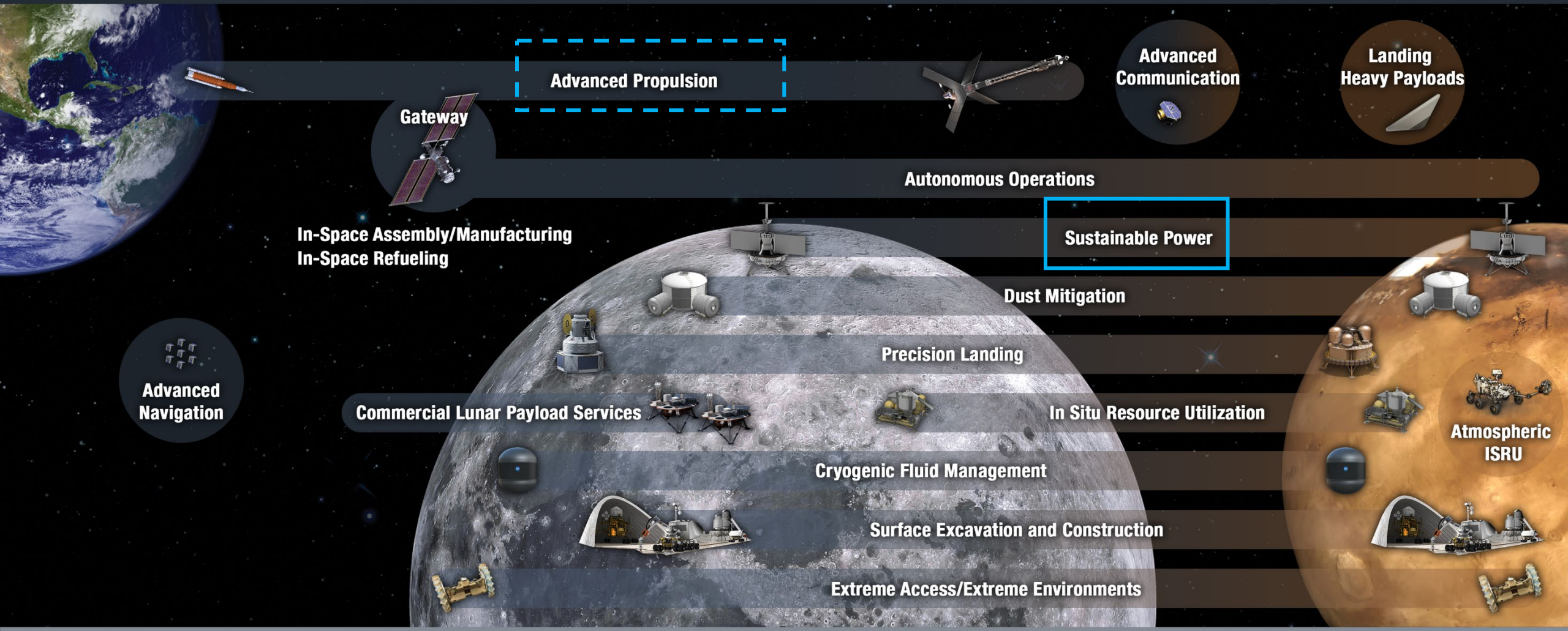
NASA's Space Power Technology Portfolio

2021 Space Power Workshop

Mr. John Scott | Principal Technologist - Power, Space Technology Mission Directorate | 04.19.2021

Technology Drives Exploration

Rapid, Safe, and Efficient Space Transportation	Expanded Access to Diverse Surface Destinations	Sustainable Living and Working Farther from Earth	Transformative Missions and Discoveries



2020 **GO | LAND | LIVE | EXPLORE** 203X

19 April 2021

STMD Strategic Framework

Lead

Ensuring American global leadership in Space Technology

- Lunar Exploration building to Mars and new discoveries at extreme locations
- Robust national space technology engine to meet national needs
- U.S. economic growth for space industry
- Expanded commercial enterprise in space

