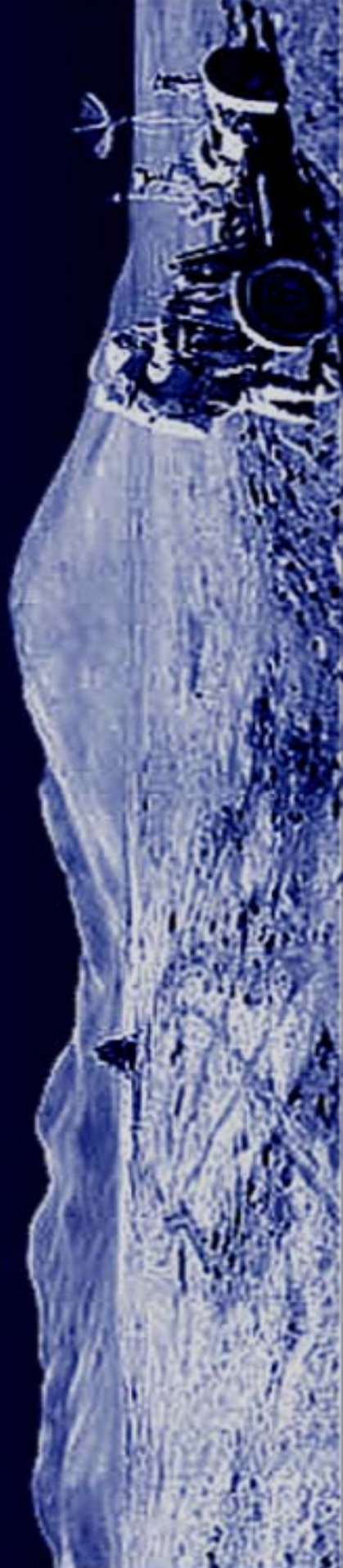


Assessing the Dangers of Moon Dust

Sarah Noble

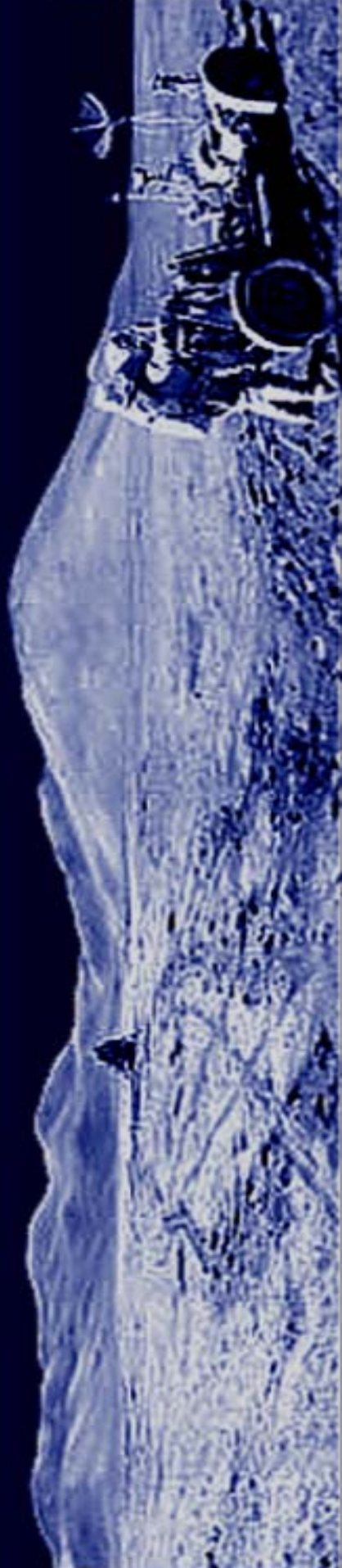
NASA Johnson Space Center

February 28, 2007



The Vision

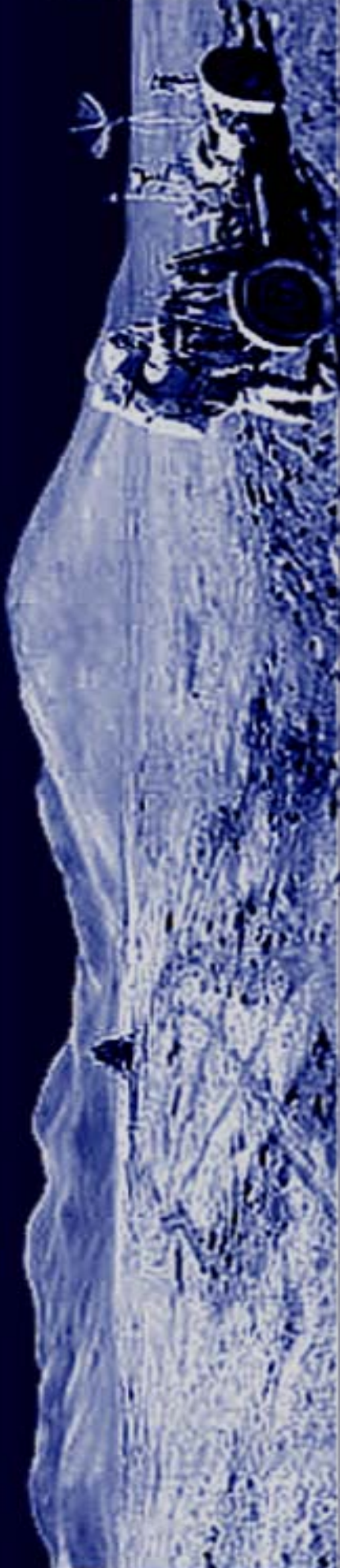
- Return to Moon by 2018
- Initially Apollo-style sorties (~ 1 week)
- Eventually manned base (6 month tours)



LADTAG

“Lunar Airborne Dust Toxicity Advisory Group”

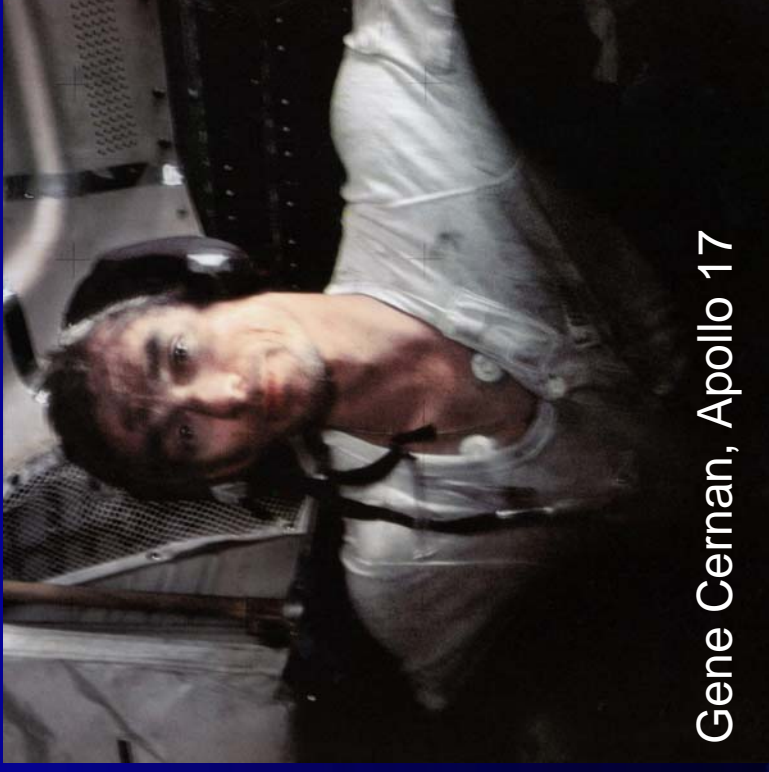
- Created by the Office of the Chief Health and Medical Officer
- Composed of
 - toxicologists, flight surgeons, other medical professionals,
 - and a handful of lunar geologists
- Goal of LADTAG is to determine what the exposure limits to Moon dust should be



