



NASA SBIR 2009 Phase I Solicitation

S3 Spacecraft and Platform Subsystems

The Science Mission Directorate will carry out the scientific exploration of our Earth, the planets, moons, comets, and asteroids of our Solar System and beyond. SMD's future direction will be moving from exploratory missions (orbiters and flybys) into more detailed/specific exploration missions that are at or near the surface of where we want to explore (landers, rovers, and sample returns), that would require new vantage points, or that would need to integrate or distribute capabilities across multiple assets. Future destinations will be more challenging to get to, have more extreme environmental conditions and challenges once you get there, and may be a challenge to get a spacecraft or data back from. A major objective of the NASA science spacecraft systems development programs is to enable science measurement capabilities using smaller and lower cost spacecraft to meet multiple mission requirements thus making the best use of our limited resources. To accomplish this objective, NASA is seeking innovations to significantly improve subsystem capabilities while reducing the mass and cost, that would in turn enable increased scientific return for future NASA missions. Innovations are sought in the areas of: Command, Data Handling, and Electronics; Thermal Control Systems; Power Generation and Conversion; Propulsion Systems; Power Management and Storage; Guidance, Navigation and Control; Sensor and Platform Data Processing & Control; Planetary Ascent Vehicles; Unmanned Aerial Vehicles and Terrestrial Balloons.

Subtopics

S3.01 Command, Data Handling, and Electronics

Lead Center: GSFC

Participating Center(s): ARC, JPL, JSC, LaRC

NASA's space based observatories, fly by spacecraft, orbiters, landers, and robotic and sample return missions, require robust command and control capabilities. Advances in technologies relevant to guidance, navigation, command and data handling are sought to support NASA's goals and several missions and projects under development.

<http://nasascience.nasa.gov/search?SearchableText=missions+under+development>
http://www.nap.edu/catalog.php?record_id=10432

The subtopic goals are to: (1) develop high-performance processors and memory architectures and reliable

electronic systems, and (2) develop an avionics architecture that is flexible, scalable, extensible, adaptable, and reusable. The subtopic objective is to elicit novel architectural concepts and component technologies that are realistic and operate effectively and credibly in environments consistent with the future NASA Science missions.

Successful proposal concepts should significantly advance the state-of-the-art. Proposals should clearly (1) state what the product is; (2) describe how it targets the technical priorities listed below; and (3) outline the feasibility of the technical and programmatic approach. If a Phase 2 proposal is awarded, the combined Phase 1 and Phase 2 developments should produce a prototype that can be characterized by NASA. The technology priorities sought are listed below.

Command and Data Handling

- Processors - General purpose (processor chips and radiation-hardened by design synthesizable IP cores) and special purpose single-chip components (DSPs) with sustainable processing performance and power efficiency (>500 MIPS at >100 MIPS/W for general purpose processing platforms, >5 GMACs at >5 GMACS/W for computationally-intensive processing platforms), and tolerance to total dose and single-event radiation effects. Concepts must include tools required to support an integrated hardware/software development flow.
- Radiation-hardened non-volatile low power memories.
- Radiation-hardened physical layer components for onboard data busses (e.g. Ethernet).
- Tunable, scalable, reconfigurable, adaptive fault-tolerant avionics.

Proposals should show an understanding of one or more relevant science needs, and present a feasible plan to fully develop a technology and infuse it into a NASA program.

The Small Spacecraft Build effort highlighted in Topic S4 (Low-cost Small Spacecraft and Technologies) of the solicitation participates in this subtopic. Offerors are encouraged to take this in consideration as a possible flight opportunity when proposing work to this subtopic.

S3.02 Thermal Control Systems

Lead Center: GSFC

Participating Center(s): ARC, GRC, JPL, MSFC

Future Spacecraft and instruments for NASA's Science Mission Directorate will require increasingly sophisticated thermal control technology. Some of these requirements include:

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1. Optical systems, lasers and detectors require tight temperature control, often to better than $\pm 1^\circ\text{C}$. Some new missions such as LISA require thermal gradients held to even tighter micro-degree levels.
 2. Exploration science missions beyond earth orbit present engineering challenges requiring systems which are more self-sufficient and reliable.
 3. The introduction of low-cost, small, rapidly configured spacecraft requires the development of new thermal technologies to reduce the time and costs typically required for analysis, design, integration, and testing of the spacecraft.

