Lunar Habitat Radiation Protection

Dust retention on Habitat
and
Lunar Dust Blower

Two different but related projects

Modify a snow blower to be used on the moon to blow lunar dust onto inflatable lunar habitats to shield the crews from radiation.

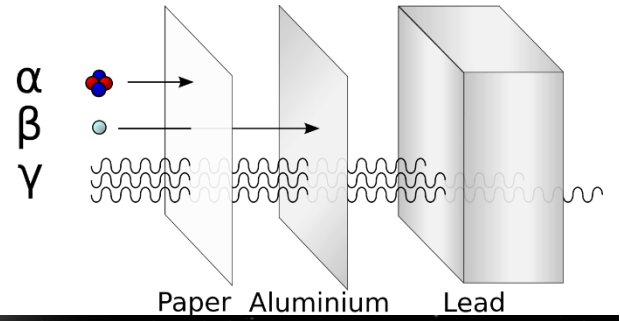
Develop a foldable waffle/baffle system for the outside of an inflatable habitat module that will prevent the lunar dust from sliding down the sides of the habitat and that will be deposited onto the top by way of Lunar Dust Blower

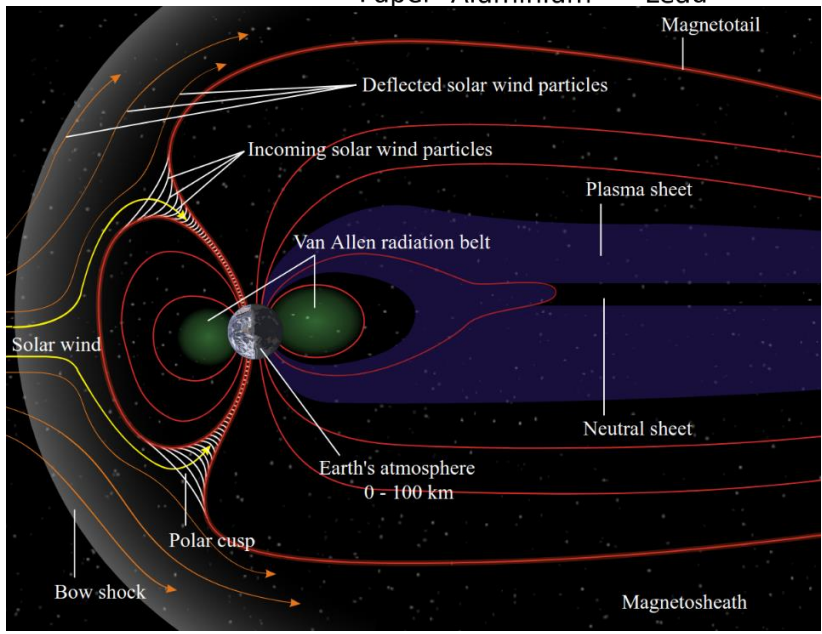
Lunar Radiation Problem

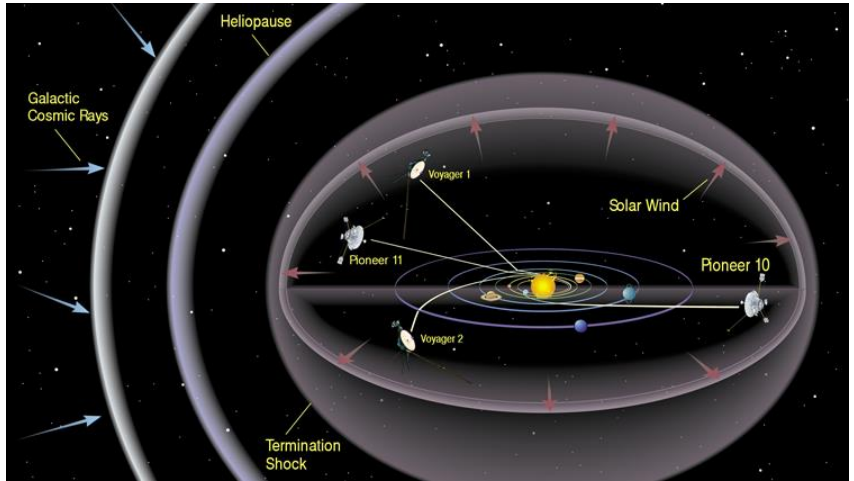
Types of radiation on the moon

One of the biggest problems of being on the moon or on Mars is the amount of radiation the crews will absorb both from solar radiation and from cosmic rays.

