NASA SBIR 2008 Phase I Solicitation

X1 Avionics and Software

Exploration Technology Development Program (ETDP) leads the Agency in the development of advanced avionics, software and information technology capabilities and research for Exploration Systems. 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. NASAâ€™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.Â

Subtopics

X1.01 Automation for Vehicle and Habitat Operations

Lead Center: ARC

Participating Center(s): JPL

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. Reusable automation software must be adaptable to new applications without undue difficulty, and easily adjusted as the application operations change. The software and the adaptation to a given application must also be trusted before it can be accepted. 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 in applying such tools across projects. Examples of needed capabilities include:

- Graphical tool for monitoring and debugging plan execution;
- Graphical tool 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. Decision support tools are needed that:

- Command and supervise complex tasks while projecting the outcome of actions 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;
- Integrate a planning and scheduling system as part of an on-board, closed loop controller;
- Scale up existing techniques to larger problem applications.

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, JSC, LaRC

The objective of this subtopic is 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 engineers, and not only specialists in the technology.

Many of the capabilities needed for successful human exploration of space will rely on software. 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. It will be challenging, but critical to NASA's exploration objectives to ensure that these capabilities are reliable and can be developed and maintained affordably. 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).

Software engineering tools and methods that address reliability for exploration missions are sought, including:

- Automated software generation methods from engineering models that ensure integrity; for example,

methods ensuring semantic equivalence between UML models and generated code, generated code optimizations that preserve semantics, and tools that provide navigable two-way traceability from models to code.
- Methods for ensuring safe modification and updates to existing code.
- Scalable verification technologies for complex mission software.
- Automated testing technology that ensures coverage targeted both at the system level and software level.
- Technology for calibrating software-based simulators and testbeds against high-fidelity hardware-in-the-loop testbeds in order to achieve dependable test coverage.
- Cost-effective architectures and methods for software fault tolerance for real-time mission-critical applications.

This subtopic also collaborates with the Small Spacecraft Build effort highlighted in Topic S4 (Low-Cost Small Spacecraft and Technologies). Respondents are encouraged to consider a possible flight opportunity for their proposed work under small spacecraft in addition to considering Exploration customers.

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

Lead Center: LaRC

Participating Center(s): GSFC, MSFC

The goal of leaving low Earth orbit for the purpose of human and robotic exploration will require avionic systems and components 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 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 optimized for numerically intensive algorithms and applications, capable of a sustained processor throughput of 5 GMACS for 16-bit operations and a sustained processor efficiency of 5 GMACS/W.
- Field Programmable Gate Array technologies providing reliable reprogrammable capabilities that are radiation hardened by design and/or radiation hardened by process.
- Innovative radiation hardened volatile and nonvolatile memory technologies.
- Packaging capable of surviving numerous thermal cycles and tolerant of the extreme temperatures on the Moon and Mars. This 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, KSC, MSFC, SSC

Innovative health management technologies are needed throughout NASAâ€™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 stringent launch availability requirements of the Constellation Program challenge traditional vehicle processing and launch operations. Some of the challenges for the new architecture include optimization of sensors (placement, physical and functional redundancy, weight and cost), validation of inherently unreliable sensors, increasing the effective capability for state determination using innovative analysis algorithms, and integration of sensor information distributed across ground support equipment and the vehicles in multiple processing locations and phases. Diagnostic and prognostic analyses which provide an accurate assessment of system and component health will ensure the completion of complex launch processing flows on schedule. 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:

- Innovative methods for sensor validation and robust state estimation in the presence of inherently unreliable sensors. Proposals should focus on data analysis and interpretation during pre-flight checkout 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.
- 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 pre-flight check-out crews, ground operations and mission support staff quickly and effectively, especially under off-nominal and emergency conditions.
- 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.

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