Overview of Survive the Night Technology Development Investments

Presentation to CLPS Survive the Night Workshop

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NASA STMD Lunar Surface Innovation Initiative

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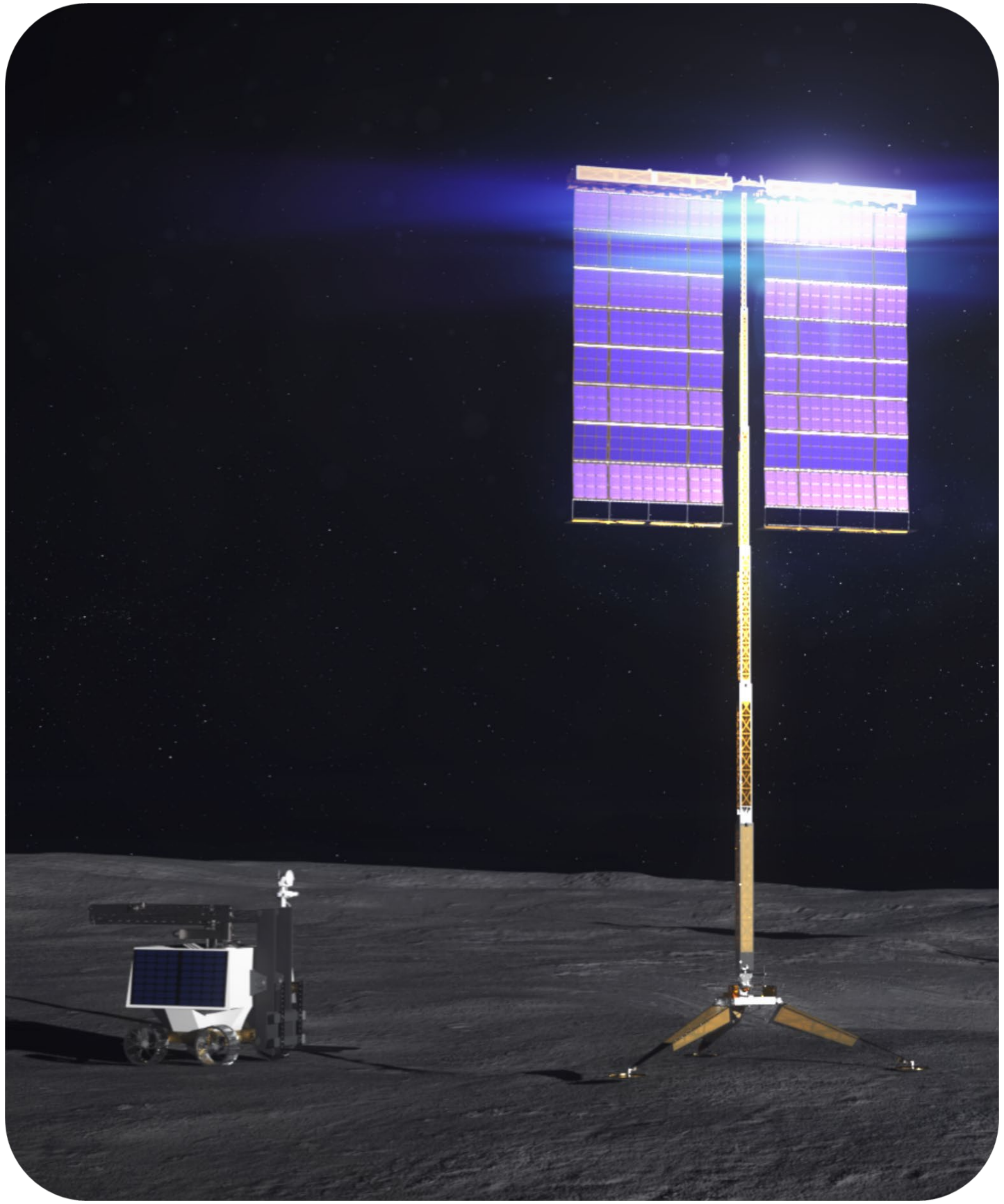
Agenda