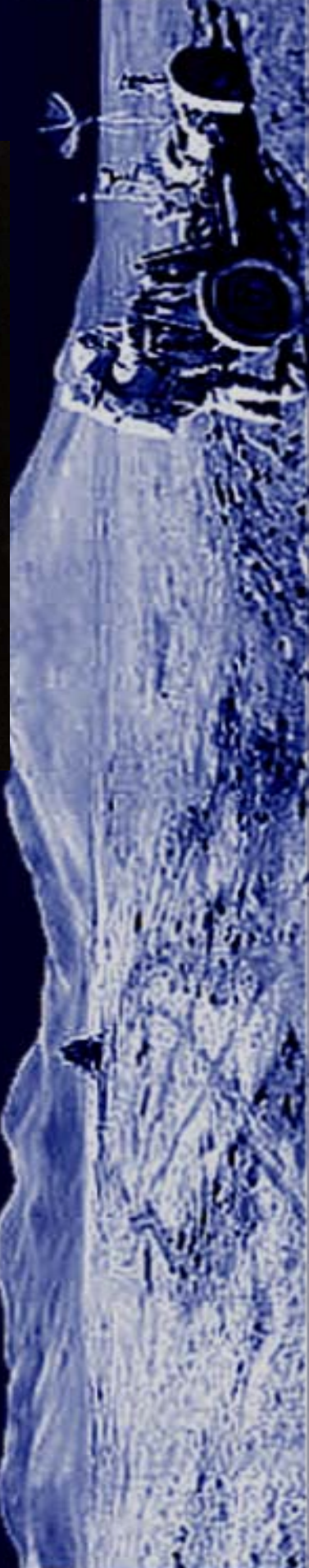
“It’s your turn to dust the habitat”

Dust sources:

- Space suits
- Equipment
- Samples



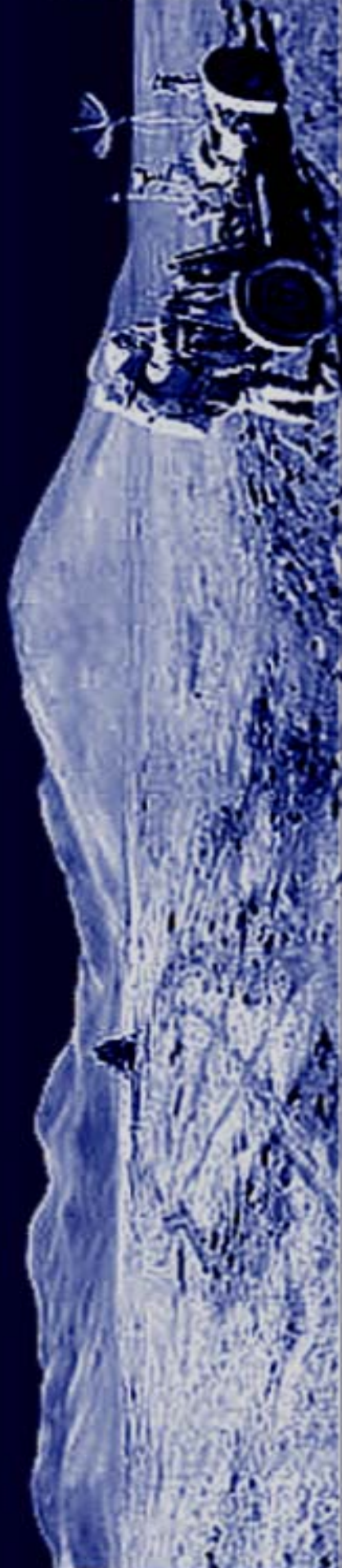
Gene Cernan, Apollo 17



Apollo Lessons

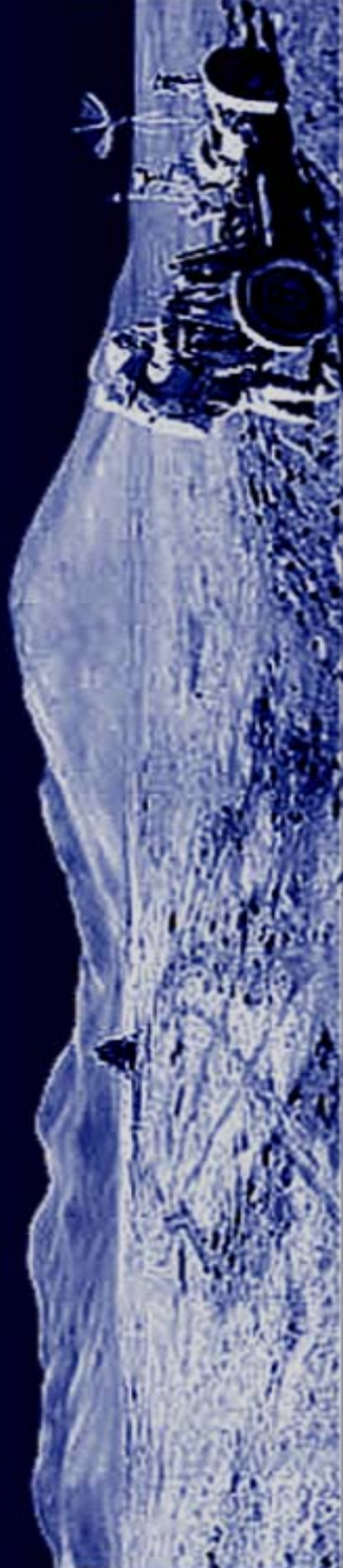
- *“The LM was filthy dirty and it had so much dust floating around in it that I took my helmet of and almost blinded myself. I immediately got my eyes full of junk, and I had to put my helmet back on.”*

– Conrad, Apollo 12 (technical crew debriefing)



Apollo Lessons

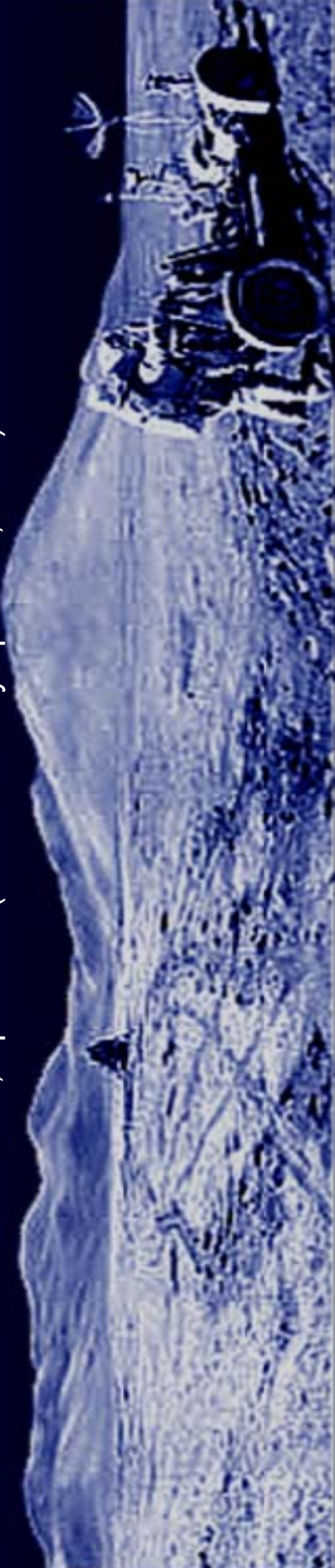
- *“There was a lot of irritation, at least to my sinuses and nostrils, soon after taking the helmet off, about 2 hours later that had decreased considerably.”*
- Schmitt, Apollo 17 (technical crew debriefing)



