



## NASA SBIR 2009 Phase I Solicitation

### X6.01 Robotic Systems for Human Exploration

Lead Center: JSC

Participating Center(s): ARC, KSC

The objective of this subtopic is to provide advanced capabilities for lunar surface system assets that deliver, handle, transfer, construct, and prepare site infrastructure for lunar operations. This includes robust dexterous manipulation capabilities; large and small cargo transporters for delivery and deployment of construction materials, power generation systems, and habitable enclosures.

This subtopic seeks to develop technologies that reduce the risk of Extra-Vehicular Activity (EVA), facilitates remote robotic operations by both flight crew and ground control, and enables autonomous robotic operations. Automation and robotics capabilities include the ability to use robots for site setup and operations, both at an outpost and at remote lunar surface locations. Site operations support focuses on two types of activities: (1) tedious, highly repetitive, long-duration tasks that cannot be performed by EVA crew and (2) rapid response for addressing emergency, time-critical situations. Candidate tasks include: systematic site survey (engineering and/or science), inspection, emergency response, site preparation (clearing, leveling, excavation, etc.), instrument deployment, payload offloading, dexterous manipulation, and regolith handling for In-situ Resource Utilization.

Maximizing the useful life of surface assets is essential to a successful lunar program. Material components must be robust and tolerate extreme temperature swings and endure harsh environmental effects due to solar events, micrometeorite bombardment, and abrasive lunar dust.

Proposals are sought for the following technology needs:

- Low-mass, high-strength, long-life, non-pneumatic wheel assembly capable of spreading the supported load over a large contact patch area and moving over surface terrain similar to loose beach sand. Range, Life, Mass, Mean-time-to-repair, and Mean-time-between-failure are key performance parameters being sought. Low psi contact patch. Minimal deformation of wheel under varying terrain makeup. Minimal rolling resistance. High performance in 4-sigma soil. 10,000 km expected life. 40K to 400K operating temperature range. Supports 100x its own mass.

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- Active and passive damping materials for suspension components that provide extended range of motion (45 degrees in pitch), extreme temperature tolerance (40K to 400K), reactive rates of 1-3 msec, and withstand torsional forces of 3000 N-m.
  - Active suspension components that reclaim and store energy absorbed through the suspension system.
  - Fluid and electrical connectors that can be repeatedly mated and de-mated (5000+ cycles) without failure in a contaminating environment consisting of regolith (abrasive dust) grains ranging in size from 100um down to 10um. Capable of carrying up to 10kw of power transmission or withstanding up to 3000psi pressures.
  - Low power sensors for inspection and surface navigation and obstacle avoidance that are not adversely affected by the accumulation of lunar dust on the sensor. Developing robust sensor technologies will enable mobility assets to execute automated path planning, automated driving, and obstacle avoidance.
  - Robot user interfaces enabling more efficient interaction with robots, facilitating situational awareness and telepresence, and reducing the amount of interaction effort required to operate robots. Appropriate user interfaces will support humans and robots operating in a shared space, close but separated, line-of-sight remote, and ground control remote. Particular interest is given to systems that robustly support robot operations with up to 10 seconds of communications delay.
  - Modular implements for digging, collecting, transporting and dumping lunar soil. The excavation rates are in the order of 50 kg/hr for regolith mining for O<sub>2</sub> production and 300 kg/hr for Site preparation tasks. Total amounts of regolith required are 100 tons for O<sub>2</sub> production and over 2,000 tons for a full outpost deployment. Excavation capabilities involve excavation and collection of both unconsolidated and consolidated surface regolith. Regolith Excavation includes tasks such as clearing and leveling landing areas and pathways, buildup of berms (2.5 m high) and burying of reactors or habitats for radiation protection (2 m deep), and regolith transportation for oxygen production (500 m distance) . Robotic excavation hardware must be able to operate over broad temperature ranges (40 K to 400 K) and in the presence of abrasive lunar regolith and partial-gravity environments. Expectations for maintenance by crew must be minimal and affordable (annual cycle). Therefore, general attributes desired for all proposed hardware include the following: lightweight, abrasion resistant, vacuum and large temperature variation compatible materials, low power, robust/low maintenance, and minimize dust generation/saltation during operation.
  - Large surface area, i.e., 100 m X 100 m, soil stabilization/solidification techniques to prevent dust and regolith disturbances/ejecta from vehicular or suited EVA traffic (7 - 70 kilopascal bearing pressure).