

Sensors and Systems for Spacesuits

Advanced Spacesuit Development

Portable Life Support Subsystem

Pressure Garment Subsystem

Presenter: Cinda Chullen

MD: HEOMD

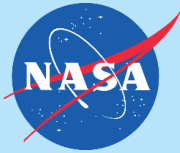
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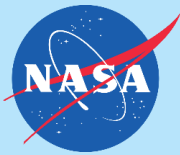
INNOVATION | PARTNERSHIP | COMMERCIALIZATION

SMALL BUSINESS INNOVATION RESEARCH (SBIR) & SMALL BUSINESS TECHNOLOGY TRANSFER (STTR)



- **An Advanced Extravehicular Mobility Unit (EMU) is being developed and tested in house at JSC**
 - Multiple programs over the last decade have contributed to the success thus far including the SBIR/STTR program
- **WHY**
 - The current EMU on International Space Station (ISS) has a limited life span
 - Future missions being contemplated will need a new spacesuit to meet the technology objectives
 - Considerable Extravehicular Activity (EVA) technology development has taken place over the last 10 years in preparation for future missions
 - EVA systems need technology development to prepare for future space missions
 - Technology developments, challenges, and future gaps have to be tackled by **government, industry (including small businesses), academia, and international partners** collaboratively
 - We want better, safer, and more efficient EVA systems
 - Increased collaboration is necessary to address the challenges and fill the gaps

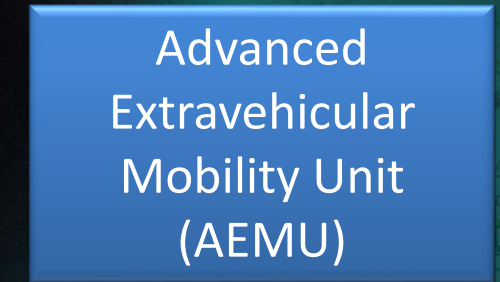
Advanced Spacesuit Development



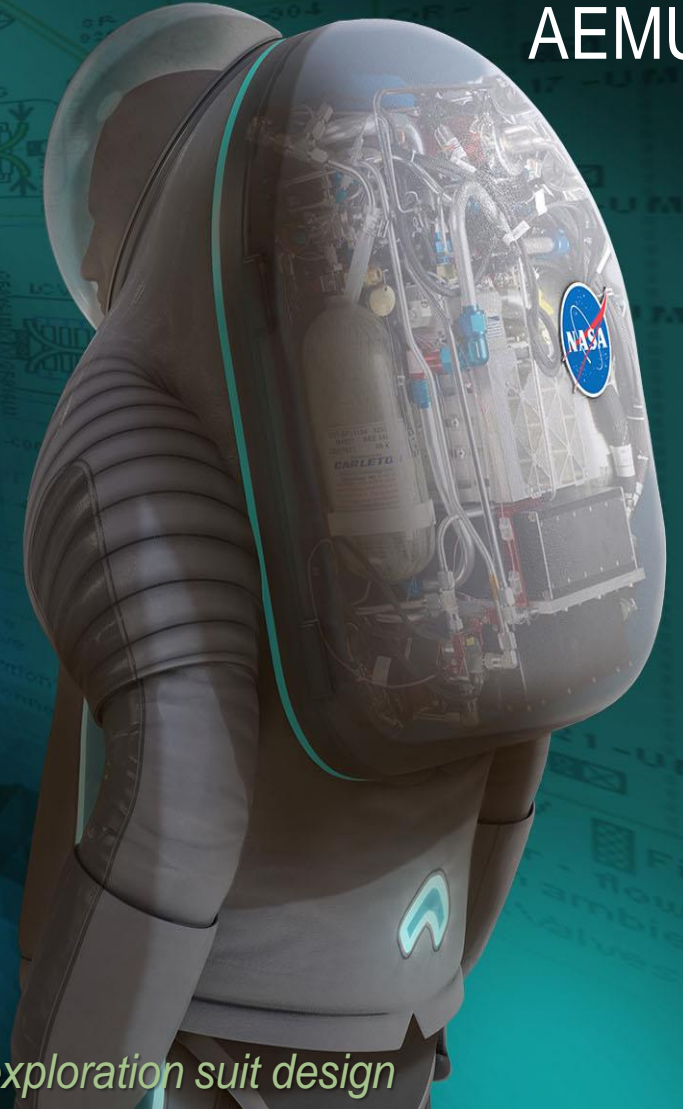
EMU



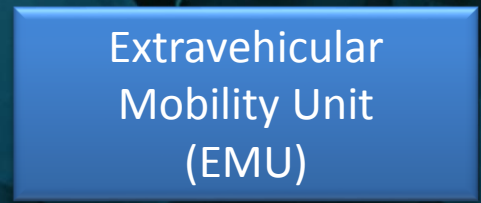
Advanced
Extravehicular
Mobility Unit
(AEMU)



AEMU

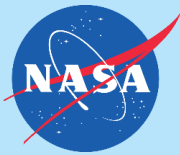


Extravehicular
Mobility Unit
(EMU)



NOTE: Images are not representative of the actual exploration suit design

Spacesuit Subsystems



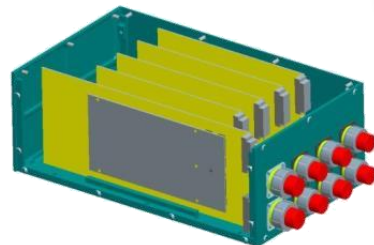
- Portable Life Support Subsystem (PLSS)



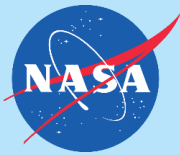
- Pressure Garment Subsystem (PGS)



- Informatics



Advanced Spacesuit Development - Subsystems



Portable Life Support Subsystem (PLSS)

- O₂ Supply
- Active Thermal control
- CO₂ removal
- Pressure regulation
- Avionics

Informatics Subsystem

- Caution & Warning Systems
- Communication, audio, & video
- Displays and Controls

