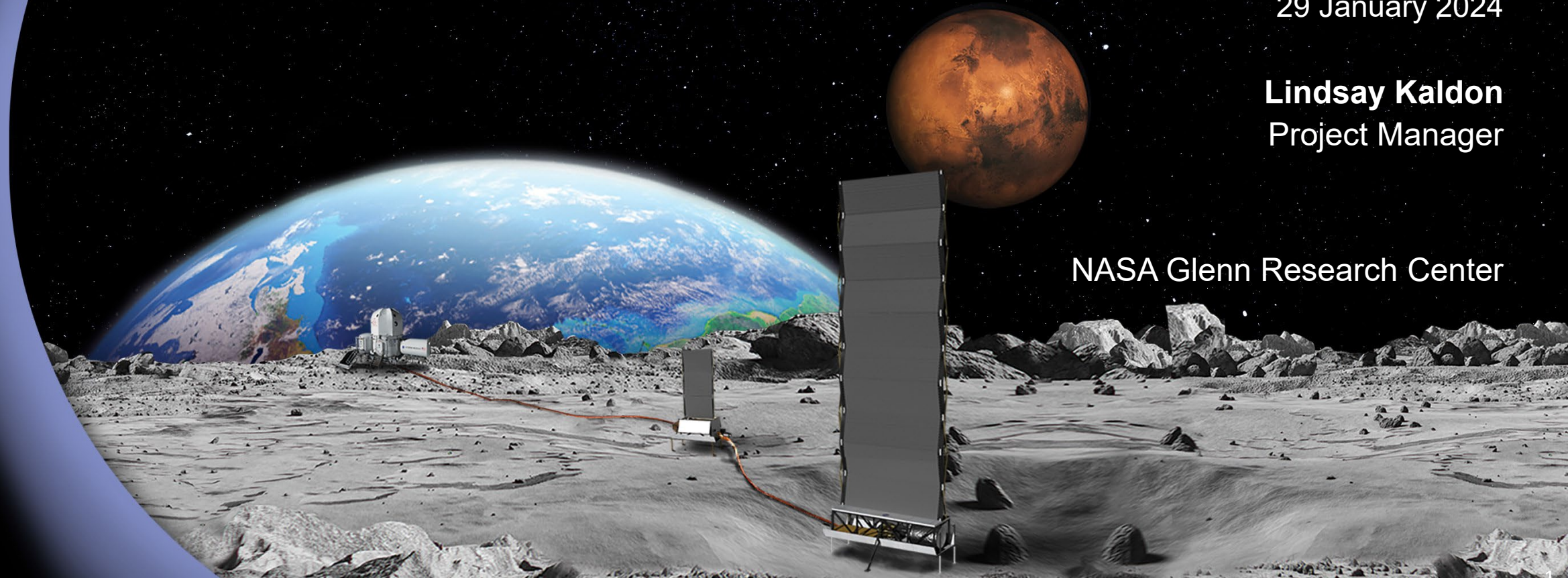
National Aeronautics and Space Administration

