NASA SBIR 2014 Phase I Solicitation

Space Technology

Space Technology for Cross-Cutting Applications Topic Z1
The Advanced Space Power Systems topic area will focus on technologies that generate power and/or store energy within the space environment. Functional areas, subtopics, of interest include:

- *High Energy Density Batteries* - Components and chemistries for rechargeable battery cells that can enable performance that approaches 500 Wh/kg and 700 Wh/l on a cell level when integrated into a full cell with other advanced components and that can sustain stable performance over > 500 cycles are sought. Advanced next generation chemistries and components must have the potential to meet performance goals while simultaneously delivering a high level of safety.
- *Advanced Photovoltaics* - System and component technologies are sought that can deliver cost, reliability, mass, volume, and efficiency improvements under typical space operating conditions. Future NASA missions may well depend on PV technologies that provide 100’s kW of prime power. Technologies considered under this subtopic must enable or enhance the ability to provide this power at considerably lower cost and specific power than present technologies.
- *Nuclear Power Systems* - Innovative solutions for integrating radioisotope and small fission power systems with electric propulsion devices for space science missions. The goal is to develop architectures that optimize the power delivery and overall propulsive capabilities.
- *Modeling and Simulation* - Innovative M&S tools that will provide insight into design decisions and trade-offs are sought. The focus is on the reduction of overall development time for advanced future systems needed for space exploration.

Sub Topics:

Z1.01 Advanced Photovoltaic Systems

Lead Center: GRC

Participating Center(s): JSC

Advanced photovoltaic (PV) power generation and enabling power system technologies are sought for improvements in capability and reliability of PV power generation for space exploration missions. Power levels for PV applications may reach 100s of kWe. System and component technologies are sought that can deliver cost, reliability, mass, volume, and efficiency improvements under various operating conditions, in extreme environments, and over wide temperature ranges.

PV technologies must enable or enhance the ability to provide low-cost, low mass and higher efficiency for power systems with particular emphasis on high power arrays to support solar electric propulsion missions.

Areas of particular emphasis for FY 2014 include:

- Automated/ modular fabrication methods for PV panels/ modules on flexible blankets (includes cell laydown, interconnects, shielding and high voltage operation mitigation techniques).
- Improvements to solar cell efficiency that is consistent with low cost, high volume fabrication techniques.
- PV module/ component technologies that emphasize low mass and cost reduction (in materials, fabrication and testing).
- Advanced PV blanket and component technology/ designs that support very high power and high voltage (>

200 V) applications.

- Integrated PV system including cells, blanket, array, inverters, interconnect technologies, storage, structures, etc. with a balance-of-components while matching specifications of various systems.
- Simulated PV capability that optimizes system components, ensures compatibility of modules/inverters, and takes temperature extremes and unique aspects of the space environment into account including radiation tolerance.

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

Z1.02 Advanced Space Battery Technology

Lead Center: GRC

Participating Center(s): JPL, JSC

NASA seeks innovative, advanced technologies for next generation battery chemistries. Breakthrough battery cell technologies that far exceed the specific energy and energy density of current state-of-the-art lithium-ion cell technologies are required to achieve NASAs far-term energy storage goals for human and robotic missions. Future NASA missions will require rechargeable battery technologies that can provide 500 Wh/kg and 700 Wh/liter and can deliver > 1000 cycles at full depth of discharge. Components and chemistries for rechargeable battery cells that can enable performance that approaches 500 Wh/kg and 700 Wh/l on a cell level when integrated into a full cell with other advanced components and that can sustain stable performance over > 500 cycles are sought. Advanced next generation chemistries and components must have the potential to meet performance goals while simultaneously delivering a high level of safety. Proposed components may include, but are not limited to:

- Methods to enable safe, stable cycling of lithium metal.
- Innovative lithium-ion conducting electrolytes that offer ionic conductivities of 10E-3 Siemens per centimeter at room temperature and that can enable safe, stable cycling of lithium metal. These may include, but are not limited to, solid state electrolytes and ionic liquids.
- Other innovative cell component technologies that can enable the desired cell- level performance when integrated into a cell with other advanced components.

