Space Nuclear Power and Propulsion (SNPP)

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Space Nuclear Technology (SNT) Portfolio Overview

NASA STMD Space Nuclear Technology portfolio within the Technology Demonstration Mission program focuses on advancing fission technology and system capabilities to meet space exploration missions needs

- Design, build, and demonstrate a space-rated fission power system that supports a sustained lunar presence and provides an extensible foundation for future planetary surface missions
- Advance a deep-space, nuclear-propulsion capability by maturing critical, high-risk technologies needed for the design and demonstration of a human rated system
- Develop collaborative, working relationships with other government organizations that share common, synergistic fission technology needs such as the DoD and DoE
- Identify industry and academic interests and alignments that will enable broad spectrum of innovative and economic technology approaches and solutions

Space Nuclear Technology Portfolio Projects

THE SPACE NUCLEAR TECHNOLOGY PORTFOLIO WITHIN MSFC-LED TDM PROGRAM CONSISTS OF TWO MAJOR FISSION TECHNOLOGY INVESTMENT AREAS

Fission Surface Power (FSP)

Solar independent, continuous power production
- Required for sustained, long-duration lunar operations
- Establishes a foundation power system for Mars mission

Space Nuclear Propulsion (SNP)

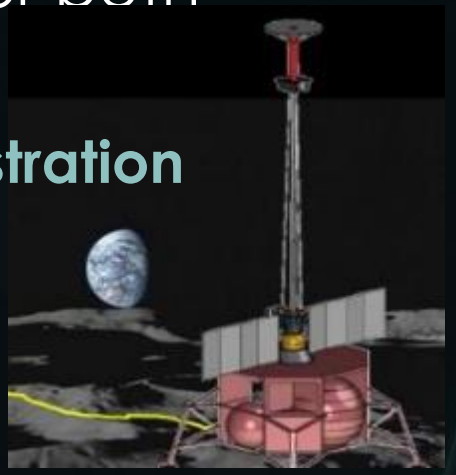
Enable opposition-class, short-duration Mars mission
- NTP focus is on fuel and reactor technology advancement
- Identify NEP subsystem capability gaps and needs
- Advance critical CFM technologies

Agency is prioritizing lunar surface power while continuing to advance nuclear propulsion capabilities to support future human missions to Mars

Space Nuclear Technology Projects

The Agency is currently engaged in advancing technologies for both propulsion and power fission systems with DOE support

Investment is focused on two Projects within the Technology Demonstration Program managed by Marshall Space Flight Center



Government Reference Design

- **Fission Surface Power**
  - Low weight reactor with 10 kWe dynamic power conversion system
  - Requires near term reactor fuels and materials development
  - Open design and trade space with industry

- **Space Nuclear Propulsion**
  - High temperature, 500 MW thermal reactor drives high Isp engine
  - Utilize a common NASA/DOE/DOD fuel production capability
  - Pursue industry solicitation for reactor designs through DOE

NTP vehicle concept

Agency reference configuration for Mars architecture is NEP

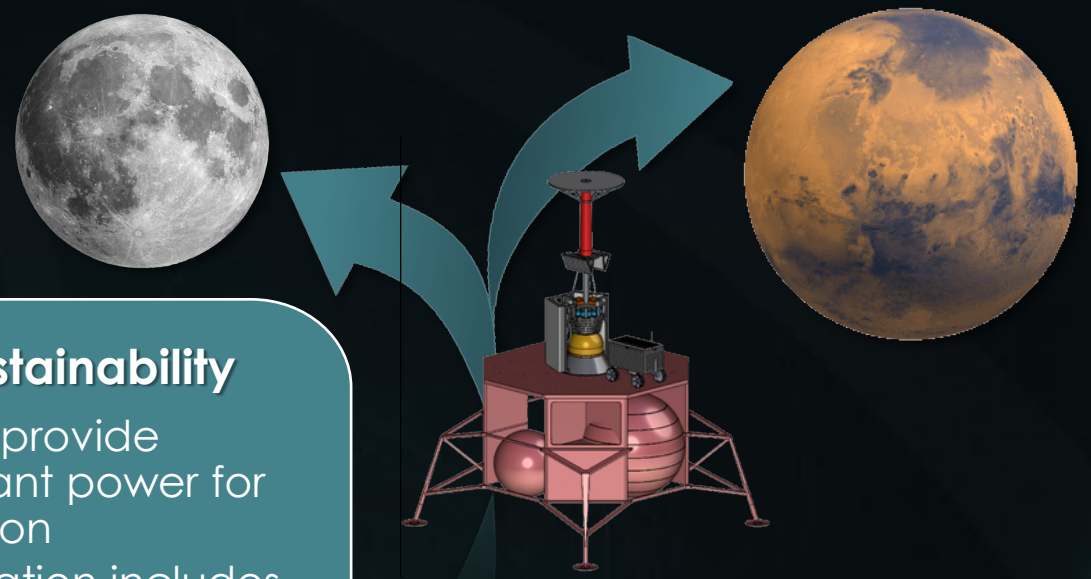
Fission Surface Power (FSP)

