EVA Exploration Virtual Collaboration Meeting - 2018

Chris Hansen, EVA Office Mgr.

August 16, 2018

Welcome!

- Overall Goal today … to communicate!
  - The last time we gathered the EVA technology community was in October of 2017
- What is today about?
  - At every workshop we solicit feedback and last year we received several comments on timing of our workshops, as a result we have decided to shift the next workshop to February of 2019
  - Today’s virtual event can be considered a pre-cursor to that workshop … we hope to accomplish at least 2 objectives
    1. Solicit help in planning for EVA Technology Workshop in 2019
    2. Provide the community an update on EVA Exploration flight and technology development that has occurred since October 2017
- We invite your input

Planning for the 2019 Workshop

- When: February 19-21, 2019
- Where: Johnson Space Center-Gilruth Facility (Houston TX)
- What: 2-3 Day interactive event, with thoughts of both NASA led day(s) and an Industry led day

- More details to come at end of the workshop on Agenda, Scope and suggested format
- Again … we want to hear your thoughts on how to better communicate

xEMU: Progress Update
Follow-up from October 2017

Brian Johnson, Exploration EVA Office Lead

August 16, 2018

xEMU: Progress Update

- The agency's EVA development plans and implementation are well grounded and moving forward!
  - √ NASA will use the existing EMU through at least 2024 for ISS operations, with possible modifications and updates to continue risk reduction and increase safety for the ISS crew.
  - √ NASA will demonstrate and test key exploration components on orbit using the ISS as a testbed.
  - √ NASA will pursue a phased approach to explore EVA capability from LEO through cislunar space to the surface of Mars.

- A key component of this plan is the development of the Exploration EMU (xEMU) for flight on ISS
  - Project is proceeding on schedule (more to come on this)

- Objective of this presentation is to …
  - Provide a summary of the programmatic story of how the xEMU Demonstration plan was created
  - Provide a backdrop for the development of the "xEMU standard" that will be discussed in next presentation

EVA Development Planning and Programmatic Timeline

- Summer / Fall of 2017 was a pivotal time for EVA development
- At the workshop in October of 2017, NASA disclosed that it was initiating development of a flight demonstration of the xEMU on ISS
- Pivoting from technology development to a formal flight project, funded by the ISS program

March - June

2017 NASA Transition Authorization Act - Response

October

xEMU Flight Demo Project Start

2017

2018

2019

Feb - June

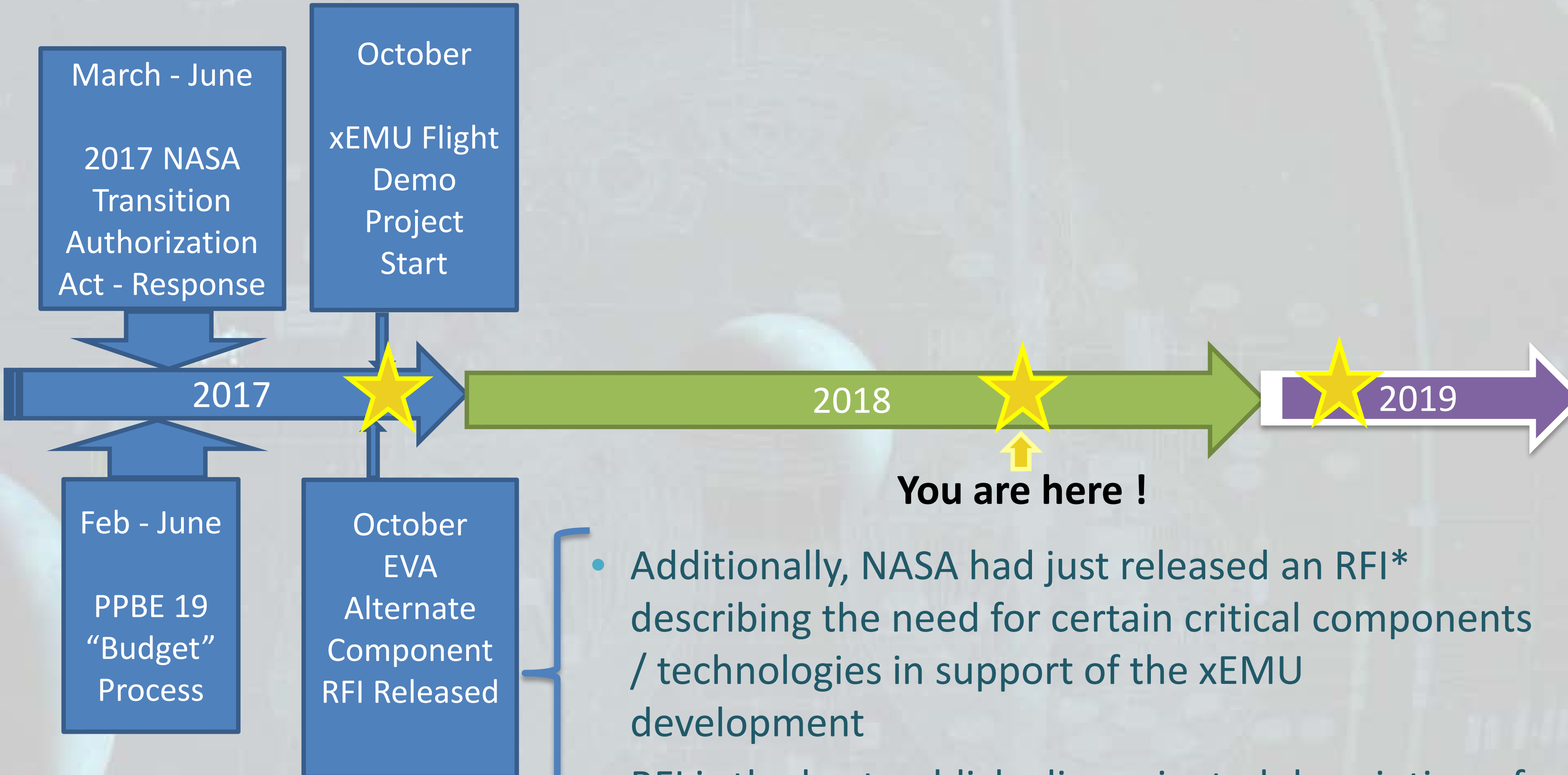
PPBE 19 “Budget” Process

October EVA Alternate Component RFI Released

You are here !

