



Making a Space Suit: Not as easy as it looks

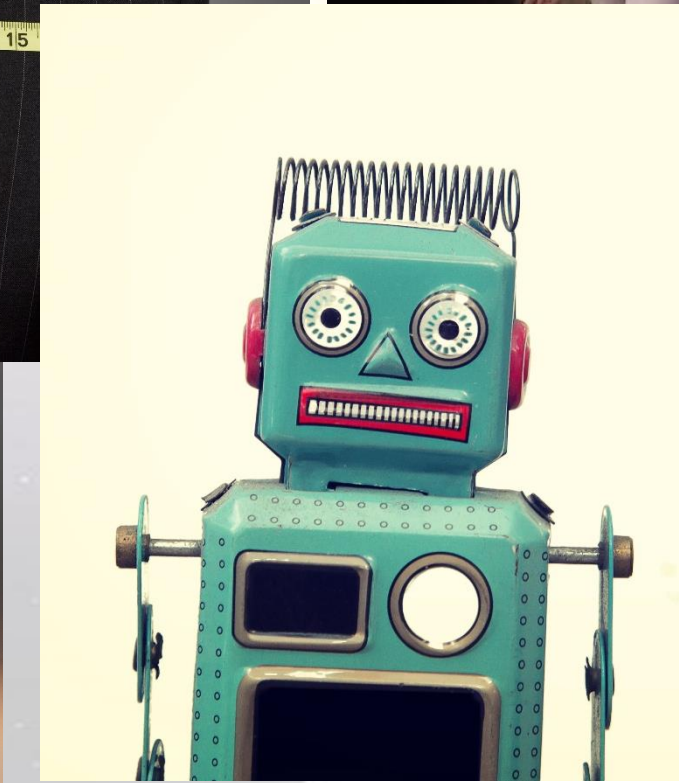
May 26, 2022

SAMPE North America

Charlotte, North Carolina

Amy Ross, NASA Johnson Space Center

What some people think



Can you find the differences?



But it made me want to use these..



I still can't knit!



Content



- Building a Space Suit: Where you are going and what you are doing
- What's next?: New places to go and new things to do

So you want to build a suit?



- First two things you need to know are:
 - Where are you going?
 - What will you be doing?



The answers = REQUIREMENTS

The Astronaut “Office”

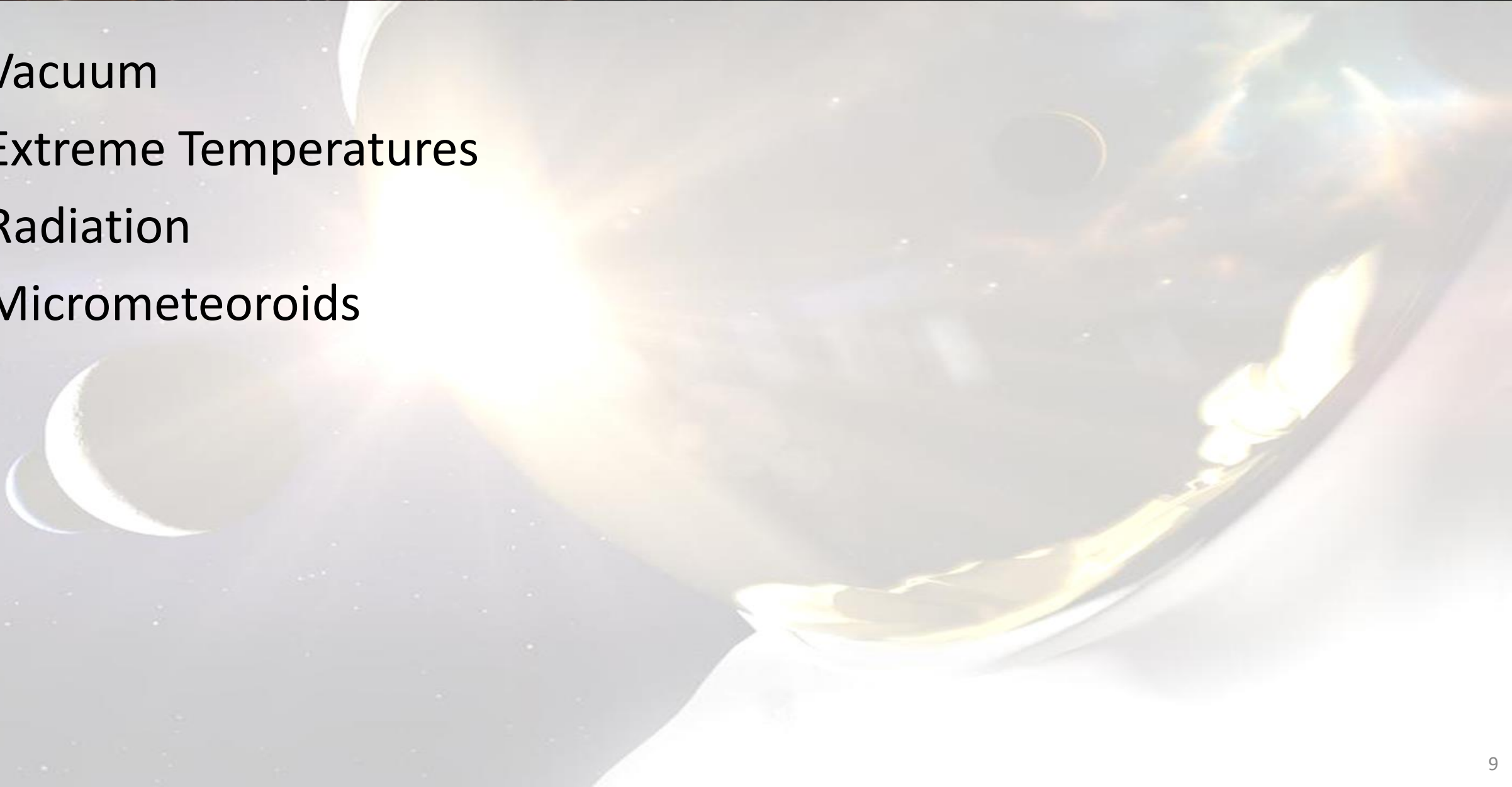


International Space Station: Low Earth Orbit (249 miles away from Earth)

Hazards Outside of ISS



- Vacuum
- Extreme Temperatures
- Radiation
- Micrometeoroids



Protection from Vacuum

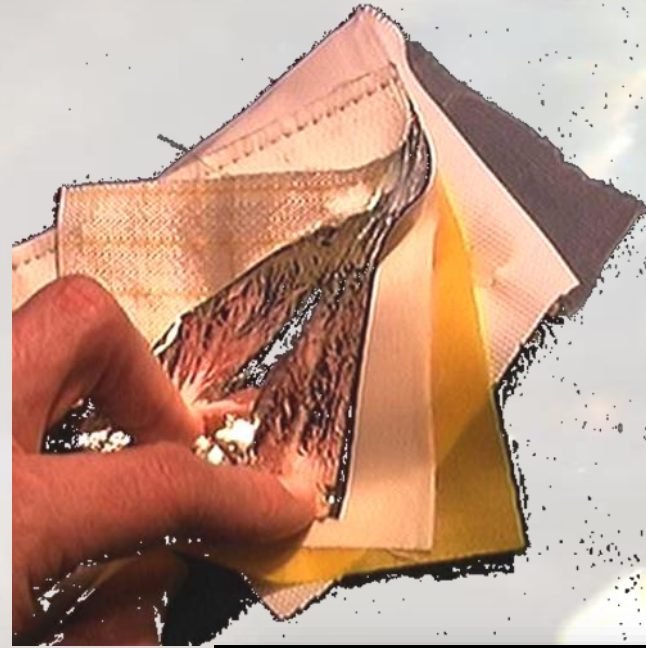


- “Vacuum” means no air to breathe
 - Humans lose consciousness in seconds and die from hypoxia in minutes without oxygen
 - Lungs cannot function without pressure differential across diaphragm that drives respiration
- Direct relationship between boiling point of water and atmospheric pressure
 - In a vacuum, water will boil at 98°F...
- Space suits provide a stable pressure environment with the balloon like bladder layer containing oxygen supplied from the portable life support system

Protection from Extreme Temperatures



- Objects outside Low Earth Orbit outside of the ISS range from -150F to +250F
- Two ways to transfer heat in space:
 - Conduction (two objects touching)
 - Radiative (heat waves from the sun get absorbed)
- Keep outside temperatures from reaching the astronaut
 - Multi-layer insulation creates gaps between fabrics to limit conduction
 - White color reflects heat



Protection from Extreme Temperatures

Liquid Cooling and Ventilation Garment (LCVG)

- LCVG conditions interior of space suit
- Cools through conductive heat transfer
 - Conformal to body
 - Over 300 ft of tubing to transfer heat away from the body via conduction
- Water supplied by the life support system
- Removes moisture through vent tubes



Protection from Radiation



- Earth's atmosphere protects us from most radiation
- In space, must limit exposure
 - Keep alpha and beta particles from reaching the astronaut
 - Helmet Visor
 - Reflective properties of MLI and orthofabric
 - Limit lifetime exposures
 - Astronauts wear dosimeters to track total radiation doses



Protection from Micrometeoroids



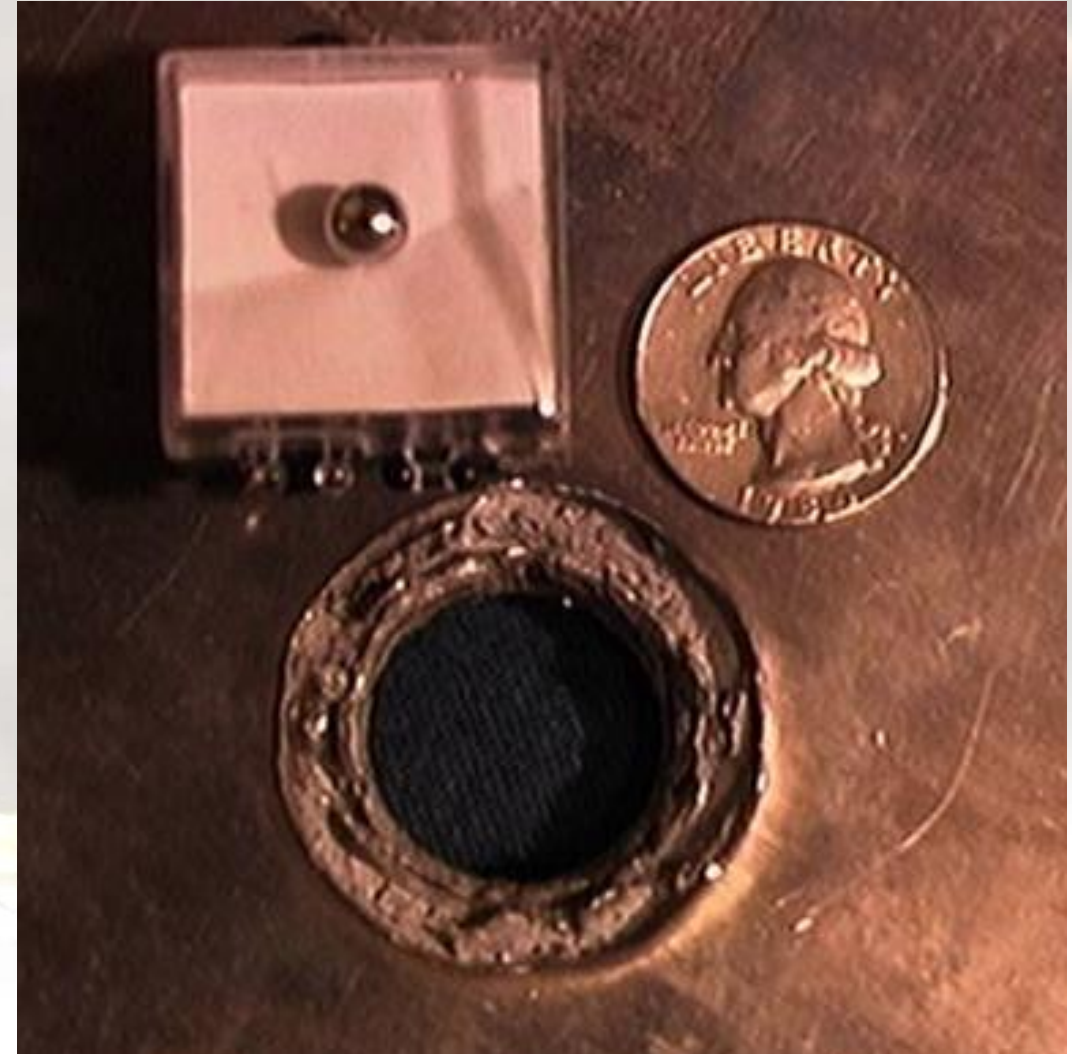
- How big is a micrometeorite?