Innovative proposals for the cross-cutting thermal control discipline are sought in the following areas:

- Methods of precise temperature measurement and control to tight temperature levels.
- High conductivity, vacuum-compatible interface materials to minimize losses across make/break interfaces.
- High conductivity materials to minimize temperature gradients and provide high efficiency light-weight radiators, including interfaces to heat pipes and fluid loops that overcomes issues with CTE mismatch.
- Advanced more efficient thermoelectric coolers capable of providing cooling at ambient and cryogenic temperatures,
- Advanced thermal control coatings, particularly those with low absorptance, high emittance, and good electrical conductivity. Also, variable emittance surfaces to modulate heat rejection are needed.
- Single and two-phase mechanically pumped fluid loop systems which accommodate multiple heat sources and sinks, and long life, lightweight pumps for these systems. Also includes advanced fluid system components such as accumulators, valves, pumps, flow rate sensors, etc. optimized for improved reliability, long life, and low resource needs.
- Phase change systems for Mars or Lunar applications. Reusable phase change systems are desired which can be employed to absorb transient heat dissipations during instrument operations. Technology is sought for phase change systems which can then either store this energy or provide an exothermic process which would provide heat for instrument power-on after the dormant phase.
- Ionic liquids, salts composed of separate cations and anions, have been known but not intensely studied. Because of their tunable and thus extremely favorable solvent and materials properties, ionic liquids are potentially useful for a wide range of space applications, e.g. liquid-mirror telescopes and heat transfer of fluids that could enhance lunar regolith geothermal potential many-fold.
- Efficient, lightweight, oil-less, high lift vapor compression systems or novel new technologies for high performance cooling up to 2 KW.
- Advanced thermal modeling techniques that can be easily integrated into existing codes, emphasizing inclusion of two-phase systems and mechanically pumped system models.
- Integration of standardized formats into existing analytical codes for the representation and exchange of thermal network models and thermal geometric models and results.
- Analytical codes to automate the generation of reduced thermal models from larger models, including routines to verify the accuracy of the reduced models.

Research should be conducted to demonstrate technical feasibility during Phase 1 and show a path toward a

Phase 2 hardware and software demonstration. Phase 2 should deliver a demonstration unit or software package for NASA testing at the completion of the Phase 2 contract.

Proposals should show an understanding of one or more relevant science needs, and present a feasible plan to fully develop a technology and infuse it into a NASA program.

S3.03 Power Generation and Conversion

Lead Center: GRC

Participating Center(s): GSFC, JPL, JSC, MSFC

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).

While power generation technology affects a wide range of NASA missions and operational environments, technologies that provide substantial benefits for key mission applications/capabilities are being sought in the following areas:

Radioisotope Power Conversion

Improvements are solicited in component and systems technology relevant to Sterling and thermophotovoltaic power conversion. For Stirling conversion, advances sought, but not limited to, include:

- Novel methods or approaches for radiation-tolerant, sensorless, autonomous control of Stirling converters with very low vibration and having low mass, size, and electromagnetic interference (EMI);
- High-temperature, high-performance regenerators and linear alternators;
- Advances applicable to Venus surface missions including high-temperature heater heads (> 850Å°C), joining techniques and regenerators (~1200Å°C), and combined electrical power generation and cooling systems applicable to Venus surface missions (~1200Å°C);
- Concepts for Stirling engine power from cold energy lunar regolith down to 2-3 meters below the surface, including Stirling Engines that will provide up to 100 watts with a mass less than 50kg for the surface lunar environment with the hot side operating at about 256 K and a cold side at about 100 degrees lower.

Thermophotovoltaic conversion is currently focused on follow-on technology for the International Lunar Network (ILN) and for the outer planets mission. Advances sought, but not limited to, include:

- Low-bandgap cells having high efficiency and high reliability;
- High temperature selective emitters;
- Low absorptance optical band-pass filters;
- Efficient multi-foil insulation.

