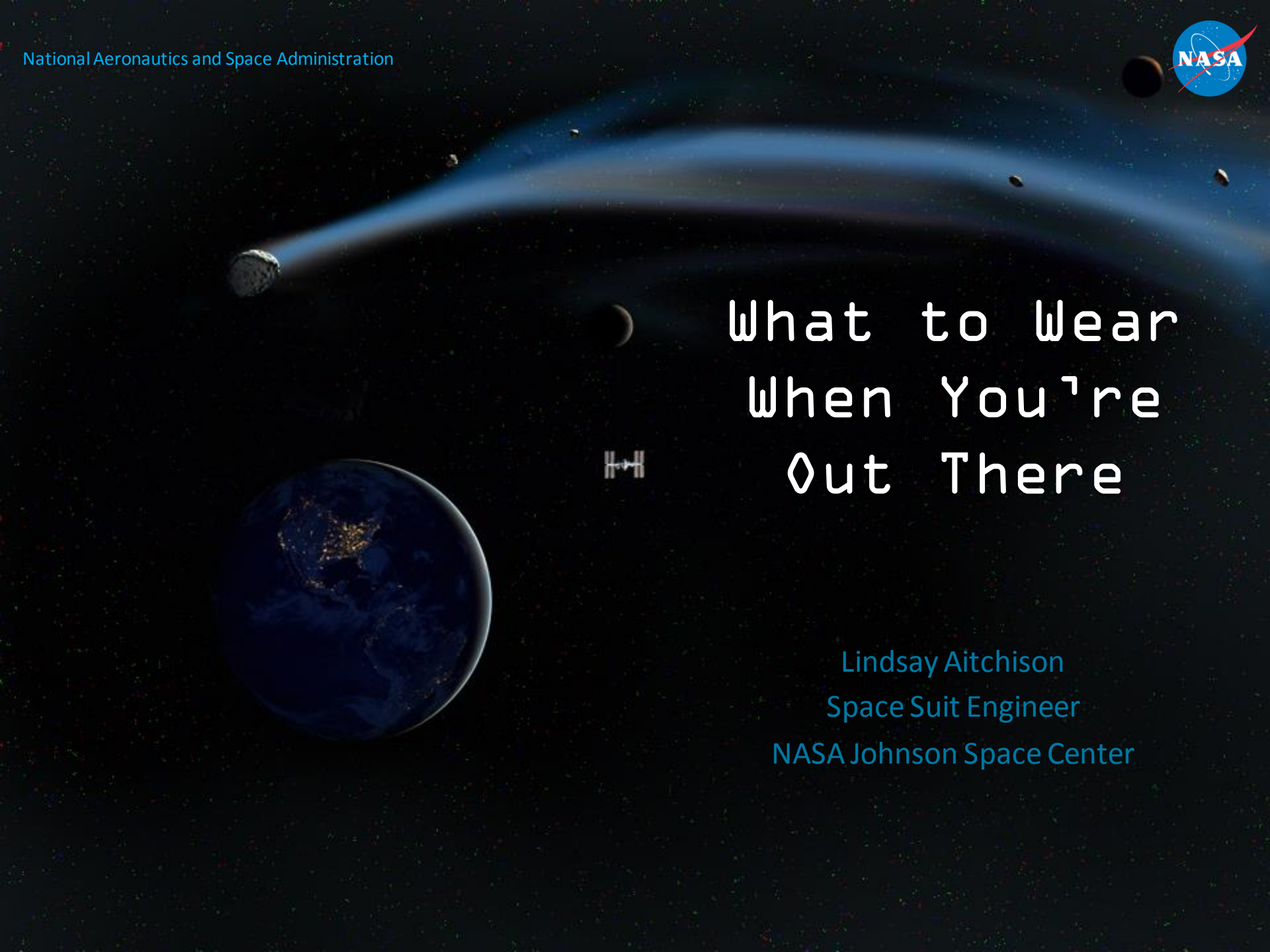
National Aeronautics and Space Administration



What to Wear When You're Out There

Lindsay Aitchison
Space Suit Engineer
NASA Johnson Space Center

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 Astronaut "Office"