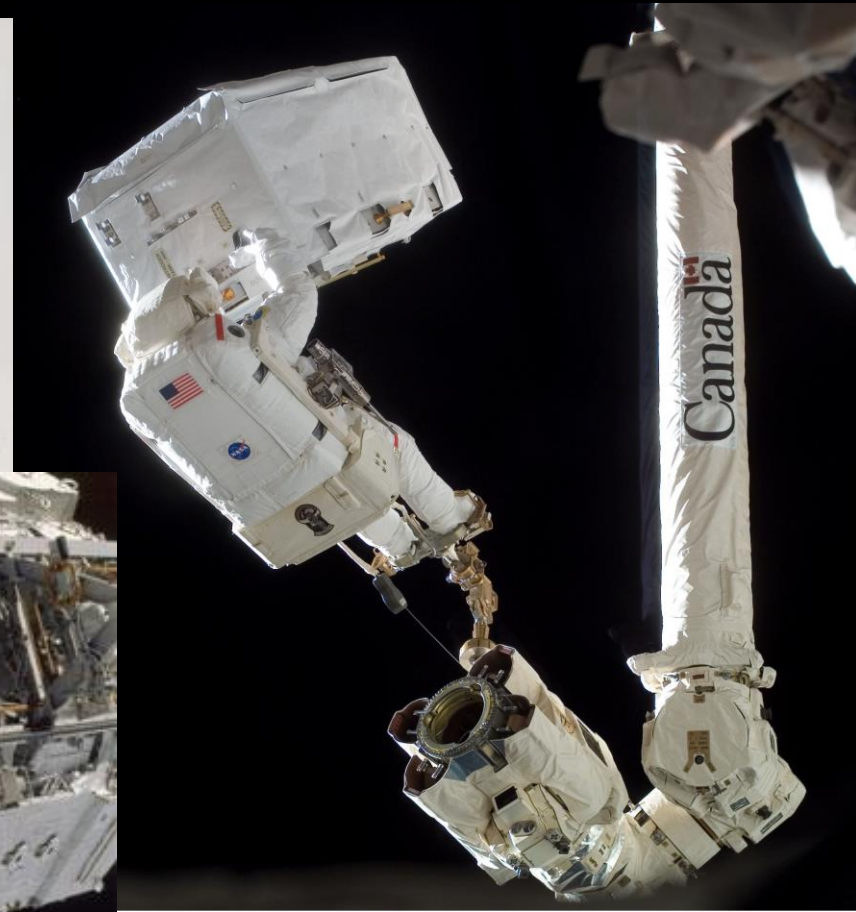
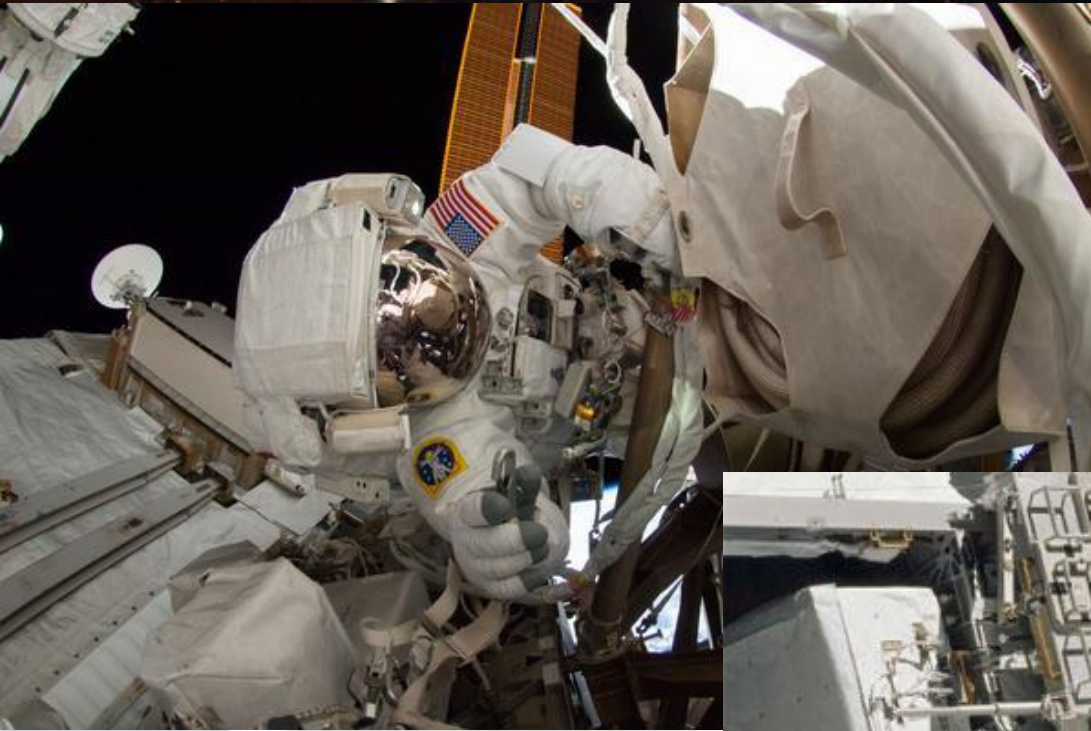
- Problem is Kinetic Energy (KE)

$$KE = \frac{1}{2} mv^2$$

- Energy from particle transferred to suit upon impact
 - Even a tiny mass moving at 17,000 mph is going to hurt
- Space suits rely on Thermal Micrometeoroid Garment (TMG) to reduce particle velocity and size



Working Outside ISS



Working in Microgravity

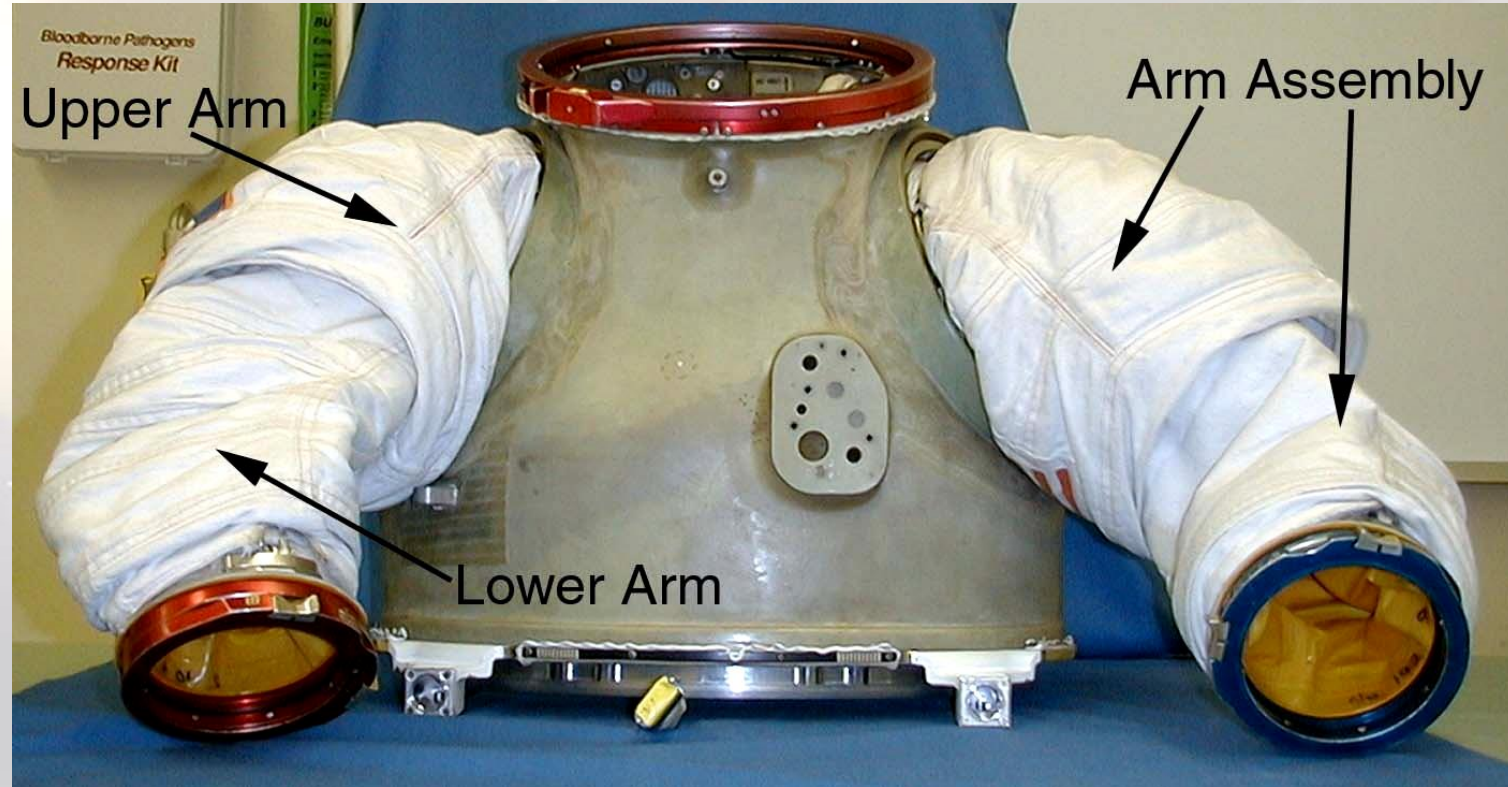
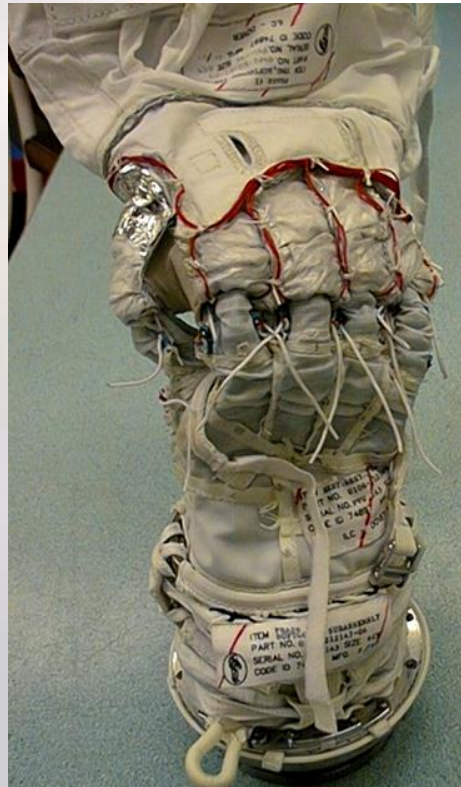