Photovoltaic Energy Conversion

Photovoltaic cell, blanket, and array technologies that lead to significant improvements in overall solar array performance (i.e. conversion efficiency >30%, array mass specific power >300watts/kilogram, decreased stowed volume, reduced initial and recurring cost, long-term operation in high radiation environments, high power arrays, and a wide range of space environmental operating conditions) are solicited. Technologies specifically addressing the following mission needs are highly sought:

- Photovoltaic cell and blanket technologies capable of low intensity, low-temperature operation applicable to outer planetary (low solar intensity) missions;
- Photovoltaic cell, blanket and array technologies capable of enhancing solar array operation in a high intensity, high-temperature environment (i.e. inner planetary and solar probe-type missions);
- Lightweight solar array technologies applicable to solar electric propulsion missions. Current missions being studied require solar arrays that provide 1 to 20 kilowatts of power at 1 AU, are greater than 300 watts/kilogram specific power, can operate in the range of 0.7 to 3 AU, provide operational array voltages up to 150 volts and have a low stowed volume.

Proposals should show an understanding of one or more relevant science needs, and present a feasible plan to fully develop a technology and infuse it into a NASA program.

S3.04 Propulsion Systems

Lead Center: GRC

Participating Center(s): JPL

The Science Mission Directorate (SMD) needs spacecraft with more demanding propulsive performance and flexibility for more ambitious missions requiring high duty cycles, more challenging environmental conditions, and extended operation. Planetary spacecraft need the ability to rendezvous with, orbit, and conduct in situ exploration of planets, moons, and other small bodies in the solar system (http://www.nap.edu/catalog.php?record_id=10432).

Future spacecraft and constellations of spacecraft will have high-precision propulsion requirements, usually in volume- and power-limited envelopes.

This subtopic seeks innovations to meet SMD propulsion requirements, which are reflected in the goals of NASA's In-Space Propulsion Technology program to reduce the travel time, mass, and cost of SMD spacecraft. Advancements in chemical and electric propulsion systems related to sample return missions to Mars, small bodies (like asteroids, comets, and Near-Earth Objects), outer planet moons, and Venus are desired. Additional electric propulsion technology innovations are also sought to enable low cost systems for Discovery class missions, and eventually to enable radioisotope electric propulsion (REP) type missions.

The focus of this solicitation is for next generation propulsion systems and components, including high-pressure chemical rocket technologies and low cost/low mass electric propulsion technologies. Specific sample return propulsion technologies of interest include higher pressure chemical propulsion system components, lightweight propulsion components, and Earth-return vehicle propulsion systems. Propulsion technologies related specifically to planetary ascent vehicles will be sought under S3.08 Planetary Ascent Vehicle.

Chemical systems for sample return missions should focus on component technologies for high-pressure (>700 psi) chemical systems such as:

- Lightweight tanks;
- Actuators and regulators;
- Self pressurizing propellants.

This subtopic also seeks proposals that explore uses of technologies that will provide superior performance in electric propulsion systems. These technologies include:

- Hall thruster power processing unit (PPU) capable of 3 ½ kW, 5A, and 700 V with a maximum mass of 5.25 kg;
- High specific impulse/low mass electric propulsion systems for sample return missions;
- Future low cost/low mass electric propulsion systems;
- Thrusters should provide thrust up to 20 mN with a specific impulse between 1600 to 3500 seconds;
- Corresponding power processing units capable up to 1 kW of input power;
- The total system mass should not exceed 3 kgs (roughly 1 kg for a thruster and 2 kg for a PPU).

Proposals should show an understanding of one or more relevant science needs, and present a feasible plan to fully develop a technology and infuse it into a NASA program.

S3.05 Power Management and Storage

Lead Center: GRC

Participating Center(s): JPL

Future NASA science objectives will include missions such as Earth Orbiting, Venus, Europa, Titan and Lunar Quest. Under this subtopic, proposals are solicited to develop energy storage and power electronics to enable or enhance the capabilities of future science missions. The unique requirements for the power systems for these missions can vary greatly, with advancements in components needed above the current State of the Art (SOA) for long life, high reliability, low mass/volume, radiation tolerance, and wide temperature operation. Other subtopics which could potentially benefit from these technology developments include X1.03 Radiation Hardened/Tolerant and Low Temperature Electronics and Processors. Battery development could also be beneficial to X7.01 Advanced Space-rated Batteries which is investigating similar, but different technologies.