Offerors may propose to develop a single component or full cells. Phase I proposals shall include quantitative analysis, data, and technical rationale that clearly demonstrates how the proposed component, components, or cells will meet or contribute to the stated (as proposed) cell performance goals by the end of a Phase II effort. If a single component is proposed, 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 in an integrated system. During the Phase I effort, the proposed component(s) shall be incorporated into an appropriate test vehicle, such as half or full cell laboratory cells, to demonstrate feasibility. Phase I proposals shall describe the technical path that will be followed to achieve the claimed (as proposed) goals. Where possible, laboratory scale prototype hardware should be proposed as deliverables to NASA in Phase I.

Z1.03 Integrated Nuclear Power & Propulsion

Lead Center: GRC

Participating Center(s): MSFC

This subtopic seeks innovative solutions for integrating radioisotope and small fission power systems with electric propulsion devices for space science missions. The goal is to develop architectures that optimize the power delivery and overall propulsive capabilities. Separate subtopics are developing innovative power generation (S3.01), power management (S3.03), and electric thruster technologies (S3.02). Here, the objective is to take existing components and assemble them into testbeds to demonstrate functionality, robustness, and performance. Emphasis is on novel integration schemes that maximize efficiency and reliability while minimizing mass. Phase I activities would develop the power architecture and identify the key design elements. Phase II activities would assemble testbeds and perform experimental testing to validate design methods. The assumed building blocks are described below with additional information available from literature searches. However, the system should be evolvable to incorporate advanced components developed under S3.01, Power Generation & Conversion; S3.02, Propulsion Systems for Robotic Science Missions; and S3.03, Power Electronics and Management, and Energy Storage.

Power sources:

- Advanced Stirling Radioisotope Generator, 140 watts at 28 Vdc.
- Multi-Mission Radioisotope Thermoelectric Generator, 110 watts at 28 Vdc.
- Small Thermoelectric Fission Power System, 0.5 to 3 kW at 28 to 100 Vdc.
- Small Stirling Fission Power Systems, 1 to 10 kW at 15 to 300 Vac, 100 hz single-phase.

Representative Electric Propulsion Devices (Isp = specific impulse):

- 200 – 600 W Hall thrusters, at 200-250 Vdc and 1300-1600 sec Isp.
- 1.4 kW – 5 kW Hall thrusters, at 300-600 Vdc and 1600-2700 sec Isp.
- 10 kW Hall thrusters, at 300 Vdc and 2200 sec Isp.
- 100-600 W Ion thrusters, at 800-1500 Vdc and 2000-3800 sec Isp.
- 2.3-5 kW Ion thrusters, at 1200-1500 Vdc and 3300-3800 sec Isp.
- 7-10 kW Ion thrusters, at 1800-2000 Vdc, and 4100-5000 sec Isp.

Z1.04 Modeling and Measurements for Propulsion and Power

Lead Center: GRC

Participating Center(s): ARC, MSFC

To reduce the development time of advanced future systems needed for space exploration, physics-based modeling tools are sought for:

- Electrochemical systems such as battery chemistries with “beyond Lithium ion” expected specific energies, proton exchange membrane and solid oxide fuel cells and electrolyzers, and chemical sensors for safety and operational monitoring.
- Electric propulsion systems such as Hall thrusters, nested Hall thrusters, ion engines, electrospray propulsion, and micro-propulsion.
- Nuclear power and propulsion systems such as 1kW-class, 10kW-class, and 100kW-class fission reactors, and nuclear thermal propulsion systems.

In each case, the emphasis is on determining performance-limiting features and determining potential means to overcome limitations. Either Dcomponents or full systems can be targeted.

Model validation is also required; improved measurement techniques needed for validation are also of interest provided they are coupled with a modeling activity outlined above.

Finally, tools that exclusively model proprietary systems will not be considered for award.

Below are listed examples of the types of models of interest for each area, and subtopics that contain additional information about systems of interest:

- Modeling the kinetics and thermodynamics of batteries, fuel cells and electrolyzers; and modeling the dielectrophoresis in the alignment of nanostructures within chemical and physical sensors for aerospace propulsion systems.

    - Z1.02 Advanced Space Battery Technology.
    - H8.01 Solid Oxide Fuel Cells and Electrolyzers.
    - T12.02 High Temperature Materials and Sensors for Propulsion Systems.
- Modeling electric propulsion (EP) life and failure mechanisms to predict the performance, plasma properties and lifetime of EP devices of interest and to help assess the interaction between the EP device plume and spacecraft surfaces.
    - H2.02 In-Space Propulsion Systems.
- Creating interfaces between reactor models and engine system models, including radiation effects; modeling NTP ground test engine exhaust filtering and containment.
    - H8.02 Space Nuclear Power Systems.
    - H2.04 Nuclear Thermal Propulsion (NTP) Ground Test Technologies.