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

Hazards Outside of ISS

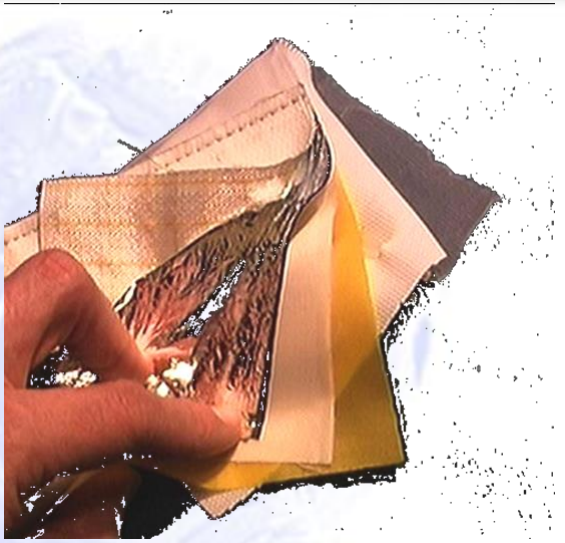
- Vacuum
- Extreme Temperatures
- Radiation
- Micrometeoroids

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
- Direct relationship between boiling point of water and atmospheric pressure
  - In a vacuum, boiling point of water is 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 ISS range from -50F to +150F
- 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

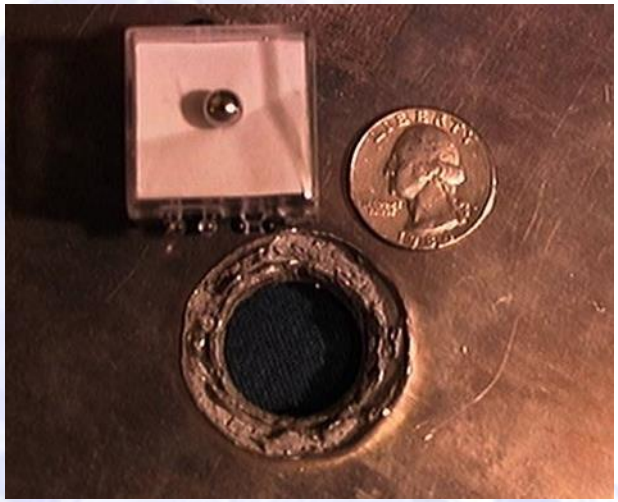
- Earth's atmosphere protects us from most radiation
- In space, must limit exposure
  - Keep alpha and beta particles from reaching the astronaut
    - Helmet Visor
    - Reflective properties of MLI and orthofabric
  - Limit lifetime exposures
    - Astronauts wear dosimeters to track total radiation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

