The Science Mission Directorate will carry out the scientific exploration of our Earth, the planets, moons, comets, and asteroids of our solar system and the universe beyond. SMD’s future direction will be moving away from exploratory missions (orbiters and flybys) into more detailed/specific exploration missions that are at or near the surface (landers, rovers, and sample returns) or at more optimal observation points in space. These future destinations will require new vantage points, or would need to integrate or distribute capabilities across multiple assets. Future destinations will also be more challenging to get to, have more extreme environmental conditions and challenges once the spacecraft gets there, and may be a challenge to get a spacecraft or data back from. A major objective of the NASA science spacecraft and platform subsystems development efforts are 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 spacecraft and platform subsystem capabilities while reducing the mass and cost, which would in turn enable increased scientific return for future NASA missions. A spacecraft bus is made up of many subsystems like:

- Propulsion.
- Thermal control.
- Power and power distribution.
- Attitude control.
- Telemetry command and control.
- Transmitters/antenna.
- Computers/on-board processing/software.
- Structural elements.

Science platforms of interest could include unmanned aerial vehicles, sounding rockets, or balloons that carry scientific instruments/payloads, to planetary ascent vehicles or Earth return vehicles that bring samples back to Earth for analysis. This topic area addresses the future needs in many of these sub-system areas, as well as their application to specific spacecraft and platform needs. For planetary missions, planetary protection requirements vary by planetary destination, and additional backward contamination requirements apply to hardware with the potential to return to Earth (e.g., as part of a sample return mission). Technologies intended for use at/around Mars, Europa (Jupiter), and Enceladus (Saturn) must be developed so as to ensure compliance with relevant planetary protection requirements. Constraints could include surface cleaning with alcohol or water, and/or sterilization treatments such as dry heat (approved specification in NPR 8020.12; exposure of hours at 115 °C or higher, non-functioning); penetrating radiation (requirements not yet established); or vapor-phase hydrogen peroxide (specification pending). Innovations for 2012 are sought in the areas of:
- Command and Data Handling, and Instrument Electronics.
- Power Generation and Conversion - Propulsion Systems.
- Power Electronics and Management, and Energy Storage.
- Unmanned Aircraft and Sounding Rocket Technologies.

Significant changes to the S3 Topic for 2011 are that the following areas will not be solicited in 2012, but may be solicited again in the 2013:

- Terrestrial and Planetary Balloons.

The following references discuss some of NASA’s science mission and technology needs:

- The 2011 Planetary Science Decadal Survey was released March 2011. This decadal survey is considering technology needs. (http://sites.nationalacademies.org/SSB/currentprojects/SSB_052412).

**Subtopics**

**S3.01 Command, Data Handling, and Electronics**

**Lead Center:** GSFC

**Participating Center(s):** JPL, 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 command and data handling and instrument electronics are sought to support NASA’s goals and several missions and projects under development.

The subtopic goals are to:

- Develop high-performance processors, memory architectures, and reliable electronic systems.
- Develop tools and technologies that would enable rapid deployment of high-reliability, high-performance onboard processing applications and would interface to external sensors on flight hardware.

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.

However, it is also expected that some commercial non-radiation hardened, higher performance capabilities should also be leveraged to meet performance, fault tolerance and recovery, power management, or other unique
Successful proposal concepts should significantly advance the state-of-the-art. Proposals should clearly:

- State what the product is.
- Identify the needs it addresses.
- Identify the improvements over the current state-of-the-art.
- Outline the feasibility of the technical and programmatic approach.
- Present how it could be infused into a NASA program.

Furthermore, proposals should indicate an understanding of the intended operating environment, including temperature and radiation. It should be noted that environmental requirements will vary significantly from mission to mission. For example, some low Earth orbit missions have a total ionizing dose (TID) radiation requirement of less than 10 krad(Si), while some planetary missions can have requirements well in excess of 1 Mrad(Si). For descriptions of radiation effects in electronics, the proposer may visit:

(http://radhome.gsfc.nasa.gov/radhome/overview.htm).

If a Phase II proposal is awarded, the combined Phase I and Phase II developments should produce a prototype that can be characterized by NASA.

