Why Does it Look Like That? The Story of Space Suit Design

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Design

Space Suits Look Like This for a Reason

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

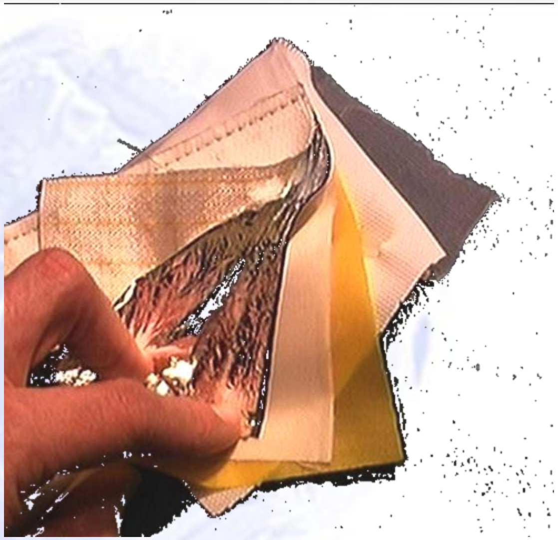
- "Vacuum" means no air to breathe
  - Humans lose consciousness in seconds and die from hypoxia in minutes without oxygen
  - Lungs cannot function without pressure differential across diaphragm that drives respiration

- 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

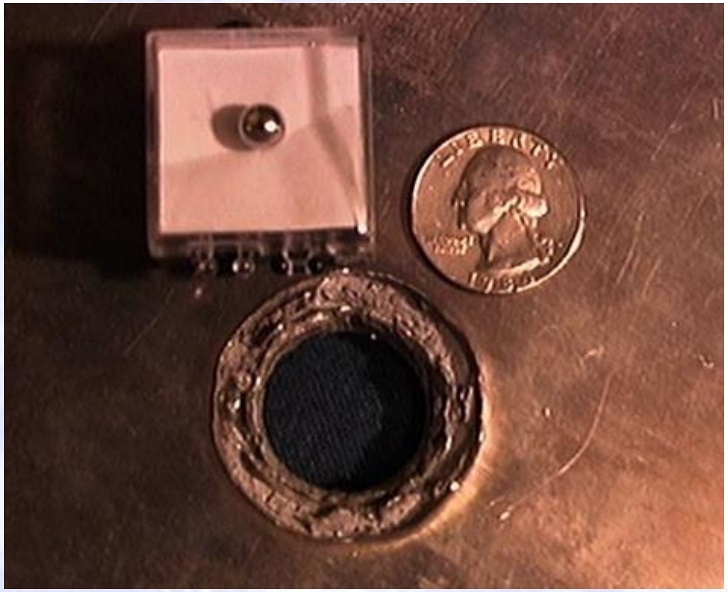
- Earth's atmosphere protects us from most radiation
- In space, must limit exposure
  - Keep alpha and beta particles from reaching the astronaut
    - Helmet Visor
    - Reflective properties of MLI and orthofabric
  - Limit lifetime exposures
    - Astronauts wear dosimeters to track total radiation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

Protection from Micrometeoroids

- How big is a micrometeorite?
  - .
- Problem is Kinetic Energy (KE)

