JSC/EC5 U.S. Spacesuit Knowledge Capture (KC) Series Synopsis

All KC events will be approved for public using NASA Form 1676.

This synopsis provides information about the Knowledge Capture event below.

Topic: Suit 101

Date: January 25, 2011 **Time:** unknown **Location:** JSC/B5S/R3204

DAA 1676 Form #: 29672

A PDF of the presentation is also attached to the DAA 1676 and this is a link to all lecture material and video: \\js-ea-fs-01\pd01\EC\Knowledge-Capture\FY11 Knowledge Capture\20110128 A.Ross_Suit-101\For 1676 Review & Public Release

*A copy of the video will be provided to NASA Center for AeroSpace Information (CASI) via the Agency's Large File Transfer (LFT), or by DVD using the USPS when the DAA 1676 review is complete.

Assessment of Export Control Applicability:

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* This PDF is also attached to this 1676 and will be used for distribution.

For 1676 review use_Synopsis_Ross_Suit 101_1-25-2011.pdf

Presenter: Amy Ross

Synopsis: A NASA spacesuit under the EVA Technology Domain consists of a suit system; a PLSS; and a Power, Avionics, and Software (PAS) system. Ross described the basic functions, components, and interfaces of the PLSS, which consists of oxygen, ventilation, and thermal control subsystems; electronics; and interfaces. Design challenges were reviewed from a packaging perspective. Ross also discussed the development of the PLSS over the last two decades.

Biography: Amy Ross has been with NASA for over 20 years, specializing in pressure garments. She has served as the Spacesuit Team lead, Spacesuit Hardware Technology Development lead, CxP Spacesuit System PGS manager, and Space Launch Initiative Crew Escape Suit Engineering lead, with most of her experience in advanced planetary spacesuit development and testing. Past projects include the shuttle spacesuit gloves, launch and entry suit gloves, and STS-100 EVA tools. Amy earned a bachelor and master of science in mechanical engineering from Purdue University and a master of science in space studies from the University of North Dakota.

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Interfacing with an EVA Suit

January 28, 2011

Amy Ross/EC5/x38235

Purpose

Provide a suit engineer perspective

to non-suit engineers

to facilitate system integration

of prototype hardware

into advanced EVA space suit prototypes

Does not cover integration with the EMU or flight systems

Does not cover launch/entry/abort suit design considerations

Basic Interface Considerations

- Safety
  - The safety of the subject and the suit hardware is the primary concern of suit engineers.
- Materials compatibility
  - Flammability
  - Offgassing
- Electrical requirements

Safety: Review of Space Suit Hazards

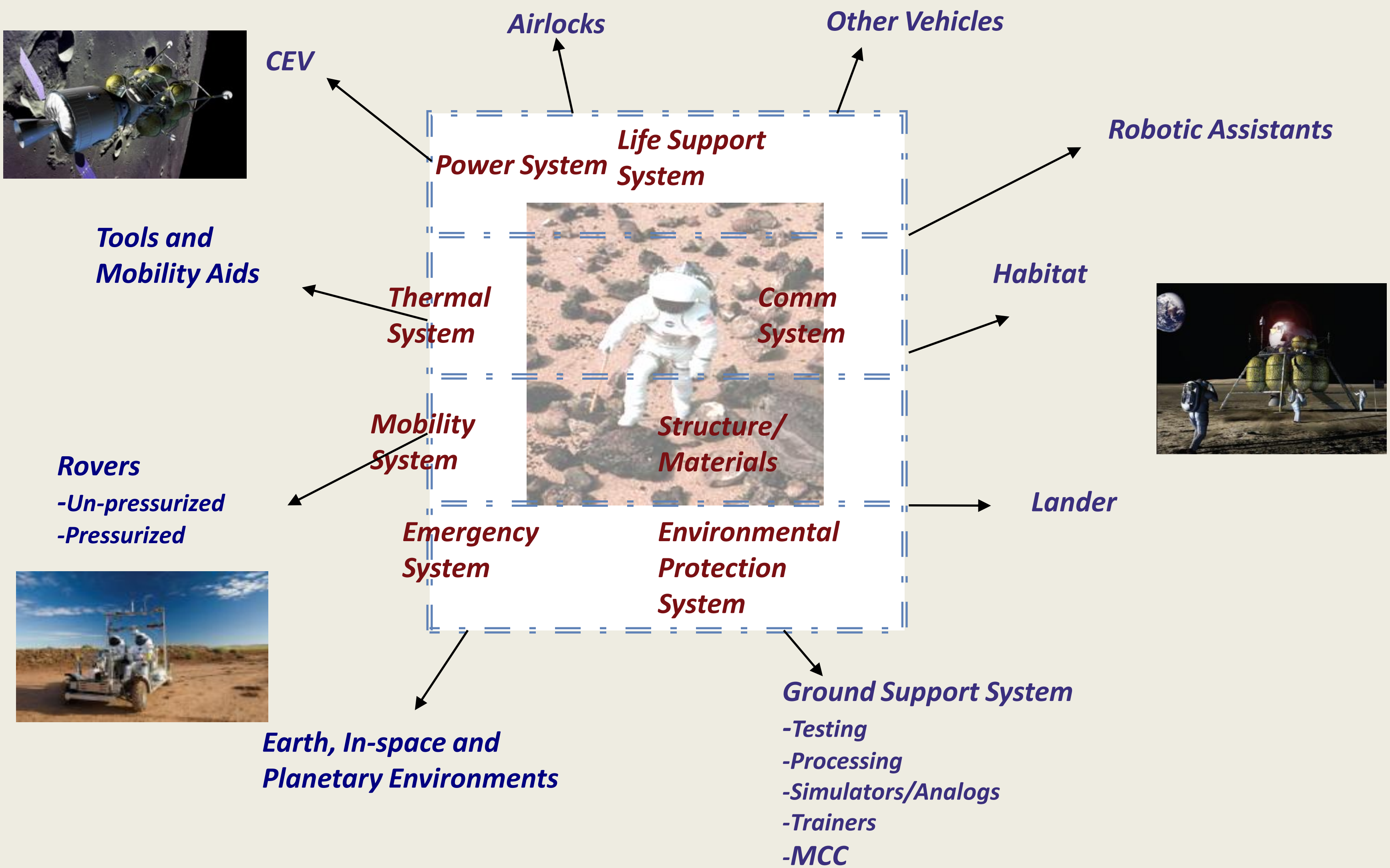
1. Barotraumas
2. Uninhabitable Environnent
3. Electrical Hazards
4. Contamination/Corrosion
5. Fire
6. General Personnel Injury
7. Test Subject Entrapment
8. Breathing Air Supply
9. Hazardous Chemicals
10. Communications
11. Sharp Edges/Corners