- Introduction

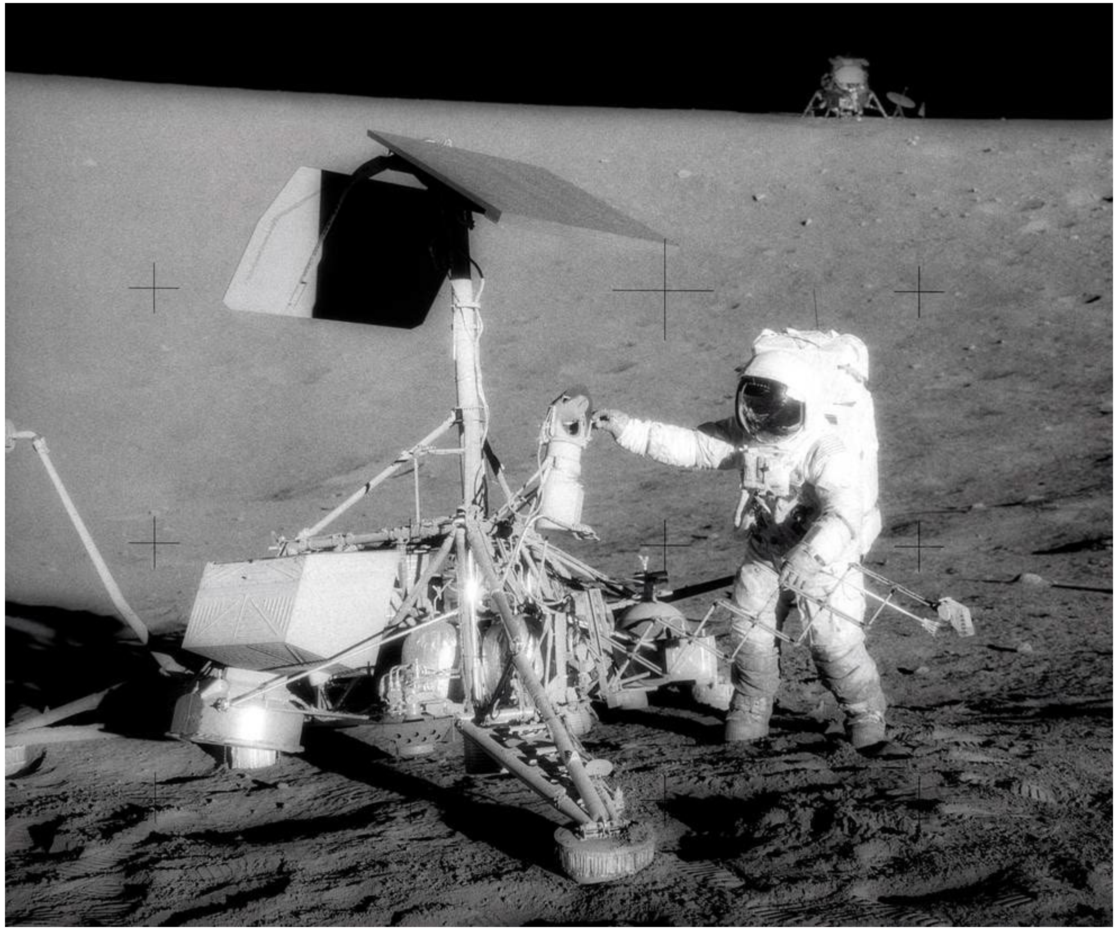
- Historical Note: Surveyor Experience
- STMD Strategic Framework
- Power Technology Research
- Thermal Management
- Cold Operable Actuators
- Lunar Terrain Modeling (LuNaMaps)
- LSIC Community Engagement



Historical Note: Surveyor Missions

- Seven Surveyor flights from 1966 – 1968 in support of Apollo development and planning
  - 2 and 4 crashed
  - https://nssdc.gsfc.nasa.gov/nmc/spacecraft/query

- 1 – **Withstood the first lunar night** and near high noon on its second lunar day, **terminated due to a dramatic drop in battery voltage just after sunset**
  - Engineering interrogations continued until January 7, 1967 (6 months)
- 3 – Failed to restart after lunar night
- 5 – Survived 3 lunar nights
  - Operated about **200 hours after sunset** second night
- 6 – Communications resumed after first lunar night, but no useful data second day
  - Operated concurrently with Surveyor 5
  - Performed first powered takeoff from the lunar surface
- 7 – Operated for **80 hours after first sunset**
  - Second lunar day operations began February 12, 1968, and were **terminated on February 21**



