EXPLORESPACE TECH
TECHNOLOGY DRIVES EXPLORATION

Space Technology Industry-Government-University Roundtable (STIGUR)

Space Nuclear Propulsion (SNP)

Dr. Anthony Calomino | Space Nuclear Technology Portfolio Manager | October 4, 2023

Fission Surface Power (FSP) Project Overview

Fission Surface Power

Project Manager: Lindsay Kaldon/NASA GRC

FSP is a Technology Demonstration Missions (TDM) project within NASA's Space Technology Mission Directorate (STMD)

Stakeholders NEED

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

PROJECT GOALS

- Design a fission power source that supports lunar and Mars surface exploration requirements
- Transition the design, development, and manufacturing of the fission power system to industry
- Build and ground test a flight-qualified, fully integrated power system for lunar demonstration

Technology Demonstration Mission

Program Director: Trudy Kortes/NASA HQ

Manages efforts that bridge the gap between technology development to mission infusion by maturing system-level capabilities in relevant environments for integration as an operational mission

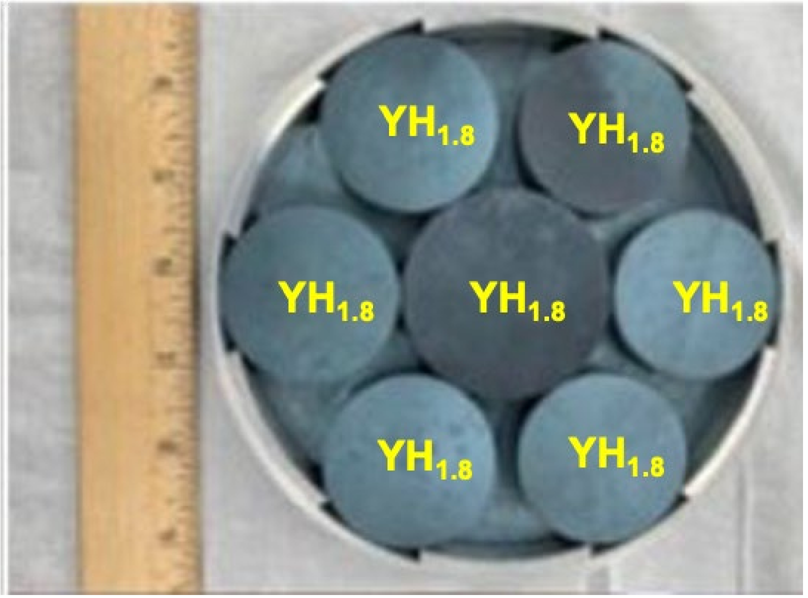
Glenn Research Center, Cleveland OH

GRC specializes in power technology, including chemical and nuclear power sources

FSP Technology Maturation Investments

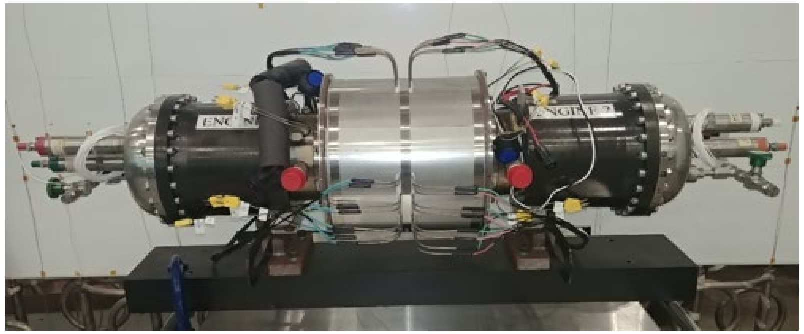
DOE-Los Alamos National Lab (LANL)/Idaho National Lab (INL):

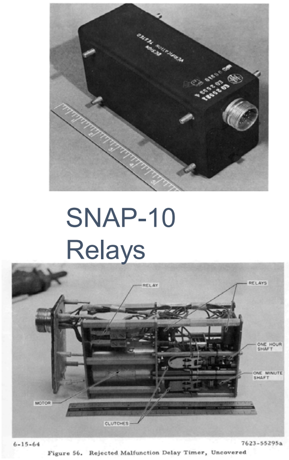
- ✓ Lightweight Reactor Moderator Materials (Metallic Hydrides)
- ✓ Lightweight Radiation Shielding
- ✓ Reactor Instrumentation & Control



NASA Glenn Research Center:

- ✓ Power Conversion (Integrated Heat Pipe-Stirling Converter Test, High-Temp Closed Cycle Brayton System)
- ✓ Power Management and Distribution (PMAD)
- ✓ Thermal (Radiator Panel Design)
- ✓ Radiation Hardening of Electronics