- Highly mobile upper body

- Angled shoulder bearings
- Upper arm bearing

-Patterned convolute elbows

-Patterned wrist joints and bearings



Working in Microgravity

- Stable lower body
 - Lower torso is anchor from which to perform work
 - Waist bearing
 - Patterned convolute knees
 - Stiff soled boots

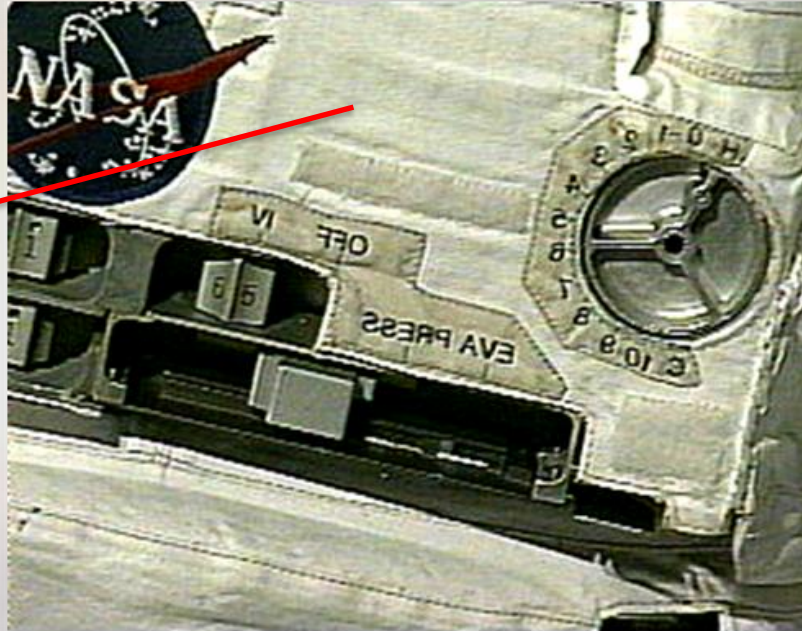


Boot and Sizing Insert



Working in Microgravity

Life Support Systems



Display and Controls
Module: temperature,
pressure, ventilation and
communication controls



Portable Life Support System

Working in Microgravity

- Foot Restraint Interface

- Boots lock into portable foot restraints for a stable work platform

- Tether Interfaces

- D-rings located on waist to attach safety tethers
- Body Restraint Tether (rigidizable tether)

- Mini Work Station

- Personal tool belt
- All tools designed to attach with bayonet fittings or tether hooks
- Mounts directly to suit torso

- Air-lock mounting

- PLSS attaches directly to inside of ISS airlock for easier donning and doffing



What's next?



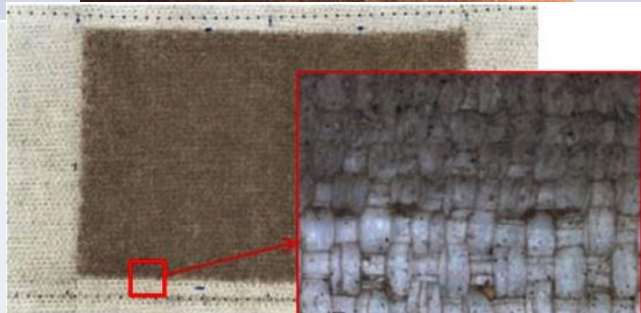
What's next?



- Astronauts will explore further from Earth meaning:
 - New environments
 - Autonomous operations
 - More mobility
 - New tools and vehicles

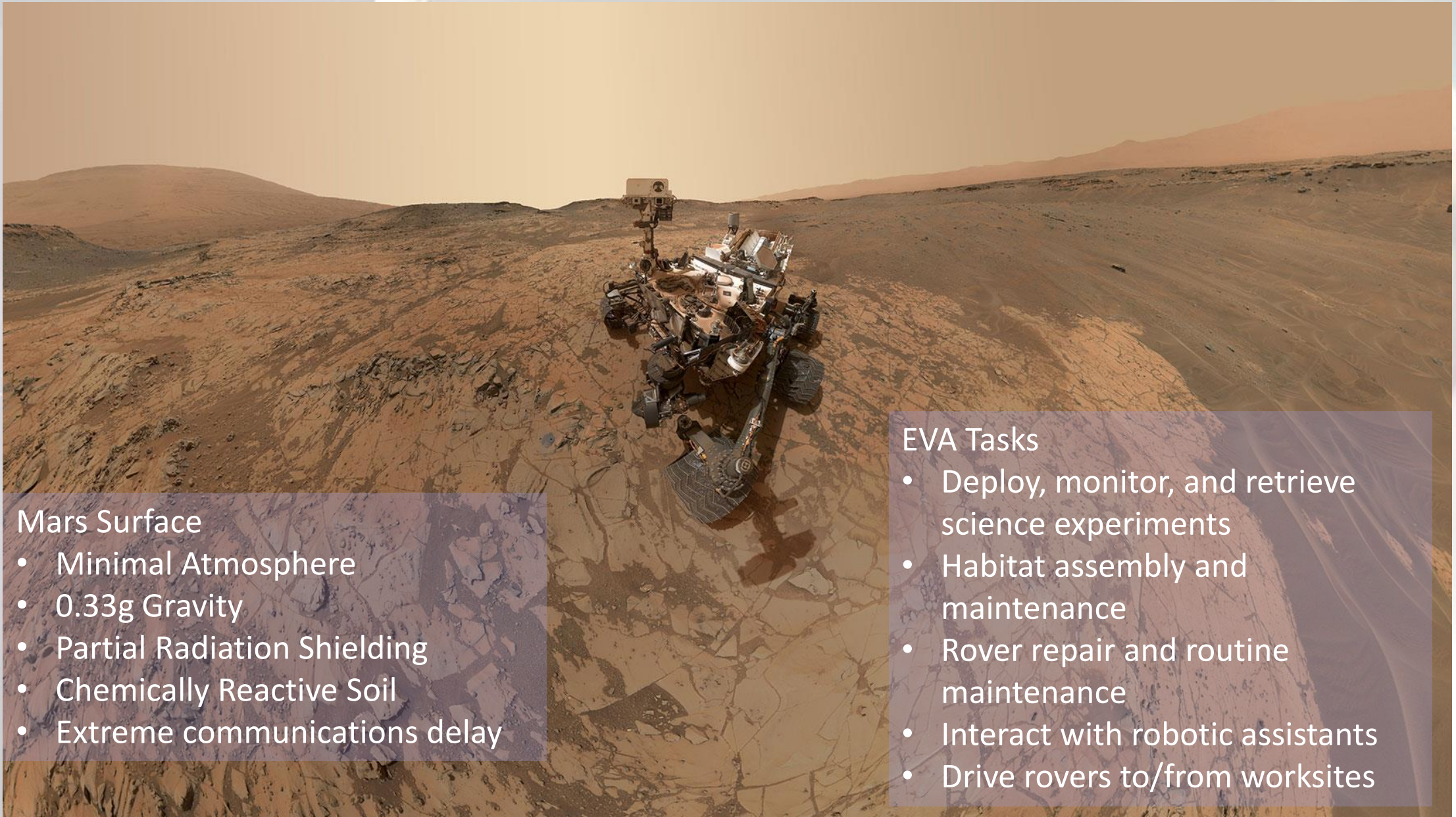
New Environments



Environment	Earth Extremes	Space Extremes
Atmospheric pressure	0.20 atm on Everest	Vacuum to 0.006 atm on Mars
Extreme temperatures	-136 (Antarctica) to 134 F (Death Valley)	-150 to 250 F in Low Earth Orbit -243 to 68 F on Mars
Micrometeoroids	Freak accident, not considered in gear design	
Dust	Yup, but it usually doesn't kill you	

Mars is 40 million miles from Earth (closest)

Mars Surface



Mars Surface

- Minimal Atmosphere
- 0.33g Gravity
- Partial Radiation Shielding
- Chemically Reactive Soil
- Extreme communications delay

EVA Tasks

- Deploy, monitor, and retrieve science experiments
- Habitat assembly and maintenance
- Rover repair and routine maintenance
- Interact with robotic assistants
- Drive rovers to/from worksites