= EVA Community Workshops

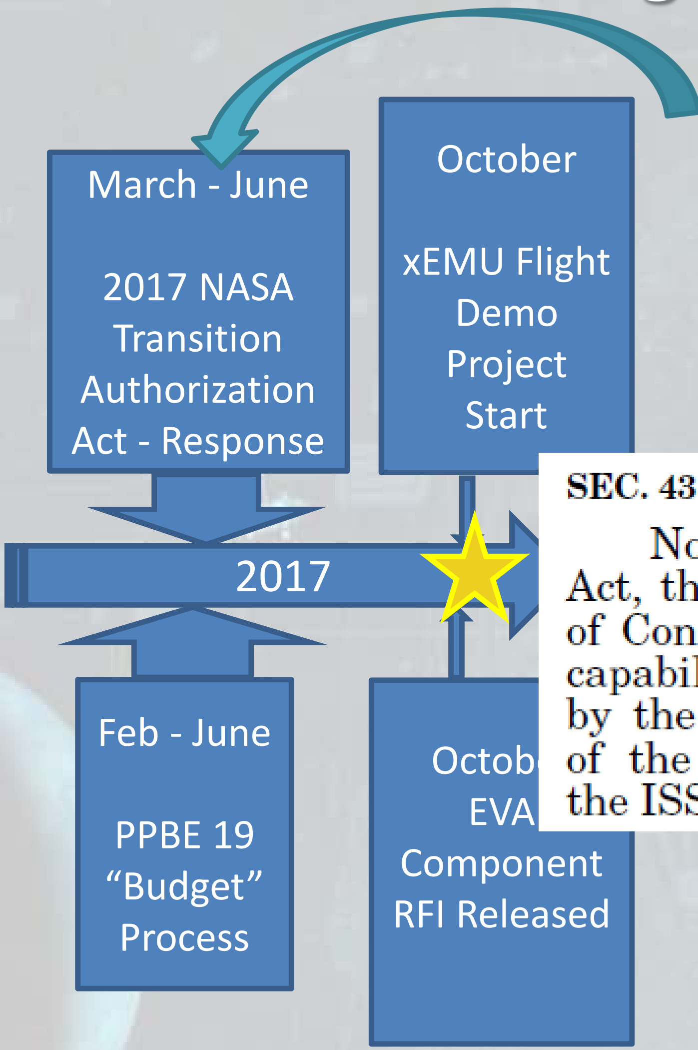
EVA Development Planning and Programmatic Timeline



- Additionally, NASA had just released an RFI* describing the need for certain critical components / technologies in support of the xEMU development
- RFI is the best publicly disseminated description of the general xEMU demonstration plan
  - http://www.fbo.gov/index?s=opportunity&mode=form&id=f1ecab434c664a76c62d74a829c5a024&tab=core&_cview=1

★ = EVA Community Workshops

EVA Development Planning and Programmatic Timeline



- The initiation of the xEMU demo project and the RFI were founded on plans developed for Congress in the spring of 2017
  - Response to a congressional actions in the 2017 NASA Transition Authorization act

SEC. 433. ADVANCED SPACE SUIT CAPABILITY.

Not later than 90 days after the date of enactment of this Act, the Administrator shall submit to the appropriate committees of Congress a detailed plan for achieving an advanced space suit capability that aligns with the crew needs for exploration enabled by the Space Launch System and Orion, including an evaluation of the merit of delivering the planned suit system for use on the ISS.

- It is within this plan that we introduce the idea of an “xEMU Standard” as the ultimate product of the flight demonstration project

★ = EVA Community Workshops

EVA Development Planning and Programmatic Timeline

- In parallel these plans were solidified and addressed within the NASA Human Exploration & Operations Mission Directorate (HEOMD) 2019 budget process

EVA Development Planning and Programmatic Timeline

SEC. 205. SPACE SUITS.

(a) FINDINGS.—Congress finds the following:

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(1) Space suits and associated extravehicular activity (in this section, referred to as "EVA") technologies are critical space exploration technologies.

(2) The NASA civil service workforce at the Johnson Space Center possesses unique capabilities to integrate, design, and validate space suits and associated EVA technologies.

(3) Maintaining a strong core competency in the design, development, manufacture, and operation of space suits and related technologies allows NASA to be an informed purchaser of competitively awarded commercial space suits and associated EVA technologies.

(4) NASA should fully utilize the International Space Station by 2025 to test future space suits and associated EVA technologies to reduce risk and improve safety.

(b) SPACE SUITS.—

(1) IN GENERAL.—NASA shall develop space suits and associated EVA technologies.

(2) MANAGEMENT.—The Johnson Space Center shall manage the space suit and EVA programs of NASA.

(3) PRIVATE SECTOR.—In carrying out this subsection, the Administrator may enter into agreements with the private sector as the Administrator considers appropriate.

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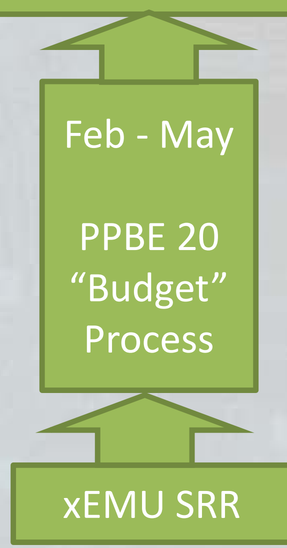


- As of 4-14-18, the House has drafted a 2-year NASA Authorization Act spanning 2018-2019
- This draft includes language on Exploration EVA, particularly guidance that "NASA should fully utilize the ISS by 2025 to test future space suits and associated EVA technologies to reduce risk and improve safety"

EVA Development Planning and Programmatic Timeline

March - June

2017 NASA Transition Authorization Act - Response

October

xEMU Flight Demo Project Start

April

2018-2019 NASA Authorization Act (DRAFT)

2017

2018

2019

Feb - June

PPBE 19 “Budget” Process

October EVA Alternate Component RFI Released

Feb - May

PPBE 20 “Budget” Process

xEMU SRR

You are here !

