NASA SBIR 2005 Phase I Solicitation

S2.05 Astrobiology

Lead Center: ARC

Participating Center(s): JPL

Astrobiology includes the study of the origin, evolution, and distribution of life in the universe. New technologies are required to enable the search for extant or extinct life elsewhere in the solar system, to obtain an organic history of planetary bodies, to discover and explore water sources elsewhere in the solar system, and to detect microorganisms and biologically important molecular structures within complex chemical mixtures. Biomarkers produced by microbial communities are profoundly affected by internal biogeochemical cycling. The small spatial scales at which these biogeochemical processes operate necessitate measurements made using microsensors. The search for life on other planetary bodies will also require systems capable of moving and deploying instruments across, and through, varied terrain to access biologically important environments.

A second element of Astrobiology is the understanding of the evolutionary development of biological processes leading from single-cell organisms to multi-cell specimens and to complex ecological systems over multiple generations. Understanding of the effects of radiation and gravity on lower organisms, plants, humans, and other animals (as well as elucidation of the basic mechanisms by which these effects occur) will be of direct benefit to the quality of life on Earth. These benefits will occur through applications in medicine, agriculture, industrial biotechnology, environmental management, and other activities dependent on understanding biological processes over multiple generations.

A third component of Astrobiology includes the study of evolution on ecological processes. Astrobiology intersects with NASA Earth Science studies through the highly accelerated rate of change in the biosphere being brought about by human actions. One particular area of study with direct links to Earth Science is microbe-environment interactions.

NASA seeks innovations in the following technology areas:

- For Mars exploration, technologies that would enable to provide a broad survey of areas in the vicinities of a rover or lander to narrow a field of search for biomarkers;
• For Mars exploration, technologies that (using X-ray, neutron, ultrasonic, and other types of tomography) would enable a noninvasive, nondestructive analysis of the subsurface environment and areas inside rocks and ice to depths 10-20 cm with spatial resolutions of 2-10 microns. Such technologies should provide the capability for analysis of structures inside opaque matrices created by endolithic organisms or fossil structures and possible elemental analysis of such structures;

• Technologies that would enable the aseptic acquisition of deep subsurface samples, the detection of aquifers, or enhance the performance of long-distance ground roving, tunneling, or flight vehicles are required;

• For Europa exploration, technologies to enable the penetration of deep ice are required;

• Desirable features for both Mars and Europa exploration include the ability to carry an array of instruments and imaging systems, to provide aseptic operation mode, and to maintain a pristine research environment;

• Low-cost, lightweight systems to assist in the selection and acquisition of the most scientifically interesting samples are also of significant interest;

• High sensitivity, (femtomole or better) high-resolution methods applicable to all biologically relevant classes of compounds for separation of complex mixtures into individual components;

• Advanced miniaturized sample acquisition and handling systems optimized for extreme environment applications;

• High sensitivity (femtomole or better) characterization of molecular structure, chirality, and isotopic composition of biogenic elements (H, C, N, O, S) embodied within individual compounds and structures;

• High spatial resolution (5 angstrom level) electron microscopy techniques to establish details of external morphology, internal structure, elemental composition, and mineralogical composition of potential biogenic structures;

• Innovative software to support studies of the origin and evolution of life. The areas of special interest are (1) biomolecular and cellular simulations, (2) evolutionary and phylogenetic algorithms and interfaces, (3) DNA computation, and (4) image reconstruction and enhancement for remote sensing;

• Technologies capable of measuring a range of volatile compounds at small spatial scales. Improved sensor designs for a wide range of analytes, including oxygen, pH, sulfide, carbon dioxide, hydrogen, and small molecular weight organic acids both on and near surfaces that could serve as habitats for microbes;

• Biotechnology - determining mutation rates and genetic stability in a variety of organisms as well as accurately determining protein regulation changes in microgravity and radiation environments;

• Automated chemical analytical instrumentation for determining gross metabolic characteristics of individual organisms and ecologies as well as chemical composition of environments;

• Spectral and imaging technology with high resolution and low power requirements;

• Habitat support - technologies for supporting miniature closed ecosystems, data collection, and transmission technologies in concert with the automated chemical instrumentation described above;

• Miniature-to-microscopic, high-resolution, field-worthy, smart sensors, or instrumentation for the accurate and unattended monitoring of environmental parameters that include, but are not limited to, solar radiation (190-800 nm at high-resolution, high-sensitivity (femtomole or better) methods for the isolation and characterization of nucleic acids (DNA and RNA) from a variety of organic and inorganic matrices;

• Mathematical models capable of predicting the combined effects of elevated pCO₂ (change in CO₂ over the eons) and solar UV radiation on carbon sequestration and N₂O emissions from experimental data obtained from field and laboratory studies of C-cycling rates, N-cycling rates, as well as diurnal and seasonal...
changes in solar UV;

- Microscopic techniques and technologies to study soil cores, microbial communities, pollen samples, etc., in a laboratory environment for the detailed spectroscopic analysis relevant to evolution as a function of climate changes; and

- Robotic systems designed to provide access to environments such as deep-ocean hydrothermal vents.