

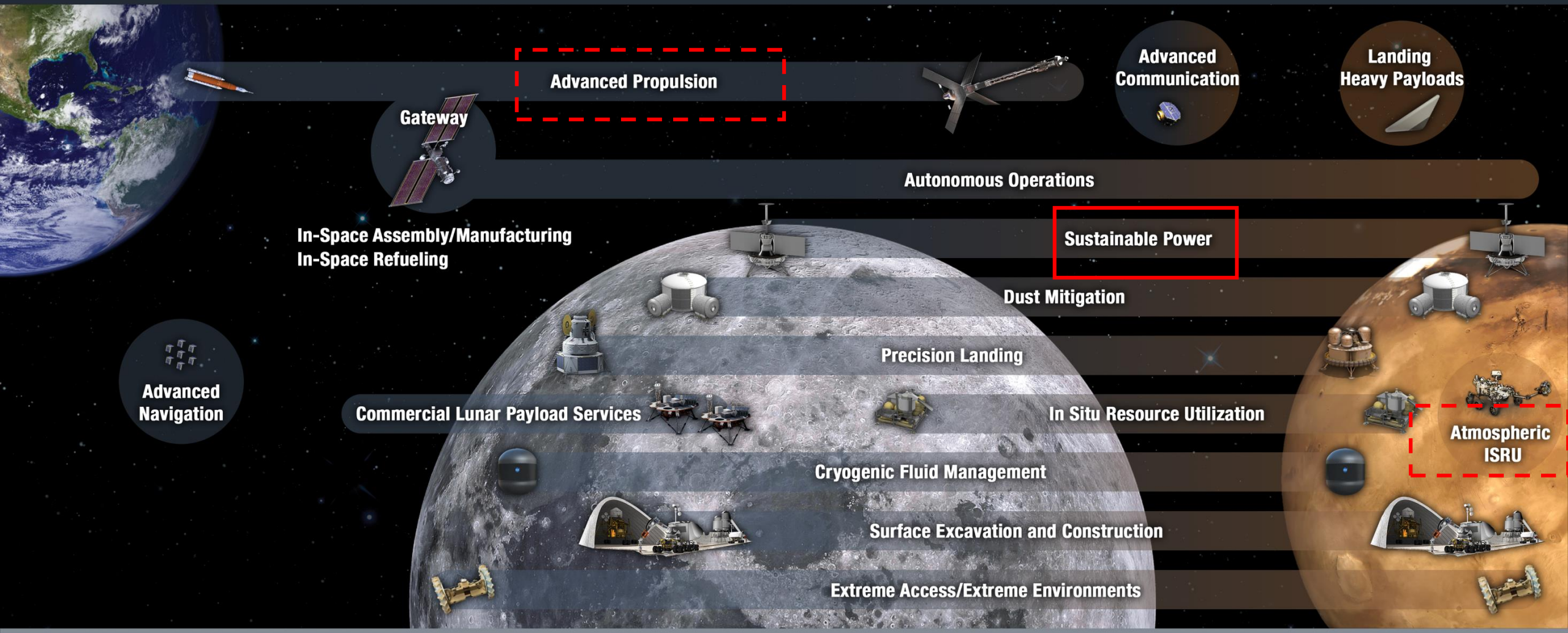
NASA's Space Power Technology Portfolio

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

STMD Strategic Framework

Lead

Ensuring American global leadership in Space Technology

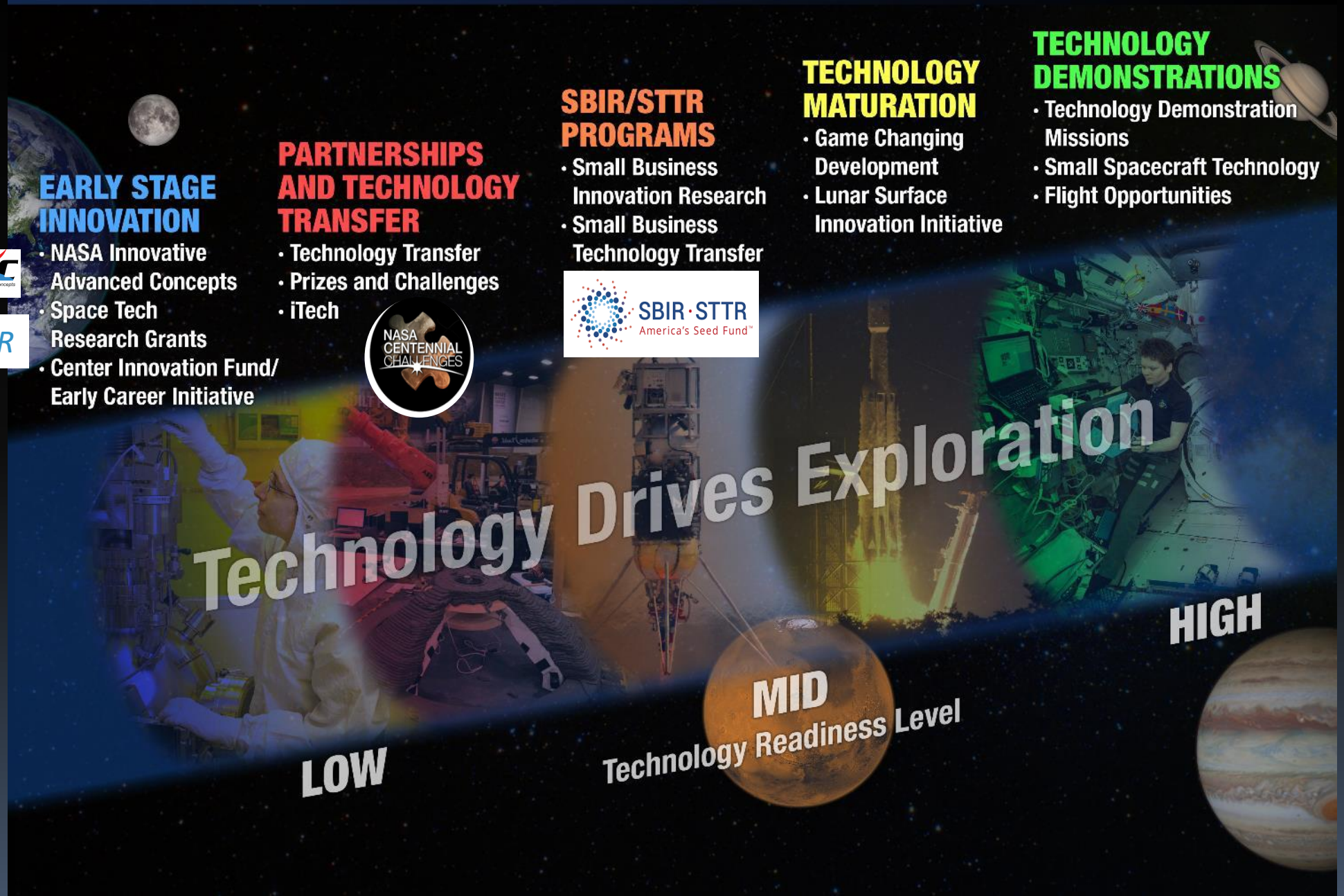
- Lunar Exploration building to Mars and new discoveries at extreme locations
- Robust national space technology engine to meet national needs