THRUSTS	OUTCOMES
Go — *Rapid, Safe, & Efficient Space Transportation*	• Develop nuclear technologies enabling fast in-space transits. • Develop cryogenic storage, transport, and fluid management technologies for surface and in-space applications. • Develop advanced propulsion technologies that enable future science/exploration missions.
Land — *Expanded Access to Diverse Surface Destinations*	• Enable Lunar/Mars global access with ~20t payloads to support human missions. • Enable science missions entering/transiting planetary atmospheres and landing on planetary bodies. • Develop technologies to land payloads within 50 meters accuracy and avoid landing hazards.
Live — *Sustainable Living and Working Farther from Earth*	• Develop exploration technologies and enable a vibrant space economy with supporting utilities and commodities • Sustainable power sources and other surface utilities to enable continuous lunar and Mars surface operations. • Scalable ISRU production/utilization capabilities including sustainable commodities on the lunar & Mars surface. • Technologies that enable surviving the extreme lunar and Mars environments. • Autonomous excavation, construction & outfitting capabilities targeting landing pads/structures/habitable buildings utilizing in situ resources. • Enable long duration human exploration missions with Advanced Life Support & Human Performance technologies.
Explore — *Transformative Missions and Discoveries*	• Develop next generation high performance computing, communications, and navigation. • Develop advanced robotics and spacecraft autonomy technologies to enable and augment science/exploration missions. • Develop technologies supporting emerging space industries including: Satellite Servicing & Assembly, In Space/Surface Manufacturing, and Small Spacecraft technologies. • Develop vehicle platform technologies supporting new discoveries.

Note: Multiple Capabilities are cross cutting and support multiple Thrusts. Primary emphasis is shown

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SPACE TECHNOLOGY PORTFOLIO

NIAC
NASA Innovative Advanced Concepts

LuSTR

Go

Power for Rapid, Safe, & Efficient Space Transportation

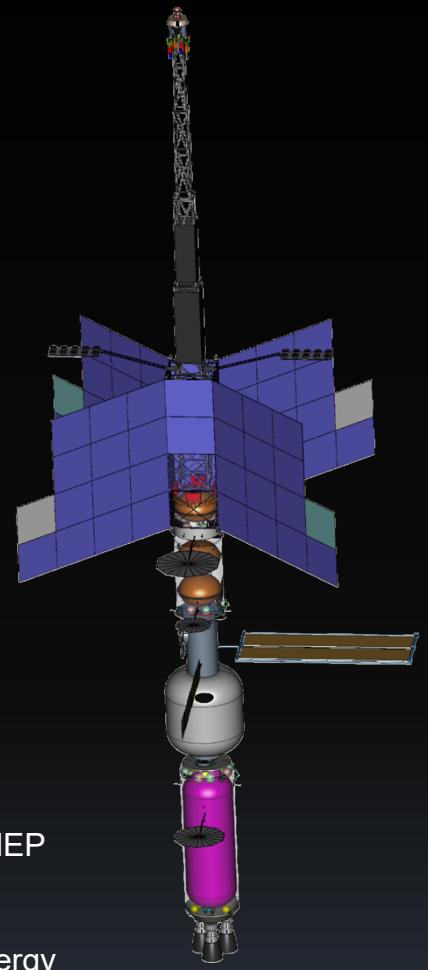
- **Develop nuclear technologies enabling fast in-space transits.**
- **Develop Advanced Propulsion technologies that enable future science/exploration missions.**

NIAC studies in nuclear fusion have produced candidates for ARPA-e explorations

- Tarditi, Aneutronic Fusion (2011)
- Slough, MSNW (2012)
- Thomas, Princeton Satellite (2016)
- Sedwick, Inertial Electrostatic (2017)
- LaPointe, Magneto-Inertial (2017)

- 2008 SBIR with Deployable Space Systems, Inc. developed Roll-out Solar Array (ROSA), now infused for ISS and Gateway and available for Artemis
- Current Photovoltaics efforts
  - Composite solar array blankets with low storage volume

Solar Electric Propulsion (SEP)
Nuclear Electric Propulsion (NEP)



Technology Demonstration Missions

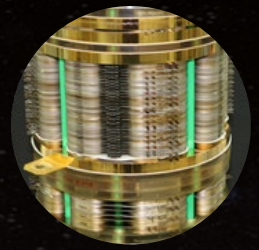
- Space Nuclear Technologies (SNT) Program studies:
  - Low specific mass multi-MW NEP system for Mars cruise ΔV (1200+K fission space power reactor with He/Xe Brayton energy conversion)
  - Nuclear Thermal Propulsion (NTP) system (25 klb_f engines)
- Solar Electric Propulsion (SEP) Program: Multi-MW photovoltaic array studies

Land

Expanded Access to Diverse Surface Destinations

- **Enable Lunar/Mars global access with ~20t payloads to support human missions.**

Primary Fuel Cells



Game Changing Development

- ACO/Lander Fuel Cell: Partner with HLS competitor for ~1 kW Proton Exchange Membrane fuel cell prototype

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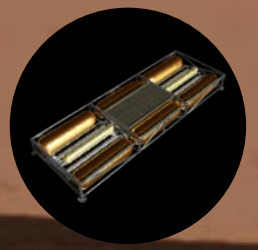
Live *Sustainable Living and Working Farther from Earth*

- Sustainable power sources and other surface utilities to enable continuous Lunar and Mars surface operations.

