National Aeronautics and Space Administration

Deep-Space Extravehicular Activity (EVA)

Briefing to the National Research Council Technical Panel

March 27, 2013

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Agenda

- Suit technology history – extremely short version
- EVA Strategic Objectives
- Broader EVA Community Involvement
- Short Term EVA Technology Challenges
- Long Term EVA Technology Challenges
- Conclusion

EVA Suit Technology History

- **EMU: Current US Operational Space Suit**
  - Put in service in 1982
  - Extravehicular Mobility Unit (EMU) mobility and EVA Tools designed for Zero-G
  - The PLSS (Primary Life Support System) was an evolution of the Apollo Space Suit
  - EMUs still supporting ISS program after multiple life extension and upgrades
- **Exploration and Technology Development Program**
  - Since ~2005, EVA has had a resurgence in development of next generation EVA suit components / subsystems
  - EVA technology challenges for potential future explorations destinations were identified and provided the focus for EVA technology advancement efforts
  - Provided basis for informed roadmaps
- **Recent Architecture Study Teams**
  - Reaffirmed development of Space Suits as one of the top “destination system” elements to be addressed

EVA / Suit Strategic Objectives

- **Long term goals for EVA System**
  - Increased Safety & Reliability
    - Significantly improve protection against MMOD (micrometeoroids and orbital debris), dust, radiation, electrical shock, and thermal extremes – “Go anywhere suit”
    - Modular systems – “Plug and Play”
    - Instant pre-EVA check outs, on board health monitoring, self healing
  - Lower System Mass
    - Zero Consumable life support
    - On back power generation
    - Combined functionality of EVA and launch entry abort (LEA) suits (increased modularity)
  - Autonomous Operation and Robotic Integration
    - Suit is a node on the network, capable of commanding and interacting with robotic support elements. Increased informatics
  - Expand Anthropometric limits, increase crew comfort, and reduce injury risk
  - Lower Cost
    - Improved analytical tools to model and predict EVA performance

Broader EVA Community Involvement

- **Attempts to involve industry, academia and other technology agencies**
  - Hosted EVA/ECLSS(environmental control life support systems) Technical Forum in Houston – May 1 and 2, 2012
- **Introductory discussion with the Russian EVA community during recent Technical Interchange Meeting on potential future Advanced EVA technology challenges discussions**
- **Recently the EVA Community reviewed the detailed functions and components that make up the EVA system to identify the technology challenges associated with the potential destination Design Reference Missions (DRMs)**
  - Assigned descriptor to each function on whether the technologies needed are enhancing or enabling for alignment with the exploration DRMs

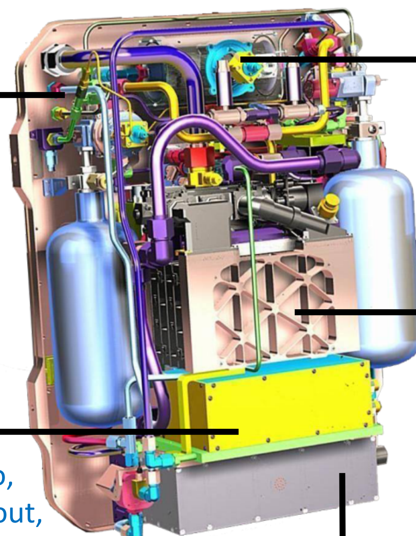
Short Term EVA Technology Challenges

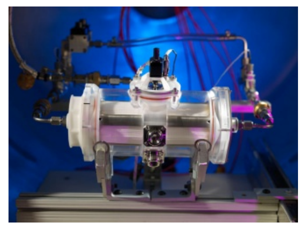
EVA Primary Functions
- *Sustain the Life of the Crewmember*
- *Perform EVA Tasks*
- *Provide Communications*

