



NASA SBIR 2009 Phase I Solicitation

S5 Robotic Exploration Technologies

NASA is pursuing technologies to enable robotic exploration of the Solar System including its planets, their moons, and small bodies. NASA has a development program that includes technologies for the atmospheric entry, descent, and landing, mobility systems, extreme environments technology, sample acquisition and preparation for in situ experiments, and in situ planetary science instruments. Robotic exploration missions that are planned include a Europa Jupiter System mission, Titan Saturn System mission, Venus In Situ Explorer, sample return from Comet or Asteroid and lunar south polar basin and continued Mars exploration missions launching every 26 months including a network lander mission, an Astrobiology Field Laboratory, a Mars Sample Return mission and other rover missions. Numerous new technologies will be required to enable such ambitious missions. The solicitation for in situ planetary instruments can be found in the in situ instruments section of this solicitation. See URL: <http://solarsystem.nasa.gov/missions/index.cfm> for mission information. See URL: <http://marstech.jpl.nasa.gov/> for additional information on Mars Exploration technologies.

Subtopics

S5.01 Planetary Entry, Descent and Landing Technology

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.

For a sample return mission, monitoring local environmental (weather) conditions on the surface just prior to planetary ascent vehicle launch, via appropriate low-mass sensors.

Proposals should show an understanding of one or more relevant science needs, and present a feasible plan to fully develop a technology and infuse it into a NASA program.

S5.02 Sample Collection, Processing, and Handling

Lead Center: JPL

Participating Center(s): ARC, GSFC, JSC

Robust systems for sample acquisition, handling and processing are critical to the next generation of robotic explorers for investigation of planetary bodies (http://books.nap.edu/openbook.php?record_id=10432&page=R1). 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). Special interest lies in sampling systems and components (actuators, gearboxes, etc.) that are suitable for use in the extremely hot high pressure environment at the Venusian surface (460°C, 93 bar). Relevant systems could be integrated on multiple platforms, however of primary interest are samplers that could be mounted on a mobile platform, such as a rover. For reference, current Mars-relevant rovers range in mass from 200 - 800 kg.

Sample Acquisition

Research should be conducted to develop compact, low-power, lightweight subsurface sampling systems that can

obtain 1 cm diameter cores of consolidated material (e.g., rock, icy regolith) up to 10 cm below the surface. Systems should be capable of autonomously acquiring and ejecting samples reliably. Also of interest are methods of autonomously exposing rock interiors from below weathered rind layers. Other sample types of interest are unconsolidated regolith, dust, and atmospheric gas.

Sample Manipulation (core management, sub-sampling/sorting, powder transport)

Sample manipulation technologies are needed to enable handling and transfer of structured and unstructured samples from a sampling device to instruments and sample processing systems. Core, cuttings, 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 fragment samples will be of similar volumes.

Sample Integrity (encapsulation and contamination)

For a sample return mission, it is critical to find solutions for maintaining physical integrity of the sample during the surface mission (rover driving loads, diurnal temperature fluctuations) as well as the return to Earth (cruise, atmospheric entry and impact). Technologies are needed for characterizing state of sample in situ - physical integrity (e.g., cracked, crushed), sample volume, mass or temperature, as well as retention of volatiles in solid (core, regolith) samples, and retention of atmospheric gas samples.

Also of particular need are means of acquiring subsurface rock and regolith samples with minimum contamination. This contamination may include contaminants in the sampling tool itself, material from one location contaminating samples collected at another location (sample cross-contamination), or Earth-source microorganisms brought to the Martian surface prior to drilling ('clean' sampling from a 'dirty' surface). Consideration should be given to use of materials and processes compatible with 110 - 125°C dry heat sterilization. In situ sterilization may be explored, as well as innovative mechanical or system solutions - e.g., single-use sample "sleeves," or fully-integrated sample acquisition and encapsulation systems.

For a sample return mission, sample transfer of a payload into a planetary ascent vehicle: Automated payload transfer mechanisms; and Orbiting Sample (OS) sealing techniques.

Proposals should show an understanding of one or more relevant science needs, and present a feasible plan to fully develop a technology and infuse it into a NASA program.

S5.03 Surface and Subsurface Robotic Exploration

Lead Center: JPL

Participating Center(s): ARC, GSFC, JSC

Technologies are needed to enable access and sample acquisition at surface and subsurface sampling sites of scientific interest on Mars or the Moon. Mobility technology is needed to enable access to difficult-to-reach sites such as access through difficult and steep terrain. Manipulation technologies are needed to deploy instruments and sampling tools from vehicles. Many scientifically valuable sites are accessible only via terrain that is too difficult or steep for state-of-the-art planetary rovers to traverse. Sites include crater walls, canyons, and gullies. Tethered systems, non-wheeled systems, and marsupial systems are 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. Single vehicle systems might utilize a 200 kg class rover and dual vehicle systems might utilize a 500 - 800 kg primary vehicle that provides long traverse to the vicinity of a challenging site and then deployment of a smaller 20 - 50 kg vehicle with steep mobility capability for access and sampling at the site.

