NASA STTR 2020 Phase I Solicitation

T4.01 Information Technologies for Intelligent and Adaptive Space Robotics

Lead Center: ARC

Participating Center(s): JSC

Technology Area: TA4 Robotics, Telerobotics and Autonomous Systems

Scope Title

Develop Information Technologies to Improve Space Robots.

Scope Description

Extensive and pervasive use of robots can significantly enhance space exploration and space science, particularly for missions that are progressively longer, complex, and distant. The performance of these robots is directly linked to the quality and capability of the information technologies used to build and operate them. With few exceptions, however, current information technology used for state-of-the-art robotics is designed only to meet the needs of terrestrial applications and environments.

The objective of this subtopic, therefore, is to encourage the adaptation, maturation, and retargeting of terrestrial information technologies for space robotics. Proposals should address at least one of the following research areas:

1. ***Perception systems for autonomous robot operations*** in man-made environments (inside spacecraft or habitats) and unstructured, natural environments (Earth, Moon, Mars). The primary objective is to significantly increase the performance and robustness of perception capabilities such as object/hazard identification, localization, mapping, etc. through new avionics (including Commercial Off-The-Shelf [COTS] processors for use in space), sensors and/or software. Proposals for small size, weight, and power (SWAP) systems or technology that can operate on existing rad-hard processors are particularly encouraged.
2. ***Robot user interfaces*** that facilitate distributed human-robot teams, geospatial data visualization, summarization and notification, performance monitoring, etc. The primary objective is to enable more effective and efficient interaction with robots remotely operated with discrete commands or supervisory control. User interface technology that helps optimize operator workload or improve human understanding of autonomous robot actions are particularly encouraged. Note: proposals to develop user interfaces for direct teleoperation (manual control), augmented/virtual reality, or telepresence are not solicited and will be considered non-responsive.
3. ***Robot Operating System v2 (ROS 2) for space robots***. The primary objective is reduce the risk of deploying, integrating, and verifying and validating the open-source ROS 2 for future space missions. Proposals that develop software technology that can facilitate integration of ROS 2 with common flight software (Core Flight Software, Integrated Test and Operations System [ITOS], etc.) and standards (Consultative Committee for Space Data Systems [CCSDS], etc.), methods to improve the suitability of ROS 2 for use with current flight computing, or tools / process to make ROS 2 (or a subset) ready for near-

term flight missions are particularly encouraged.

Proposals are particularly encouraged to develop technologies applicable to robots of similar archetypes and capabilities to current NASA robots, such as Astrobee, Curiosity, or Robonaut 2.

References

https://www.nasa.gov/astrobee

https://robonaut.jsc.nasa.gov

J. Crusan, et al. 2018. "Deep space gateway concept: Extending human presence into cislunar space", In Proceedings of IEEE Aerospace Conference, Big Sky, MT

M. Bualat, et al. 2018. "Astrobee: A new tool for ISS operations". In Proceedings of AIAA SpaceOps, Marseille, France.

T. Fong, et al. 2013. "Smart SPHERES: a telerobotic free-flyer for intravehicular activities in space". In Proceedings of AIAA Space 2013, San Diego, CA.

M. Diftler, et al. 2011. "Robonaut 2 - The first humanoid robot in space". In Proceedings of IEEE International Conference on Robotics and Automation, Shanghai, China.

Expected TRL or TRL range at completion of the project: 4 to 6

Desired Deliverables (Phase I)

Proposers should develop technologies that can be demonstrated with, or integrated to existing NASA research robots or projects to maximize relevance and infusion potential.

1. Identify scenarios, use cases, and requirements.
2. Define specifications.
3. Develop preliminary design.

Desired Deliverables (Phase II)

1. Develop prototypes (hardware and/or software).
2. Demonstrate and evaluate prototypes in real-world settings.
3. Deliver prototypes to NASA.

State of the Art and Critical Gaps

Future exploration and science missions will require robots to operate in more difficult environments, carry out more complex tasks, and handle more dynamic and varying operational constraints than the current state of the art, which relies on low-performance, rad-hard computing and execution of pre-planned command sequences. To achieve these capabilities, numerous new information technologies need to be developed, including high performance space computing, autonomy algorithms, and advanced robot software systems (on-board and off-board).

For example, in contrast to the International Space Station, which is continuously manned, the Gateway is expected to only be intermittently occupied – perhaps as little as 8% of the time. Consequently, there is a significant need for the facility to be robotically tended, in order to maintain and repair systems in the absence of human crew. These robots will perform a wide range of caretaking work including inspection, monitoring, routine maintenance, and contingency handling. To do this, significant advances will need to be made in autonomous perception and robot user interfaces, particularly to handle mission-critical and safety-critical operations.

As another example, a mission to explore and map interior oceans beneath the ice on Europa will require a robot to penetrate an unknown thickness of ice, autonomously carry out a complex set of activities, and navigate back to the surface in order to transmit data back to Earth. The robot will need to perform these tasks with minimal human involvement and while operating in an extremely harsh and dynamic environment. To do this, significant advances will need to be made in autonomous perception and on-board software, particularly to compensate for poor (bandwidth-limited, high-latency, intermittent) communications and the need for high performance autonomy.

Relevance / Science Traceability

The development of information technology for intelligent and adaptive space robotics is well aligned with NASA goals for robotics. In particular, this development directly addresses multiple areas (TA4, TA7, TA11) of the 2015 NASA technology roadmap. Additionally, this development is directly aligned with multiple portions of the NASA Autonomous Systems SCLT (Systems Capability Leadership Team) technology taxonomy. Moreover, this development directly addresses a core technology area (robotics and autonomous systems) of the NASA Strategic Space Technology Investment Plan. Finally, the technology is directly aligned with the needs of numerous projects and programs in Aeronautics Research Mission Directorate (ARMD), Human Exploration and Operations Mission Directorate (HEOMD), Science Mission Directorate (SMD), and Space Technology Mission Directorate (STMD).

- ARMD: The technology can be applied to a broad range of unmanned aerial systems (UAS), including both small-scale drones and Predator / Global Hawk type systems. The technology can also be potentially infused into other flight systems that include autonomous capabilities, such as Urban Air Mobility vehicles.
- HEOMD: The technology is directly relevant to "caretaker" robots, which are needed to monitor and maintain human spacecraft (such as the Gateway) during dormant/uncrewed periods. The technology can also be used by precursor lunar robots to perform required exploration work prior to the arrival of humans on the Moon.
- SMD: The technology is required for future missions in Earth Science, Heliophysics, and Planetary Science (including the Moon, icy moons and ocean worlds) that require higher performance and autonomy than currently possible. In particular, missions that must operate in dynamic environments, or measure varying phenomena, will require the technology developed by this subtopic.
- STMD: The technology is directly applicable to numerous current mid-TRL (Game Changing Development program) and high-TRL (Technology Demonstration Mission program) Research and Development (R&D) activities, including Astrobee, In-space Robotic Manufacturing and Assembly, etc.