



NASA SBIR 2017 Phase I Solicitation

Z5.02 Robotic Systems - Mobility Subsystems

Lead Center: JSC

Participating Center(s): ARC, GRC, KSC

Technology Area: TA4 Robotics, Telerobotics and Autonomous Systems

In the coming decades, robots will continue to change the way space is explored. Robots will be used in all mission phases: as independent explorers operating in environments too distant or hostile for humans, as precursor systems operating before crewed missions, as crew helpers working alongside and supporting humans, and as caretakers of assets left behind. As humans continue to work and live in space, they will increasingly rely on intelligent and versatile robots to perform mundane activities, freeing human and ground control teams to tend to more challenging tasks that call for human cognition and judgment.

Innovative robot technologies provide a critical capability for space exploration. Multiple forms of mobility, manipulation and human robot interaction offer great promise in exploring planetary bodies for science investigations and to support human missions. Enhancements and potentially new forms of robotic systems can be realized through advances in component technologies, such as actuation and structures. Manipulation provides a critical capability for positioning crew members and instruments in space and on planetary bodies, it allows for the handling of tools, interfaces, and materials not specifically designed for robots, and it provides a capability for drilling, extracting, handling and processing samples of multiple forms and scales. This increases the range of beneficial tasks robots can perform and allows for improved efficiency of operations across mission scenarios. Manipulation is important for human missions, human precursor missions, and unmanned science missions. Future space missions may rely on co-located and distributed teams of humans and robots that have complementary capabilities. Tasks that are considered "dull, dirty, or dangerous" can be transferred to robots, thus relieving human crew members to perform more complex tasks or those requiring real-time modifications due to contingencies. Additionally, due to the limited number of astronauts anticipated to crew planetary exploration missions, as well as their constrained schedules, ground control will need to remotely supervise and assist robots using time-delayed and limited bandwidth communications.

Proposals are sought to research and develop the following robotic technologies including mobility, manipulation and human robot interaction technologies as described by the 2015 NASA Technology Roadmap for Robotics and Autonomous Systems (Tech Area 4):

- *Extreme Terrain Mobility* - Technology to access and traverse extreme terrain topographies, such as highly-sloped crater walls, gullies, and canyons; soft terrains; or terrains with large rock densities. Key technologies include rappelling and climbing systems and systems that can traverse soft and friable terrains.
- *Below-Surface Mobility* - Technology to access through naturally-occurring terrain cavities, such as lava tubes and deep crevasses; through human-made holes, ice boreholes, or trenches; and through granular or liquid media. Challenges include lack of direct sunlight, or line-of-sight comm. Key technologies include

anchoring, burrowing, traction, downhole sensing, and tethering components.

- *Above-Surface Mobility* - Technology to provide longer range and greater coverage of planetary surfaces, independent of the terrain topography. This includes improvements to payload capacity, power, speed, and endurance in terms of time or distance. The type of above-surface mobility used on planetary bodies will be driven by environmental considerations and mission-specific requirements, which would include operation duration, coasting attitude, and the frequency of contacts with the surface.
- *Small-Body and Microgravity Mobility* - Technology to provide surface coverage and in-situ access to designated targets on small bodies with low gravity, as well as in-space mobility inside and around the ISS or other future space assets. Key technologies include human-safe gas propulsion, fan-based propulsion, hopping, flying, anchoring, wheel/track/limb hybrids, and electromagnetic formation flight.
- *Surface Mobility* - Technology to transport payloads, equipment, and other surface assets at much higher traverse speed for both manned and unmanned missions and increase the robustness of their onboard sensing, control, and navigation software. Key technologies include active suspension, traction control, real-time embedding/slip detection, and tractive elements (wheels, tracks, etc.)
- *Robot Navigation* - Technology to provide a highly reliable, well-characterized, and autonomous or semi-autonomous mobility capability to navigate to targets of interest on planetary surfaces. Key technologies include perception algorithms, pose and state estimation algorithms, and on-board autonomy (motion/path planning, target/waypoint selection, etc.).
- *Mobility Components* - Provide critical component technologies, such as compliant long-life wheels, high-torque at low speed actuators, energy-efficient and miniaturized actuators, strong abrasion-resistant tethers, and all-terrain anchors to meet future mobility needs. Provide larger payload and mobility mass fractions. Provide safe movement at speeds that are power-limited, not computation-limited, and yet do not tax human attention.
- *Manipulator Components* - Technologies should address improving kinematic configuration (serial, parallel, hybrids), dynamic performance (variable structural stiffness or compliant actuation), packaging efficiency (stowed and deployed), power density, or payload to mass ratio. This includes actuators tailored for manipulation (in terms of speed and torque range, compliance, size, and mass), lightweight structures (soft mechanisms, tendon systems, etc.), sensors and sensing approaches (both proprioceptive and exteroceptive), and embedded controllers (impedance, compliance, torque, etc.).
- *Dexterous Manipulation* - Technologies to generate smooth, human-like arm trajectories and fine end-effector motions that can flexibly manipulate objects; systems and control approaches capable of interacting with unstructured environments and human arm/hand scale interfaces; and approaches to incorporating or leveraging redundancy for robust manipulation. This includes manipulators and end-effectors, as well as the algorithms that control their motions.
- *Collaborative Manipulation* - Technologies to enable the use of multiple robotic manipulators that are either rigidly connected to a common base or to independent mobile bases. This includes algorithms and software for coordinated and cooperative motion, multi-point contact management (for highly dexterous robots or multi-robot systems), and distributed safety.
- *Grappling* - Technologies to handle large objects in microgravity environments. This includes components to grapple natural and human-made free-flying objects using surface features, and then to berth these objects to the robot's spacecraft through a rigidized interface.
- *Multi-Modal Interaction* - Technology that employs multiple display modalities and multiple communication channels to enhance human situation awareness and enable more efficient interaction. In particular, tools and techniques that combine interactive 3D computer graphics, multi-modal dialogue, haptics, spatialized sound, and other non-visual displays to create an increased sense of presence are of strong interest.
- *Distributed Collaboration and Coordination* - Technology that improves the operational efficiency of a distributed team of humans and robots. This includes performance monitoring systems for real-time evaluation of task execution; summarization and notification systems to help humans understand robot state and trends over time; and physics-based modeling and modeling/simulation of robots and their operational environments.
- *Variable Autonomy Robotic Interaction* - Technology that enables humans, both on Earth and in-mission to more effectively operate and supervise robots that may be remote or proximal. This includes decision support tools to monitor system status, assess task progress, observe the remote environment, and make informed operational decisions; interaction techniques that inspire humans to trust robot team members that are proximal and/or remote; techniques to mitigate the effects of latency on manual control; and methods to reduce dependency on high-bandwidth, high-availability communication links.

Proposals must describe how the technology will make a significant improvement over the current state of the art, rather than just an incremental enhancement. Proposals must also describe how the technology will be employed

for a specific application and how performance will be quantitatively assessed.