The technology priorities sought are listed below:

- Novel, ruggedized packaging/Interconnect for high-density packaging (enclosures, printed wiring boards) enabling miniaturization.
- Miniaturization of C&DH subsystem components that enable reduced power computing.
- Innovative approaches for single event effects mitigation technologies leveraging non-RHBD (Radiation Hardened By Design) devices for performance (speed, power, mass) that is capable of exceeding traditional RHBD devices and/or capabilities that are not yet available with RHBD devices. Area of interest for this year is to focus on processors.

Power Conversion and Distribution relevant to Command, Data Handling, and Electronics, will be covered in sub-topic S3.04 Power Electronics and Management, and Energy Storage.
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

Radioisotope technology enables a wide range of mission opportunities, both near and far from the Sun and hostile planetary environments including high energy radiation, both high and low temperature and diverse atmospheric chemistries. Technology innovations capable of advancing lifetimes, improving efficiency, highly tolerant to hostile environments are desired for all thermal to electric conversion technologies considered here. Specific systems of interest for this solicitation are listed below:

Stirling Power Conversion: advances in, but not limited to, the following:

- System specific mass greater than 10 We/kg.
- Highly reliable autonomous control.

Thermoelectric Power Conversion: advances in, but not limited to, the following:

- High temperature, high efficiency conversion greater than 10%.
- Long life, minimal degradation.

Photovoltaic Energy Conversion

Photovoltaic cell, blanket, and array technologies that lead to significant improvements in overall solar array performance (i.e., conversion efficiency >33%, array mass specific power >300 watts/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 300 volts and have a low stowed volume.

Note to Proposer: Topic H8 under the Human Exploration and Operations Mission Directorate also addresses power. Proposals more aligned with very high power or with exploration mission requirements should be proposed in H8.

S3.03 Propulsion Systems

Lead Center: GRC

Participating Center(s): JPL, MSFC

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://solarsystem.nasa.gov/multimedia/download-detail.cfm?DL_ID=742). 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. Roadmaps for propulsion technologies can be found from the National Research Council (http://www.nap.edu/openbook.php?record_id=13354&page=168) and NASA's Office of the Chief Technologist (http://www.nasa.gov/pdf/501329main_TA02-InSpaceProp-DRAFT-Nov2010-A.pdf).

The focus of this solicitation is for next generation propulsion systems and components, including chemical rocket technologies, low cost/low mass electric propulsion technologies, and micro-propulsion. Propulsion technologies related specifically to sample return vehicles will be sought under S5.04 Spacecraft Technology for Sample Return Missions. Propulsion technologies related specifically to Power Processing Units will be sought under S3.04 Power Electronics and Management, and Energy Storage

Chemical Propulsion Systems
Technology needs include:

- Alternative manufacturing processes for low cost production of components of propulsion systems less than 200 lbf class.
- Catalytic and non-catalytic ignition technologies that provide reliable long-life ignition of high-performance (Isp > 240 sec), toxic and nontoxic monopropellants.

**Electric Propulsion Systems**

This subtopic also seeks proposals that explore uses of technologies that will provide superior performance in for high specific impulse/low mass electric propulsion systems at low cost. These technologies include:

- Long-life thrusters and related system components with efficiencies > 55% and up to 1 kW of input power that operate with a specific impulse between 1600 to 3500 seconds.
- Any electric propulsion technology under 10 kW/thruster that would either significantly reduce system costs or increase system efficiency over a wide throttling range.

**Micro-Propulsion Systems**

This subtopic also seeks proposals that address the propulsion for spacecraft

- Low mass and low volume fractions.
- Wide range of ?V capability to provide 100-1000s of m/s.
- Wide range of specific impulses up to 1000s of seconds.
- Precise thrust vectoring and low vibration for precision maneuvering.
- Efficient use of onboard resources (i.e., high power efficiency and simplified thermal and propellant management).
- Affordability.
- Safety for users and primary payloads.

Proposals should show an understanding of the state of the art, how their technology is superior, and of one or more relevant science needs. The proposals should provide a feasible plan to fully develop a technology and infuse it into a NASA program.