FSP Integration Story

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.

Lunar Surface Fission Power Demonstration

- Design, fabricate and qualify a launch ready 10 kWe FSP flight unit by late 2020's
- Flight qualified hardware needed for reactor, power conversion and heat rejection



Lunar Surface Sustainability

- System design to provide dissimilar redundant power for sustained operation
- Concept of operation includes power management system, power cable, cable cart, and avionics

Mars Surface Power Needs

- Nominal 10 kWe power source meets current Mars surface power needs
- Lunar operational needs and performance metrics feed forward to lunar demonstration

Prefer HALEU fission reactor solutions based on March 2020 DOE study that showed masses comparable to HEU systems

- These are moderated reactors with lower technology maturity
- Improved alignment with industry and academic engagements

Fission Surface Power Lunar Demonstration

Fission Surface Power System Design

- Power: 10kWe
- Life: 10 year design life
- Modularity: Multi-unit interconnectivity to accommodate higher power
- Distribution: User interface near base habitat with radiation @~5 rem/yr

Fission Surface Power Project Status

- Current government reference design calls for a segmented moderated HALEU reactor with a Stirling power conversion system
  - Guides risk reduction activities for moderated reactor and Stirling power unit
  - Provides platform for understanding launch and lander integration for late 2028 mission
- Request for Information issued in July 2020 and draft RFP in December 2020
  - DOE led acquisition provides security, safety, and regulatory framework
  - Leverage industry standards for full system design and reliability
  - Simplified design requirements leave open design trade space for industry
  - Still considering opportunity for cost sharing with growing space industry

Space Nuclear Propulsion (SNP)

Space Nuclear Propulsion

STMD current nuclear propulsion technology investment remains focused on NTP, and planning meetings are examining NEP subsystem maturation requirements.

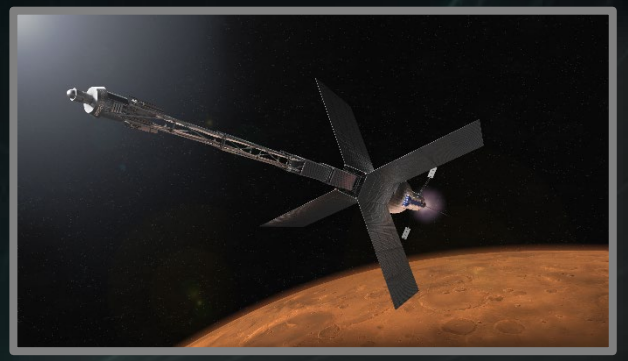
Nuclear Thermal Propulsion System

- Isp estimates are driving reactor temperature to exceed 2900 K
- Primary focus is fuel and reactor technology maturation
- Leveraging common NASA/DOE/DOD fuel production capability
- Strong DOE collaboration with SME and testing support
- Engaged with industry and current solicitation for reactor support
- Advance CFM capabilities needed for NTP systems

NTP vehicle concept

Nuclear Electric Propulsion System

- Current Agency reference configuration for Mars architecture
- Coordinating FY20-21 strategy and planning meetings to identify technology requirement leading to an implementation plan