Energy Storage

Future science missions will require advanced primary and secondary battery systems capable of operating at temperature extremes from -100°C for Titan missions to 400°C to 500°C for Venus missions, and a span of -230°C to $+120^{\circ}\text{C}$ for Lunar Quest. In addition, rechargeable electrochemical battery systems that offer greater than 50,000 charge/discharge cycles (10 year operating life) for low-earth-orbiting spacecraft, 20 year life for geosynchronous (GEO) spacecraft, are desired. Advancements to battery energy storage capabilities that address one or more of the above requirements for the stated missions combined with very high specific energy (>200 Wh/kg for secondary battery systems) and energy density, along with radiation tolerance are of interest.

Power Management and Distribution (PMAD)

Advanced electrical power technologies are required for the electrical components and systems on future platforms to address the size, mass, efficiency, capacity, durability, and reliability requirements. Of importance are expected improvements in energy density, speed, efficiency, or wide-temperature operation (-125°C to over 450°C) with a number of thermal cycles. Advancements are sought for power electronic devices, components and packaging for Venus type missions with power ranges of a few watts for minimum missions up to a few hundred watts for large missions. In addition, advancements in components or architectures for application to Radioisotope Electric Propulsion (REP) PMAD systems are considered beneficial. Technologies of interest include:

- High temperature devices and components (up to 450°C);
- Advanced electronic packaging for thermal control and electromagnetic shielding.

Research should be conducted to demonstrate technical feasibility during Phase 1 and show a path toward a Phase 2, and when possible, deliver a demonstration unit for NASA testing at the completion of the Phase 2 contract. Phase 2 emphasis should be placed on developing and demonstrating the technology under relevant test conditions. Additionally, a path should be outlined that shows how the technology could be commercialized or

further developed into science-worthy systems.

Proposals should show an understanding of one or more relevant science needs, and present a feasible plan to fully develop a technology and infuse it into a NASA program.

S3.06 Guidance, Navigation and Control

Lead Center: GSFC

Participating Center(s): ARC, JPL

Advances in the following areas of guidance, navigation and control are sought.

Navigation systems (including multiple sensors and algorithms/estimators, possibly based on existing component technologies) that work collectively on multiple vehicles to enable inertial alignment of the formation of vehicles (i.e., pointing of the line-of-sight defined by fixed points on the vehicles) on the level of milli-arcseconds relative to the background star field.

Light-weight sensors (gyroscopic or other approach) to enable milli-arcsecond class pointing measurement for individual large telescopes and low cost small spacecraft.

Isolated pointing and tracking platforms (pointing 0.5 arcseconds, jitter to 5 milli-arcsecond), targeted to placing a scientific instrument on GEO communication satellites that can track the sun for > 3 hours/day.

Working prototypes of GN&C actuators (e.g., reaction or momentum wheels) that advance mass and technology improvements for small spacecraft use. Such technologies may include such non-contact approaches such as magnetic or gas. Superconducting materials, driven by temperature conditioning may also be appropriate provided that the net power used to drive and condition the "frictionless" wheels is comparable to traditional approaches.

Proposals should show an understanding of one or more relevant science needs, and present a feasible plan to fully develop a technology and infuse it into a NASA program.

S3.07 Sensor and Platform Data Processing and Control

Lead Center: GSFC

Participating Center(s): ARC, JPL

Future NASA's science missions will require high-performance onboard data processing capabilities that far exceed those of today. These capabilities will be leveraged to provide data reduction for missions where sensor bandwidths far exceed downlink bandwidth. Improved onboard data processing will also enable autonomous/collaborative systems, where science operations are autonomously controlled via features extracted from the sensor data. Advances in technologies relevant to sensor and platform data processing and control are sought to support NASA's goals and several missions and projects under development.

