NASA SBIR 2011 Phase I Solicitation

X6 Autonomous Systems and Avionics

NASA invests in the development of autonomy and automation software, advanced avionics, integrated system health management, and robust software technology capabilities for the purpose of enabling complex missions and technology demonstrations. The software and avionics elements requested within this topic are critical to enhancing flight system functionality, reducing system vulnerability to extreme radiation and thermal environments, reducing system risk, and increasing autonomy and system reliability through processes, operations, and system management. As a game-changing and cross-cutting technology area, autonomous software and avionics are applicable to broad areas of technology emphasis, including heavy lift launch vehicle technologies, robotic precursor platforms, utilization of the International Space Station, and spacecraft technology demonstrations performed to enable long duration space missions. All of these flight applications will require unique advances in software technologies and avionics such as integrated systems health management, autonomous systems for the crew and mission operations, radiation hardened, multi-core processors, and reliable, dependable software. The exploration of space requires the best of the nation's technical community to step up to providing the technologies, engineering, and systems to explore the beyond LEO, visit asteroids and the Moon, and to extend our reach to Mars.

Subtopics

X6.01 Spacecraft Autonomy and Space Mission Automation

Lead Center: ARC

Participating Center(s): JPL, JSC

Future human spaceflight missions will place crews at large distances and light-time delays from Earth, requiring novel capabilities for crews and ground to manage spacecraft consumables such as power, water, propellant and life support systems to prevent Loss of Mission (LOM) or Loss of Crew (LOC). This capability is necessary to handle events such as leaks or failures leading to unexpected expenditure of consumables coupled with lack of communications. If crews in the spacecraft must manage, plan and operate much of the mission themselves, NASA must migrate operations functionality from the flight control room to the vehicle for use by the crew. Migrating flight controller tools and procedures to the crew on-board the spacecraft would, even if technically possible, overburden the crew. Enabling these same monitoring, tracking, and management capabilities on-board the spacecraft for a small crew to use will require significant automation and decision support software. Required capabilities to enable future human spaceflight to distant destinations include:

- Enable on-board crew management of vehicle consumables that are currently flight controller responsibilities.
- Increase the onboard capability to detect and respond to unexpected consumables-management related events and faults without dependence on ground.
- Reduce up-front and recurring software costs to produce flight-critical software.
- Provide more efficient and cost effective ground based operations through automation of consumables management processes, and up-front and recurring mission operations software costs.

The same capabilities for enabling human spaceflight missions are directly applicable to efforts to automate the operation of unmanned aircraft flying in the National Airspace (NAS) and robotic planetary explorers.

Mission Operations Automation

Peer-to-peer mission operations planning

Mixed initiative planning systems

Elicitation of mission planning constraints and preferences

Planning system software integration

Space Vehicle Automation

Autonomous rendezvous and docking software

Integrated discrete and continuous control software

Long-duration high-reliability autonomous system

Power aware computing

Robotic Systems Automation

Mutli-agent autonomous systems for mapping

Uncertainty management for mapping system

Uncertainty management for grasping robotic system

Uncertainty management for path planning and traversing

Emphasis of proposed efforts:

- Software proposals only, but emphasize hardware and operating systems the proposed software will run on (e.g., processors, sensors).
- In-space or Terrestrial applications (e.g., UAV mission management) are acceptable.
- Proposals must demonstrate mission operations cost reduction by use of standards, open source software, staff reduction, and/or decrease of software integration costs.
- Proposals must demonstrate autonomy software cost reduction by use of standards, demonstration of capability especially on long-duration missions, system integration, and/or open source software.

X6.02 Radiation Hardened/Tolerant and Low Temperature Electronics and Processors

Lead Center: MSFC

Participating Center(s): GSFC, JPL

Exploration flight projects, robotic precursors, and technology demonstrators that are designed to operate beyond low-earth orbit require avionic systems, components, and controllers that are capable of enduring 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 300 krads (Si), provide fewer Single Event Upsets (SEUs) than 10-10 to 10-11errors/bit-day, and provide single event latchup (SEL) immunity at linear energy transfer (LET) levels of 100 MeV cm^2/mg (Si) or more. All three characteristics for radiation hardened electronics of TID, SEU and SEL are needed. Electronics hardened for thermal cycling and extreme temperature ranges should perform beyond the standard military specification range of -55Â°C to 125Â°C, running as low as -230Â°C or as high as 350Â°C.

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

- Low power, high efficiency, radiation-hardened processor technologies.
- Technologies and techniques for environmentally hardened Field Programmable Gate Array (FPGA).
- 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 and other applications.

- 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. This includes the use of appropriate materials including substrates, die-attach, encapsulants, thermal compounds, etc.

X6.03 Integrated System Health Management for Flexible Exploration

Lead Center: ARC

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

Novel integrated system health management technologies will enable NASAÂ’s pursuit of a more sustainable and affordable approach to spaceflight. New heavy lift launch systems will incorporate new engines, propellants, materials, and combustion processes and will increase NASAÂ’s capabilities and significantly lower operations costs. Health management is essential for the safe and reliable operation of these complex systems. Innovative health management technologies are also essential for long-duration robotic precursor missions. Projects may focus on one or more relevant subsystems such as rocket engines, liquid propulsion systems, structures and mechanisms, thermal protection systems, power, avionics, life support, communications, and software. 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 based on existing sensor suites 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.

- 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.

- Techniques that address the particular constraints of maintaining long-duration systems health of structures, mechanical parts, electronics, and software systems are also of interest.