NASA SBIR 2007 Phase I Solicitation

O3.02 In-helmet Speech Audio Systems and Technologies

Lead Center: GRC

Participating Center(s): ARC, JSC, KSC

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. Known sources of noise within the suit are both stationary and transient in nature. Noise within the suit can be acoustically borne or it can originate from structure-borne vibration. Noise originates from suit machinery, footfalls, suit arm and hip bearing, body movement noise and turbulent flow noise from devices such as oxygen spray bars and breath noise. Static pressure levels within the spacesuit can range from a small fraction of an atmosphere during Extravehicular Activity (EVA) operations to strong hyperbaric conditions that exist during terrestrial field-testing. These changes in static pressure level have significant effects on acoustic transduction. Additionally, in some spacesuits, the crewmember is afforded a wide range of motion within the torso of the suit. The wide range of motion means that the acoustic path between a crewmember's mouth or ear and the microphone or helmet mounted speaker varies significantly with movement, resulting in decreased sound pressure levels at the microphone and/or increased interference from competing background noise sources. In addition, vehicular operations can generate high levels of noise that are not fully attenuated by the spacesuit, helmet or headsets. 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 and the performance of Automatic Speech Recognition (ASR) systems.

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 solutions mitigate many of the acoustic problems associated with in-helmet communications systems through the very short and direct acoustic transmission paths between the crewmember and the speakers and microphones. The skullcap's headsets and noise canceling microphones can also afford some degree of acoustic isolation for the crewmember from noise generated inside the spacesuit. Cap-based systems are less successful, however, in attenuating high noise levels generated outside the spacesuit (e.g., during launch, descent, burn activities, or emergency aborts), even when coupled with the launch/entry helmet. The use of noise canceling microphones can improve speech intelligibility, but only if the microphones are in close proximity to the crewmember's mouth. Many logistical issues exist for head-mounted caps. Crewmembers are not able to adjust the skullcap, headset or microphone booms during EVA operations (which can last from four to eight hours) or during launch/entry operations. Interference between the protuberances of the cap and other devices, such as drinking/feeding tubes, is a recognized issue during EVA. Comfort, hygiene, proper positioning and dislocation are major concerns for head-mounted caps. Wire fatigue and blind mating of the connectors are also problems with the cap-based systems. In order to accommodate anthropometric variations in crew heads, multiple cap sizes are required. Issues have recently been identified with existing communications systems regarding adjustment of microphone boom lengths, proper function over the wide ranges of static pressure experienced during suited operations, flow noise over the microphone elements, and integration with advanced helmet designs.

NASA is seeking systems, subsystems and/or technologies in support of improvements in speech intelligibility, speech quality, listening quality and listening effort for in-helmet aural and vocal communications. In addition, improvements in hearing protection are sought to protect the crew during all mission phases, in case hazardous acoustic levels and conditions occur.

The specific focus of this SBIR subtopic is on improving the interface between crewmember and the acoustic pickup (i.e., microphones) and generation (i.e., speaker) systems. Systems and 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, low-volume, low-distortion high-sensitivity (> 5 mV/Pa), space-qualified noise canceling microphones with low variation in sensitivity with static pressure. Changes in microphone sensitivity should be less than 2 dB over the speech band with changes in static pressure between 3 and 18 psia.
- Attenuation of external noise by passive hearing protection that is comfortable for crewmembers during extended use.

In-helmet devices will need to be compatible with high humidity, low humidity and pure oxygen environments. Devices should be able to fit a wide anthropometric range of head and physical features found within the astronaut corps.

Additionally, demonstrations of novel system concepts for in-helmet audio communication are of strong interest. A partial list of such concepts includes:

- Near-field beamforming systems;
- Optical microphone systems;
- Highly directive sound production systems such as parametric sound systems;
- Active noise cancellation systems for hearing protection;

- Bone conduction microphones.

Systems and devices must include appropriate computer processing systems. The expectation is that a working and fully functional system or device will be delivered at the end of Phase 2.