NASA SBIR/STTR
Small Business Innovation Research / Small Business Technology Transfer

NASA SBIR 2015 Phase I Solicitation

H4 Extra-Vehicular Activity and Crew Survival Systems Technology

Lead Center: JSC

Extra-Vehicular Activity (EVA) and crew survival systems technology advancements are required to enable forecasted microgravity and planetary human exploration mission scenarios and to support potential extension of the International Space Station (ISS) mission beyond 2020. Advanced EVA systems include the space suit pressure garment systems (PGS); the portable life support system (PLSS); the power, avionics and software (PAS) systems including communications, controls, and informative displays; and the common suit system interfaces. More durable, longer-life, higher-reliability technologies for Lunar and Martian environment service are needed. Technologies suitable for working on and around near earth asteroids (NEAs) are needed. Technologies are needed that enable the range and difficulty of tasks beyond state-of-the-art to encompass those anticipated for exploration, with improved comfort, productivity, less fatigue, and lower injury risks. Reductions in commodity and life-limited part consumption rates and the size/weight/power of worn systems are needed. Primary goals for crew survival systems include development of technologies enhancing crew survival in the post-landing environment, significant mass reduction of hardware, and development of space-qualified survival hardware technologies designed to operate after exposure to space vacuum and thermal effects. Launch, Entry, and Abort (LEA) crew survival equipment development is a critical need tied to any future manned Design Reference Mission (DRM), as well as providing benefit to both Orion/MPCV and Commercial Crew Program engineering efforts. All proposed Phase I research must lead to specific Phase II experimental development that could be integrated into a functional EVA system.Â

Subtopics

H4.01 Crew Survival Systems for Launch, Entry, Abort

Lead Center: JSC

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This subtopic seeks technology innovation supporting the launch, entry, and abort (LEA) crew survival equipment needs for future human exploration beyond low-earth orbit. Primary goals include development of technologies enhancing crew survival in the launch, entry, and abort phases of flight as well as the post-landing environment, significant mass reduction of hardware, and development of space-qualified survival hardware technologies designed to operate after exposure to space vacuum and thermal effects. LEA crew survival equipment development is a critical need tied to any future manned Design Reference Mission (DRM) laid out by the agency, as well as providing benefit to both Orion/MPCV and Commercial Crew Program engineering efforts. Many candidate technologies will have direct application to Orionâ€™s EM-2 mission and follow on manned spaceflight activities.

Systems and technologies relating to enhancement of post-landing survival and rescue following manned exploration spacecraft launch, entry, and abort (LEA) events are sought in the following areas:Â

- *Lightweight Survival Life Raft Materials, Construction Methods, and Related Technologies* - Programmatic need exists for a low mass, self-inflating life raft under 30 lbm. Technologies should be directed to enable crew survivability in the post landing off-shore ocean environment meeting SOLAS and/or FAA standards and Orion/MPCV Design Specification for Natural Environments (DSNE) sea state definitions while meeting a 30 lbm mass constraint. Of particular interest is significant mass reduction in raft inflation systems, innovative construction techniques and techniques / methods for enhanced operability by long-duration spaceflight de-conditioned crew members. The current space equivalent baseline is an FAA six person raft. Currently this type of raft does not exist without â€˜breakingâ€™ the 30 lbm mass requirement or sacrificing survivability attributes. Efforts should focus upon novel lighter weight materials and constructions methods, as well as inflation systems. Another area of concern from the medical community is raft ops and ingress by deconditioned crew members experiencing neurovestibular effects of long-duration spaceflight.
- *Suit-Integrated Global Coverage Personal Locating Technologies* - Current commercially-available Personal Locating Beacons (PLBs) are not optimized for use in the manned spaceflight thermal and vacuum environment or integration into a survival suit cover layer. Innovative technologies/efforts should be directed towards novel flexible patch antenna development, robust beacon packaging technologies, analytical methodology for integrated beacon operational analysis, and beacon triggering (RF, saltwater, etc.) technologies. Additionally, there is interest in prototype electronics board development for use with future satellite-based GPS/Doppler locating systems such as the NASA-led Distress Alerting Satellite System (DASS). This technology development subheading also includes development of high-reflectivity materials in the visible, IR, and radar wavelengths.
- *Occupant Protection Materials, Analytical Tools, and Technologies* - Products and materials leading to enhanced occupant protection in the capsule landing loads environment. Innovative technologies and efforts should be directed towards acceleration, vibration, and impact attenuation systems designed to mitigate dynamic flight event impacts on the crew member. Of potential interest are materials and products to protect crew members from head and neck injuries during landing load shocks. Additionally, technologies such as innovative restraint mechanisms preventing crew member flail and flail-related injuries during dynamic flight events are of potential interest. When considering impact attenuation material properties, attention should be paid to preventing crew member exposure to rate changes of acceleration greater than 500 g/s. Material space-rating requirements should be taken into account in relation to the manned spaceflight thermal / vacuum environment. Within this subtopic, analytical methods should be directed to prevention of extremity flail, head, and neck injuries during linear, vibrational, and angular acceleration events.
- *In-Suit Waste Management Technologies* - Development of technologies allowing for long-duration waste management for use by a pressurized suited crew member. In the event of cabin depressurization or other contingency, crew members may need to take refuge in LEA pressure garments for a long-duration (144-hour) return trajectory back to Earth. Technology development should be tailored to a 144-hour suited contingency, meeting the NASA Human Systems Integration Requirement (HSIR) inside an LEA suit pressurized to 4.3 PSID referenced to the ambient environment. Waste management technologies should address fecal and urine waste containment and human physiological responses / countermeasures to long duration waste management in a pressurized survival suit environment from one to six days. Advanced technologies and materials should ideally provide for urine collection of up to 1L per day per crew member, for a total of 6 days. Additionally, mitigation and/or elimination of urine-generated ammonia inside the pressure garment volume is a candidate area of interest. Fecal collection rates should be targeted for 75 grams of fecal mass and 75 mL fecal volume per crew member per day for a total of 6 days duration.

