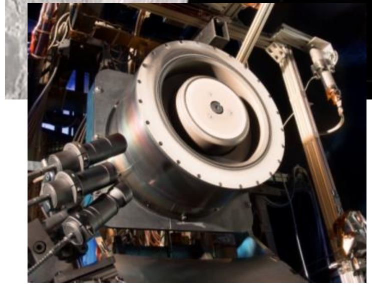
EXPLORESPACE TECH
TECHNOLOGY DRIVES EXPLORATION

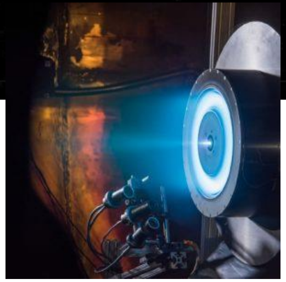
Fission Power for NASA Missions

Jeffrey Sheehy, Ph.D. | Chief Engineer, Space Technology Mission Directorate | 17 Oct 2019

Major Space Propulsion Technology Projects

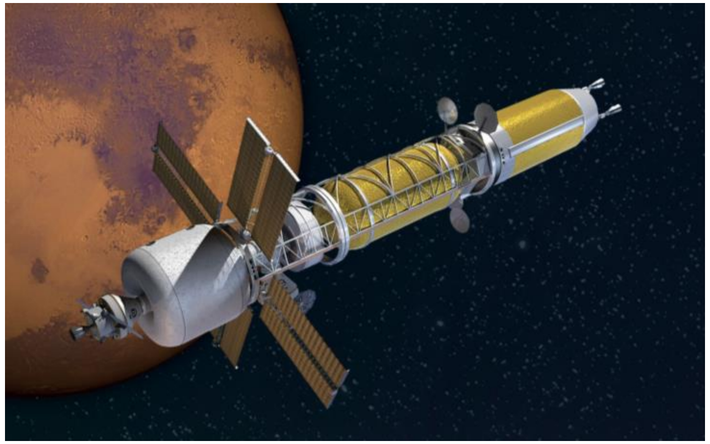
High-power solar electric propulsion string design / build / qualify for Gateway

