Technology enables us to answer our scientific questions. Without the continual development of new technologies, our thirst for knowledge will go unfulfilled. Our goal is to invent new technologies, rigorously test them here on Earth or in space and apply them to Mars Exploration. The technologies developed and tested in each mission will help enable even greater achievements in the missions that follow. See URL: [http://mars.jpl.nasa.gov/technology/](http://mars.jpl.nasa.gov/technology/) for additional information.

Subtopics

**S5.01 Detection and Reduction of Biological Contamination on Flight Hardware and in Return Sample Handling**

*Lead Center: JPL*

*Participating Center(s): ARC*

As solar system exploration continues, NASA remains committed to the implementation of its planetary protection policy and regulations. Missions designed to return the first extraterrestrial samples since the Apollo moon landings are currently in space—the Stardust and Genesis spacecraft will return cometary and solar wind particles to Earth within this decade. A mission to return samples from Mars is being planned for the next decade. Other missions will seek evidence of life through *in situ* investigations far from Earth. One of the great challenges, therefore, is to develop or find the technologies or system approaches that will make compliance with planetary protection policy routine and affordable. Planetary protection is directed to 1) the control of terrestrial microbial contamination associated with robotic space vehicles intended to land, orbit, flyby, or otherwise be *in* the vicinity of extraterrestrial solar system bodies; and 2) the control of contamination of the Earth by extraterrestrial solar system material collected and returned by such missions. The implementation of these requirements will ensure that biological safeguards to maintain extraterrestrial bodies as biological preserves for scientific investigations are being followed *in* NASA's space program. To fulfill its commitment, NASA seeks technologies and system approaches that will support compliance with planetary protection requirements.

Examples of such technologies include:
• Techniques for cleaning of organics to the nanogram per square centimeter level on complex surfaces (nondestructively and without residues) and validation of cleanliness at this level or better

• Nonabrasive cleaning techniques for narrow aperture occluded areas on spacecraft

• Techniques for in situ (i.e., at the exploration site) cleaning and sterilization to prevent cross-contamination between planetary surface samples

• A device or methodology for controlled measurement of microbial reduction at temperatures from 200–300°C to enable generation of microbial lethality curves.

Examples of systems approaches include:

• Containerization and encapsulation of samples to be returned to Earth, including innovative mechanisms for isolation, sealing, and leak detection

• System design concepts to enable facile and rapid use of cleaning and sterilization technologies during flight hardware assembly

• System design concepts to maintain the integrity of cleaned and sterilized complex flight systems and/or subsystems

• System concepts that would facilitate spacecraft sterilization at the system level just before launch or in flight

Research should be conducted to demonstrate technical feasibility during Phase I and show a path toward a Phase II hardware and software demonstration, and that will, when possible, deliver a demonstration unit or software package for JPL testing before the completion of the Phase II contract.

S5.02 Mars In Situ Robotics Technology

Lead Center: JPL
Participating Center(s): LaRC

During future exploration of planets, moons, and small solar system bodies (such as comets and asteroids), developments are needed in new innovative robotic technologies for surface operations, subsurface access, and autonomous software for each. Because of limited spacecraft resources, elements must be robust and have low power, volume, mass, computation, telemetry bandwidth, and operational overhead requirements. Successful technologies will have to operate in environments characterized by extremes of temperatures, pressures, gravity, high-gravity landing impacts, vibration, and thermal cycling. In particular, this subtopic seeks technology innovations in the following areas:

Subsurface Access: Research should be conducted to develop complete, lightweight, dry drilling systems with a penetration depth of 10–50 m and have the capability of penetrating both regolith and rocks. The development should focus on significant reduction in mass from the currently available state-of-the-art interplanetary drilling
systems as well as the automation required for real-time control and fault diagnosis and recovery. In addition, because of the lack of water in most of the environments of interest, the drilling should be performed without a lubricant between the bit and rock. Of interest also is the development of ice penetrators, designed with explicit consideration of limited computation and power, which use heat to melt their way through the surface.

Rover Technology: Long-range autonomous navigation systems that focus on long distance (greater than 5 km) traverses through natural terrain, using no \textit{a priori} knowledge of the subject terrain. Inflatable rover technology with a focus on the development of low-mass, highly capable platforms for exploration of extreme terrain through innovations in novel mechanisms and the automation required for real-time control. Systems enabling navigation in very rough terrain with explicit consideration of limited sensing, computation, and power. Development of new sensor prototypes, with a clear path to flight-ready status within a short time span and at minimum cost. Concepts for new mobility systems or components, such as innovative wheel or suspension designs. Instrument placement with a focus on improved tools for the design of manipulation systems, to perform contact and noncontact operations such as drilling, grasping, sample acquisition, sample transfer, and contact and noncontact science instrument placement and pointing. Infrastructure for research, including low-cost, mass producible, research-quality rovers and supporting elements.

Research should be conducted to demonstrate technical feasibility during Phase I and show a path toward a Phase II hardware and software demonstration that will, when possible, deliver a demonstration unit or software package for JPL testing at the completion of the Phase II contract.

\textbf{S5.03 Mars and Deep Space Telecommunications}

\textbf{Lead Center: JPL}

This subtopic seeks innovative technologies for both RF and Free-Space Optical Communications supporting missions to Mars, including both planetary and proximity ranges, and for other planetary missions and local planetary networks.

\textbf{RF Communications}

- Ultra-small, low-cost, low-power, innovative deep-space transponders and components, incorporating MMICs and Bi-CMOS circuits.
- MMIC modulators with drivers to provide large linear phase modulation (above 2.5 rad), high-data rate BPSK/QPSK modulation at X-band (8.4 GHz) and Ka-band.
- Sub-microradian antenna pointing techniques for Ka-band spacecraft antennas.
- High rate (10–200 Mbps) turbo-encoder and decoder and wavelet compression chips.
- Technologies for surface-to-surface communications in planetary environments.

- Fault-tolerant digital signal processing: Current space qualified DSP elements do not support high bandwidths because of the power consumption associated with radiation hardened manufacturing processes. Reconfigurable signal processing elements are sought that provide autonomous fault detection and correction with a graceful degradation in performance over the service life.

- Antenna systems: Novel materials and approaches are sought to construct large, inflatable reflective and RF focusing surfaces for use as large aperture antennas. Need to provide highly directional surface to orbit antenna patterns to maintain high rate data links.

**Optical Communications**

- Efficient (greater than 20% wall plug), lightweight, flight-qualifiable, variable repetition-rate (1–60 MHz), pulsed lasers with greater than 1 kW of peak power per pulse (over the entire pulse-repetition rate), and potential for up to 10 W of average power.

- Photon counting 1064 nm and 1550 nm detectors with the gain greater than 1000, detection efficiency greater than 50%, very low additive noise, about 0.5 mm in diameter, bandwidth greater than 500 MHz, saturation levels > 50Mcounts/s.

- Lightweight, compact, high precision (less than 0.1 micro-radian), high bandwidth (0–2kHz), inertial reference sensors (angle sensors, gyros) for use onboard spacecraft.

- Novel schemes for stray-light control and sunlight mitigation, especially for large (> 5 m) ground-based optical antennae that must operate when pointed to within a few (about 3) degrees of the Sun.

- Low-cost, lightweight, efficient, compact, high precision (one micro-radian accuracy) star-trackers for spaceflight application.

Research should be conducted to demonstrate technical feasibility during Phase I and show a path toward a Phase II hardware and software demonstration, and that will, when possible, deliver a demonstration unit or software package for JPL testing before completion of the Phase II contract.