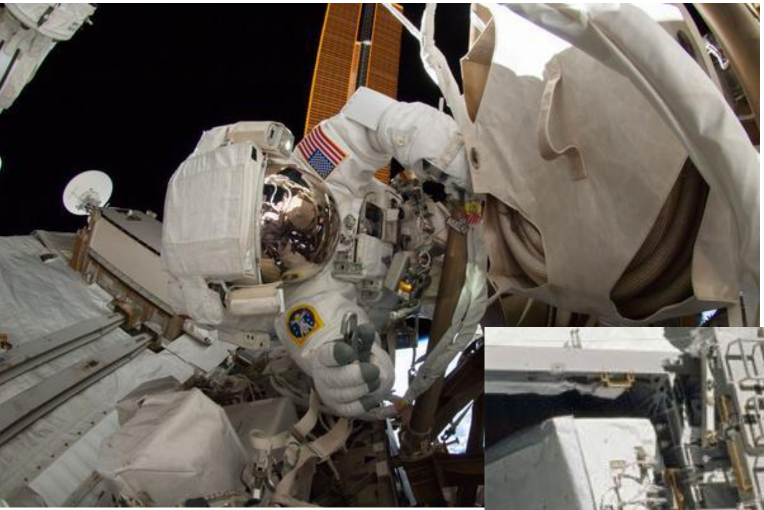
$$KE = \frac{1}{2} mv^2$$

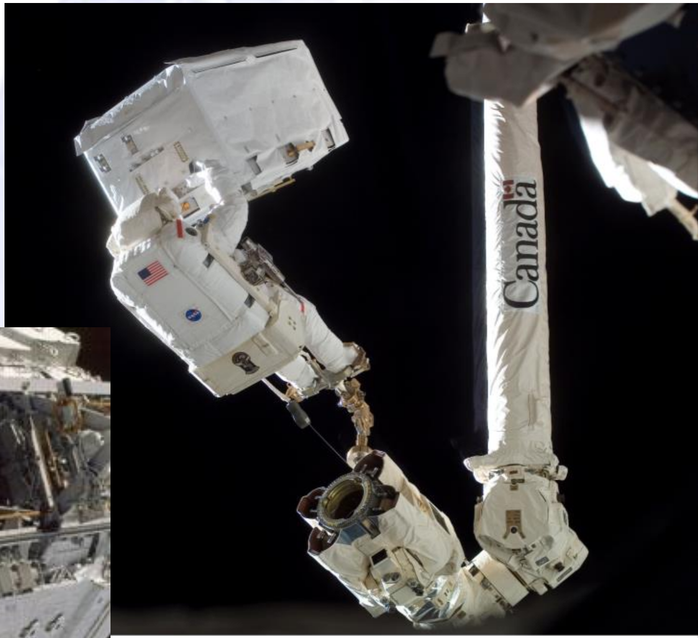
  - Energy from particle transferred to suit upon impact
  - Even a tiny mass moving at 17,000 mph is going to hurt
- Space suits rely on Thermal Micrometeoroid Garment (TMG) to reduce particle velocity and size



Working Outside ISS

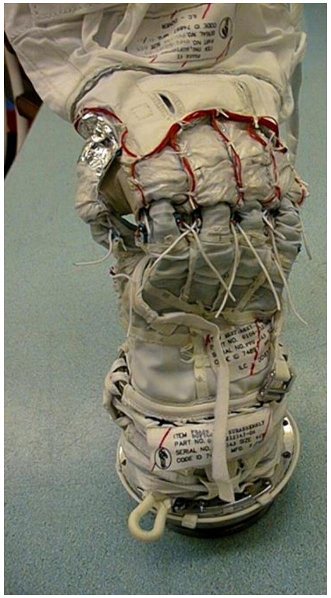
What kind of jobs do astronauts do on a spacewalk?

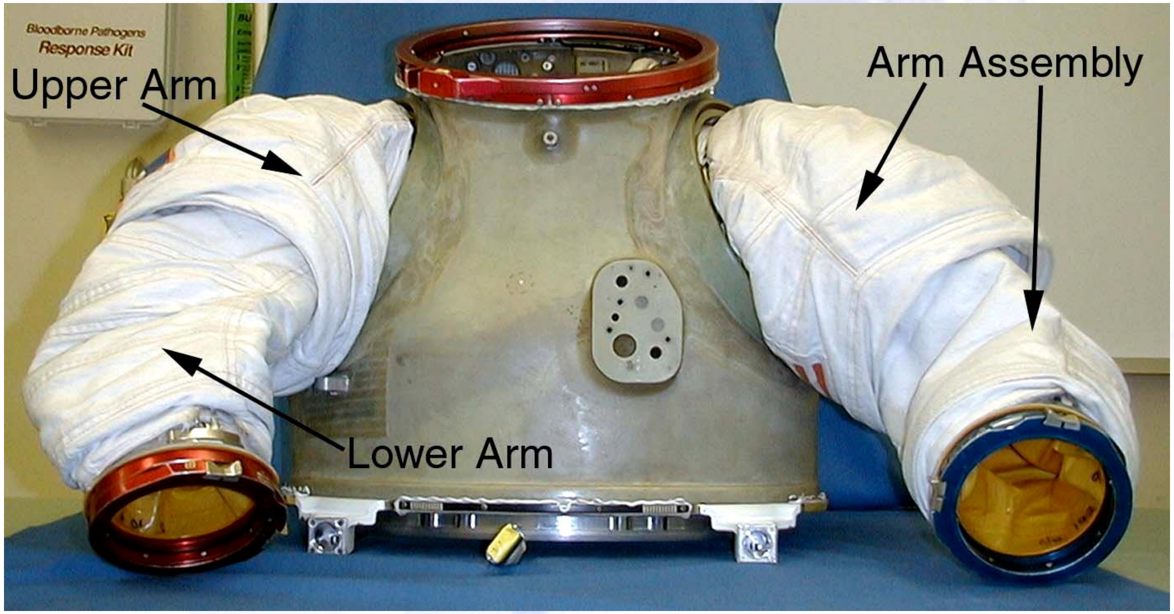




Working in Microgravity

- **Highly mobile upper body**
  - Angled shoulder bearings
  - Upper arm bearing
  - Patterned convolute elbows
  - Patterned wrist joints and bearings