Technologies to enable acquisition of subsurface samples are also needed. For Mars in particular, technologies are needed to acquire core samples in the shallow subsurface to about 10cm and to enable subsurface sampling in multiple holes at least 1 - 3 meters deep through rock, regolith or ice compositions. Shallow subsurface sampling systems need to be low mass and deeper subsurface sampling solutions need to be integratable onto 500 - 800 kg stationary landers and mobile platforms. Consideration should be given for potential failure scenarios, such as platform slip and borehole misalignment for integrated systems, and the challenges of dry drilling into mixed media including icy mixtures of rock and regolith. Systems should ensure minimal contamination of samples from Earth-source contaminants and cross-contamination from samples at different locations or depths.

Innovative component technologies for low-mass, low-power, and modular systems are of particular interest. Technical feasibility should be demonstrated during Phase 1 and a full capability unit of at least TRL level 4 - 6 should be delivered in Phase 2. Specific areas of interest include the following:

- Tether play-out and retrieval systems including tension and length sensing;
- Low-mass tether cables with power and communication;
- Steep terrain adherence for vertical and horizontal mobility;
- Modular actuators with 1000:1 scale gear ratios;
- Electro-mechanical couplers to enable change out of instruments on an arm end-effector;
- Drill, core, and boring systems for subsurface sampling to 10cm or 1 to 3 meters.
- High power piezoelectric mechanisms for drilling into Lunar Regolith; must be able to deliver high torque for short impulses to clear any obstacles;
- Shared intelligence allowing systems to collaborate and adapt exploration scenarios to new conditions.

Proposals should show an understanding of relevant science needs and present a feasible plan to fully develop a technology and infuse it into a NASA program.

S5.04 Rendezvous and Docking Technologies for Orbiting Sample Capture

Lead Center: JPL

Participating Center(s): GSFC, JSC

NASA seeks an innovative suite of products or technologies that will enable and enhance the successful tracking and capture of a sample canister in Mars orbit.

The principal means of detection and tracking is optically with visual-band cameras. The challenging technology of long-range optical sensors for detection and distant tracking is not part of this call, however, short-range optical (or other) sensors and an on-sample radio-metric-based back-up detection and tracking method is desired, including a low-power, low-mass illuminator for short-range imaging of up to 0.5km.

Sample capture mechanisms are sought, of very low mass and volume, and of low complexity and extremely high reliability, including detection of contact with the capture mechanism. Appropriate on-sample radio-beacons are sought that are compatible with NASA's radio systems; requirements for these are for long life, and independent initiation of on-orbit operation. Sample capture mechanisms should include close-proximity/contact sensors, including immediate-field imaging.

Command and sequencing software is sought that will robustly operate the onboard GN&C systems, including providing health and safety monitoring of the rendezvous and capture operation, adaptive response to anomalies and abort commanding. Onboard resources can be assumed to be those necessary to perform navigation from images or other data, compute maneuvers, and maintain the spacecraft attitude.

Methods are sought to provide a practice mechanism for testing rendezvous and proximity operations with a test sample canister on Mars orbit. The test carrier and release mechanism must be of very low mass and volume, and the test sample canister(s) should carry a radio beacon. Test canisters should be of limited life after release, ceasing broadcast, and degrading in surface reflectance in approximately one month to avoid confusion with the actual canister. The test articles may be deployed on a previous mission, or on the actual sample return mission for operational readiness testing.

Products or technologies are sought that can be made compatible with the environmental conditions of interplanetary spaceflight and the rigors normal Mars orbits. Proposals should show an understanding of one or more relevant science needs, and present a feasible plan to fully develop a technology and infuse it into a NASA program. Successful candidate products or technologies can address this call by providing one or more of the following functions, and giving estimated expected performance capabilities of the approach, including, but not limited to, accuracies, ranges, limits of operation, references to previous or related flight experience:

- Autonomously actuated mechanisms for orbiting sample capture;
 - Mechanical capture mechanisms;

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- Transfer mechanisms from capture device to containment transfer mechanism;
 - Optical and contact sensors;
 - Near field imagers (optical or other) (e.g. 10m to 1km);
 - Immediate field imagers (optical) (0.25 to 10m);
 - Detection of orbiting sample for triggering capture mechanism;
 - Near field illuminator;
 - Coherent Radio Doppler and range beacon (high-performance);
 - Low power, low mass and long life beacon for detection aid;
 - 2-way communication for activation, ranging and coherency;
 - Programmable intermittent transmission for power saving and very long dormancy period;
 - Simple Radio beacon (low-performance);
 - Simple 1-way beacon, for long-range detection and 1-way Electra Doppler extraction;
 - Timer activated, multi-year dormant life, and long active life battery;
 - Autonomous Rendezvous GN&C Command and Control system;
 - Utilize existing GN&C computation elements to command and sequence robust and safe rendezvous and capture;
 - Provide self-monitoring, correction and self-abort capability;
 - Provide for high-level Mission scenario design, monitoring and simple implementation;
 - Low-mass, low-cost sample OSC for proximity operations operational readiness tests;
 - A simple, low-cost, low-mass practice sample canister that could be deployed and provide low-risk practice runs, either for a precursor mission, or with the actual sample return mission;
 - The readiness test exercise would not capture the test article in the capture mechanism, but only perform the rendezvous and proximity ops operations.