SNAP-10 Relays

Modern equivalents

High-Temperature Brayton Power Conversion Solicitation

- Goal: Push the state of the art in space closed cycle Brayton technology to higher temperature
  - ➢ 1500 - 1700 K turbine inlet temperature range
  - ➢ 10 – 25 kWe
- Higher temperature offers improved conversion efficiency and potentially lower mass
- One-year long design studies beginning 1QR-FY24
- Received multiple proposals; multiple awards planned
- NASA investment targets feasible and achievable approaches that are low TRL yet show strong potential for a near term product
- NASA will examine opportunities to target other investments, such as higher temperature thermal radiators, to improve operational efficiency

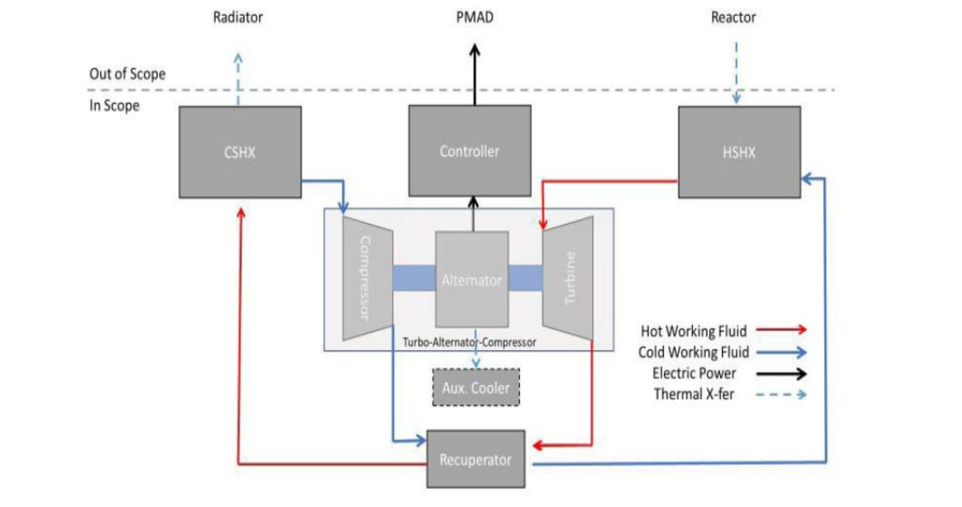
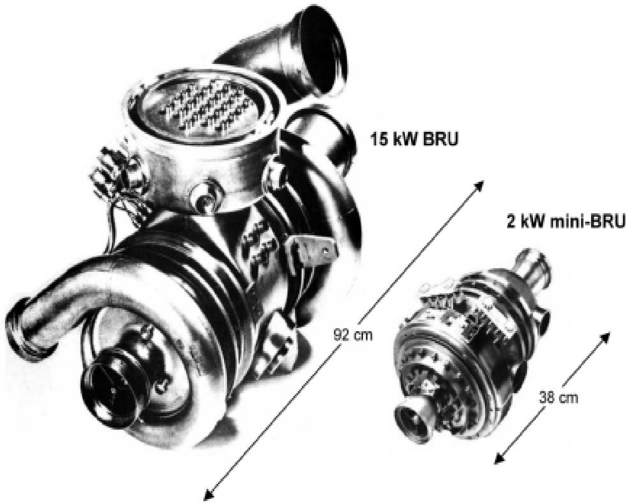


Figure 1. Notional Single, Scalable, 10-25kW Advanced Closed Brayton Convertor Diagram

