STMD Power & Energy Storage

SBIR Workshop

Mike Piszczor, Max Briggs, Lee Mason

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Disclaimer

The NASA SBIR/STTR subtopic workshop was held for informational purposes only and was an opportunity for the small businesses community to explore and share ideas related to the general technical topic areas.

In the event of any inconsistency between data provided in this presentation and the Final Solicitation, the language in the Final Solicitation, including any amendments, will govern.

Key Agency Power Technology Needs

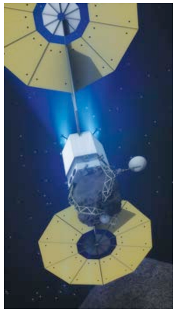
1) Power for Human Surface Missions

Stationary Power:
- 40 kW continuous power, day & night
- High system specific power >5 W/kg
- Nuclear fission or PV with energy storage
- Human-rated (safety and fault tolerance)
- Robotically-deployed (pre-crew arrival)
- Survivable for multiple crew campaigns >10 yrs

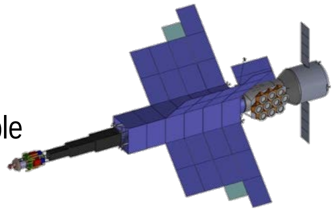
Mobile Power:
- 6 to 10 kW rechargeable power, up to 120 kWh
- Advanced batteries/fuel cells >300 Wh/kg, >200 cycles
- Maximum commonality with other surface assets
- Grid-compatible (with stationary power)

Both: Mars gravity, wind, dust, CO_2, temperature, diurnal period

2) Power for Electric Propulsion



Near Earth Systems:
- 30 to 50 kW solar array wings >100 W/kg
- Compact array stowage >40 kW/m3
- High deployed strength >0.1g and frequency >0.1 Hz
- High operating voltage >160V, PPU-compatible
- Long life >7 yrs with reuse



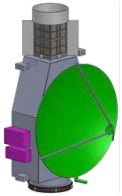
Mars and Beyond:
- 100 to 300 kW solar array wings >150W/kg
- Radiation tolerant solar cells
- Compact array stowage >60 kW/m3
- 1 to 5 MW fission reactors <5 kg/kW
- High operating voltage >300V, PPU-compatible
- Long life >5 yrs (Earth to Mars)

3) Power for Robotic Science Probes

Orbiters, Landers & Rovers:
- Power levels from 100 to 600 W at EOM
- Possibly kWs for ice melting, comm relays, EP
- Very long life >10 yrs and high reliability
- Low mass power systems >5 W/kg
- High performance RPS/fission >15% eff.
- Low intensity/low temperature PV >25% eff.
- Advanced batteries >300 Wh/kg, >200 cycles
- Extreme environments (low/high temperature, low/high solar intensity, high radiation)

4) Power for Small Spacecraft

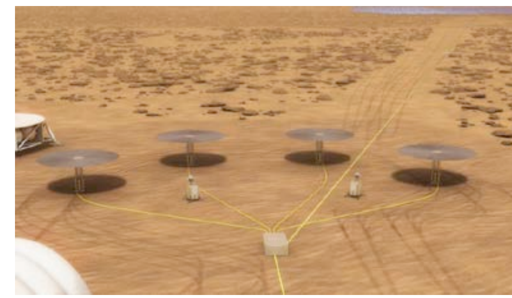
Near Earth Systems:
- Power levels from 100 to 500W
- Body-mounted or deployable solar arrays >100 W/kg
- Advanced batteries >200 Wh/kg, >200 cycles
- Compatible with 2U to 12U Cubesat platforms
- Highly integrated systems with shared structure



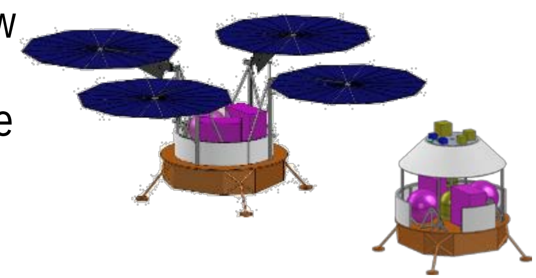
Deep Space Systems:
- Power levels from milliwatts up to 60W (nuclear)
- Small RPS using multiple RHUs or single GPHS
- Advanced conversion (TE, Stirling, Alpha/Beta-voltaic)

