NASA is aggressively pursuing the search for resources on the Moon necessary to sustain prolonged human habitation and the search for water and life on Mars using robotic explorers. NASA is investing in key capabilities to enable advanced robotic missions to the Moon and Mars. This suite of technologies will enable NASA to rapidly respond to discoveries this decade and pursue the search for water and life at Mars wherever it may lead. The technologies developed and tested in each mission will help enable even greater achievements in the missions that follow. See URL: [http://marstech.jpl.nasa.gov/](http://marstech.jpl.nasa.gov/) for additional information on Mars Exploration technologies. Key goals are to (1) conduct robotic expeditions to further science and to test new exploration approaches, technologies, and systems that will enable future human exploration of the Moon and Mars; and (2) conduct sustained, long-term robotic exploration of Mars to understand its history and evolution, to search for evidence of life, and to expand the frontiers of human experience and knowledge.

**Subtopics**

**S1.01 Surface Robotic Exploration**

**Lead Center:** JPL  
**Participating Center(s):** ARC

Sample acquisition and handling will be important elements of future landed missions. Sample manipulation technologies are needed to enable handling and transfer of unstructured samples from a sampling device to instruments and sample processing systems. Shallow core, rock, and regolith samples may be variable in size and composition so a sample manipulation system needs to be flexible enough to handle the sample variability. Core samples will be on the order of 1 cm diameter and up to 10 cm long. Soil and rock samples will be of similar volumes. Actual samples to be analyzed in instruments will likely be small subsamples so the means for subsampling and manipulation of the original sample and subsamples needs to be developed. Minimal size and mass components and systems have the greatest benefit.

Mobility technology is needed to enable access to difficult-to-reach sites such as distant locations or access through steep terrain. Many scientifically valuable sites are accessible only via terrain that is too steep for state-of-the-art planetary rovers to traverse. Sites include crater walls, canyons, and gullies. Tethered systems and marsupial systems are two examples of mobility technologies that are of interest. Tether technology could enable new approaches for deployment, retrieval and mobility. Innovative marsupial systems could allow a pair of vehicles with different mobility characteristics to collaborate to enable access to challenging terrain, e.g., a primary vehicle
could provide long traverse to the vicinity of a challenging site and then deploy a smaller vehicle with steep mobility access capability for access to the site. Innovative low-mass, low-power, and highly modular systems and subsystems are of particular interest.

The program is also interested in new sensors such as small, low-power lidar for more robust navigation.

Examples of planetary robotics system are shown at [http://robotics.jpl.nasa.gov](http://robotics.jpl.nasa.gov).

### S1.02 Subsurface Robotic Exploration

**Lead Center:** JPL  
**Participating Center(s):** ARC

Robust systems for accessing the subsurface of the Moon and Mars are critical to the next generation of robotic explorers. Limited spacecraft resources (power, volume, mass, computational capabilities, and telemetry bandwidth) demand innovative, integrated sampling systems that can survive and operate in challenging environments (extremes in temperature, pressure, gravity, vibration and thermal cycling).

Research should be conducted to develop compact, low-power, lightweight subsurface sampling systems with access to depths of 1 - 3 m below the surface. A relevant mission scenario for this type of drill would include drilling multiple holes from a mobile platform, such as a rover. For reference, current Mars-relevant rovers range in mass from 200 - 800 kg.

Consideration should be given to potential failure scenarios for integrated systems. For example, recovery and mitigation techniques for platform slip and borehole misalignment should be addressed. Significant attention should be given to the sensing and automation required for real-time control, fault diagnosis and recovery. Additional areas of interest include understanding the limitations of dry drilling into mixed media, including icy mixtures of rock and regolith.

Also of particular need are means of acquiring subsurface rock and regolith samples with minimum contamination. This contamination may include contaminants brought to the sample by the drill itself, material from one stratigraphic layer contaminating samples collected at another depth (sample cross-contamination), or Earth-source microbes brought to the Martian surface prior to drilling ('clean' sampling from a 'dirty' surface).
S1.03 Martian Entry, Descent and Landing Sensors

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

NASA seeks innovative sensor technologies to enhance success for entry, descent and landing (EDL) operations on missions to Mars. This call is not for sensor processing algorithms. Sensing technologies are desired which determine the entry point of the spacecraft in the Mars atmosphere; provide inputs to systems that control spacecraft trajectory, speed, and orientation to the surface; locate the spacecraft relative to the Martian surface; evaluate potential hazards at the landing site; and determine when the spacecraft has touched down. Appropriate sensing technologies for this topic should provide measurements of physical forces or properties that support some aspect of EDL operations. NASA also seeks to use measurements made during EDL to better characterize the Martian atmosphere, providing data for improving atmospheric modeling for future landers. Proposals are invited for innovative sensor technologies that improve the reliability of EDL operations.

Products or technologies are sought that can be made compatible with the environmental conditions of spaceflight and the rigors of landing on the Martian surface. Successful candidate sensor technologies can address this call by:

- Providing critical measurements during the entry phase (e.g., pressure and/or temperature sensors embedded into the aeroshell);
- Improving the accuracy on measurements needed for guidance decisions (e.g. surface relative velocities, altitudes, orientation, localization);
- Extending the range over which such measurements are collected (e.g. providing a method of imaging through the aeroshell, or terrain-relative navigation that does not require imaging through the aeroshell);
- Enhancing the situational awareness during landing by identifying hazards (rocks, craters, slopes), or providing indications of approach velocities and touchdown;
- Substantially reducing the amount of external processing needed to calculate the measurements; and
- Significantly reducing the impact of incorporating such sensors on the spacecraft in terms of volume, mass, placement, or cost.