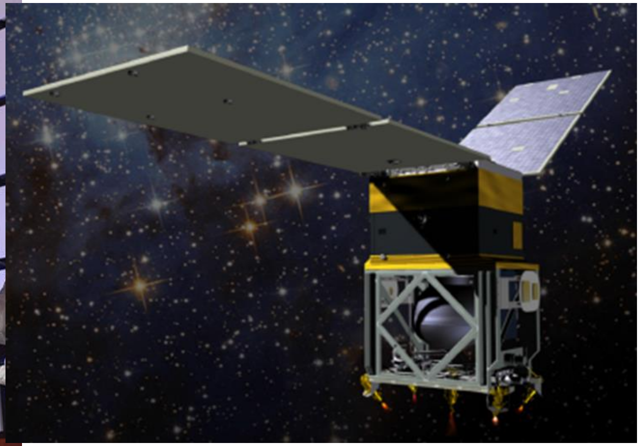




Validation of cryofluid management technologies at large scale

Nuclear thermal propulsion technology development & feasibility assessment

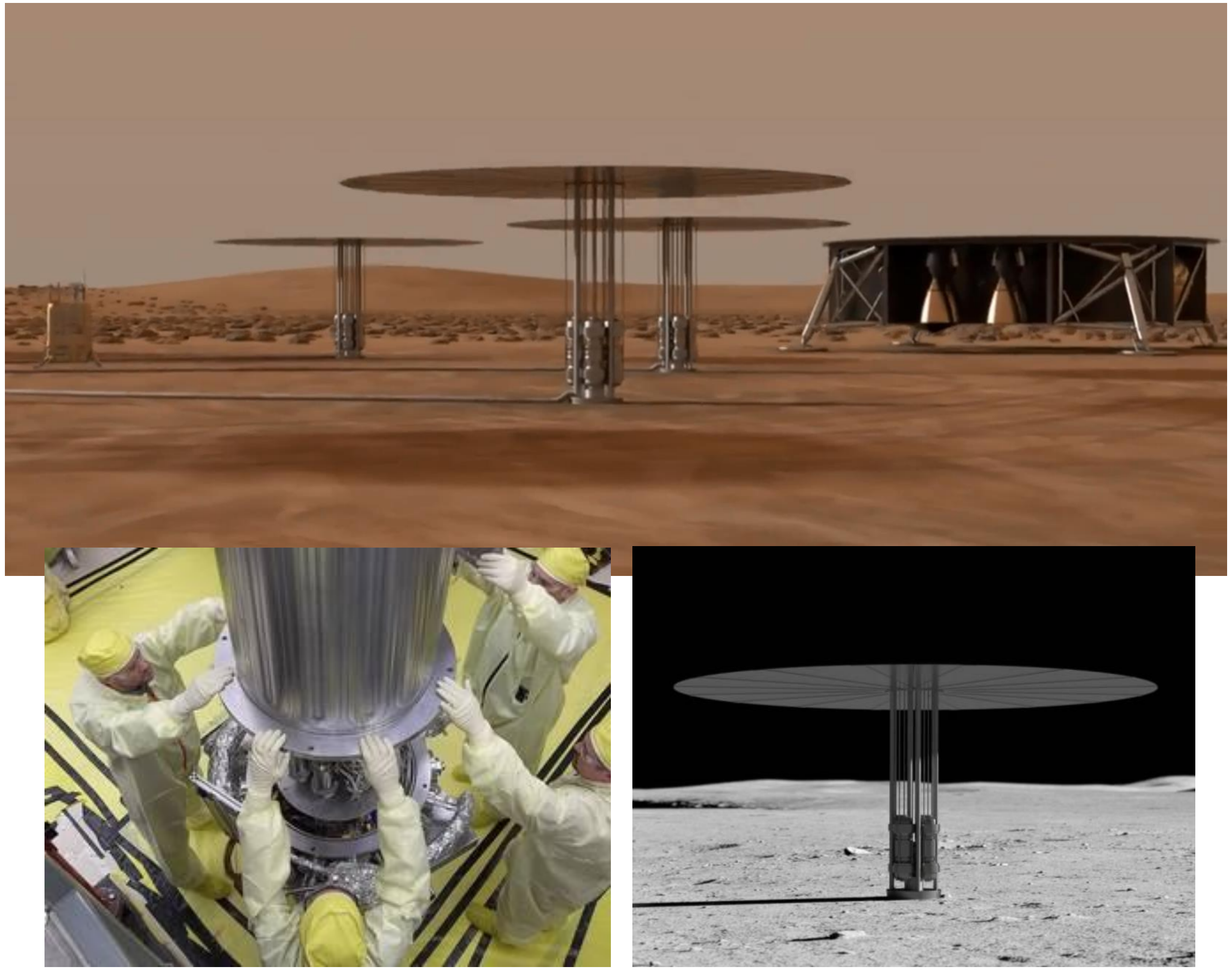




Green Propellant Infusion Mission flight demo

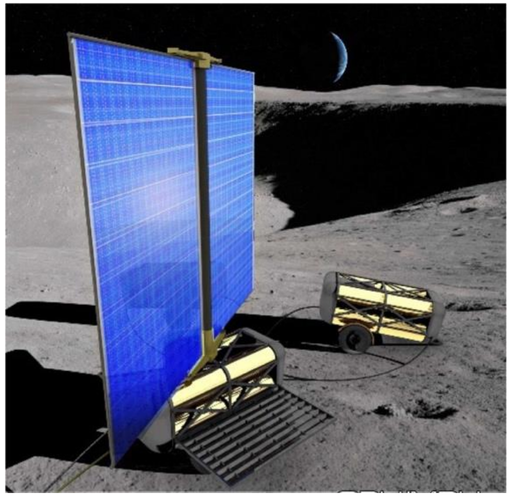
Major Space Power Technology Projects

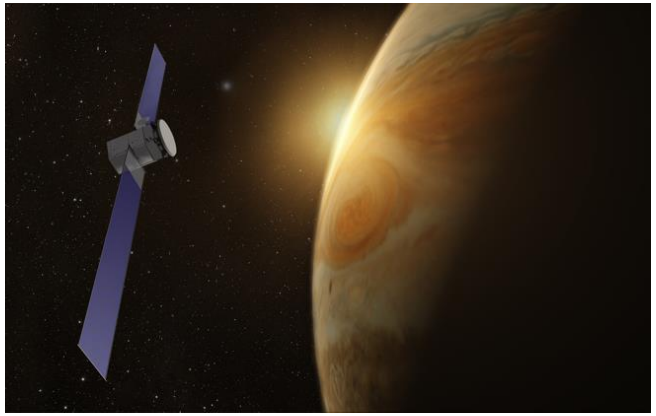
High-performance solar array development / demonstration