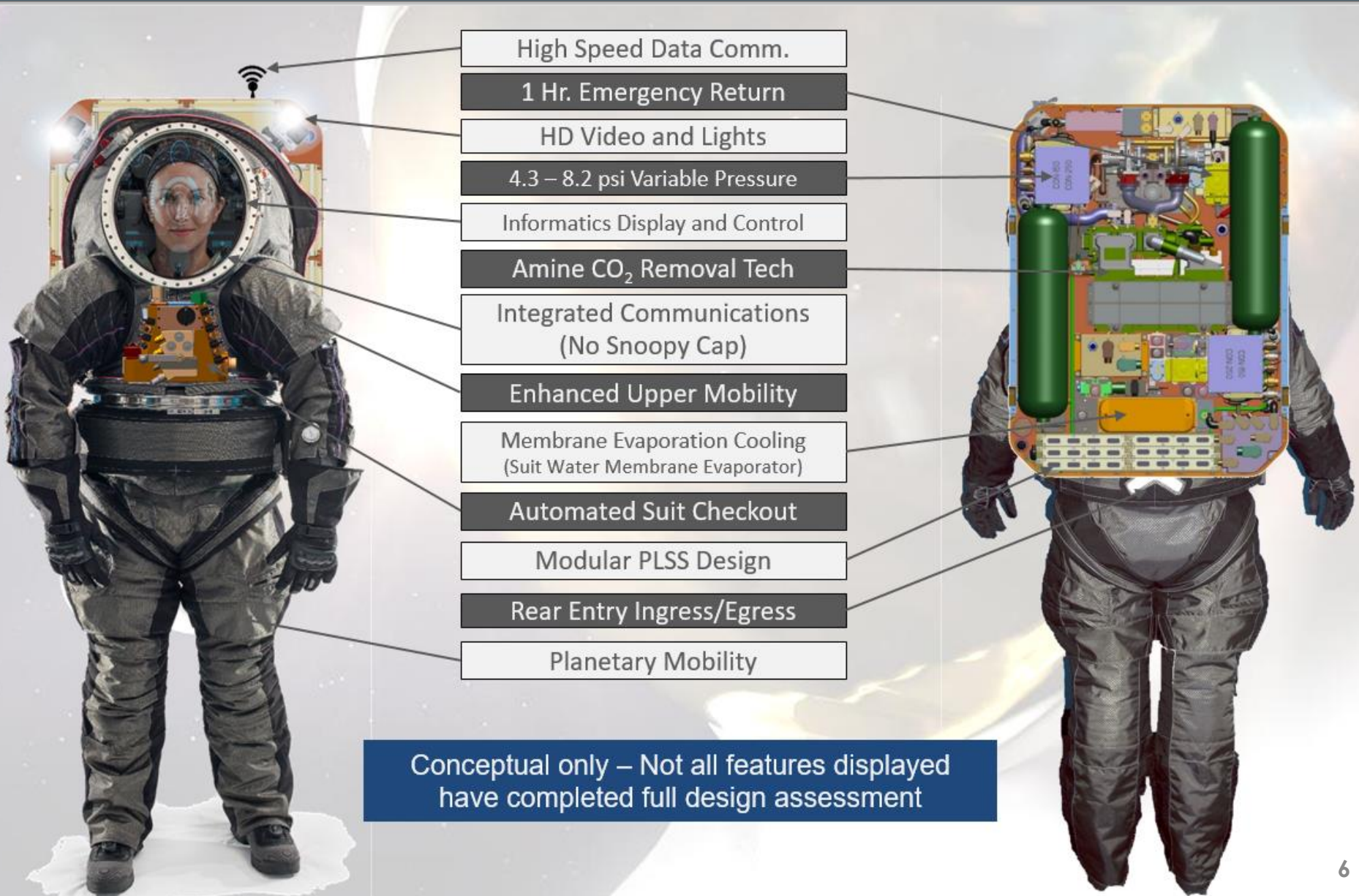
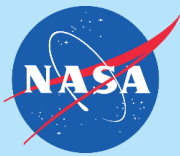
Pressure Garment Subsystem (PGS)

- Bladder and softgoods
- Gloves and boots
- Passive thermal
- Helmet, Hard Upper Torso, Lower Torso Assembly

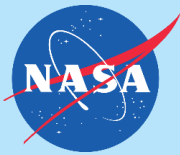


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NASA Advanced Spacesuit Reference Architecture



Conceptual only – Not all features displayed have completed full design assessment



– PLSS –

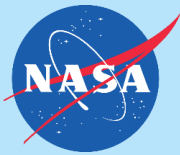
- **Rapid Cycle Amine (RCA)** swing bed enables real-time on-back regenerable CO₂ and humidity control (eliminates CO₂ removal as an EVA duration limiting consumable, eliminates Lithium Hydroxide (LiOH) as a mission consumable, eliminates power and time to regenerate Metal Oxide (MetOx) post EVA)
- **Suit Water Membrane Evaporator (SWME)** has decreased sensitivity to water quality and increased life as compared to a sublimator (100+ EVA life),
- **Variable Oxygen Regulator (VOR)** enables numerous set points that can include in-suit decompression sickness, eliminating prebreathe, or interfacing with multiple vehicles
 - **Primary Oxygen Regulator (POR)**
 - **Secondary Oxygen Regulator (SOR)**

– PGS -

- **8 psid** operations eliminates the need for prebreathe and provides in suit decompression sickness treatment
- **Rear entry** decreases donning time, pressurized sizing adjustment features

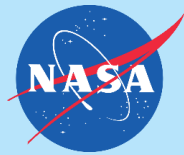
– Informatics –

- Improved capabilities include **displays** and information systems to provide crew autonomy
- **Integrated audio system** into the suit to eliminate the communications cap providing improved reliability and crew comfort
- **Advanced caution and warning** system includes sharing telemetry between EVA crew members and automated health checks



PORTABLE LIFE SUPPORT SUBSYSTEM (PLSS)

Portable Life Support Subsystem Technology Development



COMPLETE ✓

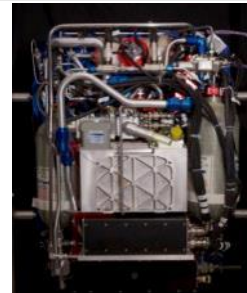
COMPLETE ✓

FY16/17/18

**PLSS 1.0
(Breadboard)**

**PLSS 2.0
(Packaged GN₂)**

**PLSS 2.5 (xPLSS)
(Flight prototype)**



Purpose:

- Schematic validation with models
- Component pneumo-hydraulic integration

- Packaged lab unit
- System level performance

- Flight design without paperwork (GN₂/Air only)
- Integrated system performance

Hardware:

- Prototype: RCA, Fan, SWME, POR, SOR
- Balance COTS/Instruments

- 2nd gen prototypes: RCA, SWME, POR, SOR
- 1st gen prototypes: remainder

- 3rd gen prototypes; RCA, SWME, POR, SOR
- 2nd gen prototypes: remainder

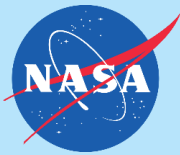
Testing:

- 8 simulated EVA transient profiles
- 397 hrs of full PLSS operation
- 595 hrs of SWME/thermal loop operation

- Pre-Installation Acceptance (PIA) test against system spec
- 19 psia air human-in-the-loop testing with the Mark III spacesuit (2hr EVAs)
- 25 EVAs, failure simulations, integration tests at vacuum

- PIA test against system spec
- 100 unmanned EVAs in vacuum
- Unmanned thermal vacuum testing
- Pressurized launch vibe testing
- EMI Testing
- Static Magnetics Testing