Fission Surface Power Project Overview

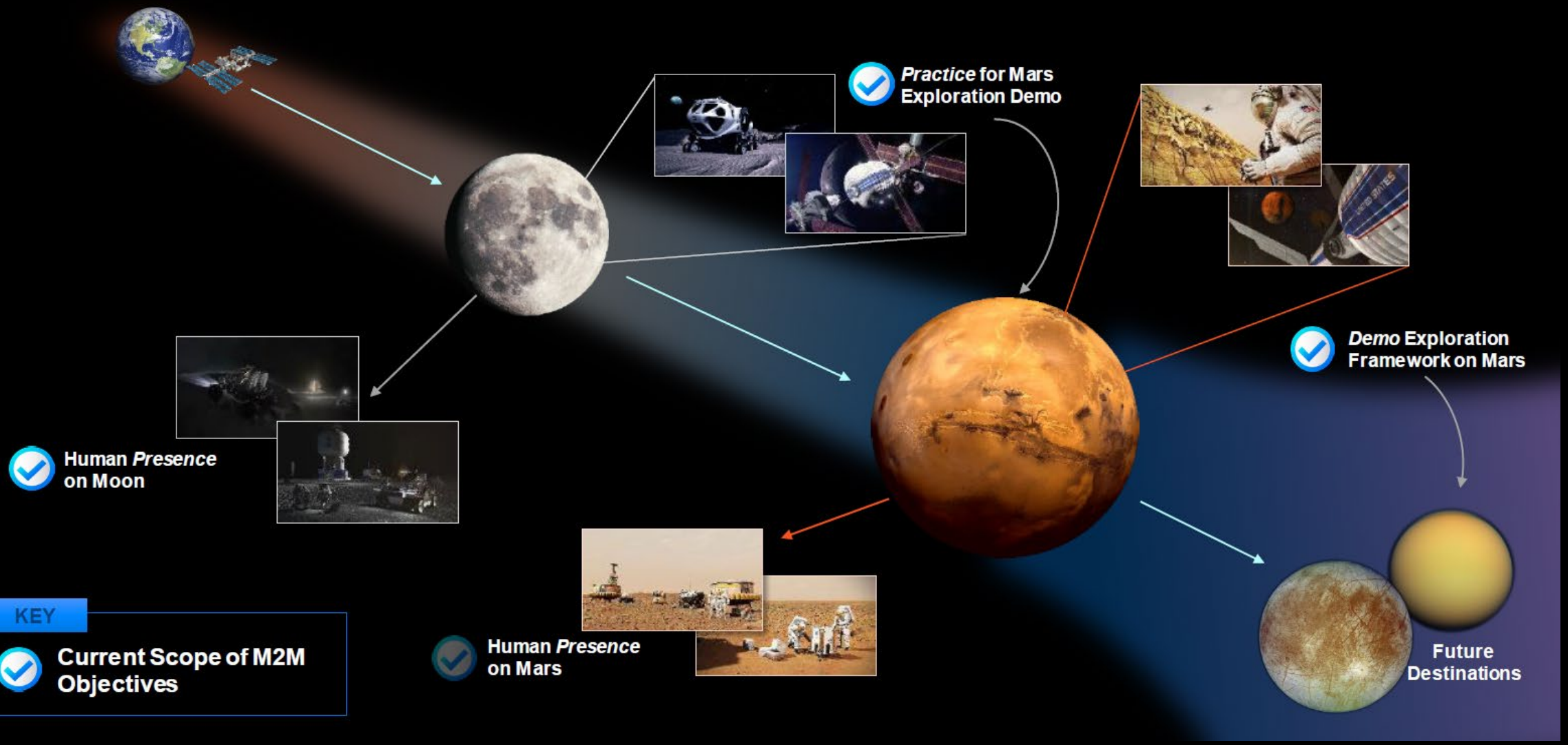
UK Space Agency Visit
Swindon, England
29 January 2024