Power for Human Surface Missions

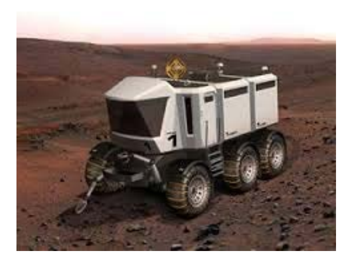
- **Primary Target is Mars, but extensibility to Moon desired**
  - Environment challenges include:
    - Mars gravity (0.38g), CO_2, dust, wind, temperature (170 to 270K), diurnal period (25 hrs)
    - Lunar gravity (0.16g), vacuum, dust, temperature (100 to 370K), diurnal period (29.5 days)



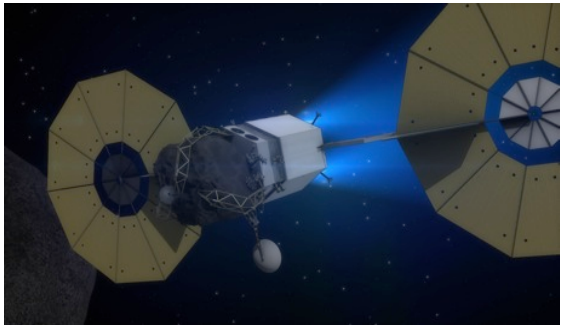
- **Stationary Power**
  - Need: Up to 40 kW day/night continuous power
  - Power for ISRU propellant production (pre-crew arrival)
  - Power for landers, habitats, life support, rover recharging (during crew operations)
  - Technology options: Nuclear Fission or PV with Energy Storage
  - Compact stowage, robotically deployed, survivable for multiple crew campaigns (>10 yrs)
  - Potential EDL/ISRU/Power Demo (late 2020s) 5 to 10 kW on Single Lander w/ISRU



- **Mobile Power**
  - Need: Up to 120 kWh for rovers and construction equipment
  - Technology options: Batteries or Fuel Cells
  - Desire maximum commonality with other surface assets: multi-use, interchangeable components, shared reactants, grid-compatible

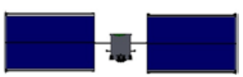


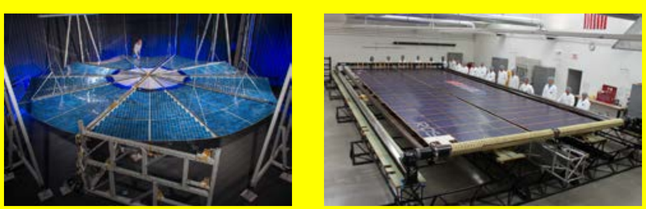
Power for Electric Propulsion



Initial SEP Capability (SEP TDM)

- 50-kW Solar Array System
- 40-kW EP System
- 5-t class Xenon Capacity with Refueling Capability
- 13-kW EP strings