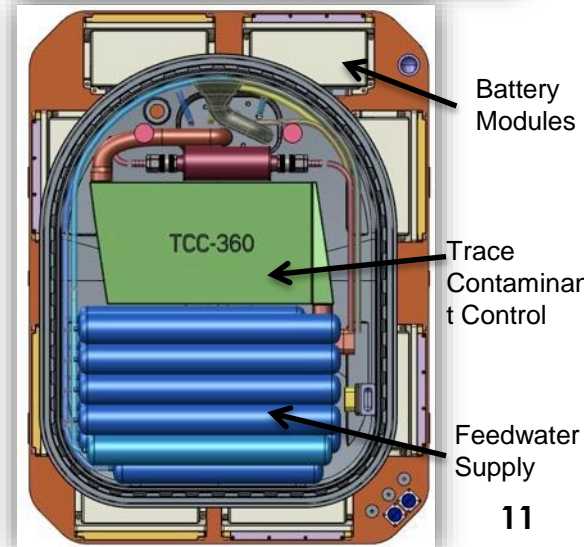
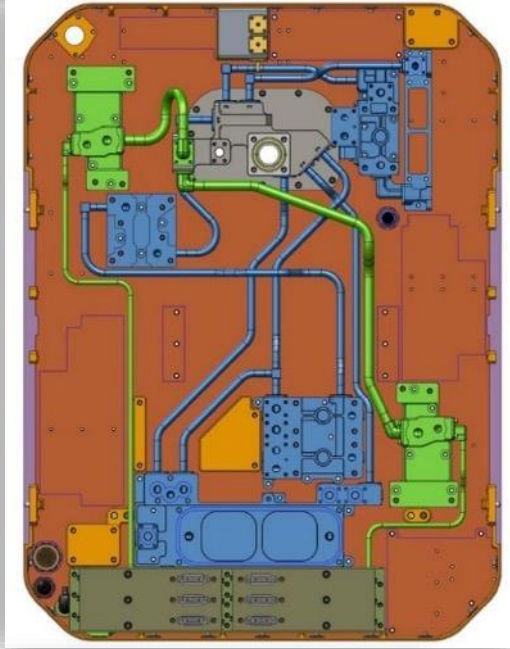
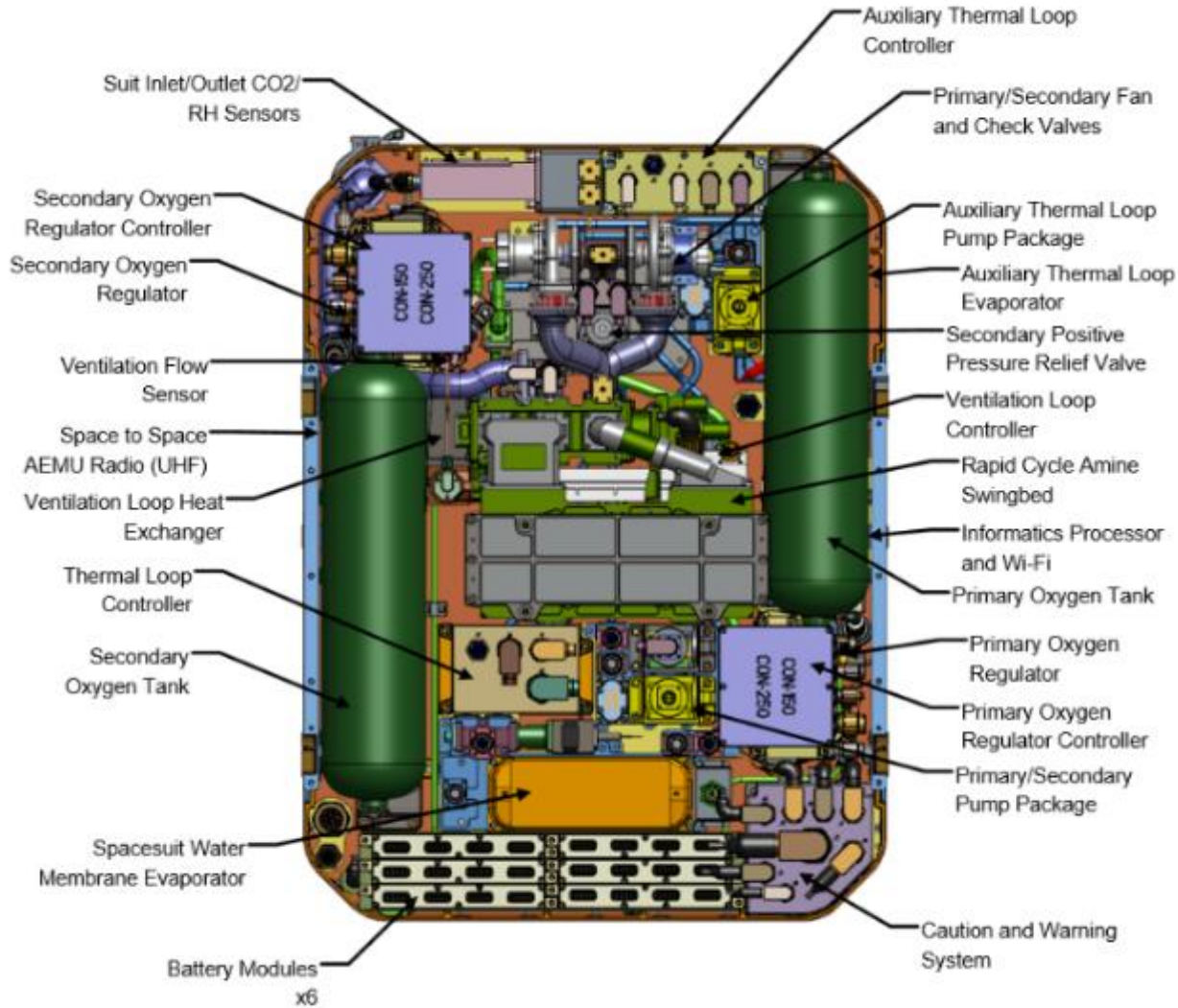
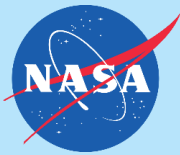
Core PLSS Component Technologies

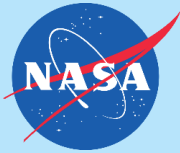


- Rapid Cycle Amine (RCA) swingbed provides CO₂ and humidity removal via a two bed chemical sorbent canister
 - Advantages: Real-time regenerative – CO₂ removal system will not limit EVA duration and reduces consumables; Eliminates most failure modes that introduce water into the helmet and space suit
 - RCA 1.0 and 2.0 were tested at a component level and within the PLSS 1.0 and PLSS 2.0 system including manufacturing, assembly, functional verifications, and air rig performance testing
- Variable Oxygen Regulator provides dual stage pressure regulation for oxygen and pressure control for space suits
 - Advantages: Continuously adjustable pressure settings (~4000 set points) to control suit pressure between 0 and 8.4 psid with robust design, tolerant of contamination & combustion events
 - VOR 1.0 and 2.0 were tested at a component level and within the PLSS 1.0 and PLSS 2.0 systems, including oxygen and contaminant compatibility testing at WSTF as well as thermal, vibration and orientation testing
- Suit Water Membrane Evaporator (SWME) provides heat rejection and water degassing via hollow fiber membranes
 - Gen2 and Gen3 SWME included improvements such as reduced size, new fabrication methods, and more flight-like backpressure valve and were tested at the component level and within the PLSS 1.0 and PLSS 2.0 systems
 - Gen4 SWME is currently under development for use in PLSS 2.5
- Highest fidelity components being incorporated into system Live Loads Testing this summer



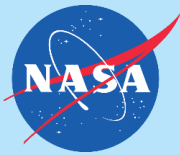
PLSS Packaging





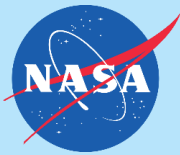
These are technology gaps from the current state of the art -- areas that would lend themselves to SBIR/STTR and STMD development projects.