Energy Storage



Surface Power

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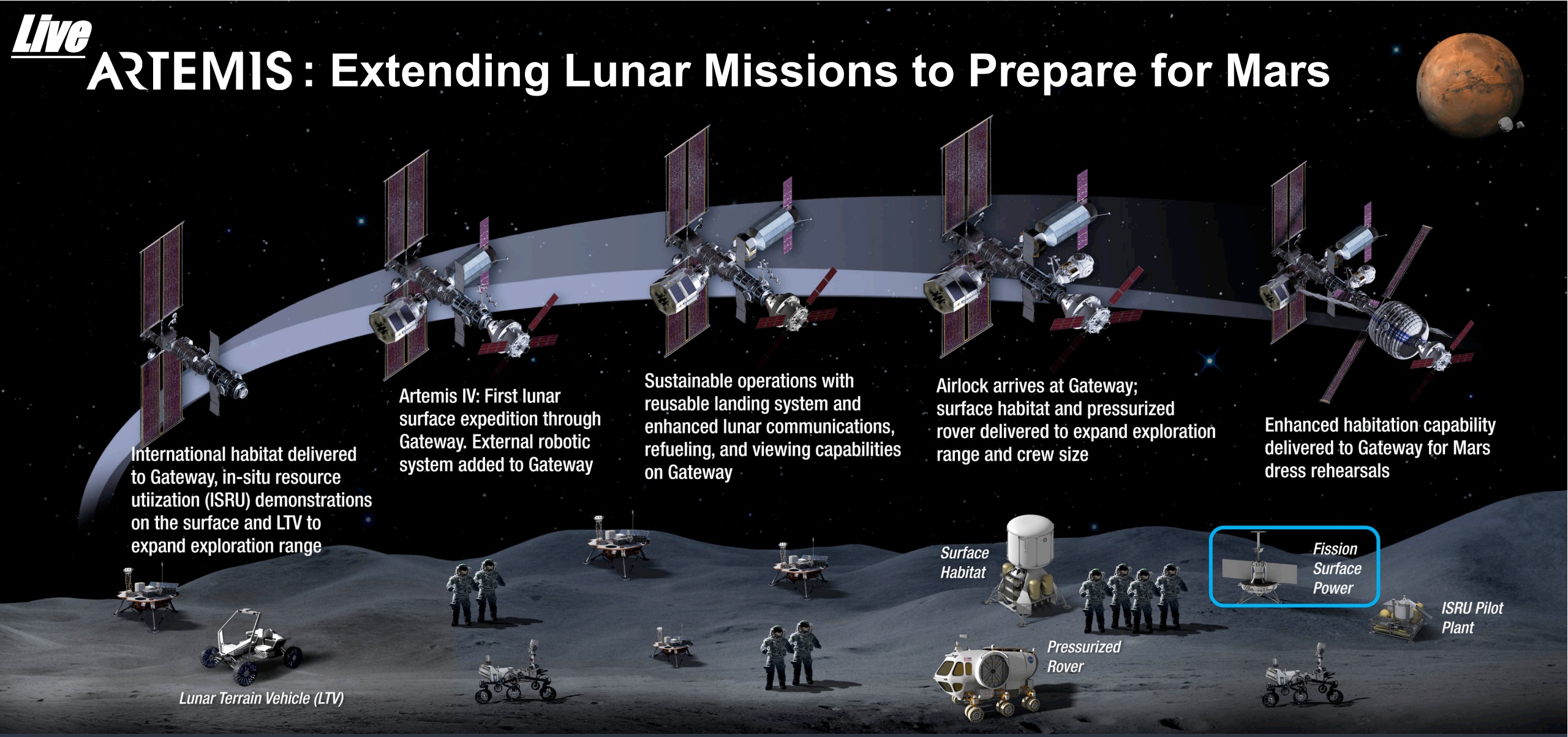
Live ARTEMIS: Extending Lunar Missions to Prepare for Mars



