NASA SBIR 2022 Phase I Solicitation

Z5.04 Intravehicular Robot (IVR) Technologies

Lead Center: ARC

Participating Center(s): JSC

Scope Title

Improve the Capability or Performance of Intravehicular Robots

Scope Description

To support human exploration beyond Earth orbit, NASA is developing Gateway, which will be an orbiting facility near the Moon. This facility will serve as a starting point for missions to cislunar space and beyond. It could enable assembly and servicing of telescopes and deep space exploration vehicles. It could also be used as a platform for astrophysics, Earth observation, heliophysics, and lunar science.

In contrast to the International Space Station (ISS), which is continuously manned, Gateway is expected to be occupied by humans only intermittently—perhaps only 1 month per year. Consequently, there is a significant need for Gateway to have autonomous capabilities for performing payload operations and spacecraft caretaking, particularly when astronauts are not present. Similar capabilities are needed for future lunar or planetary surface habitats. Intravehicular robots (IVR) can potentially perform a wide variety of tasks, including systems inspection, monitoring, diagnostics and repair, logistics and consumables stowage, exploration capability testing, aggregation of robotically returned destination surface samples, and science measurements and operations.

The objective of this subtopic is to develop technologies that can improve the capability or performance of IVR for science utilization and spacecraft caretaking.

Proposals must describe how the technology will make a significant improvement over the current state of the art (SOA), rather than just an incremental enhancement, for a specific IVR application.

Proposals are specifically sought to create IVR-relevant technologies in the following areas:

- Compact, lightweight robotic arms suitable for IVR free-flyers.
- Robotic tools.
- Compact, reliable, modular robotic actuators and controllers for IVR.
- Sensors and perception systems.
- Operational subsystems that enable extended robot operations (power systems, efficient propulsion, etc.).
- Improved robot autonomy (planning, scheduling, and task execution).
- Improved human-robot interaction between IVR and human teams on the ground under communications constraints, including low bandwidth and extended loss-of-signal periods (software architecture, remote operations methods, etc.).
Improved management of robot operational and hardware faults such that the robot can “fail operational.” For example, the software may use algorithms to determine how to automatically respond to a failure in a motion planner for move to a commanded location by taking into account a projected collision and replanning to the next closest point not in collision.

The technologies must be applicable to required IVR capabilities, such as:

- Maintenance and housekeeping (installing and stowing cables or fluid lines, plugging and unplugging MIL-STD-38999 electrical connectors and fluid quick-disconnect connectors, opening panels, swapping out NASA AMPS (Advanced Exploration Systems (AES) Modular Power Systems) avionics cards, opening and closing hatches, cleaning or swapping air filters, cleaning or sterilizing surfaces, etc.).
- Logistics management (inventory tracking, cargo transport, packing and unpacking bags, kitting items, etc.).
- Science utilization (moving samples between cold storage and instruments, swapping out consumables cartridges, moving planetary samples or SmallSat experiments in and out of airlocks, installing items fabricated using in-space manufacturing, etc.).
- Emergency management (detecting and patching leaks, detecting fires, etc.).
- Localization and navigation.
- Environment monitoring, inspection, and modeling.

The technologies must have an infusion path to NASA missions where habitats require IVR support, such as the Gateway habitat, the Artemis lunar surface habitat, or transit vehicles or surface habitats for future Mars missions. To facilitate infusion, proposals are encouraged, but not required, to:

- Target near-term integration and testing with NASA IVR platforms and analogs, such as Astrobee and Valkyrie.
- Limit dependence on third-party proprietary technologies that might complicate NASA adoption of the technology.
- Use industry standard hardware and software interfaces, architectures, and frameworks that align with relevant NASA IVR technology development to reduce future integration technical effort.

**Expected TRL or TRL Range at completion of the Project**

4 to 5

**Primary Technology Taxonomy**

**Level 1**

TX 04 Robotics Systems

**Level 2**

TX 04.X Other Robotic Systems

**Desired Deliverables of Phase I and Phase II**

- Research
- Analysis
- Prototype
- Hardware
- Software

**Desired Deliverables Description**

Deliverables should focus on prototype components, subsystems, and the demonstration thereof. Specifically,
Phase I awards shall deliver an interim and final report discussing these results. Phase II awards shall deliver demonstration reports along with supporting software, design information, and documentation.

**State of the Art and Critical Gaps**

The technology developed by this subtopic would both enable and enhance IVR such as the Astrobeefree-flying robot, Robonaut 2, and Valkyrie humanoid mobile manipulators, which are the SOA for IVR. SBIR technology would improve the capability and performance of these robots to routinely and robustly perform IVR tasks, particularly internal spacecraft payload operations and logistics. New technology created by 2022 SBIR awards could potentially be tested with these, or other, robots in ground testbeds at Ames Research Center (ARC) and Johnson Space Center (JSC) in follow-on awards. These platforms make use of the ROS (Robot Operating System) software architecture. Likewise, on-orbit testing on the ISS may be possible during follow-on awards.

The technology developed by this subtopic would also fill technical gaps identified by the Game Changing Development (GCD) Integrated System for Autonomous and Adaptive Caretaking (ISAAC) project, which is maturing autonomy technology to support the caretaking of human exploration spacecraft. In particular, the SBIR technology would help provide autonomy and robotic capabilities that are required for in-flight maintenance (both preventive and corrective) of Gateway during extended periods when crew are not present.

**Relevance / Science Traceability**

This subtopic is directly relevant to the following STMD (Space Technology Mission Directorate) investments:

- Astrobeefreeflying robot, GCD.
- Integrated System for Autonomous and Adaptive Caretaking (ISAAC), GCD.
- Smart Deep Space Habitats (SmartHabs), Space Technology Research Institutes (STRI).

This subtopic is directly relevant to the following HEOMD (Human Exploration and Operations Mission Directorate) investments:

- Astrobeefacility, ISS.
- Gateway program, AES.
- Logistics Reduction project, AES. Autonomous Systems Operations project, AES.

**References**

- What is Astrobeef? https://www.nasa.gov/astrobee
- What is a Robonaut? https://www.nasa.gov/robonaut2
- The Robot Operating System (ROS) https://www.ros.org