Apollo Lessons

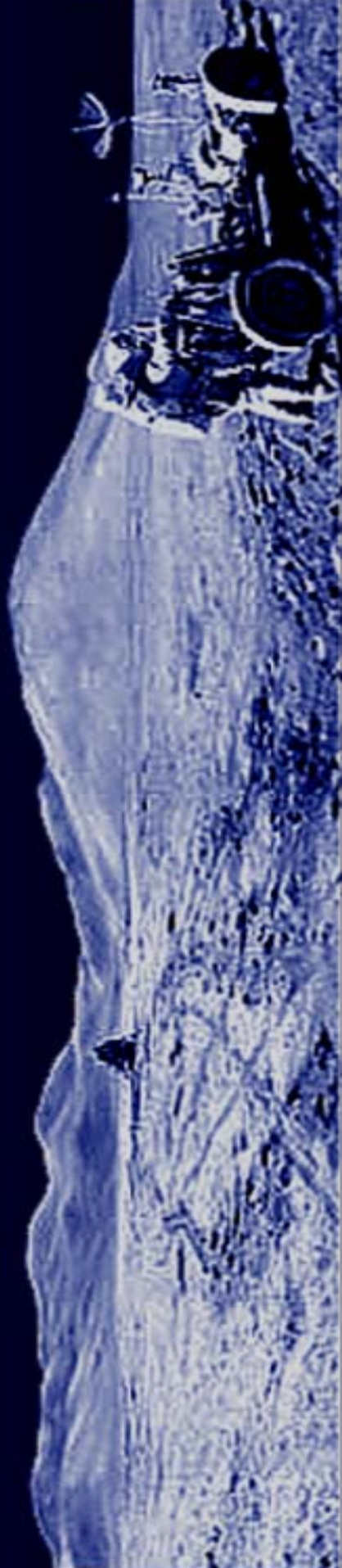
- *“I think dust is probably one of our greatest inhibitors to a nominal operation on the Moon. I think we can overcome other physiological or physical or mechanical problems except dust.”*
 - Cernan, Apollo 17 (technical crew debriefing)
- *“A common sense, layered, engineering design defense can solve any apparent problem with dust during long-term human activity and habitation in the lunar environment.”*

– Schmitt, Apollo 17 (Lunar Dust Symposium, 2004)



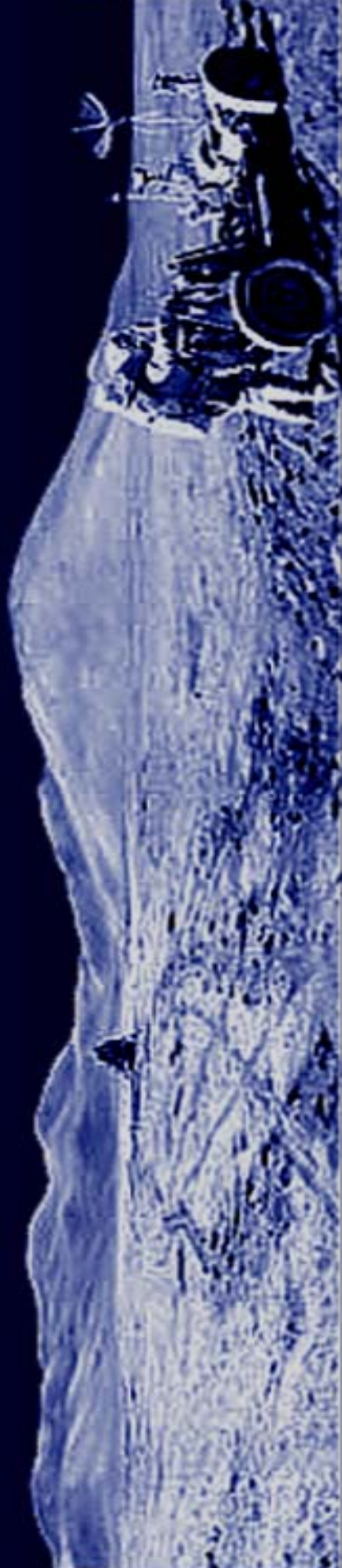
Apollo Lessons

- Several astronauts reported that the soil smelled like gunpowder (suggest reactive surfaces).
- One flight surgeon had “allergic” response to dust, which worsened with repeated exposure.
- Autopsies on five Apollo astronauts show no lung abnormalities.



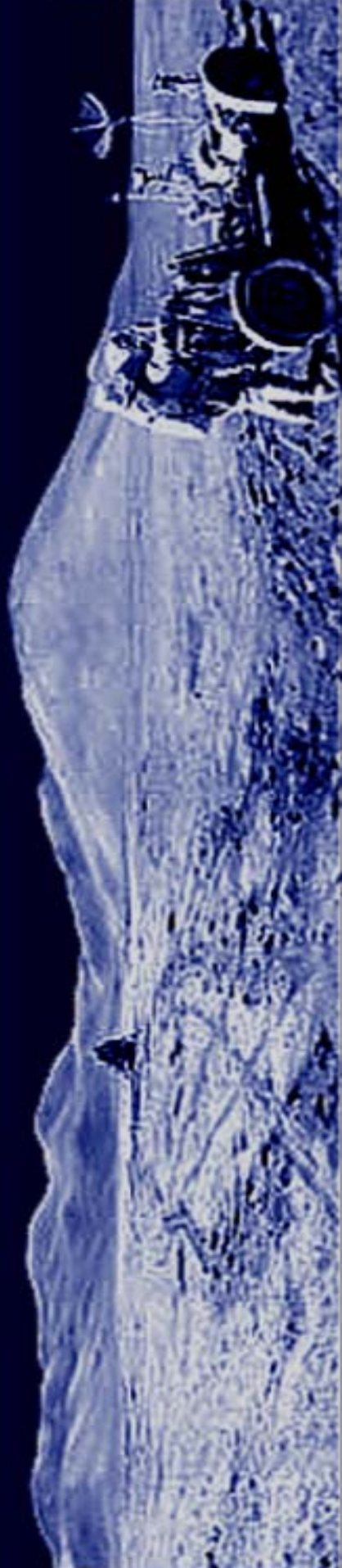
Acute problems

- Eye irritation
- Nose and throat irritation
- Skin irritation



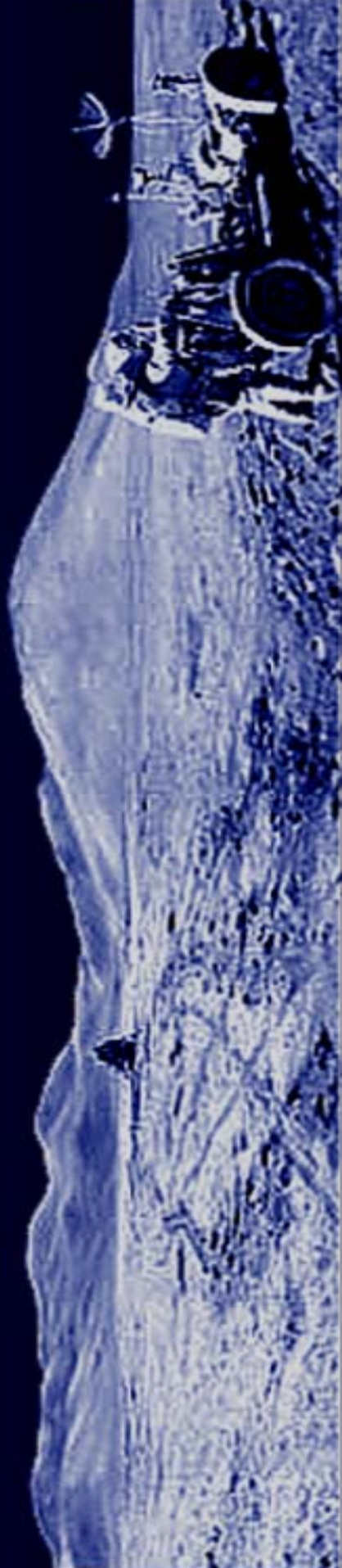
Possible longer term effects

- Inflammation in lung leading to fibrotic changes
- Translocation of smallest fraction of particles, leading to injury outside the respiratory system



