NASA SBIR 2017 Phase I Solicitation

H6.01   Integrated System Health Management for Sustainable Habitats

Lead Center: ARC

Participating Center(s): JSC, MSFC

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

Habitation systems provide a safe place for astronauts to live and work in space and on planetary surfaces. They enable crews to live and work safely in deep space, and include integrated life support systems, radiation protection, fire safety, and systems to reduce logistics and the need for resupply missions. Innovative health management technologies are needed in order to increase the safety and mission-effectiveness for future space habitats on other planets, asteroids, or lunar surfaces. For example, off-nominal or failure conditions occurring in safety-critical life support systems may need to be addressed quickly by the habitat crew without extensive technical support from Earth due to communication delays. If the crew in the habitat must manage, plan and operate much of the mission themselves, operations support must be migrated from Earth to the habitat. Enabling monitoring, tracking, and management capabilities on-board the habitat and related EVA platforms for a small crew to use will require significant automation and decision support software.

This subtopic seeks to broaden the scope of traditional caution and warning systems, which are typically triggered by out-of-bounds sensor values, by including machine learning and data mining techniques. These methods aim to reveal latent, unknown conditions while still retaining and improving the ability to provide highly accurate alerts for known issues. The performance targets for known faults and failures will be based upon false alarm rate, missed detection rate, and detection time (first time prior to the adverse event that the algorithm indicates an impending fault/failure). Methods should explore the trade space for ISHM data and processing needs in order to provide guidance for future habitat sensor and computational resource requirements.

Proposals may address specific system health management capabilities required for habitat system elements (life support systems, etc.). In addition, projects may focus on one or more relevant subsystems such as water recycling systems, photovoltaic systems, electrical power systems, and environmental monitoring systems. Proposals that involve the use of existing testbeds or facilities at one of the participating NASA centers (e.g., Sustainability Base at ARC) for technology validation, verification, and maturation are strongly encouraged. Technology Readiness Levels (TRL) of 4 to 6 or higher are sought.

Key features of Sustainability Base that make it relevant to deep space habitat technology are its use of a grey water recycling system and a photo-voltaic array. Data logged from other facility management/building automation systems include environmental data (temp, CO_2, etc.) and facility equipment sensors (flowrates, differential pressures, temperatures, etc.). Also, information on power consumption (whole building, plug load, other loads metered at the panel/circuit level) can be made available. These remaining systems, while conventionally "green," have no unique feature that can't be exclusively used for terrestrial purposes. However, the fact that all such systems require less power to support human occupancy can be used as a focal point to serve as a testbed for deep space habitats that will need to operate within finite energy budgets.

Specific technical areas of interest related to integrated systems health management include the following:

- Machine learning and data mining techniques that are capable of learning from operations data to identify statistical anomalies that may represent previously unknown system degradations. Methods should facilitate the incorporation of human feedback on the operational significance of the statistical anomalies using techniques such as active learning.
- Demonstration of advanced predictive capability using machine learning or data mining methods for known system fault or failure modes, within prescribed performance constraints related to detection time and accuracy.
- Prognostic techniques able to predict system degradation, leading to system robustness through automated fault mitigation and improved operational effectiveness. Proposals in this area should focus on systems and components commonly found in space habitats or EVA platforms.
- Innovative human-system integration methods that can convey a wealth of health and status information to mission support staff quickly and effectively, especially under off-nominal and emergency conditions.

Proposals that address lower TRL research on the foundational principles of sustainable technologies and systems involving academic partnerships should consider responding to STTR subtopic T6.01 - Closed-Loop Living System for Deep Space ECLSS with Immediate Applications for Sustainable Planet. Proposals that address bio-manufacturing research may also consider the STTR subtopic T7.01 - Advanced Bioreactor Development for in-situ Microbial Manufacturing. For integrated system health management and monitoring capabilities that support these systems, respondents are encouraged to consider the currently listed subtopic - H6.01 - Integrated System Health Management for Sustainable Habitats.