Exploration Pressure Garment

Joint EVA Working Group

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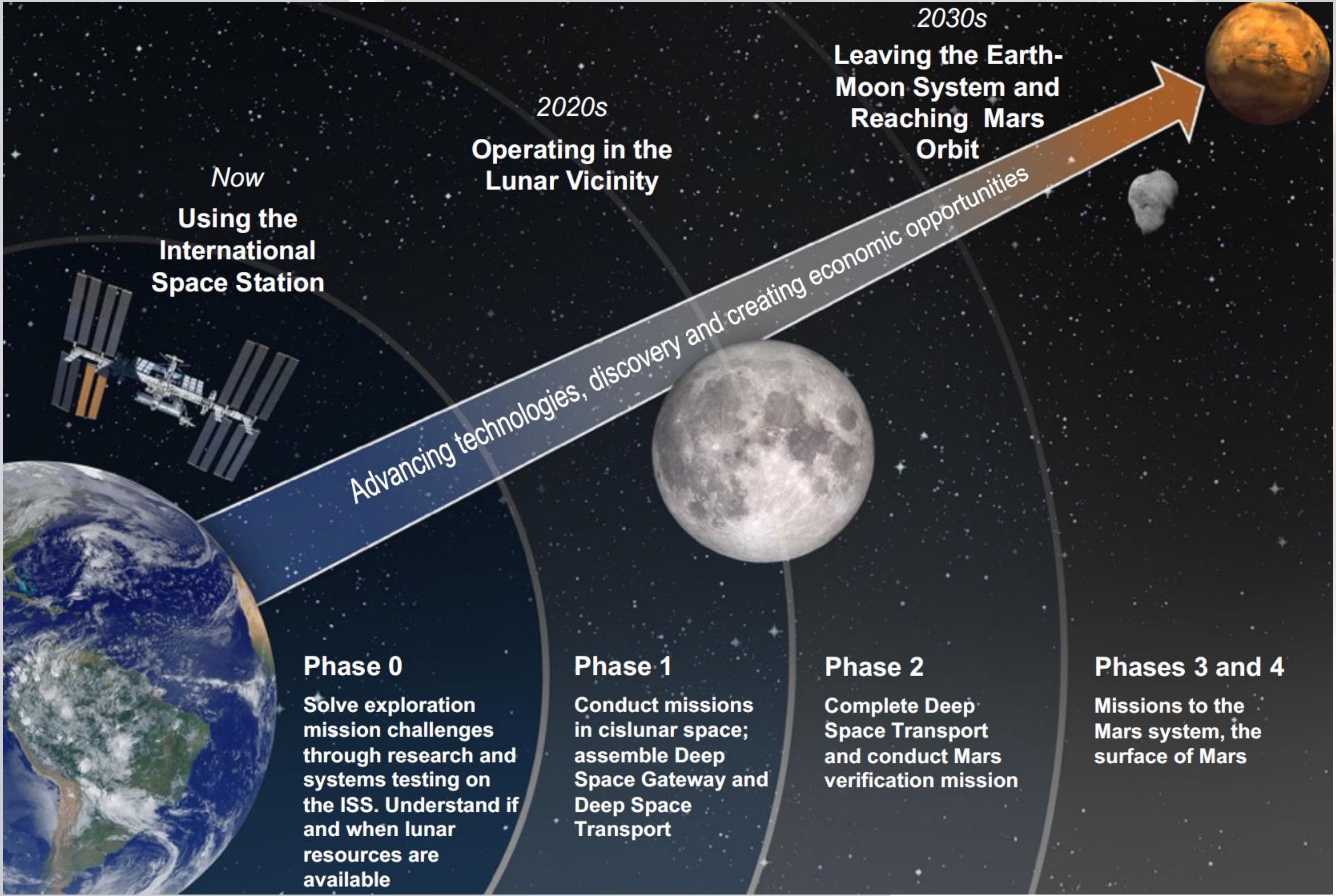
Agenda

- Context of current advanced pressure garment development
- Overview of Architecture
  - xEMU and xEMU Lite
- Development Plans