Photograph of Surveyor 3, taken by Apollo 12 lunar module pilot Alan Bean, mission commander Pete Conrad jiggles the Surveyor spacecraft to see how firmly it is situated. [https://apod.nasa.gov/apod/ap181022.html]

STMD Strategic Framework

Lead	Thrusts	Outcomes	Primary Capabilities
Ensuring American global leadership in Space Technology • Advance US space technology innovation and competitiveness in a global context • Encourage technology driven economic growth with an emphasis on the expanding space economy • Inspire and develop a diverse and powerful US aerospace technology community	**Go** Rapid, Safe, and 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.	• Nuclear Systems • Cryogenic Fluid Management • Advanced Propulsion
	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.	Entry, Descent, Landing, & Precision Landing

	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 Habitation System technologies. [Low TRL STMD; Mid-High TRL SOMD/ESDMD]
			• Advanced Power
			• In-Situ Resource Utilization
			• Advanced Thermal
			• Advanced Materials, Structures, & Construction
			• Advanced Habitation Systems

	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. • Develop technologies for science instrumentation supporting new discoveries. [Low TRL STMD/Mid-High TRL SMD. SMD funds mission specific instrumentation (TRL 1-9)] • Develop transformative technologies that enable future NASA or commercial missions and discoveries	• Advanced Avionics Systems • Advanced Communications & Navigation • Advanced Robotics • Autonomous Systems • Satellite Servicing & Assembly • Advanced Manufacturing • Small Spacecraft • Rendezvous, Proximity Operations & Capture • Sensor & Instrumentation

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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

Technologies that enable surviving the extreme lunar and Mars environments

SPACE TECHNOLOGY PORTFOLIO

Activities span the technology readiness spectrum.

EARLY STAGE INNOVATION AND PARTNERSHIPS
- Early Stage Innovation
  - Space Tech Research Grants
  - Center Innovation Fund
  - Early Career Initiative
  - Prizes, Challenges & Crowdsourcing
  - NASA Innovation Advanced Concepts
- Technology Transfer

SBIR/STTR PROGRAMS
- Small Business Innovation Research
- Small Business Technology Transfer

TECHNOLOGY MATURATION
- Game Changing Development
- Lunar Surface Innovation Initiative

TECHNOLOGY DEMONSTRATION
- Technology Demonstration Missions
- Small Spacecraft Technology
- Flight Opportunities

Technology Drives Exploration

LOW

MID

HIGH

Technology Readiness Level

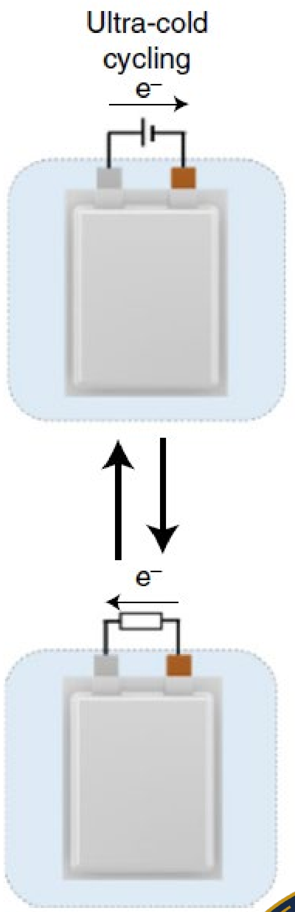
Ultra-Low Temperatures Lithium Metal Batteries

NSTGRO20

"Development of Novel Electrolytes for High-Energy Lithium Metal Batteries Operating at Ultra-Low Temperatures", John Holoubek, University of California, San Diego

