



## NASA SBIR 2011 Phase I Solicitation

### X4.03 Space Suit Radio, Sensors, Displays, Cameras, and Audio

Lead Center: GRC

Participating Center(s): JSC

Future EVAs need advances in radio technologies, including antennas, tunable RF front-ends, and power amplifiers; low-power cameras; more accurate, reliable, and packaged core temperature, CO<sub>2</sub>, and biomedical sensors; user-friendly, minimally invasive crewmember information displays; and technologies that provide improvements in speech quality, listening quality and listening effort for in-helmet aural and vocal communications. Progress in these technologies will help ensure reliable communications, crew safety and comfort, and work efficiency and autonomy. The focus of this subtopic is to advance future EVA lightweight, compact, low-power technologies in five primary areas: radios, sensors, displays, cameras, and suit audio. The expectation for all of these EVA areas is that a report demonstrating the concept, requirements, design, and technical feasibility will be delivered at the end of Phase I, and that a working and fully functional device will be delivered at the end of Phase II.

The next-generation EVA radio needs to fulfill multiple functions while satisfying stringent requirements on size, weight and power (SWaP) consumption in the ISM S-band (2.4 - 2.483 GHz) and Ka-band (approximately 26 GHz). Ideally, eventual radio SwaP reductions would result in approximately 115 cubic inches, 3.5 - 5.5 pounds, and 15 watts total power consumption, respectively. Next-generation EVA radios will need to support multiple comm loops and point-to-point EVA comm., receive caution and warning messages from the vehicle and other EVA crew, receive, store, and display voice/text messaging to handle comm delays. Moreover, next-generation EVA antenna systems that effectively present uniform coverage around the suit are needed. Likewise, the next-generation EVA radio needs RF front-end architectures capable of presenting baseband or IF signals to waveform processing hardware in multiple bands. Radiation-hardened-by-design transceiver technologies improving upon current Single Event Upset tolerant approaches, along with cognitive technologies, are needed for future EVA exploration to Near Earth Asteroids and beyond.

In addition, advances in tunable technology that permit high Q factor, minimum insertion losses, and excellent linearity are desirable at the given S- and Ka-band Gigahertz frequencies for agility. The next-generation EVA radios will need to support voice, telemetry, and standard/high definition video data flows (up to 20 Mbps); ensure rapid upgrades via scalable, open, and modular architectures; and, advance power aware technologies to optimize efficiency, conserve EVA battery lifetime power, and prolong duration of EVA operations. Finally, no matter what type of transceiver architecture is used in the next-generation EVA radio, the power amplifier is always a key component to enable new functionality, and to minimize the power consumption of the whole radio. Current amplifiers suffer from one or many of the following drawbacks: a) insufficient power added efficiency, b) insufficient linearity performance and incompatibility with modern modulation signals, and c) incompatible with silicon CMOS

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technology. Most of the commercial PAs are based on III-V GaAs material system, which is more expensive compared to the CMOS fabrication processes. Additionally, the incompatibility with silicon CMOS technology makes it impossible to realize a fully integrated radio-on-a-chip system. Consequently, the implemented radio with the existing power amplifiers requires much more SwAP and higher fabrication costs. Advances are needed in the efficiency and linearity of power amplifiers for next-generation EVA radio applications.

Crew health and suit monitoring require advancement of lightweight CO<sub>2</sub>, 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<sub>2</sub> 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.

Future EVAs need a user-friendly and minimally invasive crewmember information display device that provides significant task efficiency improvement for a broad range of EVA tasks. Current Head-Mounted Display and Near-to-Eye display technologies are a non-starter for EVA, because the display must be mechanically decoupled from the user's head in order to improve crew safety, comfort, and prevent display misalignment. This in turn makes for more difficult specifications for the eyebox (tolerance to misalignment before image goes out of focus), field of view (angle of the image created by the optics), and eye relief (working distance from the eye to the last optical element). Additionally, current Helmet-Mounted Display technologies are challenged in EVA applications due to geometric constraints within the helmet, and future display technologies must ensure suit displays can operate outside the suit protection in thermal, radiation, and vacuum environments as well as internally without imposing ignition hazards due to 100% oxygen environment. Key performance parameters (targets) include: Graphical Data Presentation: SXGA @ 40 deg FOV (possibly biocular); Decoupled from User's Head - Large Eyebox: 100 mm x 100mm x 50mm (D); Sunlight Readability: 500 fL inside visor, 1800 fL outside visor (>10 to 1 contrast).

Future EVAs need to support high definition motion and high resolution imagery with ultra compact, low-power HD cameras and low loss compressed digital data output for RF transmissions and/or IP networks. Hemispherical and dynamic cameras are desired, where hemispherical cameras take video views of a crewmember (360 degrees), distorting those views thru optics and then undistorting those views via software on the ground to pan/zoom for total situational awareness. Dynamic cameras can take stills and motion in variable bandwidths, capture image based on link quality, change frame rates, interfaced to gigabit Ethernet and in a rad-tolerant package with dynamically reconfigure compression core(s) and common 'back-end' interfaces.

The space suit environment presents a unique challenge for capturing and transmitting speech communications to and from a crewmember. The in-suit acoustic environment is characterized by highly reflective surfaces, causing high levels of reverberation, as well as spacesuit-unique noise fields; and wide swings of static pressure levels. Due to these factors, the quality of speech delivered to and from the inside of a spacesuit helmet can be low and can have a negative effect on inbound and outbound speech intelligibility. The traditional approach to overcome the challenges of the spacesuit acoustic environment is to use a skullcap-based system of microphones and speakers. Cap-based systems are less successful, however, in attenuating high noise levels generated outside the spacesuit, and many logistical issues exist for head-mounted caps (e.g., crewmembers are not able to adjust the skullcap, headset or microphone booms during EVA operations, interference between the protuberances of the cap and

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other devices, comfort, hygiene, proper positioning and dislocation, and wire fatigue and blind mating of the connectors, multiple cap sizes to accommodate anthropometric variations in crew heads).

NASA is seeking technologies in support of improvements in speech intelligibility, speech quality, listening quality and listening effort for in-helmet aural and vocal communications. The specific focus of this SBIR subtopic is on improving the interface between crewmember and the acoustic pickup (microphones) and generation (speaker) systems. Devices are sought to improve or resolve acoustic, physical and technical problems (listed above) that have been associated with skullcap-mounted speakers and microphones, or allow for the elimination of skullcap-mounted speakers and microphones. In particular, voice communications systems are sought that have provided crewmembers with adequate speech intelligibility over background noise within, and external to, the spacesuit. Overall system performance must provide Mean Opinion Score (MOS) for Listening Quality (Lq) and Listening Effort (Le) of 3.9 or greater, or Articulation Index (AI) of .7 or better or 90% Intelligibility in the crewmember's native language for both inbound and outbound speech communication. Specific technologies of interest include, but are not limited to: acoustic modeling of the in-suit acoustic environment, including the ability to model structure-borne vibration in helmet and suit structures as well as transduction to and from the acoustic medium; low-mass, low-volume, low-distortion, space-qualified speakers with low variation in sensitivity with static pressure. Changes in speaker sensitivity should be less than 2 dB over the speech band with changes in static pressure between 3 and 18 psia; low-mass, ultra-low-volume (