Mark III Hazard Analysis, JSC-ADV-590

Safety

- Other things a suit engineer is paying attention to:
  - Subject health
    - Prior to and during a test
    - Suit /on-back weight
  - Cognitive workload
  - Comm protocol
  - Field of View
  - Slip, trip, fall hazards
  - Other interfaces..

Suit System Dependencies and Interfaces



Materials Compatibility

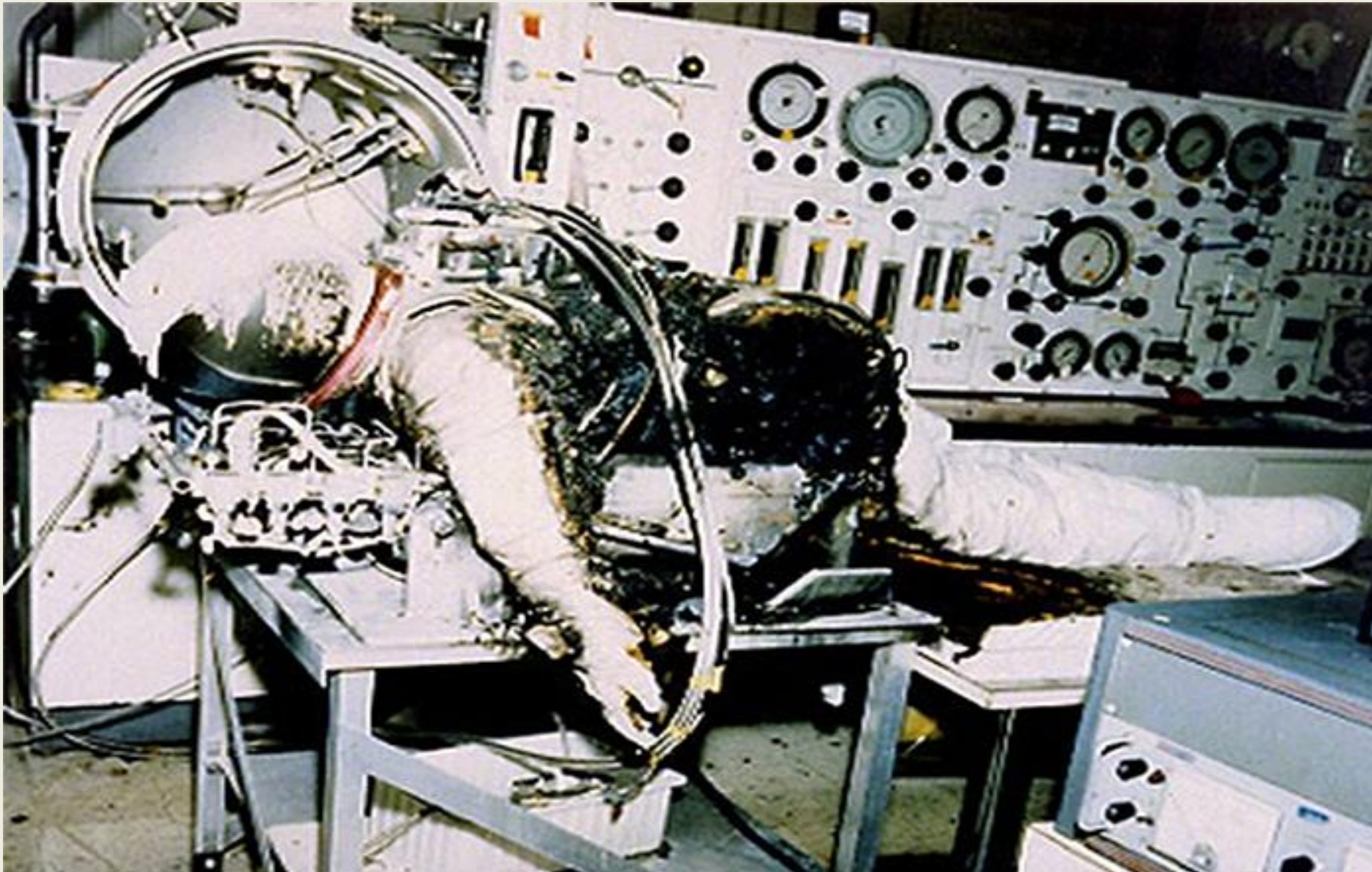
- 2 Primary materials compatibility concerns:
  - Flammability
  - Offgassing

