X1.04 Integrated System Health Management

Lead Center: ARC

Participating Center(s): JPL, KSC, MSFC

Innovative health management technologies are needed throughout NASA's Constellation architecture in order to increase the safety and mission-effectiveness of future spacecraft and launch vehicles. In human space flight, a significant concern for NASA is the safety of ground and flight crews under off-nominal or failure conditions. The new Ares Crew Launch Vehicle will provide the means to abort the crew using a launch abort system. In case of a catastrophic failure during launch or ascent, the decision to abort the crew needs to be made within a very brief timeframe and with high certainty: either false positive or false negative crew abort indications carry a large safety and cost burden. Furthermore, the Constellation architecture allows for fully-automated crew abort under certain circumstances, increasing the accuracy and sensitivity requirements on the system health management function for the Ares launch vehicle and the Orion crew capsule.

There are other health and status requirements beyond launch and ascent. Traditional means of verifying space system health and status, such as caution and warning systems that are triggered by off-nominal sensor values are rather limited in their utility. In addition to issues such as sensor failures and false alarms, redline-triggered caution and warning events are difficult to interpret, often requiring involvement of large numbers of mission support staff to isolate a failure and initiate a recovery procedure. Health and status methods that depend on support from the ground are likely to become a safety liability as communication delays or bottlenecks increase (e.g., lunar trips). Under these circumstances, autonomous and automated solutions to systems health management provide the best means of increasing crew safety and mission success probability for future space exploration missions. For deployment on human missions, health management systems must be treated as Class A human-rated systems as defined by NASA procedural requirements (NPR 7150.2) and must undergo formal verification and validation.

Future ground operations will require quick and efficient turnaround and processing of spacecraft for launch. In addition, new operations concepts must be developed to provide a high level of safety and mission assurance while reducing ground processing and mission support staff. New methods driven by health management innovation may be used to curtail system lifecycle costs through more cost-effective inspection and certification of flight systems, as well as more cost-effective management of ground and mission operations.

Proposals should be responsive to the overall goals and objectives of NASA's Constellation and Lunar Precursors and Robotics Programs. Proposals may address specific vehicle health management capabilities required for exploration system elements (crewed spacecraft, launch systems, habitats, rovers, etc.). In addition, projects may focus on one or more relevant subsystems such as solid rocket motors, liquid propulsion systems, structures and
mechanisms, thermal protection systems, power, avionics, life support, and communications. Proposals that involve the use of existing testbeds or facilities at one of the participating NASA centers (ARC, MSFC, KSC, or JPL) for technology validation and maturation are strongly encouraged.

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

- Methods and tools to enable early-stage design of health management functionality during the development of space systems. These methods and tools should provide a means to optimize health management system design at the functional level to decide on failure detection methods, sensor types and locations, and identify additional functionality to safeguard against failures before costly design decisions have been made.

- Innovative methods for sensor validation and robust state estimation in the presence of inherently unreliable sensors. Proposals should focus on data analysis and interpretation using legacy sensors rather than development of new sensors or sensor systems.

- Model-based methods for fault detection and isolation in rocket propulsion systems based on existing sensor suites during pre-launch propellant loading and during mission operations.

- Concepts for advanced built-in-tests for spacecraft avionics that reduce or eliminate the need for extensive functional verification and to predict remaining life of avionics systems based on usage history.

- Methods for robust control of critical components, subsystems, and systems and robust execution of critical sequences during launch operations or flight. Of special interest are robust recovery methods and innovative approaches to functional redundancy for the purpose of enhancing safety, availability, and maintainability.

- Prognostic techniques able to anticipate system degradation and enable further improvements in mission success probability, operational effectiveness, and automated recovery of function. Proposals in this area should focus on systems and components commonly found in spacecraft.

- Innovative human-system integration methods that can convey a wealth of health and status information to flight crews, ground and mission support staff quickly and effectively, especially under off-nominal and emergency conditions.

- Verification and validation techniques for advanced fault detection and prognostic capabilities leading to certification for use in human rated critical systems in a cost-effective manner.

- Innovative approaches to effective utilization of health information from NASA spacecraft and launch vehicles with seamless integration to ground based systems using commercial health information from programmable logic controller systems and commercial Reliability, Availability and Serviceability (RAS) systems.