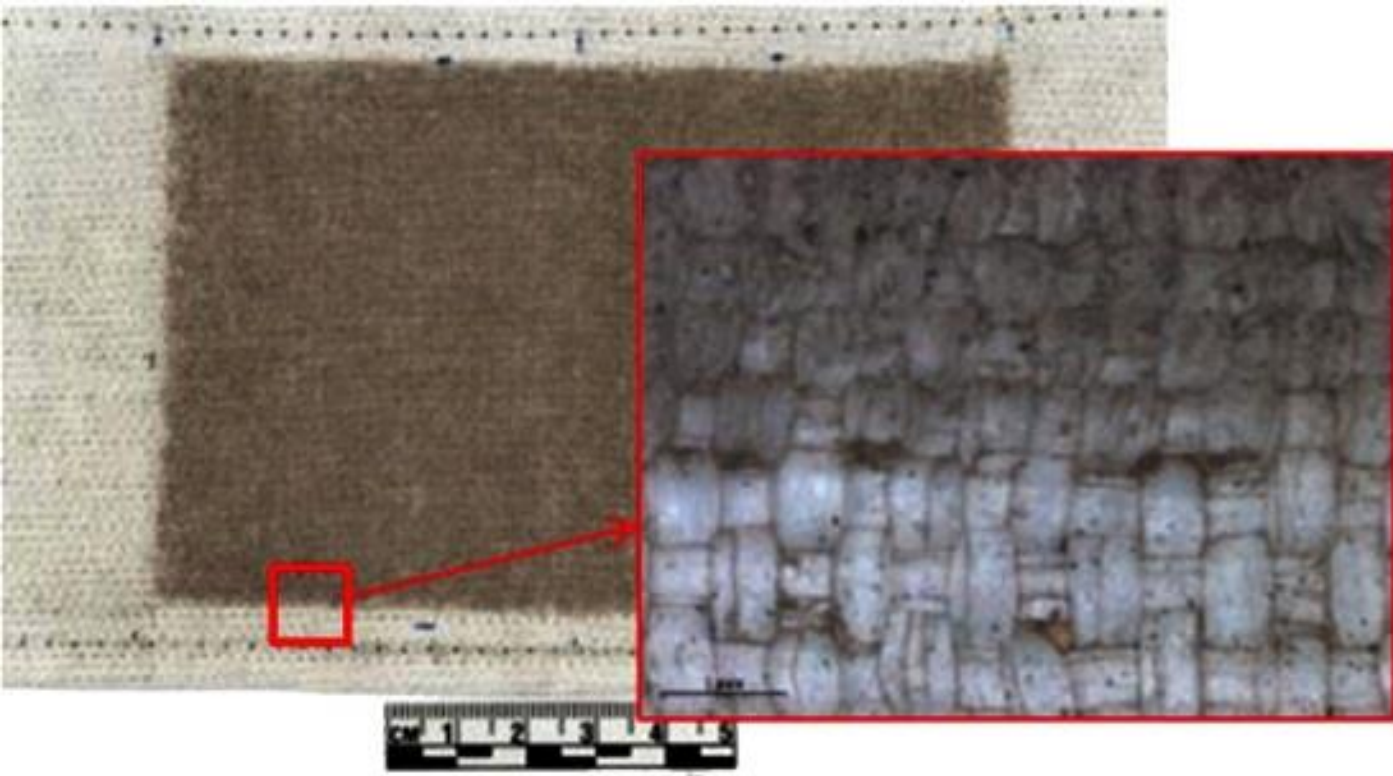
Thermal Considerations



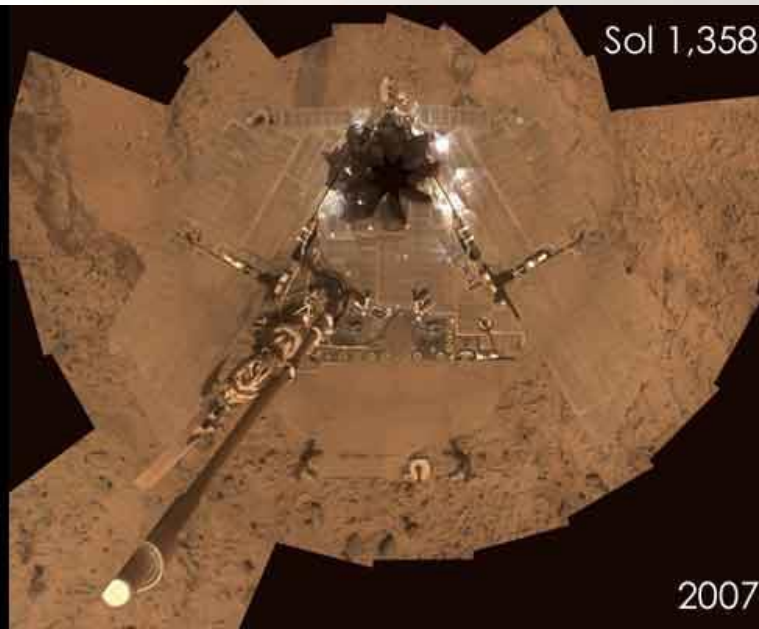
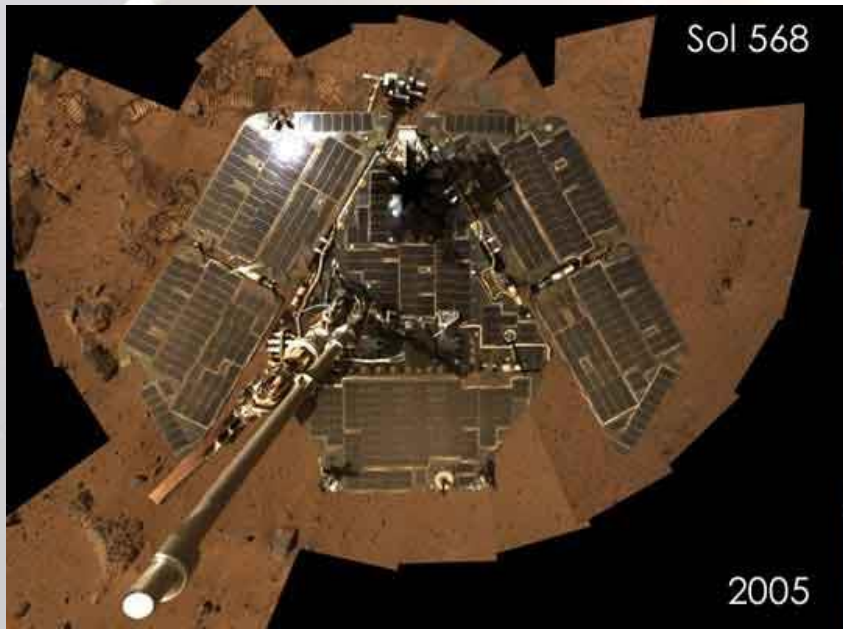
- Walking and full body mobility will recruit larger muscle groups resulting in greater human generated heat loads
 - Must provide more effective body cooling
- Presence of an atmosphere means conduction is an ever present means of heat transfer
 - Need new materials lay-ups that are effective insulators without vacuum separation



Dust Hazards

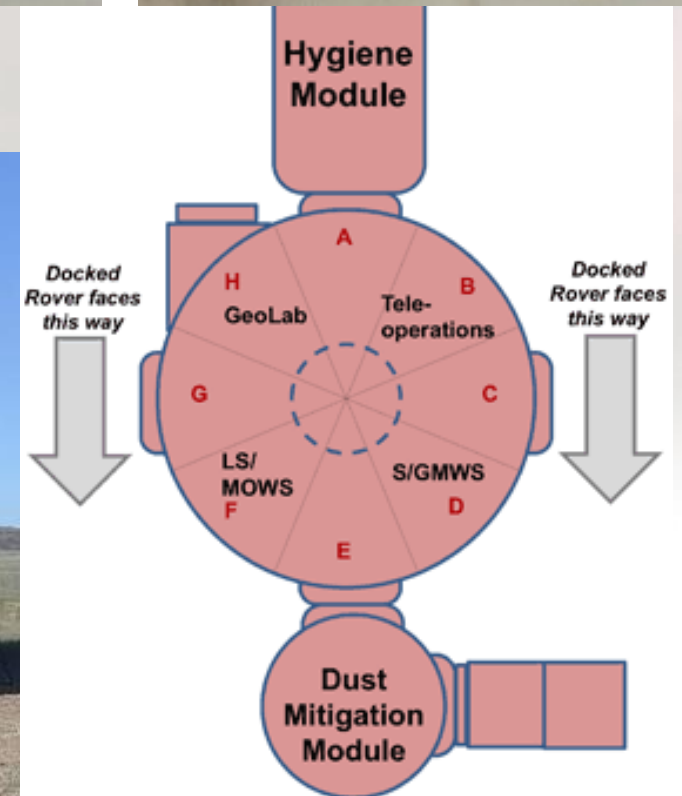


- Relatively high percentage of perchlorates in soil (toxic to humans)
- Small particles can jam mechanisms and potentially create FOD in oxygen systems
- Particles wedged in textile fibers will accelerate space suit wear over time and potentially affect thermal properties of the suit



Dust Mitigation

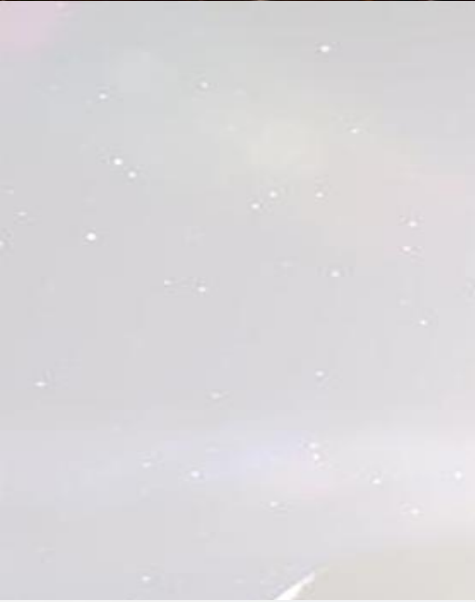
- Phased approach minimizes amount of debris brought into habitable areas
 - Incorporate dust repellant technologies into suit outer layers
 - Provide “mudroom” for coarse cleaning after each use with specialized tools or air shower
 - Suit maintenance area isolated from living quarters