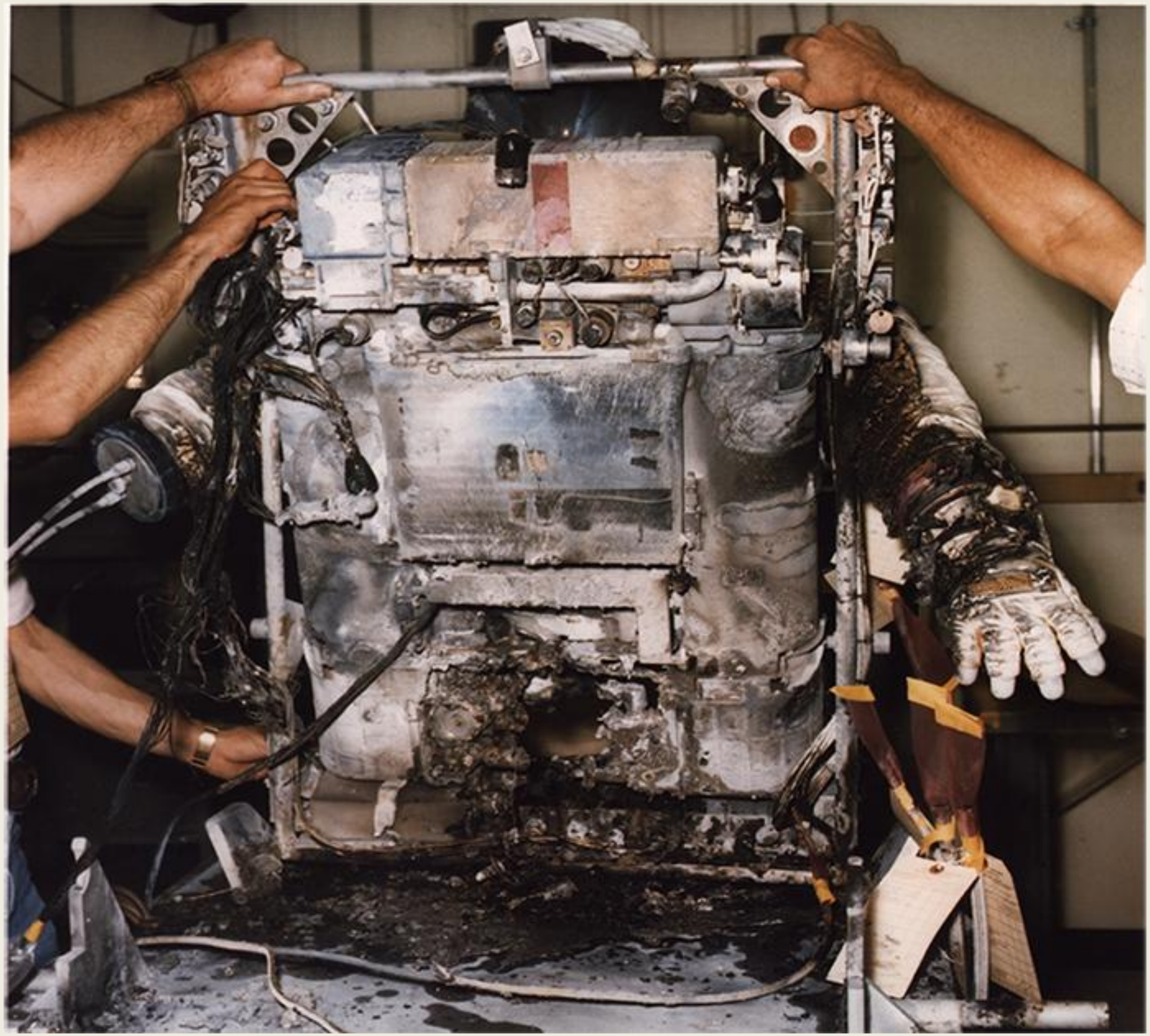
Materials Compatibility: Flammability

- Level of risk depends on environment
  - Pressure
    - Below or above ambient
  - Oxygen percentage
- Tied to hardware fidelity

Note: **EVERYTHING WILL BURN**

EMU Fire





Materials Compatibility: Flammability

- Approach is generally the same

  →CONTROL IGNITION SOURCES

  Only leg of the fire triangle that can be addressed. There is a fuel source (human, suit softgoods, etc) and there is an oxidizer.

  - Flight systems requirements in NASA-STD-(I)-6001: *Flammability, Odor, Offgassing, and Compatibility Requirements and Test Procedures for Materials in Envrionments that Support Combustion*

    (Previously published as NHB 8060.1)

Flammability is one driver for electrical limitations.
Electricity = ignition source.

Materials Compatibility: Offgassing

- Offgassing = *The evolution of gaseous products from a liquid or solid material into an atmosphere*. [NASA-STD-(I)-6001]
- Primary concern is the offgassing of toxins internal to the suit.
  - Issue is more severe if materials are exposed to a reduced pressure/vacuum.
  - Offgassing external to the suit is usually only a vacuum chamber/flight concern.
    - EX: RTV of gloves is baked out for Hubble flight so that offgassed material does not deposit on the mirror.

Materials Compatibility: Offgassing

- **ALL** materials that are exposed to the ventilation loop (internal to the suit) must be reviewed and approved for use.
  - Includes: epoxies, edge lock, label material, etc
  - Effort is significantly reduced if previously reviewed and approved materials are utilized
    - MAPTIS database
    - Documented use in a flight system
  - Detailed Bill of Materials (BOM) is key
    - If for use in breathing air environment at above ambient pressures, usually this is easy

Resources for Materials Compatibility

- Your suit engineer counterpart
- ES4 – Materials and Processes Branch
  - Alma Stephanie Tapia
  - Mike Pedley
- EC2 – Thermal Systems and Engineering Support Branch
  - Softgoods and materials
    - Evelyne Orndoff

Resources for Materials Compatibility

- NASA-STD-6016: *Standard materials and processes requirements for spacecraft*
  - Higher level than -6001; describes M&P process
- MAPTIS (Materials and Processes Technical Information System) database
  - https://maptis.nasa.gov/home.aspx
- Classes
  - "Fire Hazards in Oxygen Systems"
    - "Managing Risks in Oxygen Systems" (not offered?)
  - "Materials for Use in Oxygen Systems "– on-line

Electrical Requirements

- Major concerns are:
  - Shock
    - Burns, ventricular fibrillation, etc
  - EMI
  - Fire/ignition source