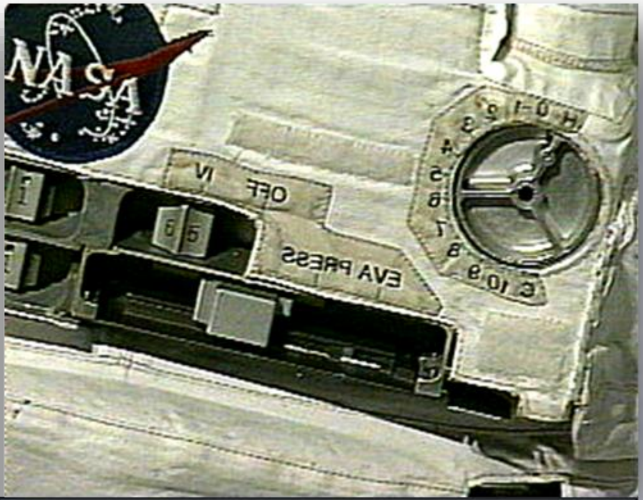
Working in Microgravity

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

Boot and Sizing Insert

Working in Microgravity

Life Support Systems



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

Portable Life Support System

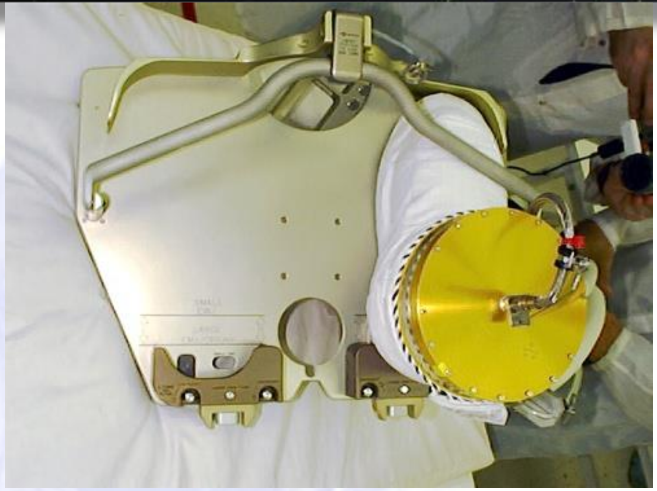
Working in Microgravity

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?

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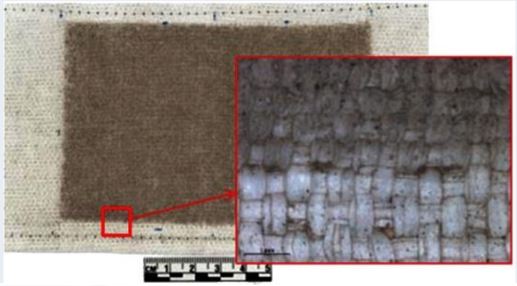
What's next?