- xEMU system requirements were vetted and approved in Spring 2018
- EVA team presented the full integrated budget and schedule plan to HEOMD
- Plan calls for delivery of xEMU demo to ISS as early as 2023

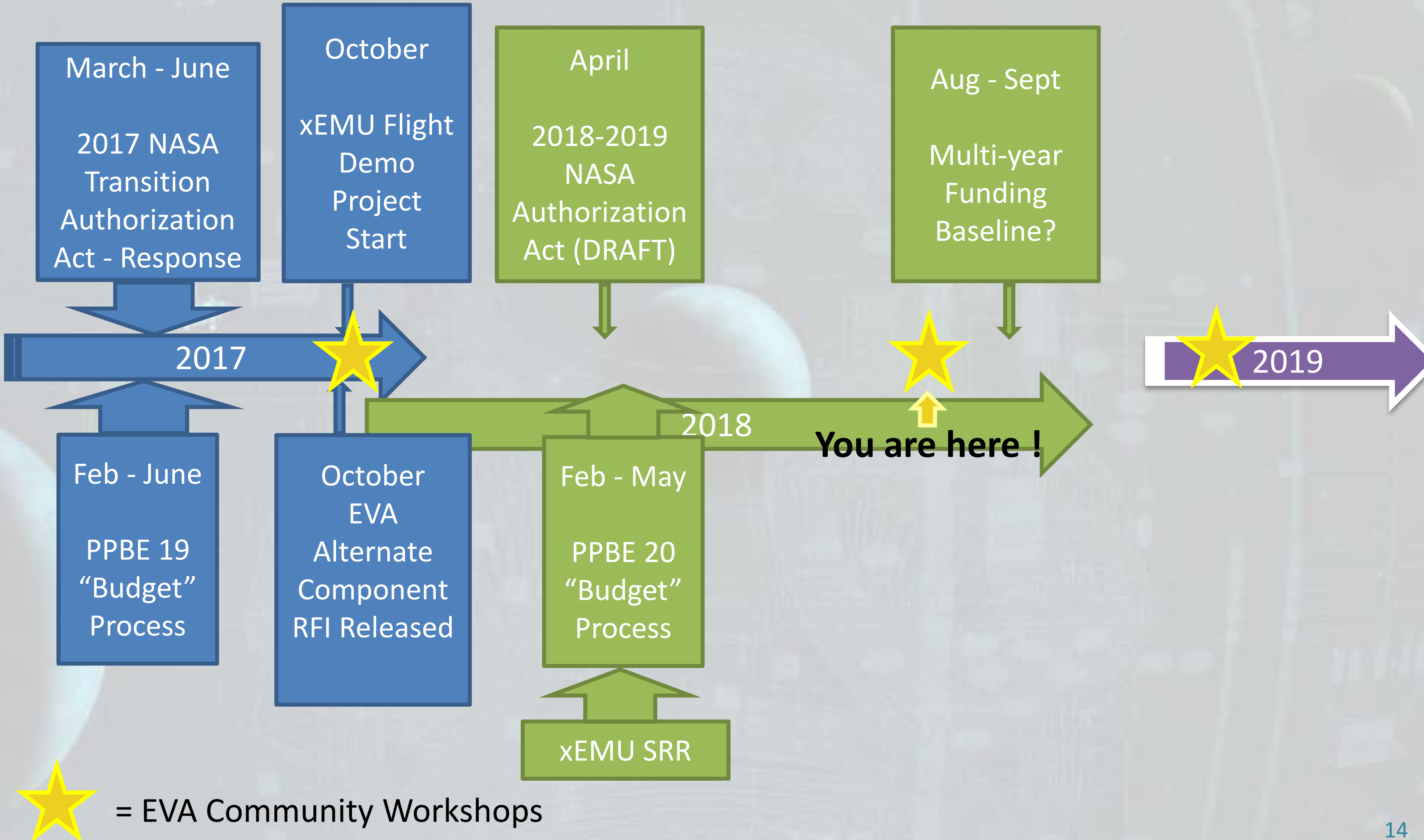
★ = EVA Community Workshops

Progress Wrap up …

- EVA community has a solid plan going forward for demonstration of an advanced exploration spacesuit
  - Based on years of technology development provided by industry and academia
- In addition to solidifying planning for the xEMU project NASA has renewed its efforts to communicate all that we can and to engage our industry partners
  - Today's event!
  - Planning for February Workshop
  - Involving suppliers in xEMU Demo technical reviews
  - Working as fast as we can to disseminate data publically given the need to conform to export control regulations
  - We are assessing what is the "xEMU Standard" and how / when do we disseminate this data

Back up

EVA Development Policy and Programmatic Timeline



xEMU: Progress Update

From Specification to Standards

Jesse Buffington

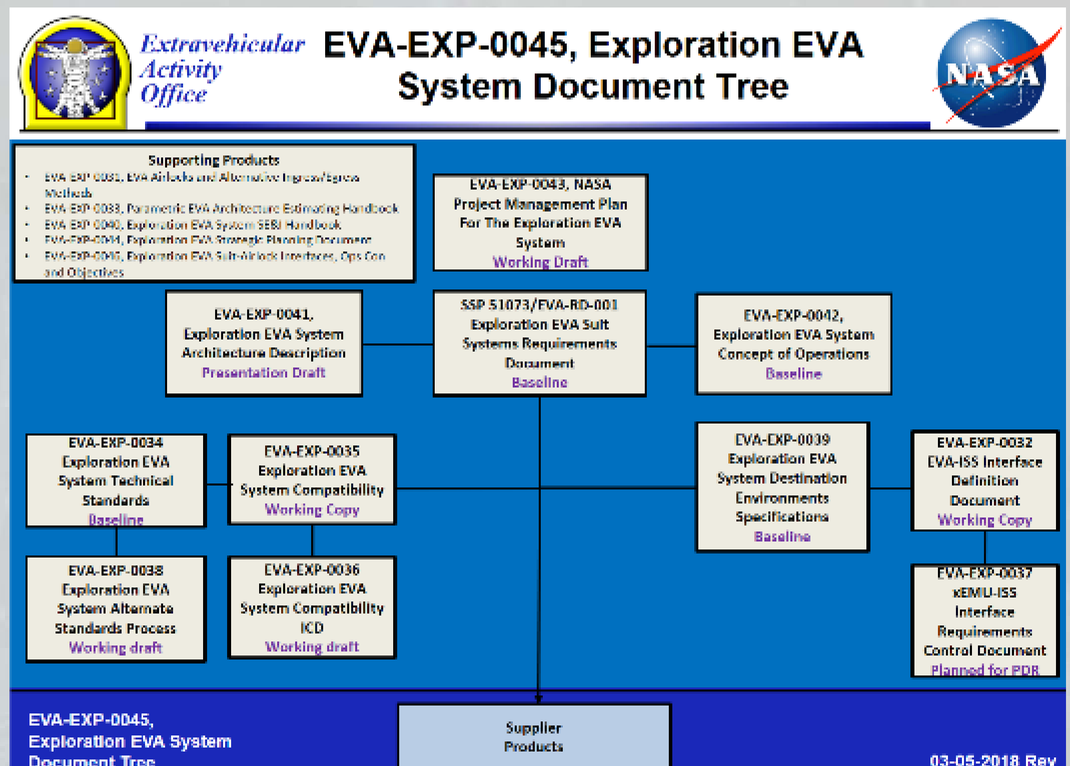
August 16, 2018

The xEVA Standard: Purpose

- The "xEVA Standard" is a concept that facilitates capture and communication of NASA's xEMU specification
- Development of the xEVA Standard will proceed in parallel with the development of the xEMU ISS Demo Suit hardware
- NASA has a range of options for what level of detail is published in the Standard
- Successful demonstration of the xEMU on ISS provides *validation* that there is at least one way the Standard can be met