- U.S. economic growth for space industry
- Expanded commercial enterprise in space

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

Revision date: : Febrary 3, 2021

SPACE TECHNOLOGY PORTFOLIO



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.**

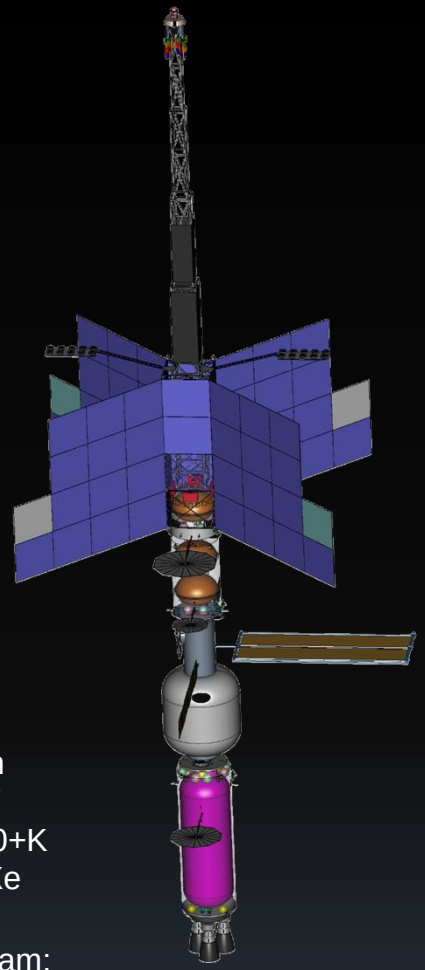
NIAC studies in nuclear fusion have produced candidates for ARPA-e explorations