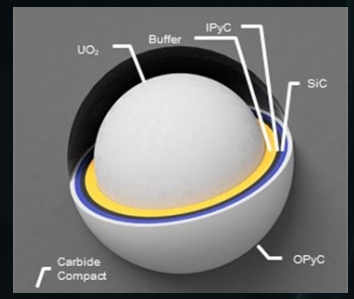


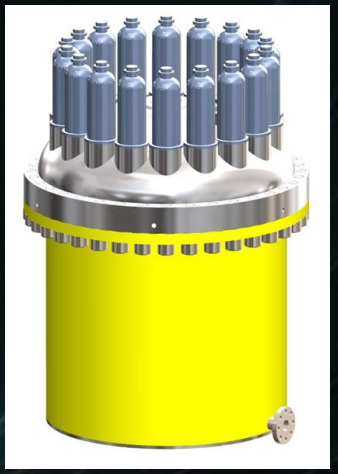
NEP vehicle concept

Nuclear Thermal Propulsion

- Reactor designs will use high assay low-enriched uranium and produce a hydrogen propellant outlet temperatures of at least 2800
- GRD is a moderator block with nominal 12,500 lbf subscale engine thrust
  - Sintered, solid-core, coated carbide fuel form
  - Operational proof-of-concept PRIME test series planned 2023
- Industry RFP was released February 12, 2021 through DOE/INL
- Industry modeling and tests will need to demonstrate reactor will meet performance requirements

Coated particle fission fuel





Moderator Block

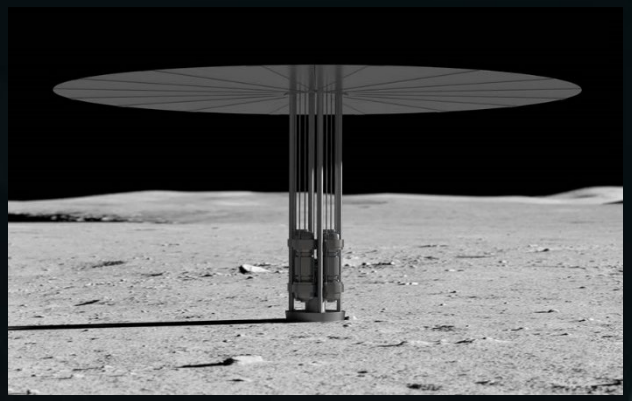
Phase 1 2-4 Contracts	Phase 2 1-2 Contracts	Phase 3 1 Contract
Reactor Preliminary Design (30% Design Review)	Reactor Detailed Design (90% Design Review)	Reactor Final Design (Fabrication, Build, and Integration)
CY 2021-22	**2022-2026**	

NASA Studies for NTP and NEP

- **NESC mission-agnostic assessment of NEP and NTP propulsion system maturity and gaps**
  - Majority of critical technologies for both propulsion systems are immature and at a high level of advancement difficulty
  - Technology development support 2039 Mars mission (dedicated and aggressive
- **Mars Transportation Architecture Study (MTAS)**
  - Fuel/reactor development for NTP and NEP are the most challenging technologies
  - Significant NEP system challenges are reactor scale and system integration
  - Significant NTP system challenges are reactor temperature and CFM
  - Technology development support a 2039 Mars mission (dedicated and aggressive)
- **National Academy of Sciences, Engineering and Medicine Study**
  - Fuel/reactor development for NTP and NEP are the most challenging technologies
  - Significant NEP system challenges are reactor scale and system integration
  - Significant NTP system challenges are reactor temperature and CFM
  - Concerns whether current investment levels in sufficient to meet the 2039 mission

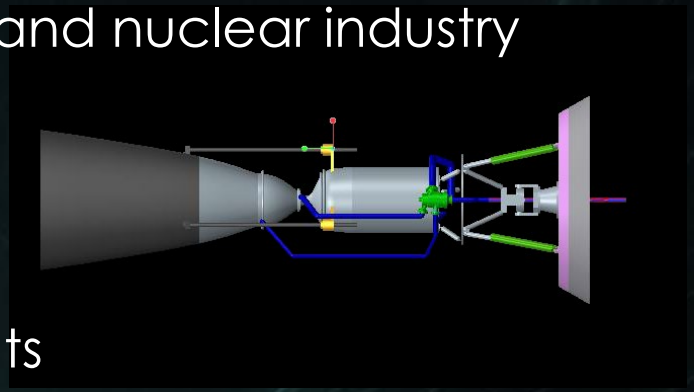
Summary

The NASA STMD Space Nuclear Technology portfolio has mission-align investments for nuclear power and propulsion with achievable goals and realistic timeframes



Opportunities

- Leverage industry design approaches for reliability and safety
- Advance US dominance for nuclear space technology capability
- Identify new ground testing approaches to verify performance and reliability
- Establish Forum for developing partnerships between aerospace and nuclear industry organizations



Challenges

- Commercial alignment with space nuclear technology needs
- Commercial alignment with government risk reduction investments
- Stable funding profiles that support technology development and flight design/build
- Definition of human rating for system operational reliability