1. Continuous CO₂/Relative Humidity removal capability that can operate within the vacuum and Martian atmospheres
 - a. Update/supersede SA9T (TEPAN)¹ state of the art
 - i. Improvements in sorbent CO₂/H₂O uptake²
 - ii. Independence of CO₂ adsorption on H₂O concentration
 - iii. Alternative processes such as temperature swing adsorption, selective permeable membranes, etc.
 - b. Augment SA9T (TEPAN) operation using thermal swing adsorption approach
 - c. Augment SA9T (TEPAN) operation using boost compressor to enable pressure swing operation in the Martian atmosphere

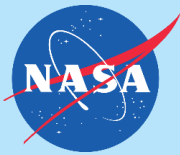


2. Continuous trace contaminant removal capability

- a. Activated charcoal is the state of the art and provides a logistics impact to all exploration reference missions³
- b. Remove ammonia (NH_3), carbon monoxide (CO), formaldehyde (CH_2O), methanethiol (also known as methyl mercaptan) (CH_3SH), etc.
- c. The minimum objective would be to remove all of the significant compounds that threaten to exceed the 7-day SMAC⁴ during an EVA with the optimal objective to enable removal of less significant compounds
- d. Ideally, this is either passive membranes or actively switched regenerating beds that can be paired with the CO_2/RH removal approach



3. **Small, oxygen compatible gas flow meter for suit operations**
 - a. Current state of the art is a flapper valve attached to a micro-switch used on ISS EMU
 - b. This is limited to a single set-point and is not capable of providing any suit health trending to enable graceful degradation and maintenance of fan performance or ventilation loop obstructions
 - c. The system is highly constrained on volume, power, mass, g-loading, pressure drop and further limited by compatibility with 100% O₂ at pressures up to 25 psia
 - i. The pressure drop over-constrains traditional flow-DP sensing methods such as orifice plates, V-cones, etc as the DP sensors themselves which have demonstrated issues such as orientation sensitivity/vibration sensitivity when measuring these low ranges (~0.7 in-H₂O at 4.3 psia, 4.5 acfm)
 - ii. In a similar fashion, commercial off-the-shelf (COTS) thermal mass flow solutions are often limited by the O₂ compatibility constraints as many non-metallics used have oxygen indexes far less than 100; potential human generated contamination and kindling chain effects also impose burdens on the designs.



4. Small hermetic micro switches

a. Current state of the art is 3-5x larger than needed

5. Rad-hard, isolated DC/DC converters with an efficiency of >80%

a. State of the art is ~70% for 28V to 5V

b. Example is the MS Kennedy P/N BBF2805S

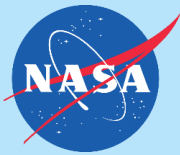
c. Developing more efficient rad-hard by design DC/DC converters that save >10% on regulated loads would reduce the waste heat rejected by the evaporator by > 5W and the battery size by 40-50Wh (size equivalent to nominal laptop battery).

6. Multi-gas monitoring

a. We cannot envision the premise now because the state of the art is too large and power hungry to enable it, but the suit could benefit from measuring:

i. Oxygen (O_2), carbon dioxide (CO_2), water (H_2O), ammonia (NH_3), carbon monoxide (CO), formaldehyde (CH_2O), methanethiol (also known as methyl mercaptan) (CH_3SH), etc.

b. The measuring of the trace contaminants becomes more necessary if we manage to achieve a pressure or temperature swing adsorption continuous removal approach for trace contaminants as it would remove the traditional activated charcoal cartridge from the list of logistics items but would require some level of validation that the function was operating beyond the human nose.



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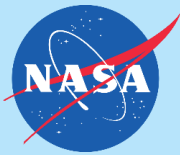
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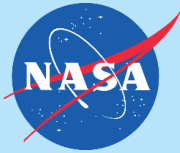
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7. **Dust-tolerant Quick Disconnects (fluids and electrical)**
 - a. Need low mating force, small, dust tolerant quick disconnects that improve on the current state of the art, the EMU Service and Cooling Umbilical (SCU)
 - b. Fluids include (2) 3750 psia oxygen ports, (3) 35 psi water, (1) 80pin electrical connection with a mandate that the connections be capable of mating/demating under all pressure combinations
8. **Power**
 - a. Safe, high-energy density power sources that are rechargeable post-EVA
 - b. Current state of the art is Li-Ion batteries with cell level energy densities of 200 Wh/kg but packaged energy densities of ~130Wh/kg after addressing mitigation for thermal runaway
9. **Heat rejection compatible with vacuum and Martian environment (depending on a future system analysis, this may not be broken)**
 - a. The current state of the art is the Spacesuit Water Membrane Evaporator (SWME) with degraded performance under Martian conditions
 - b. Lithium chloride (LiCl) radiators that capture the H₂O vapor from the SWME provide a potential solution
 - c. A boost compressor on the SWME vapor outlet could potentially yield improved cooling
 - d. A radiator that uses the reduced capacity SWME as a topping cooler could potentially work (this was examined during the schematic studies, 2006-2007)



10. Heat Transport Improvements

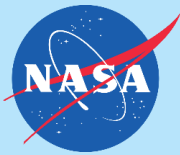
- a. Improve the Liquid Cooling and Ventilation Garment (LCVG) state of the art
- b. Improve the UA such that warmer water can be used to sink the waste heat from the human and hence reduce the evaporator size
- c. Drastically alter the human to cooling loop interfaces such as a fluid filled suit with pumped directly cooled water
- d. Alter the Thermal Micrometeoroid Garment (TMG) such that the emissivity/absorptivity can be dynamically altered to improve thermal regulation

11. Human-Machine Interface Improvements

- a. Current state of the art includes mechanical switches and a 16 x 2 Liquid Crystal Display (LCD)
- b. Low power, wide thermal range, rad tolerant high definition graphics displays that can be integrated with the suit softgoods or hard goods
- c. Heads up displays

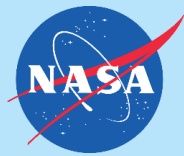
12. Suitport vehicle interfacing

- a. Airlocks are still the state of the art. If we are to ever use suitport beyond conceptual planning, investment needs to be made to assess and overcome issues with the concept



PRESSURE GARMENT SYSTEM (PGS)

Pressure Garment Technology Development



2005

CxP

2010

ETDD/ETDP

2012

AES/GCD

2016

MK III 1992



WEI 1998



REI 2006



- Exploration mission trade study support via timeline analysis and end-to-end analog testing with pressurized suits, robotic assistants, and mid-fidelity vehicles/habitats
- Exploration pressure garment requirements development
 - Suit fit and strength analysis
 - Extensive multi-suit mobility studies
 - Suited joint torque
 - Dust/dirt protection and mitigation
 - Suit mass and center of gravity