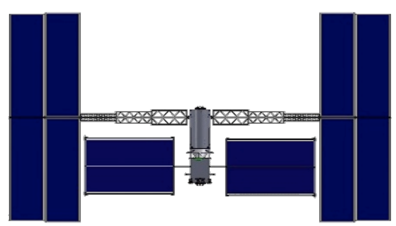


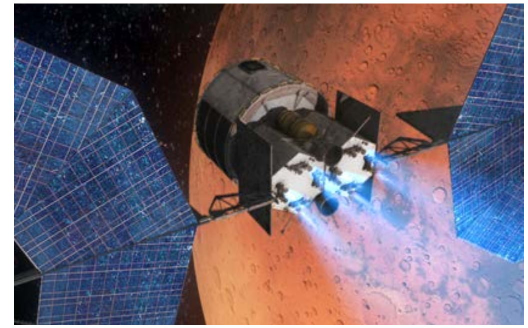


Solar Array System Tests

Proving Ground Or Split Mars Architecture

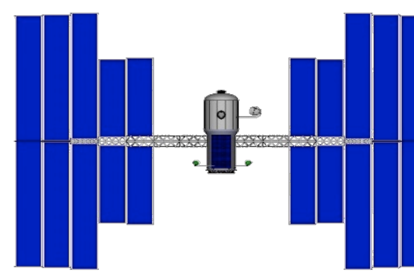
- 190-kW Solar Array
- 150-kW EP System
- 16-t class Xenon Capacity
- 13-kW EP strings





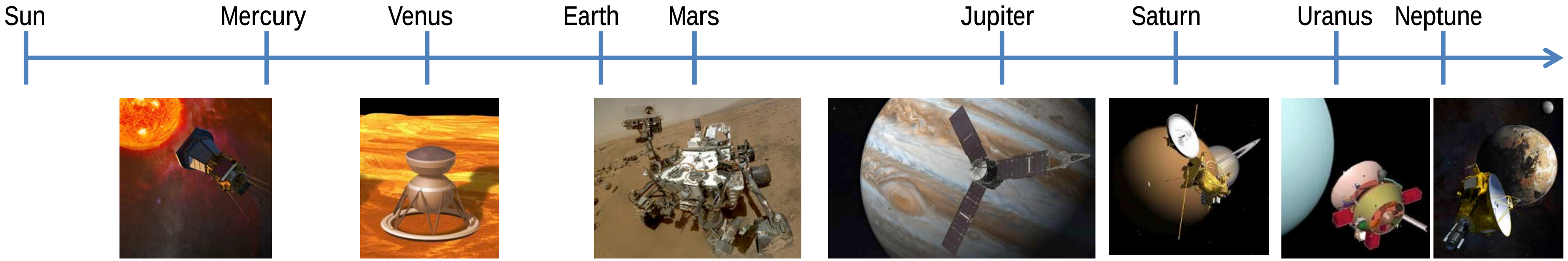
Hybrid Mars Architecture

- 400-kW class Solar Array
- 300-kW class EP System
- 16-t class Xenon Capacity
- 30-kW class EP strings or 13-kW strings



Power for Robotic Science Probes

- Key for robotic science is long life, reliable power
  - Plutonium-powered RTGs have been staple for >40 yrs but fuel availability, integration costs, schedule risk, & launch safety are impediments
  - Solar power is starting to win power trades (e.g. JUNO, Solar Probe Plus, Europa Clipper)
- Expected EOM power requirement is 100 to 600 We
  - Possibly kWs for ice melting, communication relays, electric propulsion
  - Need low mass power systems >5 W/kg and high conversion efficiency >15% nuclear, >25% solar
- Higher power provides path to increased capabilities
  - More instruments, increased duty cycles
  - High rate communications, real time tele-operations, in-situ data analysis
  - Sufficient on-board power for subsurface science (e.g. ice melting)
  - Integration with EP for lower launch mass, and multiple targets with single spacecraft
- Upcoming mission applications
  - Europa Clipper/Europa Lander
  - New Frontiers 2024, Discovery 2028
  - Future Flagships: Titan Saturn System Mission, Uranus Orbiter Probe, Neptune Systems Explorer, Saturn Ring Observer, …



Power for Small Spacecraft

Small Spacecraft Power

- Growing trend to fly greater number of small missions versus one or two large missions
- Small satellites can provide cost benefits and greater access to space
- Advanced power technologies are crucial to the small satellite and cubesat market segment
- Power system improvements can increase available power, extend mission life, and/or allow greater payload mass

Current State of the Art:

- Commercial solar arrays with >28% efficiency
- Commercial Li-ion batteries at ~150 Whr/kg
- Commercial plug and play power distribution boards and electrical controllers
- Poor reliability – high failure rates

Power Challenges:

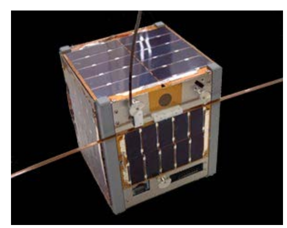
- Highly integrated systems with shared structure and thermal management
- Improved performance, increased reliability, decreased recurring cost
- Low cost power options for beyond LEO

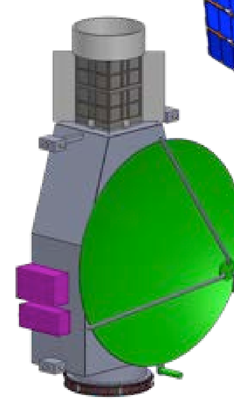
Near Earth Technology Needs:

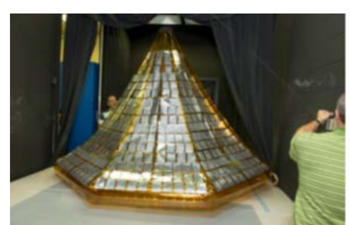
- Power levels from 100 to 500W
- Body-mounted or deployable arrays >100 W/kg
- Advanced batteries >200 Wh/kg, >200 LEO cycles
- Compatible with 2U to 12U Cubesat platforms

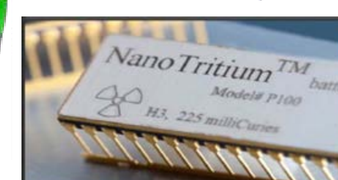
Deep Space Technology Needs:

- Power levels from milliwatts up to 60W (nuclear)
- Small RPS using multiple Radioisotope Heater Units (RHU) or single General Purpose Heat Source (GPHS)
- Advanced conversion, e.g. thermoelectric, Stirling, thermo-photovoltaic, alpha/beta-voltaics









Power-Related SBIR Subtopics

Z1 Power and Energy Storage

- Focus on technologies that generate power and/or store energy for future human and robotic space missions
- Key goal is to develop technologies that are multi-use and cross-cutting for a broad range of NASA mission applications
- Primary areas of interest include surface power, large-scale spacecraft prime power, and small-scale robotic probe power
- Applicable technologies include photovoltaic arrays, radioisotope power systems, nuclear fission, thermal energy conversion, fuel cells, batteries, and power management & distribution.

Z1.01 High Power, High Voltage Electronics

- Seeking improvements to Power Management and Distribution (PMAD) systems through increases to the operating voltages, e.g. Power Processing Units (PPUs) that convert the 300V solar array output to the 700V-2000V input level of an electric thruster
- Development and integration of commercial diodes and transistors that can be space-qualified will lead to increases in system-level performance as they will tend to increase efficiency and decrease mass
- Need to resolve issues related to parts failures space qualification testing, most importantly in terms of their radiation tolerance

Power-Related SBIR Subtopics

Z1.02 Surface Energy Storage (formerly H8.02, H8.04)

- Seeking innovative energy storage solutions for surface missions on the moon and Mars that could include landers, construction equipment, crew rovers, and science platforms
- Energy requirements for mobile assets are expected to range up to 120 kW-hr with potential for clustering of smaller building blocks to meet the total need
- Requirements for energy storage systems used in combination with surface solar arrays range from 500 kW-hr (Mars) to over 14 MW-hr (moon)
- Applicable technologies such as batteries and regenerative fuel cells should be lightweight, long-lived, and low cost with potential for multi-use (e.g. moon and Mars) and/or cross-platform use (e.g. lander and rover)
- Creative ideas that utilize local materials to store energy would also be considered under this subtopic.

