Advanced Space Suits

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What I'll Talk About

- A brief introduction
- Space suit pressure garments: What they are and do
- Materials used in space suits
- Space suit design challenges
- Questions

A brief introduction

- Overarching objective

  Provide best tool to crew for extravehicular activities during human space exploration missions

  [MARS OR BUST!]

- Scope of work: Lead NASA's advanced pressure garment development
  - Requirements definition
  - Technology development, component level development
  - Testing
  - Certification for use in test and eventually for flight

- Team: BIGGEST we've ever been
  - 6 civil servants
  - 2 rotational engineers
  - 4 technicians
  - 4 contractor engineers

Basics: Why Do You Need an EVA Suit?

Space Suits Provide 3 Basic Functions For EVA Astronauts:

1 **First, in conjunction with a portable life support system, the space suit maintains the physiological well-being of the astronaut**

- Supplying oxygen for pressurization, breathing, and ventilation
- Provide carbon dioxide and metabolic heat removal

2 **Secondly, the space suit incorporates various mobility joint systems to enable the astronaut to perform EVA tasks in the pressurized condition**

- Includes both dual-axis and single axis joints and bearings

3 **Finally, the space suit provides protection against the hazards of the particular EVA environment**

- Thermal extremes
- Meteoroid and orbital debris
- Radiation conditions
- Abrasion and sharp edges
- Sand, dust, and rocks

In essence, the space suit is a small spacecraft in itself

What Does a Planetary Walking Suit Look Like?

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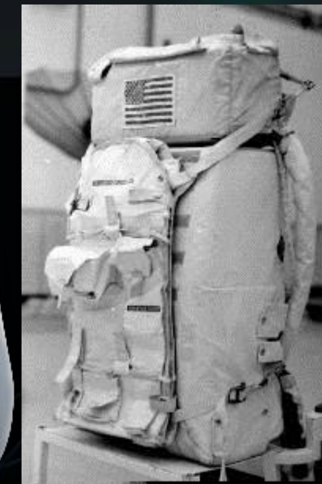
- A space suit consists of two main components: a pressure garment that covers your body and a life support system that can be worn on your back
- Pressure garments are what we typically think of as a "space suit", while the PLSS is that ill-defined box nobody pays much attention to…except, of course, if you' re in the pressure garment…



What Does a Planetary Walking Suit Look Like?

- Rear-entry
- Helmet angled and shaped for wide field view, including downward visibility
- Hard or soft torso, briefs and hip
- Waist bearing and flexion/extension joints
- Hip mobility joint system with 2 or more bearings and features for adduction/abduction
- Softgood arms and knees
- Walking boots with an ankle flexion/extension joint and ankle bearing
- Environmental protection garment that addresses dust,
  - Durability with UV radiation exposure,
  - Thermal protection in a low atmospheric pressure,
  - Durability with exposure to products of chemical react

Suits will be flexible and rugged enough to bend over, dig holes, walk up hill to the outcrop, bash rocks, collect and stash samples, and look closely at rock specimens.