Electrical Requirements

- NASA/SP-2010-3407 *Human Integration Design Handbook* (HIDH);
  - section 9.12 = Electrical Safety Hazards
  - New document and interpretation of requirements is still in work
- In general, if your system runs below 30 volts rms, your system will be approved
  - Per table 9.12-4 in -3407

Other Good References

- JPR 1700.1 *JSC Safety and Health Handbook*
- NASA/SP-2010-3407 *Human Integration Design Handbook* (HIDH)
- NASA-STD-3001 *Space Flight Human System Standard*; Volume 2 *Human Factors, Habitability, and Environmental Health*
- NASA-STD-3000 *Man-Systems Integration Standards*; Section 14
  - Superseded by -3001
  - Good as an historical reference

WARNING: APPLY WITH SUIT ENGINEER ASSISTANCE

Advanced Interface Considerations

THE HUMAN

Hardware/Human Interface

- Is complex
- Is variable
  - By suit
  - By human
    - Individual preferences
    - Anthropometry
      - Individual
      - Range
- Has physical and mental aspects
- Discuss through various examples

Anthropometry Variations

Suit Configuration Variations

From left to right: Apollo A7LB, ACES, Shuttle EMU, Mark III, Waist entry I-Suit, D-Suit, Sokol

Discussion Examples

- Injectables Project
- Cuff checklist
- Helmet-mounted display
- Microphone array

Injectables Project Example

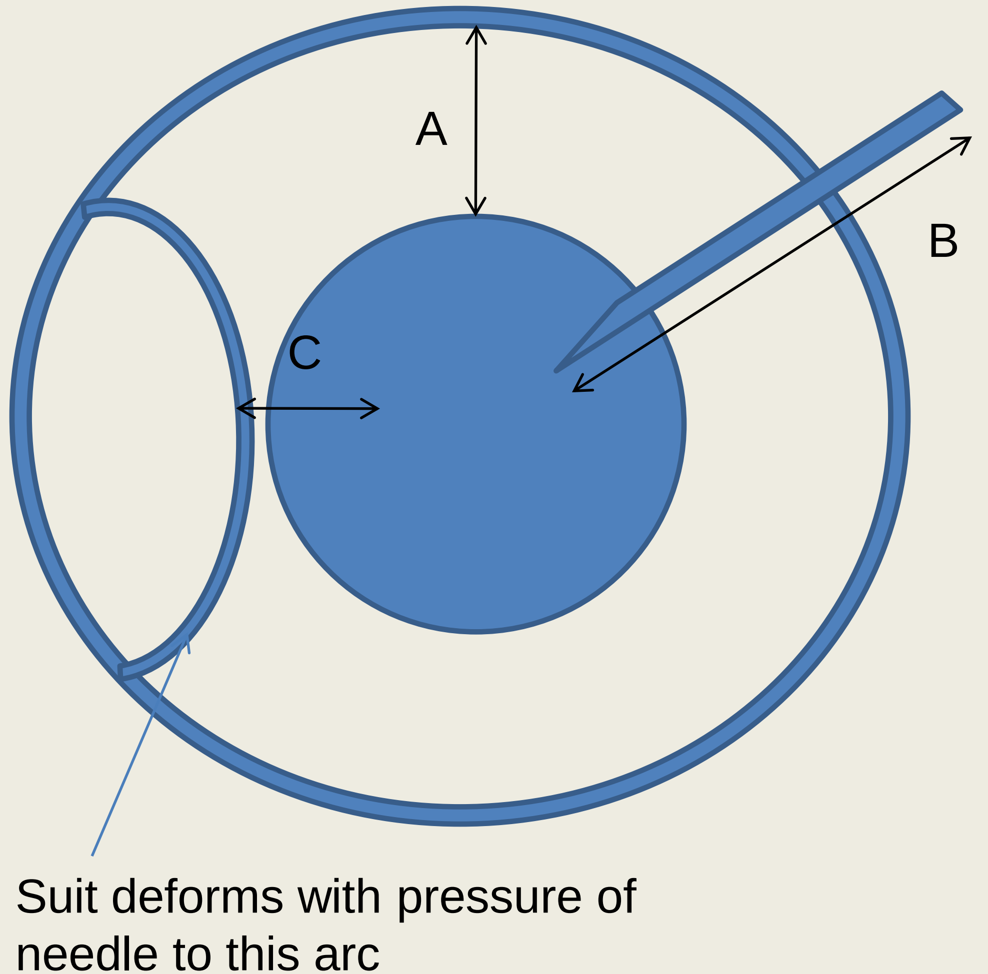
For the Injectables Project, there will be a biomedical injection patch in the thigh of the new space suit design.

In the case of an emergency scenario where the cabin has lost pressure and have donned their EVA suits, our injector will be able to provide a medical injection through this biomedical patch and into the astronaut.

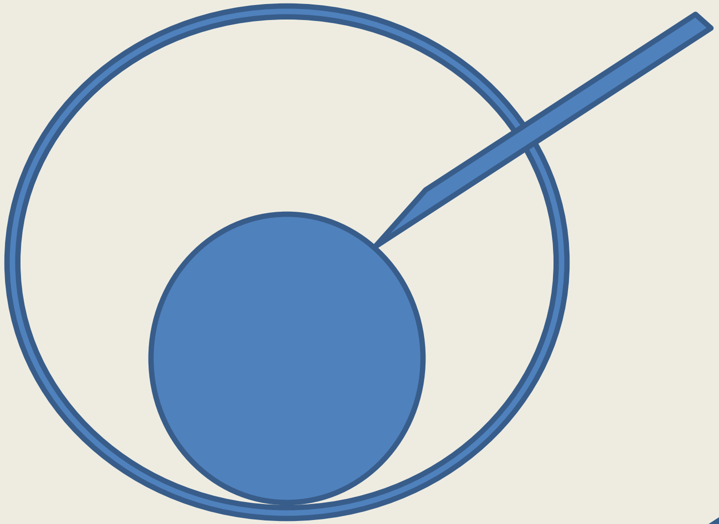
Our big question is this: when the astronaut pushes the injector up against his thigh, will the suit move? Ie., will the suit deflect until it touches up against the skin, will it remain in place because it is pressurized, or will it do something in between? This question is very important to us as it determines the length of needle we need to include in our design.

