EXPLORESPACE TECH

TECHNOLOGY DRIVES EXPLORATION

Space Technology Industry-Government-University Roundtable (STIGUR)

Dr. Anthony Calomino | Space Nuclear Technology Portfolio Manager | December 3, 2021

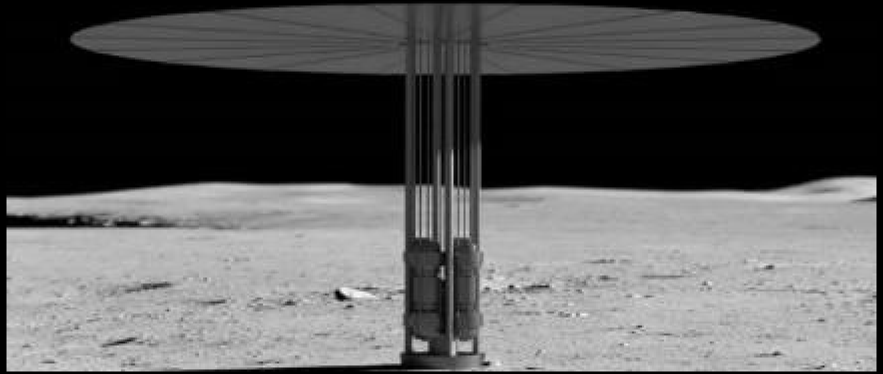
Space Nuclear Technologies

- Reliable energy production is essential to human and scientific exploration missions
- Nuclear enables higher energy systems that operate continuously in extreme environments
- NASA seeks synergy and collaboration with industry, other government agencies, and academia

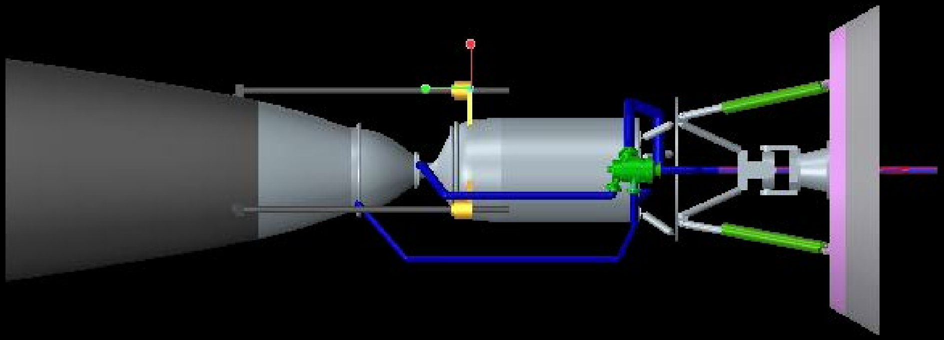
Benefits:

- ✓ Space Leadership
- ✓ National Security
- ✓ Global Competition
- ✓ Domestic Economy
- ✓ Green Energy

Space Nuclear Fission Technology Portfolio



- **Fission surface power**
  - Enable sustained, long-duration lunar operations
  - Establish an evolvable system for the Moon and Mars

