NASA STTR 2020 Phase I Solicitation

T4.04 Autonomous Systems and Operations for the Lunar Orbital Platform-Gateway

Lead Center: ARC

Participating Center(s): JSC, KSC, SSC

Technology Area: TA11 Modeling, Simulation, Information Technology and Processing

Scope Title

Artificial Intelligence for the Lunar Orbital Platform-Gateway

Scope Description

The Gateway is a planned lunar-orbit spacecraft that will have a power and propulsion system, a small habitat for the crew, a docking capability, an airlock and logistics modules. The Gateway is expected to serve as an intermediate way station between the Orion crew capsule and lunar landers as well as a platform for both crewed and un-crewed experiments. The Gateway is also intended to test technologies and operational procedures for suitability on long-duration space missions such as a mission to Mars. As such, it will require new technologies such as autonomous systems to run scientific experiments onboard, including biological experiments; perform system health management, including caution and warning; autonomous data management and other functions. In contrast to the International Space Station, Gateway is much more representative of lunar and deep-space missions---for example, the radiation environment.

This subtopic solicits autonomy, artificial intelligence and machine learning technologies to manage and operate engineered systems to facilitate long-duration space missions, with the goal of testing proposed technologies on Gateway. The current concept of operations for Gateway anticipates un-crewed (dormant) periods of up to nine months. Technologies need to be capable of or enable long-term, mostly unsupervised, autonomous operation. While crew are present, technologies need to augment the crew's abilities and allow more autonomy from Earth-based Mission Control. Additionally, the technologies may need to allow for coordination with the Orion crew capsule, lunar landers, Earth and their various systems and subsystems.

Examples of needs include but are not limited to:

1. Autonomous operations and tending of science payloads including environmental monitoring and support for live biological samples, and in-situ automated analysis of science experiments.
2. Prioritizing data for transmission from the Gateway. Given communications limitations, it may be necessary to determine what data can be stored for transmission when greater bandwidth is available, and what data can be eliminated as it will turn out to be useless, based on criteria relevant to the conduct of science and/or maintenance of the physical assets. Alternatively, it may be useful to adaptively compress data for transmission from the Gateway, which could include scientific experiment data and status, voice communications, scientific experiment data and status, and/or systems health management data.

3. Autonomous operations and health management of the Gateway. When Gateway is unoccupied, unexpected events or faults may require immediate autonomous detection and response, demonstrating this capability in the absence of support from Mission Control (which is enabling for future Mars missions and time-critical responses in lunar environment as well). Efforts to develop smart habitats will allow long-term human presence on the moon and Mars, such as the Space Technology Research Institutes (https://www.nasa.gov/press-release/nasa-selects-two-new-space-tech-research-institutes-for-smart-habitats) are relevant.

References

Basic Moon to Mars Background: https://www.nasa.gov/topics/moon-to-mars/lunar-outpost

Basic Gateway Background: https://www.nasa.gov/topics/moon-to-mars/lunar-gateway

Crusan, J. C.; Smith, R. M.; Craig, D. A.; Caram, J. M.; Guidi, J.; Gates, M.; Krezel, J. M.; and Herrmann, N. 2018. Deep Space Gateway concept: Extending human presence into cislunar space. In *Proceedings of the IEEE Aerospace Conference*.

Autonomous Biological Systems (ABS) Experiments
https://www.jstage.jst.go.jp/article/bss/12/4/12_4_363/_pdf/-char/en

Deep Space Gateway Science Opportunities
https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20180001581.pdf

Conducting Autonomous Experiments in Space
https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20180004314.pdf

Expected TRL or TRL range at completion of the project: 2 to 6

Desired Deliverables of Phase II

Prototype, Analysis, Software, Hardware, Research

Desired Deliverables Description

The deliverables range from research results to prototypes demonstrating various ways that autonomy and artificial intelligence (e.g., automated reasoning, machine learning, and discrete control) can be applied to aspects of Gateway operations and health management individually and/or jointly. As one example, for autonomous biological science experiments, the prototype could include hardware to host live samples for a minimum of 30 days that provide monitoring and environmental maintenance, as well as software to autonomously remedy issues with live science experiments. As another example, software that monitors the gateway habitat while un-crewed, automatically notifies of any off-nominal conditions, and then, when crew arrive, transitions the gateway from quiescent status to a status capable of providing the crew with life support. As another example, machine learning from the data stream of Gateway sensors to determine anomalous vs. nominal conditions and prioritize and compress data communications to Earth.

Phase 1 deliverables minimally include a detailed concept for autonomy technology to support Gateway operations such as experiments. Prototypes of software and/or hardware are strongly encouraged. Phase 2 deliverables will be full technology prototypes that could be subsequently matured for deployment on Gateway. Coordination with related efforts, such as the Space Technology Research Institutes (https://www.nasa.gov/press-release/nasa-selects-two-new-space-tech-research-institutes-for-smart-habitats) is expected to eliminate redundancy of effort and allow appropriate interactions between Gateway and smart habitats.

State of the Art and Critical Gaps

The current state-of-the-art in human spaceflight allows for autonomous operations of systems of relatively limited scope, involving only a fixed level of autonomy (e.g., amount of human involvement needed), and learning at most one type of function (e.g., navigation). The Gateway will require all operations and health management to be autonomous at different levels (almost fully autonomous when no astronauts are on board vs. limited autonomy

when astronauts are present), will require the autonomy to learn from human operations, and will require autonomy across all functions. The autonomy will also need to adapt to new missions and new technologies.

As NASA continues to expand with the eventual goal of Mars missions, the need for autonomous tending of science payloads will grow substantially. In order to address the primary health concerns for crew on these missions, it is necessary to conduct science in the most relevant environment. Acquisition of this type of data will be challenging while the gateway and Artemis missions are being performed due to limited crewed missions and limited crew time.

Relevance / Science Traceability

Gateway and other space station-like assets in the future will need: The ability to learn autonomous operations from human operations which will be critical as the assets are expected to operate increasingly autonomously due to increasing duration space missions such as missions to Mars.