Injectables Project

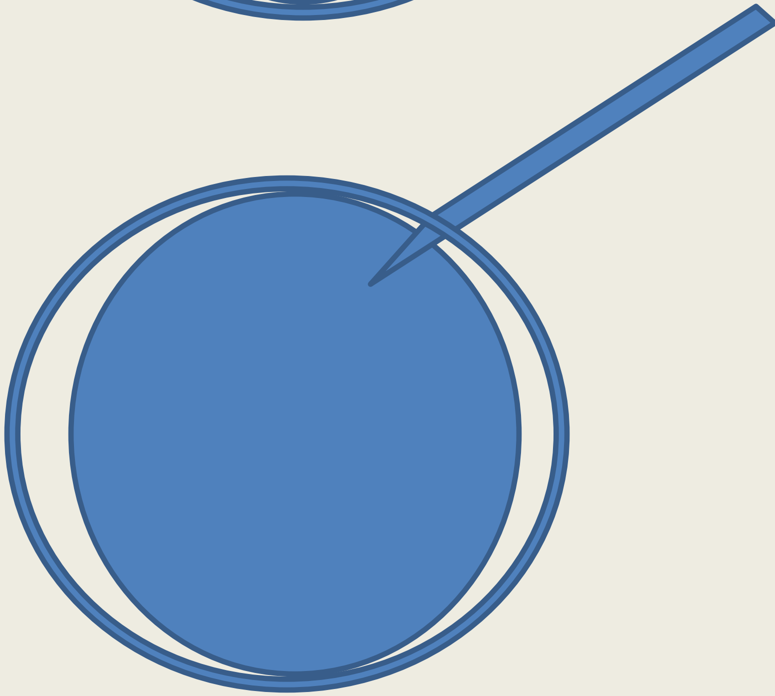
- What is the right answer?
  - A, B, or C



Injectable Example



- What if the leg position changes with respect to the suit?



- What if somebody has a larger/smaller leg?
- Does is matter where the injection is given?

Injectables Project Example

- The initial answer from the suit engineer will be, **“It depends.”**
- The suit engineer will start a conversation on design considerations:
  - Basic pressurized suit configurations
    - An invitation to visit the lab and observe a pressurized suit
  - Radius of the leg at the injection location
    - Variations in radius based on suit configuration location on the leg component, component size
  - Variability of leg position in the suit leg
  - Impact of anthropometry variations

Injection Example

- What basic suit information does the team need?
- What are the design considerations if they were attempting intraosseous infusion (as was an early requirement in CxP)?

Injectables Project Example

- The suit engineer can help the project team better understand design considerations and get them closer to an answer.

Cuff Checklist Example

Cuff Checklist Example

- We all want to provide more information to the astronaut so that they can be more autonomous on complicated and/or distant missions.
- An electron cuff checklist (ECC) is one concept
- So what issues are suit engineers going to have with an ECC?

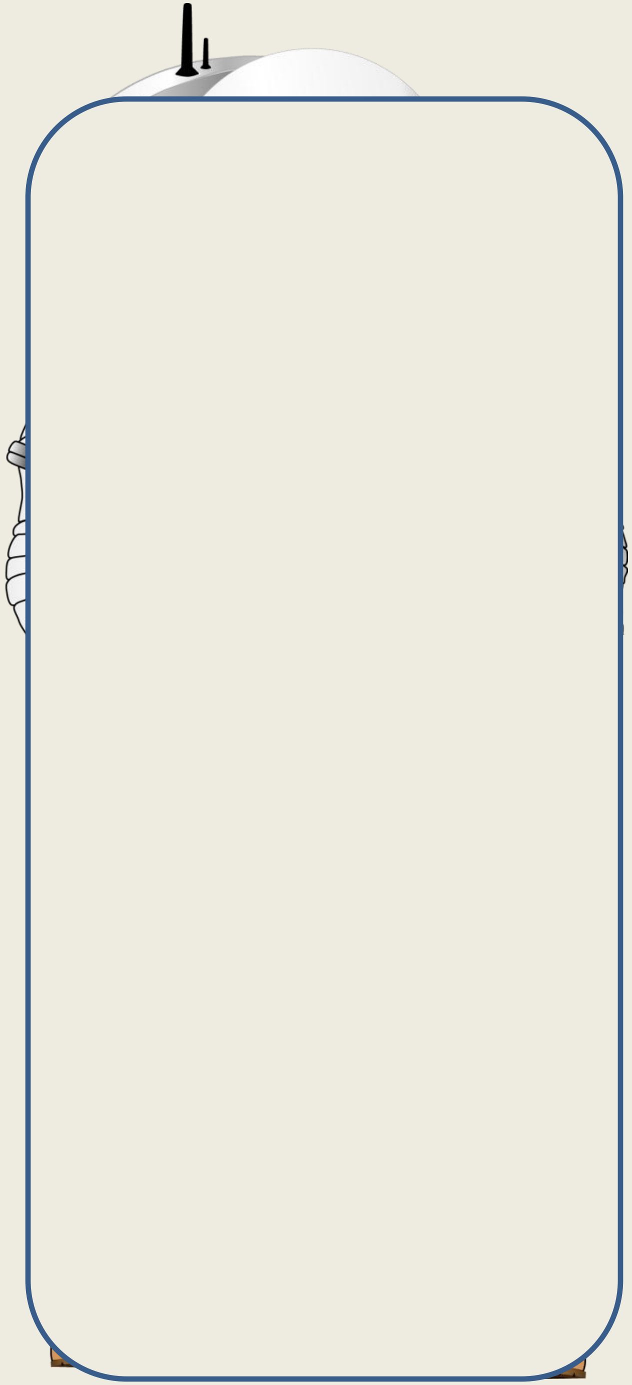
Cuff Checklist: Keep out zones

- The initial reaction from a suit engineer may be:

  ‘Where will we put it?’