Advanced Pressure Garment Team

- As the Advanced Space Suit Pressure Garment Development team, our responsibilities include:
  - Develop and validate pressure garment requirements
  - Identify and close pressure garment technology gaps
  - Characterize pressure garment technologies, components and architectures performance
  - Recommend pressure garment architectures to best achieve mission goals
  - Provide support to the ISS EMU

Design Reference Missions - Exploration



Roles

- Advanced Pressure Garment development strives toward providing hardware that addresses the most challenging exploration requirements
  - A majority of the most challenging requirements are driven by a Mars surface mission
- Current effort is focused on a near-term demonstration of an advanced suit on the ISS
  - This configuration is called xEMU-Lite.
  - The goal is to incorporate as much exploration capability as possible
  - Technology development continues for areas where we cannot meet exploration requirements

Current Focus – ISS Demonstration

- High level summary for LEO operations on ISS:
  - Series of ISS demonstration EVAs to test and demonstrate xEMU-Lite capability
    - Dual suit operations will take place with the ISS EMU and xEMU-Lite
  - Potential for replacement of the EMU PLSS and HUT with an exploration class PLSS and HUT capable of meeting ISS needs for EVA
  - Operation of the new suit system on ISS will provide an opportunity to evaluate the system design and architecture for exploration missions while in an environment more conducive to managing contingencies

Progression from xLite to m

- The current plan is to evolve the exploration suit:
  - Starting with the xEMU-Lite ISS demonstration configuration
    - Building a Z-2.5 for FY18 test
      - Validating geometry changes
  - Next incorporating additional exploration requirements to address the Deep Space Gateway mission needs and to test hardware for planetary surface exploration
    - This is the xEMU.
  - Finally, providing a full surface, long-duration exploration configuration
    - This is the mEMU

PG Development History

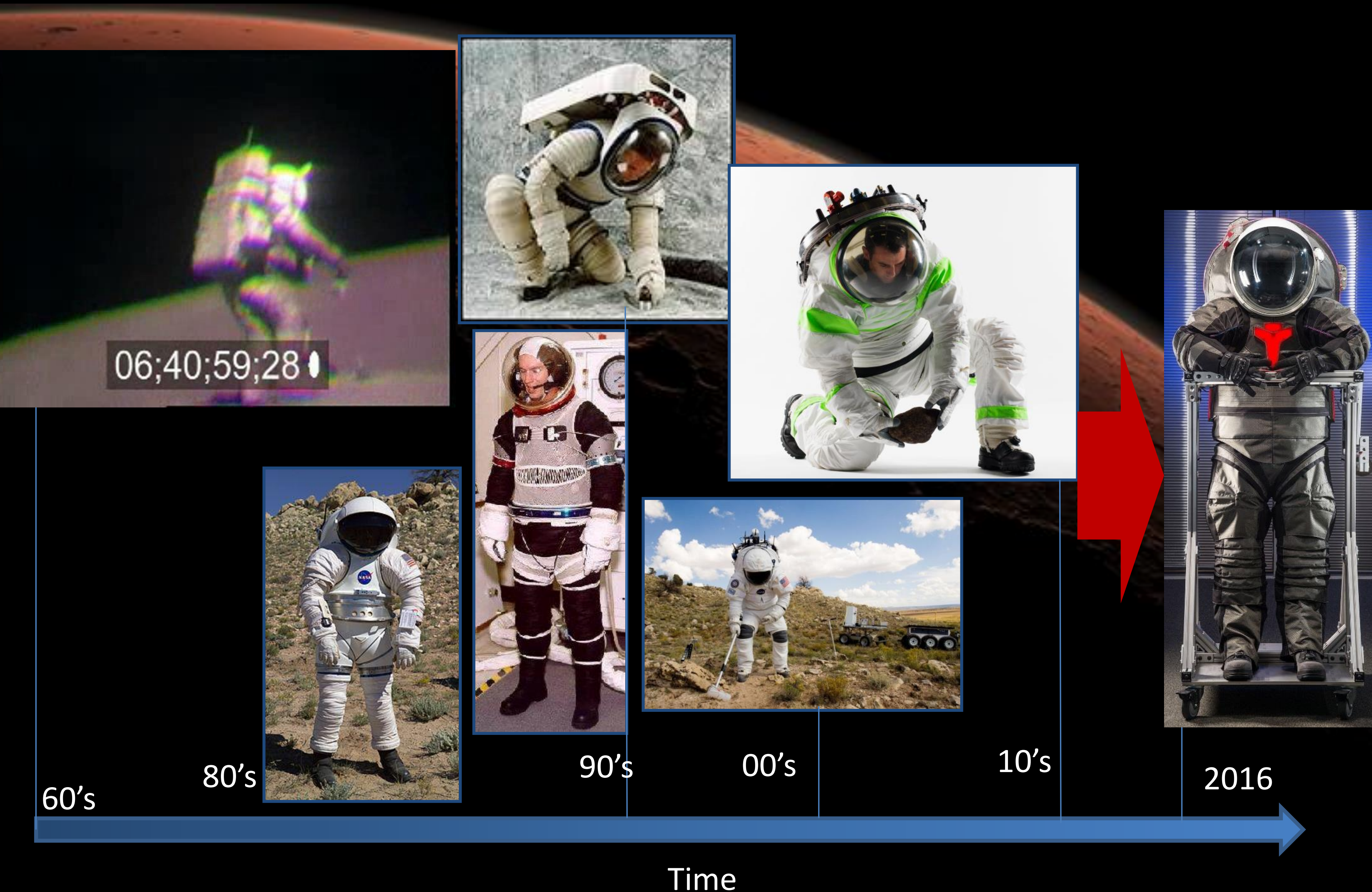
- From 1989 until present a series of pressure garments have been designed, fabricated, and tested by the Advanced Suit Lab (ASL).
- The testing performed over this 28-year period informed the architecture decisions reflected in the xPG
- The architecture is extensible to surface exploration missions
  - Detailed design changes will be required
    - Especially with regards to dust and durability/cycle life