- 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

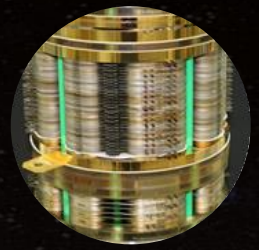
- Space Nuclear Power (SNP) Program studies: Low specific mass multi-MW NEP system for Mars cruise DV; 1200+K fission space power reactor with He/Xe Brayton energy conversion.
- Solar Electric Propulsion (SEP) Program: Multi-MW photovoltaic array studies

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

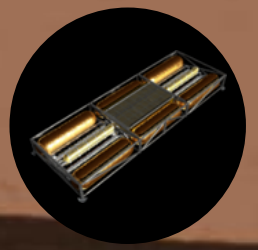
- ACO/Lander Fuel Cell: Partner with HLS competitor for ~1 kW Proton Exchange Membrane fuel cell prototype

Revision date: : May 26, 2020

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

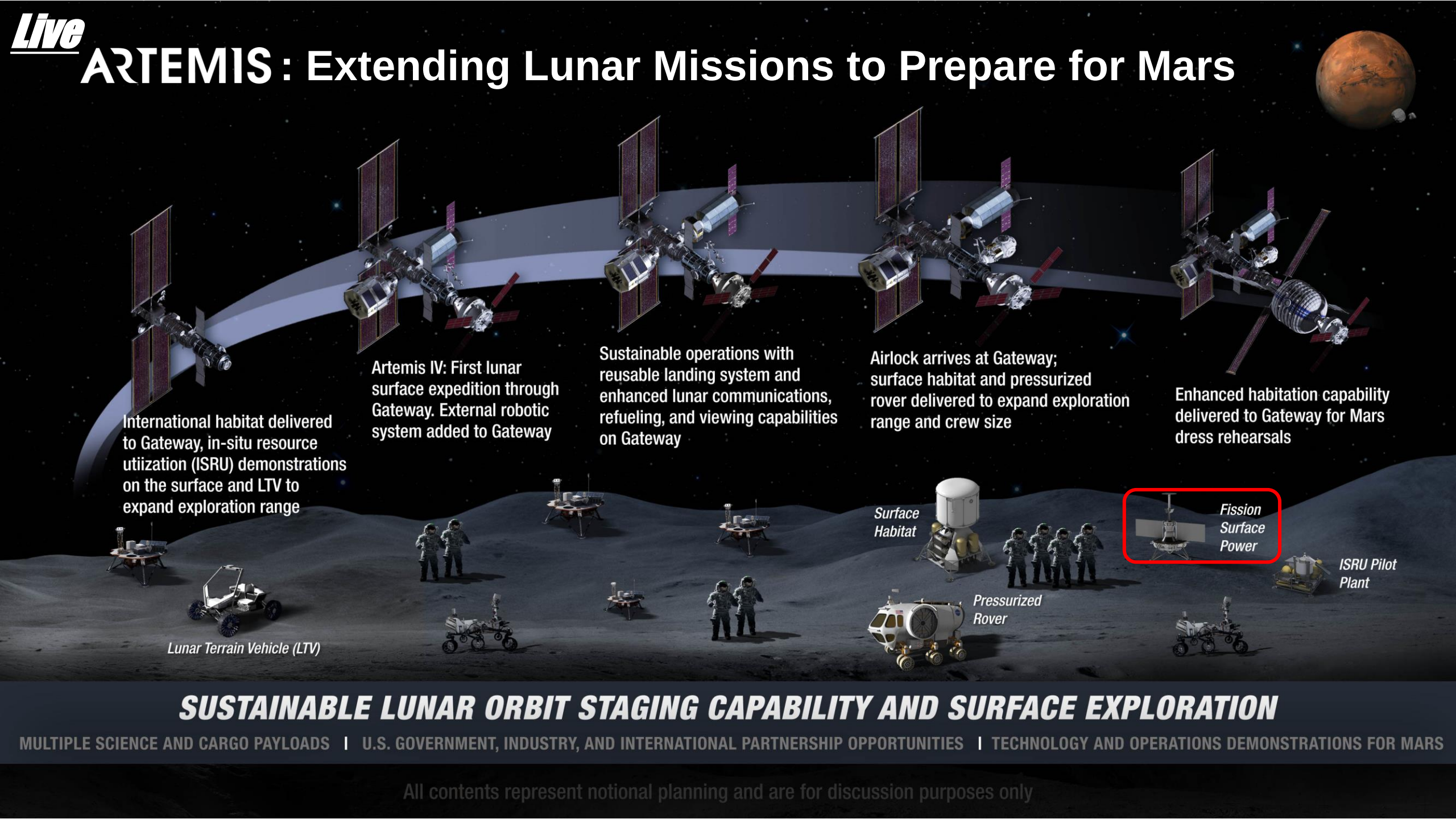


Surface Power



Lunar Surface Innovation Initiative (LSII)