  ‘There isn’t room!’

- Suit engineers can see the suit keep out zone as →



Cuff Checklist: Keep Out Zones

- Keep Out Zones are driven by:
  - Line routings
    - Breathing gas, water, electrical
  - Human anatomy and anthropometry
  - Passthrough/connector footprints
  - Mobility joints
    - Where the joints are
    - How the joints move, work envelope
  - Vehicle interfaces
    - Donning stands
    - Seats
    - Hatches/ports
  - Field of View
  - And more

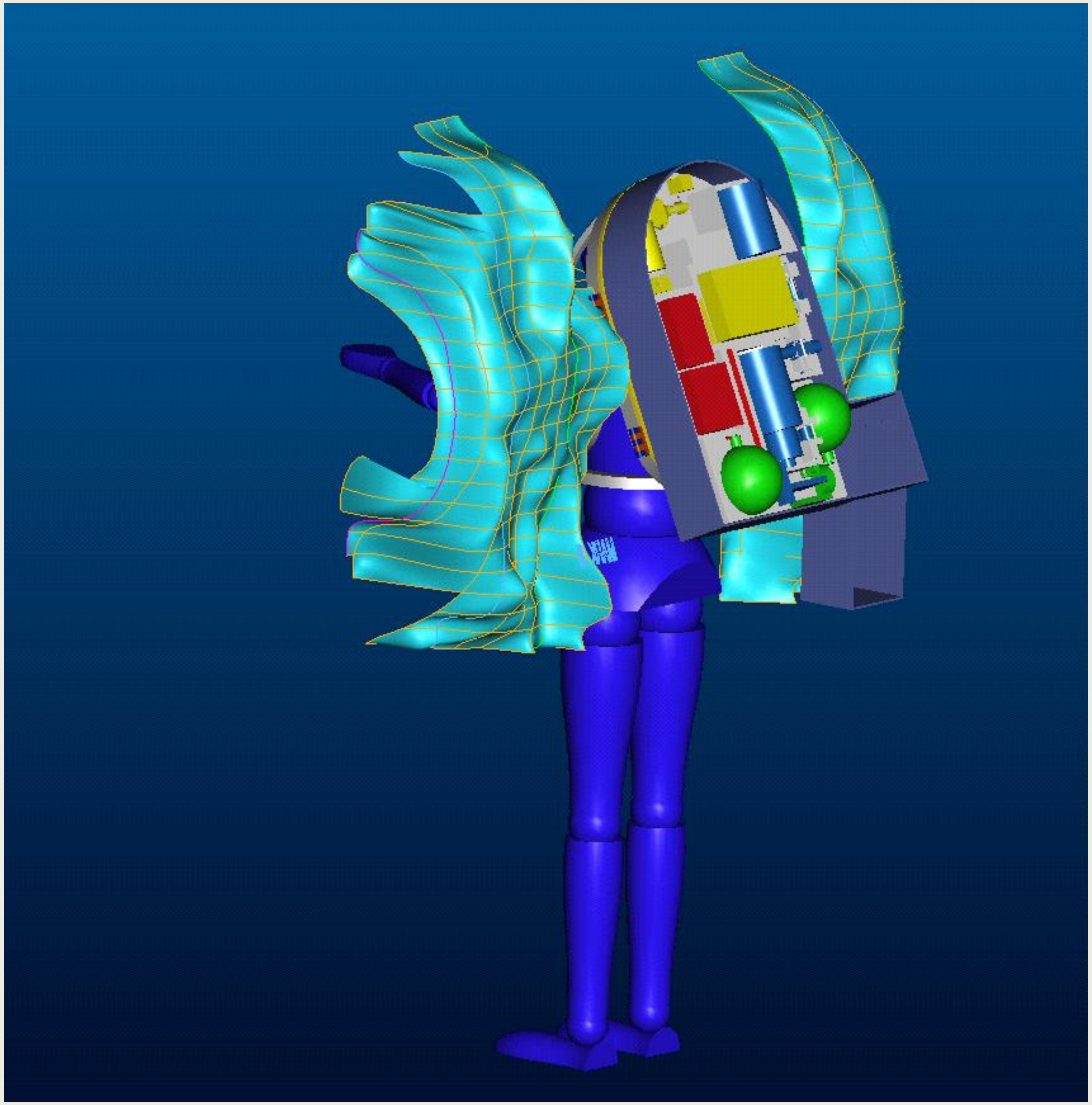
Cuff Checklist: Keep Out Zone

Keep out zone:
Joint mobility

-The ‘angel wings’ map the rear-most reach of the arm for the Mark III.

Keep out zone:
Anthropometry range

-Extra short arm



Cuff Checklist: Use Posture

Posture required for
Cuff checklist use

Can be fatiguing due to:

-suit fit

-suit mobility
  -cross-reach

-weight in gravity
  environment

Cuff Checklist Example

- Consider the following questions:
  - What joints are located in the area selected for placement of the ECC?
  - What range of motion do the joints have?
  - What anthropometric range is there for the forearm?
    - Extra small arm demonstration
  - What posture are you in to use the ECC? How frequently and for how long are you in this posture?
- Where do you put the ECC?