Protection from Micrometeoroids

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

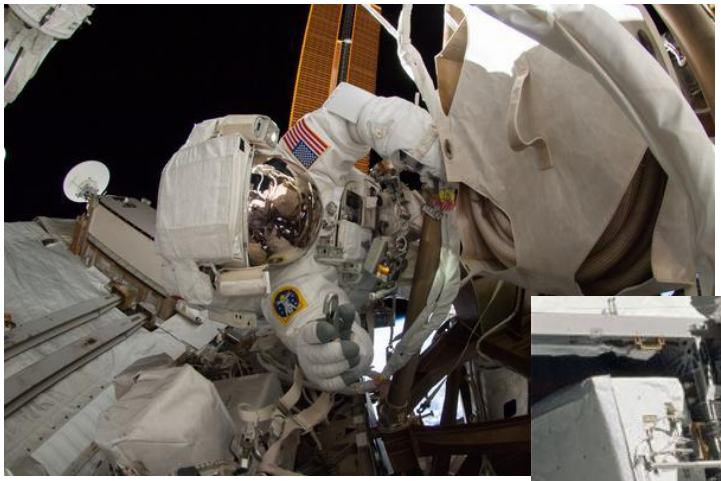
$$KE = \frac{1}{2} mv^2$$

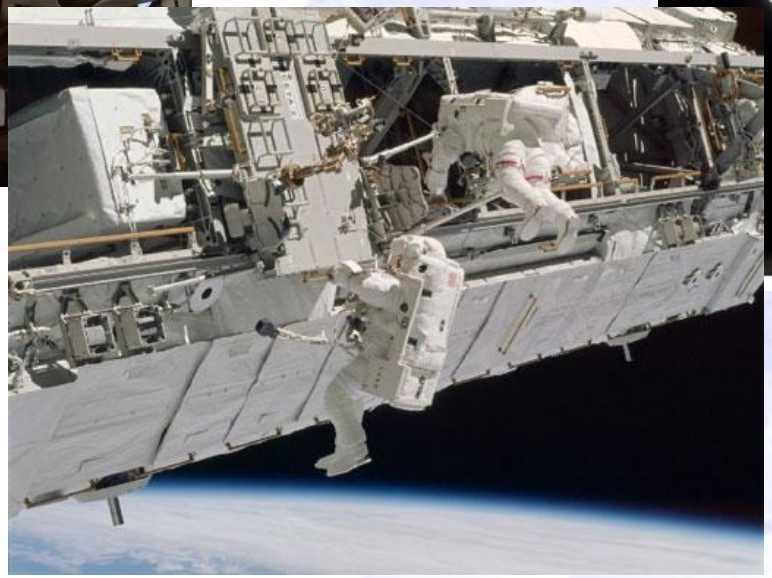
  - Energy from particle transferred to suit upon impact
  - Even a tiny mass moving at 17,000 mph is going to hurt
- Space suits rely on Thermal Micrometeoroid Garment (TMG) to reduce particle velocity and size

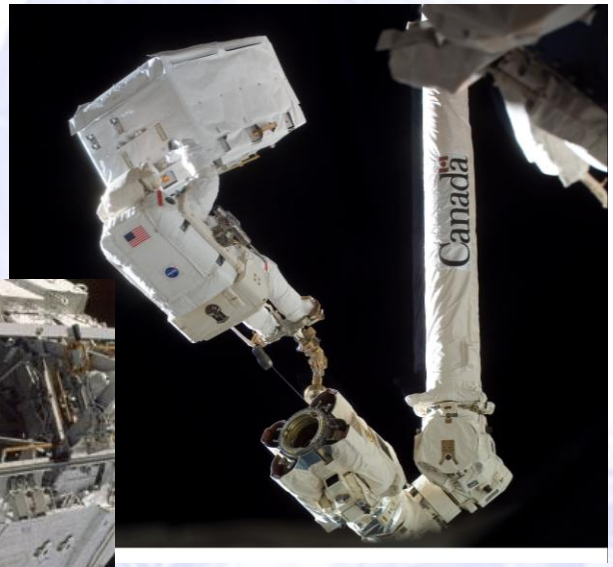


Working Outside ISS

What kind of jobs do astronauts do on a spacewalk?