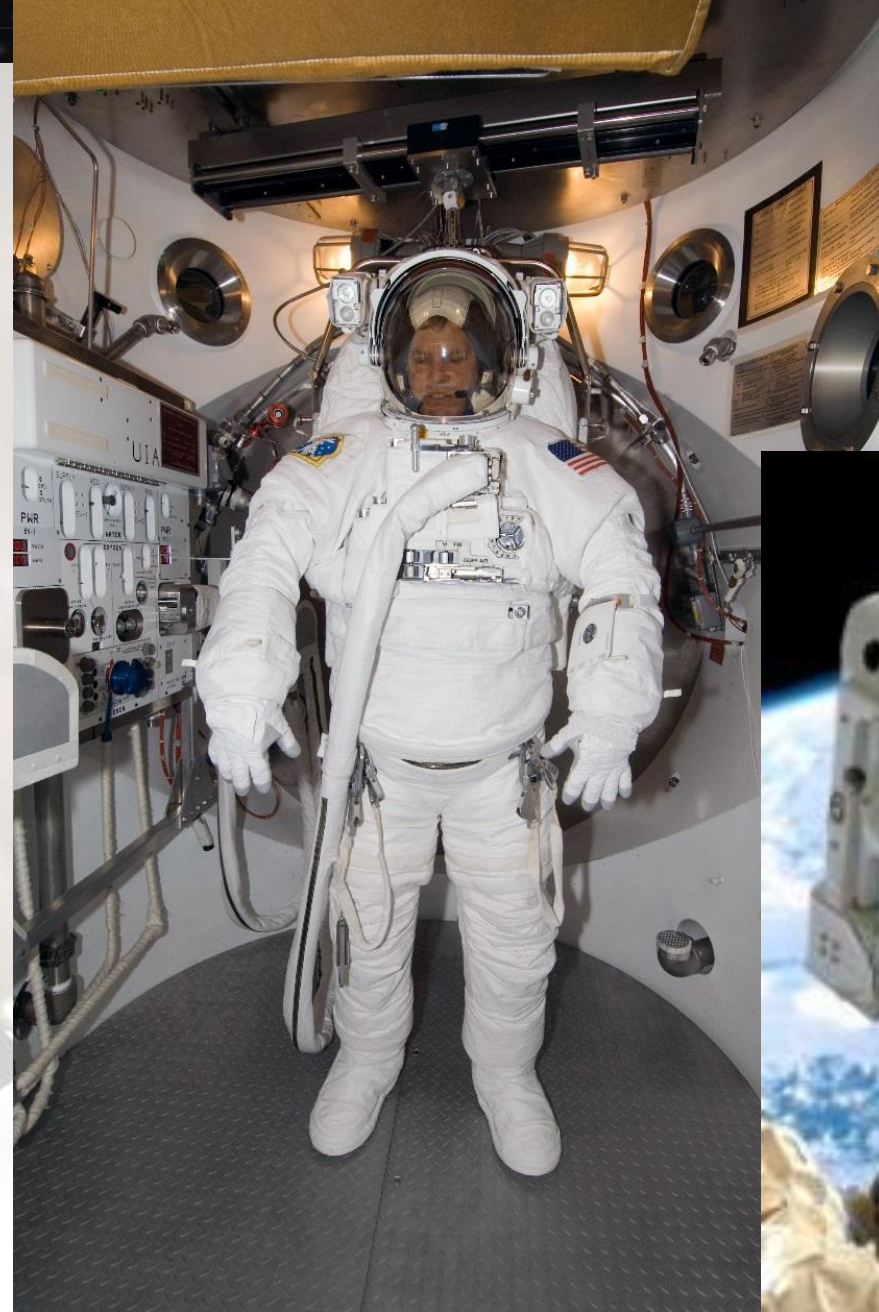
Planetary Exploration – New Tasks



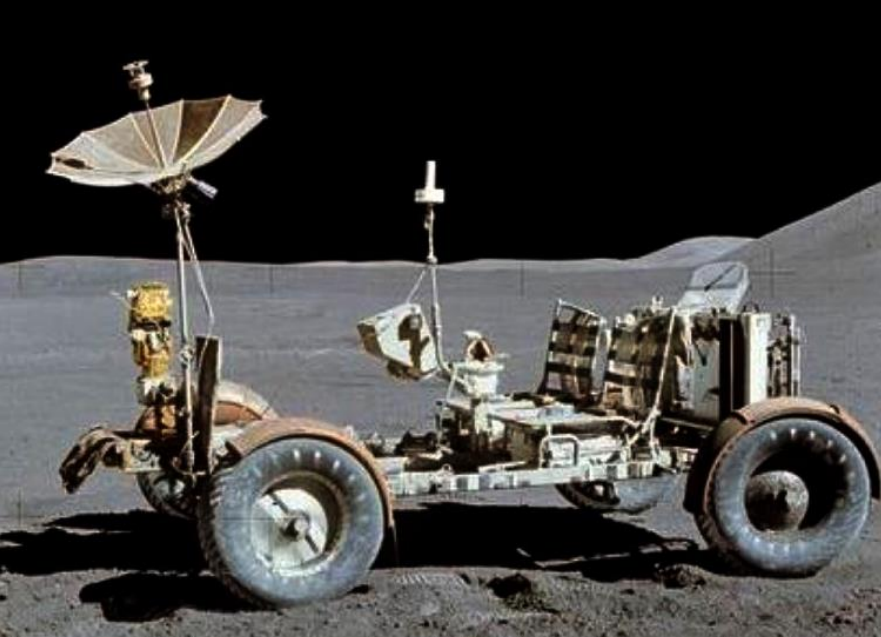
Planetary Exploration – New Tasks



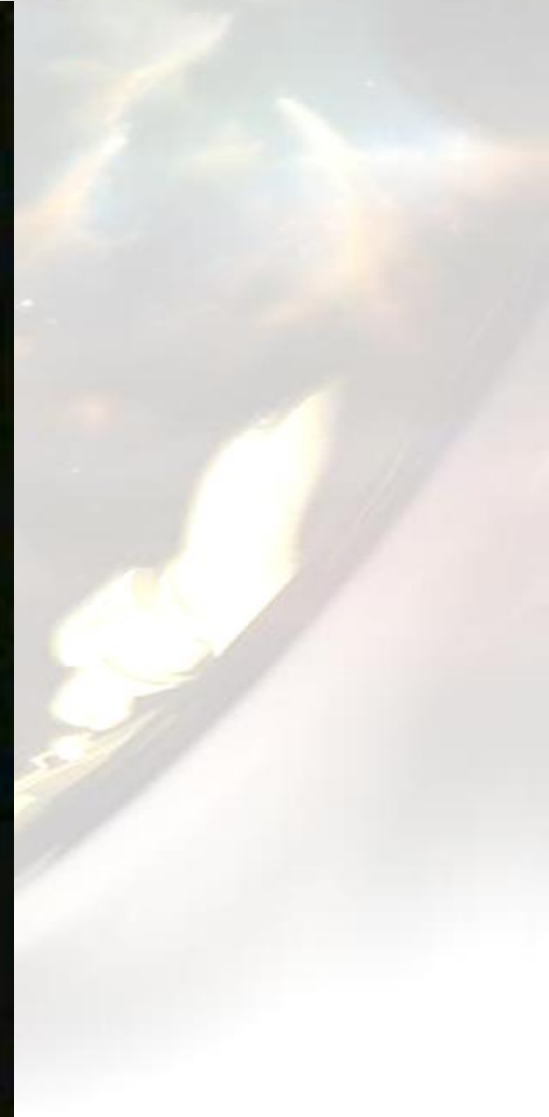
VS.



Planetary Exploration – New Vehicles



Planetary Exploration – More Mobility



Planetary Exploration – More Mobility



00:13:35.20



00:31:21.00



Space Suits in Motion



Space Suit Prototypes



Mark III



WEI-Suit



REI-Suit



Z-1



Z-2

xEMU



Not:



Next up...



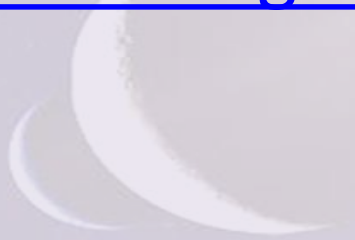
Build – Test – Refine - Repeat



#SuitUp With NASA
#JourneyToMars

Visit:

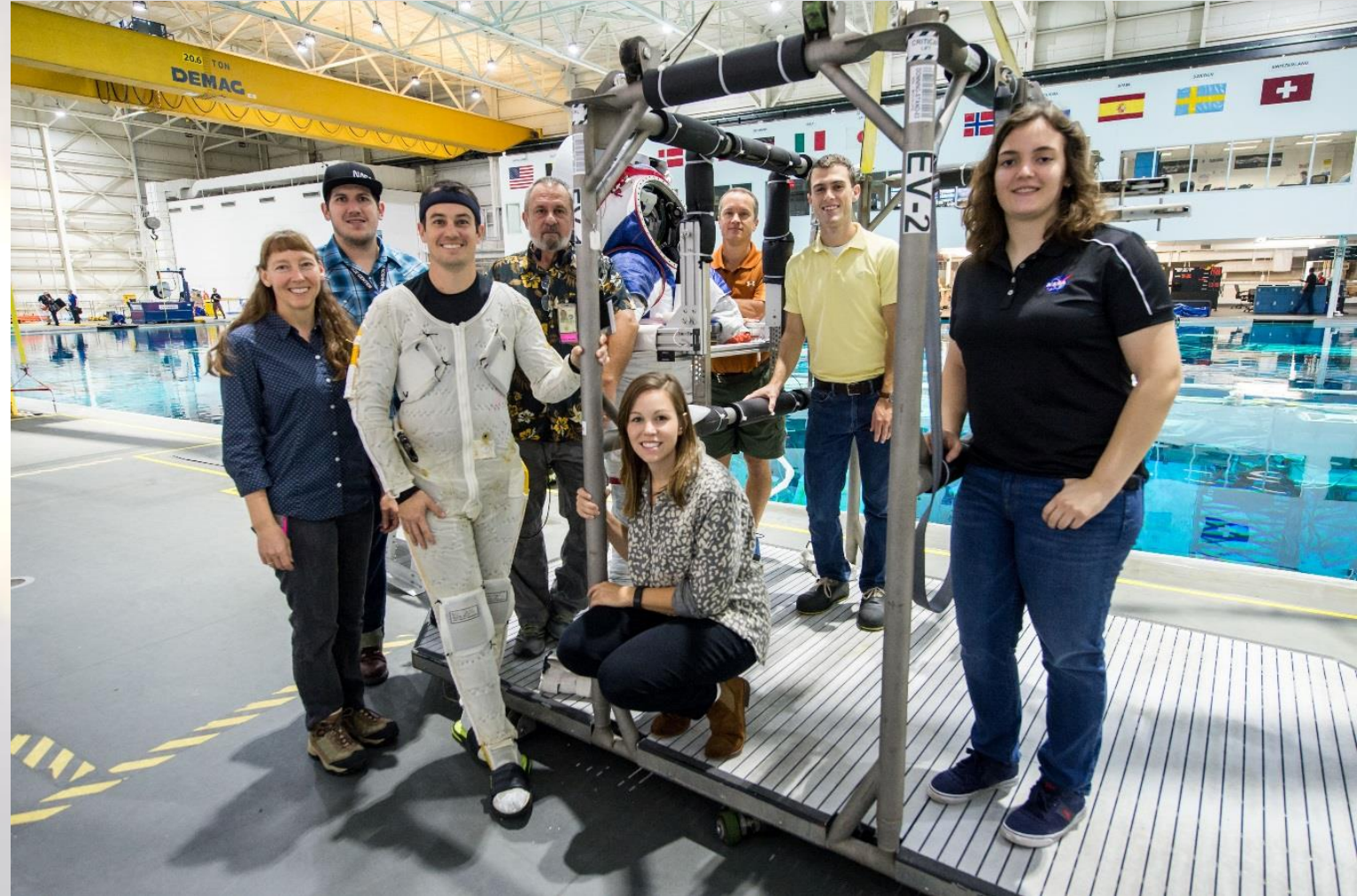
www.nasa.gov/suitup



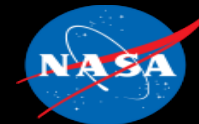
BACK UP



The People who make it happen



Features





A Space Suit is..

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 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

3

Finally, 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

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



What Does a Planetary Walking Suit Look Like?



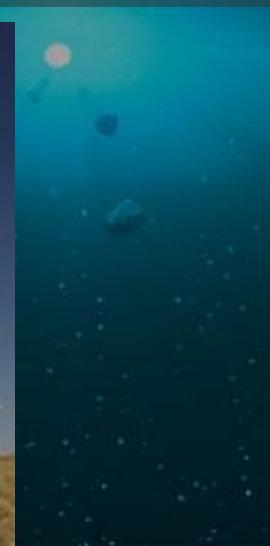
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- Rear-entry
- Helmet angled and shaped for wide field view, including downward visibility
- Hard or soft torso, briefs and hip
- Waist bearing and flexion/extension joints
- Hip mobility joint system with 2 or more bearings and features for adduction/abduction
- 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