Fission surface power system design / development / demonstration

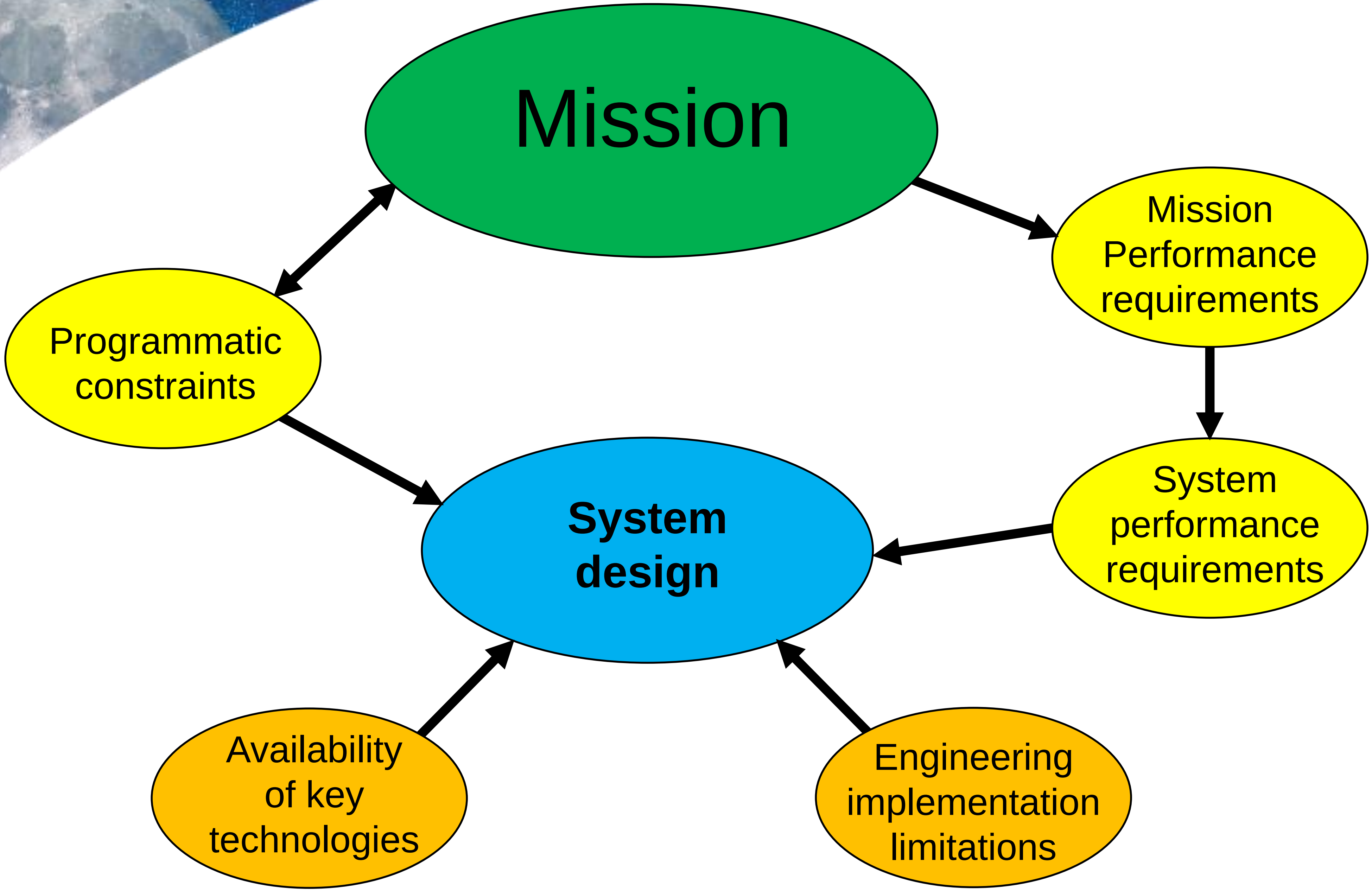
Evolvable regenerative fuel cell development