Note to Proposer: Topic H2 under the Human Exploration and Operations Directorate also addresses advanced propulsion. Proposals more aligned with exploration mission requirements should be proposed in H2.
S3.04 Power Electronics and Management, and Energy Storage

Lead Center: GRC
Participating Center(s): ARC, GSFC, JPL, JSC

Future NASA science objectives will include missions such as Earth Orbiting, Venus, Europa, Titan/Enceladus Flagship, Lunar Quest and Space Weather. 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 high energy density, high power density, long life, high reliability, low mass/volume, radiation tolerance, and wide temperature operation. Other subtopics that could potentially benefit from these technology developments include S4.01 – Planetary Entry, Descent and Landing Technology. Battery development could also be beneficial to H8.02 – Ultra High Specific Energy Batteries, which is investigating some similar technologies in the secondary battery area but with very different operational requirements. This subtopic is also directly tied to S3.03 – Propulsion Systems for the development of advanced Power Processing Units and associated components.

Power Electronics and Management

The 2009 Heliophysics roadmap (http://sec.gsfc.nasa.gov/2009_Roadmap.pdf), the 2010 SMD Science Plan (http://science.nasa.gov/about-us/science-strategy/), the 2010 Planetary Decadal Survey White Papers & Roadmap Inputs (http://sites.nationalacademies.org/SSB/CurrentProjects/ssb_052412), the 2011 PSD Relevant Technologies document, the 2006 Solar System Exploration (SSE) Roadmap (http://nasascience.nasa.gov/about-us/science-strategy), and the 2003 SSE Decadal Survey describe the need for lighter weight, lower power electronics along with radiation hardened, extreme environment electronics for planetary exploration. Radioisotope power systems (RPS) and Power Processing Units (PPUs) for Electric Propulsion (EP) are two programs of interest that would directly benefit from advancements in this technology area. Advances in electrical power technologies are required for the electrical components and systems for these future platforms to address program size, mass, efficiency, capacity, durability, and reliability requirements. In addition, the Outer Planet Assessment Group has called out high power density/high efficiency power electronics as needs for the Titan/Enceladus Flagship and planetary exploration missions. These types of missions, including Mars Sample Return using Hall thrusters and PPUs, require advancements in radiation hardened power electronics and systems beyond the state-of-the-art. 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. Novel approaches to minimizing the weight of advanced PPUs are also of interest. Advancements are sought for power electronic devices, components and packaging for programs with power ranges of a few watts for minimum missions to up to 20 kilowatts for large missions. In addition to electrical component development, RPS has a need for intelligent, fault-tolerant Power Management And Distribution (PMAD) technologies to efficiently manage the system power for these deep space missions.

SMD’s In-space Propulsion Technology and Radioisotope Power Systems programs are direct customers of this subtopic, and the solicitation is coordinated with the 2 programs each year.

Overall technologies of interest include:

- High voltage, radiation hardened, high temperature components.
- High power density/high efficiency power electronics.
- High temperature devices and components/power converters (up to 450 °C).
- Intelligent, fault-tolerant electrical components and PMAD systems.
- Advanced electronic packaging for thermal control and electromagnetic shielding.

**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 ° to 500 °C for Venus missions, and a span of -230 °C to +120 °C for Lunar Quest. The Outer Planet Assessment Group and the 2011 PSD Relevant Technologies Document have specifically called out high energy density storage systems as a need for the Titan/Enceladus Flagship and planetary exploration missions. In addition, high energy-density 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 and energy density (>200 Wh/kg for secondary battery systems), along with radiation tolerance are of interest.

In addition to batteries, other advanced energy storage/load leveling technologies designed to the above mission requirements, such as flywheels, supercapacitors or magnetic energy storage, are of interest. These technologies have the potential to minimize the size and mass of future power systems.