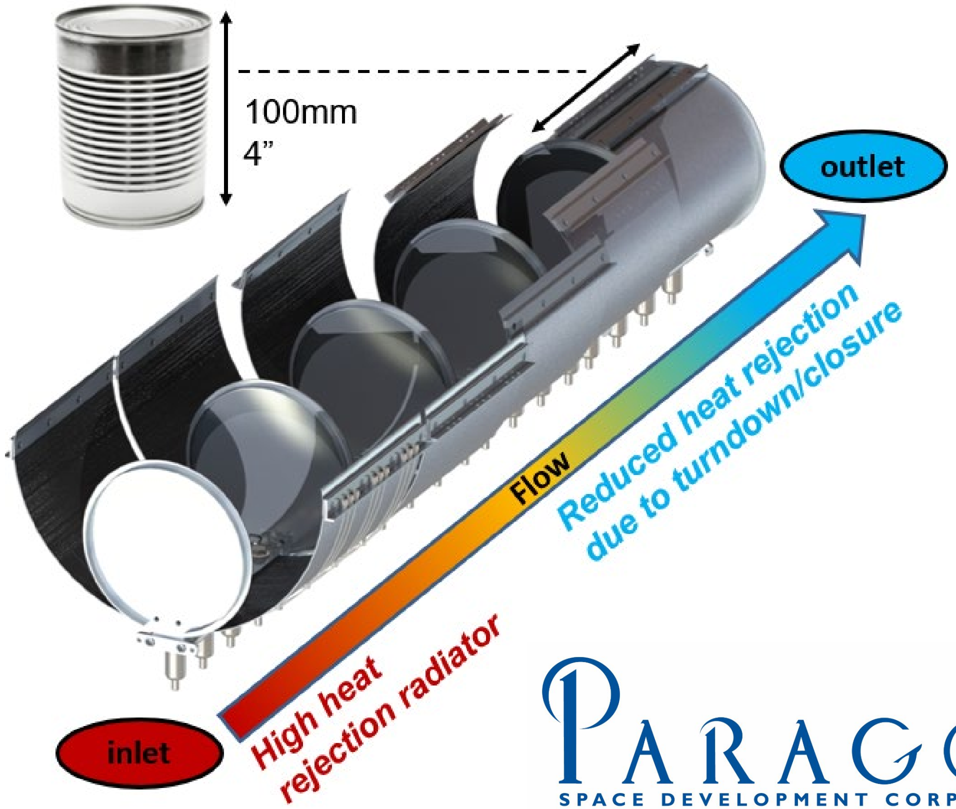
- Research on cold charge and discharge operation as well as higher energy density potential of Lithium Metal Batteries (LMB)

- Improved electrolyte demonstrates > 98 % Li metal reversibility down to -60 °C where conventional electrolytes produce catastrophic cell shorting
- Cells with improved electrolyte retain 84% and 76% of room temperature capacity cycled at −40 and −60 °C (stable over 50 cycles)



Holoubek, J., Liu, H., Wu, Z. et al. Tailoring electrolyte solvation for Li metal batteries cycled at ultra-low temperature. Nat Energy 6, 303–313 (2021). https://doi.org/10.1038/s41560-021-00783-z