PLSS advanced packaging, inter-connect and hold systems with low volume/ mass

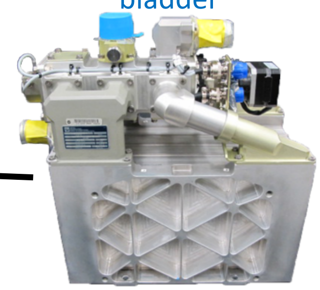
Variable Setpoint Regulator, Lightweight Tanks, Pressure Transducers for High P O2 Systems

Fan and TCC





Suit Water Membrane Evaporator and self-pressurizing water bladder



Dual-mode radio, Integrated Suit Audio, Automated suit check out, EVA Compatible Electrical Components, Miniaturized Components, EVA exploration information system, and Navigation

Ultra high energy battery

Rapid Cycling Amine: on-back regenerable CO2, sensors, and humidity control

Suitport capable upper torso with Suitport interface plate

Increased Mobility at 8 psid nominal operations

Analytical tools to improve prediction of fit, mobility, and injury protection (not shown)

Advanced gloves

Lightweight Bearings

Exploration lower torso

TMG with dust protection and alternate thermal protection for exploration environments (TMG not shown)

These technology advancements align with Agency Technology Roadmaps

Short Term EVA Technology Challenges

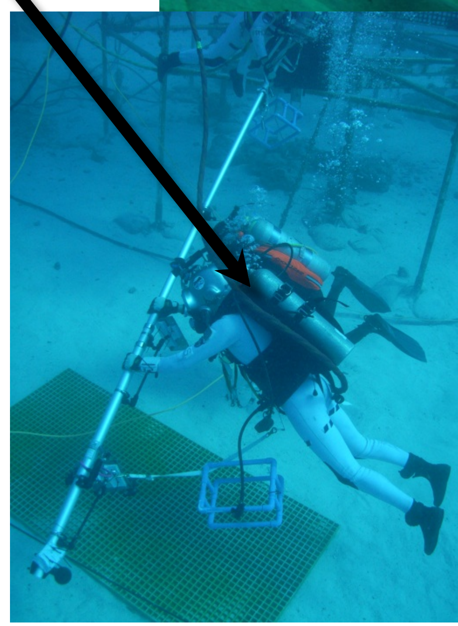
EVA Primary Functions

- *Anchoring*
- *Translation and Stabilization*
- *Surface Sampling and Collection*

Crew Local Anchor compatible with monolithic and rubble NEAs

Geological sample collection tools
- Impact collection
- Float sample
- Surface layer sample (biological)
- Subsurface tool

Translation Aids compatible with monolithic and rubble NEAs



Sample Curation and Containment

Notional EVA Suit Functionality vs. Potential Destinations

	ISS	In-Space / GEO	NEA	Mars
System				
Minimum mass beyond LEO	✗	✓	✓	✓
Dust mitigation	✗	✗	✓	✓
Service life (50 - 100 EVAs)	✗	✓	✓	✓
Field maintainable	Upgrade	✓	✓	✓
Enhanced Radiation Protection and Monitoring	✗	✓	✓ Monitor only	✓ Monitor only
Environmental Protection (e.g. thermal, micrometeoroids, charging)	✓	✓	✓	✓
Exploration Atmosphere Prebreathe	✗	✓	✓	✓
Vehicle Interfaces				
Suitport / Suitlock with Suitports Compatible	✗	✓	✓	✓
Airlock Compatible	✓	✓	✓	✓
Pressure Garment				
Component Resize and Sparing Capability	✓	✓	✓	✓
Ease of don/doff (rear hatch)	Upgrade	✓	✓	✓
Upper body mobility	✓	✓	✓	✓
Walking mobility	✗	✗	✗	✓
TMG (w/opt. dust features)	✓	✓	✓	✓
Cut/abrasion-resistant	Upgrade	✓	✓	✓
Reduce Injury	Upgrade	✓	✓	✓

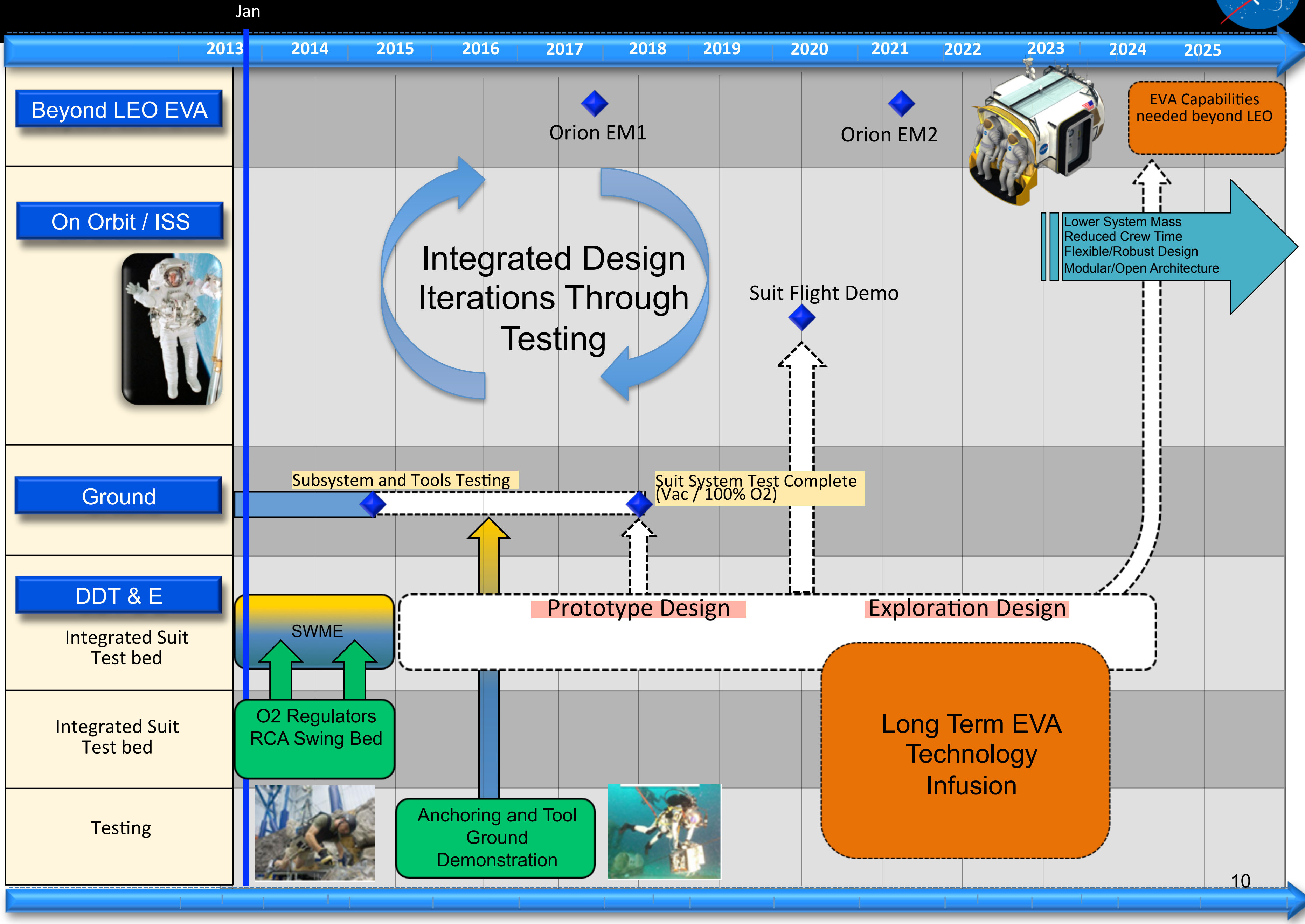
✗	= Not enabling
✓	= Enabling

Notional EVA Suit Functionality vs. Potential Destination

	ISS	In-Space / GEO	NEA	Mars
Life Support				
8 hour EVA duration	✓	✓	✓	✓
Vacuum Separable PLSS	✗	✗	✗	?
Compatible w/umbilical ops	✓	✓	✓	✓
Regenerable CO2 removal	Upgrade	✓	✓	✓
Secondary O2 supply	✓	✓	✓	✓
Variable Pressure Setpoints	Upgrade	✓	✓	✓
Avionics & Software				
High Bandwidth / Network Capable Radio	Upgrade	✓	✓	✓
Multiple voice comm loops	✓	✓	✓	✓
Caution & Warning	✓	✓	✓	✓
HD Helmet camera	Upgrade	✓	✓	✓
Navigation	✗	✗	?	✓
Graphical Display	Upgrade	✓	✓	✓
Biomed (incl. Heart Rhythm)	✓	✓	✓	✓
EVA Information Systems	Upgrade	✓	✓	✓
High Energy Density Battery	Upgrade	✓	✓	✓
Tools				
Dust cleaning/mitigation tools	✗	✗	✓	✓
Surface tools	✗	✗	✓	✓
Anchoring and Translation tools	✗	✗	✓	✗
Advanced Jetpack	✗	✓	✓	✗

✗	= Not enabling
✓	= Enabling

Current EVA Technology Timeline Roadmap



Long Term EVA Technical Challenges

- **This lists represents the EVA/Suit development/technology challenges (dependent on destination) that will be addressed closer to the needs of the potential destination**
  - **High Energy Density Battery: needed for missions with highly autonomous crewmembers**
  - **Advanced tools, Anchoring systems and Jet Pack**
  - Exploration Atmosphere Prebreathe Protocols (8.2 psia/34% O2)
  - Software Defined Radio: Flexibility for a variety of spacecrafts and destinations
  - Plasma environment and mitigation techniques
  - **Advanced Suit/Human interfaces (informatics, controls)**
  - **Suit materials / Dust (gloves, valves, switches, mechanisms, TMG [thermal/ micrometeorite garment])**
  - Dust Mitigation in Habitable Volume Ingress/Egress Concepts (Suitport/Hybrid)
  - **Radiation Protection: Particularly for GEO electron belt exposure**
  - Advanced PLSS packaging and materials assessments to protect for falls and enhance ambulation (e.g. improve CG) for partial gravity destinations
  - **Human-Robotics Interfaces, Exoskeleton**
  - Navigation: For surface operations
  - Suit Anthropometric Sizing/Spinal Elongation Mitigation
  - **Alternative heat rejection systems (e.g. radiators) for zero consumables suit**

Conclusion

- **Significant challenges exists for technologies needed for EVAs beyond low Earth orbit**
- **Ground based analog missions will be used to identify operational concepts and technology needs**
- **ISS demonstrations are being planned with a new advanced EVA suit as a test platform**
- **EVA roadmap is solidly based on last 7 years of technology development efforts, but is not complete**
  - Enabling/Enhancing technologies are being vetted for DRMs
  - Mission definition is needed for complete list of technologies and need dates

"Men must rise above the Earth to the top of the atmosphere and beyond for only then will he fully understand the world in which he lives."
– Socrates 469-399 BC

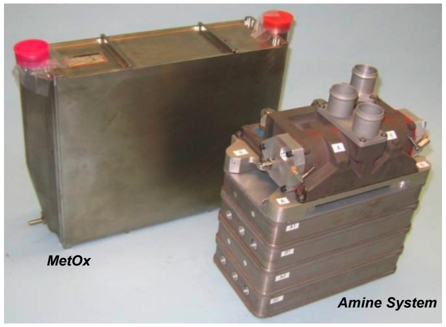
Backup

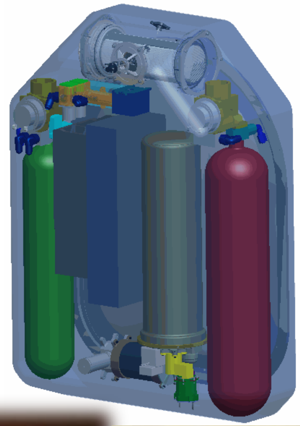
Suit – PGS Development Technology Needs

- **Suit Pressure Garment**
  - Increased mobility at increased pressures (~55kPa / 8 PSI)
  - Robust gloves and improved mobility
  - Radiation, Dust, Micro-meteoroid, and plasma protection materials (advanced materials)
  - Analytical tools to improve prediction of fit, mobility, and injury protection
  - Lightweight bearings
  - Multiple vehicle interface capabilities

PLSS Development Technology Needs

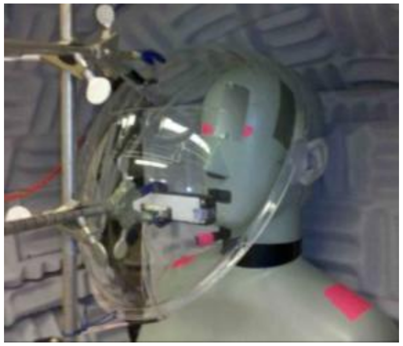
- **Life Support Systems**
  - Advanced packaging, inter-connect and hold systems with low volume/mass
  - Thermal Control Subsystem
    - Advanced Heat Rejection Technologies
      - Spacesuit Water Membrane Evaporator (SWME)
      - Reduced consumable concepts
    - Self-pressurizing water bladder
    - Avionics coldplate
    - Pumps
  - Ventilation Subsystem
    - Advanced CO_2 removal and humidity control (including sensors)
    - Fan
    - Trace Contamination Control (TCC)
  - Oxygen Systems
    - Lightweight Tanks
    - Variable Set-Point High Pressure Oxygen Regulator
    - Pressure Transducers for High Pressure O_2 Systems





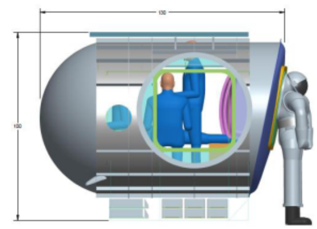
PAS Development Technology Needs

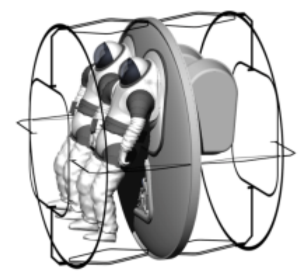
- **Power, Avionics and Software**
  - Power
    - High specific energy batteries (W-hr/kg)
  - Avionics
    - High data rate network based communication
    - Integrated Suit Audio Solutions
    - EVA/IVA compatible displays (graphical)
    - Miniaturized Electronic Components
    - EVA-Compatible Electrical Switches, Connectors, and Controls
    - On-Suit EVA Navigation
  - Software
    - EVA Information Systems / Crew Feedback
    - Advanced system health and environmental monitoring



Suitport/Hybrid

- **Suitport provides a method of rapidly starting and ending EVAs and provides an increased level of environmental containment of potentially hazardous substances that could be encountered during the EVA.**
  - ISS Airlock operations require approximately 2-4 hours of pre and post-EVA over head time, goal is to reduce this time to 30 minutes
  - Significantly decrease the exposure of the habitable volume to dust, particulates, and any other harmful materials since a vast majority of the suit remains external to the spacecraft
  - This concept can save approximately 660 kg of consumables over a two week excursion in a pressurized vehicle performing multiple EVAs daily as opposed to conventional airlock systems
  - Suitport bulkhead could conceivably interface with multiple vehicles, including MMSEV, Deep Space Habitat, new ISS element





- **"Suit box " testing of concept was performed last calendar year, create an 8 psid environment using chamber/ anti-chamber (Chamber B) to manipulate pressure delta**

- **Hybrid concept provides the same method with the addition of a hatch between the suitports and the capability to pressurize the volume around the suits**
  - Hybrid concepts should be looked at to enable suitport compatibility and dust mitigation on larger Habitat elements to allow the capability to bring suit inside for maintenance