The xEVA Standard: Supporting Materials

- The xEVA Standard will likely include portions of the Exploration EVA System Document Tree
- The EVA Office has initiated processing many of these products and posts each as the Document Availability Authorization (DAA) process is completed
- Similar to the design of the xEMU, the xEVA System Document Tree products will continue to evolve



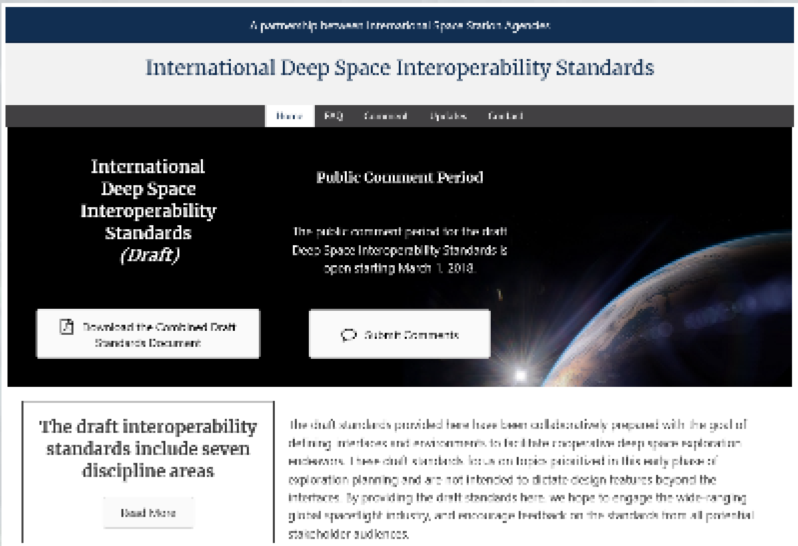
NASA Standards: Recent Examples

- There are several relevant examples within current NASA activities which provide precedence for an xEVA Standard
- NASA may take an approach similar to the International Docking System Standard (IDSS) which is publicly posted:
  - The IDSS IDD includes performance characteristics of the system such as OML/SWAP/Functions
  - The IDSS IDD heavily emphasizes the interfaces and component features allowing two separately built docking collars to join as intended

http://www.internationaldockingstandard.com/

NASA Standards: Recent Examples

- Similarly, work underway with NASA and international partners includes interoperability standards for vehicle elements and systems:



https://www.internationaldeepspacestandards.com/

- These examples and many others are available to NASA for xEVA
- The xEVA team will be exploring each of these over the next several years to determine which model is best for xEMU

The xEVA Standard: Next Steps

- The xEVA team is evaluating several options for structure, depth of detail and review process for the Standard
- In general, the Standard will progress with the xEMU Design
- It’s likely that the Standard will be revised (similar to IDSS) over time as NASA further matures xEMU for various missions
- Supporting xEVA products are and will continue to be posted, see: www.nasa.gov/suitup/reference
- At the Workshop in February, we’ll further discuss and seek feedback on the process for developing the Standard, plans for draft review and comment from the community, etc

xEMU Development Status

Liana Rodriggs

August 16, 2018

xEMU Development Overview

- The Exploration Extravehicular Mobility Unit (xEMU) Project objective is to develop an xEMU for a flight demonstration on ISS
  - The xEMU Demo suit will be designed to meet as many of the exploration requirements as feasible within cost and schedule constraints
- The NASA team that has been performing EVA technology development for 10+ years is designing the xEMU Demo and will build a single flight demonstration unit
  - NASA will be procuring components and will perform the role of system integrator
- Major milestones are shown in the table below working towards a flight demonstration at the ISS in 2023

<table>
<tr><th>FY18</th><th>FY19</th><th>FY20</th><th>FY21</th><th>FY22</th><th>FY23</th></tr>
<tr><td>SRR (Jan)</td><td>PDR</td><td></td><td>CDR</td><td></td><td>SAR & Delivery</td></tr>
<tr><td colspan="2" rowspan="2">DVT Build/Assy</td><td rowspan="2">DVT Testing</td><td colspan="2">Qual & Flight HW Build</td><td rowspan="2">Acceptance Testing</td></tr>
<tr><td></td><td>Qual Testing</td></tr>
<tr><td colspan="6">Terms and Definitions: SRR – System Requirements Review, PDR – Preliminary Design Review,
CDR – Critical Design Review, DVT – Design Verification Testing, SAR-Systems Acceptance Review</td></tr>
</table>

Development Status

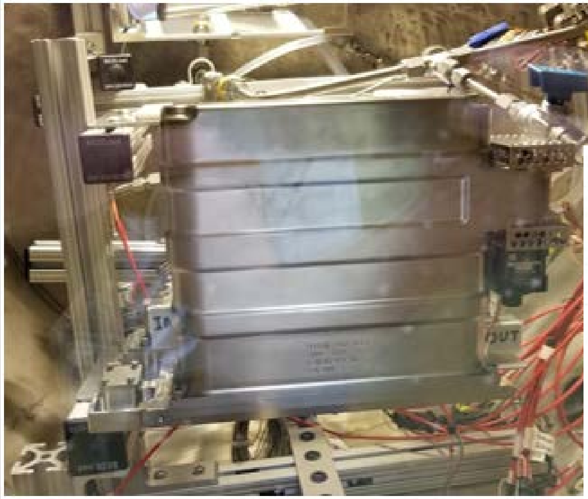
- System Requirements Review and Phase 0 Safety Review completed
  - Review focused on Project Technical Requirements Specification, EVA-ISS Interface Definition Document, Concept of Operations, ISS Demo Objectives, Safety Data Package, and Initial Assessment of Criticality with dozens of supporting documents available for reference
  - Completion of SRR set the requirements for what will be included in the demonstration and what is deferred to future development efforts
- Team is focused on preparations for PDR and DVT hardware build/test
  - xEMU DVT hardware will be the implementation of requirements set during SRR
  - DVT will be tested as a “qualification dry run” and will provide data to mature design towards CDR
    - Buys down risk of building qual and flight units in parallel
  - Design of components and system continues to mature – sampler of technical progress on next slides

