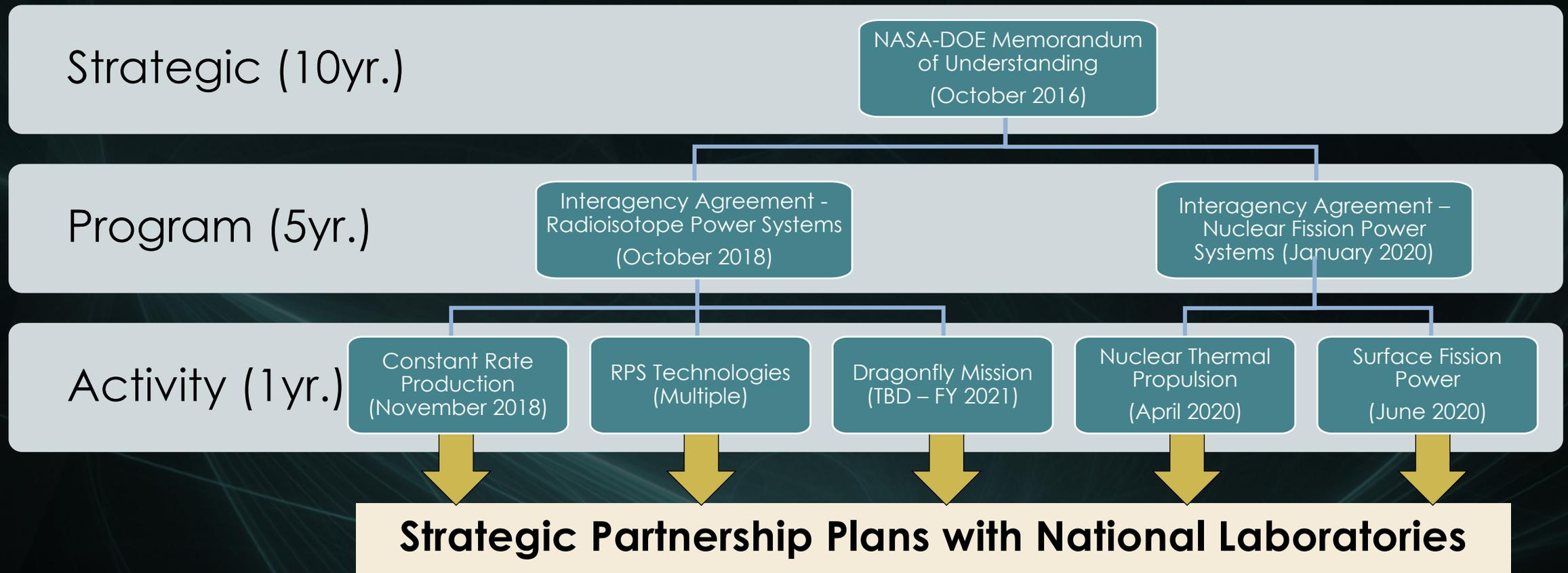


Advanced Test Reactor – INL

DOE has a long-standing partnership with multiple agencies on space nuclear power and trusted relationships with our national laboratories

DOE-NASA Partnership Model

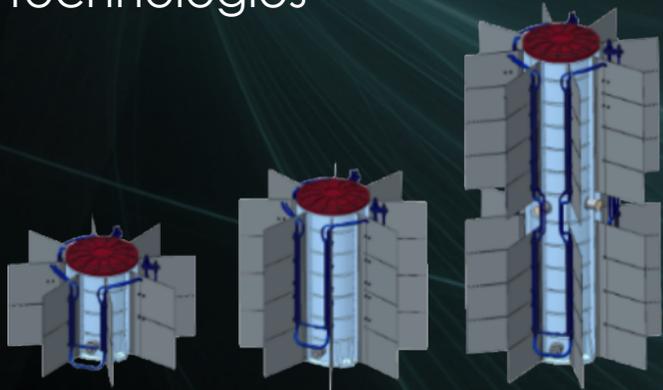
Agencies utilize a structured framework for nuclear activities to leverage DOE self-regulation and indemnification authorities



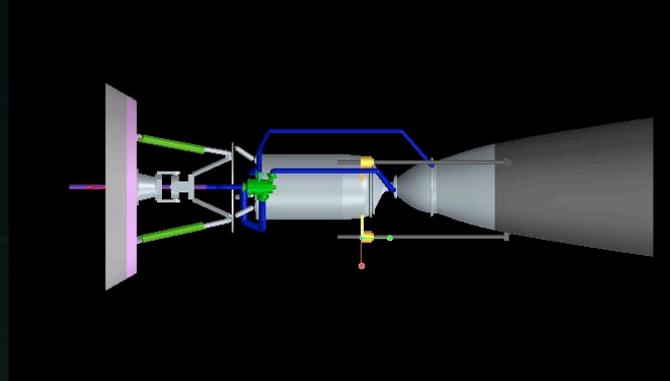
Successful DOE-NASA Power and Propulsion Collaborations