PG Development History cont.

- Primary pressure garments tested to inform xPG architecture
  - Mark III [1989/1992]
  - Waist-entry and rear-entry I-Suits [1997, 2005*]

    *First use at Desert RATS field test, developed under ILC IR&D funds
  - *D-Suit* [1997]
  - *Demonstrator Suit* [2010]
  - Z-1 [2011]
  - Z-2 [2016]

Recent Planetary PGS Architecture History



Common Architecture

- Mark III, I-Suits and Z-Suit have common upper torso geometries
  - Rear-entry
    - Hatch size and angle
  - Shoulder angles
- Walking mobility lower torso

Planetary Suit Prototypes

Mark III

WEI-Suit

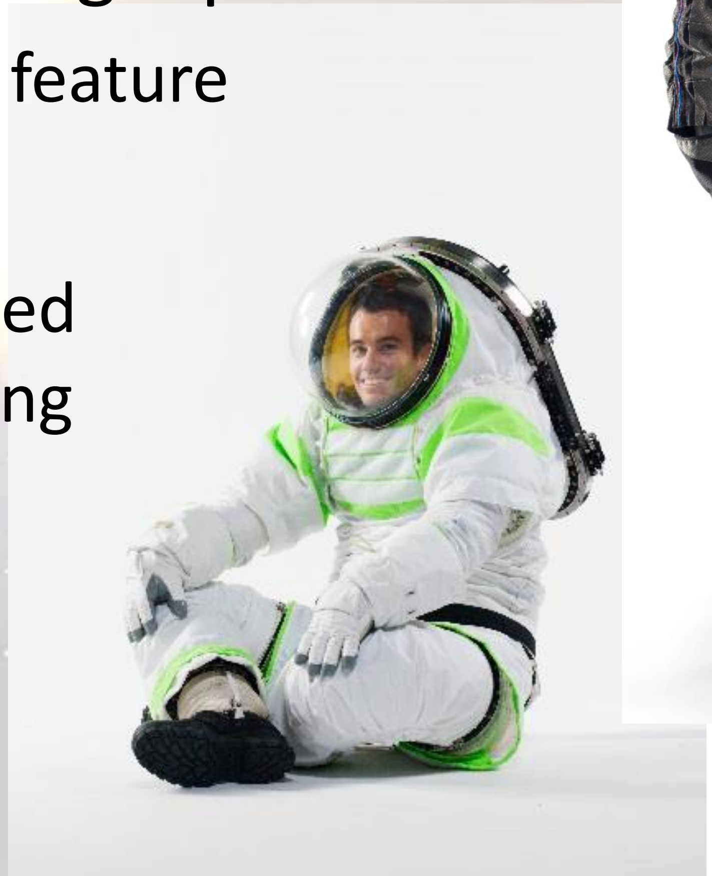
REI-Suit

Z-1

Z-2

Design variables evaluated

- Softgoods versus hard goods upper torso construction
- 3-bearing vs 2-bearing hip
  - Hip ad/ab bearing feature
- Shoulder designs
  - 2-bearing, patterned convolute, 4-bearing



Z-2 Prototype

- Received in 2016
- Matured the architecture
  - Incorporated some internal plumbing
  - Built as ‘flight-like’ hardware
  - Includes some fleet sizing features
- Intended for ‘hazardous’ test environments such as the NBL

Z-2 Features

Removable SIP Interface

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

Composite HUT (Carbon/S-Glass) (1” Vernier Sizing)

Z-1 Style Gored Lower Arm

Ti Waist Bearing w/1.75” Integral Sizing Ring

Composite Brief (Carbon/S-glass)

2 Bearing Toroidal Convolute Soft Hip

Z-1 Style Gored Lower Leg

Ankle Bearing

Planetary Walking Boots

13x11 Elliptical Hemispherical Helmet

Integrated Comm. Systems

2 Bearing Rolling Convolute Shoulder

EMU Wrist Suit Side Disconnect

RC Waist Joint

EMU Style Acme Thread FAR

Existing EMU Boot (ISS DTO) (Alternate)