Lindsay Kaldon
Project Manager

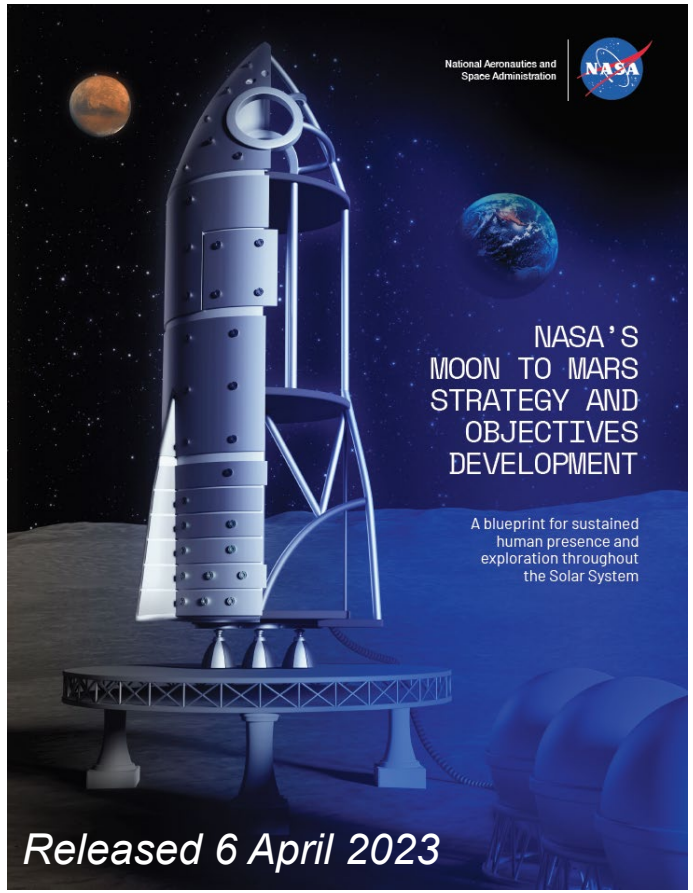
NASA Glenn Research Center



NASA Moon2Mars: Current Scope



NASA Moon2Mars Architecture: Strategy and Objectives



- **Human Lunar Return**
- **Foundational Exploration**
- **Sustained Lunar Evolution**
- **Humans to Mars**

Lunar Infrastructure (LI)

LI-1: Develop an incremental Lunar power generation and distribution system that is evolvable to support continuous robotic/human operation and is capable of scaling to global power utilization and industrial power levels.

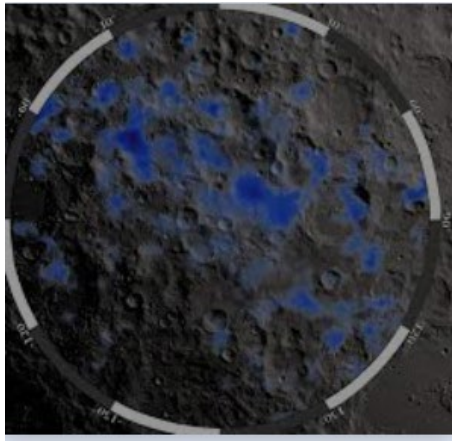
Mars Infrastructure (MI)

MI-1: Develop Mars surface power sufficient for an initial human Mars exploration campaign

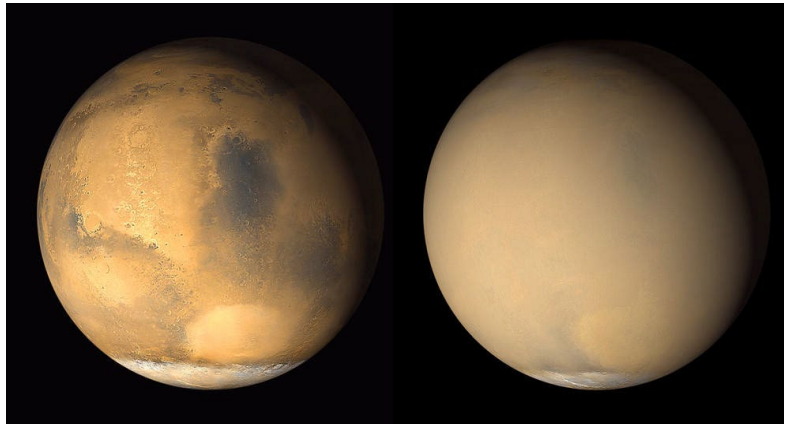
Why Develop a Fission Surface Power System?