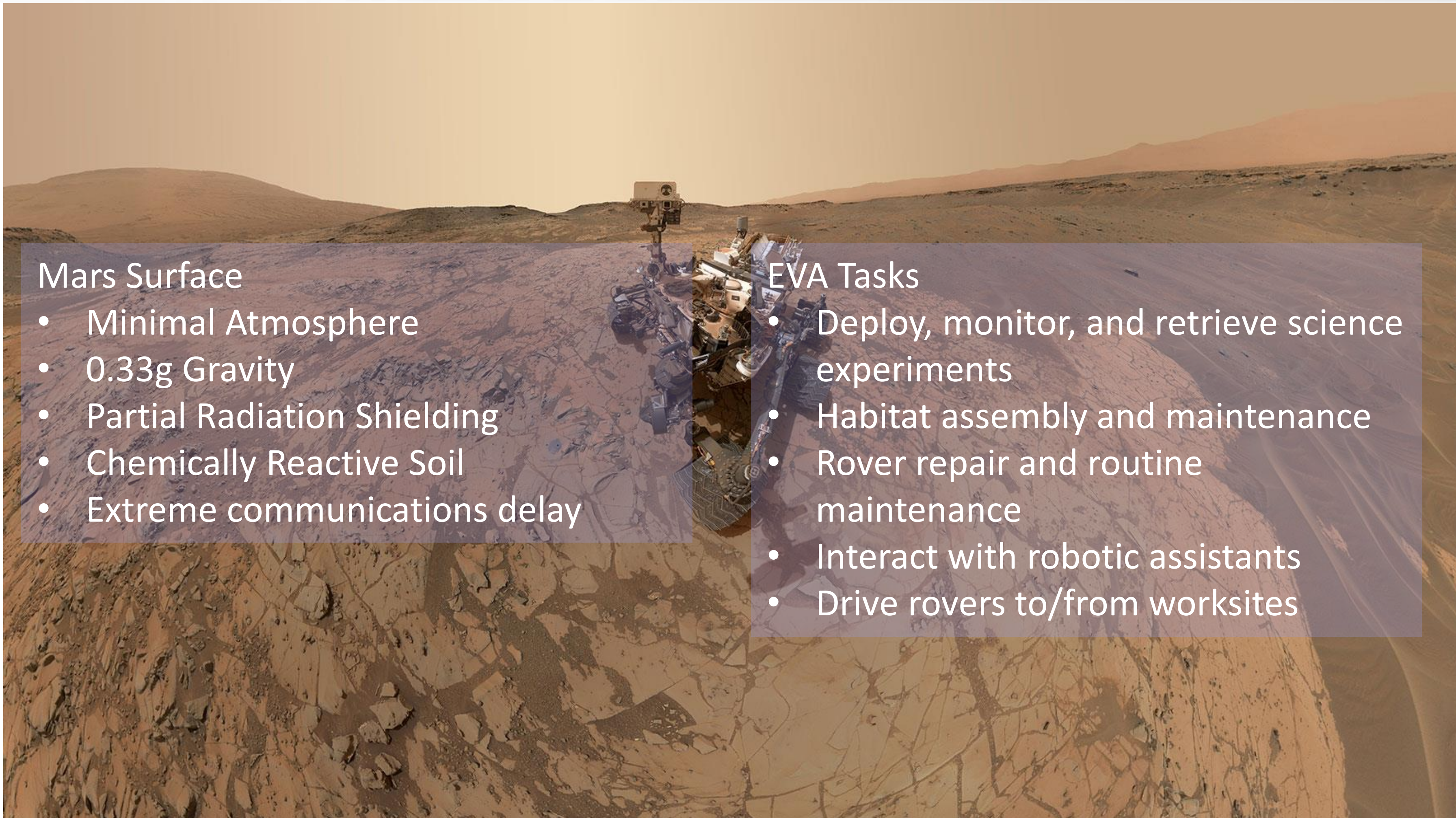
- Astronauts will explore further from Earth meaning:
  - New environments
  - Autonomous operations
  - More mobility
  - New tools and vehicles

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



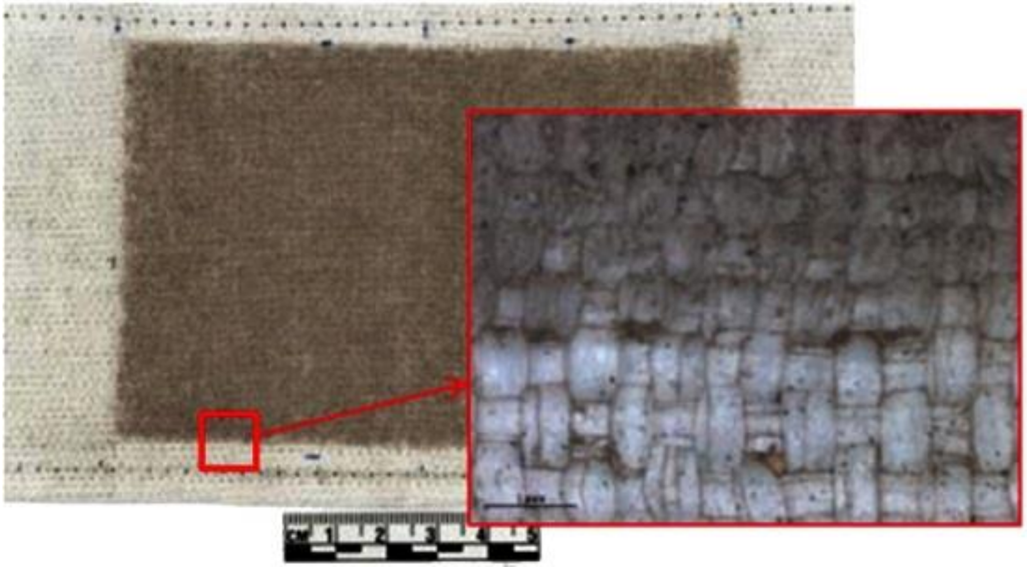
Mars Surface
- Minimal Atmosphere
- 0.33g Gravity
- Partial Radiation Shielding
- Chemically Reactive Soil
- Extreme communications delay