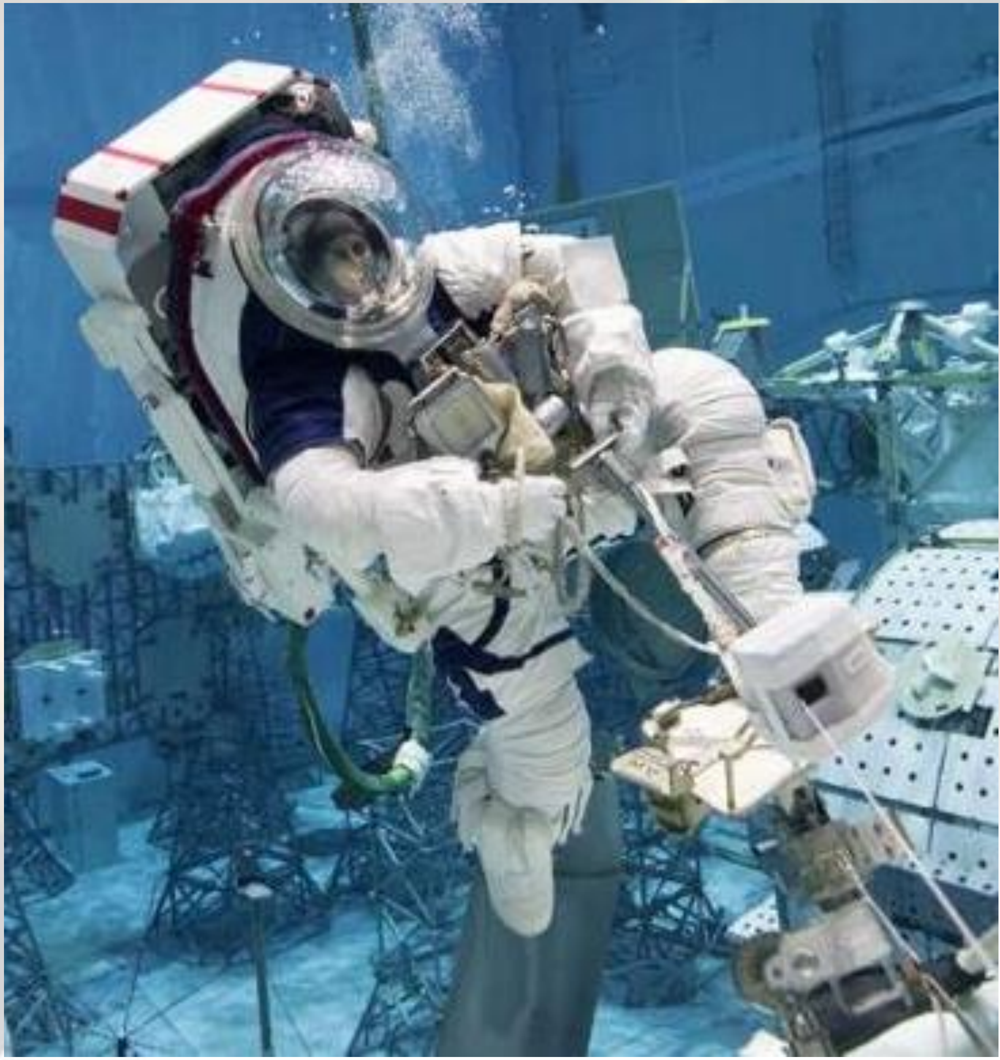
Z-2 1-g Mobility

https://io.jsc.nasa.gov/app/info.cfm?pid=27178766

- 1:47-2:32 upper torso mobility
- 5:00-6:09 walking

Z-2 NBL Runs

- Performed 16 runs + 2 test prep
- Assessed configurations using the EMU lower torso and Z-2 lower torso with the Z-2 upper torso
- Assessed complex tasks, volume constrained task sites, and airlock ingress/egress
- Last two runs investigated airlock ingress/egress with reduced front-to-back suit dimension
- Major findings:
    - Improved upper body mobility and visibility
    - Reduce helmet bubble depth
    - Airlock ingress/egress required increased control over that needed for EMU
        - However, subjects were successful in all configurations
    - Mobile lower torso provided improved capability in most cases



Z-2 NBL Runs

Anticipate utilizing a more realistic EVA timeline approach to Z-2.5 testing

Z-2 NBL Video

- All NBL video was sent live to SCH
- Video from Z-2 runs

- https://io.jsc.nasa.gov/app/browse.cfm?cid=2228092&sr=221&rpp=55
  - ELTA, translation
  - 5:47:09-5:48:48
  - Or https://io.jsc.nasa.gov/app/browse.cfm?cid=2228092&sr=221&rpp=55
  - 31:48-33:30

