NASA SBIR 2016 Phase I Solicitation

H8 High Efficiency Space Power

This topic solicits technology for power systems to be used for the human exploration of space. Power system needs consistent with human spaceflight include:

- Fuel cells compatible with methane-fueled landers, and electrolyzers and fuel cells compatible with materials extracted from lunar regolith and/or the Martian soil or atmosphere.
- Advanced battery cell technologies addressing NASA-unique environments and missions.
- Photovoltaic component and system technologies to power electric spacecraft and/or Mars surface systems.
- Thermal energy conversion.

Solid oxide technology is of interest for fuel cells and electrolyzers to enable:

- The operation of fuel cells using hydrocarbon reactants, including methane and fuels generated on-site at the Moon or Mars.
- Electrolysis systems capable of generating oxygen by electrolyzing CO_2 (from the Mars atmosphere, trash processing, life support, or volatiles released from soils), and/or water from either extraterrestrial soils, life support systems, or the byproduct of Sabatier processes. Both component and system level technologies are of interest.

Breakthrough battery cell technologies that far exceed the specific energy and energy density or temperature performance of state-of-the-art lithium-based cell technologies are sought to achieve NASA-unique energy storage goals for human missions to cis-lunar space and Mars. Applications include extravehicular activities, human-rated landers, and Mars ascent vehicles. The sub-topic solicitation describes the NASA-unique metrics being sought for new energy storage technologies.

Advanced photovoltaic (PV) power generation and enabling power system technologies are sought with improvements in power system performance (conversion efficiency, mass, stowed volume, etc.), mission operation capability, and reliability for PV power systems supporting NASA human exploration missions using solar electric propulsion (SEP) or on the surface of Mars. The sub-topic solicitation describes the specific metrics being sought for new photovoltaic technologies and systems.

Subtopics

H8.01 Thermal Energy Conversion

Lead Center: GRC

Participating Center(s): JPL, JSC, MSFC

NASA needs innovative technologies that convert thermal energy into electricity for space power generation on orbiting platforms, extraterrestrial surfaces, and space transportation vehicles. The thermal energy could be supplied by nuclear reactors, radioisotope heat sources, solar concentrators, chemical reactions, or as waste heat from other space systems. The focus of this subtopic is the energy conversion subsystem. Proposals are requested on thermal energy conversion approaches that offer high efficiency, low mass, high reliability, long life, and low cost. Candidate technologies include thermodynamic heat engines such as Stirling, Brayton, and Rankine as well as thermoelectric and thermionic devices. Ancillary components used to deliver heat (e.g., heat transport loops, heat pipes) to the energy conversion and reject waste heat (e.g., heat pipes, radiators) are also of interest.

The primary mission pull is providing electric power for human Mars surface missions that require kilowatts for remote science stations and rovers, or 10s of kilowatts for crew habitats and in-situ resource utilization plants. A secondary mission pull is providing electric power for Mars transportation vehicles that require 10s of kilowatts for crew life support and vehicle subsystems. The Mars missions may be preceded by human precursor missions to near earth objects, cis-lunar space, and the lunar surface during which the Mars technologies could be demonstrated. The anticipated heat source temperature ranges are 800 to 1300 K for nuclear, solar, and chemical sources and less than 400 to 500 K for waste heat. The expected operating lifetime ranges from several years to greater than 10 years.

The proposals should focus on energy conversion subsystems and components with a current technology readiness level of 2 or 3. The Phase I effort should include conceptual design with analytical or experimental proof-of-concept based on the expected operating environment and system interfaces (e.g., heat source, heat rejection). The Phase II effort should include development of breadboards or prototypes that can be operated at the contractor's facility to demonstrate functionality in a laboratory environment. If the contractor testing is successful, the hardware will be considered for integration into NASA ground tests and flight experiments with representative system interfaces and relevant operating environments. Upon completion of successful integrated system tests at NASA, Phase III projects would be pursued to infuse the technologies into flight projects.

H8.02 Solid Oxide Fuel Cells and Electrolyzers

Lead Center: GRC

Participating Center(s): JPL, JSC

Technologies are sought that improve the durability, efficiency, and reliability of solid oxide systems. Of particular interest are those technologies that address challenges common to both fuel cells fed by oxygen and methane and electrolyzers fed by carbon dioxide and/or water. Hydrocarbon fuels of interest include methane and fuels generated by processing lunar and Mars soils. Primary solid oxide components and systems of interest are:

- Solid oxide fuel cell, stack, materials and system development for operation on propellant grade direct methane in designs scalable to 1 to 3 kW at maturity. Strong preference for high power density configurations.
- Cell and stack development capable of Mars atmosphere electrolysis should consider feasibility at 0.4 to 0.8 kg/hr O_2; scalable to 2 to 3.5 kg/hr O_2 at maturity. CO_2 electrolysis or co-electrolysis designs must have demonstrated capability of withstanding 15 psid in Phase I with pathway to up to 50 psid in Phase II.

Proposed technologies should demonstrate the following characteristics:

- The developed systems are expected to operate as specified after at least 20 thermal cycles during Phase I and greater than 70 thermal cycles for Phase II. The heat up rate must be stated in the proposal.
- The developed systems are expected to operate with less than five percent degradation after at least 500 hours of steady state operation on propellant-grade methane and oxygen. Operation for 2500 hours and less than five percent degradation is expected of a mature system.
- Fuel reforming must be water neutral. Integrated systems that minimize components and complexity are favored.