Extreme environment solar power technology development

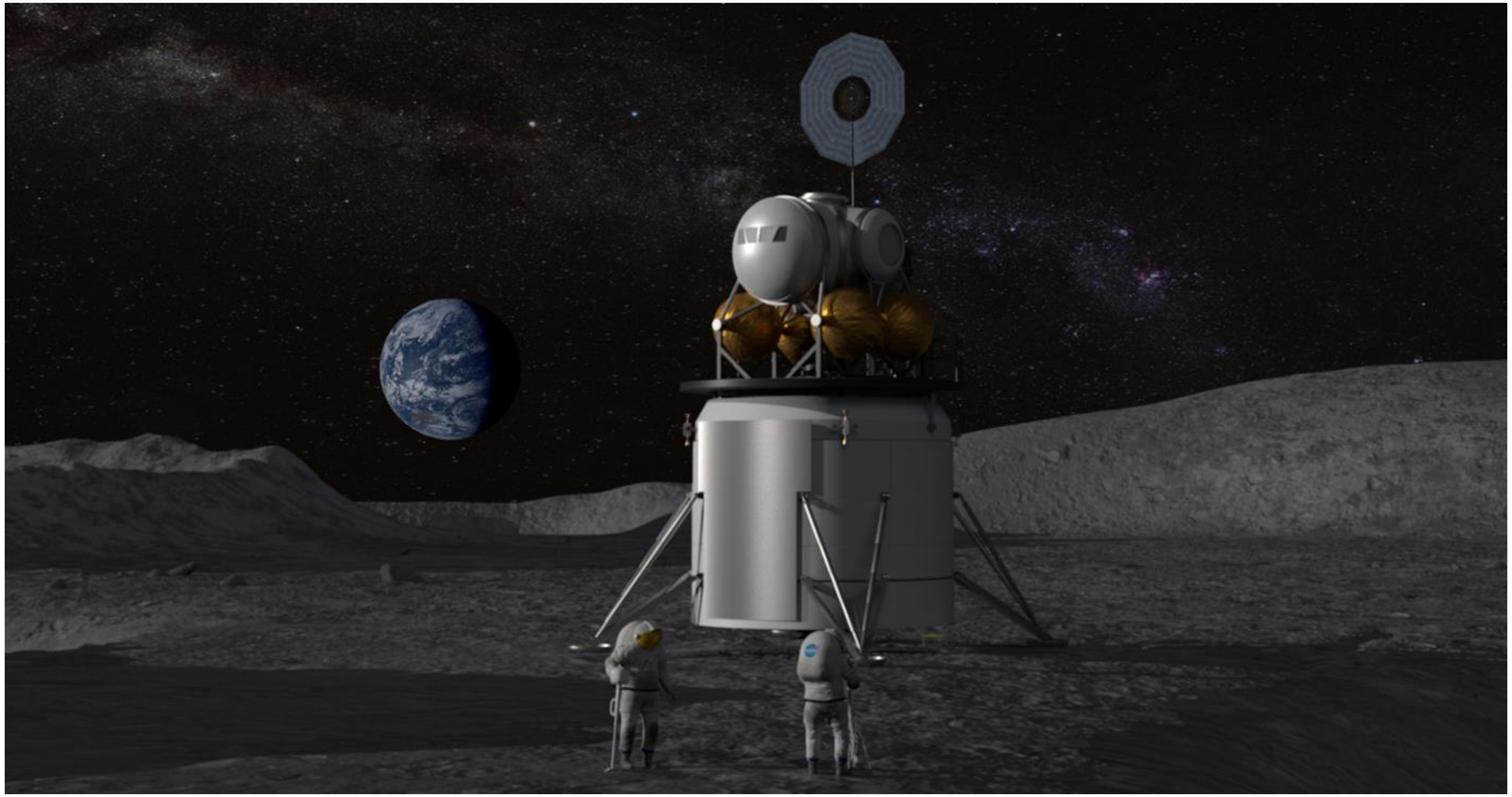
NASA Is Mission Driven



Boots on the Moon by 2024

Speech by Vice President Pence, 26 Mar 2019:

" … at the direction of the President of the United States, it is the stated policy of this administration and the United States of America to **return American astronauts to the Moon within the next five years** … The President has directed NASA and Administrator Jim Bridenstine to **accomplish this goal by any means necessary** … In order to succeed, as the Administrator will discuss today, **we must focus on the mission over the means**."