- https://io.jsc.nasa.gov/app/browse.cfm?cid=2318587&sr=67&rpp=66
  - ZLTA; APFR ops
  - 4:58:50-5:02:50

Overview of xEMU PGS

Feature	xEMU
Operating Pressure	8.2 psi
Design Environment	Deep Space Microgravity Surface
Mobility	Upper Torso + Full Lower Torso

- Includes:
  - Cis-lunar and lunar surface (via lunar kit) mission and environment requirements
  - High durability/ cycle life
  - Dust tolerant EPG, bearings, and mechanisms

xEMU Lite vs xEMU

xEMU Lite
ISS Demonstration
and
Potential EMU Replacement

xEMU Lite	Feature	xEMU
4.3 psi	**Operating Pressure**	8.2 psi
LEO Microgravity	**Design Environment**	Deep Space Microgravity Surface
Upper Torso + Min. Lower Torso	**Mobility**	Upper Torso + Full Lower Torso
Scarred for future upgrade	**Crew Autonomy**	Graphical Display

xEMU
Deep Space EVA
For
Gateway and Mars Transit

Overview of xEMU Lite PGS

Feature	xEMU Lite
Operating Pressure	4.3 psi*
Design Environment	LEO Microgravity
Mobility	Upper Torso + Min. Lower Torso

- Includes:
  - Integrated comm system (ICS)
  - Biomed
  - Mechanical extra-vehicular visor assembly (EVVA)
  - Liquid cooling and ventilation system (LCVG)
  - Environmental protection garment (EPG) interfaces (for dust tolerance)