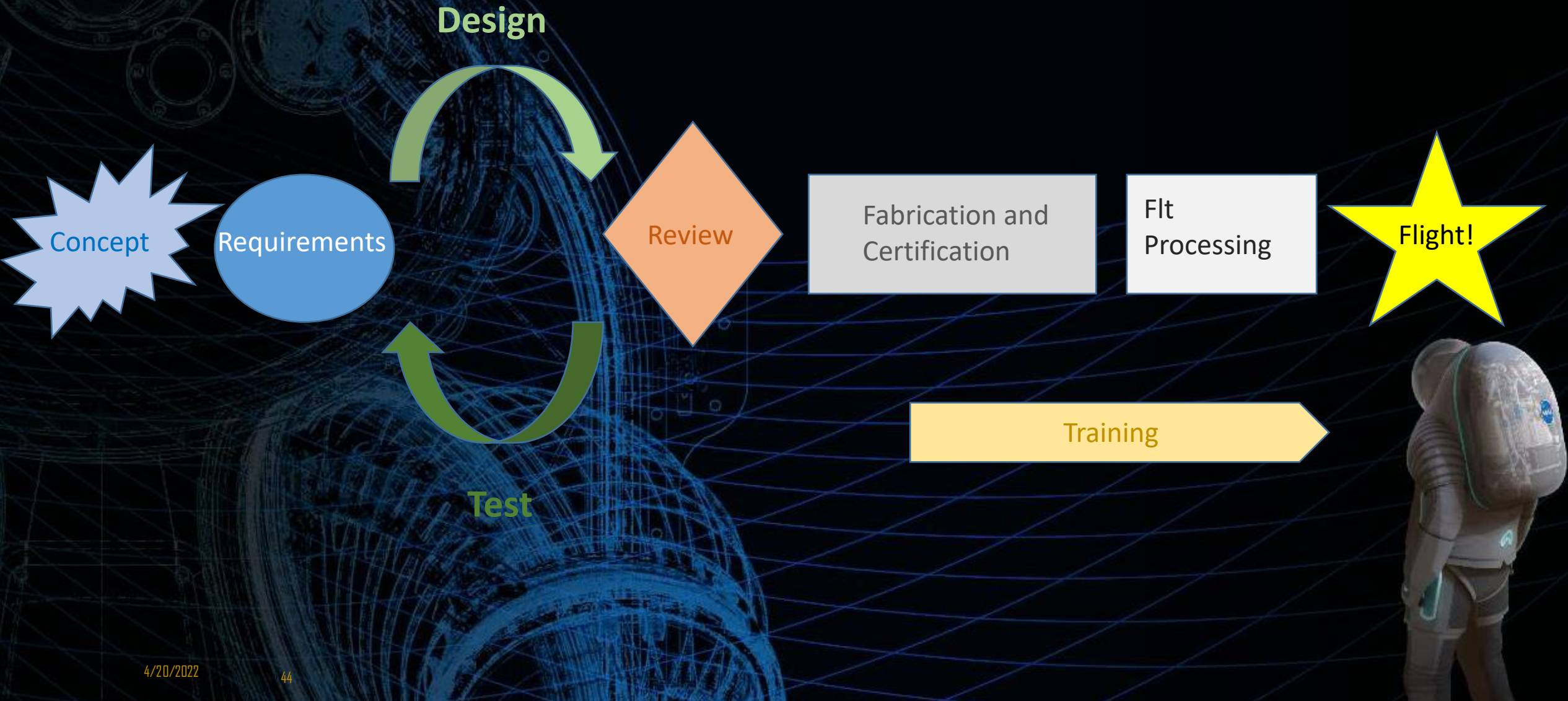
4/20/2022



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.



Hardware Development Process



Next up...