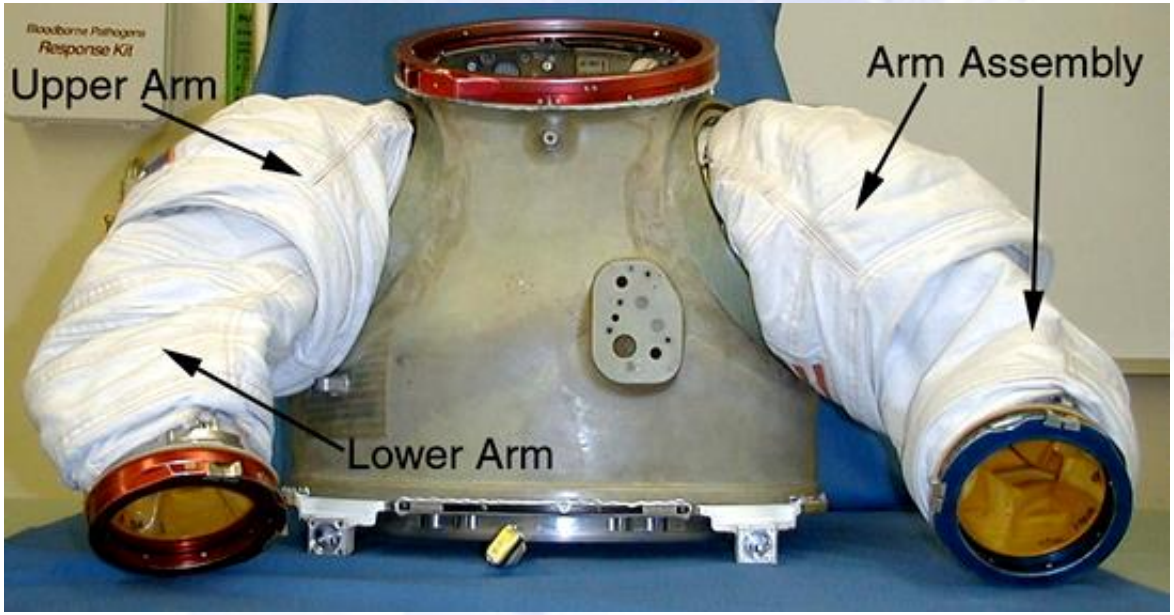






Working in Space

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



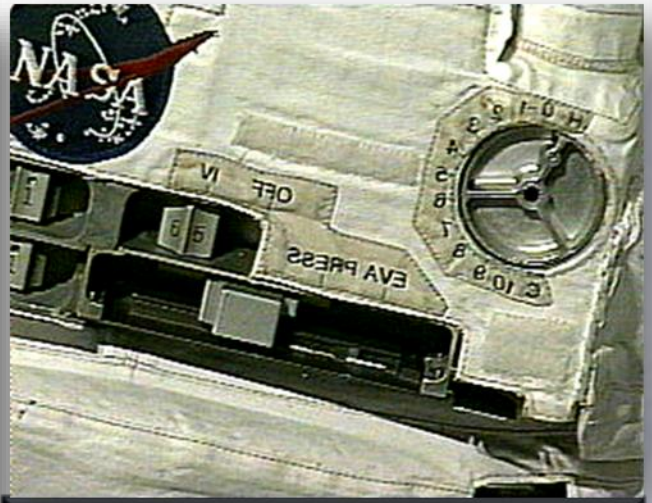
Working in Space

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

Boot and Sizing Insert

Working in Space

Life Support Systems

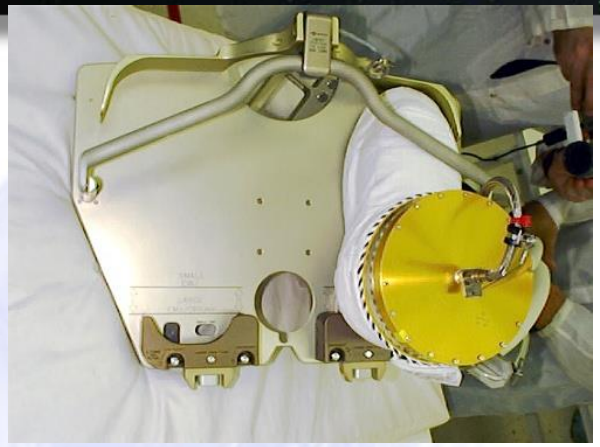


Display and Controls Module: temperature, pressure, ventilation and communication controls