*exploration PGS components will be designed for 8 psi

Schedule

	FY18	FY19	FY20	FY21
xEMU Lite Milestones	SRR	PDR	DVT Build/Test	CDR
Terms and Definitions: SRR – System Requirements Review, PDR – Preliminary Design Review, CDR – Critical Design Review, DVT – Design Verification Testing				

- Project-level System Requirements Review (SRR) in January 2018
- PLSS Subsystem design TIM in late spring 2018
  - Informal peer review
- PGS Subsystem design TIM in fall of 2018
  - Informal peer review
- Project-level Preliminary Design Review (PDR) in mid-2019
  - Initial assumption is that we there will be a series of informal component PDR's leading to the system review
- Project CDR in FY21
- Flight demonstration by mid-2020's

xPGS Lite FY18 Scope

Biomed

LCVG

Dust mitigation

Component-level Development

- In general, each of the components follow the same basic development approach
  - Design and fabricate and test **prototype** unit (Z-2.5)
  - Update design based on test results in time for FY19 system PDR
  - Design, Fabricate, and Test Design Verification Test (**DVT**)/Engineering Unit (EU) hardware
  - Update design based on test results in time for FY21 system CDR
  - Build training, **qual**, and flight hardware
  - Train and qual test
  - Fly!

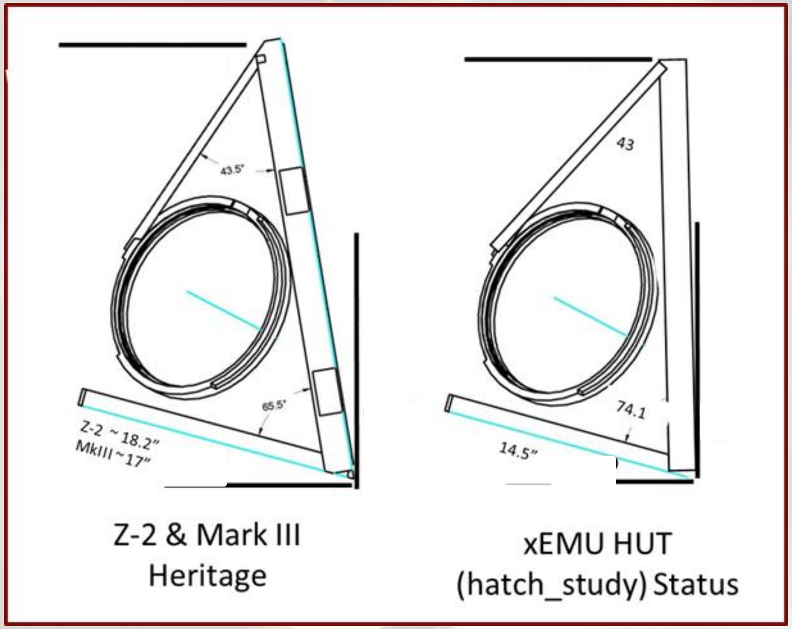
Upper Torso

- Rear-entry
  - Provides improved placement of shoulder bearings to allow more natural shoulder movement and mobility
  - Limits stresses placed on shoulders during suit don/doff
  - Expect a reduction in incidence of shoulder injury

