NASA SBIR 2009 Phase I Solicitation

X1 Avionics and Software

The Exploration Technology Development Program (ETDP) leads the Agency in the development of advanced avionics, software and information technology capabilities and research for the Exploration Systems Mission Directorate. The Avionics and Software elements perform mission-driven research and development to enable new system functionality, reduce risk, and enhance the capability for NASA's exploration missions. NASA's focus has clarified around Exploration, and the agency's expertise and capabilities are being called upon to support these missions. The Ares Launch Vehicle, the Orion Crew Exploration Vehicle (CEV), the Altair Lunar Lander, and future lunar surface systems will each require unique advances in avionic and software technologies such as integrated systems health management, autonomous systems for the crew and mission operations, radiation hardened processing, and reliable, dependable software. Exploration requires the best of the nation's technical community to step up to providing the technologies, engineering, and systems to regain the frontiers of the Moon, to extend our reach to Mars, and to explore the beyond.

Subtopics

X1.01 Automation for Vehicle Habitat Operations

Lead Center: ARC

Participating Center(s): JPL, JSC

Automation will be instrumental for decreasing workload, reducing dependence on Earth-based support staff, enhancing response time, and releasing crew and operators from routine tasks to focus on those requiring human judgment, leading to increased efficiency and reduced mission risk. To enable the application of intelligent automation and autonomy techniques, the technologies need to address two significant challenges: adaptability and software validation. Proposals are solicited in the areas of:

- **Automation Support Tools**: Support tools are needed to facilitate the authoring and validation of plans and execution scripts. Tools that are not tied specifically to one executive would provide NASA the most flexibility.Examples include: Graphical tool for monitoring and debugging plan execution and for creating and editing execution scripts; Tools for authoring and validating execution plans; User friendly abstraction of low-level execution languages by adding syntactic enhancements.

- **Decision Support**: Systems Decision support systems amplify the efficiency of operators by providing the information they need when and where they need it. Examples: Command and supervise complex tasks while projecting the outcome and identify potential problems; Understand system state, including visualization and summarization; Allow the system to interact with a user when generating the plan and allow evaluation of alternate courses of action; Integration of a planning and scheduling system as part of an on-board, closed loop controller.

- **Trustable Systems**: Systems that support or interact with crew require a very high level of reliability. Tools are needed that improve the reliability and trustworthiness of autonomous systems.These include: Ability to predict what the system will do; Guarantees of behavioral properties; Other properties that increase the operator's trust; Verifiability (e.g., restricted executive languages that facilitate model-based verification).

X1.02 Reliable Software for Exploration Systems

Lead Center: ARC

Participating Center(s): JPL, LaRC

This subtopic seeks to develop software engineering technologies that enable engineers to cost-effectively develop and maintain NASA mission-critical software systems. Particular emphasis will be on software engineering technologies applicable to the high levels of reliability needed for human-rated space vehicles. A key requirement is that proposals address the usability of software engineering technologies by NASA (including contractors) and not specialists. In addition to traditional capabilities, such as GNC (guidance, navigation, and control) or C&DH (command and data handling), new capabilities are under development: integrated vehicle health management, autonomous vehicle-centered operations, automated mission operations, and further out - mixed human-robotic teams to accomplish mission objectives. Mission phases that can be addressed include not only the software life-cycle (requirement engineering through verification and validation) but also upstream activities (e.g., mission planning that incorporates trade-space for software-based capabilities) and post-deployment (e.g., new approaches for computing fault tolerance, rapid reconfiguration, and certification of mission-critical software systems). Specific software engineering tools and methods are sought in the following areas:

- Automated software generation methods from engineering models that are highly reliable;

- Scalable verification technology for complex mission software, e.g., model-checking technology that addresses the 'state explosion' problem and static-analysis technology that addresses mission-critical properties at the system level;

- Automated testing that ensures coverage targeted both at the system level and software level, such as model-based testing where test-case generation and test monitoring are done automatically from system-level models;

- Technology for calibrating software-based simulators against high-fidelity hardware-in-the-loop test-beds to achieve dependable test coverage;

- Technology for verifying and validating autonomy capabilities including intelligent execution systems, model-based diagnosis, and Integrated Systems Health Management (ISHM);

- Methods and tools for development and validation of autonomic software systems (systems that are self protecting and self healing).