Cuff Checklist Example

- Where else can you put it?
  - Chest mounted?
    - But impacts FOV needed for walking
    - Fatiguing arm and viewing posture
      - Extreme joint angles
      - Limit of downward visibility
  - Helmet-mounted?
    - That’s our next example

Chest-mounted Display

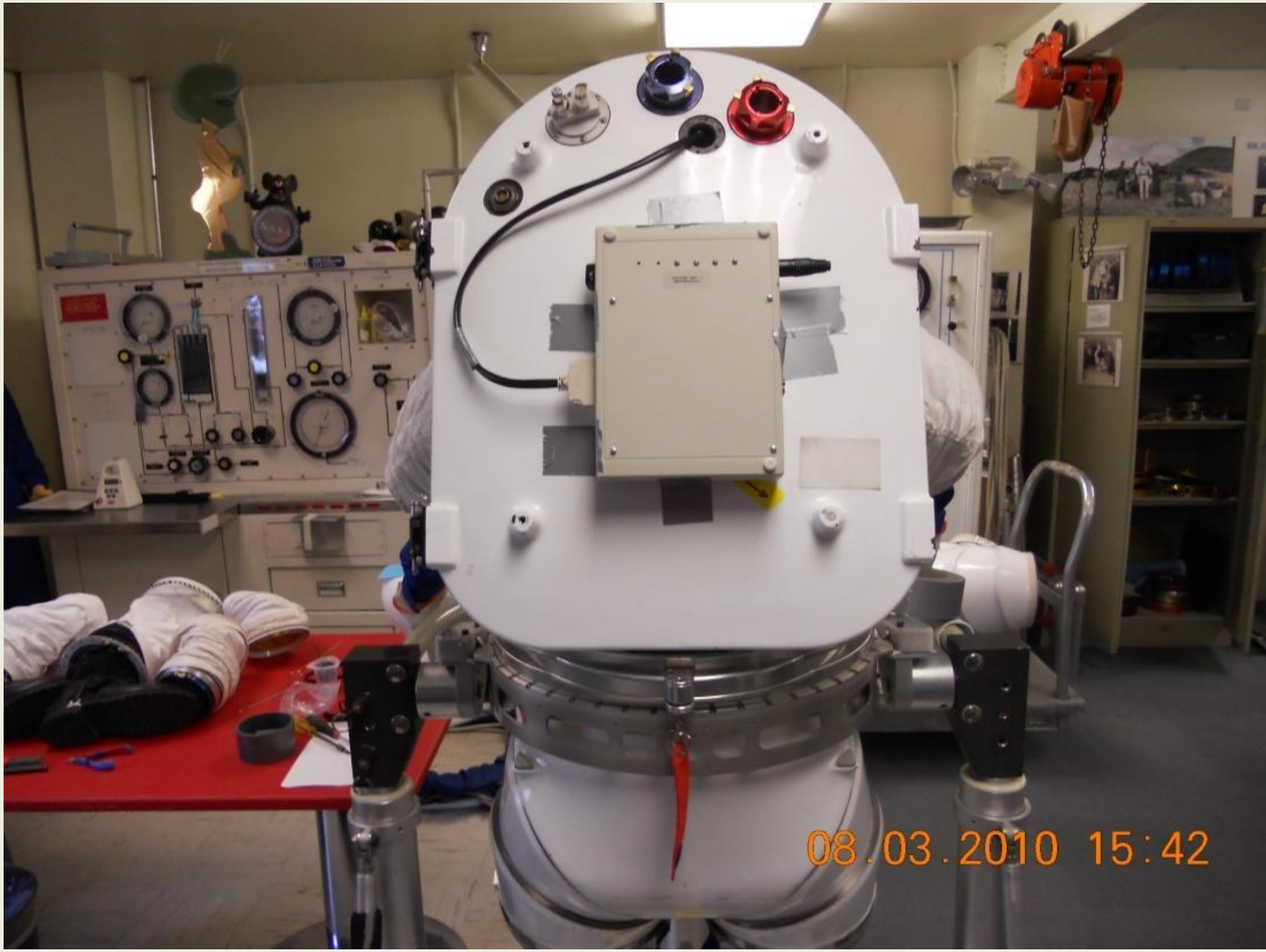
Helmet/head-Mounted Display (HMD) Example

HMD Example: Position in suit can change due to posture

HMD Example: What are you carrying? Where? Impact to FOV?

HMD Example:

- What are you carrying? Where? How?
- Test pass-through



HMD Example: Considerations

- Posture changes position in the suit
- What you are carrying and where
  – Additional weight, power, interferences
- Use issues
  – FOV
  – System operation
- Delicate component issues
  – I busted a $300 (or $3000) fiber optic cable
  – The subjects will cough and spit on it and rub and bump against it.

HMD Example

- Suit hardware design and integration is a group effort
- Suit engineers can't just give you 1 answer
  - **It depends!**
- Conversations with suit engineers throughout the design and test process will produce a functional compromise
  - We'll help to:
    - find a place to put it
    - make it usable in the suit
    - get your data

Microphone Array Example

Microphone Array Example

- Your turn:
  - What will the suit engineer want to discuss?

Microphone Array Example

- Form factor
- CO_2 washout
- Human motion within the suit
  - Activity
  - Posture
  - Person

Microphone Array Example

- Comm pre-amp box
  - Means you don't always know if it will work or not until you try

Summary of Examples

- There are a lot of considerations when interfacing with a suit.
- Talk to suit engineers.

This is a group effort

and

This is an interative effort

and

The answer is:

IT DEPENDS!

Testing Hardware with a Space Suit

So you built something and now you want to test it.

- You'll need to work with a Suit Test Engineer
- All new hardware being tested with a suit will need to pass a TRR and probably a CPHS review
  - This is the hardware owner's responsibility

Suit Test Engineer Responsibilities

- Suit test engineer (STE) is responsible for:
  - The safety of the subject
  - The safety of the suit test technicians
  - The safety of the suit hardware
  - Test situational awareness

- STEs are trained and certified.
  - 2 STEs are current. 3 are in training/partially certified.
  - STEs also serve as hardware owners for the suits in the ASL.