Hardware Development Update

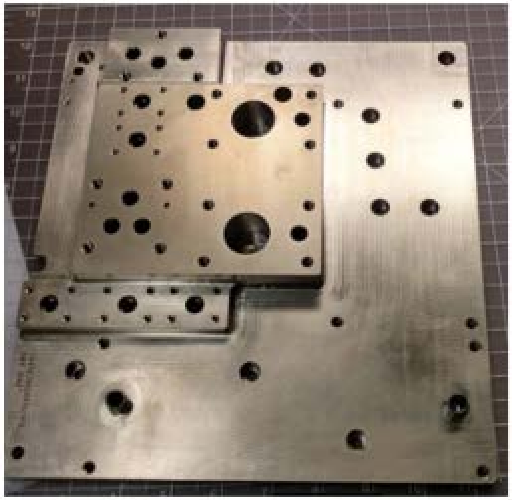
- Conducted a 2 ½ day Technical Interchange Meeting to status the design of the Portable Life Support Subsystem (PLSS)
  - Included review of components and subsystem-level design and analyses and status of progress towards Preliminary Design Review (PDR)
  - PLSS packaging update completed just prior to review to modify package size and shape and incorporate other improvements

Hardware Development Update

- Completed 285 hours to-date, of a planned 800 hours of life testing of the Suit Water Membrane Evaporator (SWME)
- Tested a CO_2 Swing Bed System to evaluate performance characteristics
- Evaluated manufacturing techniques for the PLSS backplate and manufactured pathfinder



HX-440 Assembly, 800 Hour Test In Progress



85% Complete

IOS Sensor and SBS Testing in VTL2

Hardware Development Update

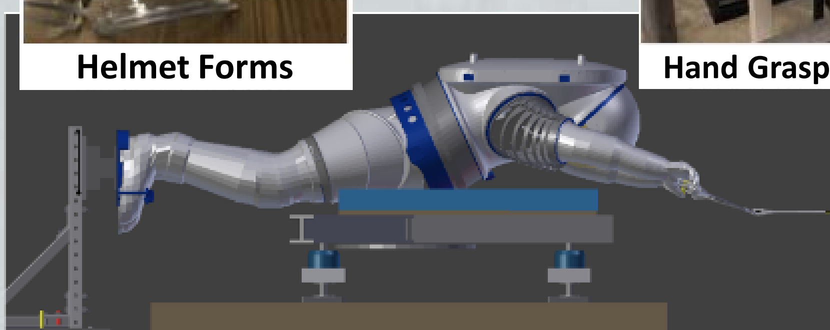
- Updated design of Hard Upper Torso (HUT) and helmet to incorporate lessons learned from last year's NBL testing
  - Procured updated HUT and helmet, along with waist adapter ring and visor assembly for assembly into Z-2.5 for NBL testing later this year
- Designed test methodology for manloads testing and completed hand grasp breakaway evaluations for upcoming testing


Z-2.5 Suit HUT Finishing


Z-2.5 Suit HUT Hatch


Helmet Forms


Hand Grasp Breakaway Evaluation


3D Rendering of the Full Suited Manloads Test

Hardware Development Update

- Performed Integrated Communication System (ICS) testing to evaluate susceptibility of ICS to produce acoustic feedback when connected to ISS audio system
- Performed suited evaluation of Environmental Protection Garment (EPG) sleeve concepts
- Modified a Gen #1 OSS Liquid Cooling and Ventilation Garment (LCVG) to add a redundant cooling loop and conducted fit-check with 3D printed Z-2.5 HUT

Integrated Communications Testing Z-2.5 3D Printed HUT

Range-of-Motion Evaluation of Different EPG Sleeve Concepts

Modified Generation 2 Prototype LCVG

Looking ahead

- More details will be presented at the EVA Workshop in February, such as:
  - Update on technical progress
  - Major risks
  - Schedule
  - Competitive acquisition strategy
  - Objectives and approach to demonstration EVA’s
- Other developments are occurring in parallel that will feed into the xEMU such as the EVA Data Recorder development
- Beyond the xEMU Demonstration, additional development is needed to fully realize all of the exploration capabilities of the xEMU in support of future missions

QUESTIONS?

The Road Ahead

Brian Alpert
EVA Strategic Planning and Architecture Lead

August 16, 2018

The Road Ahead: ISS Demo

EVA Technology and EMU Upgrades

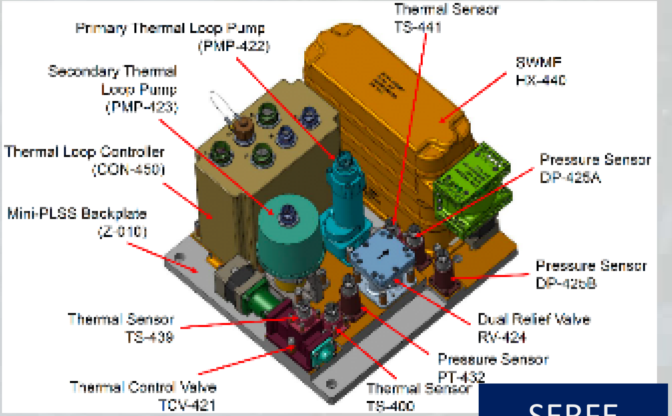
On-orbit ISS - 2018

- ISS Airlock Umbilical Interface Assembly (UIA):
  Installed in June. Incorporates scarring for increased Oxygen pressure to support recharging of higher pressure EVA suit oxygen bottles.
- Long Life Battery 2 (LLB-2):
  Advanced Lithium-Ion batteries delivered in May and June. These batteries incorporate the latest safety features for mitigating thermal runaway.
- EVA Data Recorder (EDaR):
  Delivered in May. EDaR will be added to the EMUs to enable high-speed recording of all critical sensor data. This same system will be used on xEMU.

LLB-2

FY19 Delivery:

- Spacesuit Evaporation Rejection Flight Experiment (SERFE):
  This payload is essentially the entire xEMU thermal system and incorporates the latest advancements in packaging, thermal evaporation systems, and water flow systems (i.e. pumps).
- High-definition EVA Camera Assembly (HECA):
  Upgrade for EMU and the baseline camera set for the xEMU. Real-time transmission and store/forward capability.