Portable Life Support System

Working in Space

- 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

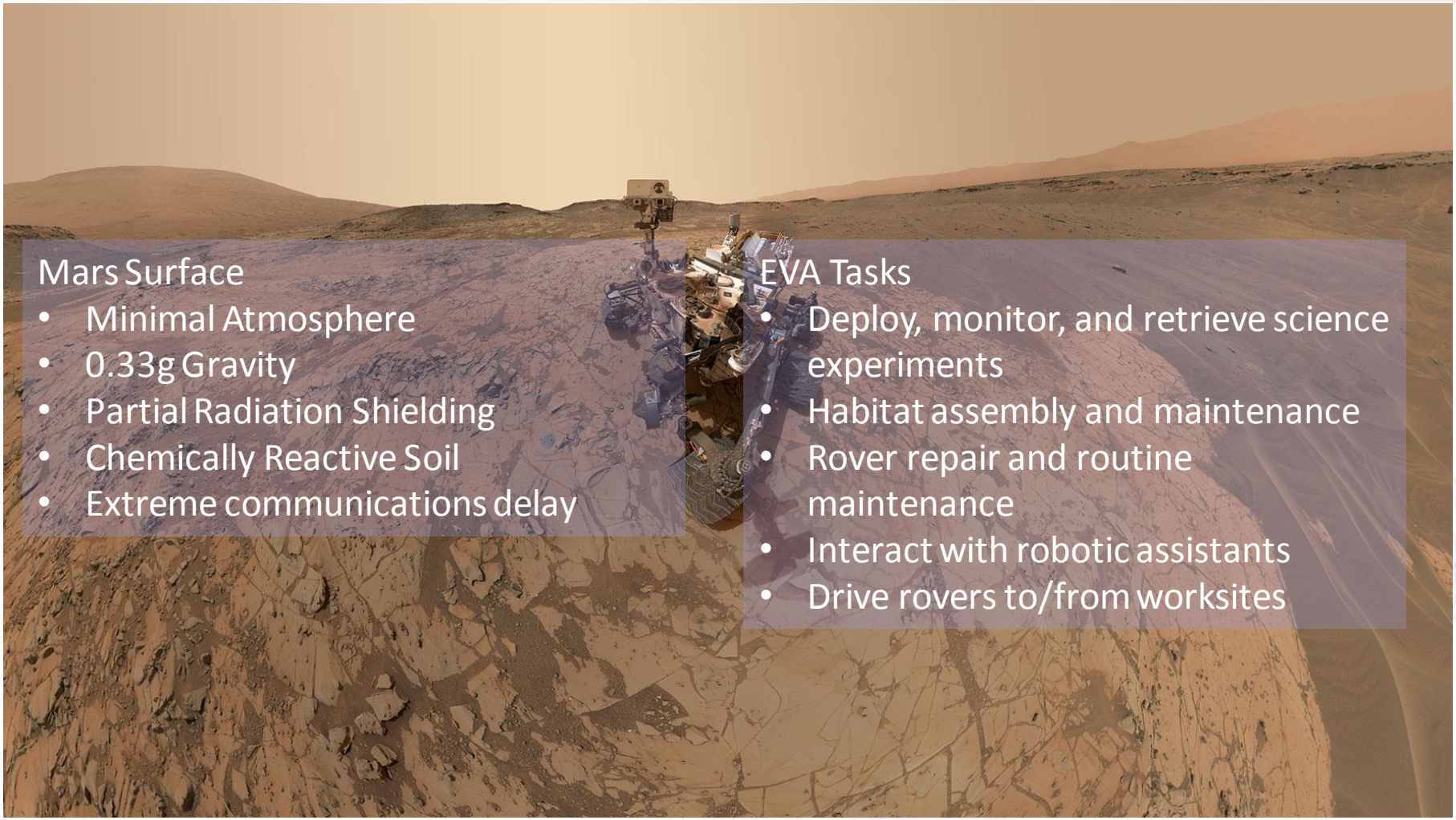


What's next?

What's next?