45



Build — Test — Refine - Repeat

Partial Gravity Translation and Mobility



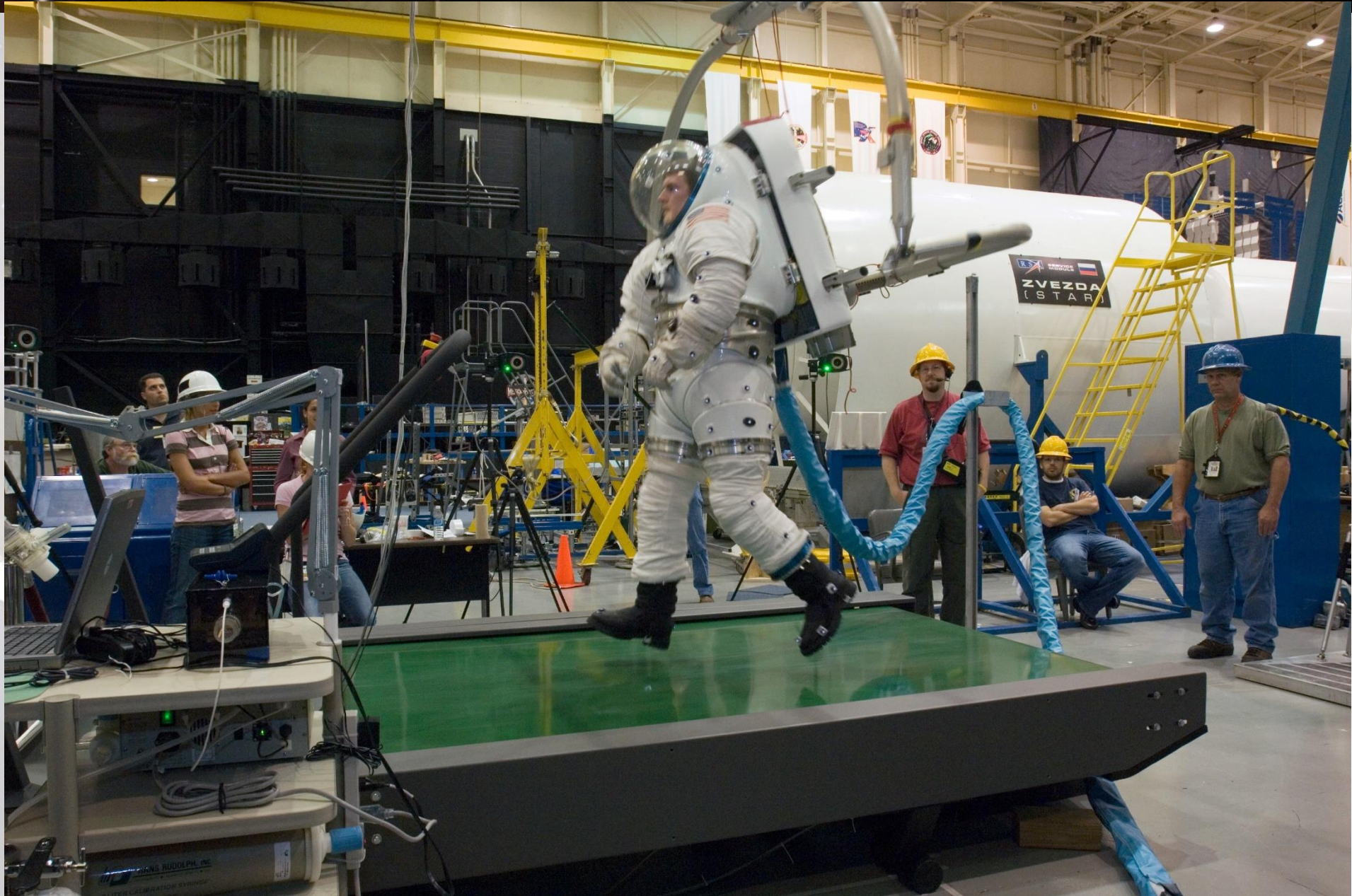
Desert RATS



Desert RATS



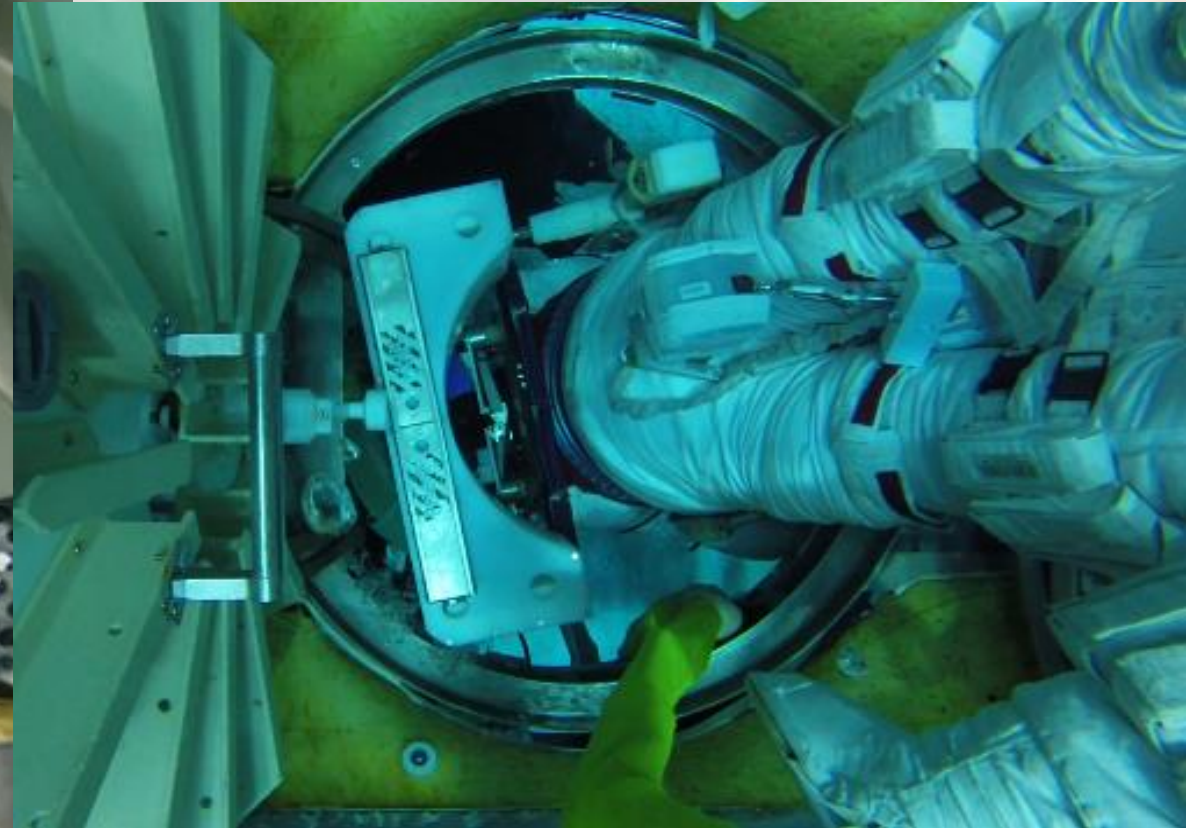
Translation



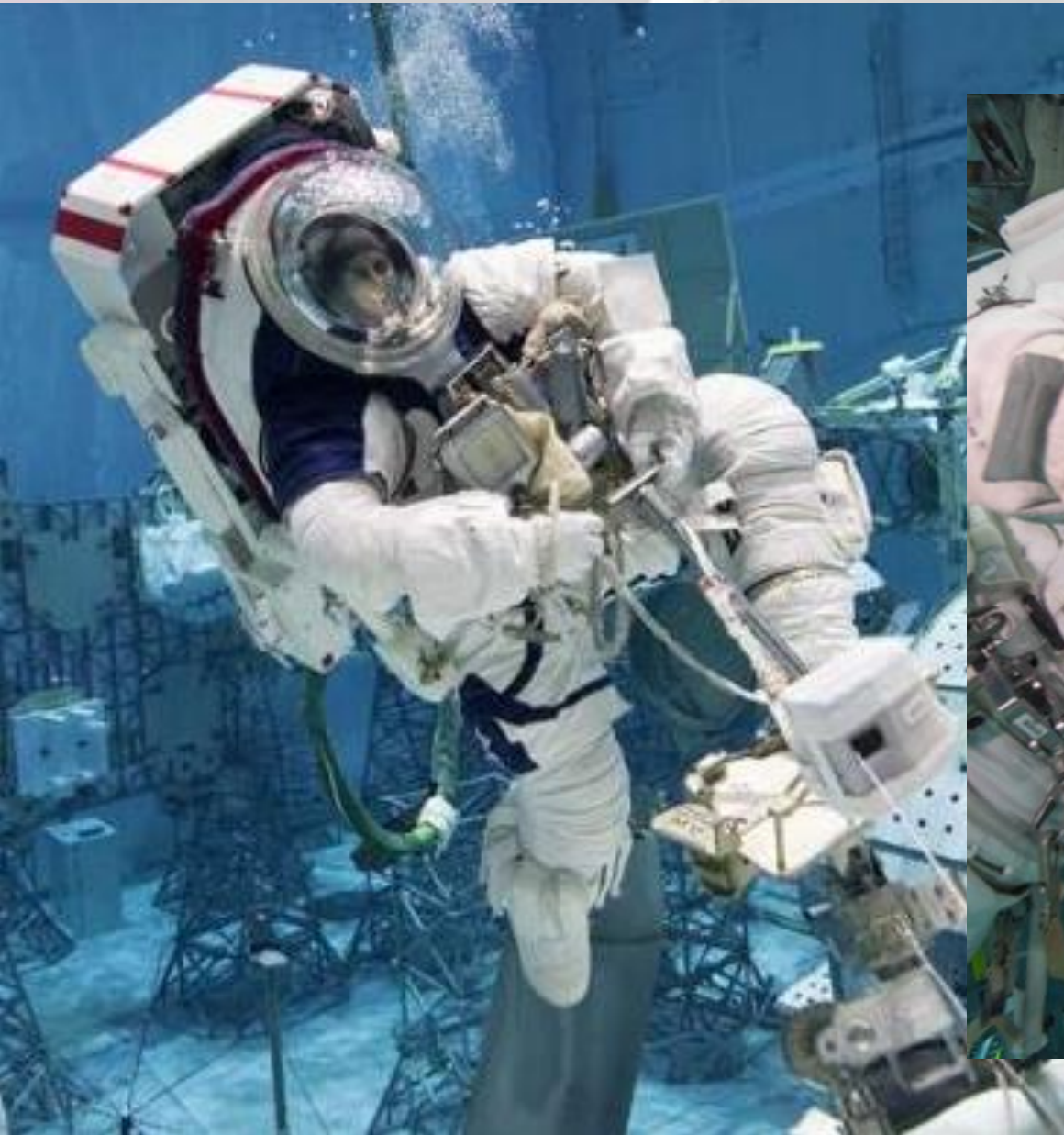
Translation-PLSS HITL



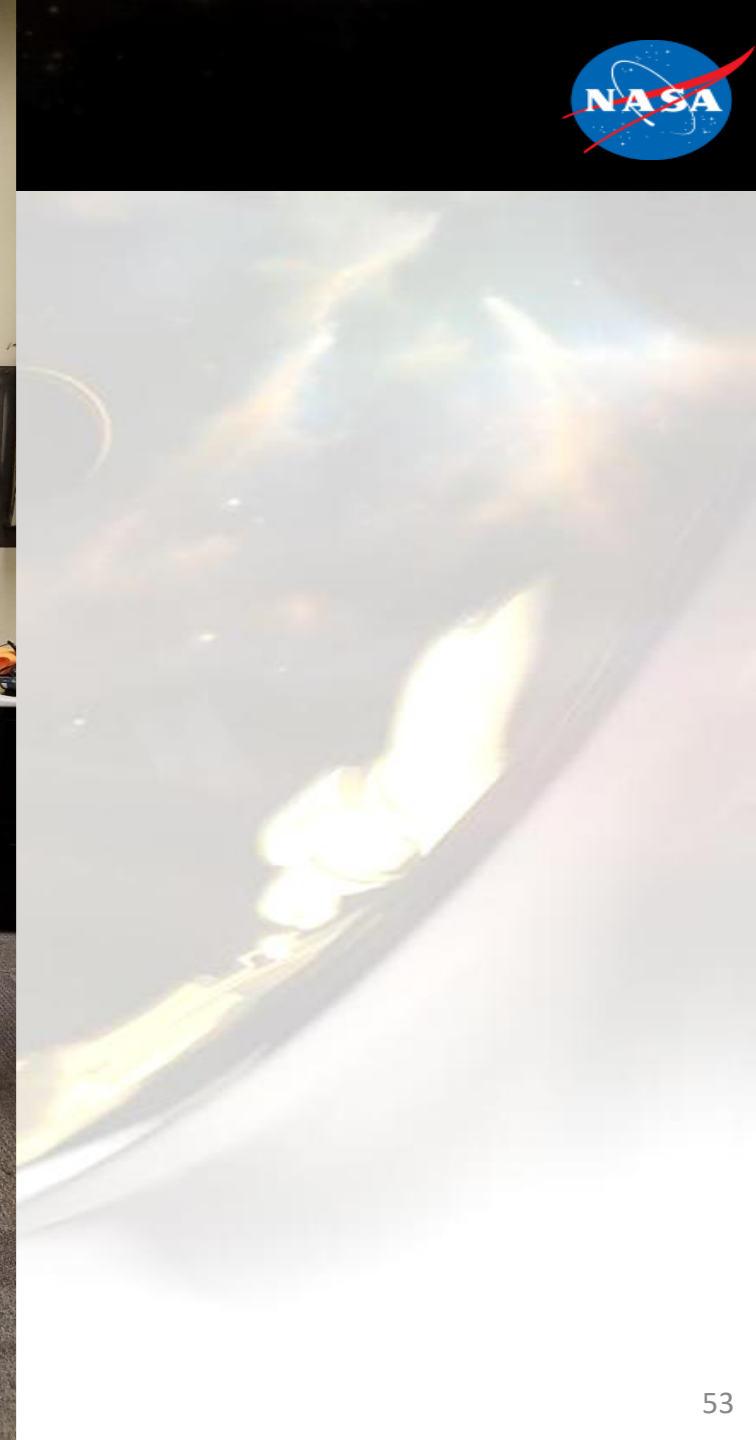
Z-2 NBL Runs



Z-2 NBL Runs



Z-2.5



Data Collection Lessons Learned



+/- with Objective Data



- Can be extremely difficult to obtain
 - Have no method to understand the interaction of the human with the suit
 - Exception: sensor glove
 - Have obtained objective data that does not inherently make sense
 - Suited values exceed unsuited values
- Can be harder to apply to hardware design
- + Is 'manager friendly' and is perceived as more legitimate by engineering peers



+/- with Subjective Data



- Less 'manager friendly'
- Requires context and system knowledge to correctly interpret and apply
 - Less knowledgeable groups can use data inappropriately
- Rating scales are imperfect tools
 - Found that some subjects are relatively poor at rating Perceived Exertion so that it correlates to actual
 - while providing numbers, are open to interpretation
 - Too gross vs too fine of a scale
- + A focus on the comments drives dialogue regarding comments
- + Frequently the most valuable data