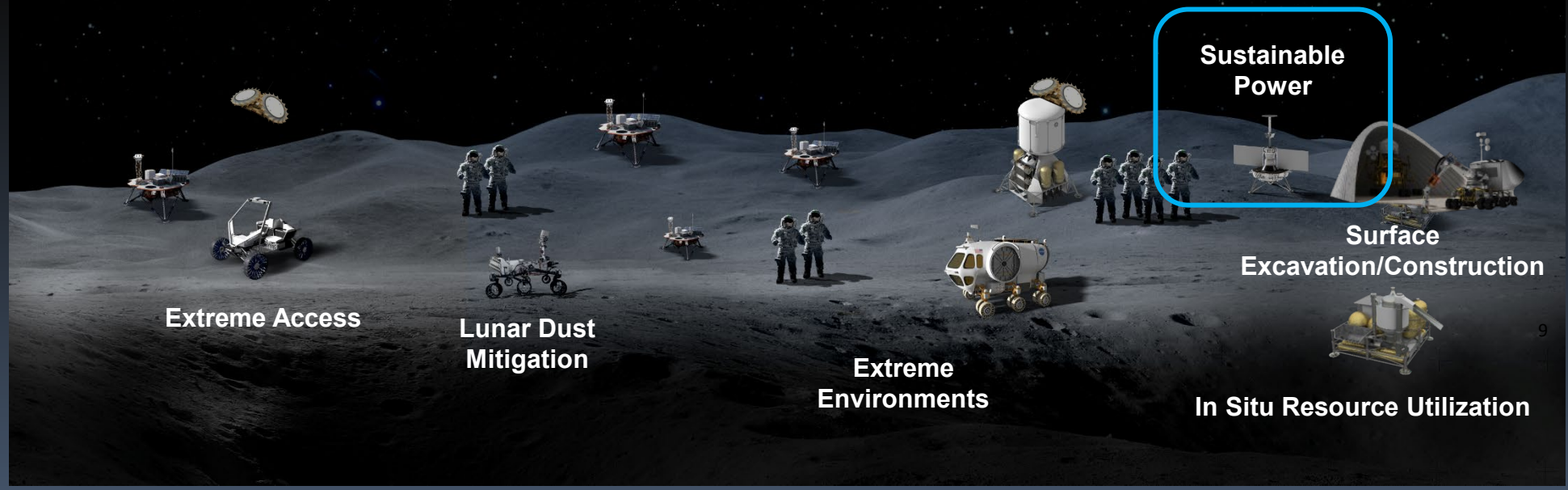
SUSTAINABLE LUNAR ORBIT STAGING CAPABILITY AND SURFACE EXPLORATION

MULTIPLE SCIENCE AND CARGO PAYLOADS | U.S. GOVERNMENT, INDUSTRY, AND INTERNATIONAL PARTNERSHIP OPPORTUNITIES | TECHNOLOGY AND OPERATIONS DEMONSTRATIONS FOR MARS

Lunar Surface Innovation Initiative (LSII)

LSII works across industry, academia and government through in-house efforts and public-private partnerships to develop transformative capabilities for lunar surface exploration

- The Lunar Surface Innovation Consortium (LSIC) includes academia, industry, non-profits and other government agencies
- Formulating and integrating technology maturation activities across the TRL pipeline and Space Tech programs
- Leveraging innovative procurement mechanisms to expedite technology development
- Utilizing early uncrewed lunar surface flight opportunities to inform key technology development



Live Sustainable Living and Working Farther from Earth

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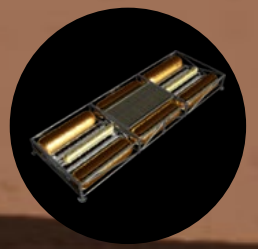
Energy Storage



Surface Power

Space Tech Research Grants

- Fuel Cells/Batteries
  - Metal combustion
  - Solid state, Low-temperature batteries (*several grants)*
  - Li-S batteries
  - Ca-based batteries
- Photovoltaic Arrays
  - III-V on Si multi-junction photovoltaic cells

LuSTR

- Wireless power transfer (UCSB)
- Si-C power electronics (Vanderbilt)
- Flexible microgrids (Ohio State)

SBIR·STTR America's Seed Fund™

- Nuclear Power
  - Integrated neutron-gamma shielding
  - Stirling convertor
  - Heat pipe thermal management
- Fuel Cells/Batteries
  - Primary solid oxide fuel cell
  - Li-S battery
- Photovoltaic Arrays
  - Radiation-hardened IMM multi-junction photovoltaic cells
- Power Distribution and Control
  - Radiation-hardened Si-C electronics