Sustainable Presence by 2028

White House Fact Sheet, 26 Mar 2019:

“The United States will seek to **land on the Moon’s South Pole by 2024, establish a sustainable human presence on the Moon by 2028, and chart a future path for Mars exploration**. NASA’s lunar presence will focus on science, resource management, and risk reduction for future missions to Mars.”

Key Technology Challenges

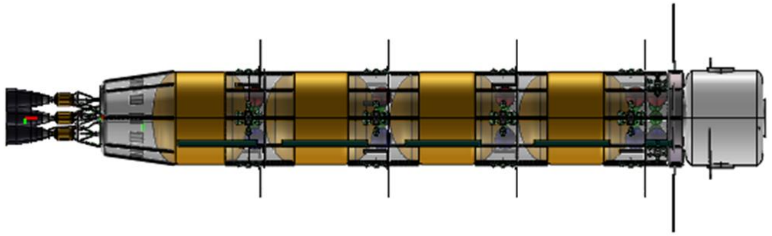
- Sustainable Power
- Advanced Propulsion
- Lunar Ice to Water
- Regolith to Oxygen
- Water to Cryogenic Propellant
- Cryogenic Propellant Management
- Reusable Cryogenic Propulsion
- Landing Heavy Payloads

- In-Space Assembly
- In-Space Production
- Extreme Access
- Extreme Environments
- Surface Construction
- Lunar Dust Mitigation
- Space Weather Modeling

Nuclear Thermal Propulsion Project Overview

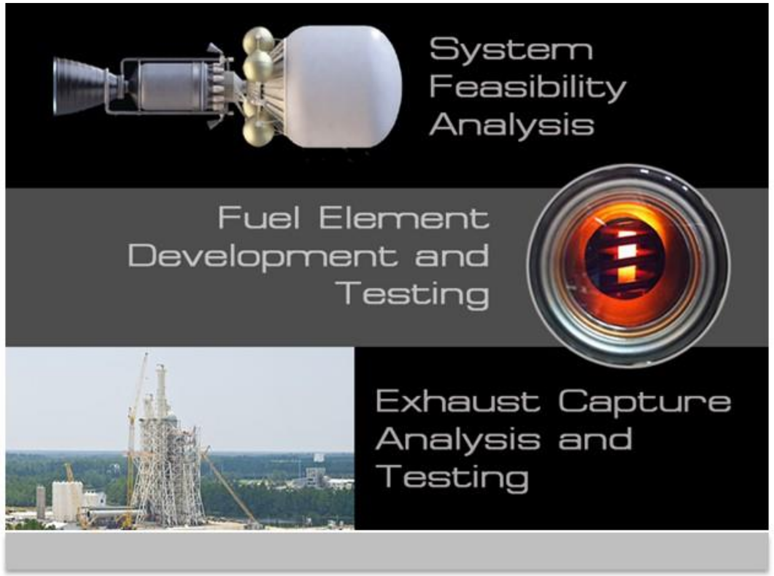
NTP key benefits:

- Faster transit times
- Reduced architectural mass
- Increased mission flexibility



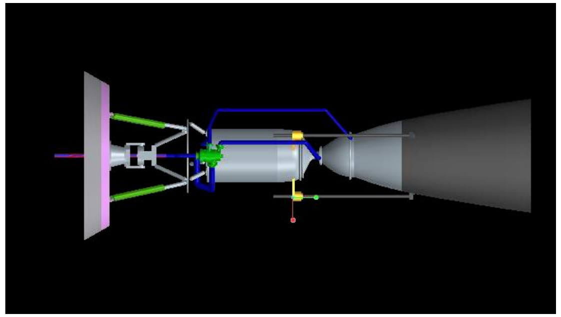
Main project objective:

- Determine the feasibility and affordability of an LEU-based NTP engine with solid cost and schedule confidence



