The goal of this subtopic is to develop innovative human-rated aeroassist systems for missions including lunar return to Earth and precursor missions for human Mars exploration. Systems are needed to support the following flight regimes: aerocapture, entry interface to subsonic speeds, and Mach 5 to subsonic speeds. Systems must be capable of controlled flight and be compatible with pinpoint, soft landing systems, which achieve landing accuracies of 10s of meters at touchdown or powered descent initiation. These systems must be compatible with launch vehicles and transit vehicles and capable of safely discarding unneeded and constraining hardware on landing and providing surface access. Technology needs include aeroassist system design, Thermal Protection System (TPS) designs, modeling capabilities, sensor systems, and navigation technologies that support reliable aerocapture or aerobraking of multi-metric-ton-class piloted or cargo spacecraft. In particular, this subtopic seeks innovations in the following areas:

- Innovative aeroassist system designs. This includes low-mass, rigid aeroassist systems based on robust, high-temperature structures and adhesives, modular or deployable/inflatable aeroshells with large surface area, and inflatable ballutes;

- TPS designs for human-rated aeroassist vehicles returning to Earth from the Moon and Mars, and for Mars aerocapture and Entry, Descent and Landing (EDL). Innovative TPS concepts are solicited to reduce current TPS mass fractions by 25% to 50% and to reduce TPS costs;

- Ablative and reusable TPS materials and concepts that significantly enhance performance and reduce mass. This includes development and characterization of single- and multi-use TPS materials, TPS for rigid aeroshells, and flexible TPS materials for deployable aeroshells. Thermo-chemical and mechanical properties data for probabilistic design, spallation characteristics, and accurate simulation tools to predict material behaviors and material compatibility are required. Innovative TPS concepts are solicited to reduce current TPS mass fractions by 25% to 50% and to reduce TPS costs;

- Aerothermodynamic modeling tools with greater accuracy and less uncertainty: (1) Innovative and accurate computer modeling of fluid structure interactions, including flow stability and surface deflections under dynamic conditions for decelerator deployment and inflation; (2) Modeling and simulation of convection/radiation/ablation coupled three-dimensional flow fields, for both optically thick and thin shock layers and highly ionized flows; (3) Accurate prediction of wake heating including radiative heating components; (4) Accurate prediction of single and multiple rocket plume effects (e.g., reaction control system thrusters) on the vehicle aerodynamics and heating;
Innovative sensor systems which are capable of providing real-time or near real-time updates to atmospheric pressure, temperature, density, and winds to support the guidance systems used on aeroassist vehicles;

Innovative sensor systems for inflatable aeroassist vehicles capable of providing real-time aerosurface temperature, strain, deflection, flight loads, and other significant parameters; and

Lightweight flexible materials that will reduce the mass and increase the strength and thermal characteristics for applications to deployable aeroshells and supersonic deployed decelerators.

Focus should be on aeroassist systems applied to the following mission classes:

- **Earth return of piloted spacecraft from the Moon.** Return-to-Earth scenarios for human lunar missions include: (1) short-range direct entry and landing; (2) extended-range entry using a skip out of the atmosphere with subsequent EDL to the Earth's surface; and (3) aerocapture into a low-energy Earth orbit followed by EDL. Inertial arrival speeds of approximately 11 km/s (up to 12 km/s for some abort scenarios) with entry masses of at least 5 metric tons are expected for normal lunar return. Acceptable sustained loads for these piloted missions are limited to about 5 gs perpendicular to the human spine in the "eye balls in" direction; and

- **Mars precursor missions for human exploration.** These include robotic missions designed to deliver pre-deployed cargo or to conduct technology demonstrations in anticipation of follow-on human Mars missions. Candidate human mission scenarios for Mars include human and cargo aerocapture into a Mars orbit followed by EDL to the Mars surface and return to Earth. Mars aerocapture missions are expected to have arrival speeds of 6 to 8 km/s and aerocapture mass on the order of many 10s of metric tons. Return-to-Earth scenarios for human Mars missions are similar to those for lunar missions, except for higher arrival speeds (11.5 - 12.5 km/s, up to 14 km/s for some off-nominal scenarios).

Note: Related technologies of interest but covered under other SBIR subtopics include:

- Inflatable and other innovative structures (X2.02 Structures and Habitats); and

- Aeroassist systems for deep space robotic science missions (S5.01 Low Thrust and Propellantless Propulsion Technologies).