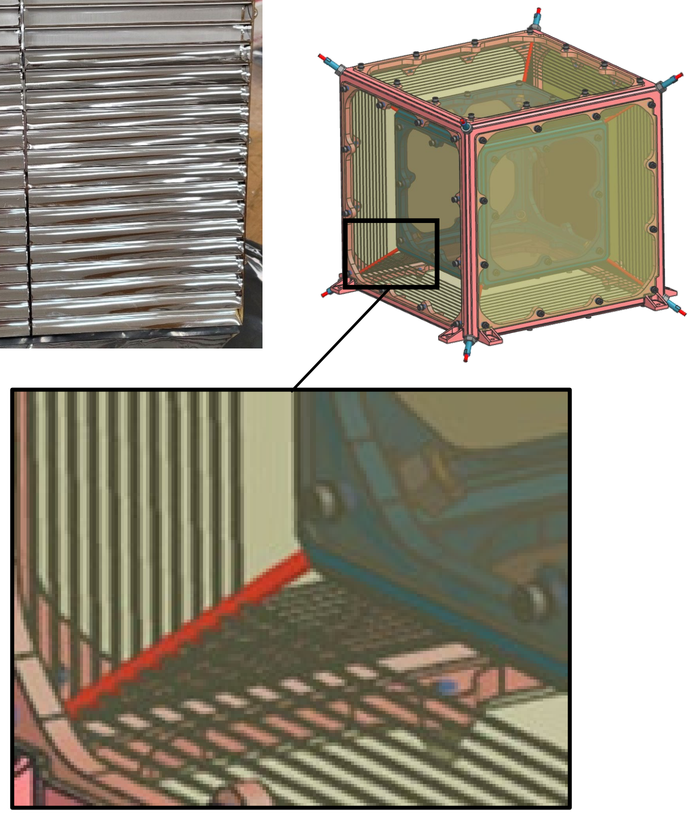
Thermal Management



PARAGON SPACE DEVELOPMENT CORPORATION

Shape Memory Alloys for Regulating TCS in Space (SMARTS) is developing a complete, compact, rugged, and environmentally activated thermal control system (TCS) (completed 2022)

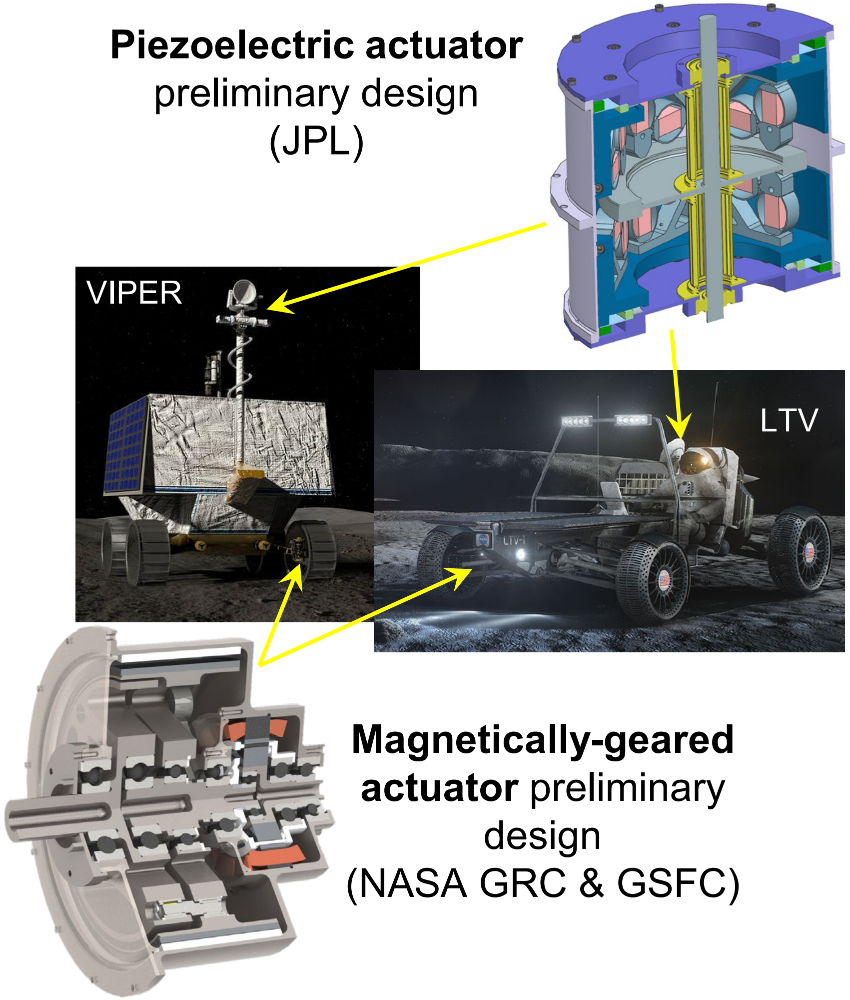
Planetary and Lunar Environment Thermal Toolbox Elements (PALETTE) is developing passive thermal management tools necessary for future instrument and system operation in extreme environments.