Nuclear Power for the Moon and Mars

- Nuclear power systems will enable robust exploration of the Moon and Mars
  - Reliable and robust energy production is essential to human and scientific exploration missions to the Moon (to support Artemis) and Mars
  - Fission power systems can provide abundant and continuous surface power in all environmental conditions on the Moon and Mars:
    - Lunar night is 14.5 Earth days long and permanently shadowed regions may contain water ice. Surface nuclear power is required for a sustainable lunar presence
    - Mars has recurring planet-wide dust storms that can last for weeks or months
  - A fission system designed for a capability demonstration on the Moon will be directly applicable to human Mars exploration
  - Recent analyses indicate that a Mars fission surface power system is likely to enable 2x less mass to be flown to space and be more reliable than a comparable solar power system in the 10 to 40 kWe class

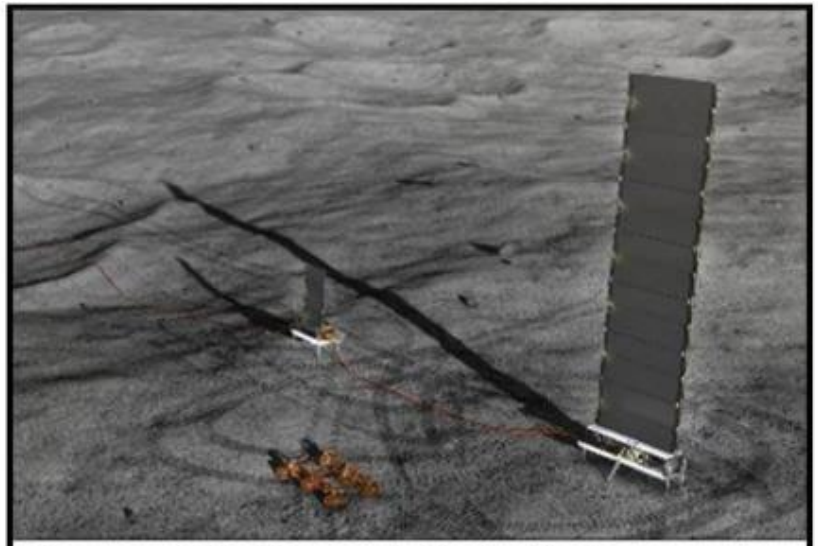


Permanently Shadowed Region...
lunar.gsfc.nasa.gov



nasa.gov

Fission Surface Power (FSP) Overview



Power: 40 kWe scalable to higher power
Mobility: Capable of being transported
Mass: less than 6,000 kg
Life: 10 years

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

- **Support Moon and Mars mission requirements**
- **Deliver a flight qualified Lunar demonstration system**
- **Transition FSP technology to industry**

- Develop a 40 kWe HALEU lunar fission power system for a launch date by the end of the decade
- Final design must show extensibility to support a Mars human exploration mission
- Project scope includes technology development, design, engineering, and delivery of integrated system
- Project near-term focus remains in technology development and formulation
- DOE/Idaho National Laboratory (INL) is managing nuclear industry design contracts

Established FSP system design can be leveraged for subscale NEP flight demonstrator or terrestrial application

FSP Overview Continued…

Industry will design and develop the system in two phases:

- **Phase 1: Completed Sept 2023**
  - Three industry teams worked 1-year contracts for initial designs

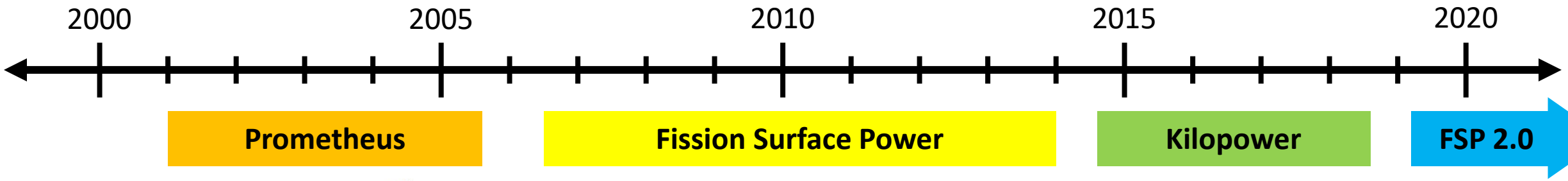
    Westinghouse / Aerojet Rocketdyne; Intuitive Machines / X-energy; Lockheed Martin / BWXT (BWX Technologies, Inc.)

