NASA SBIR 2021 Phase I Solicitation

Z1.05 Lunar and Planetary Surface Power Management and Distribution

Lead Center: GRC

Participating Center(s): GSFC, JSC

Scope Title:

Innovative Ways to Transmit Power Over Long Distances for Lunar and Mars Missions

Scope Description:

The Global Exploration Roadmap (January 2018) and the Space Policy Directive (December 2017) detail NASAâ€™s plans for future human-rated space missions. A major component of these plansÂ involves establishing bases on the lunar surface for sustained presence and a new transportation capability andÂ surface assets for a human exploration mission to Mars. Surface power generation on planetary surfacesÂ is envisioned to require 10 to 50 kW to be efficiently transmitted distances greater than 1 km to remotely located mission elements such as habitat modules, landers, ascent vehicles, etc. While current state-of-the-art space power systems are similar in power level (e.g., the International Space Station), the transmission distances are only 10s of meters, so new high-power, high-voltage and/or new power-beaming technologies are sought to enable surface power transmission over long distances. Examples of the innovative technologies sought are lower mass/higher efficiency power electronic regulators, switchgear, cabling, connectors, wireless sensors, power beaming, power scavenging, and power management control. The technologies of interest would need to operate in extreme-temperature environments, including lunar night, and could experience temperature changes from -153Â to 123 Â°C for lunar applications, and -125Â to 80 Â°C for Mars bases. In addition to temperature extremes, technologies would need to withstand (have minimal degradation from) lunar dust/regolith, Mars dust storms, and space radiation levels.

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In addition, new human Mars transportation capabilities are expected to require multiple

channels of 100 kW or more to be efficiently transmitted 100s of meters from an alternating currentÂ (AC) power generatorÂ to multiple electric thrusters requiring high-voltage direct-current (DC) power. Technologies sought include high-performance rotary alternators, high-performance transformers, rectifiers, and cabling.Â

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While this subtopic would directly address the lunar and Mars base initiatives, technologies developed could also benefit other NASA Mission Directorates, including SMD (Science Mission Directorate) and ARMD (Aeronautics Research Mission Directorate). Specific projects that could find value in the technologies developed herein include Gateway, In Situ Resource Utilization (ISRU), Advanced Modular Power Systems (AMPS), In-Space Electric Propulsion, Planetary Exploration, and Hybrid Gas-Electric Propulsion. The power levels may be different, but the technology concepts could be similar, especially when dealing with temperature extremes and the need for electronics with higher power density and efficiency.

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Specific technologies of interest would include:

- Application of wide band-gap electronics in DC-DC isolating converters with wide temperature (-70Â to 150 Â°C), high power density (>2 kW/kg), high-efficiency (>96%) power electronics and associated drivers for voltage regulation.
- Low-mass, highly conductive wires and terminations that provide reliable small gauges for long-distance power transmission in the 1 to 10 kW range, low-mass insulation materials with increased dielectric breakdown strength and void reductions with 1,000 V or greater ratings, and low-loss/low-mass shielding.
- Power-beaming concepts to enable highly efficient flexible/mobile power transfer in the 100 to 1,000 W range, including the fusion of power, communication, and navigation.
- Power generation and distribution components of a 3-phase/1,200-Hz permanent magnet alternator, 480 VAC to 650 VDC power management, and distribution with direct drive to Hall thrusters.Â Key components of the distribution include high-performance rotary alternators and AC transmission technologies, including alternator voltage, step-up/step-down transformers, rectifiers, and power cabling.

Note: to propose power connection/termination-related technologies that are impervious to environmental dust and enable robotic deployment, such as robotically enabled high-voltage connectors and/or near-field wireless power transfer in the 1 to 10 kW range, see subtopic titledÂ Dust-Tolerant Mechanisms.

Expected TRL or TRL Range at completion of the Project:Â 3 to 6Â
Primary Technology Taxonomy:Â

Level 1: TX 03 Aerospace Power and Energy StorageÂ
Level 2: TX 03.3 Power Management and DistributionÂ
Desired Deliverables of Phase I and Phase II:

- Research
- Analysis
- Prototype
- Hardware

Desired Deliverables Description:

Typically, deliverables under Phase I proposals are geared toward a technology concept with associated analysis and design. A final report usually suffices in summarizing the work, but if a prototype is preffered. Phase II hardware prototypes will have opportunities for infusion into NASA technology testbeds and commercial landers.

State of the Art and Critical Gaps:

While high-power terrestrial distribution systems exist, there is no equivalent to a lunar or planetary base. Unique challenges must be overcome in order to enable a realistic power architecture for these future applications, especially when dealing with the environmental extremes that will be encountered. The temperature swings will be a critical requirement on any technology developed, from power converters to cabling or power-beaming concepts. In addition, proposals will have to consider lunar regolith and Mars dust storms. To enable a new Mars transportation capability for human exploration, new technologyÂ development must be started soon to address the very unique needs of a mixed AC/DC space-rated power system to prove feasibility and provide realistic performance metrics for detailed vehicle design concepts and mission trade studies.Â

Relevance / Science Traceability:

This subtopic would directly address a remaining technology gap in the lunar and Mars surface mission concepts and Mars human transportation needs. There are potential infusion opportunities with SMD (Science Mission Directorate) Commercial Lander Payload Services (CLPS) and HEOMD (Human Exploration and Operations Mission Directorate) Flexible Lunar Exploration (FLEx) Landers. In addition, technologies developed could benefit other NASA missions, including Gateway. The power levels may be different, but the technology concepts could be similar, especially when dealing with temperature extremes.

References:

The Global Exploration Roadmap, January 2018:Â https://www.nasa.gov/sites/default/files/atoms/files/ger_2018_small_mobile.pdf

Space Policy Directive-1, Reinvigorating America's Human Space Exploration Program, December 11, 2017:Â https://www.federalregister.gov/documents/2017/12/14/2017-27160/reinvigorating-americas-human-space-exploration-program