X1.03 Radiation Hardened/Tolerant and Low Temperature Electronics and Processors

Lead Center: LaRC

Participating Center(s): GSFC, JPL, MSFC

Constellation projects that are designed to leave low-earth orbit (Orion, Ares V Earth Departure Stage, Altair, Lunar Surface Systems, EVA suits, etc.) require avionic systems, components, and controllers that are capable of operating in the extreme temperature and radiation environments of deep space, the lunar surface, and eventually the Martian surface. Spacecraft vehicle electronics will be required to operate across a wide temperature range and must be capable of enduring frequent (and often rapid) thermal-cycling. Packaging for these electronics must be able to accommodate the mechanical stress and fatigue associated with the thermal cycling. Spacecraft vehicle electronics must be radiation hardened for the target environment. They must be capable of operating through a minimum total ionizing dose (TID) of 100 krads (Si) or more and providing single-event latchup immunity (SEL) of 100 MeV cm^2/mg or more.

Considering the extreme environment performance parameters for thermal and radiation extremes, proposals are sought in the following specific areas:

- Low power, high efficiency, radiation-hardened processor technologies;
- Field Programmable Gate Array (FPGA) technologies;
- Innovative radiation hardened volatile and nonvolatile memory technologies;
- Tightly-integrated electronic sensor and actuator modules that include power, command and control, and processing;
- Radiation-hardened analog application specific integrated circuits (ASICs) for spacecraft power management;
- Radiation-hardened DC-to-DC converters and point-of-load power distribution circuits;
- Computer Aided Design (CAD) tools for predicting the electrical performance, reliability, and life cycle for low-temperature and wide-temperature electronic systems and components;
- Physics-based device models valid at temperature ranging from -230Â°C to +130Â°C to enable design, verification and fabrication of custom mixed-signal and analog circuits;
- Circuit design and layout methodologies/techniques that facilitate improved radiation hardness and low-temperature (-230Â°C) analog and mixed-signal circuit performance;
- Packaging capable of surviving numerous thermal cycles and tolerant of the extreme temperatures on the Moon and Mars, which includes the use of appropriate materials including substrates, die-attach, encapsulants, thermal compounds, etc.

X1.04 Integrated System Health Management for Ground Operations

Lead Center: ARC

Participating Center(s): JPL, JSC, KSC, MSFC, SSC

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 within a very brief timeframe and with high certainty. Health management is essential for dormant periods between human habitation, and for transition of assets (such as lunar habitats) to crewed operations. In addition, the long-duration health of software systems themselves are also critical. 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, communications, and software. Proposals that involve the use of existing testbeds or facilities at NASA are strongly encouraged. Specific technical areas of interest are methods and tools for:

- Early-stage design of health management functionality during the development of space systems, including failure detection methods, sensor types and locations that enable fault detection to line replaceable units.
- Sensor validation and robust state estimation in the presence of inherently unreliable sensors. Focus on data analysis and interpretation using legacy sensors.
- Model-based fault detection and isolation in rocket propulsion systems based on existing sensor suites during pre-launch and flight mission operations that enables fault detection within time ranges to allow mission abort.
- Automatic construction of models used in model-based diagnostic strategies, limiting model construction times to 60% of the time required using manual methods.
- Advanced built-in-tests for spacecraft avionics that provide 95% functional coverage and reduce or eliminate the need for extensive functional verification and to predict remaining life of avionics systems.
- Prognostic techniques able to anticipate system degradation before loss of critical functions and enable further improvements in mission success probability, operational effectiveness, and automated recovery of function.
- Approaches for effective utilization of 100% of the health information on critical functions from spacecraft and launch vehicles with integration to ground based systems using commercial health information from programmable logic controller and RAS system.
- Techniques that address the particular constraints of maintaining long-duration systems health of structures, mechanical parts, electronics, and software systems on lunar surfaces are of special interest.