SERFE

The Road Ahead: ISS Demo

- xEMU Flight Demonstration - 2023
  – Test objectives: Reviewed at SRR, baselining post PDR
  – Will perform EVAs (1 EMU and 1 xEMU Demo)
  – Finalizing test plan; expect multiple EVAs over months on ISS
  – Lessons Learned

xEMU Demo

- After ISS Demo … branching out options
  – xEMU as continued option with EMU (depends on ISS life) to develop standards
  – Support for commercial opportunities to develop their own capabilities
  – xEMU for Gateway

The Road Ahead: Cis-Lunar Space

- NASA is working with Commercial and International partners on plans to expand human presence into Cis-Lunar space

- NASA is studying a Gateway mission with the objective to build a human-tended space station parked in lunar orbit
  - Notionally this space station would be visited by a crew of up to 4 for up to 30 days at least 1 per year

- EVA and Airlock objectives can be found in released documents
  - “Lunar Orbital Platform – Gateway Management Directive” (DSG-MD-10000)
  - “Human Exploration and Operations Exploration Objectives” (HEOMD-001)

xEMU

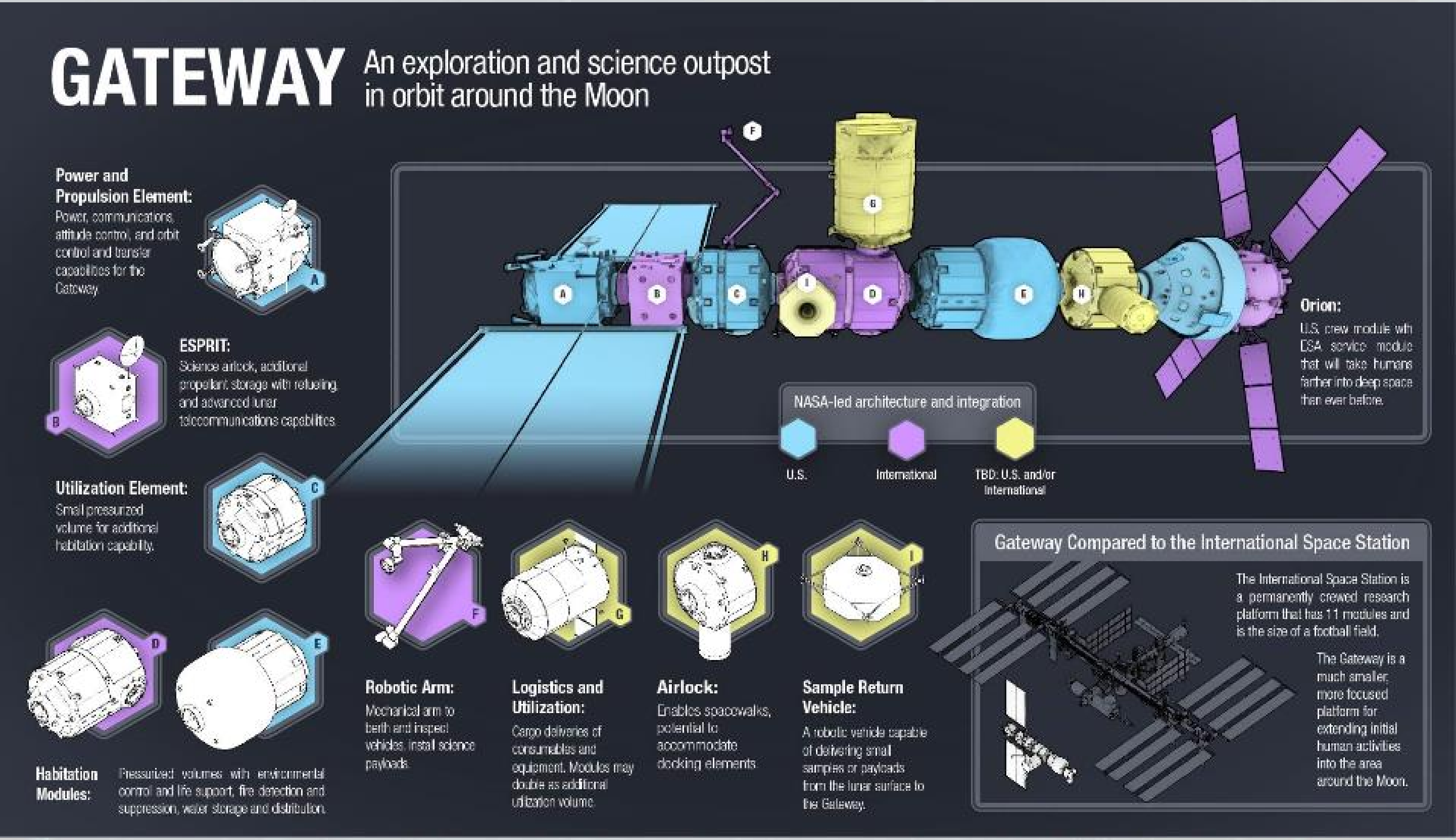
The Road Ahead: Cis-Lunar Space

- Implementation of the Gateway mission has matured tremendously in the past year
  - Finishing up 2nd Integrated Analysis Cycle in August
  - Preparing for Formulation Sync Review in September 2018 (System level requirements)
  - Power and Propulsion Element (PPE) request for proposal has been released (acquisition)

- EVA concepts in Gateway
  - Airlock launches at end of sequence: All external work is via robotics until Airlock arrives; no capsule-based EVA
  - Carrying EVA-specific requirements (Exploration EVA System Compatibility, module specific, no requirements for PPE)