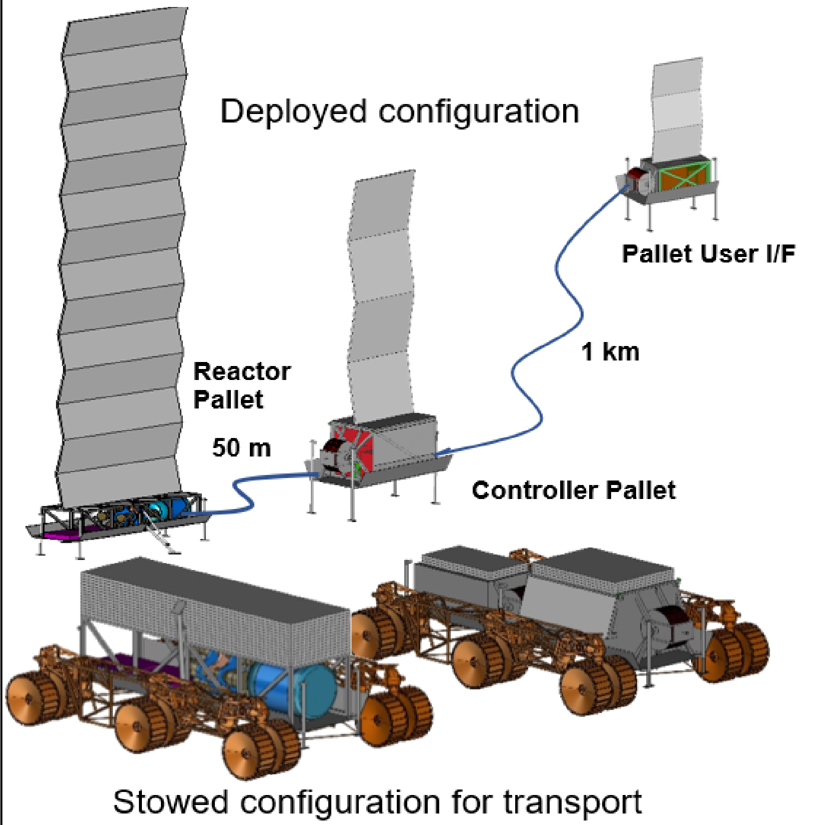


Historical Space Closed Cycle Brayton Systems (Source: NASA)

NASA/DOE Government Reference Design (GRD) Approach

Current Concept:

- **FSP System delivered in 3 pallets:** Reactor, Controller, User Interface
- **Reactor Pallet:**
  - Moderated HALEU reactor with radiation shielding to protect power plant equipment, electrical controls (50 M) and crew habitation area (1 km)
  - Power conversion system (Brayton or Stirling)
  - Deployable radiators that leverage the International Space Station design but higher operating temperature (>400 K)
  - Shielded Ka-Band link for communications to Earth
- **Controller Pallet:** Electrical controllers, high-voltage boost electronics, thermal management, and 50 m cable spool
- **User Interface:** Electronics to convert high transmission voltage to 120 Vdc for loads



Rover and Lander not in Project Scope

A 40 kWe transportable FSP system is feasible

Fission Surface Power System Development

Phase 1

- 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:

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.

FSP Design Scalability

FSP technology solutions that can scale to higher output power with minimum additional design, development, and testing are desired. To the maximum degree practical, FSP technology elements that have clear traceability to the design of a megawatt-class power system needed for a nuclear electric propulsion capability should be pursued.

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.

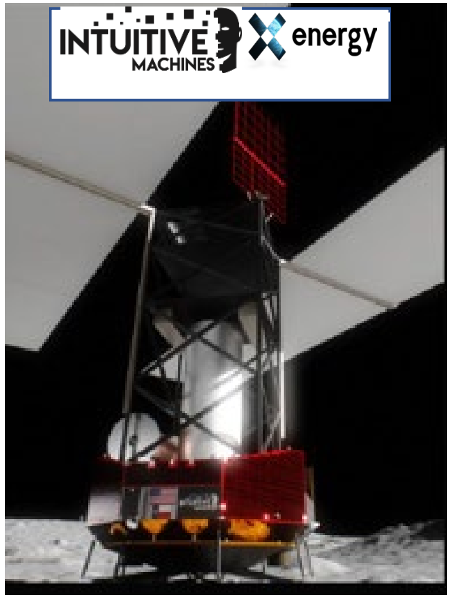
Phase 2

- Will be a separate, open and competitive procurement
- Deliverables include a qualification unit and flight unit

Fission Surface Power System Development Cont.

Phase 1 Results

- Lockheed/Westinghouse designs utilize Brayton engines, IX design utilizes Stirling engines
- Overall system mass ranges from ~ 7,000 kg – 12,000 kg (design goal was 6,000 kg)
- Specific mass values range from ~ 175-300 kg/kWe
- Power production can be scaled from 20 kWe to 2 MWe without major re-design of the reactor
- Phase 2 cost estimates provided as Phase 1 deliverable range



Results will be used to help define requirements for Phase 2

Summary

FSP completed three industry-led concept designs that can be used to formulate system requirements for an integrated lunar power plant

- Phase 1A follow-on contract efforts planned to begin 1QFY24

NASA government-led investment strategy is focused on risk mitigation of high-value, low-maturity reactor technologies

- Hydride moderators, lightweight shields, power conversion, power management, and heat rejection

Evolution of the Government Reference Design will continue to guide technology investment and system design decisions

- Design is used to assess potential impacts of advanced reactor and power technologies

FSP is actively seeking partnerships with other government agencies

- DoD has interest in low-power, mobile reactor technology to support for remote operations
- UK, and CSA have expressed interest to collaborate with NASA on FSP development