<http://nasascience.nasa.gov/search?SearchableText=missions+under+development>
http://www.nap.edu/catalog.php?record_id=10432

The subtopic goals are to: (1) develop device technologies and architectures that can yield a 10x to 100x improvement in on-board computing power is required to enable the next generation of Earth Science, Space Science and Exploration missions; and (2) develop tool technologies that can enable rapid development of high reliability, high performance onboard data processing applications for these missions.

Successful proposal concepts will significantly exceed the present state-of-the-art. Proposals will clearly (1) state what the product is; (2) describe how it targets the technical priorities listed below; and (3) outline the feasibility of the technical and programmatic approach. If a Phase 2 proposal is awarded, the combined Phase 1 and Phase 2 developments shall produce a prototype that is testable by NASA. The technology priorities sought are listed below.

Device Technologies and Architectures

- Highly reliable, radiation tolerant, special purpose data processing devices (FPGA, multi-core, DSP) that enable accelerated onboard data processing;
- Hybrid onboard processing architectures using multiple heterogeneous processing elements (CPU, FPGA, DSP, multi-core);
- Architectures providing software-based radiation mitigation strategies for commercial processing elements.

Development Tool Technologies

- Hybrid system design tools that (a) take full advantage of hybrid processing platforms, and (b) automate/accelerate the design and verification process.

Proposals should show an understanding of one or more relevant science needs, and present a feasible plan to fully develop a technology and infuse it into a NASA program.

S3.08 Planetary Ascent Vehicles

Lead Center: GRC

Participating Center(s): AFRC, JPL, MSFC

NASA aims to design, build and test vehicles that will be launched from the surface of other planets and place a payload, Orbiting Sample (OS), into orbit. We are seeking proposals for the development of innovative technologies to support future planetary ascent vehicles. Immediate focus is the Mars ascent vehicle. Technology innovations should either enhance vehicle capabilities (e.g., launch success probability, mission success, improved performance or margins, and improved environmental robustness) or ease implementation in spaceborne missions (e.g., reduce size, mass, power, and thermal requirements, improve reliability and ability to withstand the ~20 g lateral g-loading, or lower cost). The areas of interest for this call are listed below.

Advanced solid propellant engine system technologies:

- Solid propellant technology with specific impulse performance potential higher than HTPB and CTPB;
- Propellant blend with high performance and low storage and operating capability down to 150 K;
- Low temperature seals and components;
- Light weight and reliable thrust vector control;
- Other light weight system and component technologies.

Alternate propellants, thrusters and propulsion system technologies for the planetary ascent vehicles:

- Higher performing monopropellants with specific impulse >240 secs;
- High chamber pressure thrusters > 500 psia;
- Pressurization component technologies to reduce system mass (filters, solenoid valves, latch valves, tanks, fill and drain and check valves);
- Small lightweight pump technologies to operate at >500 psi output pressure;
- Non-pyrotechnic isolation valves.

Proposals should show an understanding of one or more relevant science needs, and present a feasible plan to fully develop a technology and infuse it into a NASA program.

S3.09 Technologies for Unmanned Atmospheric Platforms

Lead Center: AFRC

Participating Center(s): ARC, GRC, GSFC, JPL, LaRC

Unmanned Aerial Vehicles (UAVs) offer significant potential new capabilities for scientific earth exploration over a large range of mission durations, altitudes, and geographical locations. UAVs can carry earth resources remote sensing and atmospheric sampling instruments on scientific investigations including the Polar Regions. The potential for these robotic systems has just begun to be realized, and to date their earth observation and atmospheric sampling capabilities are in a state of infancy when compared to platform requirements needed to address national concern over global climate and environmental changes. Current UAV operations are restricted from operations in inclement weather particularly when airframe icing or freezing of fuel may become issues. Airframe icing limits both aircraft flight envelope and may affect scientific payload operations.

UAVs must adhere to regulatory requirements for flight operations within the national airspace. These regulatory issues pose challenges to the trade space of potential solutions. UAVs can be roughly categorized into 1) larger/high value assets and 2) smaller/lower value or expendable assets. Such categorization of UAVs may drive different technology solutions to meet the technology needs as described below.