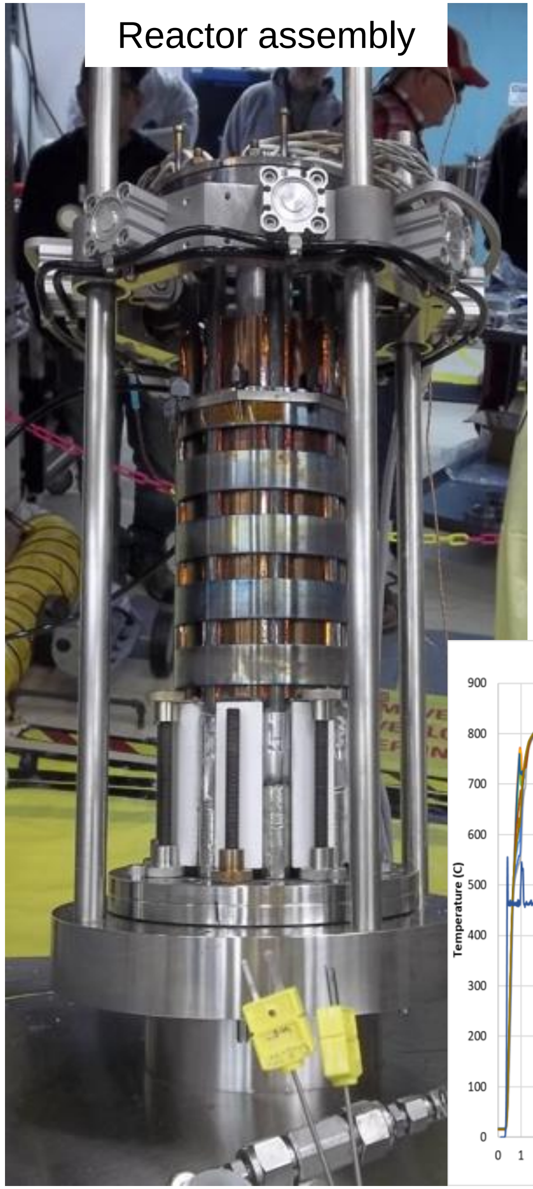
Major project elements:

- Evaluate the implications of using LEU fuel on NTP engine design and system performance
- Develop critical fuel element materials and manufacturing technologies
- Design, fabricate, and test fuel elements
- Develop conceptual designs for reactor and engine
- Develop relevant cryogenic propellant management technologies
- Assess options for ground and flight testing of an NTP engine
- Perform detailed NTP system feasibility analysis, including schedule and cost estimates for development through the first flight set



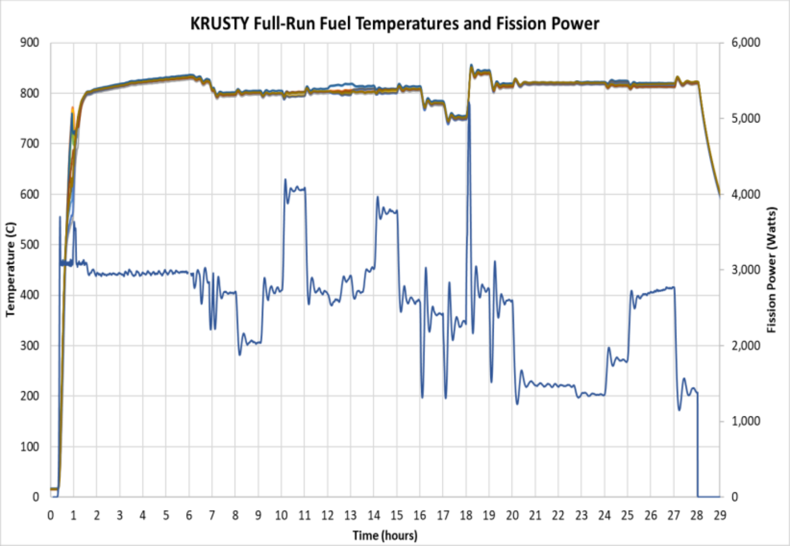
Fission Surface Power Test Summary

- **Designed with flight-like components** including uranium core, neutron reflector, heat pipes, and Stirling engines
- **Integrated into flight-like power system** with realistic configuration and interfaces
- **Tested at flight-like conditions** including full thermal power and operating conditions, and prototypic system dynamics, in a vacuum **environment**
- **Successful Mar 2018 full power test demonstrated:**
  - Fast startup to full temperature and power
  - Predictable and well-behaved performance
  - Automatic, self-regulating thermal output
  - Multiple fault tolerance without power loss