Rear Entry Donning

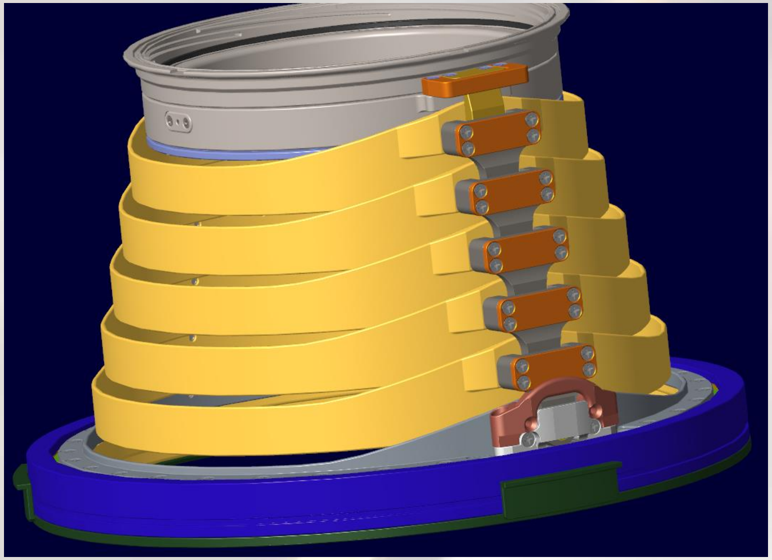
Upper Torso

- Composite structure
  - Z-2.5 will be aluminum
- Shoulder harness
- Self don/doff
  - Goal for DTO
- Implementing geometry changes to reduce front to back dimension
  - Maintaining scye angles
- Increasing design fidelity with interfaces
- Incorporating additional fault tolerance
  - e.g. Secondary hatch seal
- Z-2.5 NBL testing will assess geometry changes
  - Impact on surface activities unknown until able to evaluate



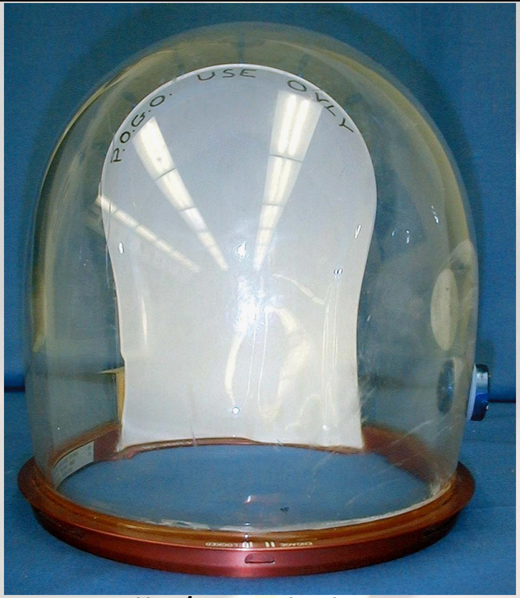
Shoulder

- Have tested more shoulders than any other joint
- Selected external link rolling convolute
  - Long history of performance
    - Mobility and durability
  - Will leverage recent design refinements
  - Performs well at 8 psi



Helmet

- Includes pressure bubble, protective visor, male side of helmet disconnect, EVVA attachment features
- Selected shape is a hemi-ellipsoid with constant longitudinal radius
  - Provides increased visibility, especially downward, for walking on planetary surfaces
  - 10” x 13” inner dimension
    - Considering shorter long axis
    - Managing depth
      - Z-2 was too deep