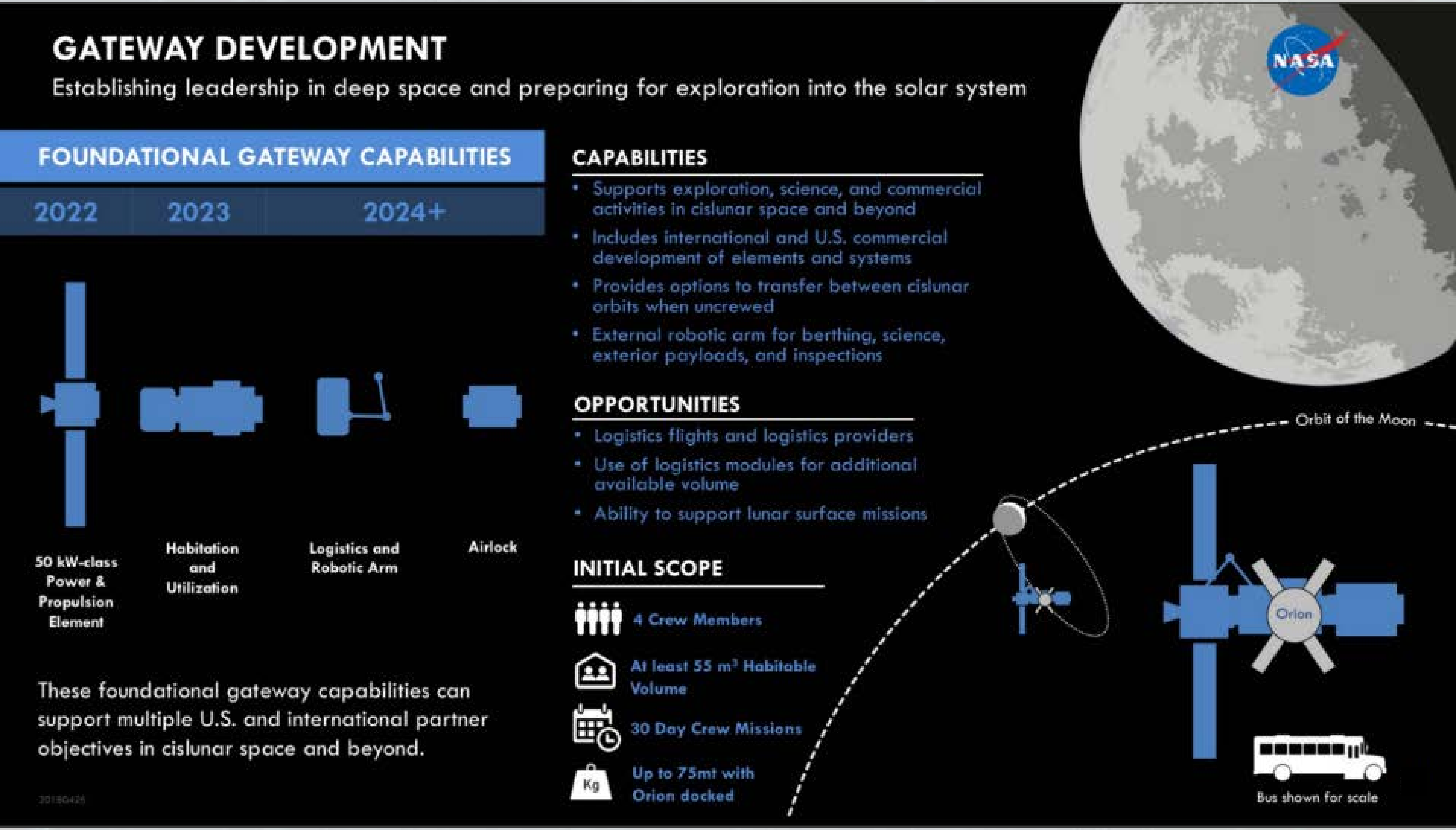
- EVA engagement with Gateway
  - Gateway working on Level 2 and Functional allocation
  - Working Airlock requirements and interfaces, external interfaces, and crew rescue capability
  - Working with Habitat Broad Agency Announcement study teams
  - Working with International Partners via the International Exploration Capability Study Team

Gateway Overview



https://www.nasa.gov/feature/nasas-exploration-campaign-back-to-the-moon-and-on-to-mars

Gateway Development



https://fiso.spiritastro.net/telecon/Guidi_6-13-18/Guidi_6-13-18.pdf

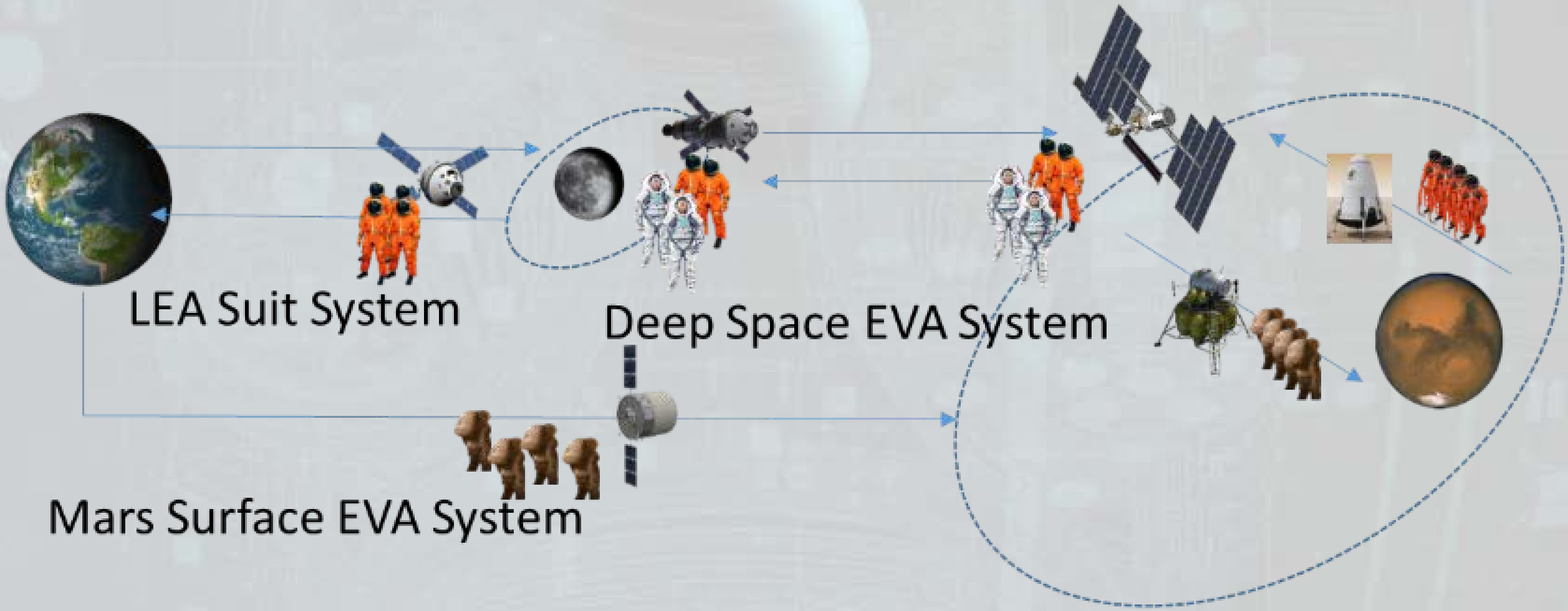
The Road Ahead: Lunar Surface

- NASA recently vocal about shifting focus towards lunar exploration missions as a stepping stone towards Mars, as well as engaging commercial and international partners going forward
  - US Space Policy Directive -1: "… will refocus America's space program on… returning American astronauts to the Moon… for long-term exploration and use"

- System-level Exploration EVA Requirements encapsulate Lunar Surface needs
  - To the best of our knowledge we have captured requirements in "Exploration EVA Suit Systems Requirements" (SSP 51073/EVA-RD-001)
  - Knowledge gaps remain:
    - ISS xEMU Demo suit will not invoke all Cis-Lunar and Lunar Surface requirements … extensibility actions in work and due at PDR in 2019
    - Goal is to truly understand the challenges to upgrading the xEMU Demo technologies

The Road Ahead: Mars

- Engaging with Mars Study Capability team, supporting concept of operations studies, and supporting analog mission research
- Identifying technology and knowledge gaps towards development of EVA capabilities for Mars Surface ops