Cold Operable Actuators

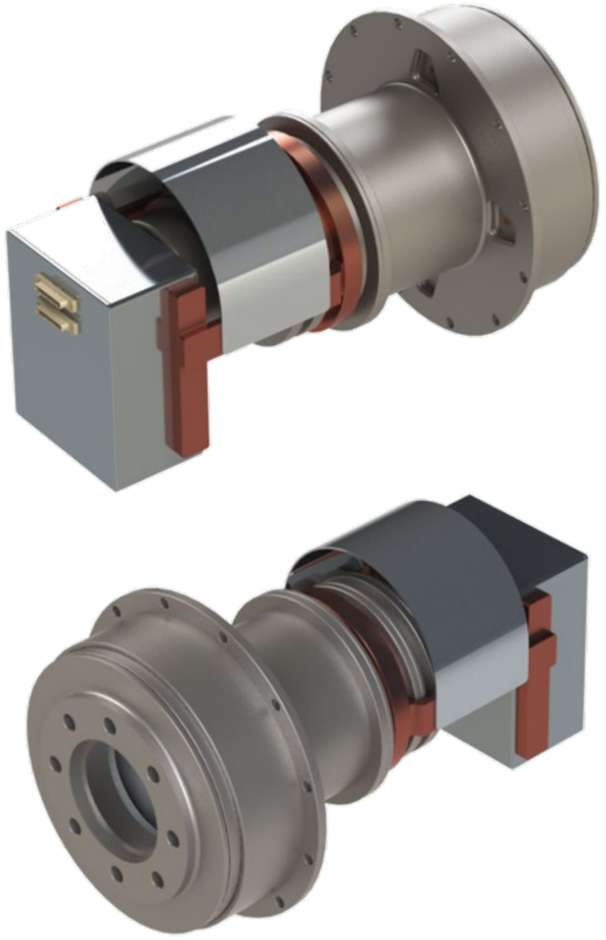
Bulk Metallic Glass (BMG) gearboxes that function without heaters in a 100 K environment

Engineering Model (EM) Planetary Gearboxes just prior to motor integration and closeout



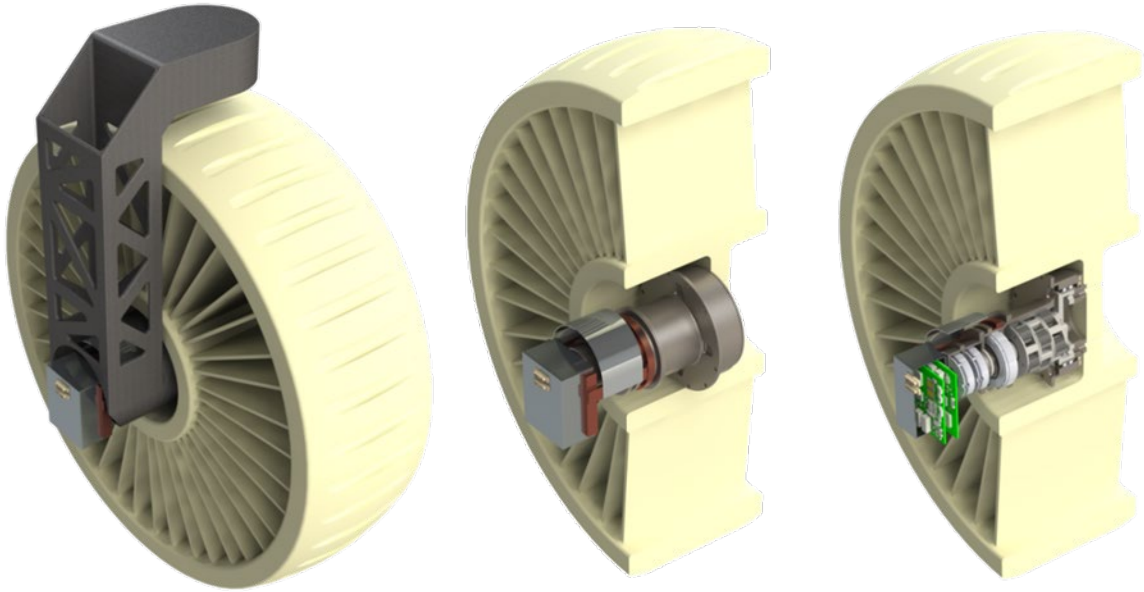
Motor for Dusty and Extremely Cold Environment (MDECE) will operate unheated and continuously for long durations at an ambient temperature of −240 C (33 K)

