Spacecraft propulsion technology innovations are sought for upcoming deep space science missions. Propulsion system functions for these missions include primary propulsion, maneuvering, planetary injection, and planetary descent and ascent. Innovations are needed to reduce spacecraft propulsion system mass, volume, and/or cost. Applicable propulsion technologies include solar electric, chemical and thermal, solar sails, aeroassist and aerocapture and emerging technologies.

**Solar Electric Propulsion**

Innovations in electric propulsion system technologies are being sought for space science applications. One area of emphasis pertains to high-performance propulsion systems capable of delivering specific impulse (Isp) greater than 2000 s, using electrical power from radioisotope or solar energy sources. Thruster technologies include, but are not limited to, ion engines, Hall thrusters, and pulsed electromagnetic devices. Other areas of interest include propellant storage, direct drive and other innovative power processing, power management and distribution, heat-to-electrical power conversion, and waste heat disposal. Innovations considered here may focus on the component, subsystem or system level, and must ultimately result in significant improvements in spacecraft capability, longevity, mass, volume, and/or cost.

**Solar Sails**

Solar sails are envisioned as a low-cost, efficient transport system for future near-Earth and deep space missions. NASA mission's enabled and enhanced by solar sail propulsion include Tech Pull Missions such as Geotail, Comet Sample and Titan Flyby all to be launched between 2009 and 2012. Another category of NASA missions is the Particle Acceleration Solar Orbiter, including the L1-Diamond and the Solar Polar Imager, both to be launched between 2015 and 2028. Solar Sails are enabling for several strategic missions in the Sun-Earth Connection Space Science theme, including Solar Polar Imager and Interstellar Probe, the latter being a sail mission to explore interstellar space. Missions in the Exploration of the Solar System theme would be broadly enhanced by the availability of proven sail technology. Innovations are sought that will lower the cost and risk associated with sail development and application, and enhance sail delivery performance. Innovations are sought in the following areas: systems engineering, materials, structures, mechanical systems, fabrication, packaging and deployment, system control (attitude, etc.), maneuvering and navigation, operations, durability and survivability, and sail impact on science. Development of ultra-lightweight inflatable and deployable support structures is of significant interest,
including rigidization approaches. Innovations in ultra-light reflective thin films are also sought. Three parameters have been used as sail performance metrics in mission applications: sail size, sail survivability for close solar approaches, and areal density (ratio of mass of the sail to area of the sail). In addition, important programmatic metrics are cost, benefit, and risk. Technologies of interest should be geared toward a wide range of sail sizes, solar closest approach distances, and aerial densities, and may be optimized for one portion of the range rather than trying to cover the whole range. Sail sizes may range from very small (meter-sized for use with very tiny picosat payloads or for use as auxiliary propulsion), to medium (50–100 m size for achieving high-inclination solar orbits or non-Keplerian near-Earth orbits) and ultimately to the very large (hundreds of meters for levitated orbits, high delta V, and for use in leaving the Solar System at high speed). Sail weight should include, but not be limited to, ultra-lightweight sail materials (Chemical and Thermal Propulsion

Innovations in low-thrust chemical propulsion system technologies are being sought for Space Science missions applications. One area of interest is a bipropellant engine with Isp greater than 360 s. Component, subsystem, or system level technology development will be considered but work must ultimately result in significant reductions in spacecraft system mass, volume, and/or cost. Other areas to be considered include lightweight, compact and low-power propellant management components, such as valves, flow control/regulation, fluid isolation, dependable ignition systems, and lightweight tankage.

Aeroassist

Aeroassist is a general term given to various techniques to maneuver a space vehicle within an atmosphere, using aerodynamic forces in lieu of propulsion fuel. Aeroassist systems enable shorter interplanetary cruise times, increased payload mass, and reduced mission costs. Subsets of aeroassist are aerocapture and aerogravity assist. Aerocapture relies on the exchange of momentum with an atmosphere to achieve a decelerating thrust leading to orbit capture. This technique permits spacecraft to be launched from Earth at higher velocities, thus providing a shorter overall trip time. At the destination, the velocity is reduced by aerodynamic drag within the atmosphere. Without aerocapture, a substantial propulsion system would be needed on the spacecraft to perform the same reduction of velocity. Aerogravity assist is an extension of the established technique of gravity assist with a planetary body to achieve increases in interplanetary velocities. Aerogravity assist involves using propulsion in conjunction with aerodynamics through a planetary atmosphere to achieve a greater turning angle during planetary fly-by. In particular, this subtopic seeks technology innovations that are in the following areas:

Aerocapture

Thermal Protection Systems: Development of advanced thermal protection systems and insulators. Materials need high strength (modulus in the tens of GPa) and very low density (tens of kg/m³). Improvements needed in materials include having highly anisotropic thermal properties, i.e., high thermal diffusivity tangential to the spacecraft shape and low thermal diffusivity normal to the spacecraft shape.

Sensors for Inflatable Decelerators: Health monitoring method for inflatable thin film systems.

Analytical Tools: Development of advanced tools to perform coupled aeroelastic and aerothermal analysis of inflatable decelerator systems.

Aerogravity Assist

Aerogravity Assist Technology Analysis: Research advancements in leading edge materials and provide CFD analysis of heating environment for aerogravity assist maneuvers at a small planet (e.g., Venus).
Emerging Propulsion Technologies

This effort will focus on technologies supporting innovative and advanced concepts for propellantless propulsion and other revolutionary transportation technologies. The categories under Emerging Propulsion Technologies include, but are not limited to: electrodynamic and momentum-exchange tether propulsion, beamed energy, ultra-light solar sails, bimodal sails, and low to medium power electric propulsion (including pulse inductive devices). The electrodynamic tether propulsion uses electromagnetic interaction with a planetary magnetic field to exchange angular momentum. Momentum exchange tethers (such as the MXER tether concept use a strong tether to transfer angular momentum and orbital energy to a payload. Beamed energy propulsion concepts include lasers or microwave energy to directly propel a spacecraft or to supply power that is utilized for propulsion onboard the spacecraft. Ultra-light or bimodal sail propulsion developing conventional solar sails into extremely high-performing systems. The low to medium electric propulsion is a general category for fresh variations of electric thrusters (Hall, MHD, PIT, etc.) that support near or mid-term solar powered spacecraft (e.g., below ~50 kW). Unique, innovative and novel propulsion ideas are sought but with reasonable expectations to progress to hardware prototypes. The concept must be above TRL 2 with rapid demonstration to TRL 4 expected. Distinctive variations of existing propulsion methods or chief subsystem component improvements are also suitable for submission. Proposals should provide development of specific innovative technologies or techniques supporting any of the above approaches. A clear plan for demonstrating feasibility, noting any test and experiment requirements, is also recommended. Key to each idea is an unambiguous knowledge of past research and concepts conducted on related work, and specifically, how this new proposal differs to the extent that it appears to offer a significant benefit. Identification of the fundamental technology to be developed is also crucial.