Z1.03 Surface Power Generation (formerly H8.01)

- Seeking novel fission-based power generation technologies for surface missions on the moon and Mars that could include landers, crewed habitats, and in-situ resource utilization plants
- Power requirements are expected to range up to 40 kW with potential for clustering of smaller building blocks to meet the total need
- Applicable technologies should be lightweight, long-lived, low cost with potential for use on both the moon and Mars
- Emphasis on the key non-nuclear components and sub-systems, e.g. power conversion technologies that enable system-level specific power >5 W/kg, advanced manufacture of heat exchangers for power conversion, reliable and radiation-hard controllers, reactor and power conversion thermal interfaces, neutron reflectors, and radiation shielding

Both: Strong consideration should be given to environmental robustness for surface environments that include day/night thermal cycling, natural radiation, partial gravity, vacuum or very low ambient pressure, dust, and wind

Power-Related SBIR Subtopics

Z8.03 Small Spacecraft Power and Thermal Control

- SmallSat and CubeSat missions require reliable operation for several years in potentially harsh radiation environments
- Need to extend beyond current commercial components to address robustness needed for long duration missions and develop high reliability smallsat power generation and storage and thermal control systems
- Emphasis on energy management systems that combine power generation, storage and heat rejection in the compact cubesat platform as well as systems that enable electric propulsion
- Modular, highly-reliable solar array, battery, power system electronics technologies that enabling scalable smallsat and cubesat power systems.

H5.01 Mars Surface Solar Array Structures

- Initial manned missions to the Mars surface may use large photovoltaic (PV) solar arrays to generate power for habitats, ISRU, science investigations, and battery charging, e.g. solar array “farm”
- Equipment may be prepositioned and validated prior to human landings using autonomous deployment/assembly
- Modular solar array designs could be based on individual deployable structures or a single monolithic structure
- Thrust areas include lightweight structures, robust deployment/retraction mechanisms, and autonomous assembly focusing on the process of post-landing deployment and erection of a large solar power system on the surface of Mars
- Each lander might have its own modular power system that could be relocated closer to the loads to reduce cabling lengths and grow available power as the human Mars base grows.

Power-Related SBIR Subtopics

S3.01 Power Generation and Conversion

- Future NASA science missions will employ Earth orbiting spacecraft, planetary spacecraft, balloons, aircraft, surface assets, and marine craft as observation platforms
- Proposals are solicited to develop advanced power-generation and conversion technologies to enable or enhance the capabilities of future science missions
- Requirements for these missions are varied and include long life, high reliability, significantly lower mass and volume, higher mass specific power, and improved efficiency over the state of practice for components and systems
- Other desired capabilities are high radiation tolerance and the ability to operate in extreme environments (high and low temperatures and over wide temperature ranges)
- Emphasis on the following areas: 1) Photovoltaic Energy Conversion, 2) Stirling Power Conversion, and 3) Direct Energy Conversion.

S3.03 Power Electronics and Management, and Energy Storage

- Proposals are solicited to develop energy storage and power electronics to enable or enhance the capabilities of future NASA science missions
- Advances in electrical power technologies are required for the electrical components and systems of these future spacecraft/platforms to address size, mass, efficiency, capacity, durability, and reliability requirements
- Seeking improvements in energy density, speed, efficiency, or wide-temperature operation (-125° C to over 450° C) with multiple thermal cycles
- Advancements are sought for power electronic devices, components, packaging and cabling for power ranges of a few watts for minimum missions to up to 20 kilowatts for large missions
- Advanced primary and secondary battery systems capable of operating at temperature extremes from -100° C for Titan missions to 400 to 500° C for Venus missions, and a span of -230° C to +120° C for Lunar missions
- High energy-density rechargeable battery systems with >200 Wh/kg that offer >10 year operating life for LEO spacecraft, >20 year life for GEO spacecraft and high radiation tolerance

Summary

- NASA needs innovative power and energy storage technologies to perform future missions
- Areas of emphasis include:
  - Power for Human Surface Missions
  - Power for Electric Propulsion
  - Power for Robotic Science Probes
  - Power for Small Spacecraft
- The SBIR Program provides abundant opportunities for industry to develop new power technologies
  - Power and Energy Storage (Z1)
  - Small Spacecraft Power (Z8)
  - Solar Array Structures (H5)
  - Robotic Science Power (S3)