Research done in Phase I of these efforts should focus on technical feasibility with an emphasis on hardware development that can be further expanded in a future Phase II award cycle. Phase II products must include a demonstration unit suitable for testing by NASA. Prototyping should be tailored to applications to ongoing HEO Mission Directorate missions and possible collaborative use in both the governmental and commercial manned spaceflight disciplines. Minimum deliverables at the end of Phase I are analysis and/or test reports, with priority given to functional hardware prototypes for further evaluation. Technical maturation plans should be submitted with Phase I submittals, as well as any expected commercial applications both internal and external to the manned spaceflight enterprise.

H4.02 EVA Space Suit Pressure Garment Systems

Lead Center: JSC

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Space suit pressure garments technology developments are focused on providing enabling technologies for long-duration missions inclusive of extensive extra-vehicular activity (EVA). To that end, priority technologies address mass reductions, durability and reliability. Mass reduction for exploration pressure garments is driven, in addition to launch mass considerations, by the human factor of on-back weight for a planetary walking suit configuration following a long-duration micro-gravity transit, which may reduce astronaut load bearing capability. Driving reference missions such as a1.5-year Mars surface stay include on the order of 700 hours of EVA. Therefore, long-duration exploration missions require, in some cases orders of magnitude, increases in suit durability or new approaches to providing long duration mission EVA capability or logistics. The following technology areas address mass reduction, increased durability, or both.

Multi-function Materials

The pressure garment must perform functions such as: gas retention and structural integrity including fall cases; mobility to perform science and surface asset set-up and maintenance; and environmental protection from thermal extremes, micrometeoroids and secondary impacts, dust, and tears. The combination of performance of two or more of these functions in single pressure garment material layer contributes to mass reduction. For example, a composite structure that provides gas retention, structural integrity, and thermal protection/regulation would be beneficial. Another example would be a fabric that mitigates the effects of dust and is thermal protection in a single layer is sought.

Self-diagnosing and Self-healing Materials

Fabric wear due to repetitive joint cycling, dust and UV radiation exposure, and handling is anticipated. To improve safety and decrease crew time investment in the EVA system, materials that can indicate wear or self-heal are valuable. Current materials with these capabilities are heavy, stiff, or require prohibitive power quantities. Ideally, self-diagnosing and self-healing capabilities would be combined in with a material that also performs one of the functions described in the â€˜Multi-function materialsâ€™ section

Titanium Bearings

This topic addresses both mass reduction and increasing durability. The emphasis on mass reduction is countered by the need for increased mobility, which tends to increase mass due to the addition of low torques bearings in joint mobility systems. Titanium bearings are being incorporated to decrease the mass of joint mobility systems. However, refinement of titanium bearings to meet durability requirements is required based on 2014 bearing in-configuration oxygen compatibility testing, which passed for flammability, but indicated cycle wear issues. To address titanium bearing wear, coatings, treatments, lubricants, ball material, and space ball materials are all considerations to be investigated. Titanium bearings that can withstand 8 psi suit pressure plug loads in addition to suit manloads over tens of thousands of cycles are required for exploration pressure garments.

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H4.03 EVA Space Suit Power, Avionics, and Software Systems

Lead Center: JSC

Participating Center(s): GRC

Space suit power, avionics and software (PAS) advancements are needed to extend EVA capability on ISS beyond 2020, as well as future human space exploration missions. NASA is presently developing a space suit system called the Advanced Extravehicular Mobility Unit (AEMU). The AEMU PAS system is responsible for power supply and distribution for the overall EVA system, collecting and transferring several types of data to and from other mission assets, providing avionics hardware to perform numerous data display and in-suit processing functions, and furnishing information systems to supply data to enable crew members to perform their tasks with autonomy and efficiency. Current space suits are equipped with radio transmitters/receivers so that spacewalking astronauts can talk with ground controllers and/or other astronauts. The astronauts wear headsets with microphones and earphones. The transmitters/receivers are located in the backpacks worn by the astronauts only operate in the UHF band.