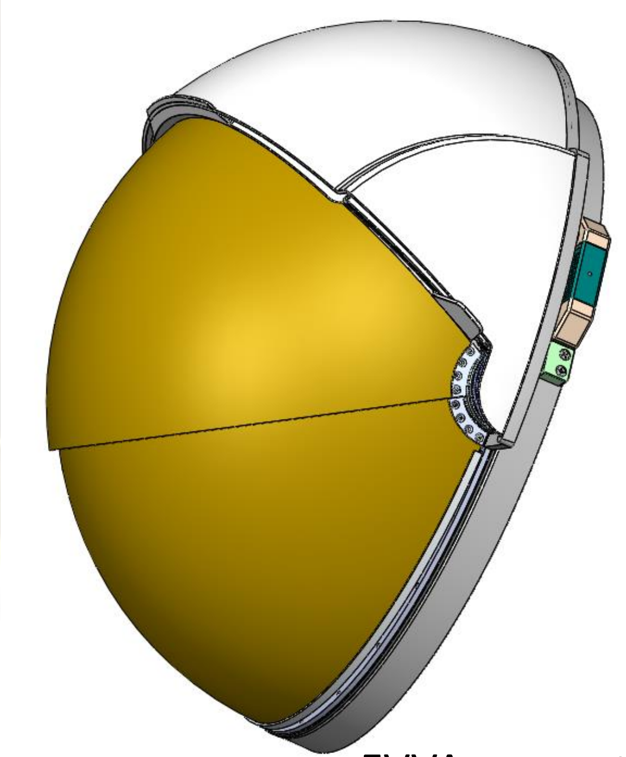


Apollo/EMU helmet

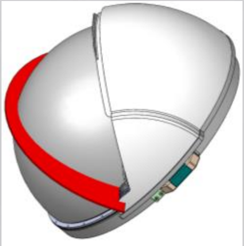
Z-2 helmet

EVVA

- Includes outer shell, visor (tinted), shades (opaque), and coatings
  - Mechanical system can be realized in the DTO timeframe
- Visor
  - Sectioned
    - Evaluating acceptability
  - Provides 120° longitudinal field of view (FOV)
    - Determined during Z-2 NBL test
  - Provides 160° peripheral FOV
    - EMU requires 170°
    - Reduction is caused by interference at the hinge



EVVA concept



Integrated Communication System

- ICS removes the communication carrier assembly (CCA) from the head of the astronaut and places it onto the suit
  - Addresses many comfort and interference issues associated with the CCA
    - ICS design must address performance with head movement and ambient noise
  - ICS prototypes have been tested in the previous advanced prototype suits
  - Mics on neck ring, speakers in hatch
- Most recent, highest-fidelity system was included in Z-2 testing
  - Mics and speakers on neck ring
- ICS architecture will return to the mics on neck ring and speakers in hatch configuration

Z-2 ICS

Biomed

- SOA
  - Circa 1975 signal conditioner + wired electrodes
- Measure heart rhythm
  - Sole physiological monitoring requirement for PGS
  - Required signal quality is an open issue
  - Goal of moving the signal conditioner outside of the PGS

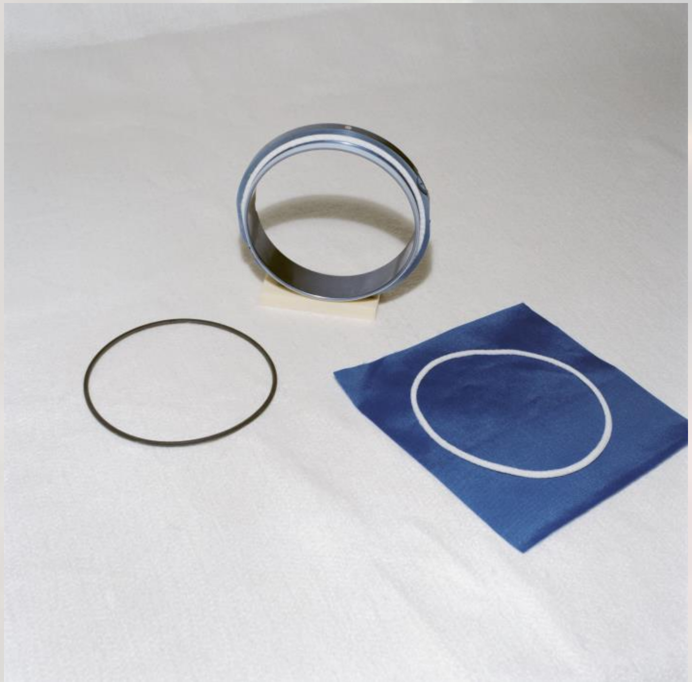
EMU Biomed Signal Conditioner

Environment Protection Garment

- Z-2.5 cover layer will be build in house
  - HUT and shoulders
- Development focus is on dust tolerant EPG interfaces
  - Both adherence and penetration/permeation
  - Developing test methodology
- Current scope likely precludes new EPG material lay-up for DTO
  - Can use EMU TMG lay-up
  - Research and development will continue at a low level
    - SBIR/STTR on materials and coatings

Dust Tolerant Mechanisms

- FY18 scope includes:
  - Refine bearing dust tolerance test method and testing hardware
    - Evaluate of current dust tolerant prototypes
  - Develop modular bearing dust mitigation concept test set-up
    - Commercial bearings in housings that incorporate dust mitigation features
  - Incorporate lessons learned



Liquid Cooling and Ventilation Garment

- FY18 scope:
  - Test available prototypes
  - Design auxiliary multiple water connector
  - Modify current prototype for Z-2.5 run
  - Start xEMU-Lite LCVG design