Reactor assembly

Installing heat pipes and clamps around HEU core



Rationale Underlying KRUSTY Test

Key considerations for the Kilopower Reactor Using Stirling Technology (KRUSTY) test:

- **Mission capture prospects for a small fission reactor**
  - Enabling for human exploration of Moon & Mars
  - Enabling for robust robotic science missions using nuclear electric propulsion

- **Component availability**
  - UMo fuel available relatively quickly and affordably from DOE
  - Stirling engines available at no cost from the ASRG program
  - Na heat pipes developed under a NASA SBIR project

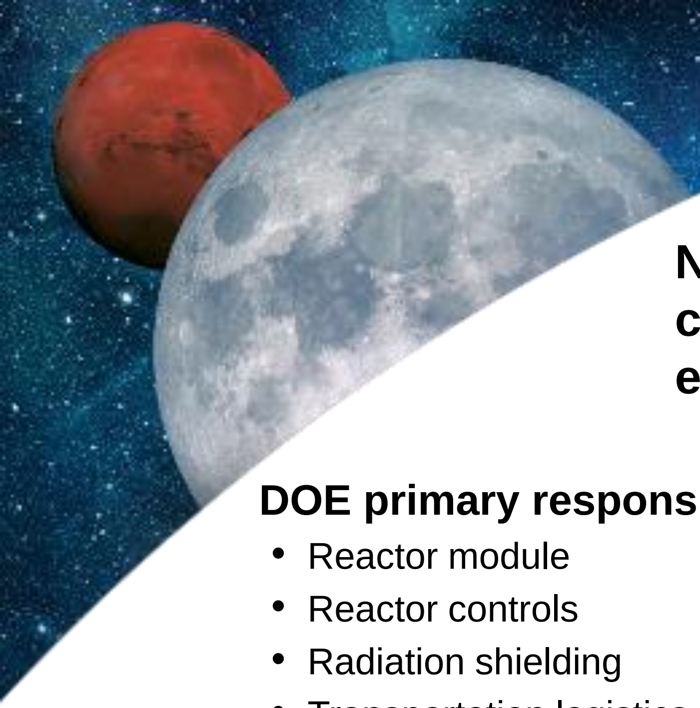
- **Facility availability**
  - Utilized personnel and infrastructure of the National Criticality Experiments Research Center at the NNSS Device Assembly Facility

- **Demonstrate capability to develop a space reactor**
  - NASA and DOE had not built a space reactor since the 1960s; several attempts since then had failed due to complexity & cost, so there were doubts that it could be done

- **Affordability and timeliness**
  - No other version of the test could have been done as quickly (3.5 yr) or inexpensively ($12.7 M NASA cost)

- **Managing technical & programmatic risk**
  - Avoid a lengthy & risky new fuel development
  - Accommodate the system with no major changes to the existing test stand, Safety Design Basis, standard operating procedures, or approved reactor safety systems

- **Cross-agency benefits**
  - NNSA and National Criticality Safety Program identified benefits from testing a space reactor, including data on BeO reflector materials, which led NNSA to co-fund the test



NASA/DOE Fission Surface Power Design Study

NASA and DOE are collaborating on a study to define a fission power system concept for a 10 kWe class flight demonstration to the Moon in 2027, with extensibility to human Mars missions. Final report is due in early 2020.

DOE primary responsibilities:
- Reactor module
- Reactor controls
- Radiation shielding
- Transportation logistics
- Pre-launch site testing
- Safety
- Security

NASA primary responsibilities:
- Power conversion
- Heat rejection
- Power management & distribution
- Lander integration
- Mission concept of operations
- Launch approval

Joint responsibilities:
- System integration & interfaces
- Primary heat transport
- Power system concept of operations
- Flight certification
- Communication strategy
- Industry & commercial partnerships
- Cost & schedule

The study final report will include:
- TRL assessment and technology maturation plan
- Comparison of reactor fuel options (including LEU & HEU)
- System mass sensitivity analysis relative to 2000 kg target
- Concepts for packaging on lunar lander and deployment
- Radiation dose vs distance sensitivity analysis
- Analysis of reactor maximum operating lifetime
- Analysis of core load-following characteristics
- Strategies for processing and launching the reactor
- Hardware heritage description
- CAD models
- Full system mass with appropriate growth allowances
- Estimated development cost & schedule
- Development & programmatic risk assessment
- Acceptance and qualification test plans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