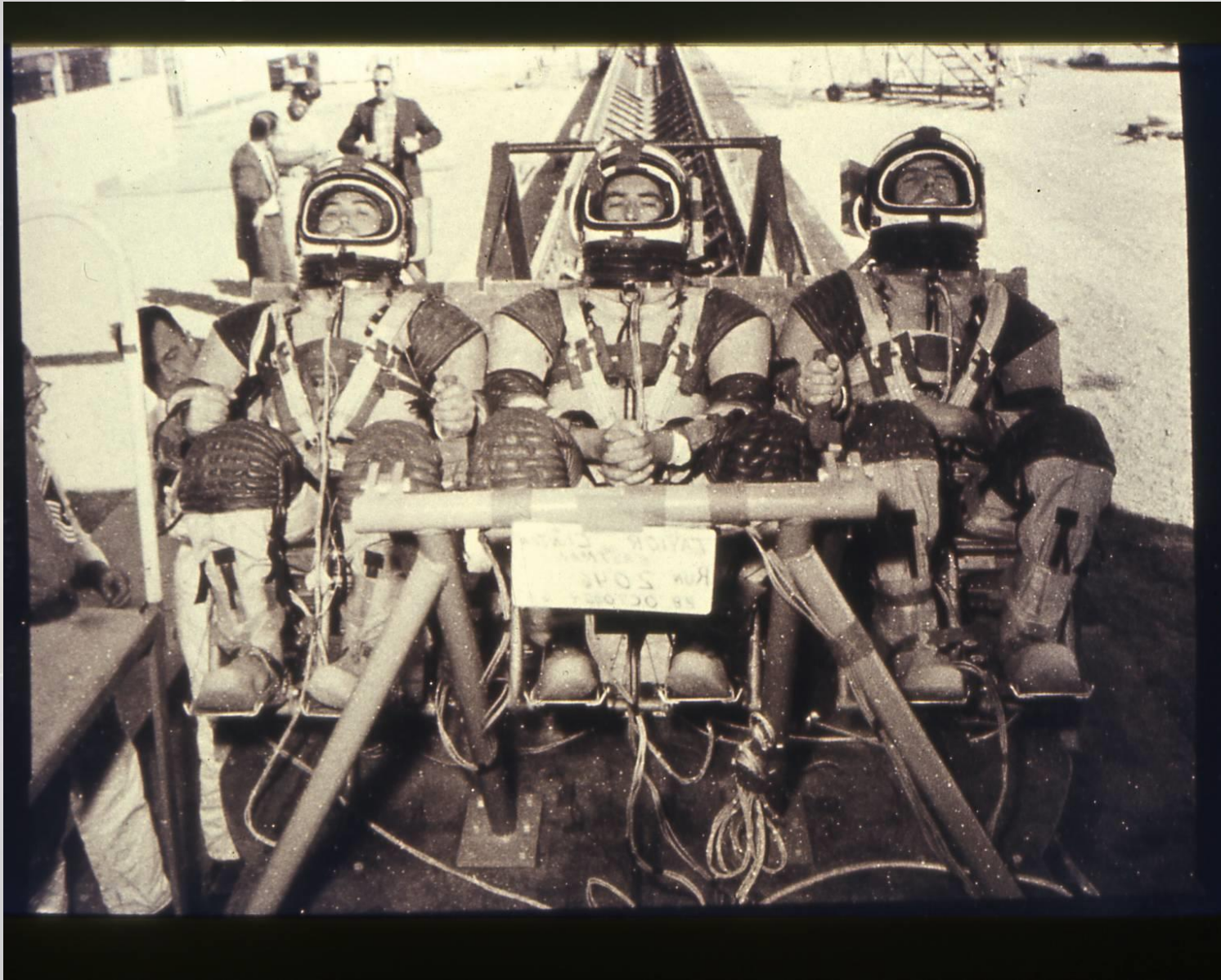
Personal Experience: Test Subject



Personal Experience: Test Director



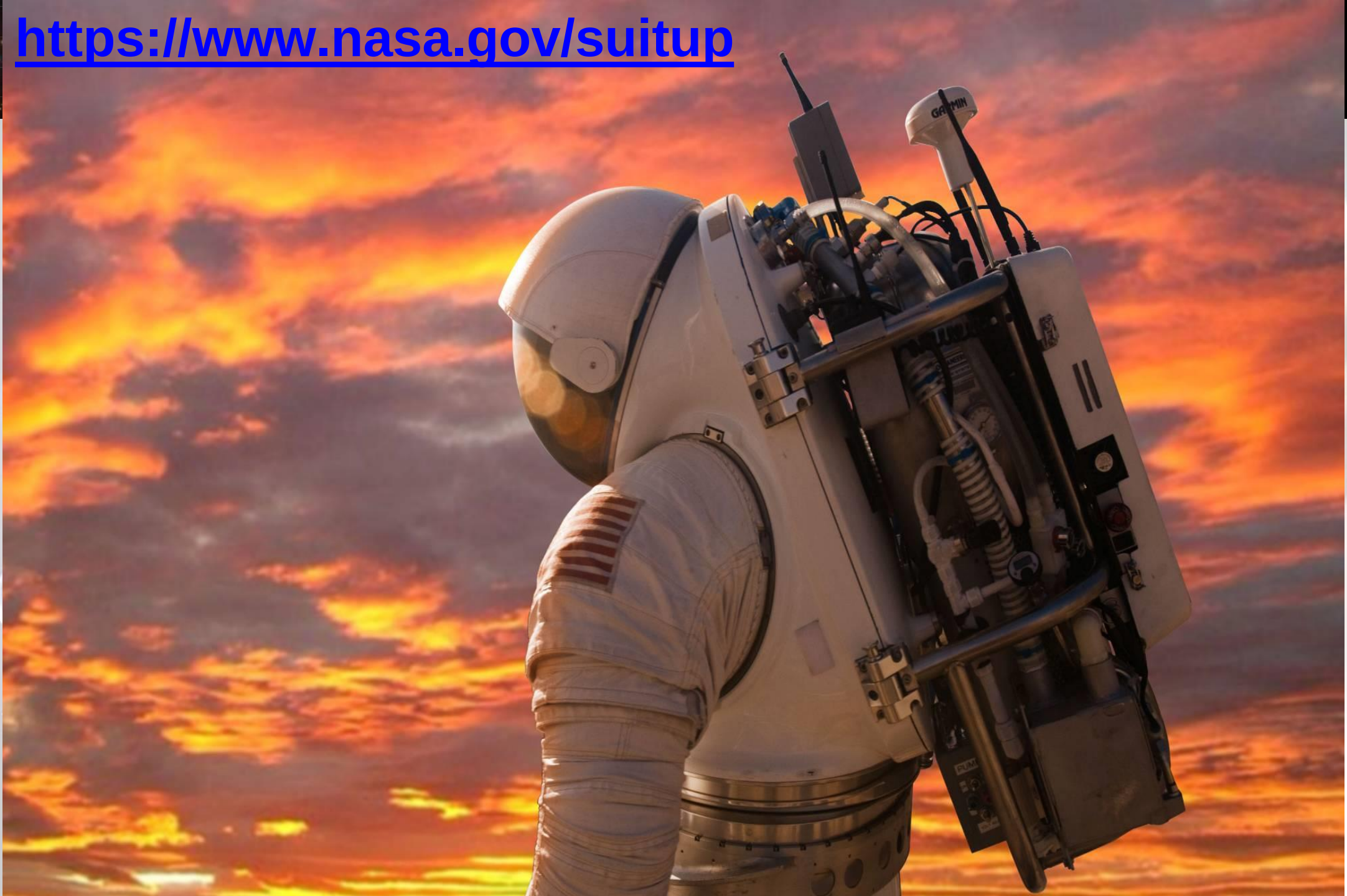
When it is better to be the Test Director..



Questions?



<https://www.nasa.gov/suitup>



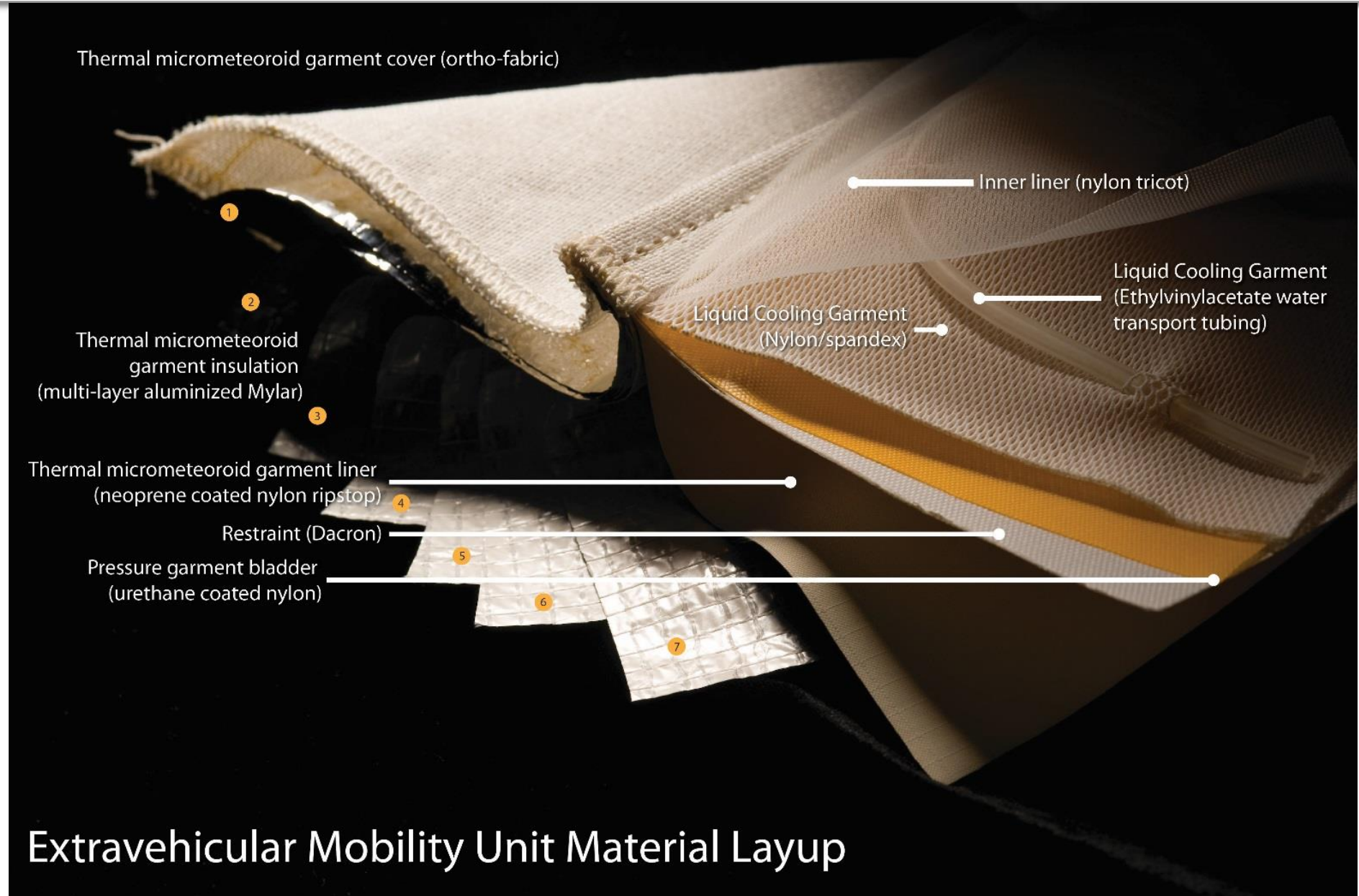
Space Suits Look Like This for a Reason



Materials used in Space Suits



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

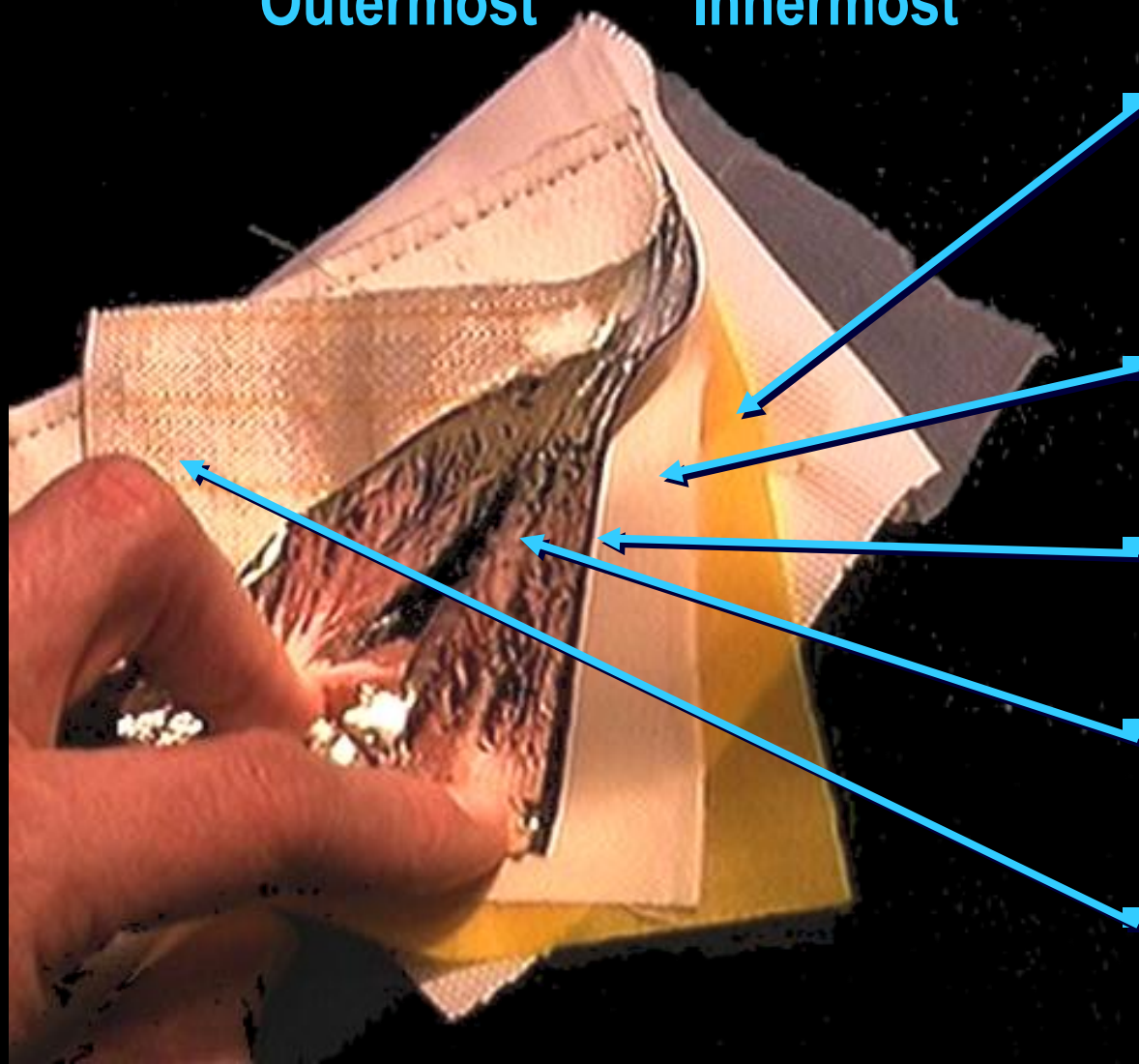




EMU Suit Layers

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