This SBIR Topic seeks innovative concepts for technologies that will reduce life-cycle mission costs by providing high-confidence design of onboard autonomy, including safe and reliable human autonomy interaction. NASA is preparing for human-robotic exploration of the Moon and Mars. Traditional means of providing system information, such as inspections and preventive maintenance, have limited utility for exploration missions. Other solutions, such as telemetry data, become less useful as communication bandwidth shrinks and communication delays increase. Under these circumstances, increasing the autonomy of the onboard systems provides the best means of managing system operations. Autonomous onboard system technologies involve the use of goal-oriented operations, requiring means for sensing the environment and making intelligent choices with regard to resources, procedures, health and safety, logistics, and configuration. The Software, Intelligent Systems and Modeling (SISM) Element program will develop and test reliable software, autonomous and human-robotic systems, and model-based methods for design, analysis, and operations. SISM is being formulated in collaboration with several ESRT Technology Maturation Program elements (for example, Advanced Space Operations, Lunar and Planetary Surface Operations, and Advanced Space Platforms and Systems), as well as the Human-Systems Integration Program in HSRT. In addition, this Element Program is cognizant of on-going FY04 SBIR tasks in related areas, such as advanced modeling and simulation. To focus the role of this SBIR Topic within the overall scope of SISM, there will be an emphasis on concepts that reduce life-cycle costs by increasing the usability of key classes of advanced design methods and tools. The key classes of methods and tools are defined by the two subtopics, Software Engineering (X5.01) and Human-Autonomy Interaction (X5.02). These kinds of design and test technologies have made great advances during the past ten years, but the usability of the technologies, and therefore their actual impact, has lagged behind their potential impact.

Subtopics

X5.01 Software Engineering

Lead Center: ARC

Participating Center(s): GSFC, JSC

The objective of this subtopic is to bring to fruition 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 for sustaining engineering: achieving affordable reliability over successive spirals of mission software development, maintenance, and upgrades for Crew Exploration Vehicle and Project Constellation. A key requirement is that projects address the usability of software engineering technologies by NASA (including NASA contractors) engineers, and not only specialists.
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 mixed human-robotic teams to accomplish mission objectives. These capabilities will be needed in exploration spirals 2 and 3, including the extended lunar missions. Ensuring that these capabilities are reliable and can be developed and maintained affordably, will be challenging but critical to both the lunar missions and the subsequent Martian missions. Proposals should clearly indicate how the technology is expected to address the challenge of reliability and affordability. 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., simulation-based acquisition for software capabilities; mission planning that incorporates trade-space development of 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. Projects can address technology development and maturation that provide for the following and related capabilities:

- Software-based radiation fault tolerance for computation;
- Methods and tools for development and validation of autonomic software systems (systems that are self protecting and self healing);
- 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 and test-beds against high-fidelity hardware-in-the-loop test-beds in order to achieve dependable test coverage; and
- Technology for verifying and validating autonomy capabilities including intelligent execution systems, model-based diagnosis, and adaptive control.

A requirement for a sustainable and affordable human exploration presence in space is the need for modular, reusable elements and subsystems. Major subsystems (e.g., integrated vehicle health management) will present challenges in terms of software-based reconfigurability needed over a long sequence of missions. Projects can address technology development and maturation that provide for the following and related capabilities:

- Software reuse for mission-critical, real-time applications;
- Architectures that facilitate reconfiguration with upgraded components;
- Affordable verification, validation, and certification of upgraded components and sub-systems within a
system (or system-of-systems) context;

- Intelligent management of software assets;
- Middleware that enables software platforms to migrate to new hardware platforms (e.g., middleware that enables command and control software to be transparently ported to distributed grid and cluster computer platforms).

X5.02 Human Autonomy Interaction

Lead Center: JSC
Participating Center(s): ARC, GSFC

Autonomous and automated operations will be required for systems fulfilling the Vision for Space Exploration. This subtopic addresses the need for modeling and analysis tools and technologies for design, test, and evaluation of human-autonomy interaction systems. The tools will support analyses of scenarios, tasks, information, and communication. They can validate and build confidence in human-autonomy interfaces and interaction support by identifying and mitigating risks (e.g., workload, situational awareness, and error). The technologies will interoperate with models and tools for design, evaluation, and certification of hardware and software systems, and will support understanding by engineers and planners who are not experts in human-system design or human factors. They will be cost-effective to use and be easily updated and reconfigured to reflect changes in designs and plans.

The human-autonomy modeling and analysis technology will be applied to astronaut crew-autonomy and ground-crew-autonomy interactions in space missions. Autonomous systems can include exploration vehicles and subsystems, science stations, robots, robotic manipulators, rovers, and communications satellites. Autonomous operations can include rendezvous, proximity operations, mating of on-orbit elements, in-space assembly, maintenance, and robotic operations, including inspection, material transport, and sampling. These operations can be nominal, off-nominal, or contingency operations. Autonomy will be essential to ensure safe robot operation in the proximity of critical systems and humans. Autonomous functions can include science traverse and path planning, crew and resource scheduling, procedure execution, and control of subsystems such as power, thermal, propulsion, and communications.

Innovative human-autonomy modeling and analysis technologies are needed to address unique challenges of space missions. These include multi-modal interfaces, asynchronous communication with long delays and long blackouts, unanticipated problems, and rare crew interactions by exception. Human-autonomy interactions can include supervisory control, communication, and coordination in shared planning and operations. They can include interactions to adapt, modify, and maintain systems to respond to emerging requirements and challenges. The interactions can also include dynamic control and adjustment of level of autonomy or supervision, type of coordination, and type of communication.

This subtopic seeks projects that will demonstrate innovative technologies for use by engineering and operations teams for analyzing human-autonomy interactions and risks and for evaluating proposed mitigations of these risks, within the constraints of an affordable and timely mission design and planning process.