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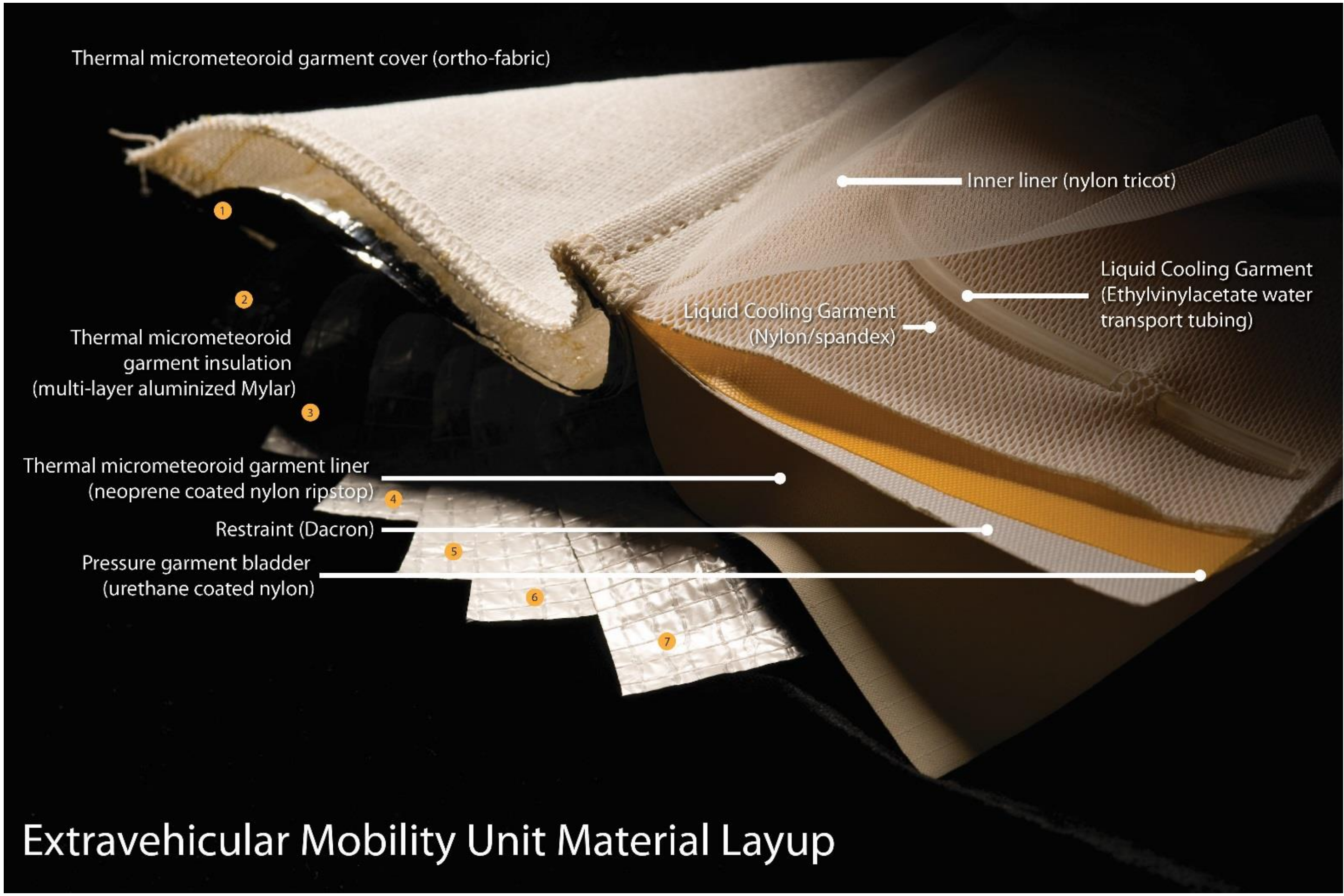
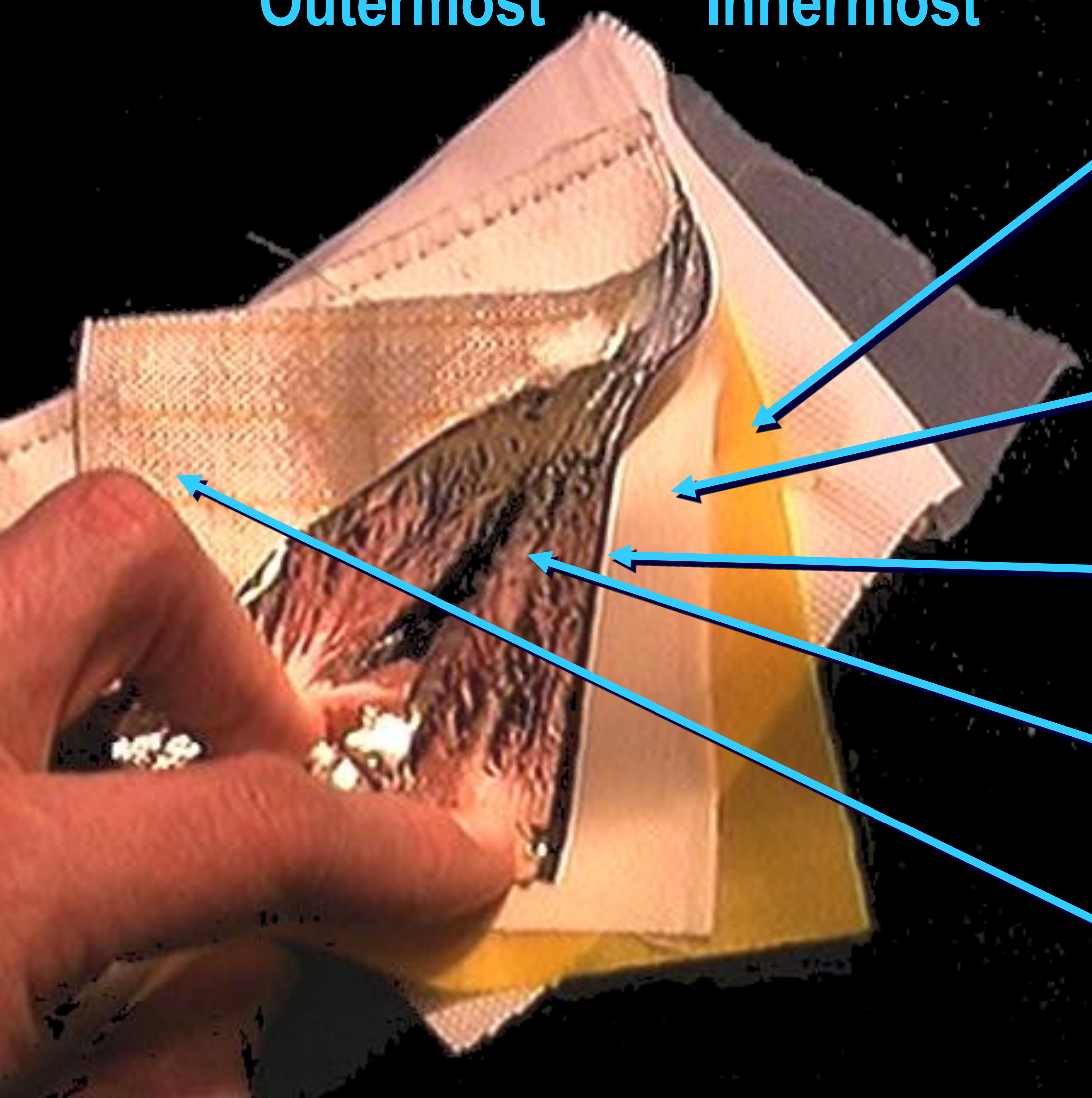
Materials used in Space Suits