Radioisotope Power Systems

- NASA, partnered with DOE, is working on a dynamic conversion generator system concept focused on a lunar demo aimed at surviving the lunar night
- NASA and DOE are developing more efficient technologies with dynamic power systems and assessing multiple thermodynamic power system technologies



Space Nuclear Propulsion



- NASA is working with DOE to advance reactor operational temperature capability beyond 2900 K to support nuclear thermal propulsion needs
- DOE is supporting NASA Mars Transportation Architecture Study (MTAS) assessment for technology maturation needs of nuclear electric propulsion fission power reactors

Fission Surface Power

- DOE leads development of a low mass surface fission reactors and partnered in the technology maturation for power conversion and waste heat rejection systems
- DOE and NASA are pursuing multiple industry reactor design engagements and recently released an RFI for a 10 kWe full lunar demonstration system



Fission Surface Power Expectations

- Establishing inter-disciplinary industry teams to partner with NASA and DOE to provide a full-mission concept leading to a launch-ready fission surface power system by 2027
- Identifying and maturing critical technologies and manufacturing approaches required to advance fission surface power supply chain capabilities
- Gaining valuable insights into barriers and challenges faced by industry in furthering space nuclear power and propulsion technologies

Industry participation is key to long-term success

Fission Surface Power

NASA/DOE Space Nuclear Technology, August 20, 2020

Todd Tofil, Project Manager, Fission Surface Power

Bradley Gravatt, INL Contract Specialist



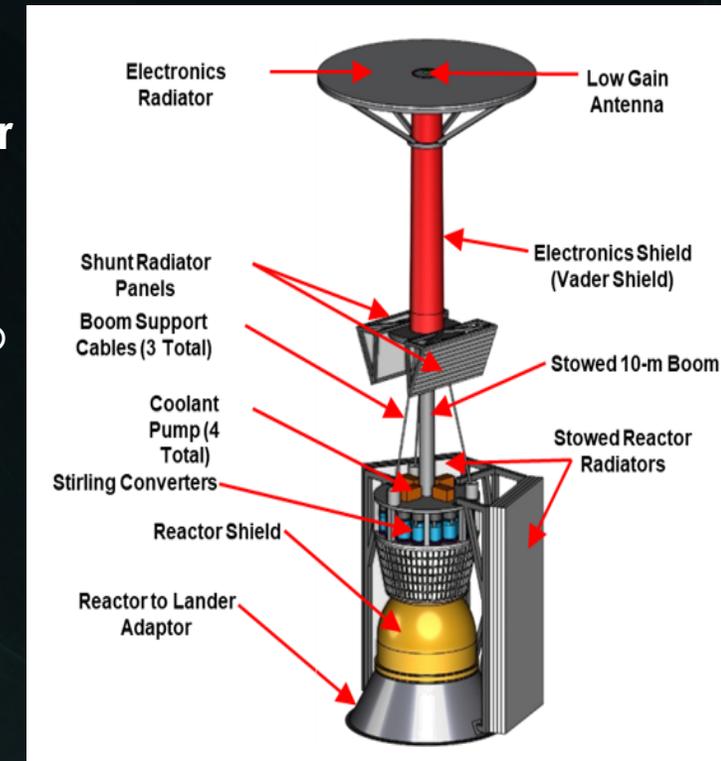
Background

- In 2018, KRUSTY demonstrated a full-power 1kW, highly enriched uranium (HEU) system, two-80W Stirling converters, 8 heat pipes
- Collaboration between GRC and DOE
- The experiment demonstrated a 28-hour, full-power fission test that included startup, ramp to full power, steady operation and shutdown
 - Throughout the experiment, the team simulated power reduction, failed engines and failed heat pipes, showing that the system could continue to operate and successfully handle multiple failures

Current Activities (1 of 3)

Government Design Study:

- **Developed a hardware concept and cost estimate**
 - HEU-Fast was the COMPASS reference
 - 1kW-class Stirling converters
- **Requirements include 10kWe, 120Vdc output at end of 1km cable, 1 year demo, radiation dose, remains on Lander while on the Moon**
- **Continuing a system design**
 - Will pursue LEU-Segmented as Primary and HEU-Fast Spectrum as Backup
- **Perform government reference design to coincide with future Phase 1 Industry Contracts (all designs will be unique, trade space is open)**
 - “Smart buyer”; enables assessment of industry design initiative
 - Informs requirements and risks for RFP 2
 - LEU-segmented, sodium heat pipe, pumped coolant loop, 1.3 kW-class Stirling converters & controllers
 - Includes: Full System Design (RF communication, C&DH, PMAD, thermal, software, mission ops, etc.)