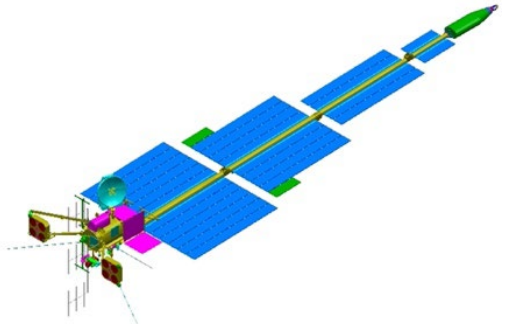
  - Deliverables included design documents, requirements, schedule and cost estimates for Phase 2



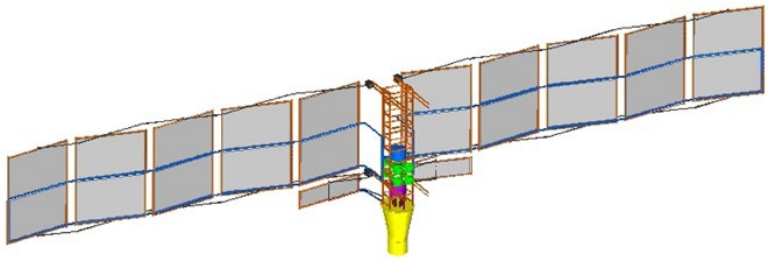
- **Phase 2:**
  - Planned to be a separate, open and competitive procurement
  - Deliverables include an engineering development unit and flight unit

Brief History of NASA Developments

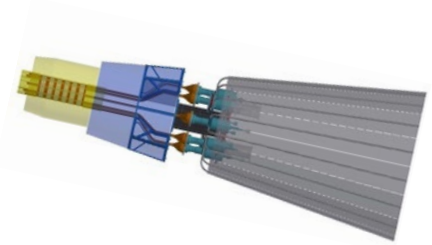




- 200 kWe, 20 yr life
- NEP science mission to Jovian moons
- 1200K HeXe-cooled UN reactor with Brayton
- 6600 kg, 33 kg/kWe
- Prime selected and PMSR completed (~$400M spent)

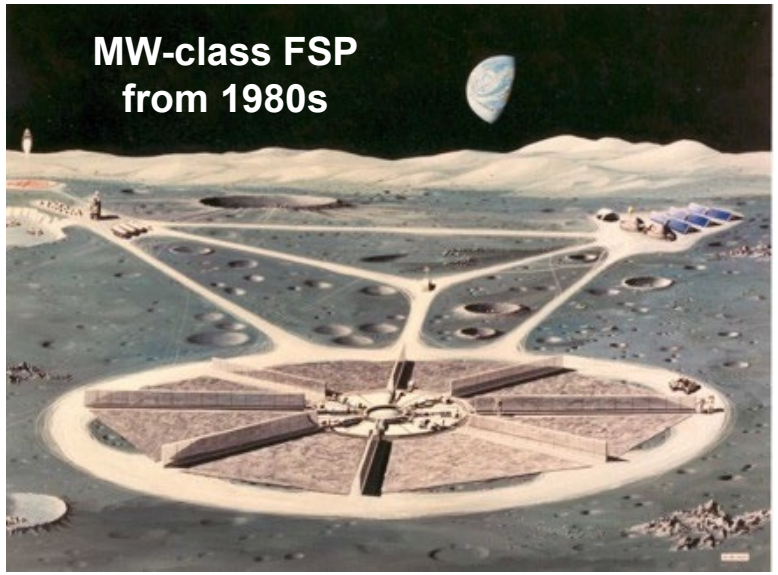


- 40 kWe, 8 yr life
- Long-duration lunar & Mars surface power
- 900K NaK-cooled UO2 reactor with Stirling
- 5800 kg, 145 kg/kWe
- Non-nuclear system test completed (~$50M spent)