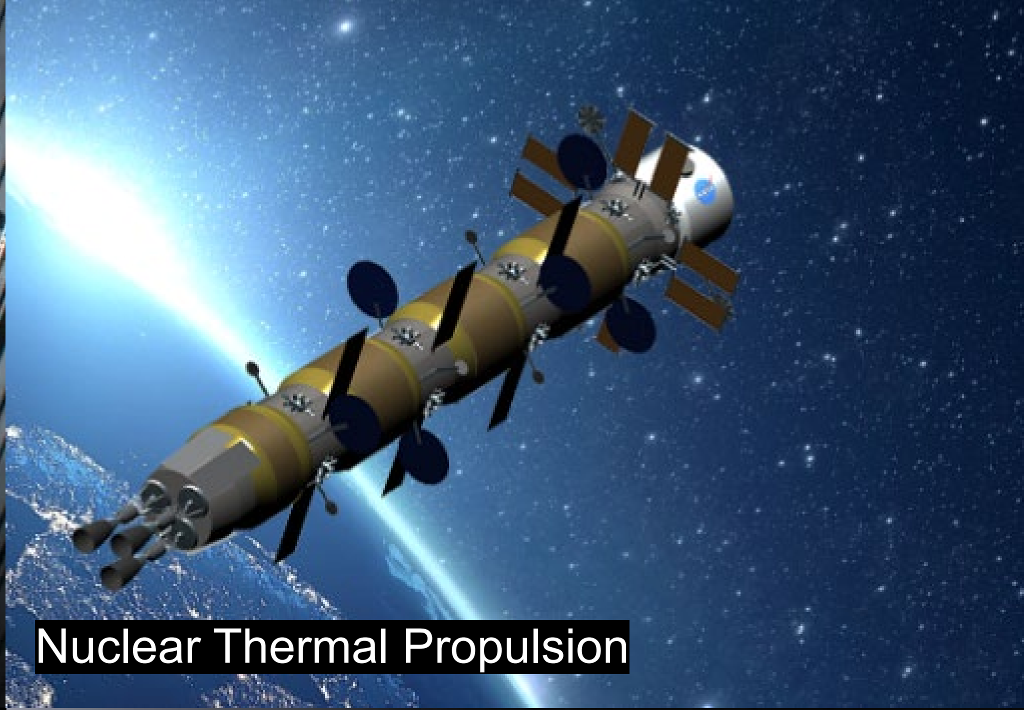


- **Space nuclear propulsion**
  - Advance a fast transit, in-space, nuclear propulsion capability
  - Evaluating nuclear thermal and electric propulsion options

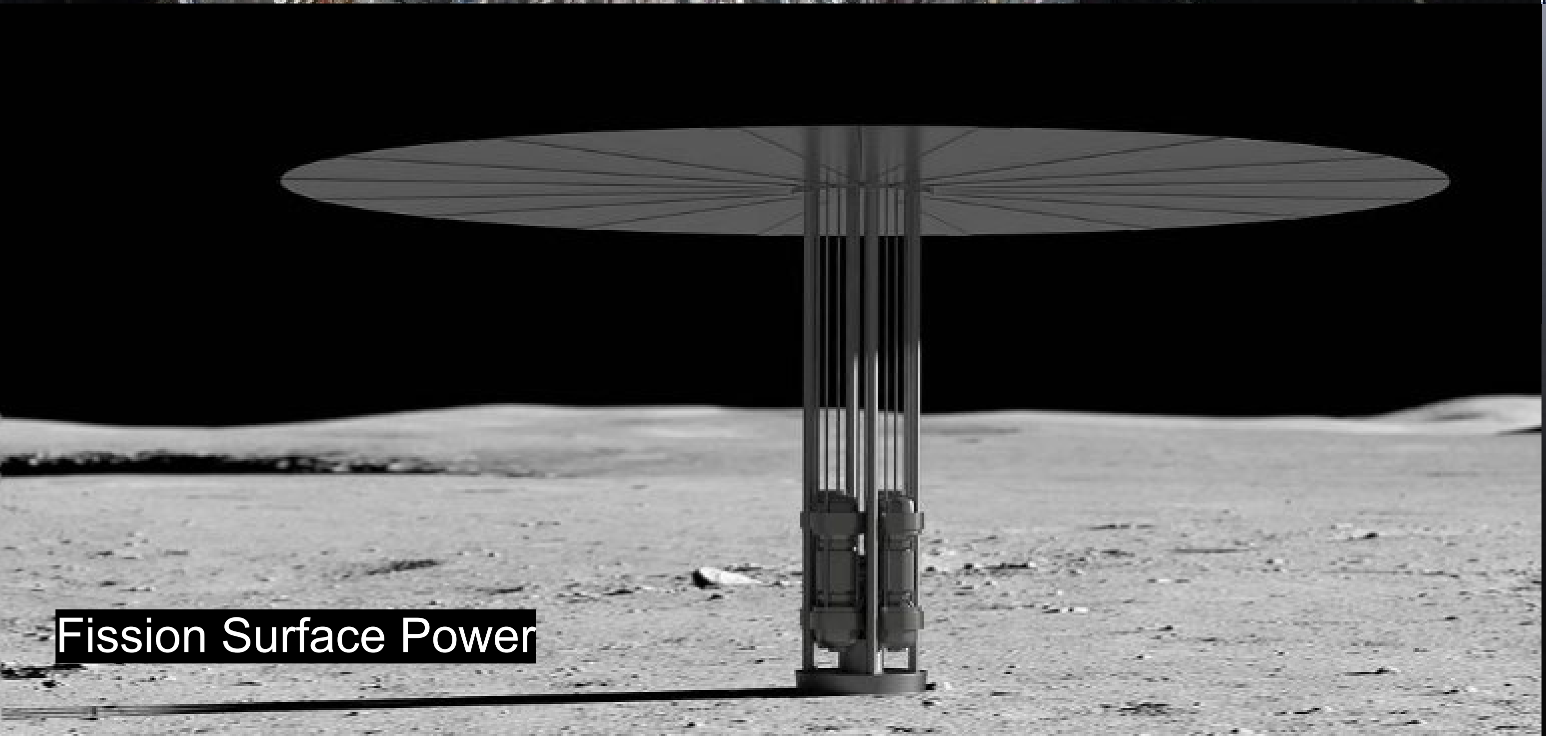
NASA's priority is surface fission power for lunar operations.

NASA and DOE are working together to develop low-enriched uranium solutions.

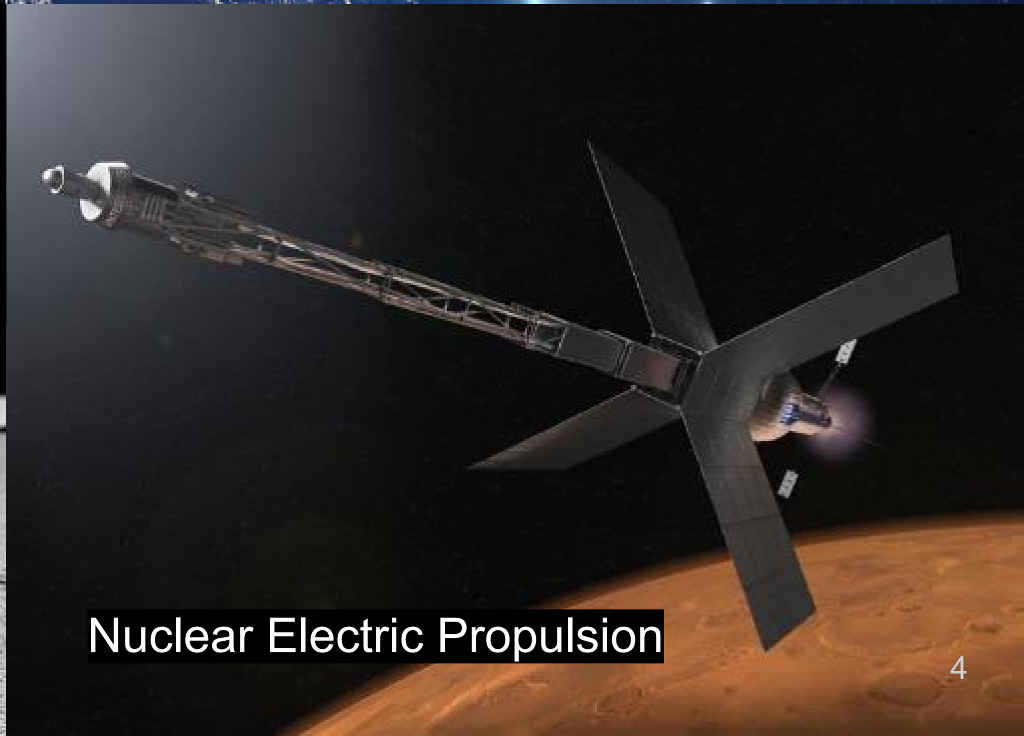
Cryogenic Fluid Management



Nuclear Thermal Propulsion



Fission Surface Power

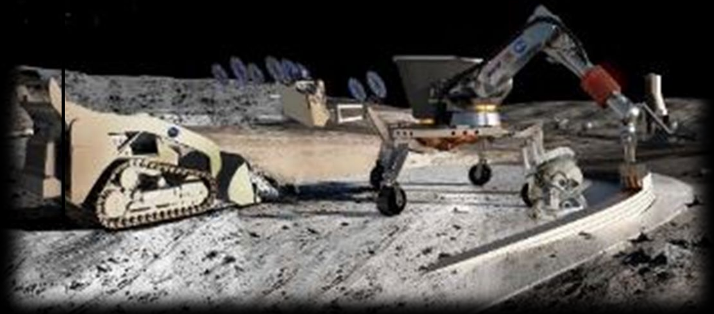


Nuclear Electric Propulsion

Fission Surface Power

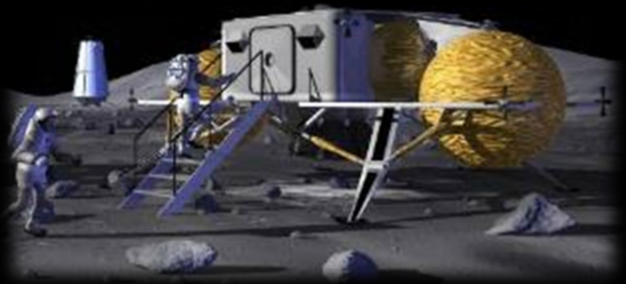
- Power: 40 kWe with technology extensible to higher power
- Mobility: Capable of being transported on a rover
- Size: Capable of fitting on a large lander
- Mass: Capable of fitting on a large lander

Surface Operations



ISRU Operations

Habitat Operations

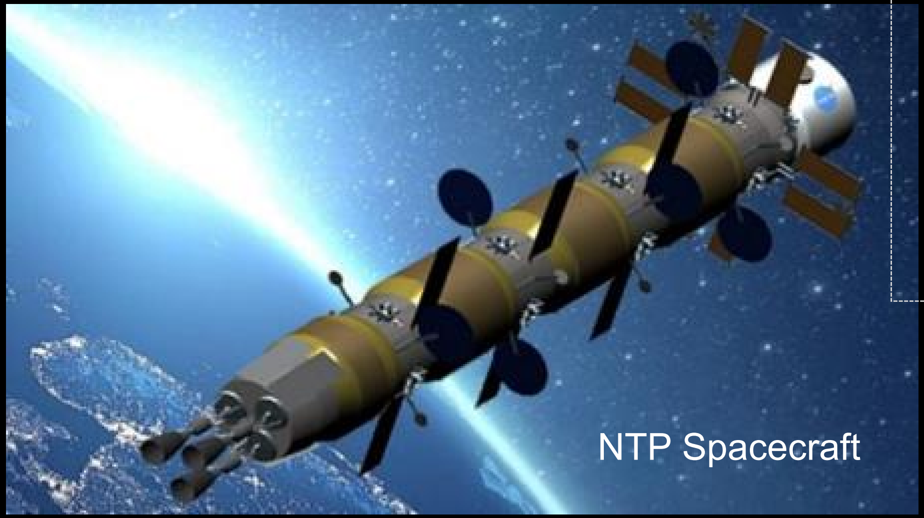


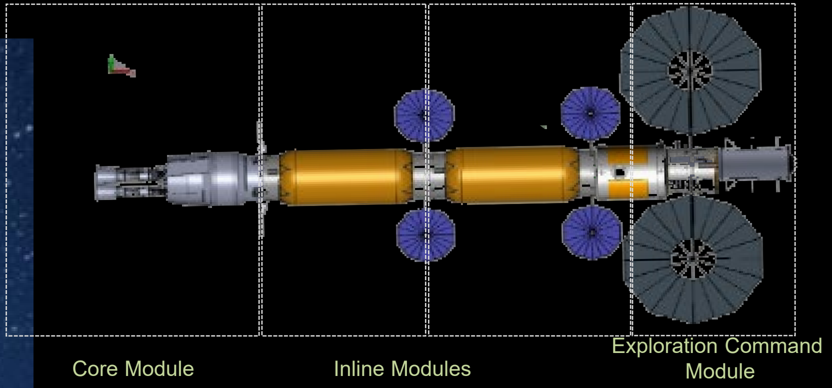
FSP industry solicitation released November 18, 2021
Two phase acquisition strategy for industry solutions:

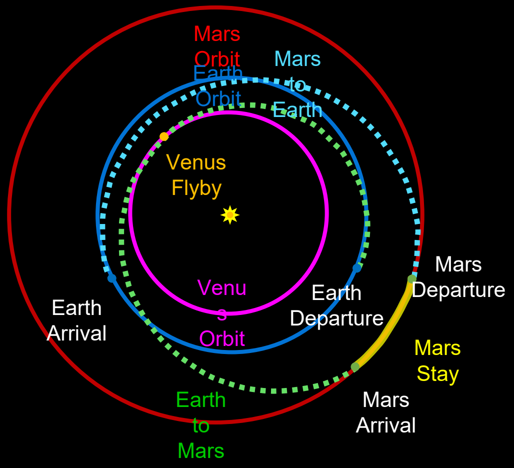
- Phase 1: Three 12-month efforts for a preliminary design
- Phase 2: System design, build, test, and delivery

Nuclear Thermal Propulsion

Nuclear thermal propulsion provides a balance of high propellant efficiency (900 sec Isp) and high thrust (>75,000 lb) capability.







NTP technology maturation plan considerations

- Multi 100-megawatt, high-assay, low enriched uranium reactor
- Extreme temperature reactor fuels and materials
- Reactor materials, manufacturing, and design methods
- Integrated subscale engine design and build
- Storage and management of cryogenic space propellants

Fuel and Reactor Maturation Testing

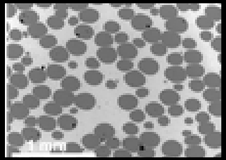
✓ Design-independent reactor risks identified and addressed with government Test Reference Design concept and test assessments capabilities

1) Fuel and Moderator Development

Assess performance at prototypic conditions during steady--state operation and start-up transient characterized to satisfy reactor mission lifetime

Coated Kernels

Solid Core Fuel



Moderator

2) Manufacturing Demonstration

Demonstrate new manufacturing processes proposed to enable a reactor through fabrication of representative design elements

Fuel Wafers

Flow Tubes and Fuel Elements

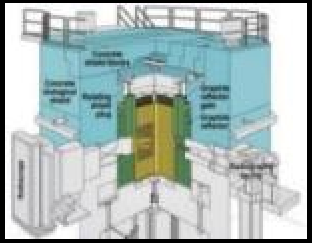
3) Nominal and Off-nominal Reactor Operation

Demonstrate the engineering functionality of representative design elements through combined thermal and nuclear loads testing to increase confidence

CFEET

NTREES

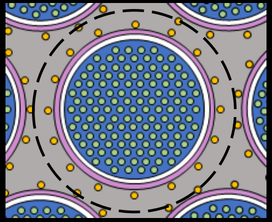
TREAT



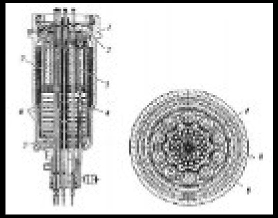
4) New Test Methods and Facilities

Modify existing facilities to enhance protoypical test capabilities and identify new, high-value test facilities that may be needed to reduce design risks

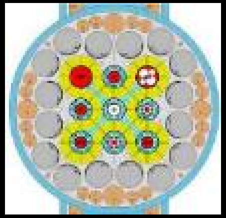
Representative Unit



Flowing Hydrogen/TREAT



SMART



Space Nuclear Technology Accomplishments

Fission Surface Power

- Established a HA-LEU government reference design to guide technology and design decisions
- Completed power conversion system and power transmission studies
- Released Phase I request for proposal to industry for industry-led designs
- Completed power conversion technology maturation SOW with planned release in December 2021

Space Nuclear Propulsion

- Successfully fabricated and tested cermet fuel element feature design
- Awarded three Phase I industry design awards with kick-off in September 2021
- Completed critical design to integrate flowing hydrogen in the INL TREAT facility
- Completed ground site studies for potential modified open-air test of subscale engine

Nuclear Thermal Propulsion Reactor Design

NASA selected three industry reactor preliminary design efforts in August 2021

- ✓ Preliminary design of a 12,500 lb, 900 sec Isp, HA-LEU powered reactor with a mass of less than 3500 kg
- ✓ Demonstrate design feasibility, manufacturability, and scalability

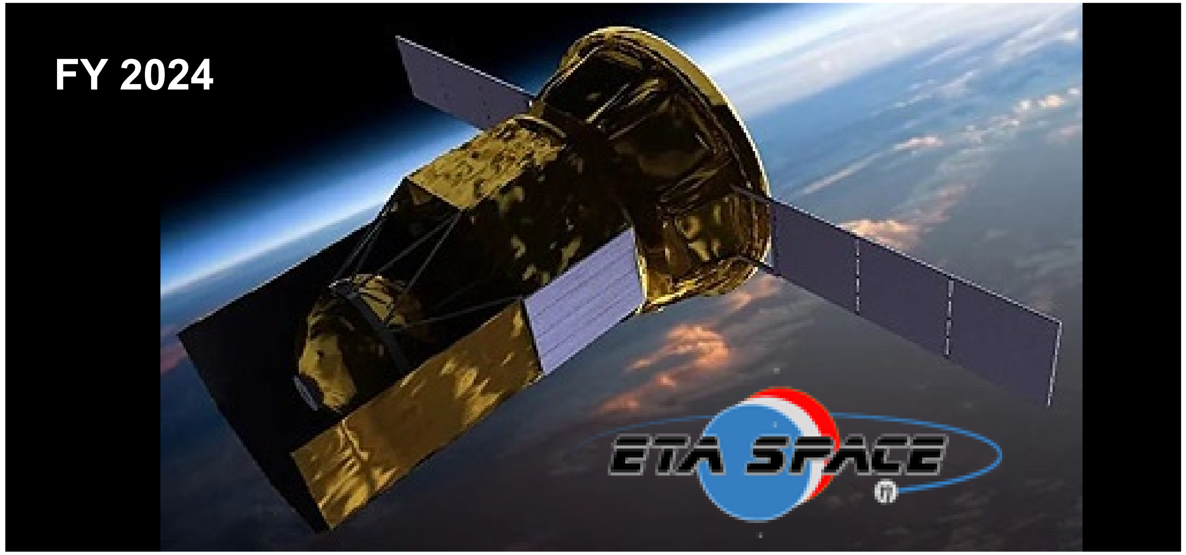
BWXT joined with Lockheed Martin, and Aerojet Rocketdyne are pursuing a metal hydride moderator block design with cercer fuel

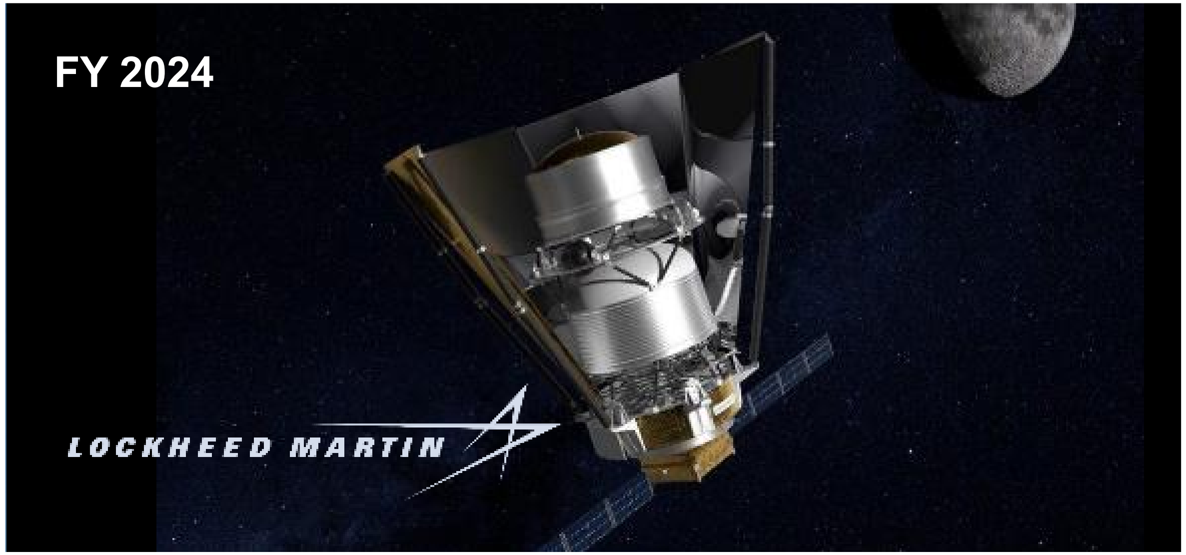
USNC partnered with Blue Origin, General Electric and Framatone are designing a beryllium moderator block reactor using cercer fuel

