Advanced Extra Vehicular Activity (EVA) systems are necessary for the successful support of the International Space Station (ISS) beyond 2020 and future human space exploration missions. Advanced EVA systems include the space suit pressure garment, airlocks, the Portable Life Support System (PLSS), Avionics and Displays, and EVA Integrated Systems. Future human space exploration missions will require innovative approaches for maximizing human productivity and for providing the capability to perform useful tasks, such as assembling and servicing large in-space systems and exploring surfaces of the Moon, Mars, and small bodies. Top level requirements include reduction of system weight and volume, low or non-consuming systems, increased hardware reliability, durability, operating life, increased human comfort, and less restrictive work performance in the space environment. All proposed Phase I research must lead to specific Phase II experimental development that could be integrated into a functional EVA system.

Subtopics

X4.01 Space Suit Pressure Garment and Airlock Technologies
Lead Center: JSC
Participating Center(s): GRC

X4.02 Space Suit Life Support Systems
Lead Center: JSC
Participating Center(s): GRC
X4.03 Space Suit Radio, Displays, Cameras, and Integrated Systems

Lead Center: JSC
Participating Center(s): GRC

Tunable RF Front End and Transceiver

A major impetus behind the MEMS technology stems from compactness, which leads to lower power dissipation, higher levels of integration, lower weight, volume, and cost. To shrink form factor and enable efficient surface operations, one of the cornerstone components of this radio is the tunable filter. Recent advances in RF MEMs filters and resonator technology have permitted very high quality factors (>1000) at GHz frequencies. Achieving high and excellent tuning range (>2:1) to bandwidth ratio without cryogenic cooling is now viable for the S-band frequency. For reliability, the tunable filter should employ a contact-less tuning scheme.

Power-Aware Processing

To support Quality of Service (QoS) of different applications, it's inadequate to optimize power at design time, but dynamic power management must be employed to ensure power efficiency. To maximize power efficiency, the radio must be able to adjust power and update rates to suit for diverse missions. Users should have the ability to specify QoS for different data streams. The radio must have the capability to scale power, select optimum modes of operation, and minimum energy profiles. During low-rate-processing intensive modes, including local processing and compression of telemetry data and voice, highly energy-efficient low-voltage, low-performance modes must be used. For high-rate-processing intensive modes, like advance signal encoding of high definition imagery, medium performance modes must be used; and during active communication modes (which may have a low duty-cycle), ultra-high-performance modes must be used. Accordingly, the digital platform must be highly agile and use-case aware to continuously minimize energy. Below are some desirable features to consider:

Variation-Tolerant, Performance-Scalable Architectures

Hardware must sense its own limitation at a dynamically varying, performance-driven optimal energy operating point, and reconfigure accordingly. If variability is stressed at the low-voltage operating point, redundant hardware should be used to improve reliability; if throughput is stressed at the high-performance operating point, redundant hardware should be used to increase parallelism.

Energy-Aware Algorithms for Adaptive Hardware

Algorithms must be aware of the different hardware operating-points and associated architecture. For instance, during low-power modes targeting voice and data (for telemetry), occasional high through-put applications (like high-rate imagery) should dynamically switch to algorithms employing extreme parallelism in order to support a minimum operating voltage.

Modularity and Extensibility

Enabling platform must support open architecture and accommodate rapid upgrades, multiple protocols, new technology advances, complete re-configurability of functionality, and evolution of planetary communications and network infrastructure.

Phase I Deliverables: Given maximum range of 4km, telemetry, voice at 8 kbps, high definition imagery at 20 Mbps, and S-band frequency operating at 2.4 - 2.483 GHz, assess radio ultimate mass, size, and power. This should be
backed with analyses and simulation to ensure achievable performance and power targets.

One significant prerequisite to Phase II is the development of a promising and novel MEMS-based radio architecture that comprises: a highly programmable frontend and highly programmable digital basebands with the MAC implementation of multiple protocols and Advanced Encryption Standard (AES) encryption. The offeror must demonstrate the ability to achieve significant advantages in compactness, power efficiency, and reliability.

**Phase II Deliverables:** Develop a reliable, intelligent, and power-efficient MEMS-based EVA radio prototype unit that demonstrates robust RF performance, frequency agility, re-configurability, and dynamic power management for voice, telemetry, and high definition imagery under power budget constraints.

Demonstrate a highly programmable frontend and digital basebands with the MAC implementation for multiple open standard protocols. Consider a three-node network configuration for interoperability.

Integrate AES encryption as well as power-aware technologies and ensure QoS applications fall within prescribed power constraints.

**Displays**

To surmount geometric constraints, compact external flat panel or helmet-mounted display technologies are needed to improve situational awareness, mobility, suit monitoring, and task management. Hands-free interactive control of visual information (text, graphics, images, and video) using conversational spoken dialogue can improve work efficiency over audio communications as well as increase productivity and safety. High resolution suit displays must be able to operate outside the protection of the suit in bright surroundings, thermal, radiation, and vacuum environments as well as internally without imposing ignition hazards due to 100 percent oxygen environment.

**Sensors**

Crew health and suit monitoring require advancement of lightweight CO\(_2\), biomedical (heart rate, blood OX, EKG) and core temperature sensors with reduced size, increased reliability, and greater packaging flexibility. Consequently, technologies are needed to provide high accuracy, low mass, and low-power sensors that measure flow rate, pressure, temperature, and relative humidity or dew point. All sensors must operate in a low pressure 100% O\(_2\) environment with high humidity and may be exposed to liquid condensate.

Because missions must be designed with appropriate radiation shielding and adjusted to keep the radiation doses within tolerable limits, real-time, accurate, instantaneous and integrated radiation dose measurements and readout are needed such as novel dosimeter sensors. Given sufficient warning, astronauts can move to a more shielded part of the space vehicle and lessen dose impact. As cosmic rays impinge upon the vehicle leaving the magnetosphere, sensors are needed to determine the type of radiation and dose as well as reduce the potential risk of biological tissue damage.
High Definition (HD) Cameras

Ultra-compact, low-power, HD cameras are needed to support both high definition motion and high resolution still imagery, providing low loss compressed digital data output for transmission over RF and/or IP networks. Key features include advanced wireless networking for transmitting video at high bandwidth, high-quality image compression algorithms, radiation tolerant image sensor and processing platform capable of running video compression in near real time. The cameras must provide excellent situational awareness for crew members and quality imagery for remote viewing, scientific research, exploration, and public relations. They will be mounted on space and planetary vehicles (e.g. rovers), so remote operation (pan, tilt, focus, zoom, light level controls) can be controlled by astronaut in a suit, and the image projected onto a helmet display or remotely for Earth-based operations.

Integrated Systems

A complete system of displays, cameras, sensors must be integrated under a common interface. A key enabler will be advanced spoken dialogs. Typing or using a touch menu is too cumbersome with space suit gloves. Voice commands are much more natural for the suited astronaut and can increase situational awareness. In case of voice failure, a backup system can be implemented to perform all critical functions. Not only can this capability reduce crew workload, but it can immensely enhance operational efficiency. Such functions can alert crew about progressive deterioration of equipment preceding failures. Sensor data can be read out to determine the heart rate, body temperature, and CO\textsubscript{2} levels. Cameras can be turned on, aimed at precise locations, and either still or motion imagery can be taken.

Rather than separate control interfaces, a total solution is needed for integrating a suite of space suit functions: displays, cameras, sensors, audio, and voice. Hands-free interaction requires automated planning, scheduling, consumable management, suit monitoring, and display presentation. Advanced spoken dialogue system which works in an acoustic environment of the space suit and provides an interface to control all space suit, display, camera, sensor, and audio functions will allow a natural operation of complex suite of space suit capabilities.