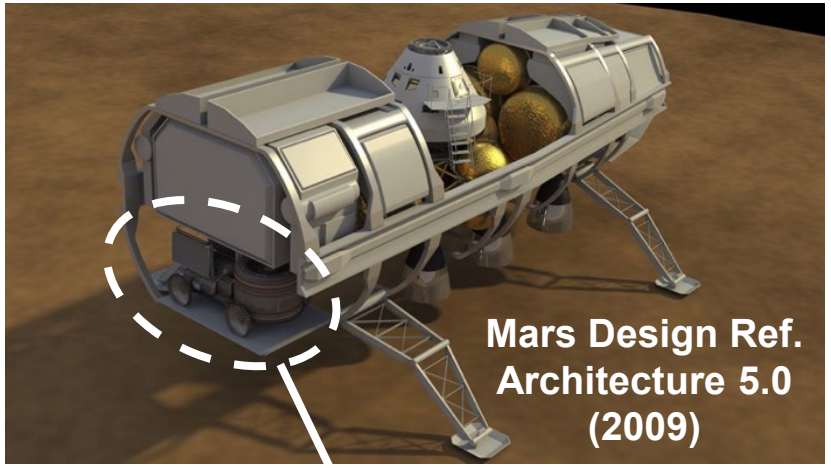


- 1 kWe, 10 yr life
- Low-tech fission alternative to RPS
- 1100K Na HP-cooled UMo reactor with Stirling
- 400 kg, 400 kg/kWe
- Reactor prototype test completed (~$20M spent)