General Atomics teamed with X-Energy and Aerojet Rocketdyne propose to design a cercer fueled reactor that builds on Project Rover

Cryogenic Fluid Management Technology

NASA public-private partnerships advancing cryogenic fluid management through flight demonstrations

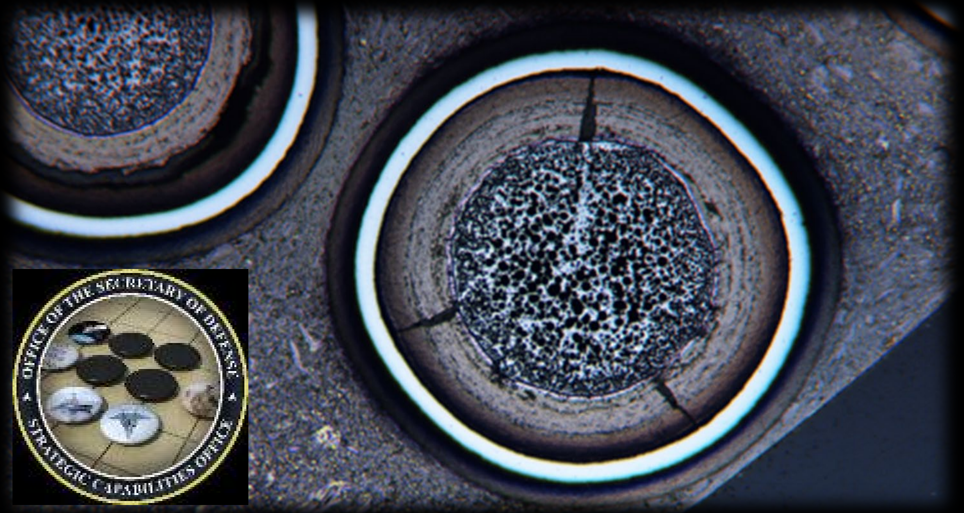




Interagency Collaborations

Propulsion

Fuel



Leverage Commonality:

- ✓ Reactor Designs
- ✓ Fuel Production
- ✓ Reactor Materials
- ✓ Launch Regulations

Facilities

Coordination

DEFENSE
INNOVATION UNIT

Interagency Engagements

DARPA – DRACO NTP Flight Demonstration

Program and technical teams provide support to proposal evaluations, contract management, cryogenic thermal management, fission reactor technology, and turbine machinery design

DOD/SCO – Mobile Terrestrial Power Plant

Partnered support to establish commercial source for coated fission fuel forms and participation in mobile reactor design advancements

USSF – Space Nuclear Systems Capabilities

Joint meetings to provide insight on space power investment initiatives, planned capabilities, development strategy

DIU – Low Kilowatt In Space Nuclear Power

Shared subject matter expertise supporting proposal evaluations, space nuclear electric propulsion technology, and small fission reactor development investments

DOE – Organic Authority and Nuclear Energy Expertise

Integrated technology development teams are maturing moderated LEU fission reactor designs and materials, design database development, digital modeling, and advancing nuclear test capabilities for space systems

Federal Policy and Processes

NSPM-20
Updates launch approval process and establishes quantified risk levels

SPD-6
Defines national strategy for use of space nuclear power and propulsion systems

Nuclear Regulatory Commission

Department Of Transportation

Defines:

- ✓ Agency launch authority
- ✓ Interagency reviews (INSRB)
- ✓ Use of HEU for SNPP
- ✓ Commercial launch process
- ✓ Process for interagency roadmap

OSTP/NSTC
Integrated implementation of SPD-6 and EO 13972 with integrated interagency roadmap

EO 13972
Directs NASA to utilize **common nuclear systems for exploration missions through 2040**

Mars Mission and Technology Trade Studies

Comparison of NEP and NTP:

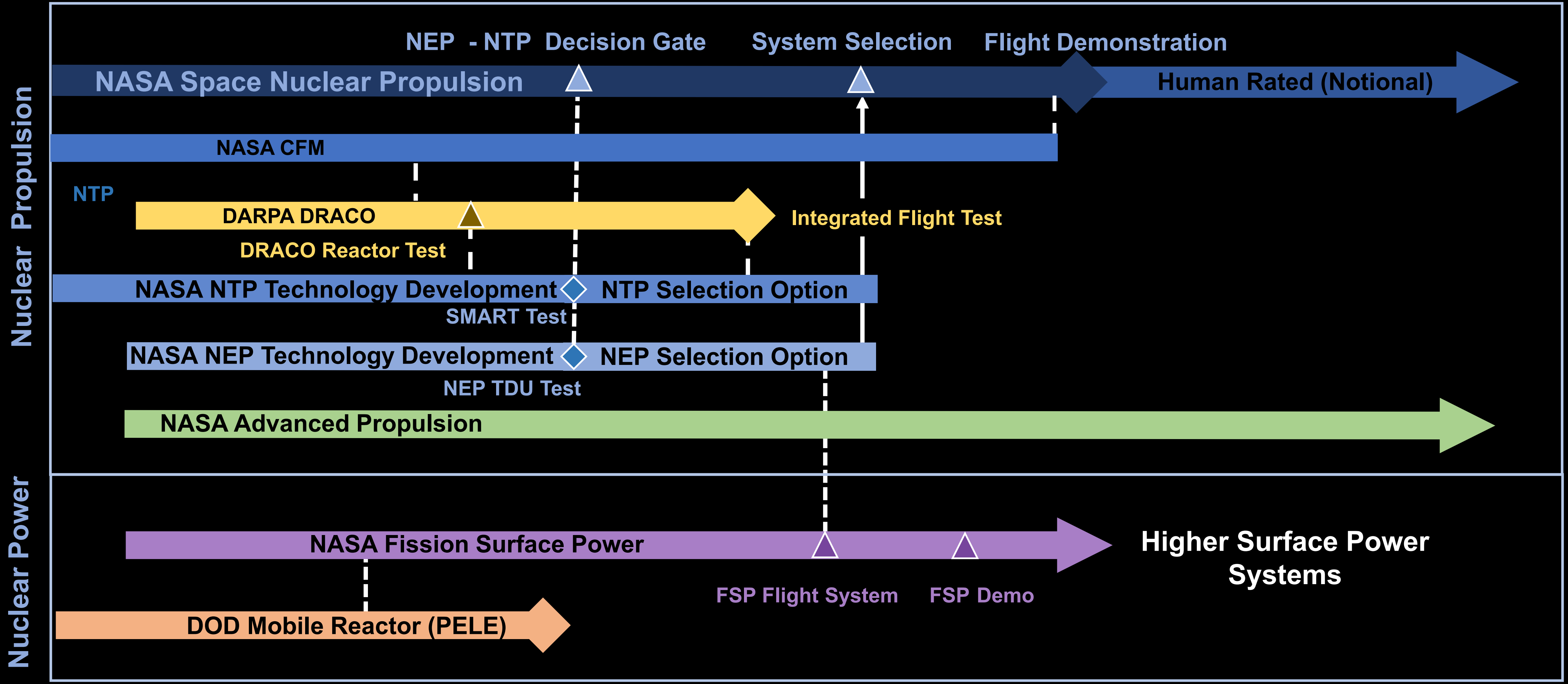
- National Academies of Science, Engineering, and Medicine (2021)
- NASA Engineering & Safety Center (2020)
- Mars Transportation Architecture Study (upcoming)

Key Takeaways:

1. Majority technology needs for both systems require aggressive development
2. NASA needs concurrent investment for both NEP and NTP to support an informed capability selection
3. Capability needs for NEP and NTP have comparatively equal levels of technology maturity and advancement difficulty
4. NEP requires less mass and significantly fewer launches for on-orbit staging

NASA is currently formulating elements for a NEP technology maturation effort

Preliminary Space Nuclear Fission Systems Roadmap



Plan enactment requires sustained commitment and substantial investment over the next 10-20 years