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

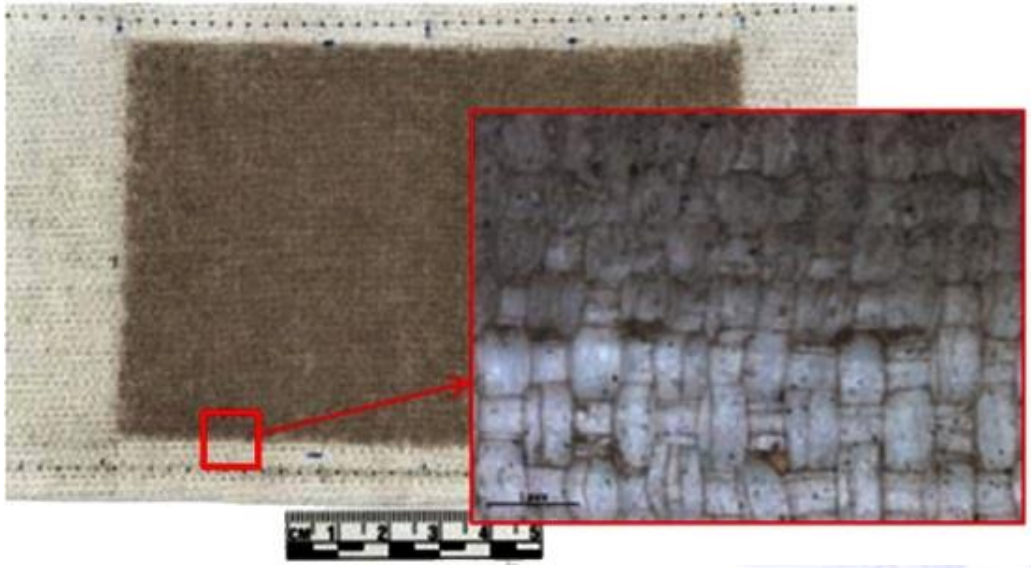
Mars Surface

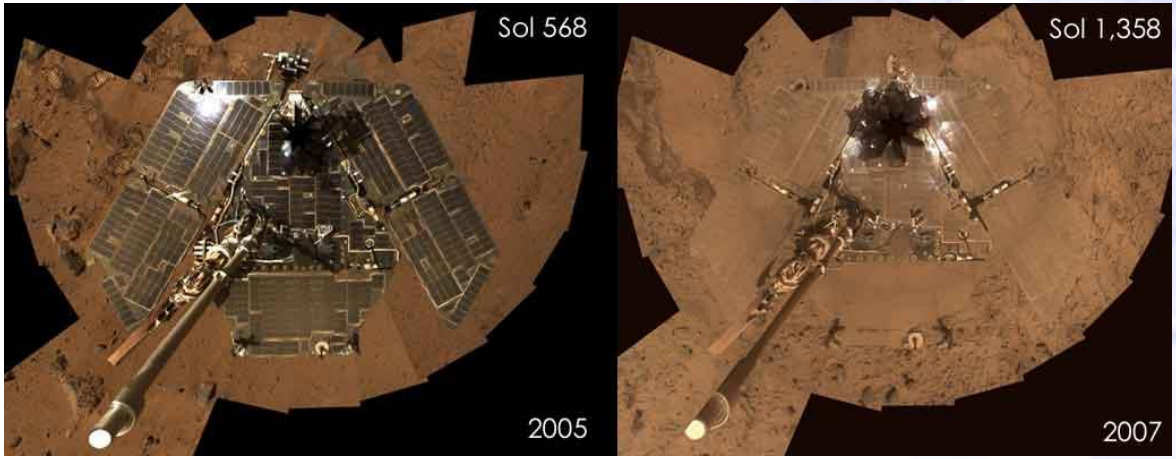


Mars Surface
- Minimal Atmosphere
- 0.33g Gravity
- Partial Radiation Shielding
- Chemically Reactive Soil
- Extreme communications delay

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

Dust Hazards

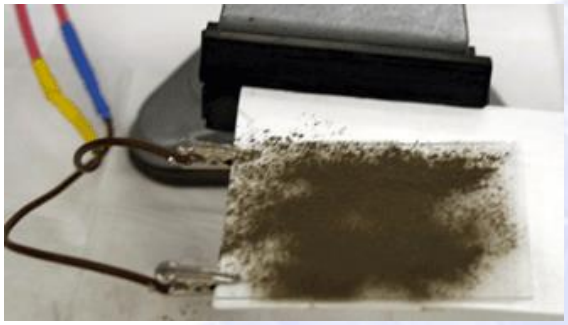


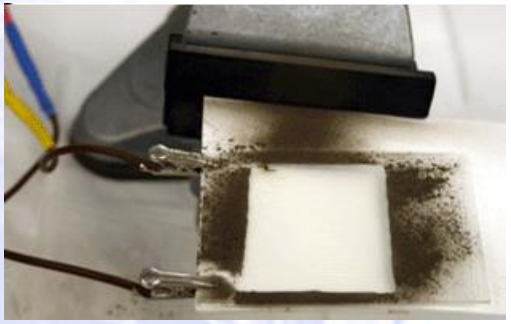


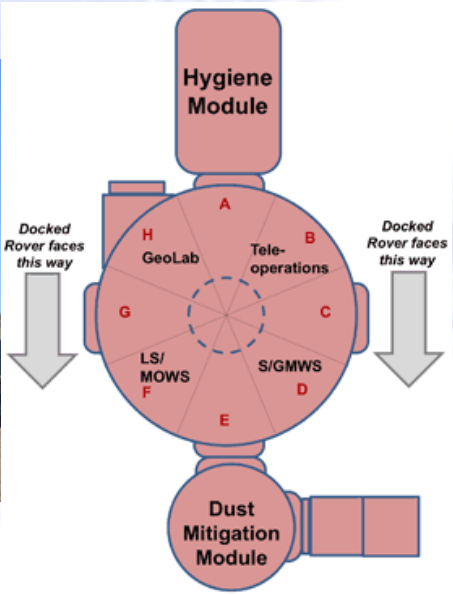
- Relatively high percentage of perchlorates in soil (toxic to humans)
- Small particles can jam mechanisms and potentially create FOD in oxygen systems
- Particles wedged in textile fibers will accelerate space suit wear over time and potentially affect thermal properties of the suit

