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 advanced chemical, solar sails, aerocapture, and emerging technologies.

Advanced Chemical Propulsion

Innovations in low-thrust chemical propulsion system technologies are being sought for deep-space, scientific, robotic mission applications. Delta Vs for the missions of interest range from 1000 m/sec to 3000 m/sec. Technologies of interest are bipropellant engines with Isp greater than 360 seconds, both pressure-fed and pump-fed, with chamber pressures ranging from 100 to 500 psia. Throttling capability is desired for engines used for planetary ascent, descent, and orbit insertion maneuvers. Passive long-term storage (greater than 5 years) for advanced bipropellant propulsion systems for deep space missions are of interest. Reliable ignition systems are needed for non-hypergolic propellants. Activities in development of lightweight, compact, and low-power propellant management components, such as valves, flow control/regulation, fluid isolation, and lightweight tankage are also solicited. Advanced materials to allow development of systems for use with advanced bipropellants (higher Isp, higher pressure) are also solicited.

Solar Sail Propulsion

Solar sails have been studied for a variety of missions and have the potential to provide cost-effective, propellantless propulsion that enables longer on-station operation, increased scientific payload mass fraction, and access to previously inaccessible orbits (e.g., non-Keplerian, high solar latitudes, etc.).

NASA missions enabled and enhanced by solar sail propulsion include those that can provide: 1) situational awareness for human and robotic exploration in the Earth-Moon system (e.g., Heliostorm, L1 Diamond); 2) comprehensive monitoring of the inner heliosphere (e.g., Solar Sentinels, Solar Polar Imager, Particle Acceleration Solar Observatory); and 3) pathfinder exploration beyond the solar system (Interstellar Probe). The technology required for these missions can further be classified into two categories: 1) near-term (2; and 2) far-term (>15
years) for use in orbits at 25 AU with a propulsive area of greater than 1 x 10^5 m^2. A solar sail propulsion system includes the sail membrane and support structure, the thrust vector control subsystem, the health and monitoring diagnostic subsystem, and the launch stowage structure. Three parameters that are used as sail performance metrics in mission applications are: sail size, sail durability in its orbital environment, and areal density (ratio of sail system mass to propulsive area of the sail). In addition, important programmatic metrics are cost, benefit, and risk. Innovations are sought that will lower the cost and risk associated with sail system development through advancements in: manufacturing, fabrication, and assembly; durable lightweight materials, structures, and mechanisms; comprehensive simulations of maneuvering, navigation, trajectory control, propulsive performance, and operations; and integrated diagnostic health monitoring.

**Tether Technologies**

This effort focuses on technologies supporting innovative and advanced concepts for propellantless propulsion based upon space tethers concepts. The categories under Tether Technologies include, but are not limited to: ElectroDynamic (ED) tether propulsion, Momentum eXchange Electrodynamic Reboost (MXER) tethers or its subsystems, Jovian tether mission concepts, Earth orbiting telescope ED tether reboost, and other innovative space tether technologies. In general, the electrodynamic tether propulsion method exchanges momentum with a planet's rotational angular momentum through electrodynamic interaction with the planetary magnetic field. Momentum exchange tethers or MXER concepts use orbital energy to provide a high thrust to a payload in LEO. Distinctive variations of existing propulsion methods or chief subsystem component improvements are also suitable for submission. Proposals should provide the development plan of specific innovative technologies or techniques supporting the planned research. Identification of the fundamental technology to be developed is also crucial. A clear plan for demonstrating feasibility, noting any test and experiment requirements, is recommended. Key to each idea is an unambiguous knowledge of past research/concepts conducted on related work and specifically how this new proposal differs from, or enhances, the existing tether roadmaps, particularly for robotic mission support.

**Aeroassist**

Aeroassist is a general term given to various techniques to maneuver a space vehicle within an atmosphere using aerodynamic forces in lieu of propulsive 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 for planetary aerocapture.

Low Temperature/High Temperature Adhesives Trade Study: aerocapture inflatable decelerators are currently proposed to be manufactured from thin film materials and/or high temperature fabrics, stowed during transport, and inflated prior to atmospheric entry for aerocapture applications at planetary destinations.
Prior to the aerocapture maneuver, the inflatable decelerator will be stowed for many years (up to 10) in an uncontrolled space environment (-130°C) during transport to outer solar system destinations;

Before atmospheric entry, the inflatable decelerator will be unstowed and inflated; and

During the aerocapture maneuver, up to 24 hours after the inflation process, the inflatable decelerator will experience temperatures to 500°C (or higher).

Conduct a thorough study of the adhesives trade space and select and test adhesive candidates that will maintain bond strength during the temperature extremes and long-term space exposure experienced by inflatable decelerators. The product of this study will be a report thoroughly documenting sample preparation, test procedures, and test results of all materials investigated. This report will be disseminated to inflatable decelerator developers.