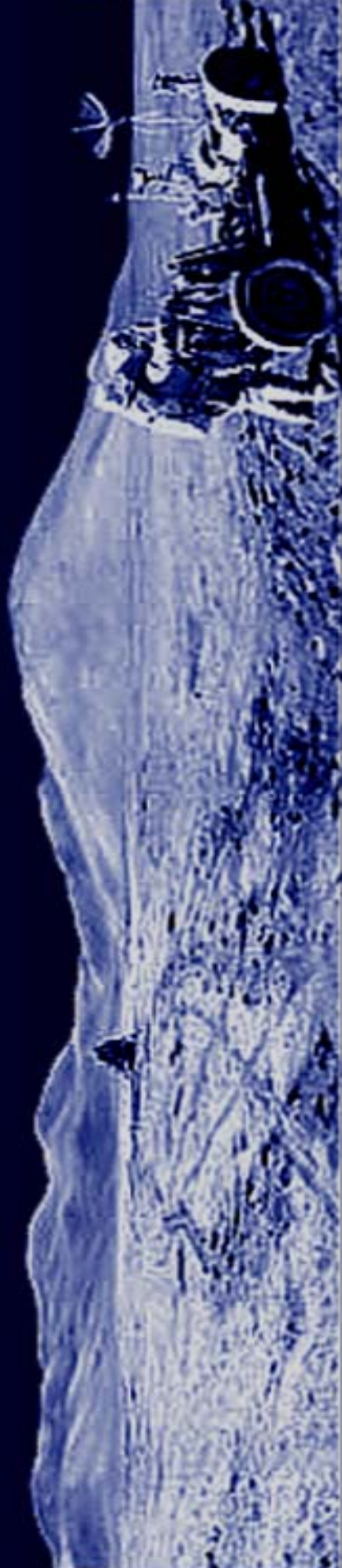
Other effects

- Dust can pose a serious hazard for suit components, zippers, and seals
 - Create coatings that prevents seal
 - Abrasiveness that can lead to holes in material and ill fitting joints
 - Grains can cause zippers to stick and joints to bind



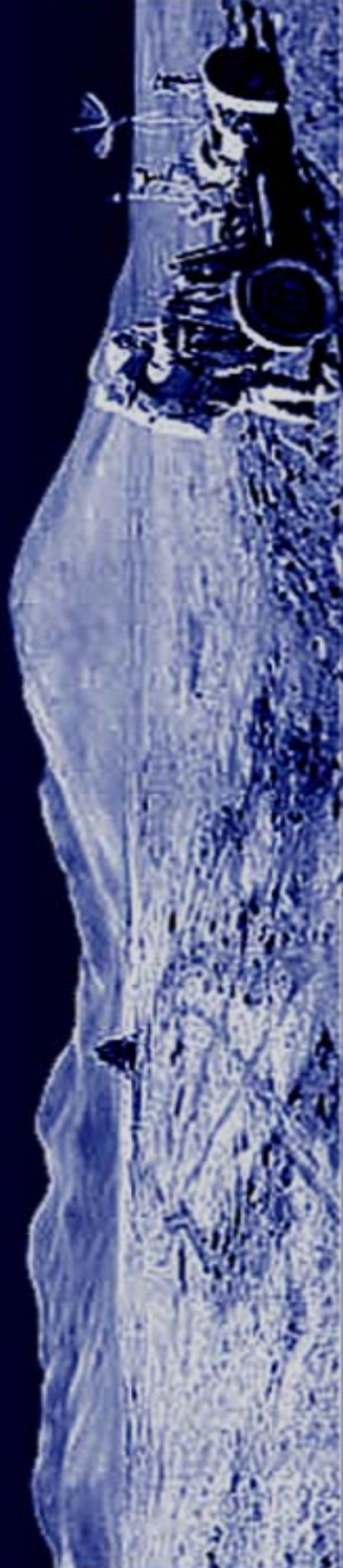
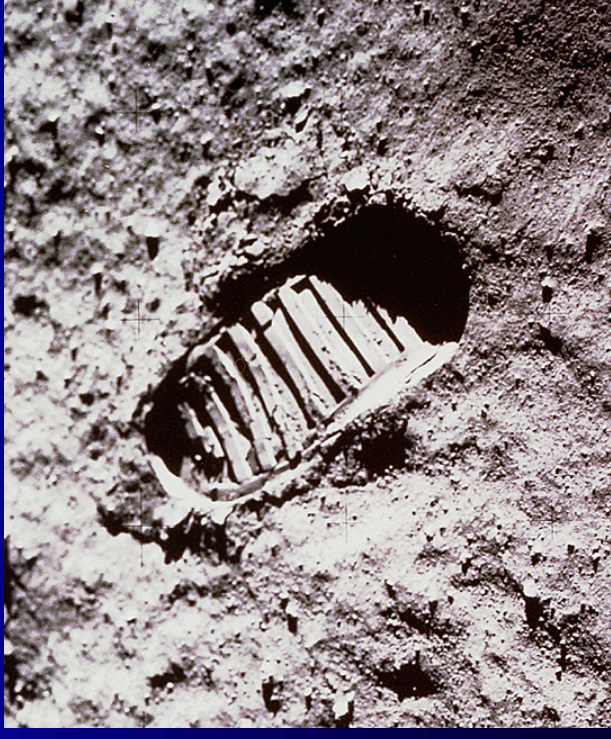
Some Definitions

- Regolith - Loose, unconsolidated rock, mineral, and glass fragments produced by impacts
- Soil – defined as the <1 cm fraction of regolith, though colloquially used as the <1 mm fraction
- Dust ~ <20 μm



What does Moon dust look like?

- Comminuted by impacts
- No air or water
- Solar wind
- Micrometeorites



What does Moon dust look like?