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

A method for growing arrays of large-area device-size films of step-free (i.e., atomically flat) SiC surfaces for semiconductor electronic device applications is disclosed. This method utilizes a lateral growth process that better overcomes the effect of extended defects in the seed crystal substrate that limited the obtainable step-free area achievable by prior art processes. The step-free SiC surface is particularly suited for the heteroepitaxial growth of 3C (cubic) SiC, AlN, and GaN films used for the fabrication of both surface-sensitive devices (i.e., surface channel field effect transistors such as HEMT’s and MOSFET’s) as well as high-electric field devices (pn diodes and other solid-state power switching devices) that are sensitive to extended crystal defects.
All 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.

**Unmanned Aircraft Systems**

Unmanned Aircraft Systems (UAS) offer significant potential for Suborbital Scientific Earth Exploration Missions over a very large range of payload complexities, mission durations, altitudes, and extreme environmental conditions. To more fully realize the potential improvement in capabilities for atmospheric sampling and remote sensing, new technologies are needed. Scientific observation and documentation of environmental phenomena on both global and localized scales that will advance climate research and monitoring; e.g., U.S. Global Change Research Program as well as Arctic and Antarctic research activities (Ice Bridge, etc.).

NASA is increasing scientific participation to understand impacts associated with worldwide environmental changes. Capability for suborbital unmanned flight operations in either the North or South Polar Regions are limited because of technology gaps for remote telemetry capabilities and precision flight path control requirements. It is also highly desirable to have UAS ability to perform atmospheric and surface sampling.

**Telemetry, Tracking and Control**

Low cost over-the-horizon global communications and networks are needed. Efficient and cost effective systems that enable unmanned collaborative multi-platform Earth observation missions are desired.

**Avionics and Flight Control**

Precise/repeatable flight path control capabilities are needed to enable repeat path observations for Earth monitoring on seasonal and multi-year cycles. In addition, long endurance atmospheric sampling in extreme conditions (hurricanes, volcanic plumes) can provide needed observations that are otherwise not possible at this time:

- Precision flight path control solutions in smooth atmospheric conditions.
- Attitude and navigation control in highly turbulent atmospheric conditions.
- Low cost, high precision inertial navigation systems (}

**UA Integrated Vehicle Health Management**
• Fuel Heat/Anti-freezing.
• Unmanned platform icing detection and minimization.

Guided Dropsondes

NASA Earth Science Research activities can benefit from more capable dropsondes than are currently available. Specifically, dropsondes that can effectively be guided through atmospheric regions of interest such as volcanic plumes could enable unprecedented observations of important phenomena. Capabilities of interest include:

• Compatibility with existing dropsonde dispensing systems on NASA/NOAA P-3's, the NASA Global Hawk, and other unmanned aircraft.
• Guidance schemes, autonomous or active control.
• Cross-range performance and flight path accuracy.
• Operational considerations including airspace utilization and de-confliction.

Novel Platforms and Systems

Innovative fixed wing, rotary wing, or lighter than air platforms and associated systems offering unique capabilities for Earth science research and environmental monitoring are desired. Commercially viable concepts that may have alternative short-term utility for other civil research agencies are in-scope. Systems that are tailored to support new miniaturized instruments for Earth science research, for example those developed under subtopic S1.08 (Airborne Measurement Systems), are encouraged.

Sounding Rockets

The NASA Sounding Rocket Program (NSRP) provides low-cost, sub-orbital access to space in support of space and Earth sciences research and technology development sponsored by NASA and other users by providing payload development, launch vehicles, and mission support services. NASA utilizes a variety of vehicle systems comprised of military surplus and commercially available rocket motors, capable of lofting scientific payloads, up to 1300lbs, to altitudes from 100km to 1500km.

NASA launches sounding rocket vehicles worldwide, from both land-based and water-based ranges, based on the science needs to study phenomenon in specific locations.

NASA is seeking innovations to enhance capabilities and operations in the following areas:
• Autonomous vehicle environmental diagnostics system capable of monitoring flight loading (thermal, acceleration, stress/strain) for solid rocket vehicle systems.
• Location determination systems to provide over-the-horizon position of buoyant payloads to facilitate expedient location and retrieval from the ocean.
• Flotation systems, ranging from tethered flotation devices to self-encapsulation systems, for augmenting buoyancy of sealed payload systems launched from water-based launch ranges.