NASA CENTENNIAL CHALLENGES

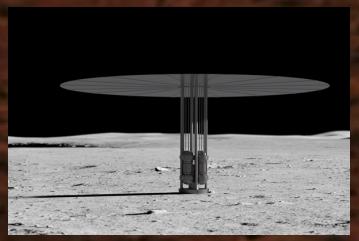
- Watts-on-the-Moon Challenge

Game Changing Development

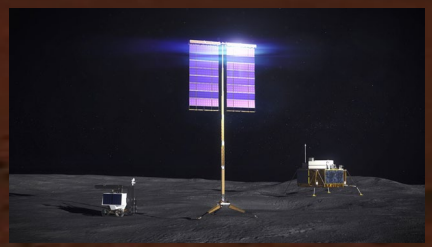
- Fuel Cells:
  - AMPES – Primary PEM fuel cell
  - ERFC – Regenerative PEM fuel cell
  - BRAC – Regenerative alkaline fuel cell
  - PFSOFC – Primary solid oxide fuel cell propellant-fed
- Photovoltaic Arrays:
  - VSAT – 10 kW_e vertically deployed PV array
  - ACO/FSAP – Flexible meta-morphic-α PV arrays
  - Lunar dust mitigation on flexible PV arrays
- Power Distribution and Control
  - Ultra-fast proximity charging – inductive battery charging
  - TP/RPCD – Radiation-hardened switching power controller

Technology Demonstration Missions

- Fission Surface Power (FSP): 10+ kW_e fission reactor with Stirling conversion



FSP



VSAT

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Live *Sustainable Living and Working Farther from Earth*

https://www.youtube.com/watch?v=m-yAcTujeRI&feature=emb_title

Lunar Surface Innovation Initiative (LSII)

NASA CENTENNIAL CHALLENGES

NASA'S **WATTS ON THE MOON** CHALLENGE

NASA seeks to incentivize flexible, robust energy distribution, management and storage solutions to power future Moon missions.

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Distribute and store/manage power for multiple activities and missions

PRIZE PURSE:

Up to $5M PRIZE PURSE

Phase 1: Up to $0.5 M/ 8 months

Phase 2: Up to $4.5 M/ 28 months

In judging

Explore

Transformative Missions and Discoveries

- **Develop vehicle platform technologies supporting new discoveries.**

Space Tech Research Grants

- Energy Harvesting
  - SEEPS
  - 2D materials
- Radioisotope Power
  - p-type thermoelectrics
  - Combustion synthesis of thermoelectrics

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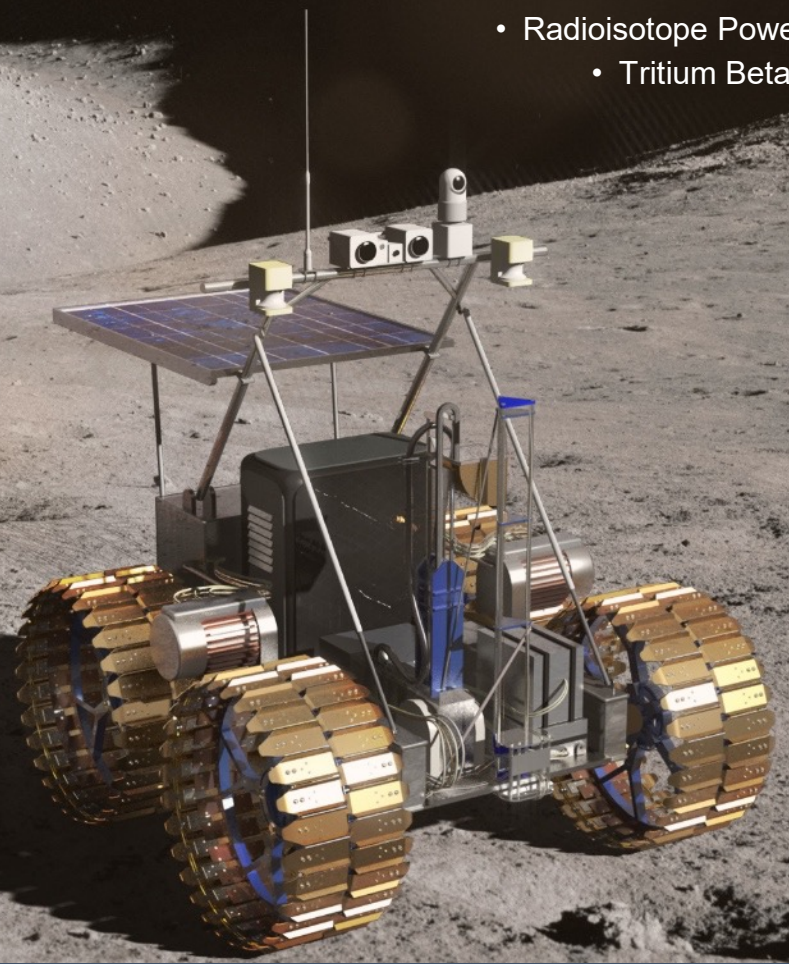
America's Seed Fund™

- Radioisotope Power
  - Tritium Betavoltaics

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www.nasa.gov/spacetech