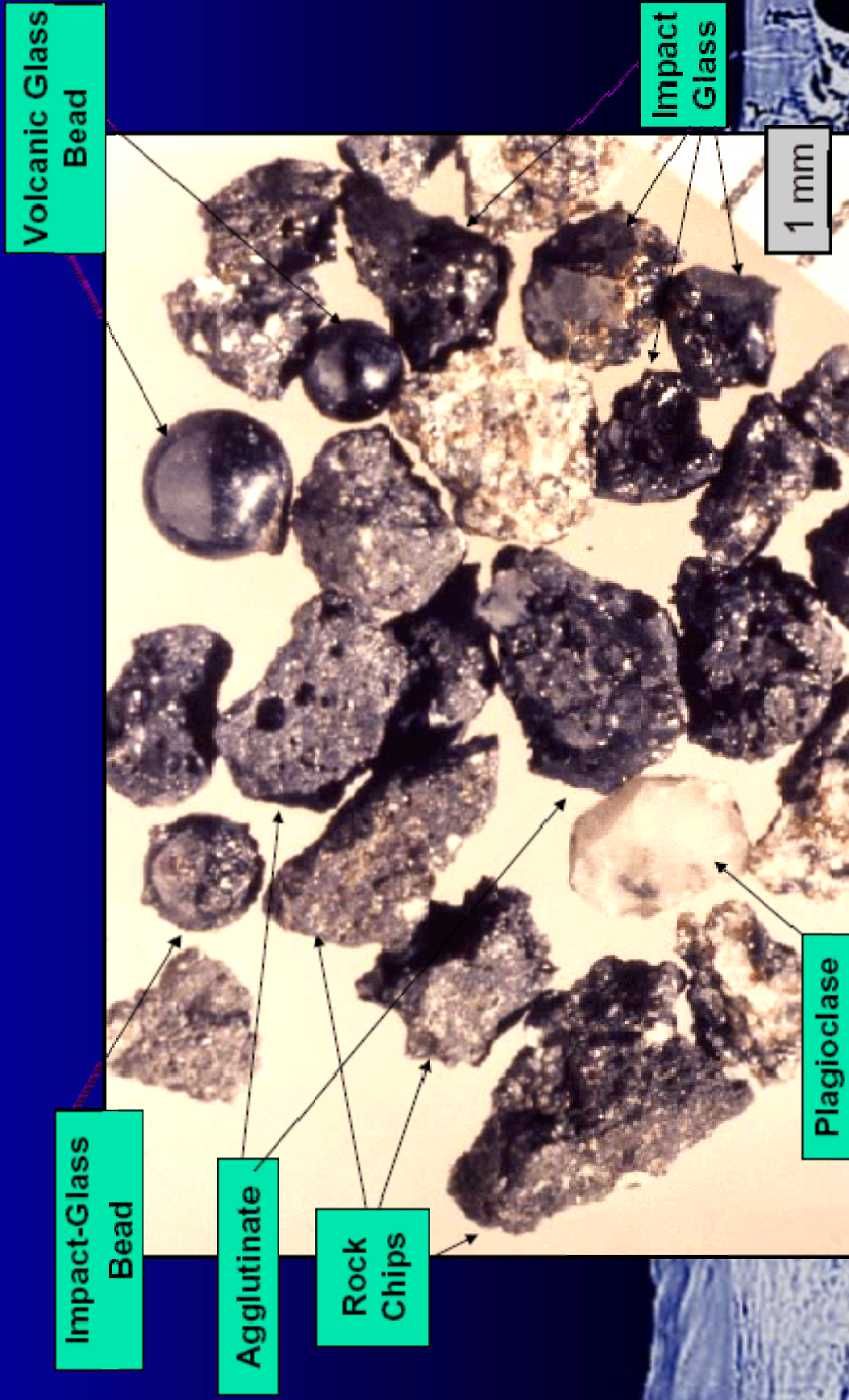
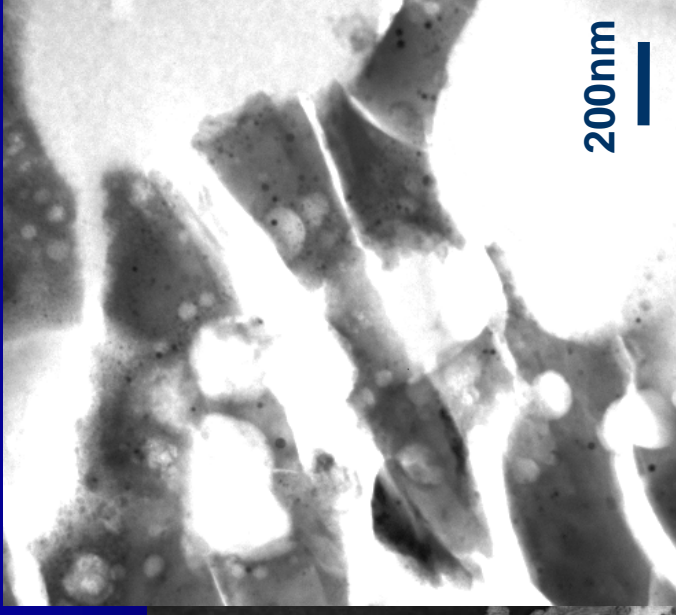
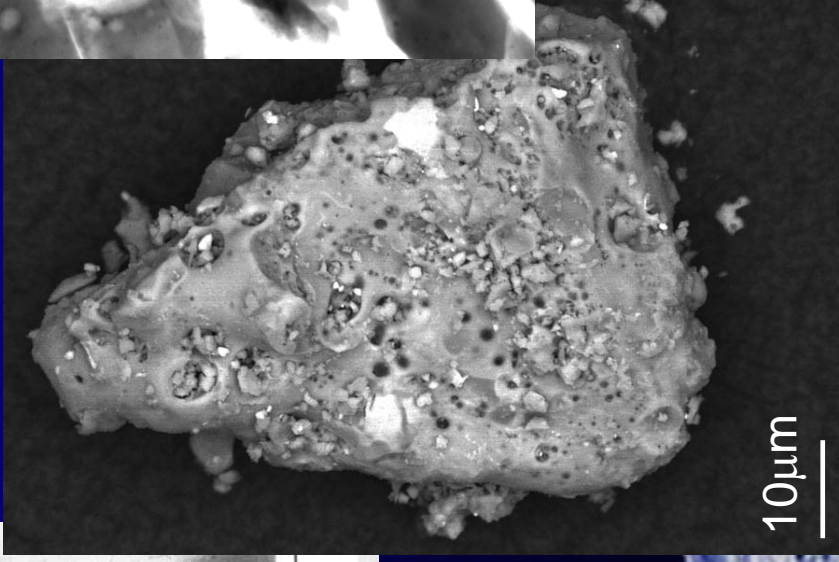
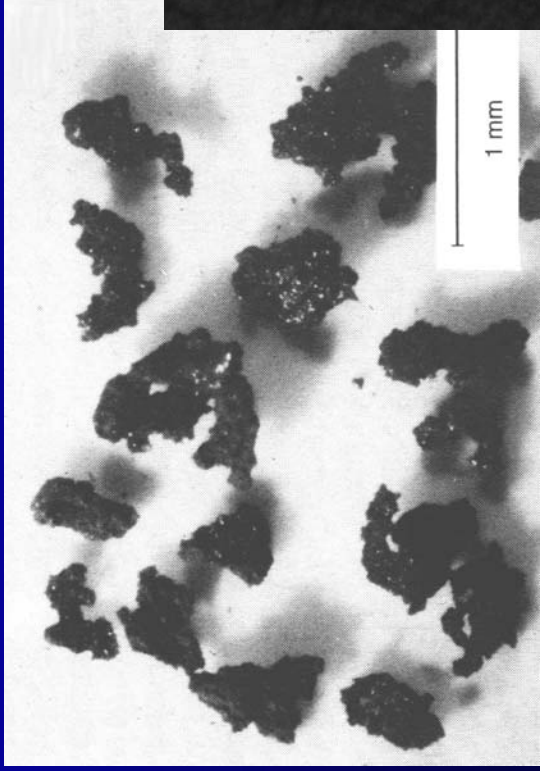
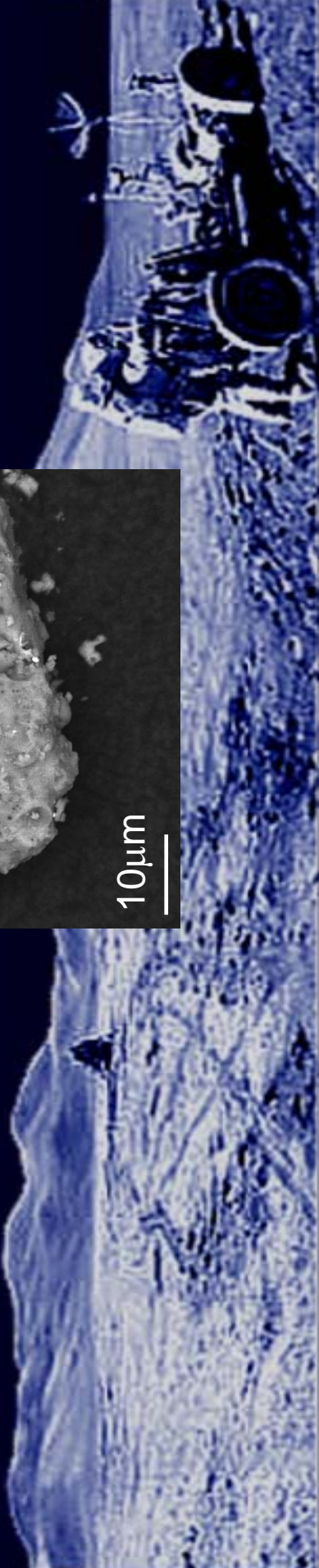


Image courtesy L. Taylor, U.Tenn.