- Softgoods lay-up
- Metals
  - Stainless steel, aluminum, titanium
- Composites
  - Z-2 composites include PW IM-10 sandwiched in 8HS S-2 glass
- Plastics
  - Polycarbonate



EMU Suit Layers

Outermost **Innermost**



- Pressure Garment Bladder - urethane coated nylon oxford fabric
- Pressure Garment Cover-Restraint - dacron
- TMG Liner – neoprene coated nylon ripstop
- TMG Insulation – 5-7 layers of aluminized mylar
- Thermal Micrometeoroid Garment (TMG) Cover

Space Suit Design Challenges

Defining requirements for a unique application using standard test methods

- "Outer Layer Cut Resistance" requirement
  - Tested current outer layer materials, Orthofabric and Polytetrafluoroethylene (PTFE) fabric
    - ASTM F1790-05 "Standard Test Method for Measuring Cut Resistance of Materials"
    - Testing against a standard is attractive:
      - clearly defined verification method to a quantitative value.

- Flaw: Doesn't necessarily address the needed performance for the new system because it only quantifies current performance within the specific scope of the test and because extrapolation could be imperfect.
    - "What if the test standard selected does not characterize the attribute of the current material that provides the desired performance?"
    - "What if the test standard does not accurately represent the environment/conditions that the hardware would actually be exposed to?"

Space Suit Design Challenges

Defining requirements for a unique application using customized test methods

- Develop a test protocol that directly addresses the performance in question
  - Effort to modify ASTM D 3884-01 “Standard Guide for Abrasion Resistance of Textile Fabrics (Rotary Platform, Double Head Method)”,
    - added measured quantities of lunar simulant JSC-1 to the wheel abrasion test.

- Flaw: protocol was tested separately at Glenn Research and Johnson Space Centers, results did not correlate

ASTM D 3884-01 test device

Space Suit Design Challenges

- Another customized test: tumble test development.
  - Cylinders of current and candidate materials were tumbled in a rotary drum with simulated rocks and simulant dust.
    - Before and after testing a visual inspection, material strength (tensile and tear) tests, and scanning electron microscope (SEM) images were performed.
- Method recently revised using squares or lay-ups of material secured to the inside surface of the rotary drum in an effort to increase the efficiency of the test.

- Flaw: method provides significant comparative information, but has not resulted in a clear quantitative requirement.

Rotary Drum test device

Space Suit Design Challenges

- Space suit must be strong, durable, and light-weight
  - -Approach: replace stainless steel bearings with titanium
- Issue: oxygen compatibility
  - -Approach: cycle testing in oxygen environment at White Sands Test Facility
- Obtained proof of oxygen compatibility, but discovered new issue:
  - -wear

Additional Space Suit Design Challenges

- Durability/cycle life requirements
  - For a human mission to Mars: ~ 10^6 walking cycles
- Radiation Environment
  - Materials life
  - Do no additional harm
- Composites
  - Impact requirements
  - Manufacturability of composites
    - In or out of autoclave
    - Availability/cost
    - Time of manufacture
    - Quality assurance
    - Metal to Composites interfaces
- Secondary impactors

References:

Ross, Amy, Lindsay Aitchison, Richard Rhodes, “Advanced Extra-vehicular Pressure Garment Requirements Development”, ICES-2015-031, 45th International Conference on Environmental System, ICES, Inc., Bellevue, WA; July 2015.

Rhodes, Richard, Brian Basttisti, Raymond Ytuarte, Bradley Schultz, “Development and Evaluation of Titanium Spacesuit Bearings”, ICES-2016-60, 46th International Conference on Environmental System, ICES, Inc., Vienna, Austria; July 2016.

https://www.nasa.gov/suitup