BACK UP

Exploration EVA System Document Tree

Supporting Products

- EVA-EXP-0031, EVA Airlocks and Alternative Ingress/Egress Methods
- EVA-EXP-0033, Parametric EVA Architecture Estimating Handbook
- EVA-EXP-0040, Exploration EVA System SE&I Handbook
- EVA-EXP-0044, Exploration EVA Strategic Planning Document
- EVA-EXP-0046, Exploration EVA Suit-Airlock Interfaces, Ops Con and Objectives

EVA-EXP-0043, NASA Project Management Plan For The Exploration EVA System
Working Draft

EVA-EXP-0041, Exploration EVA System Architecture Description
Presentation Draft

SSP 51073/EVA-RD-001 Exploration EVA Suit Systems Requirements Document
Baseline

EVA-EXP-0042, Exploration EVA System Concept of Operations
Baseline

EVA-EXP-0034 Exploration EVA System Technical Standards
Baseline

EVA-EXP-0035 Exploration EVA System Compatibility
Working Copy

EVA-EXP-0039 Exploration EVA System Destination Environments Specifications
Baseline

EVA-EXP-0032 EVA-ISS Interface Definition Document
Working Copy

EVA-EXP-0038 Exploration EVA System Alternate Standards Process
Working draft

EVA-EXP-0036 Exploration EVA System Compatibility ICD
Working draft

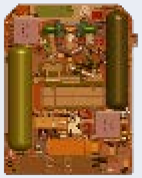
EVA-EXP-0037 xEMU-ISS Interface Requirements Control Document
Planned for PDR

Supplier Products

EVA-EXP-0045, Exploration EVA System Document Tree

03-05-2018 Rev

Suit Architecture

Configuration	Pressure Garment	Life Support	Description
Orion Crew Survival Systems (OCSS) 	 OCSS suit	 Umbilical	Orion Crew Survival Systems (OCSS) includes the LEA-optimized suit and associated survival systems hardware being delivered to Orion. (Current EC GFE project; PDR summer 2017)
Exploration Extravehicular Mobility Unit (xEMU) 	 xPGS	 xPLSS	xEMU is the dedicated EVA suit system for use on the Gateway stack to demonstrate EVA capability and then serve as the in-transit EVA suit for Mars missions.
Exploration Extravehicular Mobility Unit with Lunar kit (xEMU-L) 	 xPGS-L	 xPLSS	xEMU with minimal upgrades (such as TMG and dust tolerant connectors) and delta certification could serve as the system for surface EVA for Lunar missions. (minimal tech dev required for TMG materials and dust mitigation)
Mars Extravehicular Mobility Unit (mEMU) 	 mPGS	 mPLSS	mEMU is a Mars environment optimized, highly mobile EVA suit (based on xEMU), for missions up to 500 days on surface. (tech dev required for materials and PLSS function in partial atmosphere)

Reference ICES-2018-54 “Methodology for Extravehicular Activity (EVA) Technology Identification, Prioritization, and Maturation

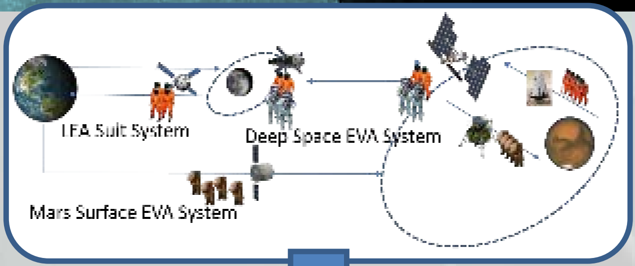
EVA Technology Gaps

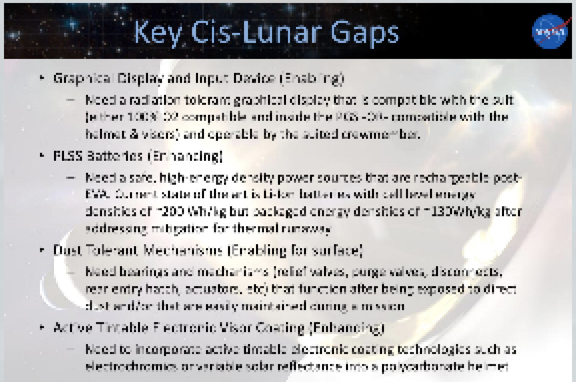
Raul Blanco

August 16, 2018

Last Workshop

- At the last EVA Workshop
  - NASA HEOMD-001 Exploration Phases
  - Resulting Suit System Capability Requirements and Nomenclature
  - Gap identification, prioritization, and implementation work methodology
  - Recent examples (high level summary)





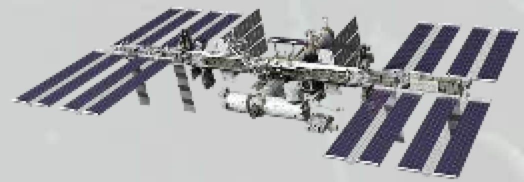
https://nvite.jsc.nasa.gov/presentations/D2_SMT%20Gaps_Blanco.pdf

Motivation

- NASA needs industry and academia help in closing gaps
- Communicating our needs and priorities with you:
  - Gives businesses an opportunity to direct IR&D towards NASA stated priorities
  - Gives academia an opportunity to direct research in areas that are relevant to NASA stated priorities
  - Helps SBIR proposers understand more context on why the annual EVA subtopics are chosen
  - Decreases our likelihood of missing a gap

Current **Schedule Based** Gap Closure **Priorities**

1. Support ISS EVA through life of program
   – Use ISS as a testbed

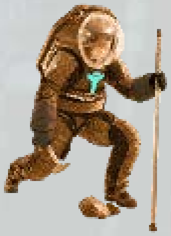


2. Complete development of the Orion Crew Survival System (OCSS) as to support Exploration Mission 2 (EM-2) schedule

3. Leverage xEMU demo and develop technologies to support complete xEMU readiness for Gateway

4. Invest in enabling technologies for a potential Lunar surface mission

5. Invest in long development time enabling and enhancing technologies to enable mEMU



February Workshop Plans

- Update to NASA HEOMD-001 Exploration Phases and resulting high level suit architecture (if any)
- Detail of gaps between xEMU ISS Demo and xEMU for Gateway
- High level summary of key gaps between xEMU ISS Demo and xEMU for lunar surface mission
- High level summary of key gaps for xEMU to mEMU
- Walk through of either on-line gap tool or through newly published data file

Online EVA Resources

https://www.nasa.gov/suitup/reference

Stephanie Sipila

August 16, 2018

Questions?