Proposals should show an understanding of one or more relevant science needs, and present a feasible plan to fully develop a technology and infuse it into a NASA program.

S5.05 Extreme Environments Technology

Lead Center: JPL

Participating Center(s): ARC, GRC, GSFC, MSFC

High Temperature, High Pressure, and Chemically Corrosive Environments

NASA is interested in expanding its ability to explore the deep atmosphere and surface of Venus through the use of long-lived (days or weeks) balloons and landers. Survivability in extreme high temperatures and high pressures is also required for deep atmospheric probes to giant planets. Proposals are sought for technologies that enable the in situ exploration of the surface and deep atmosphere of Venus and the deep atmospheres of Jupiter or Saturn for future NASA missions. Venus features a dense, CO₂ atmosphere completely covered by sulfuric acid clouds at about 55 km above the surface, a surface temperature of about 486°C and a surface pressure of about 90 bars. Technologies of interest include high temperature electronics components, high temperature energy storage systems, light mass refrigeration systems, high temperature optical window systems (that are transparent in IR, visible and UV wavelengths) and pressure vessel components compatible with materials such as steel, titanium and beryllium such as low leak rate wide temperature (-50°C to 500°C) seals capable of operating between 0 and 90 bars.

Low Temperature Environments

Low temperature survivability is required for missions to Titan, the surface of Europa and comets. Also Moon equatorial regions experience wide temperature swings from -180°C to +130°C during the lunar day/night cycle, and the sustained temperature at the shadowed regions of lunar poles can be as low as -230°C. Mars diurnal temperature changes from about -120°C to +20°C. Proposals are sought for technologies that enable NASA's long duration missions to low temperature and wide temperature environments. Technologies of interests include low power rad-tolerant RF electronics, mixed signal electronics, power electronics, electronic packaging (including passives, connectors, wiring harness and materials used in advanced electronics assembly), actuators and energy storage sources capable of operating across an ultra-wide temperature range from -230°C to 200°C and computer Aided Design (CAD) tools for modeling and predicting the electrical performance, reliability, and life cycle for low-temperature electronic systems and components.

Research should be conducted to demonstrate technical feasibility during Phase 1 and show a path toward a Phase 2 hardware/software demonstration, and when possible, deliver a demonstration unit for functional and environmental testing at the completion of the Phase 2 contract.

S5.06 Planetary Balloon Technology

Lead Center: JPL

Innovations in materials, structures, and systems concepts have enabled buoyant vehicles to play an expanding role in planning NASA's future Solar System Exploration Program. Balloons and airships are expected to carry scientific payloads on Venus and Titan in order to investigate their atmospheres in situ and their surfaces from close proximity. Their envelopes will be subject to extreme environments and must support missions with a range

of durations. Proposals are sought in the following areas:

Metal Balloons for High Temperature Venus Exploration

Balloons made of metals are a potential solution to the problem of enabling long duration flight in the hot lower atmosphere of Venus. Proposals are sought for metal balloon concepts and prototypes that provide 1-5 m³ of fully inflated volume, areal densities of 1 kg/m² or less, sulfuric acid compatibility at 85% concentration, and operation at 460Å°C for a period of up to 1 year.

Rapid Buoyancy Modulation System for a Titan Montgolfiere Balloon

Montgolfiere, or hot air, balloons are under development for use on a future mission to Titan. While systems are feasible based on the waste heat from a radioisotope power system (RPS), the large thermal inertias make it dangerous for such balloons to fly near the surface because of their inability to quickly respond to atmospheric turbulence or approach topographic hazards. Proposals are therefore sought for a rapid buoyancy modulation system that can be integrated into a 10 m diameter Titan Montgolfiere balloon operating at 90 K and using a steady-state RPS heat source in the range of 2 - 4 kW. This system needs to be lightweight (less than 10 kg) and consume a small amount of electrical power (less than 5 W average).

Gas Management Systems for Titan Aerobots

Hydrogen-filled aerobots at Titan must contend with the problem of gas leakage over long duration (1 year or more) flights. Proposals are sought for the development and testing of two kinds of prototype devices that can be carried on the aerobot to compensate for these gas leakage problems: one device is to produce make-up hydrogen gas from atmospheric methane; the other device is to remove atmospheric gas (mostly nitrogen) that leaks from the ballonets into the hydrogen-filled blimp. Both kinds of devices will need to operate on no more than 15 W of electrical power each while compensating for a leakage rate of at least 40 g/week of hydrogen or 500 g/week of nitrogen.

Proposals should show an understanding of one or more relevant science needs, and present a feasible plan to fully develop a technology and infuse it into a NASA program.