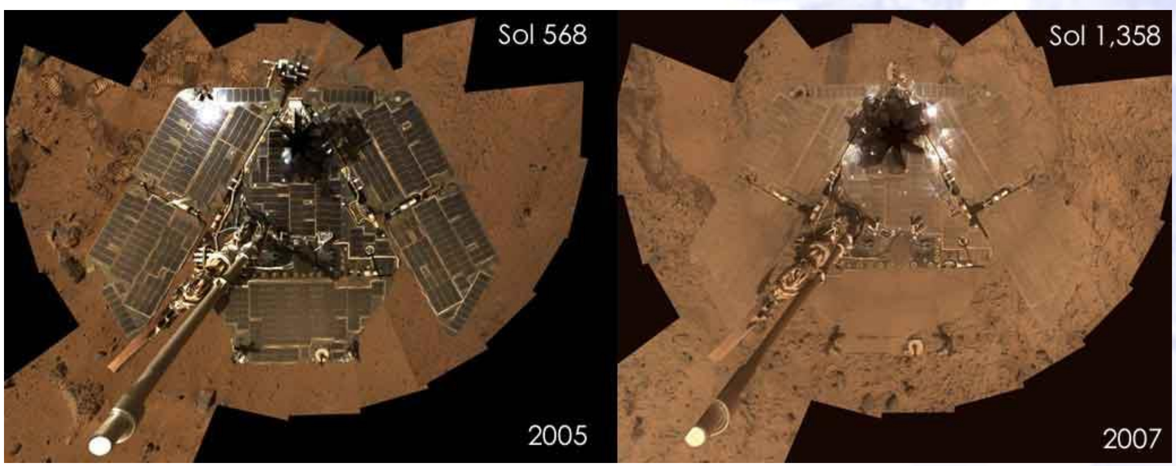
EVA Tasks
- Deploy, monitor, and retrieve science experiments
- Habitat assembly and maintenance
- Rover repair and routine maintenance
- Interact with robotic assistants
- Drive rovers to/from worksites

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

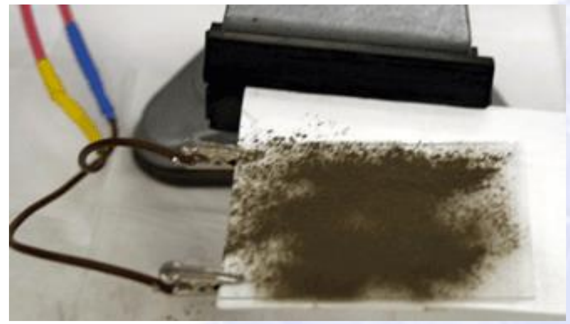


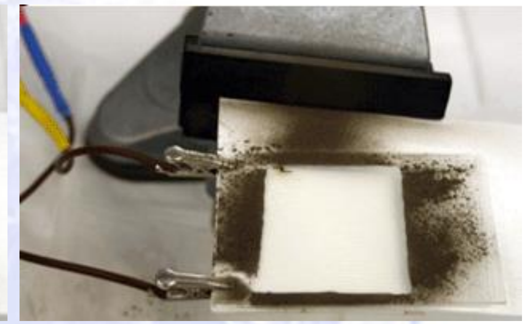


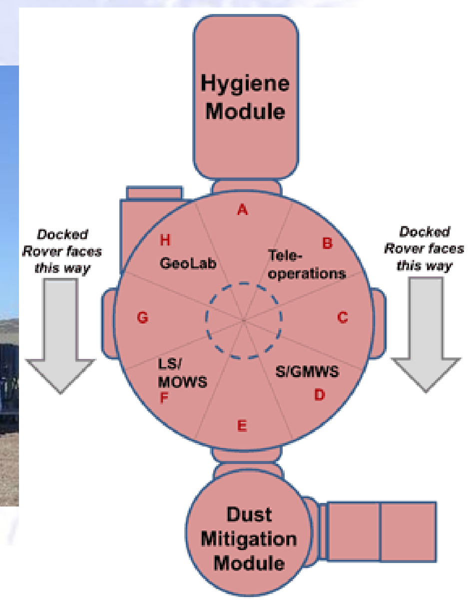
- Relatively high percentage of perchlorates in soil (toxic to humans)
- Small particles can jam mechanisms and potentially create FOD in oxygen systems
- Particles wedged in textile fibers will accelerate space suit wear over time and potentially affect thermal properties of the suit