- Precision flight path control for highly repeatable terrain monitoring over daily, seasonal or multi-year cycles;
- Highly accurate UAV platform attitude control with corresponding science payload instrument stability and pointing accuracy;
- Lower-cost over-the-horizon telemetry alternatives for real-time collaborative data sharing and decision-making involving multiple in-flight and ground-based instruments;
- Drop-sonde and surface sampling probes remote from the unmanned aircraft;
- Airframe icing detection and mitigation to enable UAV severe weather flight operations;
- UAV flight systems to enable long endurance inclement weather operations; systems such as fuel anti-freezing thermal management will be needed.

Proposals should show an understanding of one or more relevant science needs, and present a feasible plan to fully develop a technology and infuse it into a NASA program.

S3.10 Terrestrial Balloon Technologies

Lead Center: GSFC

Currently, NASA is developing a Super Pressure terrestrial vehicle targeting 100 day duration missions in mid-latitude. This added capability will greatly enable new science investigations. The design of the current pumpkin shape vehicle utilizes light weight polyethylene film and high strength tendons made of twisted Zylon® yarn. The in-flight performance and health of the vehicle relies on accurate information on a number of environmental, design, and operational parameters. Therefore, NASA is seeking innovations in the following specific areas:

Balloon Instrumentation

Devices or methods to accurately and continuously measure ambient air, helium gas, balloon film temperatures, and film strain. These measurements are needed to accurately model the balloon performance during a typical flight at altitudes of approximately 120,000 feet. The measurements must compensate for the effects of direct solar radiation through shielding or calculation. Minimal mass and volume are highly desired. For film measurements, a non-invasive and non-contact approach is highly desired for the thin polyethylene film used as the balloon envelope, with film thickness ranging from 0.8 to 1.5 mil. The devices of interest must be compatible with existing NASA balloon packaging, inflation, and launch methods. These instruments must also be able to interface with existing NASA balloon flight support systems or alternatively, a definition of a telemetry solution be provided.

Device and method to recover a scientific balloon from Antarctica

Scientific balloons are recovered after flight from the interior of Antarctica. These balloons are either loaded onto aircraft used for remote field operation support, or are loaded upon passing overland traverse vehicles to carry back to McMurdo Station for later disposal. Better methods and/or equipment are needed to expedite the operation and reduce the burden on resources used for recovery of scientific balloons in Antarctica. Current methods to recover balloons are resource and time intensive. In these remote locations, resources and available time are limited. Balloons must be cut up into bundles of manageable size and weight in order to fit inside aircraft that are currently used in support of the United States Antarctic Program (USAP). Scientific balloons weigh up to approximately 2000 kg. The balloon is made up of layers of polyethylene film that are 0.8 to 1.5 mil thick. Each balloon is made up of approximately 200 gores that are heat-sealed together. Each gore seal incorporates load tendons that are made of either polyester load tapes or woven Zylon® fibers. Each balloon incorporates metal end-fittings that can be cut out by hand. Folds, twists and binding of material are characteristics of balloons being recovered. The Antarctic operating environment can be -50 degrees Celsius. Environmental sensitivity is also an issue in Antarctica. Existing aircraft recovery assets include ski-equipped Twin Otters and a DC-3 Basler.

Devices or methods to accurately and continuously measure individual axial loading on an array of ~50 or up to 300 separate tendons during a Super Pressure balloon mission

Tendons are the load carrying member in the pumpkin design. During a typical mission, loading on individual tendons should not exceed a critical design limit to ensure structural integrity and survival. Tendons are typically captured at the fitting via individual pins. Loading levels on the tendons can range from ~20 N to ~8,000 N and temperature can vary from room temperature to the troposphere temperatures of -90 degrees Celsius or colder. The devices of interest shall be easily integrated with the tendons or fittings during balloon fabrication and shall have minimal impact on the overall mass of the balloon system. Support telemetry and instrumentation is not part of this initiative; however, data from any sensors (devices) that are selected from this initiative must be able to be stored on board and/or telemetered in-flight using single-channel (two-wire) interface into existing NASA balloon flight support systems.

Proposals should show an understanding of one or more relevant science needs, and present a feasible plan to fully develop a technology and infuse it into a NASA program.