Distributed Extreme Environments Drive System



2021 SBIR S-Ph2

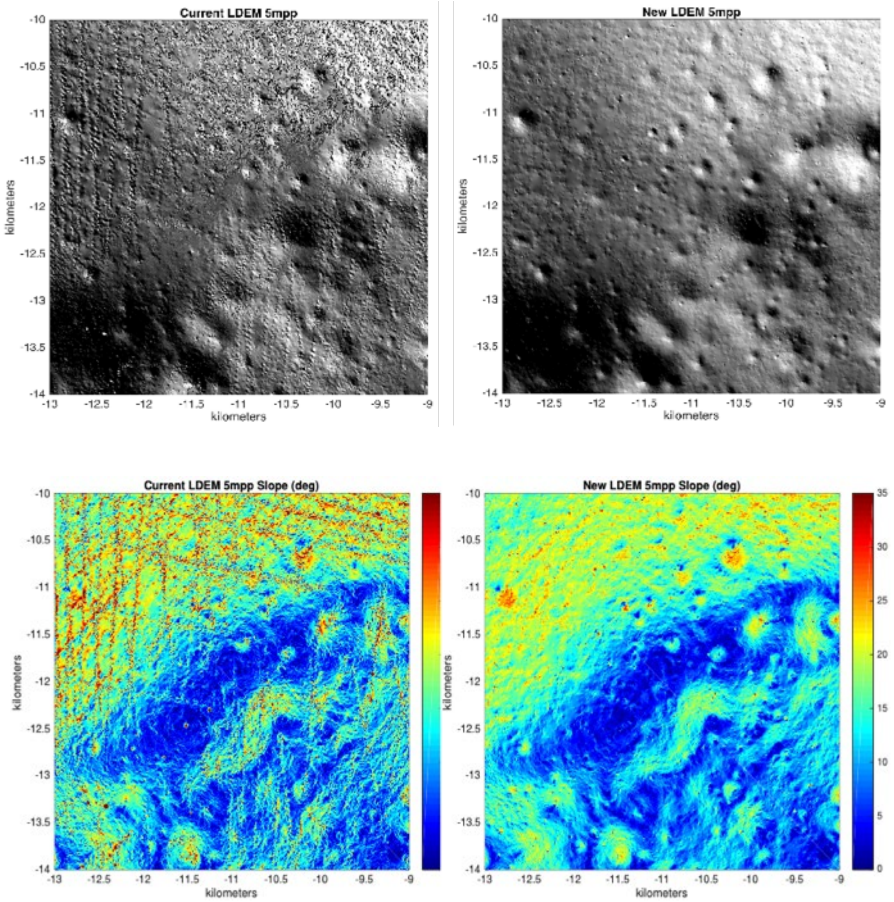
Distributed Extreme Environments Drive System (DEEDS) is a modular, scalable, electro-mechanical actuation system designed to survive and operate through the lunar night. The goal of the DEEDS program is to demonstrate -180°C operations.



Lunar Rover Wheel Drive Application for DEEDS

Lunar Navigation Maps (LuNaMaps)

- Develop a suite of methods and tools to render Digital Elevation Maps (DEMs) for onboard navigation, mission planning, and other purposes
- Improve the coverage, accuracy, and resolution of existing lunar maps by merging orbital reconnaissance data
  - Synthetically enhance map products derived from orbital imagery to include lander-scale features
  - Evaluate terrain rendering tools to determine performance limitations and future needs for simulation, testing and V&V of lunar maps
- Coupled with rendering software and a solar model, site illumination can be evaluated



LOLA DEM (top) and slope map (bottom) of a high-priority landing site at the lunar south pole (5 m/pix) before (left) and after (right) cleaning.

Lunar Surface Innovation Consortium (LSIC)

Nationwide alliance of universities, commercial companies, non-profit research institutions, NASA, and Other Government Agencies with a vested interest in our nation's campaign to establish a sustained presence on the Moon.