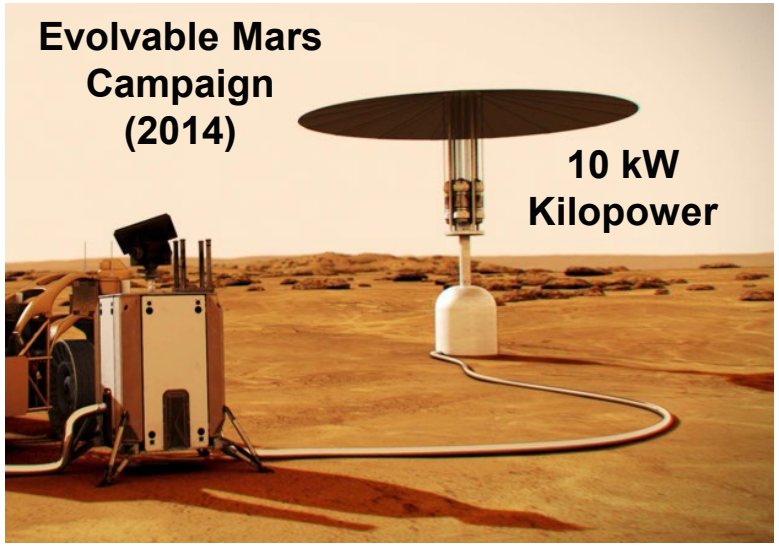
Prior FSP Concepts

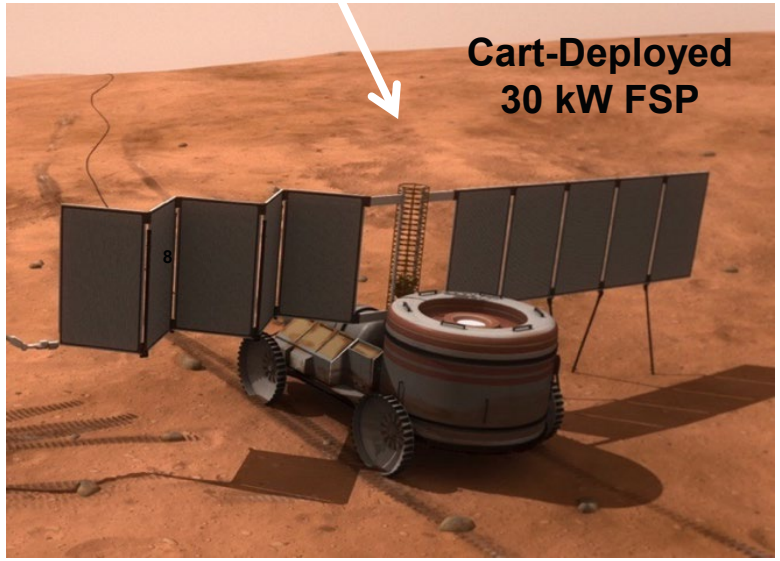








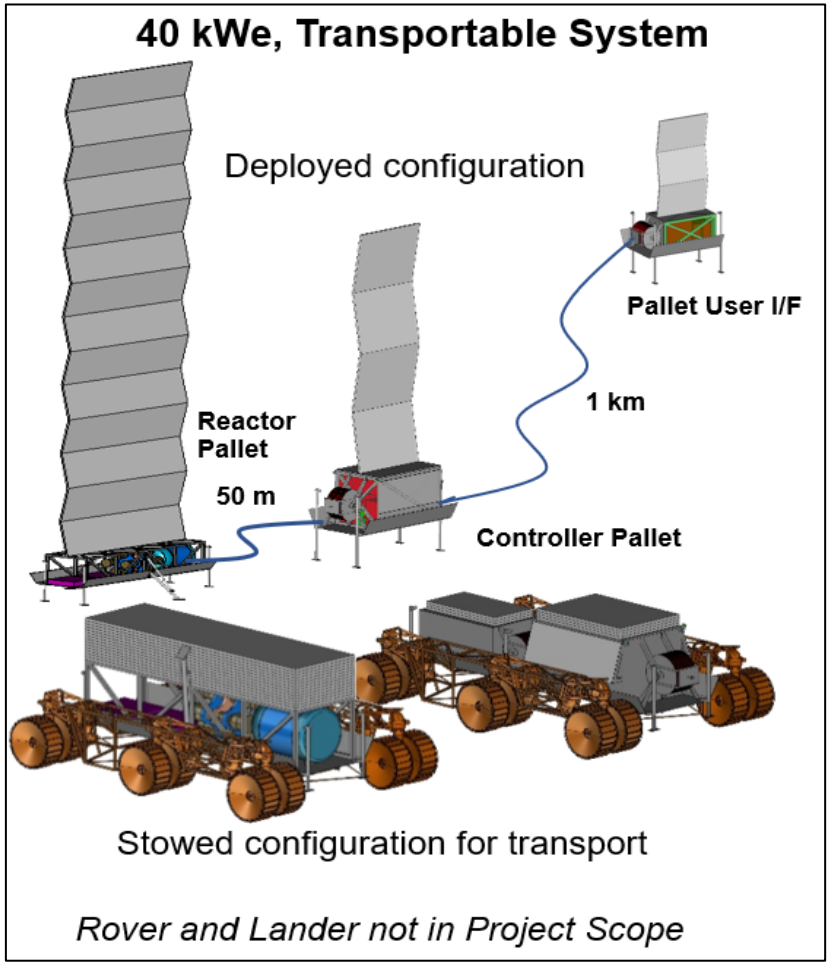




NASA Government Reference Design Concept

Concept Results (Glenn Research Center's COMPASS Team):