- Minimal cooling is available for power applications. Some cooling in the final application will be provided by means of conduction through the stack to a radiator exposed to space or other company proposed solution that minimizes resources required.
- Minimal power (heating plus electrolysis) required for CO_2 electrolysis applications.
- Demonstrate electrolysis of the following input gases: 100% CO_2, Mars atmosphere mixture (95.7% CO_2, 2.7% N_2, 1.6% Ar), 100% water vapor, and 0.7 to 1.6:1 CO_2:H_2O mass ratio. A final test using pure CO_2 of 500 hours (or stopping at 40% voltage degradation) is required. Description of technical path to achieve up to 11,000 hrs for human missions is requested.

H8.03 Advanced Photovoltaic Systems

Lead Center: GRC

Participating Center(s): JSC

Advanced photovoltaic (PV) power generation and enabling power system technologies are sought with improvements in power system performance (conversion efficiency, mass, stowed volume, etc.), mission operation capability, and reliability for PV power systems supporting NASA human exploration missions. Power levels may cover ranges of 25-250 kWe to MegaWatt-class systems. Component technologies and array concept designs are sought that can address all or parts of the following: improved efficiency (>30% cell conversion efficiency at Air Mass zero), cost (50% reduction compared to state-of-the-art (SOA) through modularization, automated manufacturing, and reduced material costs), improved reliability, reduced mass (50% reduction compared to SOA designs), reduced stowed volume (designs capable of accommodating 100kW power levels within a single launch), high array bus voltages (> 250 V), and long-lived, reliable operation within the expected space environment (i.e., high radiation environments, both high and low temperature and light intensity extremes, planetary surface dust conditions, electric propulsion plume impingement erosion, and minimal arcing/degradation due to interactions with the space plasma). The technologies being sought should enable or enhance the ability to provide low-cost, low mass, and higher efficiency solar power systems that support high power Solar Electric Propulsion (SEP), high radiation/extreme environments, and Mars surface NASA missions. Areas of particular emphasis include:

- Advanced PV blanket and component technology with designs that support very high power and high voltage (> 250 V) applications.
- Array structures and blankets optimized for Mars surface gravity and maximum wind loading conditions while still preserving the low mass, low stowed volume, high reliability, and possible retraction/redeployment capabilities.
- Array/blanket designs capable of operating in high dust environments.
- PV blanket, component technology, and arrays optimized for extreme environment conditions (high radiation, low/high temperature extremes, exposure to SEP plume environments, etc.).
- PV module/component technologies that emphasize low mass and cost reduction (via materials, fabrication, and reduced testing).
- Improvements to solar cell efficiency consistent with low cost, high volume fabrication techniques that are applicable to HEOMD missions.
- Automated/modular fabrication methods for PV panels/modules on flexible blankets (includes cell laydown, interconnects, shielding and high voltage operation mitigation techniques).

Research should be conducted to demonstrate technical feasibility during Phase I and show a path toward a Phase I hardware demonstration, and when possible, deliver a demonstration unit for functional and environmental testing at the completion of the Phase II contract.

H8.04 Advanced Next Generation Batteries

Lead Center: GRC

Participating Center(s): JPL, JSC

Breakthrough battery cell technologies that far exceed the specific energy and energy density or temperature performance of state-of-the-art lithium-based cell technologies are required to achieve far-term energy storage goals for human and robotic missions to the moon, Near Earth Orbit, Venus, and Mars. NASA is seeking innovative, advanced electrochemical cell and battery technologies that can aggressively address requirements for these future missions. Proposed chemistries and components must meet performance goals while simultaneously delivering a high level of safety. Components and systems that can enable one of the following sets of cell-level performance goals (simultaneously, within the same system) are sought for specific missions:

- Extravehicular Activities. 450 Wh/kg, 1000-1500 Wh/L, >100 full cycles, >5 year calendar life, up to C/5 rate capability, operation at 0 to 40° C, retention of at least 90% of room temperature capacity during operation at 0°C, and tolerant to electrical and mechanical abuse (i.e., abuse does not result in fire or thermal runaway).
- Human Lunar and Mars Landers and Rovers. 300-375 Wh/kg, 1000-1500 Wh/L, up to 2000 full cycles, >10 year calendar life, >C/2 rate capability, operation at -60 to 30°C, and retention of at least 80% of room temperature capacity during operation at -60° C.
- Mars Ascent Vehicle - Quiescent capability. >250-300 Wh/kg, 1000-1500 Wh/L, few cycles, >15 year shelf life after activation and very limited cycling, and C-rate capability. Extremely high reliability and very low irreversible capacity loss required after 15 year quiescent period. Calendar life and reliable operation after quiescent period are paramount.

Offerors may propose to develop a single or multiple components, or a full cell system. Phase I proposals shall include quantitative analysis, scientific evidence, and technical rationale that clearly demonstrates how the proposed component or components will meet or contribute to the cell performance goals by the end of a Phase II effort. If a single component(s) is proposed rather than full cells, the Offeror shall also include in their justification of the proposed technology the performance that other advanced cell components must achieve in order to meet the claimed cell-level goals. Additionally, Phase I proposals shall describe the technical path that will be followed to achieve the claimed goals. Where possible, laboratory scale prototype hardware should be proposed as deliverables to NASA in Phase I.

Phase I Deliverables - Laboratory scale prototype hardware.

Phase II Deliverables - Incremental hardware deliverables and breadboard demonstration.