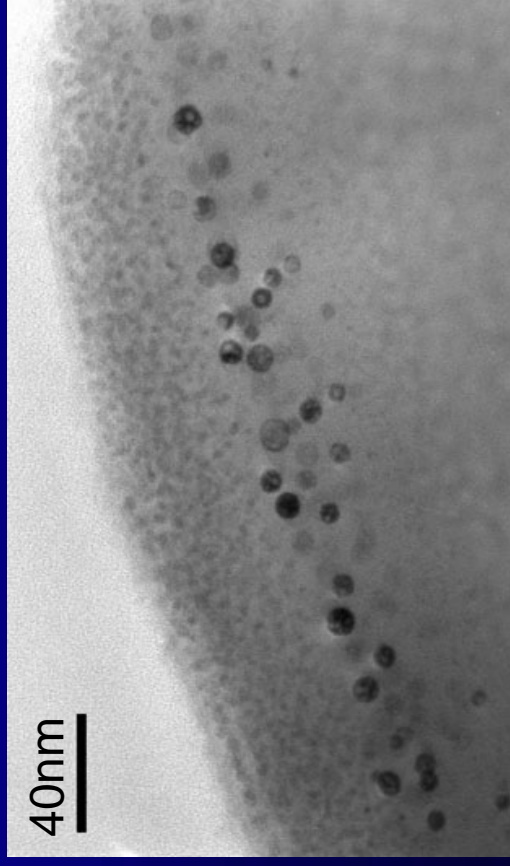
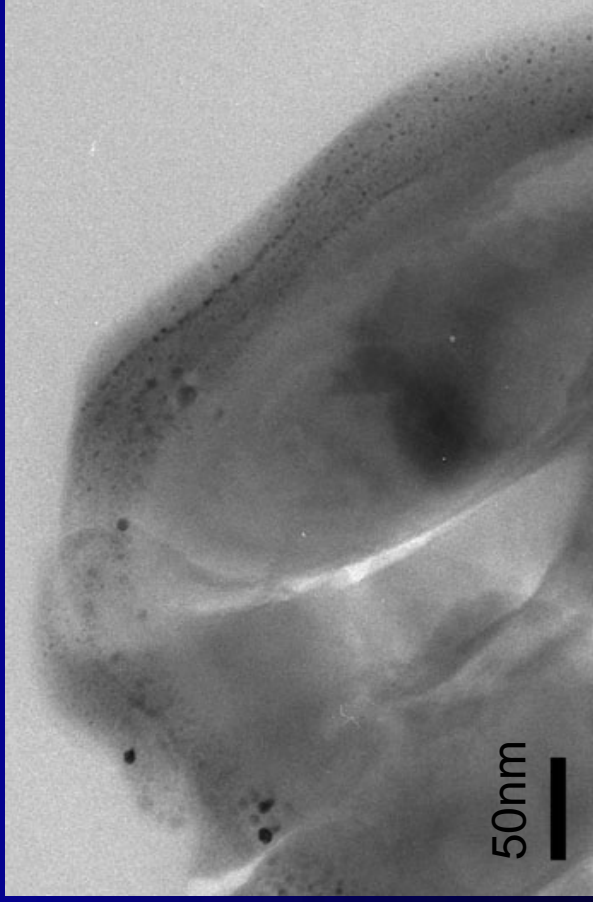
What does Moon dust look like?



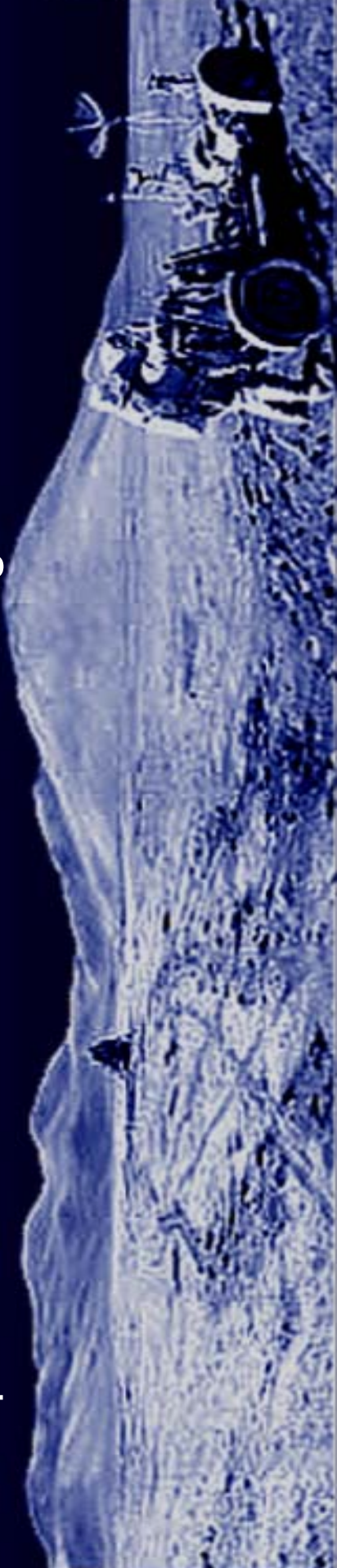
Lunar soils can be up to 70% agglutinates



What does Moon dust look like?



Nanophase iron-rich rims coat individual grains.

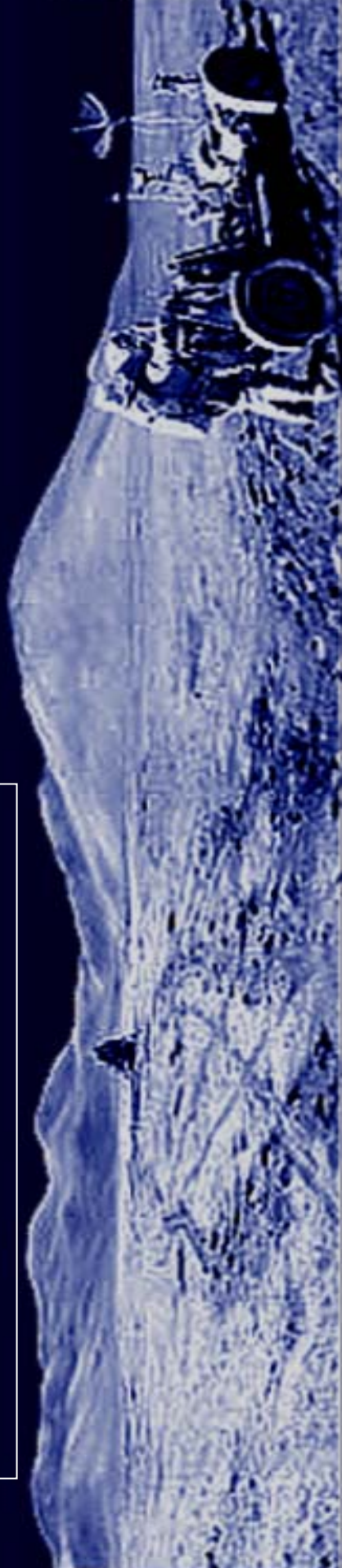


Planned Studies

- Understand soil properties, especially the finest fraction

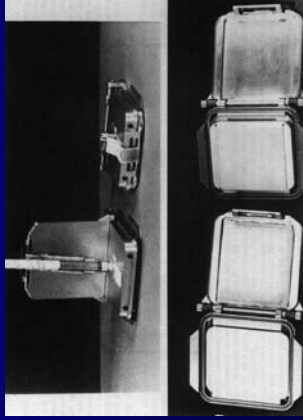
- Simulant
- Real lunar soil
- “Activated” lunar soil
- In-situ

- Biochemical assays
- Cell cultures
- Animal studies



Planned Studies: “Forensic geology”

Step 1: Follow the dust pathways to understand what gets in:



Clam Shell Sampling Devices

- What’s on the surface?



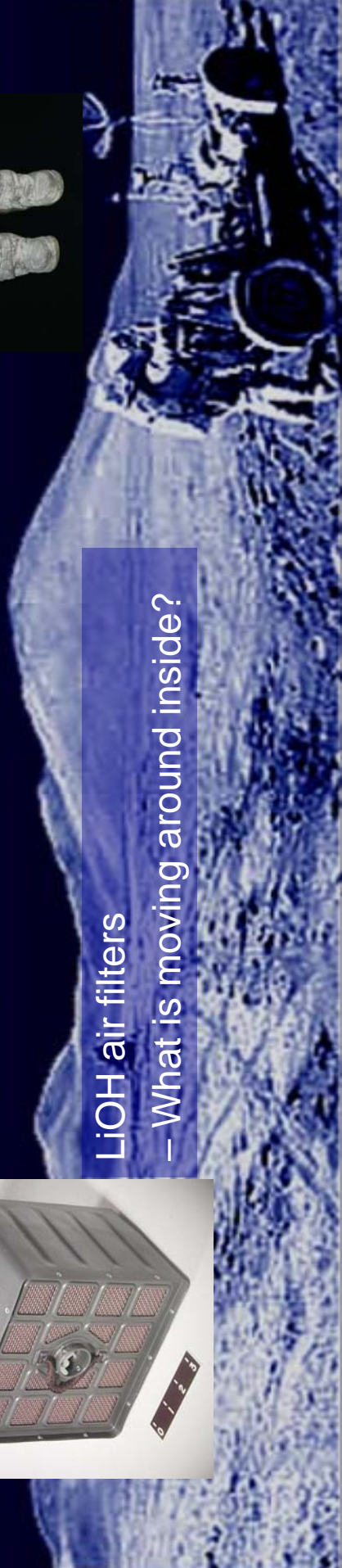
Apollo Space Suits
and vacuumed particles

- What got carried in?