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

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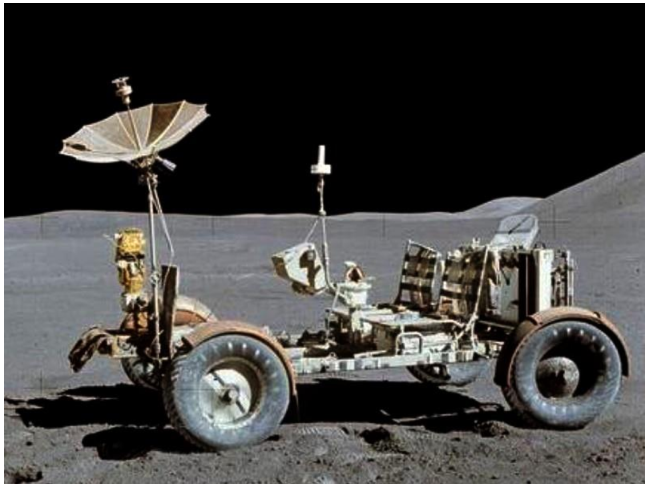
VS.

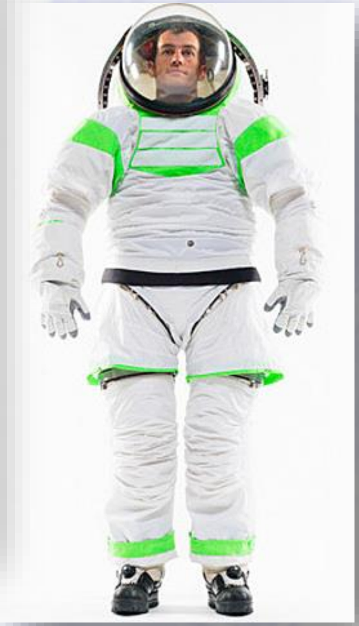
Planetary Exploration - New Vehicles



Planetary Exploration - More Mobility