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

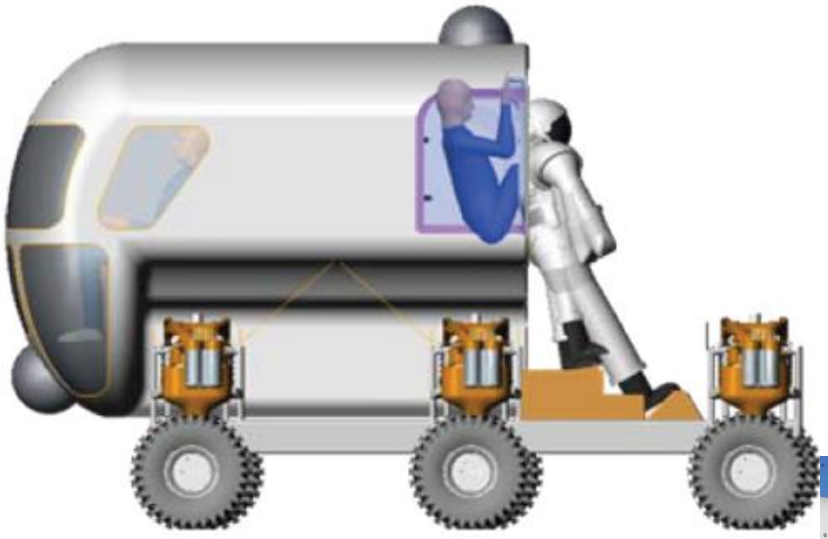






Dust Mitigation

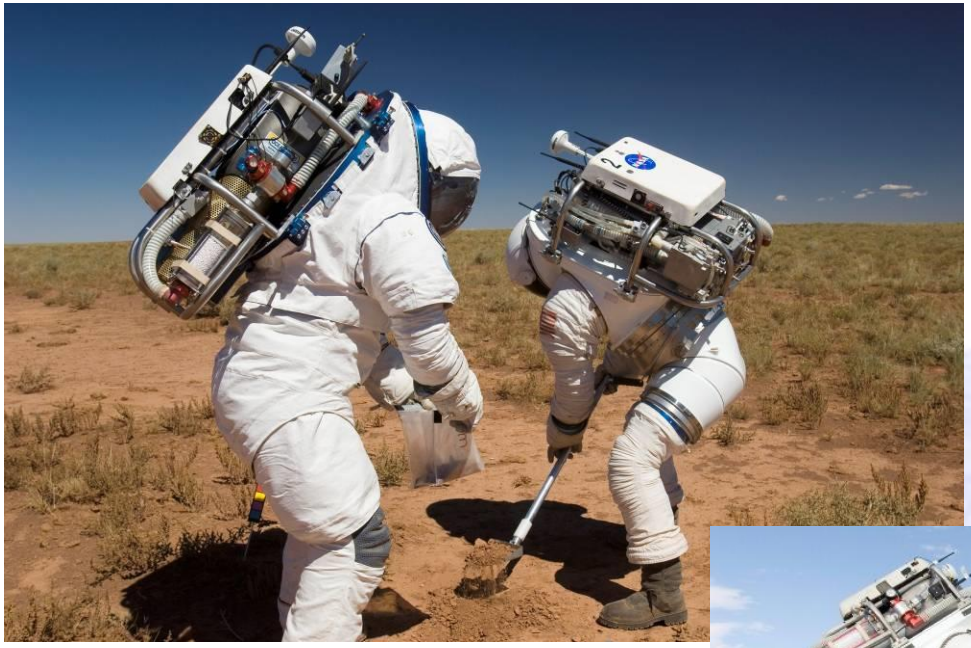
- Short excursions with pressurized rovers can keep the suits outside for duration of trip