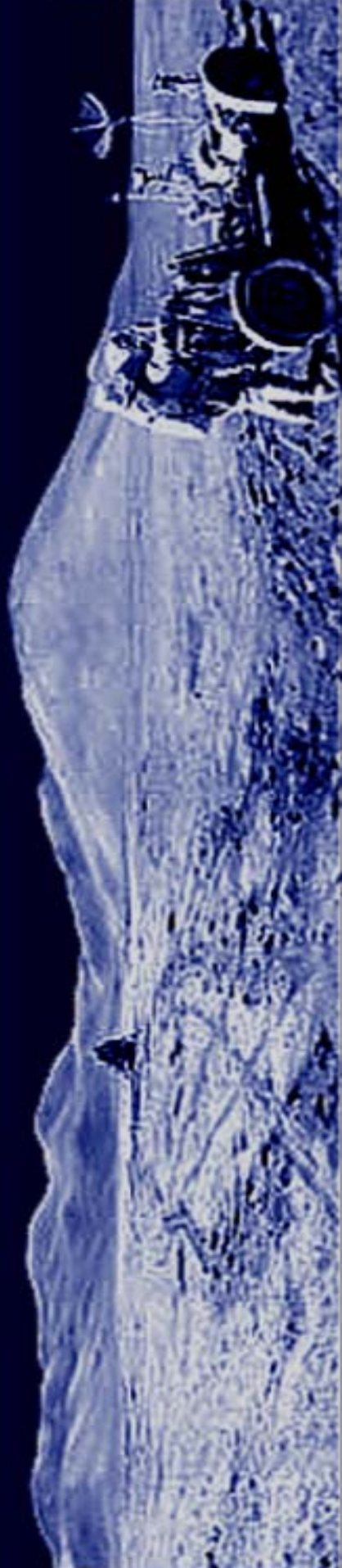
LiOH air filters

- What is moving around inside?



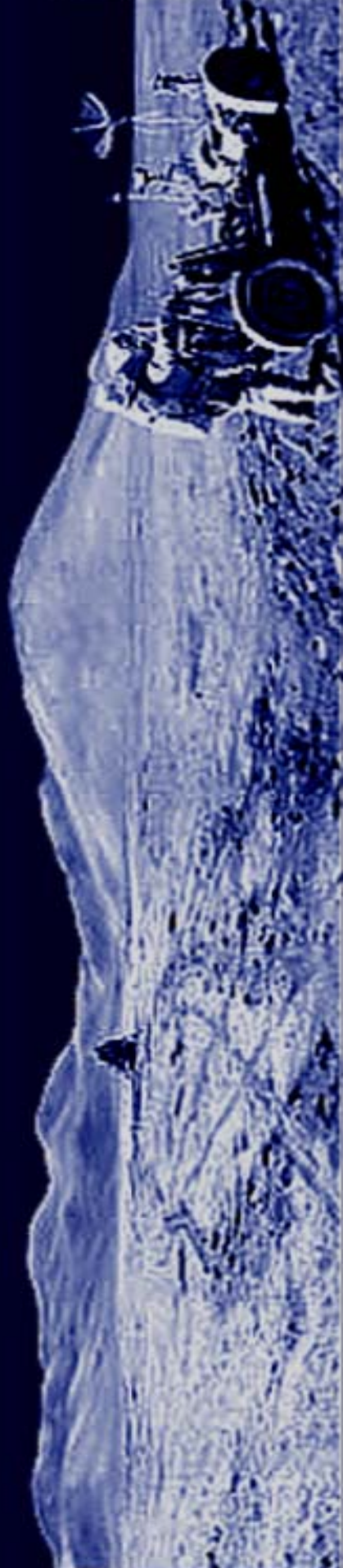
Planned Studies: Simulant vs. Real

- Point of using simulant is to practice and perfect techniques.
- Also good to test simulant itself.
- Even our best simulants don't do a good job of reproducing the properties of soil.



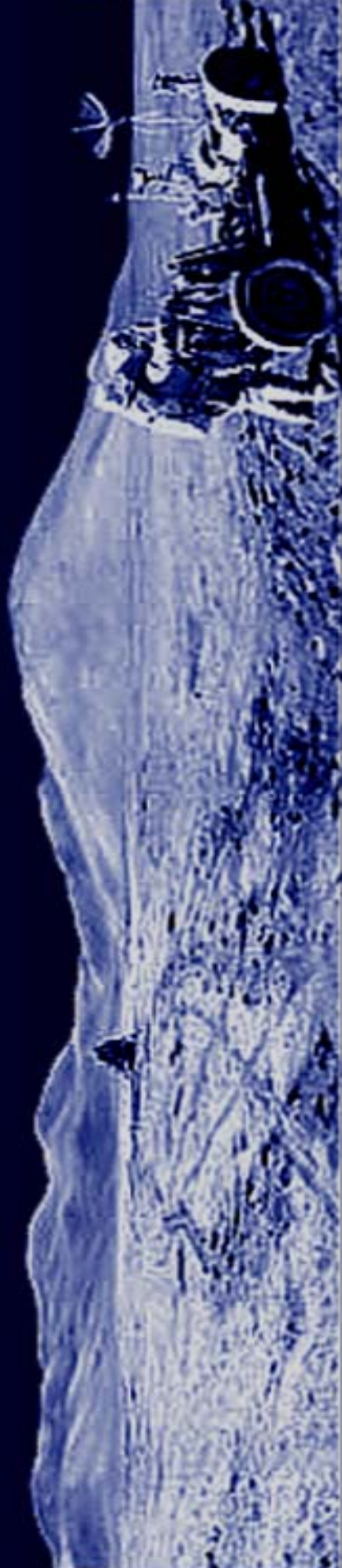
Planned Studies: Utilizing Real Samples

- Lunar soil is a precious commodity.
- Inhalation studies, in particular, require fairly large quantities of very small particles, which are difficult to separate.
- Soil sitting on Earth for nearly 40 years is not necessarily the same as fresh soil.
- Lunar soil is not all the same:
 - highlands vs mare
 - mature vs. immature



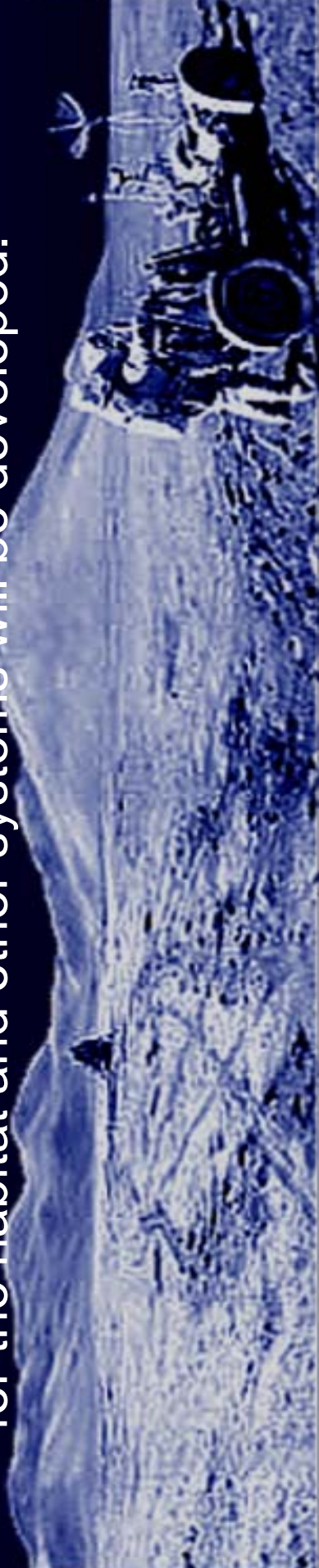
Planned Studies: Activating Samples

- We will attempt to recreate some of the conditions on the lunar surface through:
 - heating/drying the samples
 - exposing them to UV
 - bombarding them with protons
 - And/or crushing to expose fresh surfaces