Z-1 2011



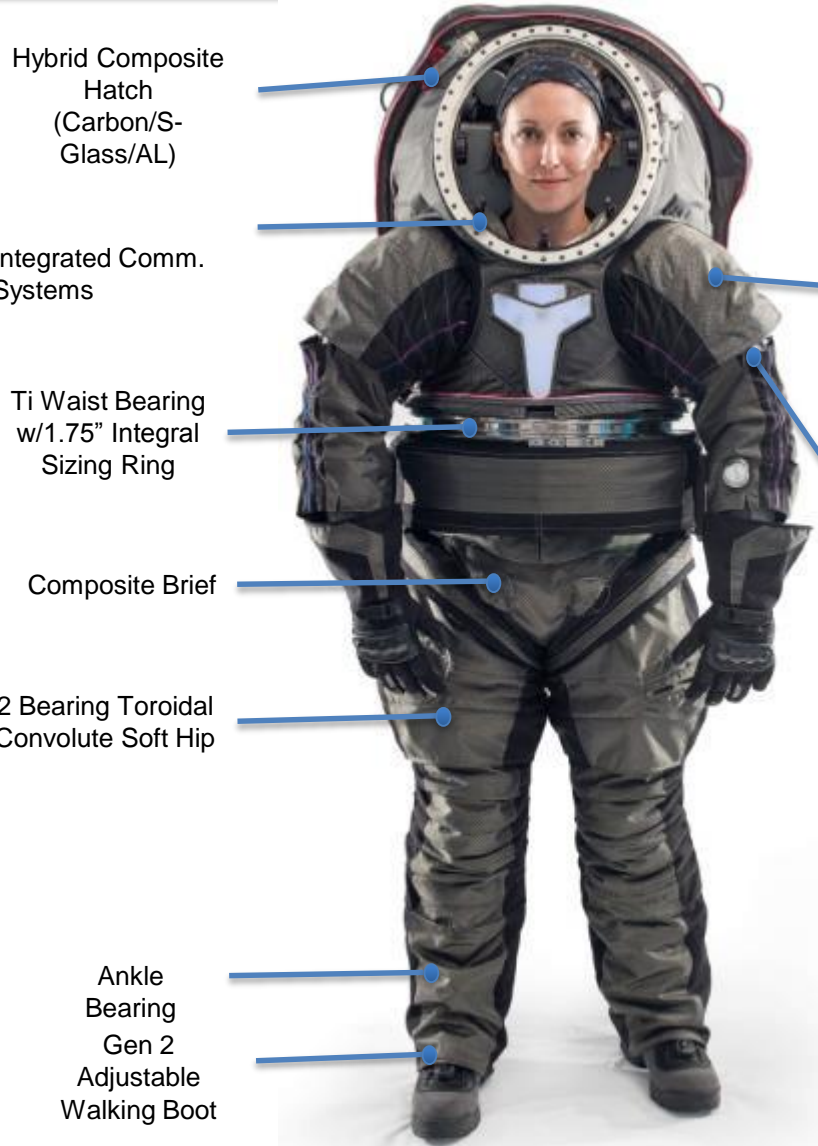
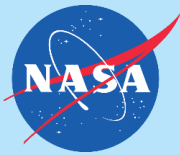
- Mobility demonstrator
- First prototype compatible with delta pressure suitport don/doff evaluations
- Optimized for larger crew population

Z-2 2016



- Highest fidelity planetary prototype since Apollo
- Rated for 100% oxygen environments
- Certified for testing in the NBL
- Optimized for smaller crew population

Z-2 Design Features



Hybrid Composite Hatch
(Carbon/S-Glass/AL)

Integrated Comm. Systems

Ti Waist Bearing w/1.75" Integral Sizing Ring

Composite Brief

2 Bearing Toroidal Convolute Soft Hip

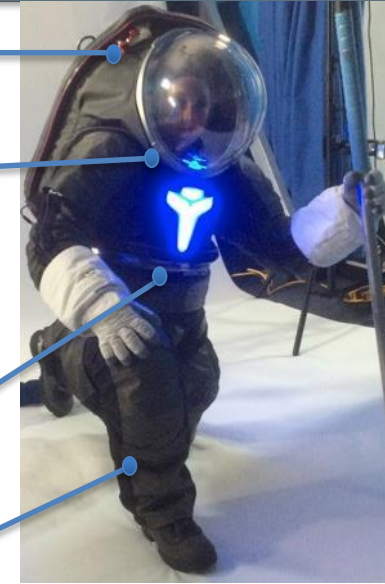
Ankle Bearing
Gen 2
Adjustable Walking Boot

Removable SIP
(not shown)
13x11 Elliptical Hemispherical Helmet

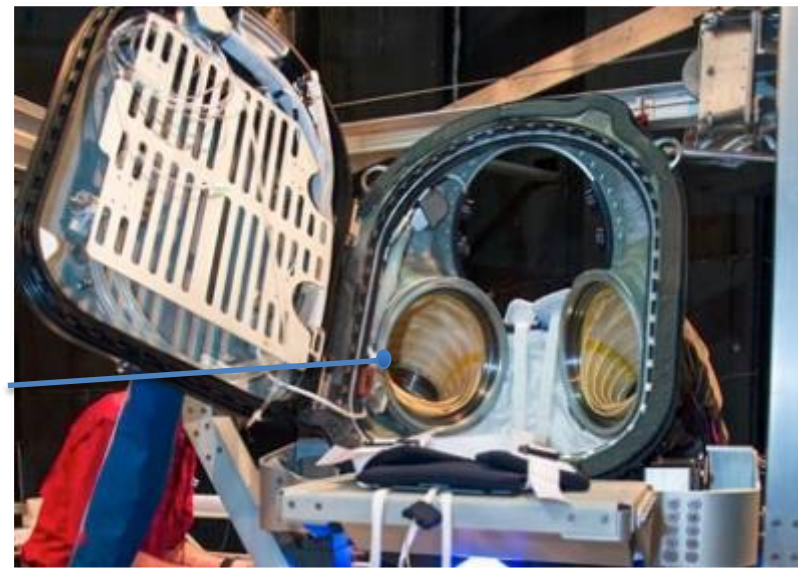
2 Bearing Rolling Convolute Shoulder

RC Waist Joint

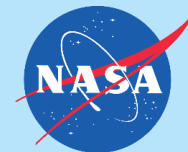
EMU Style Acme Thread FAR



Composite Hard Upper Torso (HUT)
(Carbon/S-Glass)
(1" Vernier Sizing)



High Performance EVA Glove (HPEG)



- Gas Pressurized EVA Gloves
 - Link-net bladder/restraint test article
 - Completed fabrication
 - Received one pair in Jun 2016
 - Gas pressurized glove prototypes
 - Completed fabrication
 - Held Pre-Test Review
 - Completed verification testing
 - Received two pairs in Aug 2016
 - Testing of prototypes Fall 2016
- Mechanical Counter Pressure Gloves
 - Held Pre-Test Review
 - Completed manned glovebox testing
 - Received prototype hardware in Jul 2016



**Link-Net Bladder/Restraint
and Cover Layer**

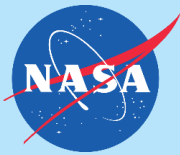


**Gas Pressurized Glove
Prototypes**

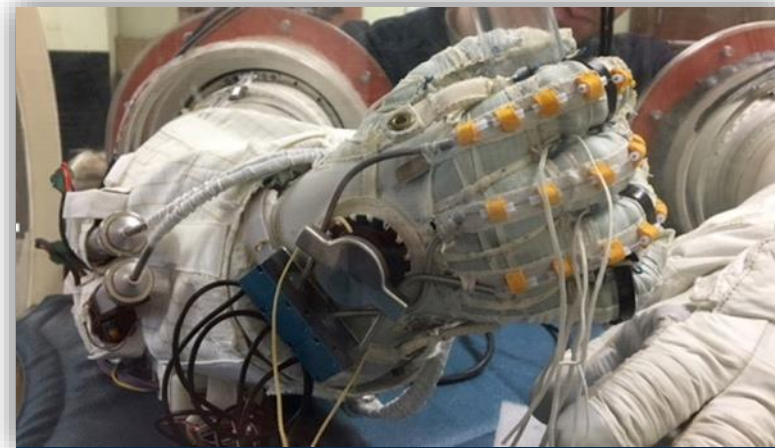


**Glovebox Testing of Mechanical Counter Pressure
Prototypes**

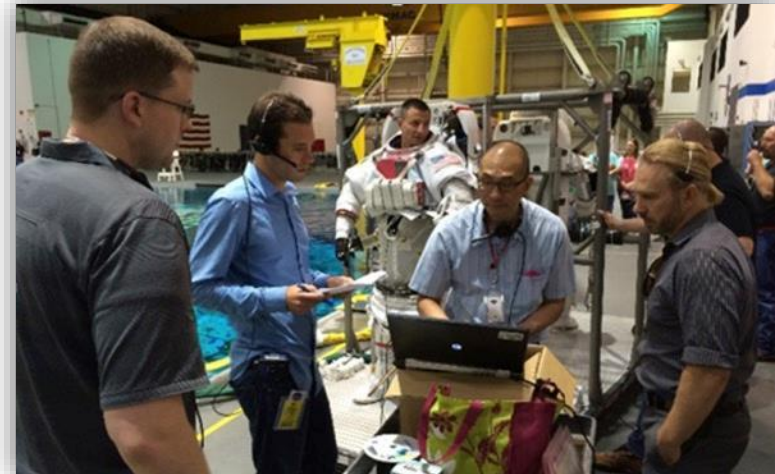
High Performance EVA Glove (HPEG)