ASL test process: STE responsibility

- Review integrated hazard analysis and detailed test plan.
  - Provide collective feedback from ASL team feedback to Test Requestor
- Review list of test subjects and identify suitability for test and if fit-checks required
- Support test and any associated fit-checks as assigned
- Attend TRRB

Per the Advanced Suit Lab User Guide -draft

ASL Test process: Requestor responsibility

Review electronic calendar to identify available test dates (ref. section 5.3)

- Write detailed test plan and integrated test hazard analysis
- Submit test WAD package with all necessary signatures and attachments (ref. section 5.2.4.1)
- Negotiate funding for technicians with a DO Manager
- Identify test subjects with physicals appropriate to test- proof of physical status must be provided to STE prior to test

NOTE: While it is the test requestor's responsibility to identify and schedule test subjects, a list of previously fit-checked individuals may be obtained from the Lab Operations Manager upon request.

- Submit WAD for test subject fit-checks, if required

- Schedule and conduct Test Readiness Review Board (TRRB) – invite all required participants such as Medical Officer, Test Safety Officer, suit technician, suit test engineer, and facility representative, as indicated in EA-WI-024
- Provide certification letters for test subjects, Test Director and/or Test Conductor(s) (see example in App. B) at TRRB
- Attend weekly Coordination meeting Monday prior to test activity (ref. section 5.1.1)
- Provide layman's summary, informed consent, and photo consent documents to test subjects, if required by TRRB
- Schedule Test Director/Conductor(s) for event

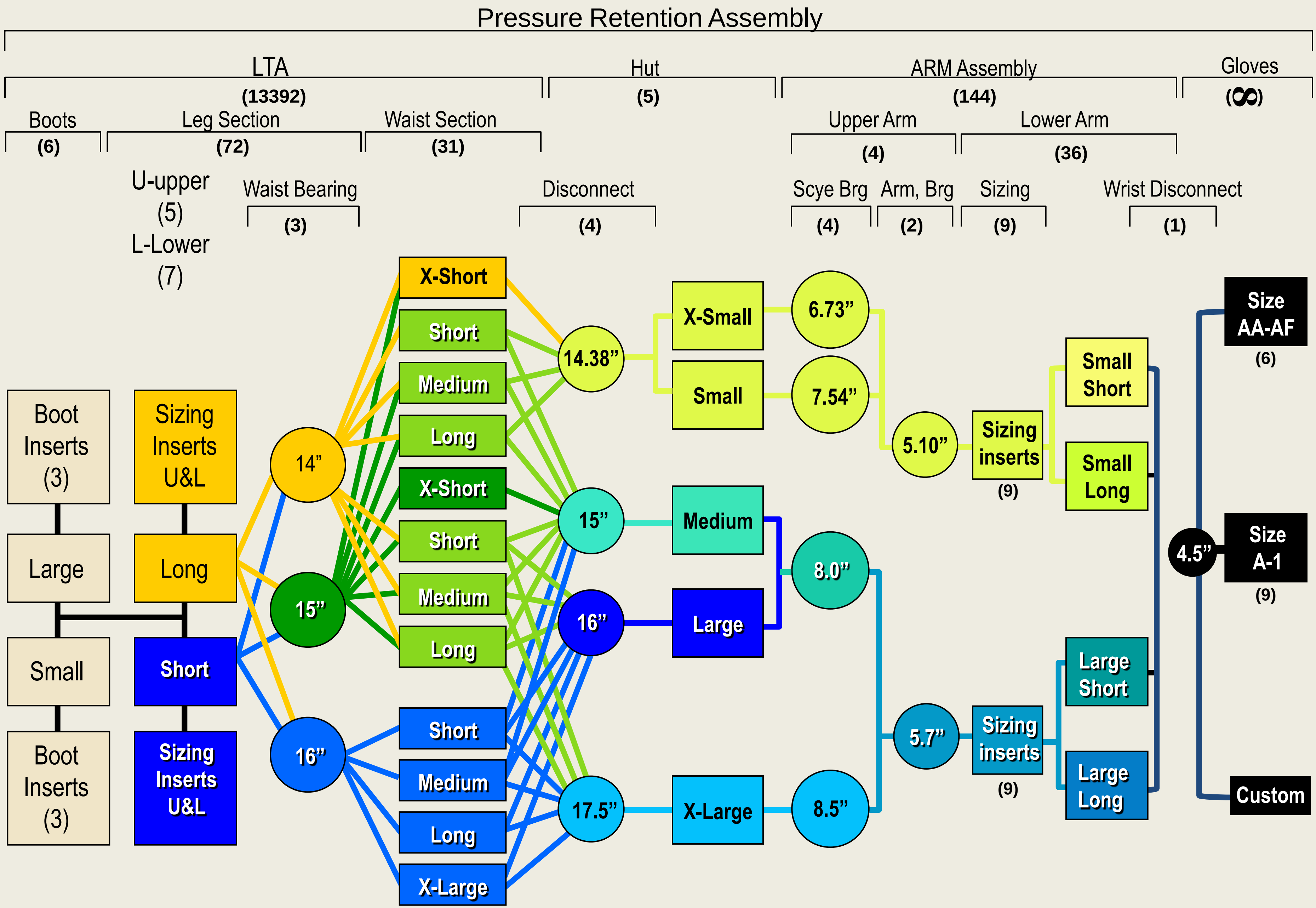
BACK-UP

Interactions with suit engineers

- Suit engineers wear 3 hats
  - Suit designer
  - Researcher
  - Suit Test Engineer

It is helpful that you and the suit engineer are clear what hat the suit engineer is wearing during any given conversation.

Shuttle EMU Spacesuit Sizing System



HMD Example: Position in suit can change due to posture

When talking to an STE..

- They are going to be thinking about:
  - Test safety
  - Test logistics
    - Schedule
      - Coordination with other lab activities
      - Fit checks, prep/post, suit resize between runs, team workload
    - Hardware requirements
      - Appropriate suit hardware for test, required support hardware (water cooler; which air supply-test stand, K-bottles, air cart, helmet off; comm set up; etc)
    - How to best help you meet your test and data needs


NASA