Cross Cutting Advanced Manufacturing Processes for Large Scale Bulk Metallic Glass Systems for Aerospace Applications Topic Z2

Amorphous metals (also known as bulk metallic glasses) are a unique class of non-crystalline metals that possess the ability to be cast into high-tolerance hardware using similar processing techniques as plastics and yet retain mechanical properties similar (and in most cases superior to) titanium alloys Amorphous metals are a relatively new class of metal alloys that have mechanical properties and processing characteristics which set them apart from similar crystalline alloys (e.g., titanium, aluminum, or steel). Glassy metals are first designed by finding deep eutectic melting points in multi-element alloys such that when cooled at a high rate (usually >1000 K/s) crystal nucleation and growth does not occur and the amorphous liquid structure is frozen into the solid. Further work on amorphous metals has led to the development of composites consisting of an amorphous matrix phase reinforced with soft, crystalline dendrites which improve the composite's toughness and ductility. The properties of the amorphous metal can thus be tuned by the second phase. Strength, hardness, ductility, fatigue life, toughness, density, thermal expansion, thermal diffusivity, among others, can all be adjusted in these amorphous metal composites. Special emphasis is placed on new processes for fabricating large sheets (width >150 mm, uniform thickness nominally between 0.1 and 1 mm, length > 2 x width to continuous) of bulk metallic glass alloys and advanced low-density thin ply, hybrid carbon fiber/BMG unidirectional impregnated tapes at widths greater than 75 mm.

Sub Topics:

Z2.01 Cross Cutting Advanced Manufacturing Process for Large Scale Bulk Metallic Glass Systems for Aerospace Applications

Lead Center: JPL

Participating Center(s): LaRC, MSFC

Amorphous metals (also known as bulk metallic glasses) are a unique class of non-crystalline metals that possess the ability to be cast into high-tolerance hardware using similar processing techniques as plastics and yet retain mechanical properties similar (and in most cases superior to) titanium alloys Amorphous metals have mechanical properties and processing characteristics which set them apart from similar crystalline alloys (e.g., titanium, aluminum, or steel). They are metastable, resulting in manufacturing challenges as well as post processing and machining challenges, especially when scaling these materials. If BMGs can be scaled up to usable sheets (sizes greater than 150 mm wide), these materials see a greater infusion threshold in aerospace and defense applications. Specific applications for BMG sheets include MMOD shielding and multifunctional structures; casings and structural components on launch vehicles and habitats.

BMG alloys (to include but not limited to Al-based, Zr-, Mg-, Fe-, etc.) are desired in sheet form at a width >150 mm, a uniform thickness nominally between 0.1 and 1 mm, a length > 2 x width to continuous. In addition to BMG alloy sheets, the development of BMG composite sheets consisting of an amorphous matrix phase reinforced with soft, crystalline dendrites which improve the composite's toughness and ductility are also desired. BMG composite sheets at a width >150 mm, a uniform thickness nominally between 0.1 and 1 mm, a length > 2 x width to continuous. The properties of the amorphous metal can thus be tuned by the second phase. Strength, hardness, ductility, fatigue life, toughness, density, thermal expansion, thermal diffusivity, among others, can all be adjusted in these amorphous metal composites.

Special emphasis is placed on new processes for fabricating large BMG alloy and BMG composite sheets (width >150 mm, uniform thickness nominally between 0.1 and 1 mm, length > 2 x width to continuous) of bulk metallic glass alloys and advanced low-density thin ply, hybrid carbon fiber/BMG unidirectional impregnated tapes at widths greater than 75 mm.

A phase I effort should demonstrate one or more manufacturing/processing approach(s) that yield a sheet with the following dimensions: width >150 mm and uniform thickness nominally between 0.1 and 1 mm, length > 2 x width to continuous) of bulk metallic glass alloys and/or advanced low-density thin ply, hybrid carbon fiber/BMG unidirectional impregnated tapes approaching widths greater than 75 mm as proof of concept. Material should be delivered to the sponsor for evaluation. Plans for meeting dimensional goals, measuring manufacturing characteristics including but not limited to thickness, width, fraction or percent crystallinity, porosity or other defects, and evaluating manufacturing capability including but not limited to capacity/lead time, yield, cost reduction and process improvement opportunities to be reported at the conclusion of phase I.