- Robotically Assisted EVA Gloves
 - Completed hardware upgrades to the 2nd Space Suit RoboGlove (SSRG) prototype
 - New system includes **sensors** that determine finger position to enable more precise control and “power steering” to ease the effort required to execute grasps
 - Evaluations Sep 2016
- **Sensor Suite**
 - Completed successful NBL test on July 11, 2016
 - Over 4 hours of data collected
 - Approximately **30 sensors** measuring fingernail strain, force, temperature and humidity
 - Test report Fall of 2016
 - Future work will assess the sensor suite’s ability to evaluate various prototype gloves



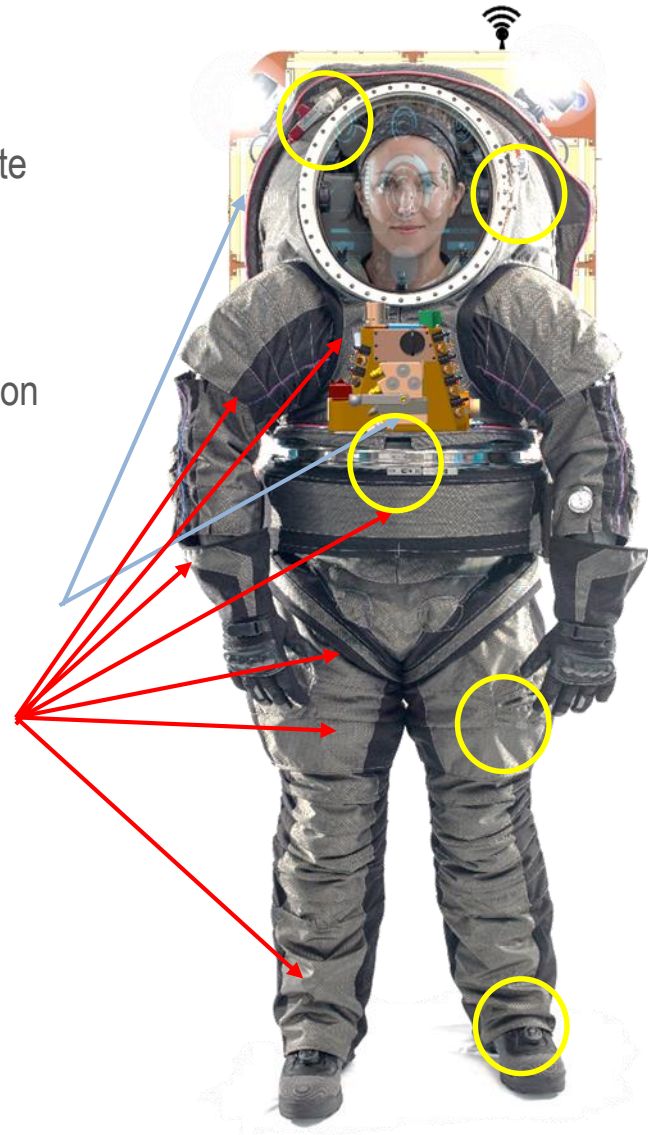
New enhancements on SSRG prototype 2



Sensor Suite NBL Test

Dust Tolerant Mechanisms

- Space suits for planetary exploration will be required to operate nominally in a coarse dirt and fine dust environment for up to 600 hrs with minimal maintenance required
- Nominal operation is considered less than 10% increase in running torque for bearings, less than 10% increase in actuation torque for disconnects, and less than 2 sccm increase in leakage
- Key mechanisms in space suits include:
 - Quick disconnects for oxygen, water, and power/data lines; gas exhaust ports, relief and purge valves
 - Bearings in the pressure garment arms, legs, and waist
 - Component hard disconnects at the pressure garment wrist, arm, waist thigh, and ankle; and hinges at the pressure garment rear hatch
- Desired Technology Capabilities:
 - Mechanisms with quick change-out dust seals
 - Mechanisms with active dust repellent properties



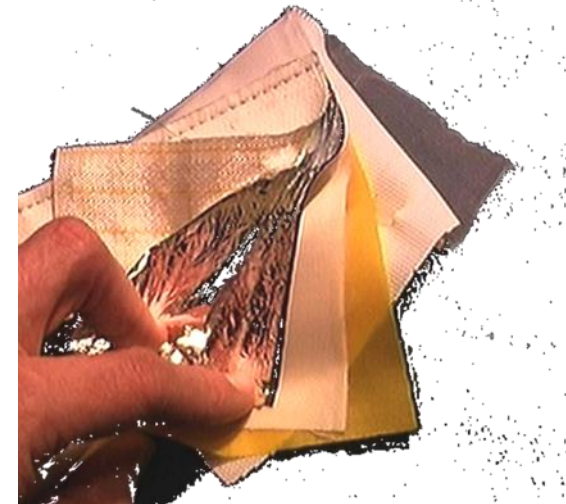
Textiles for High Abrasion Environments

- NASA needs suit material(s) and systems of layers of materials that are capable of long duration exposure to dust and abrasive activities that are also flexible so as not to compromise mobility (walking, kneeling, etc.)
- Desired Technology Capabilities:
 - Self-healing textiles
 - Damage sensing textiles
 - Manufacturing techniques to minimize dust migration between textile layers
 - Textiles or coatings with active dust repellent features
 - Textiles or coatings with passive dust repellent features



Thermal Insulation for Non-Vacuum Environments

- Current space suit insulation technologies rely heavily on the vacuum of the low-earth orbit environment to minimize heat transfer by separation of layers in the space suit material lay-up
- However, various exploration destinations, and specifically Mars, exhibit low pressure atmosphere which allows convection to occur
- Desired Technology Capabilities:
 - Lightweight, flexible, durable, and thin to minimize interference with mobility features of suits (Note: If one or more of the above characteristics is an issue, but could be resolved for space suit application through development, the technology is of interest)
 - Adaptable for seasonal variations in temperature

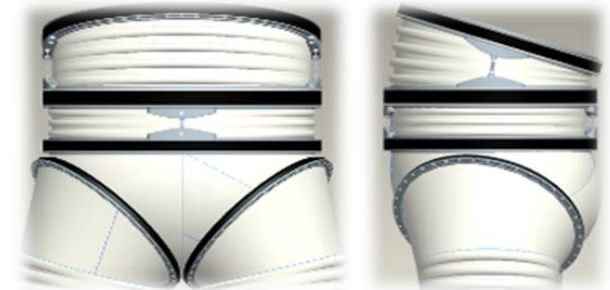
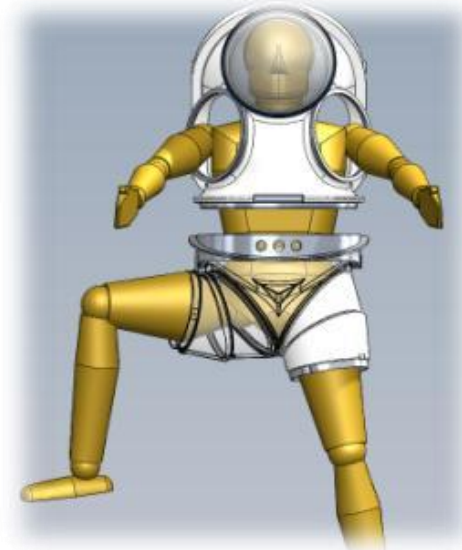