While a sufficient amount of radiation hardened electronics are available in areas such as serial processors, digital memory and Field Programmable Gate Arrays, a significant risk for the development of spacesuit avionics is the non-availability certain ancillary electronic devices that are rated for spaceflight. NASA is, therefore, seeking flight rated electronic devices needed to complement the existing inventory of flight rated parts so as to enable the creation of an advanced avionics suite for spacesuits. The suit and its corresponding avionics should be capable of being stowed inside a spacecraft outside the low-Earth orbit (LEO) environment for periods of up to 5 years (TBR). Devices should also be capable of supporting EVA sorties of at least 8 hours and total lifetime operational durations of at least 2300 hours (TBR) for a Mars surface mission. Assumptions may be made for inherent radiation shielding provided by the primary life-support system (PLSS) and possibly the power, avionics, and software (PAS) subsystem enclosure, but proposers are welcome to include shielding technologies at the board and individual part level to reduce the radiation requirements of the actual device. Devices should be immune to single event latch-up (SEL) for particles with Linear Energy Transfer (LET) values of at least 75 Mev-cm^2/mg. and maintain full functionality for total ionizing doses of at least 20 Krad (Si). Criticality 1 devices (life support) must be fully mitigated against single event errors (SEE) for all potential mission radiation environments, including solar flares. Lower criticality devices can be less tolerant of SEEs, but must still operate with acceptable error rates in all potential radiation environments. Power consumption should be no more than 2X similar COTS or mil-spec devices. Devices should be vacuum compatible and need to support conduction cooling. Need currently exists for a number of devices, as described below. However this list should not be considered to be exhaustive and proposals will be considered for other devices that are peculiar to a spacesuit avionics suite. Additionally, proposals are invited for simplified, low-cost and low-impact methods to adapt or test commercial or military-spec devices so as to yield a flight-rated part to the above levels. In no particular order of priority, key innovations sought include:Â

- Wireless Communication:
  - 802.11n baseband processor that supports channel bonding and possibly multiple RF channels.
  - Low-power (<5W), low-rate (500-1000kbps) baseband software-defined radio that is, at the very least, capable of supporting the existing Space-to-Space Communications System (SSCS) wireless suit interface.
  - Dual-band WLAN-class RF front-end module capable of supporting the SSCS (410 to 420 MHz) and a channel-bonded 802.11n system (40MHz of bandwidth) operating at the 2.4GHz ISM band. Consideration will also be given to devices capable of supporting the 802.11n system operating in the 900MHz region. Consideration for supporting multiple antennas for the 802.11n system will be given, but this is not required.
- Human-Machine Interface (HMI) for Informatics:
  - Input device technologies that provide mouse-like functionality or a minimum of directional control to navigate display menu system. In general devices need to minimize hand use. Technologies that require hand use must be limited to operation with a single gloved EVA hand. Devices must minimize SWAP and computing power needed for final implementation. Solutions must be reliable and robust enough for vacuum space environments.Â
- Safety Critical Switches and Controls:
  - Very low profile switches and controls for EVA Criticality 1 systems. Highly reliable and robust devices that provide traditional toggle switch, rotary dial, and linear slider control functionality in a very low profile package which permits higher packaging density compared to traditional solutions for vacuum space operations. Switches and controls must still be sized for easy operation with EVA gloves.

- Audio:
  - Simultaneously sampled, deep bit-width, low rate Analog to Digital Converter (ADC) circuits and/or Pulse Density Modulator (PDM) circuits. Requirements are for devices with dynamic range greater than 90 dB (threshold) and as much as 110 dB (goal) with sampling rates > 24 kS/s (threshold) and as high as 48 kS/s (goal). Requirements exist for 8 channel devices (threshold) simultaneously sampled (< 1 ps jitter) with a goal of 16 channels. Devices should support a Least Significant Bit (in Pulse Code Modulation) of 1 micro-Volt or less with a noise floor of 10 micro-Volts or less.
  - Highly linear, high Signal to Noise Ratio (SNR) Micro Electro Mechanical System (MEMS) microphones with PDM output. Microphones should exhibit < 1% THD at 105 dBSPL (threshold) and 115 dBSP (goal). Microphones should have frequency response of +/-10 dB from 80 Hz to 12 kHz and SNR > 50 dB (threshold) and > 60 dB (goal).
  - High dynamic range, audio frequency Digital to Analog Converters (DACS). Converters should provide>100 dB spur free dynamic range (TBR).
  - High efficiency, low power (< 1 W output), audio frequency power amplifiers.
  - High efficiency, audio frequency pre amplifiers with adjustable gain (0 to 30 dB).
  - High speed (> 100 Mb/s) serial communications transceivers suitable for protocols such as Ethernet, Low Voltage Differential Signal (LVDS) and Rocket-IO.

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