LSIC Objectives include:

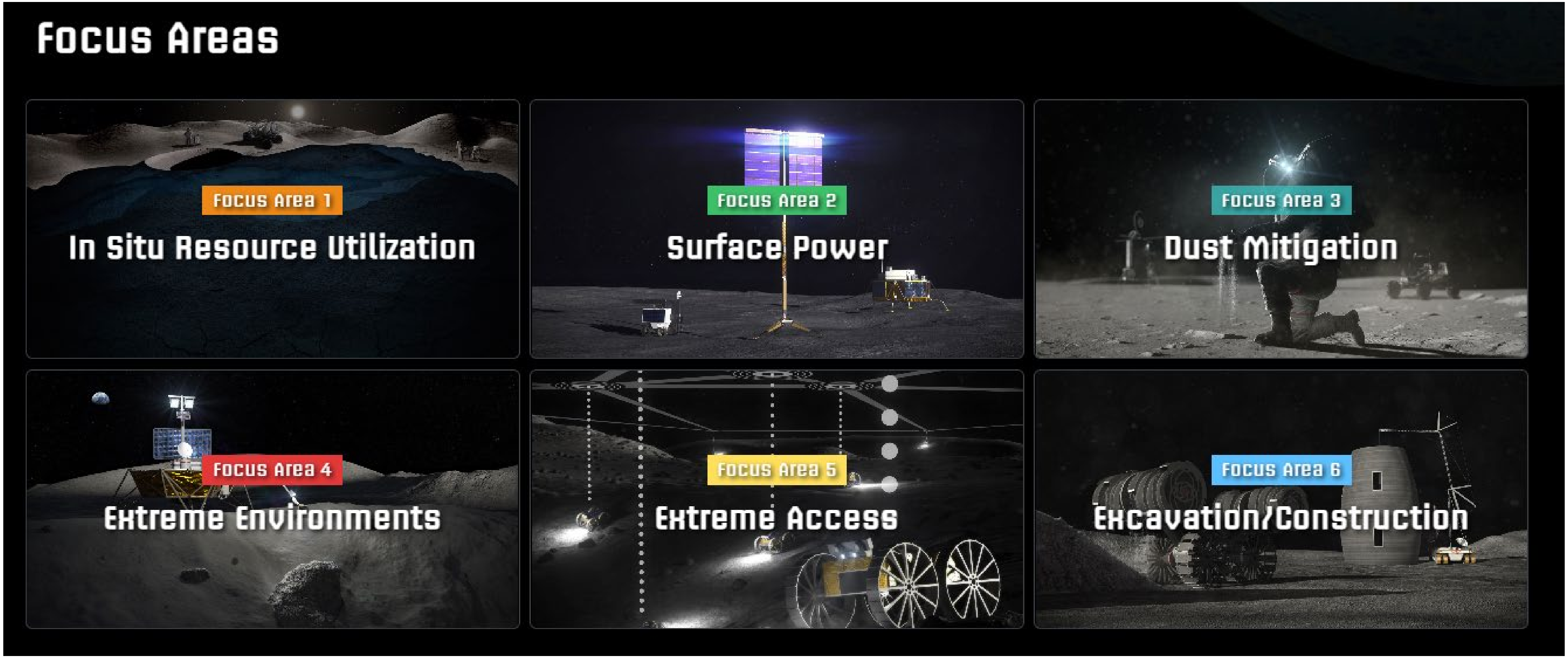
- Identifying lunar surface technology needs and assessing the readiness of relative systems and components
- Making recommendations for a cohesive, executable strategy for development and deployment of the technologies required for successful lunar surface exploration
- Providing a central resource for gathering information, analytical integration of lunar surface technology demonstration interfaces, and sharing of results.

Focus Groups (FG) are the primary means for consistent interaction with the LSIC Community. This includes:

- Establishing collaborative relationships among members via virtual monthly forums, quarterly virtual workshops, and LSIC member site visits
- Building community and developing talent
- Compiling member input and reporting outcomes and recommendations

If interested in further information, please visit lsic.jhuapl.edu

LSIC Focus Groups



Technology Development Investments Summary

- Framework and organization structured for targeted development addressing high-priority gaps
- Pipeline of technologies at various levels of maturity
- Various approaches to the system-level challenge of sustaining presence on the lunar surface
- Community engagement to foster and be responsive to community input and interests
- All of this enables us to adapt as we learn more

Technology Drives Exploration