Mass Reduction Strategies

- Launch mass from Earth's surface has always been a challenge but introduction of gravity environment for EVA will create greater need for reduced on-back mass.
- Gravity environments will increase the need for finer alignment of EVA suit system CG to optimize mobility and efficiency.
- Desired Technology Capabilities:
 - Composite lay-ups that meet load requirements (pressure and impact) with minimal mass
 - High reliability methods for fabricating complex composite geometries
 - In-situ printing of replacement suit components
 - Lightweight bearings

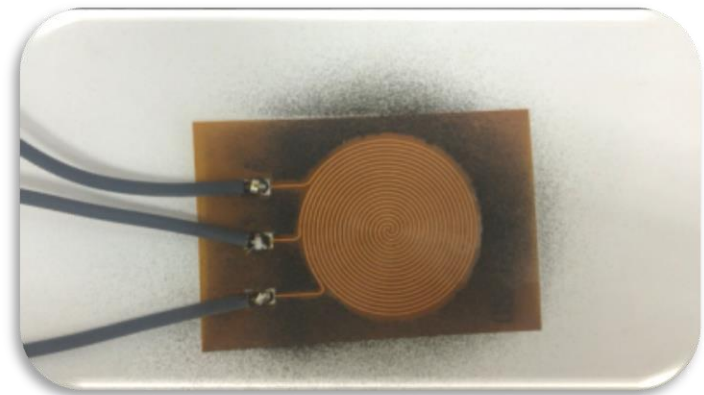


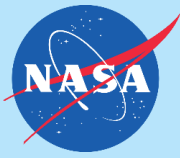
- Other focus areas for technology development:
 - **Visors** – Better shading for UV
 - **Environmental Protection Garment**
 - Quick change out, micrometeorite tolerant, and dust tolerant
 - **Biomed Sensors**
 - Required: Heart Rate, EKG, & O₂ Tolerant
 - Desired: Respiration & non-contact
 - **Bearings**
 - Lightweight bearings (possibly non-metallic to mitigate shock paths)



Dust Mitigation Strategy for Remote Habitats

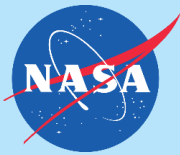
- Exclusion of dust from habitable environments is a system level challenge
- Space suited crewmembers will bring some amount of dust into the habitat following each EVA. In reduced gravity environments fine dust does not quickly settle out of the habitat atmosphere.
- Desired Technology Capabilities:
 - System to remove/repel dust from space suits
 - System to remove and collect dust from the habitat atmosphere
 - System to remove and collect dust from habitat surfaces
 - System of locks that employ the above to mitigate dust in the habitable volumes





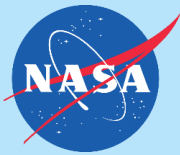
SBIR INFUSION SUCCESS STORIES

SBIR Infusion Success Story



Vista Photonics Multi-Gas Monitor

Vista Photonics Multi-Gas Monitor



- NASA wanted to improve its ability to monitor the ISS habitable environment
- **SBIR Phase I awarded** to Vista Photonics, Inc.
 - **Purpose:** Develop a single, portable gas analyzer that can detect multiple gases (i.e., oxygen, carbon dioxide, water vapor, and ammonia)
 - Multi-Gas Monitor (MGM) is the first laser sensor to continuously measure these gases on a spacecraft
 - Monitoring these gases is crucial for ensuring crewmembers' health aboard the ISS
 - Prior to the MGM, three separate devices were used to monitor these gases
- **November 2013:** MGM launched on Soyuz 37
- **February 2014:** MGM activated
- Device has operated well past its initial 6-month technology demonstration period
- NASA is now expanding the technology's gas-monitoring capabilities for use in Orion
- **January 14, 2015:**
 - Astronauts and cosmonauts onboard the ISS evacuated to the Russian side of the outpost after an ammonia leak was detected
 - MGM, which detects ammonia, helped determine that the ammonia leak aboard the ISS was a false alarm

Vista Photonics, Inc.

Compact Optical Carbon Dioxide Monitor for EVA Phase I SBIR 2008

- Concept Development
- Low power infrared optical source
- High-sensitivity of established optical absorption detection techniques

Compact Optical Carbon Dioxide Monitor for EVA Phase II SBIR 2009

- Develop rugged, compact, low-power optical sensor prototypes
- CO₂ at EVA-relevant concentrations
- Wavelength modulation spectroscopy (WMS)



In Situ Water Isotope Analyzer for Moon Exploration SBIR Phase II, IIe, III 2010-2013

- Combined ultrasensitive WMS with emerging long wavelength infrared laser diodes
- Improved CO₂, H₂O, and O₂ sensing

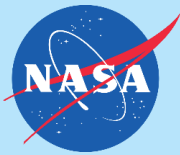


High-Performance Infrared Laser Sensor Technology & ISS EMU Sensor Candidate SBIR CRP, Phase III 2015-2017

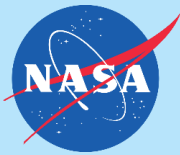
- First Prototype – PLSS Gas Sensor delivered with upgraded line locking from MGM
- Delivered the In-Flight Contingency Monitor (IFCM) for Orion



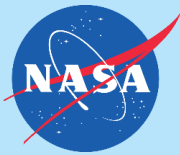
Role of Small Businesses in EVA Topic Area



- Infusion Success! → A small business solution via the SBIR/STTR process is now baselined in the PLSS. Therefore, a significant contributor to the advanced spacesuit development.
- We want more successes!!
- For the EVA Topic Area, the list of technology needs presented herein is the most recent exhausted listing published for the EVA Topic Area at one time.
- Most of the technology needs listed herein are technology gaps from the current state of the art -- areas that would lend themselves to SBIR/STTR and STMD development projects.
- Small businesses are encourage to review the technology needs presented within and feel free to contact any of the POCs to find out more.
 - If you have a good idea or a potential solution to any of the technology needs, we want to hear about it.
- It is okay for small businesses to not have flight experience. NASA can provide you guidance should you have an idea or a potential solution.
 - For example, Orion is currently evaluating the potential of certifying one of their small business vendors so they can provide flight hardware to NASA directly.