**10 kWe Fission Reactor Concept
for Lunar Operations**

Current Activities (2 of 3)

Nuclear Reactor - Technology Maturation:

- **Collaboration with DOE and their FFRDCs: Separate and Independent of Industry Contracts**
- **Design-neutral technology maturation for critical components**
 - Technology common to any lunar nuclear plant design irrespective of fuel type, moderator usage, mode of cooling and/or power conversion
 - The purpose is to: (a) to reduce to overall program/schedule and (b) to aid in the industry design assessments
- **Preliminary Tech Mat plan could include:**
 - High Reliability Control and Plant Health Monitoring System
 - Low Specific Weight Gamma- and neutron-shield
 - Neutronic Data and Qualification of Moderator Materials
- **Government can make data available for contractor to use at their discretion**

Current Activities (3 of 3)

Power Conversion System - Technology Maturation:

- **Led by NASA GRC: Separate and Independent of Industry Contracts**
 - Supports government in-house reference design
 - Industry to develop 1.3kW-class Stirling converter and controller
 - Intent is to leverage commercial terrestrial unit design
 - Requirements development is in-progress
- **Government can make data available for contractor to use at their discretion**

Request for Information (RFI) Summary

- RFI informs subsequent RFP 1 (Phase I)
- Requesting innovative technical approaches at a preliminary design level for a Fission Surface Power (FSP) system for a 1 year demo of a 10kWe system for the Moon, followed by 9 years of operations.
- Other industry requests:
 - Approach to design reliability
 - Process leading to a test qualified flight unit by December 31, 2026
 - Approach to modularity, connecting multiple reactors
 - Specifics on tech maturation needs, development risks, tradeoff between subsystem maturity versus schedule and cost risk
 - Identify technology advancements needed to achieve a TRL 6 by critical design
 - Approach to ground testing for reliability and life
 - Cost and schedule estimates for Phase I & Phase II
 - Partnership arrangements (Space, nuclear, power conversion, operations, etc.)

RFP 1: EDU Design Expectations and Constraints

- Up to 3 contracts selected; notional 9 month performance period
 - Planned RFP release in early Fall 2020
- Idaho National Laboratory will manage the contracts
- Design of the EDU
 - Industry's design and construction standards may be used
 - It should be as similar to the flight unit as practicable in all ways
 - It should represent the flight configuration and operation of the full power conversion system, heat rejection system, and all other subsystems
 - Deliver an interim review and a final review, contract documents
 - The final product should be a preliminary (30%) design of the EDU
 - Typical products should include requirements development & decomposition to subsystems, internal interface definition, risk identification, technology development plan, modeling and analytical results, subsystem design specifications, drawings, cost and schedule for Phase 1 and Phase 2, contract document deliverables
 - Assume the lander will not provide any services while on the Moon

RFP 2: EDU Final Design, Design and Build of the Flight Unit

- RFP 2 – (Phase II): Separate Competitive Procurement – (assembled and test qualified flight unit by Dec 2026)
 - Nominally 1 contract team will be selected
 - Intended Tasks and Deliverables:
 - Support safety analysis and launch approval process
 - Mature technologies and subsystems as needed
 - Complete final design, hardware build, and ground test needed for prototype FSP- EDU
 - Deliver a test-qualified FSP Flight System (FSP-FS) to the launch site for deployment to the Moon
 - Develop all ground support equipment
 - Support lander integration
 - Support system operation during the 1-year lunar demonstration

Procurement Activities Summary

- INL/BEA will be facilitating the RFP.
- Intend to publish the RFP by the first part of October.
- The RFP phase is expected to have a duration of appx. 6 weeks.
- The RFP will follow a “Best Value” solicitation approach where both cost and technical capability will be taken into consideration.
- A Source Evaluation Board consisting of members from DOE, NASA, and INL/BEA will evaluate responsive proposals.
- Note: It is recommended that prospective bidders begin registering in INL’s Vendor Portal (vendor.inl.gov)
 - Additional general procurement information may be found there as well.

INL/BEA Contract Specialist – Brad Gravatt (Bradley.Gravatt@inl.gov)

Questions?

Key Requirements

| | Moon | Mars |
|----------------------------------|--|--|
| Power Levels | 10 kWe at 1 km from source | 10 kWe at 1 km from source |
| Launch Dates | 2027 | 2035 |
| Fission Power System Mass | Goal 2000 kg; 3500 kg max | Optimize based on shielding requirements TBD |
| Design life | Capability Demonstration Mission = 1 year | >15 years |
| | Follow-on mission = 9 years | |
| Load Bus | 120 Vdc | 120 Vdc |
| Operation | Operate autonomously, with the capability of autonomous or commanded on/off cycles | Operate autonomously, with the capability of autonomous or commanded on/off cycles |
| Radiation | Protect human life and critical electronics from reactor-created radiation | Protect human life and critical electronics from reactor-created radiation |
| Fault Tolerance | Survive a credible failure without reducing electric power capacity by more than 50% | Survive a credible failure without reducing electric power capacity by more than 50% |