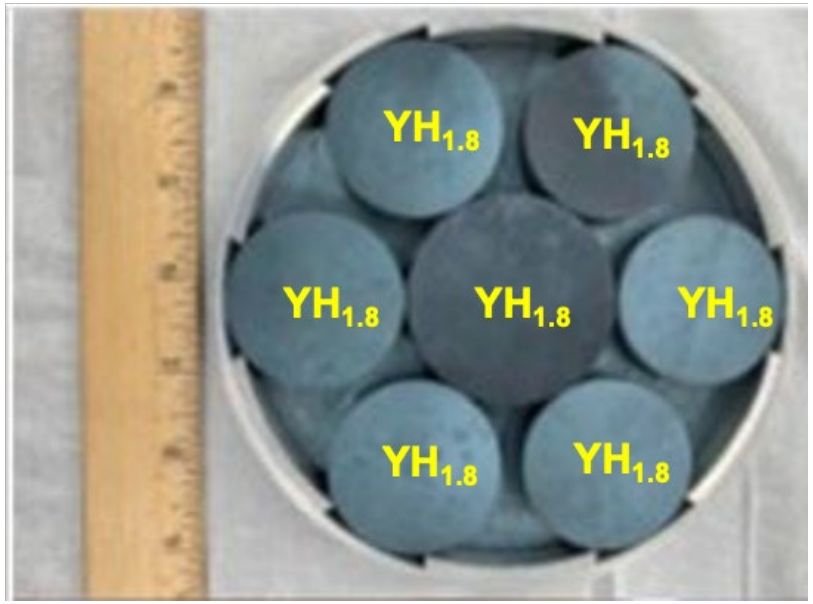
- **FSP System delivered in 3 pallets:** Reactor, Controller, User Load Interface
- **Reactor Pallet:**
  - A HALEU-moderated reactor with radiation shielding to protect co-located plant equipment, nearby electrical controls (50 m), and crew habitation area (1 km)
  - Power conversion may consist of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



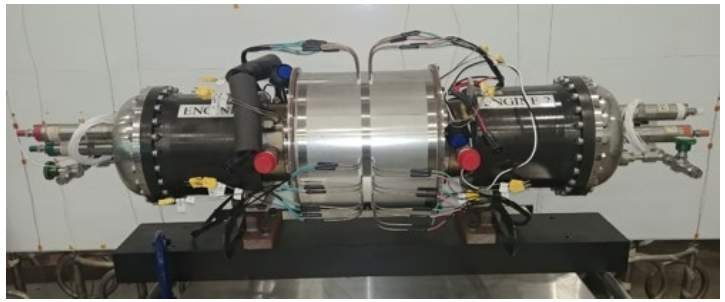
A 40 kWe transportable FSP system is feasible

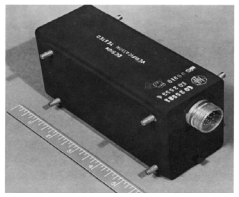
NASA Technology Maturation Investments

- **Current Tech Maturation efforts**
  - Integrated Heat Pipe-Stirling Converter Test
  - High Voltage PMAD Demonstration Test
  - Advanced Brayton Power Conversion System (PCS)
  - DOE: Moderator Materials, Shield Manufacturing, Instrumentation & Control

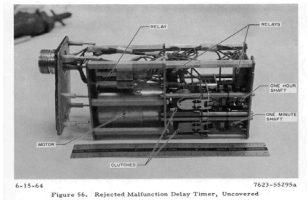


- **Potential Future Tech Maturation**
  - High Temperature SiC Sensors
  - Radiator Launch and Landing Survivability
  - Reactor Control Rod/Drive Mechanisms
  - PMAD Parts Testing





SNAP-10 Relays







Summary

- NASA is working with the Department of Energy and their federally funded laboratories to establish a lunar fission surface power system that is directly applicable for Moon and Mars
- NASA-GRC technology investments are targeting key non-nuclear systems needs, including power conversion solutions, radiation hardening of electronics, and power distribution capabilities critical to nuclear systems
- NASA will continue to be closely engaged with industry, academia, and other external stakeholders (both domestic and international) to seek innovative, unique designs for fission surface power systems