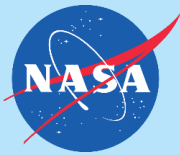


- **SBIRs – Phase I (SBIR 2017-I, 6/2017)**
 1. Adv Materials Innovations, San Diego, CA
 - “Sensor to Measure Space Suit Interactions with the Human Body”
 2. Composites Automation, LLC, Newark, DE
 - “Impact Resistant Composite Structures for Space Suit Applications”
 3. Create, LLC, Hanover NH
 - “Compact, High-Accuracy Oxygen Flow Meter”
 4. Maher & Associates, LLC, Baltimore, MD
 - “Damage Tolerant Composite Systems for Spacesuits”
 5. Somatis Sensor Solutions, Las Angeles, CA
 - “Flexible Polymer Sensor for Space Suits”
 6. STF Technologies, LLC, Newark, DE
 - “Impact-Resistant, Damage-Tolerant Composites with STF Energy Absorbing Layers”

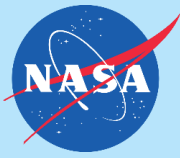


- **SBIRs – Phase II**

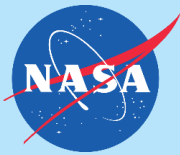
1. Intelligent Optical Systems, Inc. (SBIR 2014-II, 5/2015)
 - “Non-Intrusive, Distributed Gas Sensing Technology for Advanced Spacesuits”
2. NEI Corporation, Piscataway, NJ (SBIR 2014-II, 7/2015)
 - “Shock Hazard Prevention Through Self-Healing Insulative Coating on SSA Metallic Bearings”
3. Air-Lock, Inc., Milford, CT (SBIR 2015-II, 4/2016)
 - “Contact Stress Design Parameters for Titanium Bearings”
4. Innoflight, Inc., San Diego, CA (SBIR 2015-II, 5/2016)
 - “Compact Wireless EVA Communication System”
5. Nanosonic, Inc., Pembroke, VA (SBIR 2015-II, 6/2016)
 - “Multifunctional, Self-Healing Hybridsil Materials for EVA Space Suit Pressure Garment Systems”
6. Serionix, Champaign, IL (SBIR 2016-II, 4/2017)
 - “Fiber-Based Adsorbents Tailored for PLSS Ammonia and Formaldehyde Removal”
7. Precision Combustion, Inc., North Haven, CT (SBIR 2016-II, 4/2017)
 - “Novel, Vacuum-Regenerable Trace Contaminant Control System for Advanced Spacesuit Applications”



- **STTRs – Phase I (STTR 2017-I, 6/2017)**
 1. Creare, LLC, Hanover NH
 - “Volume Sensor for Flexible Fluid Reservoirs in Microgravity”
 - Dartmouth College, Hanover NH
- **STTRs – Phase I (STTR 2016-I, 6/2016)**
 1. LUNA, Inc., Roanoke, VA
 - “Environmentally Protective Fabrics for Spacesuits”
 - North Carolina State University, Raleigh, NC
 2. Seacoast Science, Inc., Carlsbad, CA
 - “Low Mass/Power Sensor Suite for Spacesuits”
 - Case Western Reserve University, Cleveland, OH
 3. STF Technologies, LLC, Newark, DE
 - “Shear Thickening Fluid Enhanced Textiles for Durable, Puncture- and Cut-Resistant Environmental Protection Garments”
 - University of Delaware, Newark, DE
- **STTRs – Phase II (STTR 2015-II, 9/2016)**
 1. Intelligent Optical Systems, Inc., Torrance, CA
 - “Advanced Gas Sensing Technology for Space Suits”
 - University of North Texas, Denton, TX
 2. N5 Sensors, Inc., Germantown, MD
 - “Nanoengineering Hybrid Gas Sensors for Spacesuit Monitoring”
 - George Mason University, Fairfax, VA

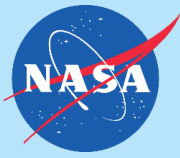


HOW TO GET STARTED



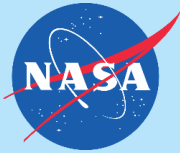
Tips for success in the EVA Topic Area

- Be aware of technology needs before the solicitations are released
- Reach out to the EVA Topic Manager, Subtopic Managers, and Subsystem Team Leads to see what is going on and what may be upcoming.
 - A comment we received from one vendor only days before the black-out period, “If I would have known in advance it was so easy to contact you, I would have done it weeks ago”.
 - We have provided tours of our labs to help understand the complexity of the suit development. This is to also share what in house work is currently being done and what development is still needed. Tours are not provided during black-out period.
- Talk to an NASA EVA discipline expert about good ideas for the suit
 - They can provide guidance & insight
 - Major component leads are good to contact as well
- Be cautious during Phase I Solicitations - Once proposal period starts, a **black-out period** begins – discussions are no longer allowed



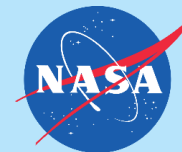
Tips for success in the EVA Topic Area

- Attend workshops and conferences
 - International Conference on Environmental Systems (ICES) <https://www.ices.space/>
 - SBIR/STTR Industry Day
- Visit the SBIR/STTR Website regularly <http://sbir.nasa.gov>
- Research the Technology Roadmaps for EVA technology gaps
 - Although these Roadmaps were developed some time ago, they are still relevant for EVA technology
 - <http://www.nasa.gov/offices/oct/home/roadmaps/index.html>
- Subscribe to the SBIR/STTR News
- Be attentive to recommendations from Investigation Reports



Tips for success in the EVA Topic Area

- **BE AWARE!!!**
- Schedules and solicitation cycles vary
- If you are lucky enough to win a SBIR/STTR contract
 - Deliver all products on time
 - **Communicate, Communicate, Communicate** with your Contracting Officer Representative
 - The most successful vendors communicate regularly their successes and set backs
 - Stay on schedule or get ahead!
 - **We love hardware, testing, and lots of data in Phase I's and Phase II's.**
- **READ, READ, READ** your contract
 - There are deadlines for Phase II-Extended, Phase II-Enhancement, and Phase II-Expanded
 - Several of our vendors have just missed their windows of opportunity for Phase II opportunities because they did not read their contracts and the criteria



Websites

- NASA SBIR/STTR website → <http://sbir.nasa.gov>
- International Conference on Environmental Systems (ICES) → <https://www.ices.space/>
- ICES proceedings are located at → <https://www.ices.space/conference-proceedings.html>
- Space Technology Roadmaps → <http://www.nasa.gov/offices/oct/home/roadmaps/index.html>
- Spacesuit Knowledge Capture (NESC Academy Online) → <http://nescacademy.nasa.gov/category/5/sub/27>

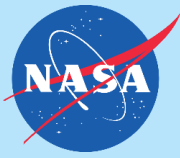
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¹Birbara, P.J., Filburn, T.P., Michels, H.H., Nalette, T.A., Hamilton Sundstrand Corporation, Windsor Locks, CT, U.S. Patent for a “Sorbent System and Method for Absorbing Carbon Dioxide (CO₂) from the Atmosphere of a Closed Habitable Environment,” U.S. Patent Number 6,364,938 B1, April 2, 2002.

²Chullen, C., Campbell, C., Papale, W., Murray, S., Wichowski, R., Conger, B., and McMillin, S., “Design and Development Comparison of Rapid Cycle Amine 1.0, 2.0, and 3.0”, *46th International Conference on Environmental Systems*, ICES-2016-073, Vienna, Austria, July 10-14, 2016.

³Paul, H., Jennings, M., and Waguespack, G., “Requirements and Sizing Investigation for Constellation Space Suit Portable Life Support System Trace Contaminant Control”, *40th International Conference on Environmental Systems*, Barcelona, Spain, July 2010.

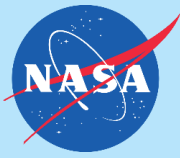
⁴James, J., “Spacecraft Maximum Allowable Concentrations for Airborne Contaminants,” JSC-20584, Houston: NASA/Johnson Space Center, November 2008.



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QUESTIONS



The End

THANK YOU FOR YOUR PARTICIPATION!



NOTE: *This presentation will be accessible through the Industry Day website.*