This Topic covers a range of key technology options associated with future space exploration systems and architectures that are resilient, reliable, and reconfigurable through the use of miniaturization, modularization of key functions in novel systems approaches. Platforms technologies that support self-assembly and in-space assembly, as well as in-space maintenance and servicing, are included. These efforts are coordinated with in-space assembly and related R&D within the Advanced Space Operations Topic (e.g., involving extra-vehicular activity (EVA) systems, robotics, etc.).

Subtopics

X8.01 Vehicle Health Management Systems

Lead Center: ARC
Participating Center(s): JSC, MSFC, SSC

In order to meet the automation and autonomy requirements of the Vision for Space Exploration, innovative health management technologies are required throughout the system lifecycle including design, development, test, validation, integration, operation, maintenance, and disposition. Traditional means of supporting vehicle health such as invasive inspections are extremely limited in their utility for exploration missions. Other solutions such as ground-based monitoring of telemetry data become less useful as communication delays or bottlenecks increase. 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.

Another significant concern is in mission operations. Operations models that require large numbers of ground controllers and other mission support staff will be cost prohibitive in the future. Future systems must provide appropriate levels of safety and mission success factors while reducing support staff on the ground. In addition, future space missions will have to maintain a healthy balance and seamless transition between crewed and robotic operations.

Proposals should be responsive to the overall goals and objectives of the Exploration System-of-Systems as defined in Project Constellation requirements. 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 propulsion, structures, thermal protection...
systems, power, avionics, life support, and communications. Proposals that involve the use of existing NASA health management test beds (power, propulsion, systems integration, life support, diagnostics, networking, etc.) for technology validation are encouraged.

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

- Methods and tools to enable concurrent design of system function and health management 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;

- Health monitoring and management technologies to enable situational awareness of system health, safety, and margins. Solutions may include novel approaches to fault detection and isolation, diagnostics, and mitigation of system degradations and failures. Solutions may also include innovative health management system architectures that are robust to single point failures and are scalable, modular, and expandable without costly redesigns;

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

- System-of-systems health management concepts to provide robust cooperation of multiple Exploration elements, e.g., spacecraft constellations or rendezvous and docking operations;

- Prognostic techniques able to anticipate system degradation and enable further improvements in mission success probability, operational effectiveness, human-machine teaming, and automated recovery of function;

- Real-time data analysis methods for structural sensing, including detection, localization, damage assessment, and automated assessment of thermal protection system integrity;

- Crew-automation interfaces that are capable of reporting quantitative/qualitative sensor readings, assessing system status, explaining current conditions, predicting likely system behaviors, and proposing corrective actions in a manner that does not exceed the capacity of human understanding, especially in high-risk situations requiring rapid human response. Innovative ways for the health management system to convey a wealth of information quickly and effectively are desired; and

- End-to-end health management system architectures that are integrated with and validated on spacecraft subsystems on ground-based (or virtual) test beds.

**X8.02 Intelligent Modular Systems**

**Lead Center:** MSFC

**Participating Center(s):** GSFC, JSC

This subtopic will involve development and demonstration of a range of technologies for reconfigurable, intelligent, modular space subsystems, systems, and systems of systems. Technologies should focus on establishing the
validity of new approaches to Earth-Moon human and robotic operations, with a view toward longer-term applications for the inner Solar System (e.g., Mars) exploration missions. Many of these future missions, systems, and capabilities imply the need for the development of large and complex systems and infrastructures in space. But, the size-constraints, mass-capability, and cost of launching large monolithic payloads into space limit the development and realization of these capabilities. If a different design approach using intelligent modular systems rather than monolithic payloads is used, these large space systems become more tractable. Also, intelligent modular systems include low system impact of a single launch vehicle loss, since modular systems are launched on multiple vehicles at multiple times. Replacement of modules over the system lifetime is, in many cases, a more reasonable approach to maintaining a system; and, graceful degradation of the system capability can be more readily managed with modular units. Hardware costs of multiple identical units can be reduced through economies of scale, and modular approaches can accommodate cost-phased programs that develop and fly a “pilot” system, which can initially prove a capability, and then be added to later as demand for capability increases. Technologies of interest include:

**Modular Structures (MSFC)**

Structural technologies of interest include inflatable, erectable, deployable, or easily connected modules to create large space structures. Assembly technology of interest may include approaches for integrating deployable modular units with larger structures such as habitation modules or propellant tanks, and approaches for assembly of erectable modules that form backbones or support trusses. Attachment technologies such as autonomous rendezvous and docking, innovative connectors and joining, bonding techniques, and module positioning and alignment systems are also of interest.

**Adaptable and Reconfigurable Modular Systems (GSFC)**

Integrated, reconfigurable modular systems incorporating multiple elements such as solar collection arrays, radiators, power, data, utility lines, science instruments, plug and play avionics, and integrated inspection and verification techniques are solicited, including modular structures using embedded sensors and actuators.

**Human-Robotic Modular Systems (JSC)**

Multi-functional robotic hardware and software systems are of interest to aide in surface and in-space operations. Robotic surface operations including exploration, assembly, fabrication, construction and transportation operations are of interest as well as similar systems for in-space operations. In addition, techniques are solicited for effective, efficient, and intuitive operation and control of robotic hardware through design and development of advanced human-computer interfaces.