NASA SBIR 2019 Phase I Solicitation

H6.01 Integrated Systems Health Management for Sustainable Habitats

Lead Center: ARC

Participating Center(s): MSFC

Technology Area: TA6 Human Health, Life Support and Habitation Systems

Novel Machine Learning Concepts for Automated Space Habitats

Methods and tools are needed that can adapt to novel, but benign configuration changes on space habitat environmental control and life support systems. They should automatically learn how to make the distinction between these nominal conditions that should not be reported and abnormal conditions that need to be reported. Where reports are needed, these are ideally delivered early to provide ample time for the system (or operators) to react to either prevent an impending fault or to prepare to take mitigating action.

Furthermore, proposed tools and techniques should be capable of carrying out adaptation and selection of conditions that need to be reported in an automated way. These tools should have the capability to:

- Recognize acceptable changes.
- Extract relevant features.
- Establish novel threshold conditions upon which to act, either in the parameter space or probabilistically.

Methods based upon machine learning and data mining should aim to reveal latent, unknown conditions while still retaining and improving the ability to provide highly accurate alerts for known issues. However, it is recognized that the cataloguing and selection of threshold parameters to characterize abnormal conditions for known issues is a daunting task, regardless of which space they are represented in. For any given representation, such limit checks are still vulnerable to false positives (incorrectly calling a fault) as well as false negatives (missing the occurrence of a fault). Both of these types of errors need to be managed and minimized to acceptable levels while also keeping the early warning metric in mind. As such, mechanisms are needed to assure that these techniques will perform as desired relative to these metrics. For the techniques proposed, the performance targets for known faults and failures will be based upon the following specified performance metrics:

- False alarm rate.
- Missed detection rate.
- Detection time (first time prior to the adverse event that the algorithm indicates an impending fault/failure).

Methods should also explore the trade space for Integrated Systems Health Management 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 the ones previously

described. The Sustainability Base is a green building test-bed whose requirements, as a low-power and low-consumable habitat, are included in those for deep space habitats. Data available includes photo-voltaic array, electrical power, grey water recycling, environmental data (temp, CO_2, etc.) and facility equipment sensors (flowrates, differential pressures, temperatures, etc.). There is also the possibility that data from deep space habitat laboratories and prototypes might become available. 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.

Deliverables are expected in the Technology Readiness Levels (TRL) range of of 4-6 or higher and ideally include working integrated software framework capable of direct compatibility with existing programmatic tools by the end of Phase II.

References:

- https://www.nasa.gov/feature/nasa-s-lunar-outpost-will-extend-human-presence-in-deep-space
- The solution should be able to interface with software by employing the tools at the links provided below, to enable compatible programmatic interfaces:
    - https://cfs.gsfc.nasa.gov/
    - https://github.com/nasa/trick