ARTEMIS : Extending Lunar Missions to Prepare for Mars



SUSTAINABLE LUNAR ORBIT STAGING CAPABILITY AND SURFACE EXPLORATION

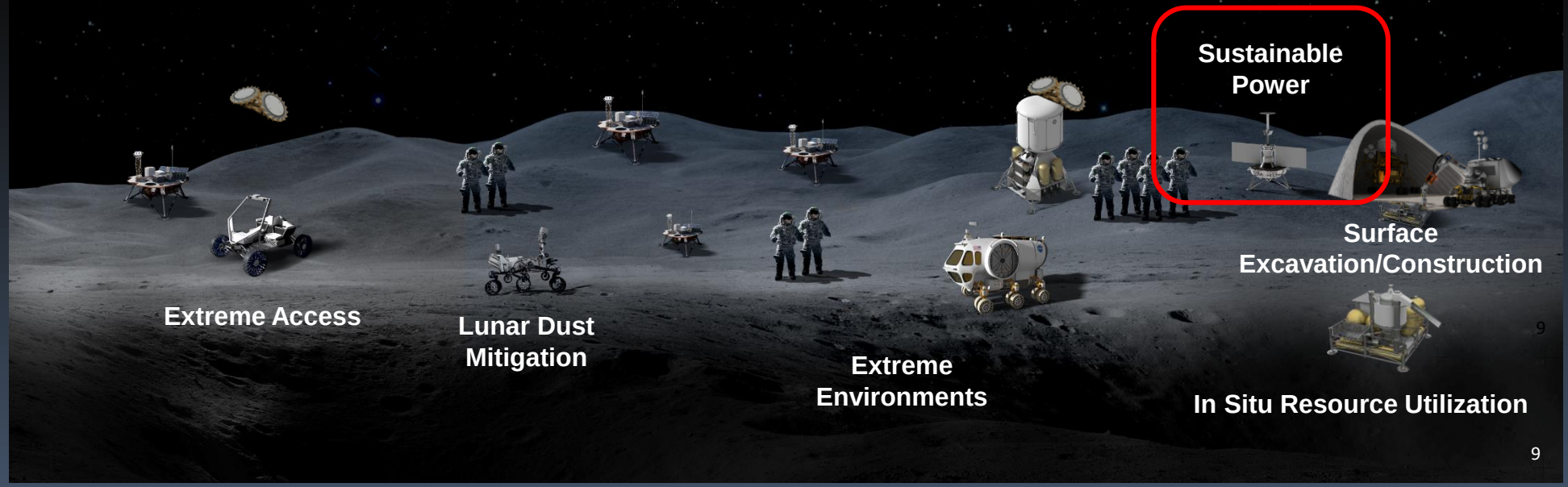
MULTIPLE SCIENCE AND CARGO PAYLOADS | U.S. GOVERNMENT, INDUSTRY, AND INTERNATIONAL PARTNERSHIP OPPORTUNITIES | TECHNOLOGY AND OPERATIONS DEMONSTRATIONS FOR MARS

All contents represent notional planning and are for discussion purposes only

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

- Established the Lunar Surface Innovation Consortium (LSIC) comprised academia, industry, non-profits and other government agencies
- Formulated and integrated 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

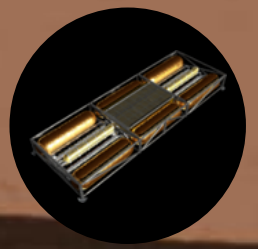


9

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



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 SImulti-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 managment
- 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

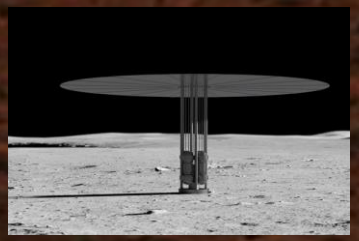
- Watts-on-the-Moon Challenge

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: 10+ kW_e fission reactor with Stirling conversion



FSP



VSAT

Revision date: : April 8, 2021

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.



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

Revision date: : May 26, 2020

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

SBIR · STTR
America's Seed Fund™

- Radioisotope Power
  - Tritium Betavoltaics




NASA
www.nasa.gov/spacetech