A Phase II effort should demonstrate the manufacturing capability from Phase I that produces a BMG alloy and/or BMG composite sheet with a width >150 mm, uniform thickness nominally between 0.1 and 1 mm, length > 2 x width to continuous). The sheet should then be post processed and formed into a complex structural component from either/or of the large sheets of bulk metallic glass alloys and/or advanced low-density thin ply, hybrid carbon fiber/BMG unidirectional impregnated tapes at widths greater than 75 mm. Manufacturing variability of critical characteristics, including but not limited to thickness, width, fraction or percent crystallinity, porosity or other defects, should be measured. Manufacturing capability including but not limited to capacity/lead time, yield, cost reduction and process improvement opportunities (future work) should be reported. Material should be delivered to the sponsor for evaluation.

Advanced Photovoltaic Systems Topic Z1.01

Advanced photovoltaic (PV) power generation and enabling power system technologies are sought for improvements in capability and reliability of PV power generation for space exploration missions. Power levels for PV applications may reach 100s of kWe. System and component technologies are sought that can deliver cost, reliability, mass, volume, and efficiency improvements under various operating conditions, in extreme environments, and over wide temperature ranges.

PV technologies must enable or enhance the ability to provide low-cost, low mass and higher efficiency for power systems with particular emphasis on high power arrays to support solar electric propulsion missions.

Areas of particular emphasis for FY 2014 include:

- Automated/ modular fabrication methods for PV panels/ modules on flexible blankets (includes cell laydown, interconnects, shielding and high voltage operation mitigation techniques).
- Improvements to solar cell efficiency that is consistent with low cost, high volume fabrication techniques.
- PV module/ component technologies that emphasize low mass and cost reduction (in materials, fabrication and testing).
- Advanced PV blanket and component technology/ designs that support very high power and high voltage (> 200 V) applications.
- Integrated PV system including cells, blanket, array, inverters, interconnect technologies, storage, structures, etc. with a balance-of-components while matching specifications of various systems.
- Simulated PV capability that optimizes system components, ensures compatibility of modules/inverters, and takes temperature extremes and unique aspects of the space environment into account including radiation tolerance.

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Sub Topics:

Advanced Space Battery Technology Topic Z1.02

NASA seeks innovative, advanced technologies for next generation battery chemistries. Breakthrough battery cell technologies that far exceed the specific energy and energy density of current state-of-the-art lithium-ion cell technologies are required to achieve NASAs far-term energy storage goals for human and robotic missions. Future NASA missions will require rechargeable battery technologies that can provide 500 Wh/kg and 700 Wh/liter and can deliver > 1000 cycles at full depth of discharge. Components and chemistries for rechargeable battery cells that can enable performance that approaches 500 Wh/kg and 700 Wh/l on a cell level when integrated into a full cell with other advanced components and that can sustain stable performance over > 500 cycles are sought. Advanced next generation chemistries and components must have the potential to meet performance goals while simultaneously delivering a high level of safety. Proposed components may include, but are not limited to:

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Sub Topics:
Integrated Nuclear Power & Propulsion Topic Z1.03
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Sub Topics:
Modeling and Measurements for Propulsion and Power Topic Z1.04
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modeling tools are sought for:

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    - Z1.02 Advanced Space Battery Technology.
    - H8.01 Solid Oxide Fuel Cells and Electrolyzers.
    - T12.02 High Temperature Materials and Sensors for Propulsion Systems.
- Modeling electric propulsion (EP) life and failure mechanisms to predict the performance, plasma properties and lifetime of EP devices of interest and to help assess the interaction between the EP device plume and spacecraft surfaces.
    - H2.02 In-Space Propulsion Systems.
- Creating interfaces between reactor models and engine system models, including radiation effects; modeling NTP ground test engine exhaust filtering and containment.
    - H8.02 Space Nuclear Power Systems.
    - H2.04 Nuclear Thermal Propulsion (NTP) Ground Test Technologies.

Sub Topics:
Cross Cutting Advanced Manufacturing Process for Large Scale Bulk Metallic Glass Systems for Aerospace Applications Topic Z2.01
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Sub Topics: