EVA Technology Collaboration Workshop

Welcome!

Chris Hansen
EVA Office, Manager
NASA / Johnson Space Center

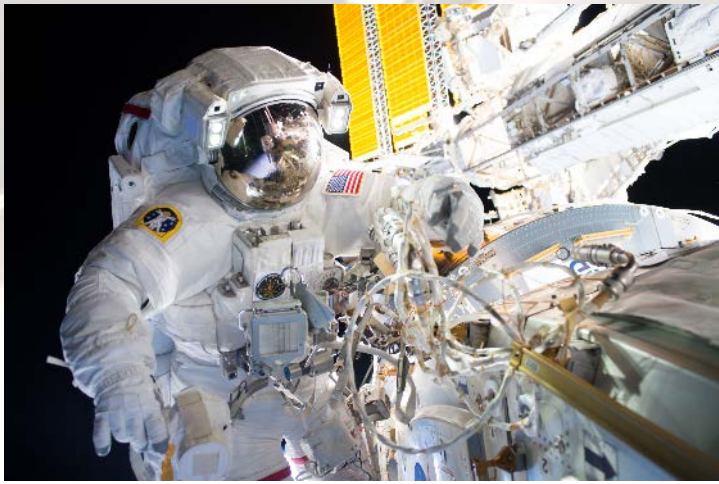
NASA Exploration Goals

"NASA is working hard to send humans to an asteroid by 2025 and Mars in the 2030s. The powerful new Space Launch System rocket and the Orion spacecraft will travel into deep space, building on our decades of robotic Mars exploration, lessons learned on the International Space Station, and groundbreaking new technologies."

(http://www.nasa.gov/topics/journeytomars/index.html)

- EVA systems will obviously play a major role as a critical destination system for any future human exploration mission

- We will rely heavily on the lessons learned on ISS and the technology development progressing on:
  - Spacesuits
  - EVA Tools
  - Vehicle Interfaces (e.g. airlock interfaces)
  - Operations & Training



EVA 36: Jeff Williams Expedition 48, 8/19/2016

EVA Vision / Workshop Goals

EVA Vision

"Achieve affordable, effective, and safe EVA capabilities that enhance the human experience as we explore beyond Earth"

Goal of this Workshop

- Provide a forum where NASA and EVA external affiliates can come together and discuss promising advancements in EVA applicable technologies and operations.
  - Share (at a high level) EVA technology development accomplishments and plans between NASA and external community
  - Provides opportunity for external inputs into NASA's perception of gaps, needs, and portfolios to support future exploration missions
- Establish as an annual event … so we will be looking for your feedback

EVA Innovation and Inclusion

EVA community is fostering and enhancing a culture of inclusion and innovation

- **NASA Internal:** EVA Office is committed towards developing an integrated EVA strategy for the agency and enhancing communication internally

- **Industry/Academia:** Improve communication of needs and accomplishments to all parties interested in EVA
  - Utilize face to face forums to enhance communication … today!
  - Support conference attendance and paper submissions
  - Make EVA technology data available to a wider audience
    - EVA.NASA.GOV site was recently opened up and available to NASA contractors with VPN access
    - Goal is to further expand on the data library and availability of this site

- **Media / Press / General Public**
  - Improve availability of materials to support outreach and education events
  - Maintain current and relevant data on public websites
    - Suit Up Website established for 50th year of EVA https://www.nasa.gov/suitup
    - Use / Maintain other NASA public websites as appropriate (https://techport.nasa.gov/home)

- **Legislative / Independent Audits:** Improve responsiveness to actions and queries

Workshop Agenda / Objectives

Day 1: Share EVA technology development accomplishments and plans between NASA and external community

Suit, tools, vehicle support, testing and operation development

Day 2: Invite external parties interested in EVA development to share their accomplishments and thoughts about EVA technologies

Day 3: Provide private forum for any parties wishing to unveil activities to NASA only

EVA Technology Development: Overview, Status and Process

Brian Johnson
EVA Exploration Office, Manager
EVA Office - JSC

EVA Community: Who are we?

EVA Flight Operations & EVA Flight / Technology Development are accomplished via a small yet diverse community

HQ
Study Teams / SMT

Current Programs (ISS)
Future Programs (ARCM)

FOD (Crew / MOD)

SR&QA

Human Health & Performance

Engineering & Chief Engineer (Sustaining and Tech Dev)

Industry / Academia
Procurement & Strategic Partnerships

EVA Office – Planning, Integration & Coordination

HUMAN EXPLORATION

NASA's Journey to Mars

National Aeronautics and Space Administration

NASA

EARTH RELIANT

MISSION: 6 TO 12 MONTHS
RETURN TO EARTH: HOURS

Mastering fundamentals aboard the International Space Station

U.S. companies provide access to low-Earth orbit

PROVING GROUND

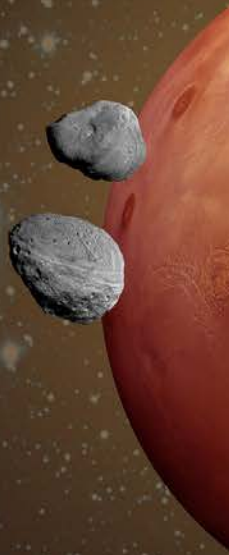
MISSION: 1 TO 12 MONTHS
RETURN TO EARTH: DAYS

Expanding capabilities by visiting an asteroid redirected to a lunar distant retrograde orbit

The next step: traveling beyond low-Earth orbit with the Space Launch System rocket and Orion spacecraft

MARS READY

MISSION: 2 TO 3 YEARS
RETURN TO EARTH: MONTHS



Developing planetary independence by exploring Mars, its moons and other deep space destinations

www.nasa.gov

NP-2016-02-006A-JSC

DRMs to Risk/Gap Identification

How Technology / Knowledge Gaps are Identified

- Mission Class / Design Reference Missions (DRM):
  - Ex. Asteroid Redirect Mission

    7 identified in OCT Roadmap (http://www.nasa.gov/sites/default/files/atoms/files/2015_nasa_technology_roadmaps_ta_0_introduction_crosscutting_index_final_0.pdf)
  - Global Exploration Roadmap provides mission themes and areas of investigation including new space suit

    (https://www.nasa.gov/sites/default/files/files/GER-2013_Small.pdf)
- Functions / Capabilities
  - Operation Concept documents
  - Capability Definition Documents
  - Enhancing vs. Enabling determination
- Performance Goals
  - System level requirements development
- Technology / Knowledge Gaps & Risk Identification
  - Assess State of Art (SOA) vs. goals
  - Assess technical challenges

Forums Used

EVA System Maturation Team (SMT)

- One of 14 NASA HQ chartered teams

EVA Exploration Working Group (EEWG)

– Charted by EVA Office , nominally supported by multiple directorates at JSC

Collaborating Forums

- Human Research Project Workshop
- Science & Tools Collaboration
- Science & Technology Mission Directorate - SBIR Meetings

EVA Gap Lists

- The best publically available summary of EVA technology challenges is located in the 2015 NASA Technology Roadmaps
  - TA 6.2 EVA Systems (27 candidates)
  - TA 7.3.1 EVA Mobility (7 candidates)
  - Portions of other sections
- Additionally, EVA related Human Health and Performance risks are captured in Human Research Roadmap
  - 1 EVA general risk with ~7 gaps
- These technology candidates and tasks are further broken down into much larger / detailed task lists

OCT Roadmap - http://www.nasa.gov/offices/oct/home/roadmaps/index.html
HRP Roadmap - https://humanresearchroadmap.nasa.gov/

Closure Plans to Tactical Planning

- Technology / Knowledge Gap Closure Planning
  - EVA SMT maintains a running list > 200 technology / knowledge and > 100 closure plans
  - EEWG mechanizes annual reviews to ascertain progress to closure and reassess needs based on latest prioritization criteria
- Annual / Tactical Plan Communication
  - EVA Office is developing an annual EVA development plan to trace all known and funded effort - between gaps list and individual organization detailed plans.
  - Goal is more transparency … allow industry / academia to see what NASA has prioritized on an annual basis
- For example
  - HRP documented a fiscal year plan in 2016 … "Integrated EVA Research Plan – 2016" with a goal to put out similar plan in for FY2017
    - ICES-2016-370 (proposed vs. funded planning)
  - Analog testing plans, Engineering plans …

Portfolio Considerations

- Closure plans involve variety of efforts / tasks
  - Architecture / System / Component Trade Studies
  - Component development & testing (low to mid TRL)
  - System development & testing
  - Analog testing
  - Requirements validation
  - Applied Research (primarily HRP)
- Constraints
  - Fiscal resources (no mission driver)
  - Changing program oversight for EVA Technology Development
- Over-arching goal
  - Major improvement in safety, effectivity and performance
  - Major reduction in cost and schedule risk associated with any future flight development
    - Any technology that is “backwards compatible” to EMU or ISS EVA operations should be assessed for flight development now.

EVA Technology Development

- So that is the process …

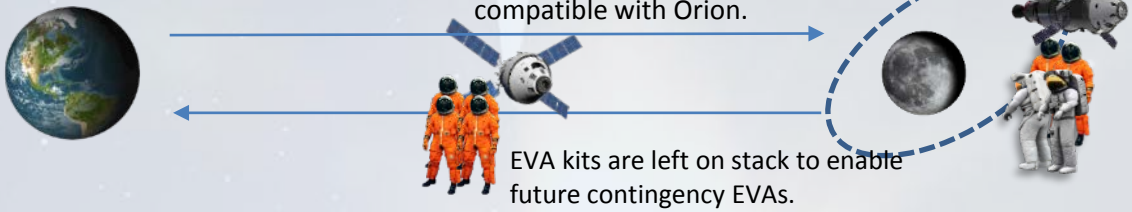
but where is EVA development today ???

EVA Suit Architecture

- EVA community has rigorously evaluated transportation architectures over recent and heritage programs and consistently comes back to a general “2 Suit Architecture”:
  1. Launch Entry Abort (LEA) Suit, typically w/ Contingency EVA capability – Transportation Focus
  2. A dedicated, nominal EVA suit – Destination Focus
- After years of DRM assessments, EVA has reduced the trade space to addressing a short list of “destination classes”
  - Micro-gravity / Vacuum on Engineered Surface (ISS, Cis Lunar)
  - Micro-gravity / Vacuum on Natural Surface (Asteroid)
  - Partial gravity / Vacuum (Lunar Surface)
  - Partial gravity / Partial Atmosphere (Mars surface)
- A single 2-Suit Reference architecture is being assessed that could effectively accomplish all near term missions (thru 2030)
  - Mission duration, # of EVAs and unique environments may require variants or add-on capabilities

Phase 1 Mission Concept Definitions

Cis-Lunar Orbit

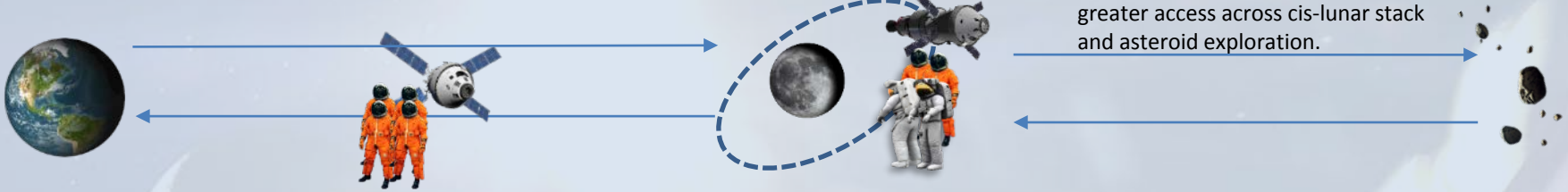


OCSS is the only suit compatible with Orion.

OCSS is the "safe haven" for vehicle failures in micro-g.

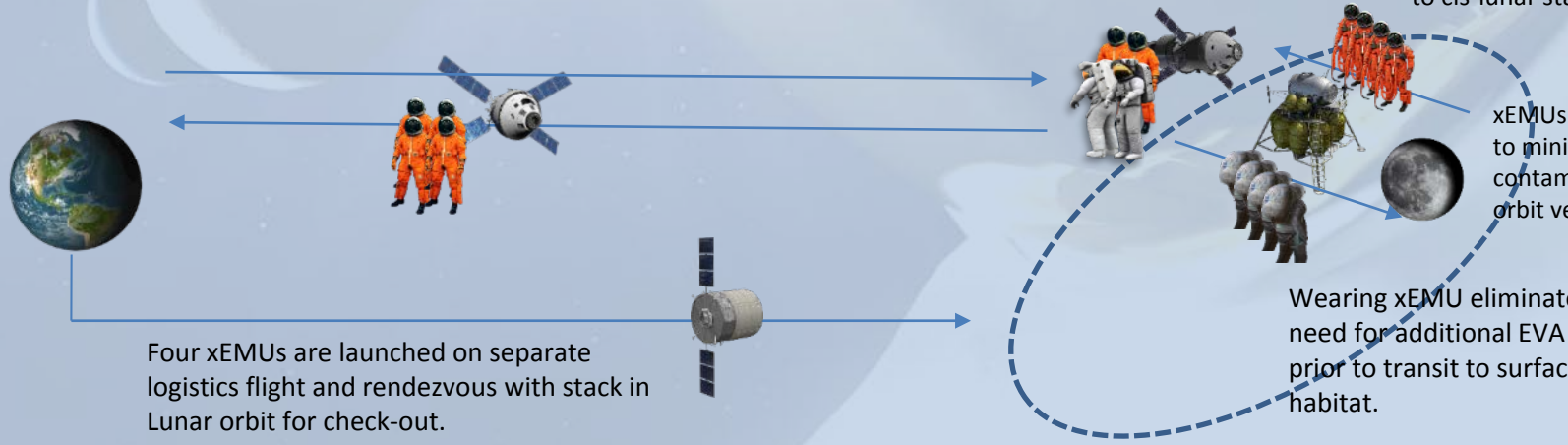
EVA kits are left on stack to enable future contingency EVAs.

Asteroid Redirect Crewed Mission



OCSS EVA with PLSS enables greater access across cis-lunar stack and asteroid exploration.

Lunar Surface



OCSS EVA with umbilical used for contingency EVA transfer to cis-lunar stack.

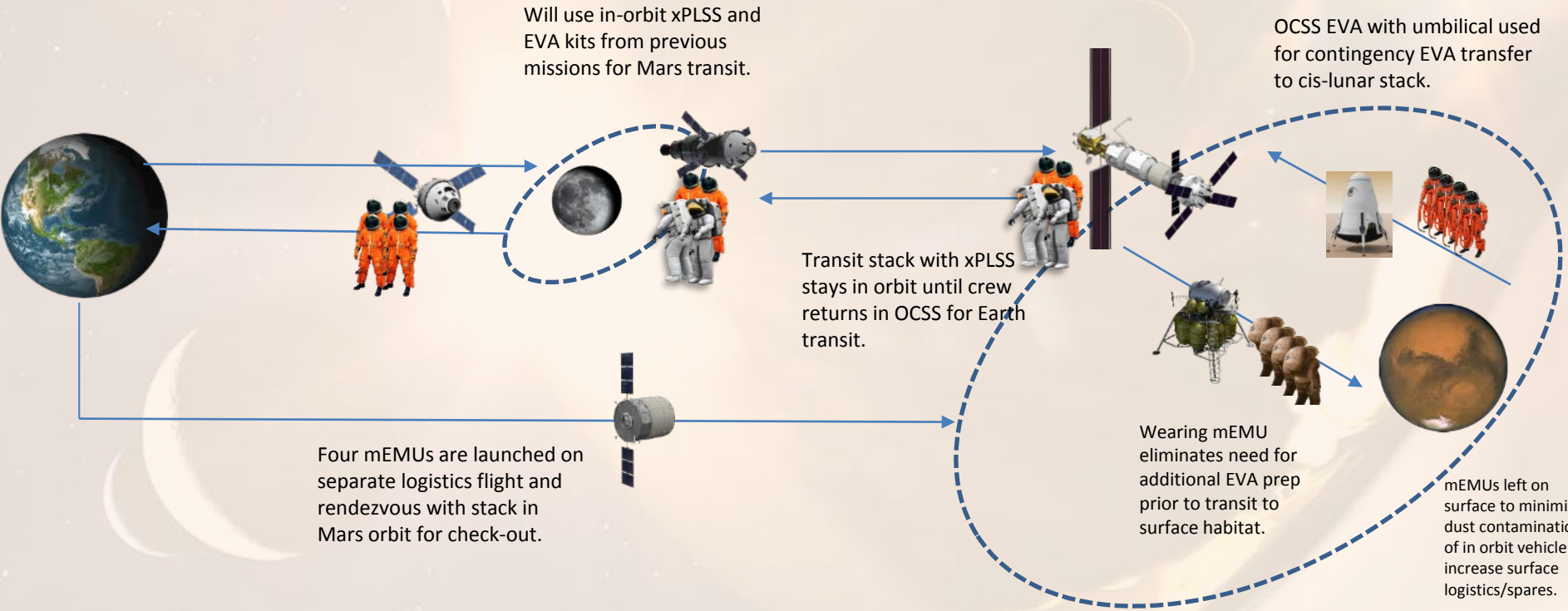
xEMUs left on surface to minimize dust contamination of in orbit vehicle.

Wearing xEMU eliminates need for additional EVA prep prior to transit to surface habitat.

Four xEMUs are launched on separate logistics flight and rendezvous with stack in Lunar orbit for check-out.

Phase 2 Mission Concept Definitions

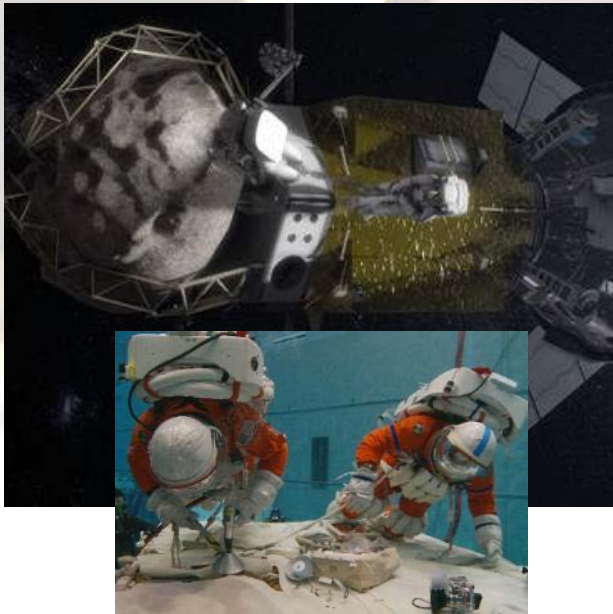
Mars Surface (2030's)



EVA Pending Missions

- Orion Program has baselined the development of the next generation LEA Suit; OCSS (Orion Crew Survival Suit)
  - EVA contingency capability is a draft requirement
  - Suit modification assessments have been performed suggesting OCSS pressure garment is viable for a short EVA (~4 hours)
  - OCSS development is an “in-house” GFE project

- The crewed segment of the Asteroid Redirect Mission Program is currently in formulation.
  - EVA capability will be utilized to obtain and curate geological samples
  - Assessments are still in work evaluating “capsule based*” EVA out of Orion (with the OCSS LEA suit) vs. other space craft options (with a new Exploration EMU)

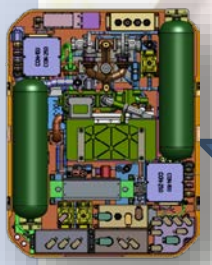


*A movie of a “capsule based” EVA can be found at
http://www.nasa.gov/mission_pages/asteroids/initiative/index.html

EVA Technology Maturation

Technology Maturation	Product Level of Maturation	EVA Examples
TRL 1-2 (Basic Research)	Research / Knowledge Gaps	• EVA focused SBIRs / STTRs via STMD • Architecture Studies
TRL 3-4 (Concepts / Breadboard)	Concepts / Component Prototyping	• EVA focused SBIRs / STTRs via STMD • EVA component tasks via HEO / ISS
TRL 5-6 (Prototype Component / System in Relevant Environment)	High fidelity Component / Subsystem testing	• Packaged Life Support Reference / Pressure Garment Subsystem testing via HEO / ISS
TRL 7-8 (Actual Component / System in Operational Environment)	System testing Flight Demonstration	• ISS Demo (future)
TRL 9 (Operations)	ISS or Cis-Lunar Mission Operations	• TBD

Executing Today!



Suit Technology Development

- Significant progress has been made in the past 6+ years creating an extensive EVA Suit and Life Support technology development base
  - People – large cadre of civil servants and industry base supporting component development, subsystem integration and testing
  - Facilities – JSC has extensive lab / testing capabilities that will be supportive throughout the DDT&E phases
  - Hardware

Suit Technology	TRL	Suit Technology	TRL
Pressure Garment System	4	CO2 Sensor	4
Communication System (Radio)	4	Battery	2
CO2 Removal System (Swingbed)	4	Thermal Loop Pump	4
Variable Control Regulators	5	Vent Loop Fan	4
Display and Control Unit	3	Service and Cooling Umbilical	4
Caution and Warning System	3	Integrated Comm System	4
Software BUS (LVDS)	3	Active Thermal Control (SWME)	4
Informatics Displays	2	Informatics Controls	2

NASA Technology Development Reference Approach

- A reference system architecture is necessary to enable system evaluation of these technologies … raise system level TRL

- NASA with support from industry partners have over the years evaluated conceptual schematics and architectures

- Architectures have been refined into reference system designs based on several factors
  - Performance (meet mission needs)
  - Safety & Reliability (redundancy, hazard control, …)
  - Operations and Maintenance (crew time)
  - Logistics (launch mass, on-back mass, consumables, etc.)
  - Extensibility

A reference system approach for EVA allows NASA mature and validate a suite of technologies at a subsystem level.

NASA Technology Development Reference Approach

- Suit Life Support System:
  - NASA, with the help of industry partners, downselcted to a basic LSS schematic utilizing a suite of technologies that could support LEO, Cis-Lunar and Lunar surface missions
    - PLSS Schematic Study created in 2005
  - This schematic has been in constant update as the technologies have matured.
  - A goal to achieve a PDR maturity in 2018 to validate system reference. This reference is intended to inform vs. become THE eventual flight baseline
- Suit Pressure Garment
  - Z- Series with focus on rear entry and improved fit & mobility in multiple g-fields (extensible to planetary missions)
- EVA Tools:
  - Pursuing closure of gaps via collaboration with scientific community. Focusing on sample collection and curation
    - New techniques and worksite stabilization given a non-engineered body.
- Vehicle Interface:
  - Focusing on “ISS-like” accommodations which would be extensible to Cis-Lunar.
  - Feasibility assessments of “Suit port” capability were completed. Feasibility was validated but concept not deemed required for Cis-Lunar.

NASA Technology Development Testing, Analogs, and Training

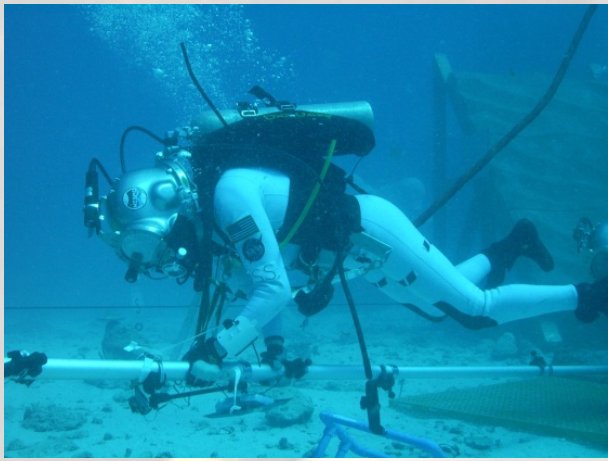
- Advancements in hardware are not the sole focus of EVA technology development
- EVA community is constantly assessing methods for improving the fidelity of ground testing and training
  - Ex. ARGOS
- Similar goals …
  - Validation of performance in a higher fidelity test
  - High Availability of ground support systems and people
  - Affordability
  - More impactful training (reduced crew time on the ground and on-orbit)
- Data from one integrated EVA test can be used by all in the community to inform design, operations and human / systems integration.

2017 EVA Development Objectives

- Continue to foster and support EVA technology focus areas for small businesses (SBIRs/ STTRs)
- Focus on Suit PLSS reference design maturity
  - Validate system architecture … raise system TRL
- Focus on testing and retrieving the performance data out of the prototype hardware procured over the past several years
  - Ex. Z-2 Pressure Garment in NBL
- Execute component flight development of new technologies that can support EMU today and advanced suits tomorrow
  - Ex. CO2 sensor upgrade

2017 EVA Development Objectives

- Continue to support Analog testing that can effectively close knowledge gaps
  - Ex. increased communication delay
- Develop EVA tools to support mission operations on “non engineered surfaces”
  - Ex. Tool operations and development via NEEMO



- Continue to advance new methods for integrated testing with human-in-the-loop capability
  - Ex. ARGOS, Virtual Reality
- Continue to refine and trace resolution of EVA related technology gaps
  - Trades, studies, Analog testing, EVA system testing
  - Ensure technology portfolio is in-sync with perceived needs
- Continue to refine operation concepts and system level requirements for near term missions

BACK UP

Points of Contact

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