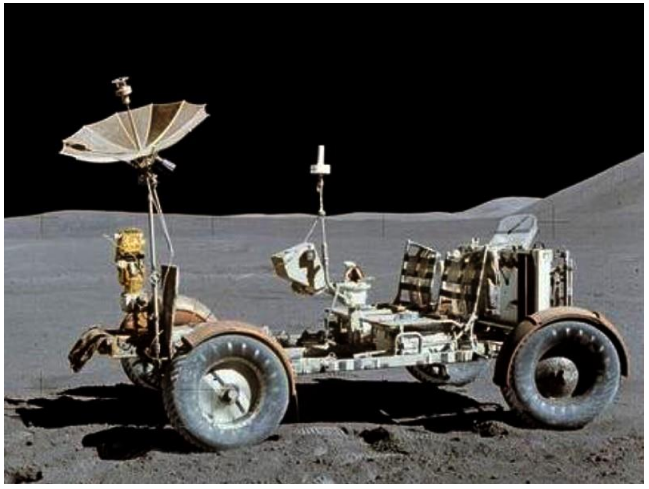
Thermal Considerations

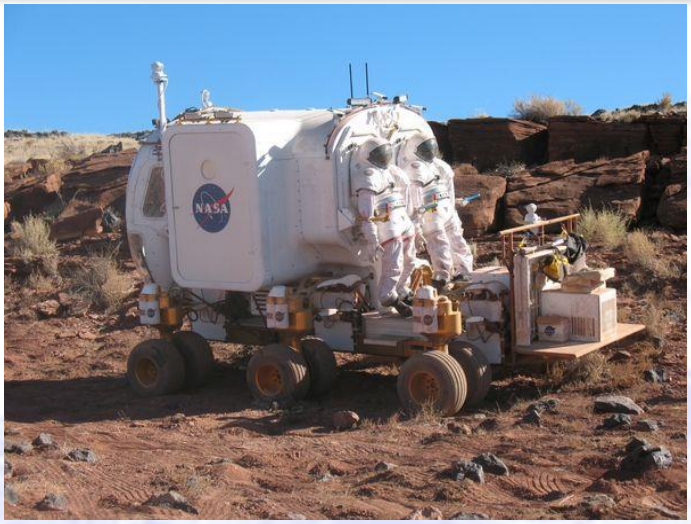
- Walking and full body mobility will recruit larger muscle groups resulting in greater human generated heat loads
  - Must provide more effective body cooling
- Presence of an atmosphere means conduction is an ever present means of heat transfer
  - Need new materials lay-ups that are effective insulators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

Planetary Exploration - New Tasks



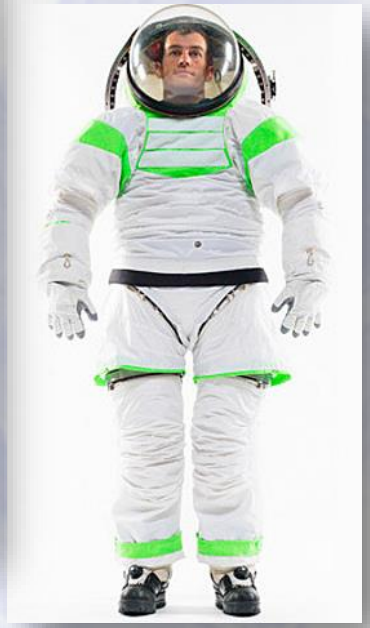
Planetary Exploration - New Vehicles



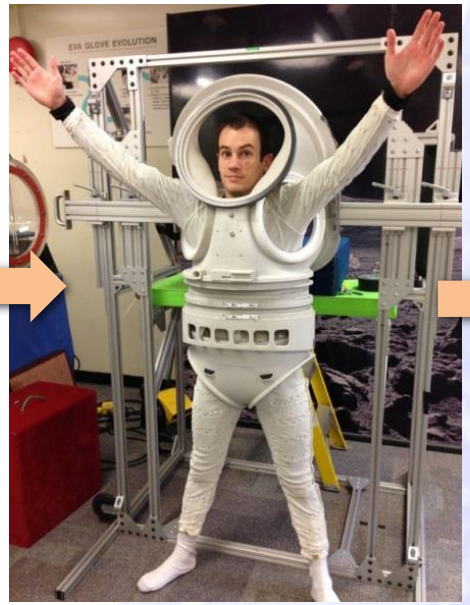


Planetary Exploration - More Mobility

Mars Suit Prototypes



Next up…



Build – Test – Refine - Repeat

#SuitUp With NASA

#JourneyToMars

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