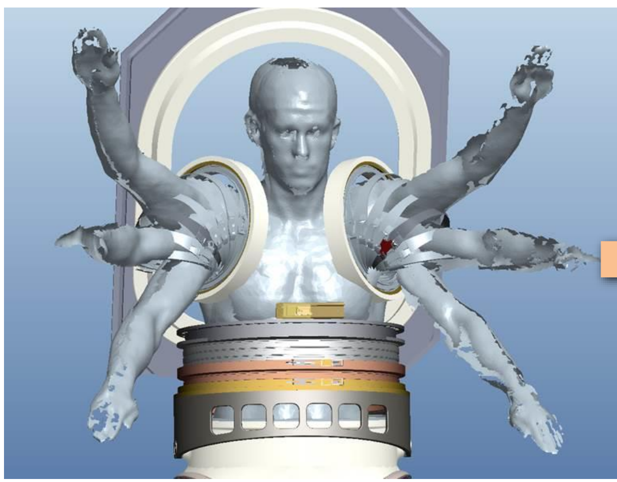
Mars Suit Prototypes



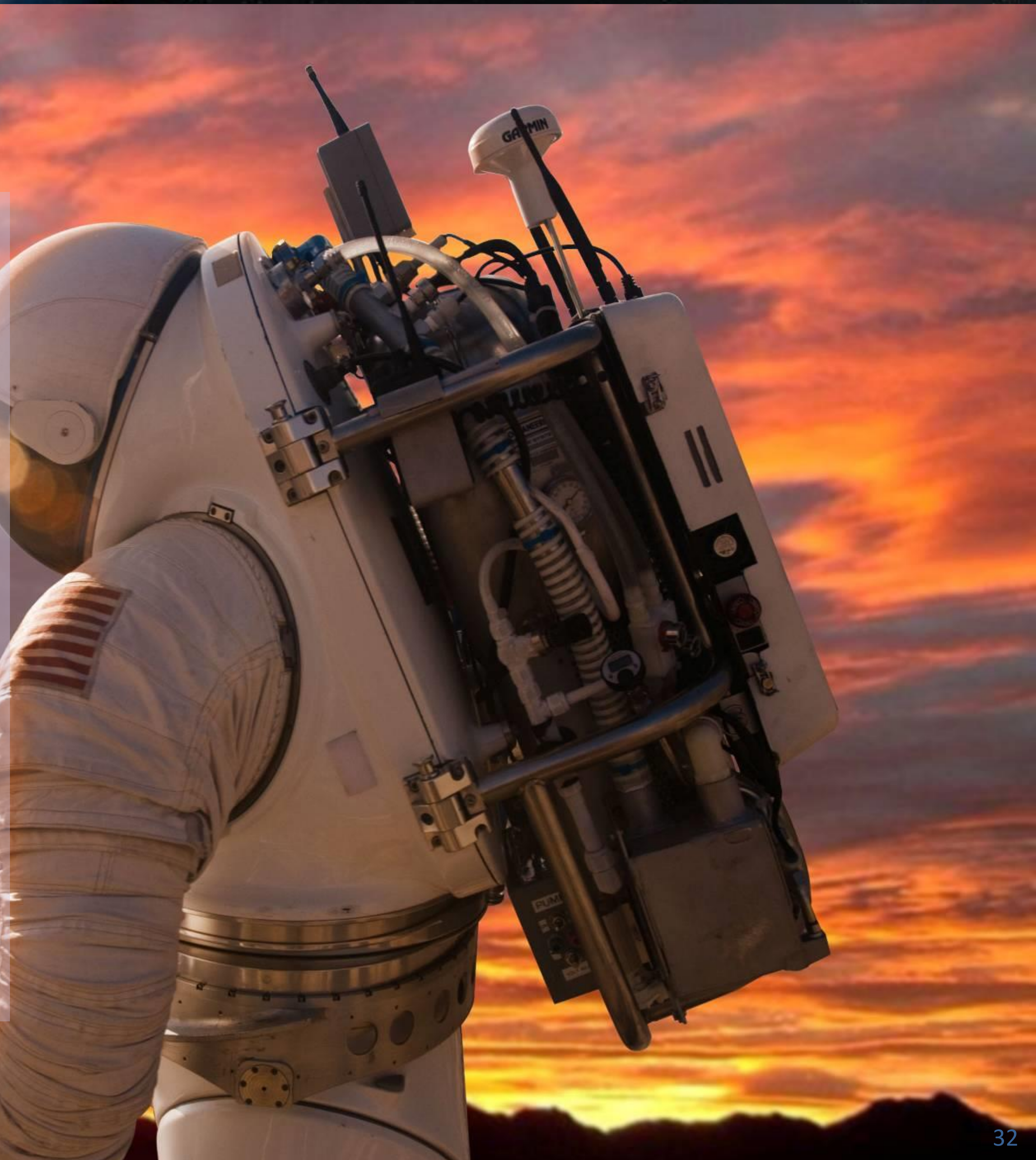




Not:

Next up…



Build – Test – Refine - Repeat



#SuitUp With NASA

#JourneyToMars

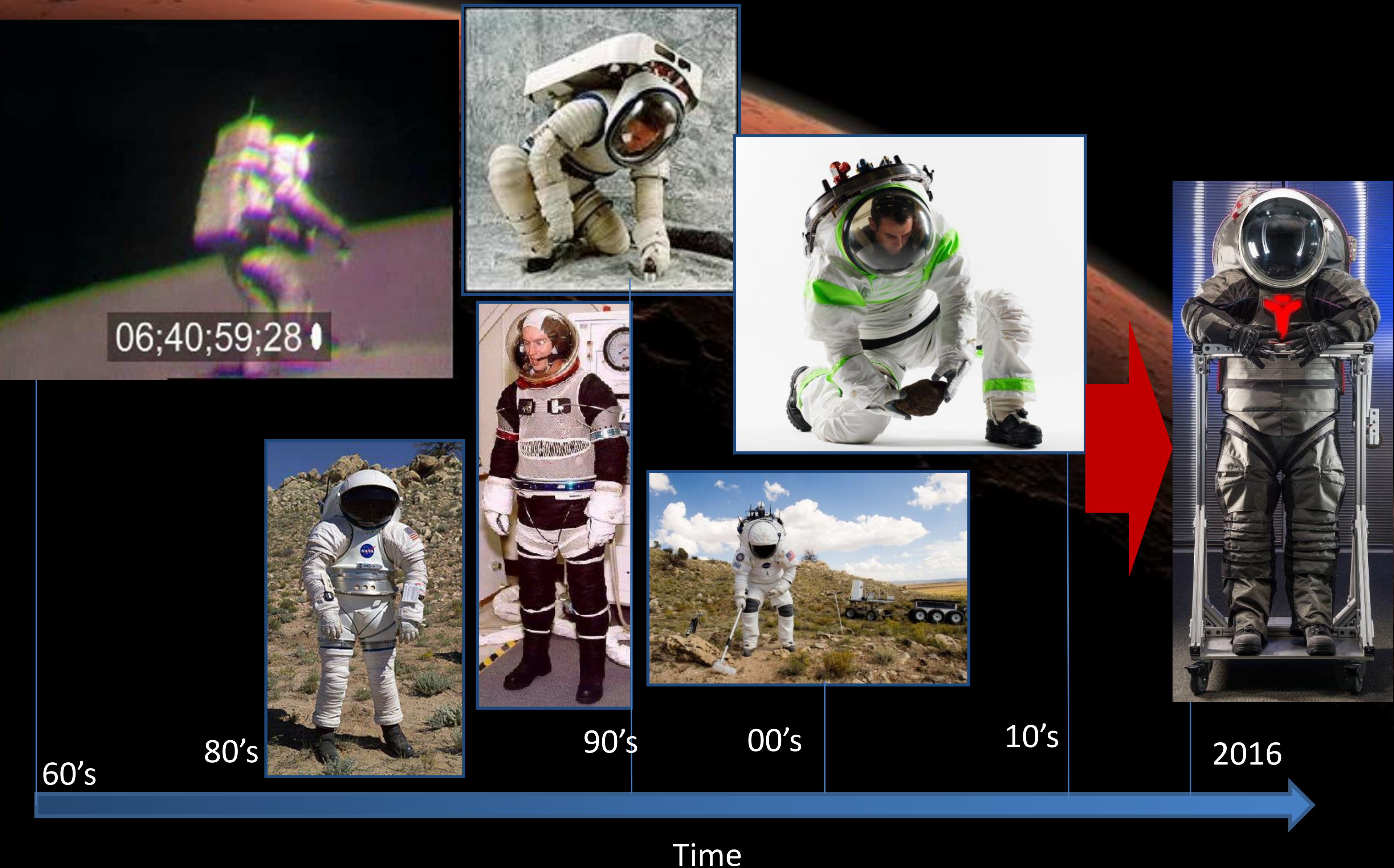
Visit:

www.nasa.gov/suitup

For More on Z-2 Visit:

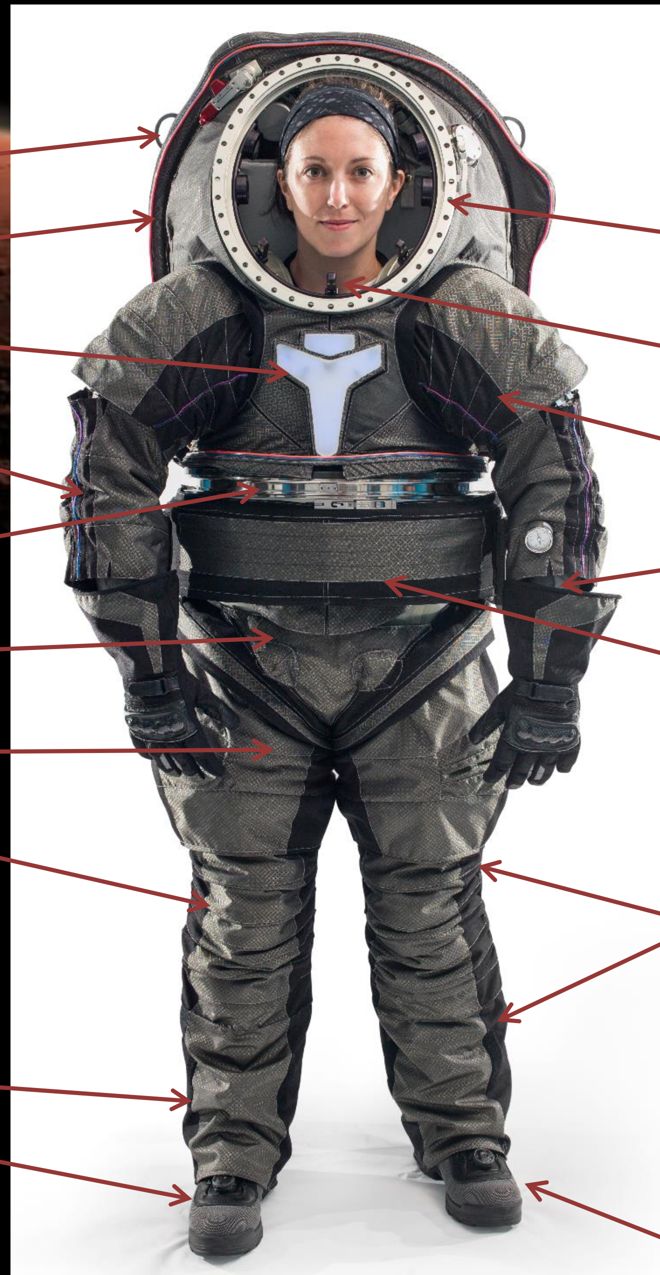
http://jscfeatures.jsc.nasa.gov/Z2

Mobility – Lessons Learned



The People who make it happen

Features



Existing EMU Boot (ISS DTO) (Alternate)

Dust Mitigation

- Short excursions with pressurized rovers can keep the suits outside for duration of trip