NASA SBIR 2019 Phase I Solicitation

H10.02 Autonomous Control Technologies (ACT) for Ground Operations

Lead Center: KSC

Participating Center(s): ARC, LaRC, SSC

Technology Area: TA4 Robotics, Telerobotics and Autonomous Systems

Autonomous Control Technologies (ACT) are needed to reduce operations and maintenance (O&M) costs of ground test and payload operations on ground, and to increase systems availability to support mission operations. These technologies are also required for extended surface operations and maintenance on the Moon and Mars. They are also required in activities where human intervention/interaction needs to be minimized, such as in hazardous locations/ operations and in support of remote operations.

ACT performs functions such as systems and components fault prediction and diagnostics, anomaly detection, fault detection and isolation, and enables variable levels of autonomous control and recovery from faults, where recovery may include reconfiguration or repair. ACT are enabled by System Health Management (ISHM) technologies, methodologies, and approaches; command and control architectures; computing architectures; software for decision- making and control; and intelligent components and devices.

ACT will be applied to activities such as rocket engine test facilities, propellant servicing and launch of vehicles and will complement In-Situ Resources Utilization (ISRU) operations by utilizing ISRU-generated commodities to support transportation activities. ACT will also enable surface operations and maintenance, which differs significantly from traditional launch processing operations, due to the required high degree of autonomy and reliability for unattended operations during extended periods of time. ACT enables Autonomous Propellant Management (APM), which requires the unattended or minimally attended storage, transfer, monitoring, and sampling of cryogenic or other propellant use in launch systems. APM includes pre-planned nominal processes, such as vehicle fill and drain, as well as contingency and off-nominal processes, such as emergency safing, venting and system reconfiguration.

ACT capabilities will also enable the autonomous command, monitoring and control of the overall integrated system, resulting from the integration of loading systems and all other associated systems involved in the loading process.

The system autonomy software itself includes both prerequisite control logic (PCL) and reaction control logic (RCL) programming, and may utilize some form of machine learning, neural network, or other form of artificial intelligence to adapt to degraded system components or other forms of off-nominal conditions. In addition to cryogenic and other propellants, propellant management systems may utilize additional commodities to prepare a vehicle for launch, such as high pressure gasses for purges, pressurization, or conditioning, and may include power and data interfaces with the vehicle to configure vehicle valves or other internal systems and utilize on-board instrumentation to gain visibility into the vehicle during loading.

ACT must also support tasks such as systems setup, testing and checkout, troubleshooting, maintenance, upgrades and repair. These additional tasks drive the need for autonomous element to element interface connection and separation, multi-element inspection, and recovery of high value cryogenic propellants and gasses to avoid system losses.

Specifically, this subtopic seeks the application of high-fidelity, physics-based, cryogenic-thermal models and simulations capable of real-time and faster than real-time performance. Along with these simulations, the subtopic seeks the creation of simulation component libraries (generic components), capable to be tailored, to support the rapid prototyping of cryogenic-thermal models. The subtopic also seeks supervisory control software for autonomous control and recovery of propellant loading systems and infrastructure and software development tools to support the rapid prototyping of autonomous control applications. Furthermore, the subtopic seeks architectures that support integration of the above capabilities for integrated autonomous operations.

For all above technologies, research should be conducted to demonstrate technical feasibility during Phase I and show a path toward Phase II demonstration and delivering a demonstration package for NASA testing in operational or analog test environments at the completion of the Phase II effort.

Ideally, Phase I deliverables should include:

Research, identification and evaluation of candidate technologies or concepts for systems and components fault detection, isolation and recovery, fault prediction and diagnosis, and decision-making algorithms for control to enable autonomy of ground systems. Demonstration of the technical feasibility and show a path towards a demonstration. Concept methodology should include the path for adaptation of the technology, infusion strategies (including risk trades), and business model. It should identify improvements over the current state of the art for both operations and systems development and the feasibility of the approach in a multi-customer environment. Bench or lab-level demonstrations are desirable. Deliverables must include a report documenting findings.

Ideally, Phase II deliverables shall:

Place an emphasis on developing, prototyping and demonstrating the technology under simulated operational conditions using analog earth-based systems including dynamic events such as commodity loading, disconnect or engine testing. Deliverables shall include a report outlining the path showing how the technology could be matured and applied to mission-worthy systems, functional and performance test results and other associated documentation. Deliverable of a functional prototype (software and hardware) is expected at the completion of the Phase II effort. The technology concept at the end of Phase II should be at a Technology Readiness Level (TRL) of 6 or higher.

In addition to reducing O&M costs in ground operations, this subtopic provides NASA's Human Exploration & Operations Mission Directorate (HEOMD) with an on-ramp for technologies that enable the unattended setup, operation, and maintenance of ground systems and systems on the surfaces of other planets and moons. These types of technology developments are identified in the NASA Strategic Technology Area (TA) roadmaps, published by the Office of the Chief Technologist (OCT), under TA4: Robotics and Autonomous Systems and TA13: Ground and Launch Systems. This subtopic produces technologies which will also be of use to NASA's Space Technology Mission Directorate (STMD). Autonomous strategies have crosscutting value in other applications and with other mission directorates.

References:

- NASA OCT webpage: https://www.nasa.gov/offices/oct/home/index.html
- 2017 NASA Strategic Space Technology Investment Plan (STIP), found at NASA's OCT webpage: https://www.nasa.gov/offices/oct/feature/nasa-releases-2017-nasa-strategic-technology-investment-plan
- NASA Technology Roadmaps, found within NASA's OCT, are a set of documents that consider a wide range of needed technology candidates and development pathways for the next 20 years (2015-2035). Roadmaps are found at: https://www.nasa.gov/offices/oct/home/roadmaps/index.html. Of special interest are the following Roadmaps:
    - Technology Area TA4: Robotics and Autonomous Systems
    - Technology Area TA13: Ground and Launch Systems
    - Technology Area TA11: Modeling, Simulation, Information Technology and Processing