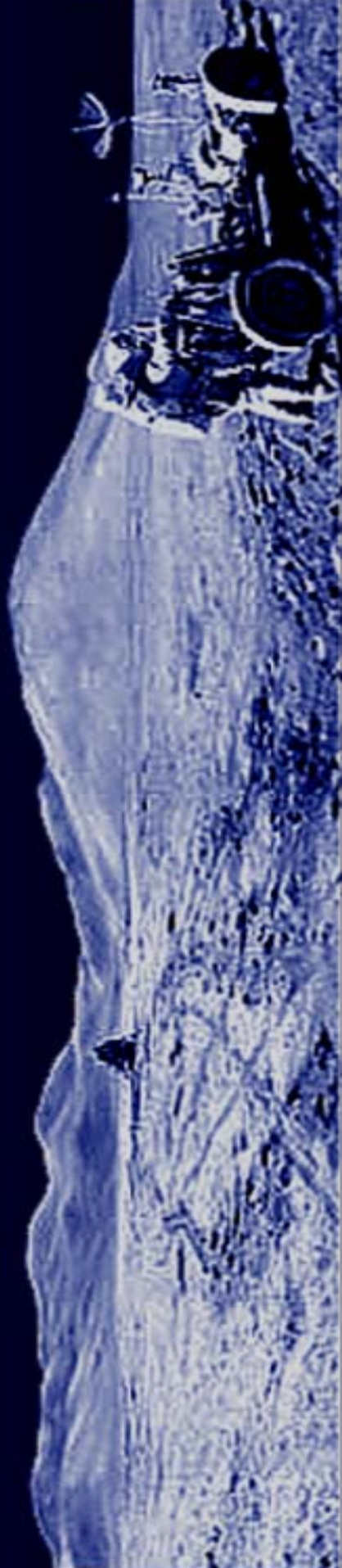
Planned Studies: In-situ Experiments

- No laboratory on Earth can reproduce the environmental conditions on the lunar surface.
- We need to decide if in-situ experiments are necessary
- Even if they are deemed necessary, we won't have results until well after the time frame when requirements for the habitat and other systems will be developed.



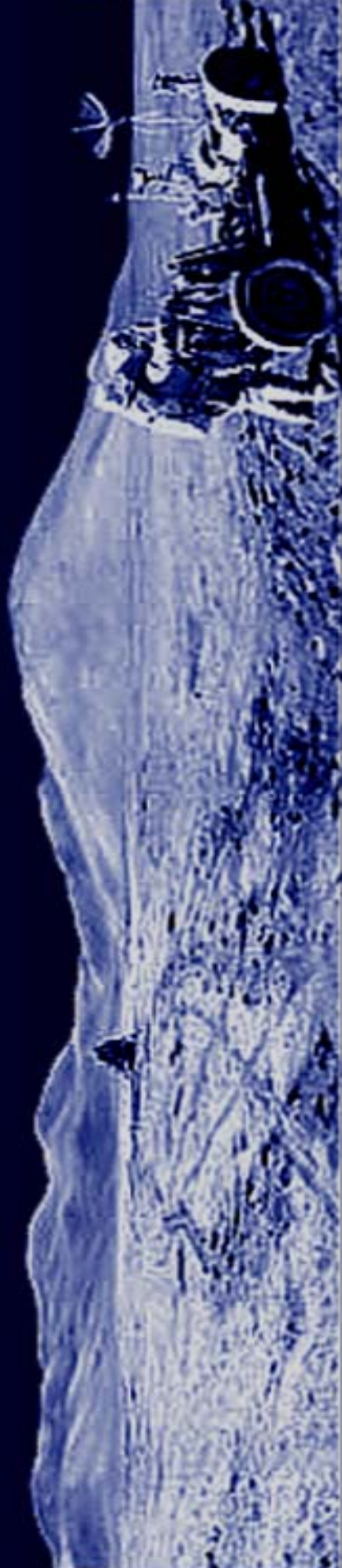
Dealing with Uncertainty

- Decisions have to be made in order to move forward.
- We will not have all the information we need to make a fully informed decision.



Communicating Across Disciplines

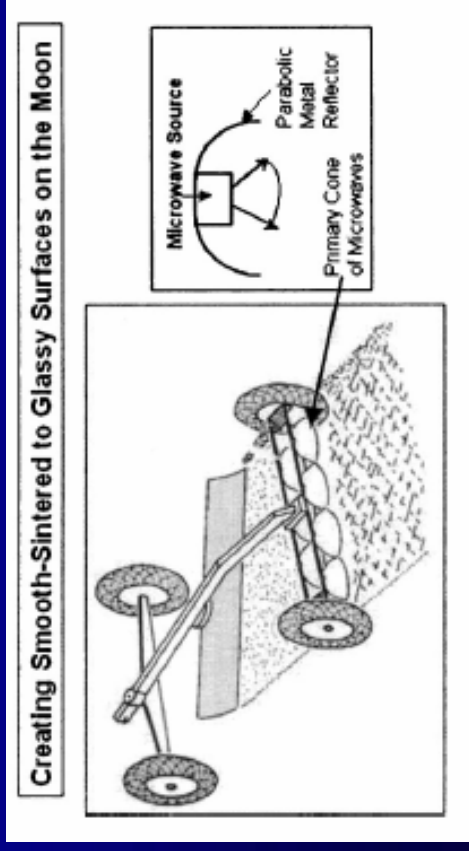
- Jargon = Bad
- Acronyms = Bad
- Need to be clear about what you need and what you can offer



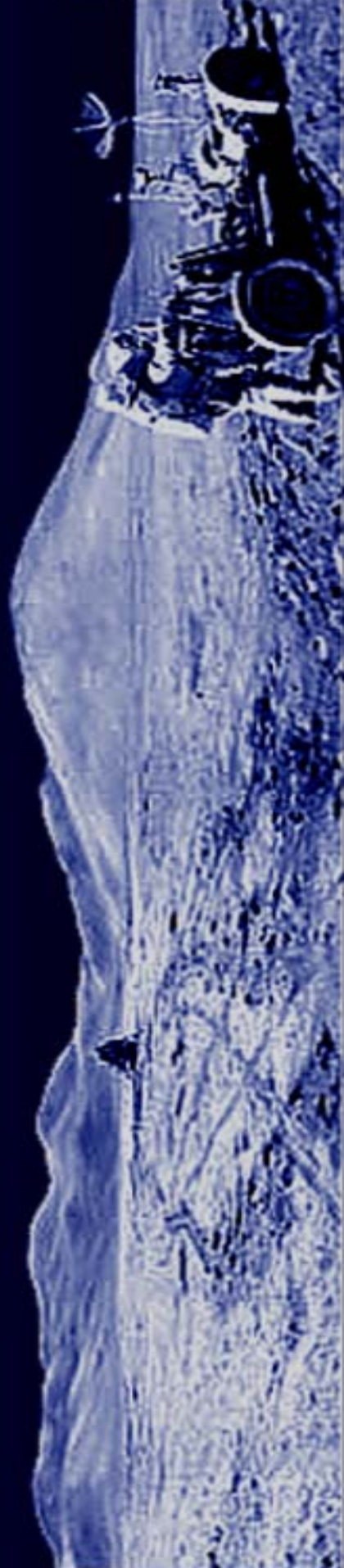
Making Lemonade

(turning lunar soil from a liability to an asset)

- Magnetic “lint” brushes
- Electromagnetic air filters
- Microwave sintering of soil
- Radiation shielding



Taylor and Meek, 2005



On to Mars

- Mars dust is very different from lunar dust
- It's finer
- There are frequent dust storms
- No samples means that we don't understand Mars dust properties as well