- Alpha, Beta, gamma, neutron —Radiation from radioactive materials like uranium and thorium and other naturally radioactive elements give off several different kinds of radiation. Alpha particles are usually 2 protons and 2 neutrons and have a positive charge. Beta particles are fast moving electrons that come from the nucleus and have a negative charge. Neutrons are fast moving particles without charge that are ejected from the nucleus of the atom. Gamma rays are an electromagnetic
- Solar particles—The Sun is mostly made of hydrogen that is being fused into helium. The Sun's gravity is what holds it all together but the heat and energy of the Sun pushes some of it off as charged particles. Most of the particles coming off the sun are protons and electrons—hydrogen parts. Helium nuclei (alpha particles) to a lesser extent. Most of these particles are coming off the Sun at very high speeds and can cause damage to electrical equipment as well as damage tissue as it passes through living organisms.
- Solar flares—there are times when the sun goes through changes that cause it to throw off large amounts of charged particles in a specific direction. There have been times when the Earth gets in the way of the solar flares and they damage satellites and disrupt the electrical grid around the globe. These would be especially damaging to people that are not protected. Suits and the think cladding of a space craft is not enough to protect the astronauts from these very energetic charged particles.
- Cosmic rays are particles from stars all over the galaxy mostly hydrogen and helium nuclei particles (but can be any other much heavier atom) that have been stripped of their electrons and are accelerated to near light speed. The heavier nuclei are especially hazardous because of the amount of energy and the charge they carry.
- High energy cosmic rays and neutrons can also collide with other atoms in the structure like aluminum, stainless steel or titanium and cause a secondary radiation from the structure.



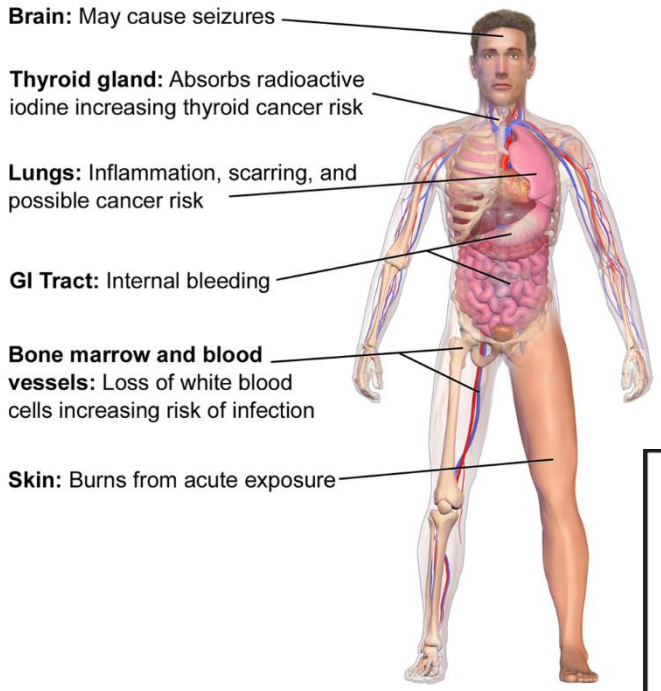




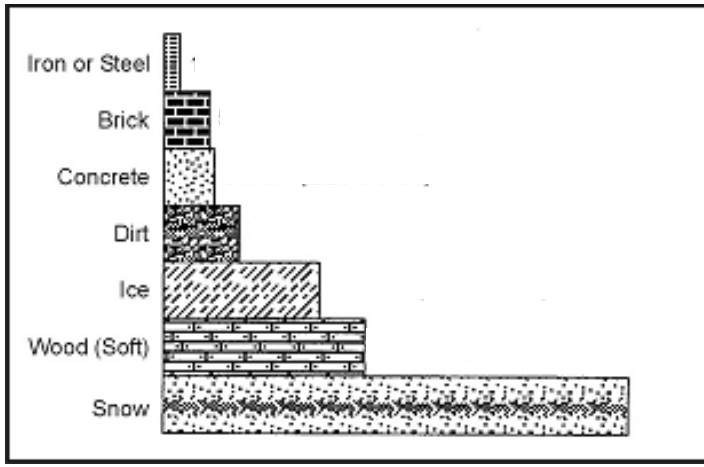
Types of protection

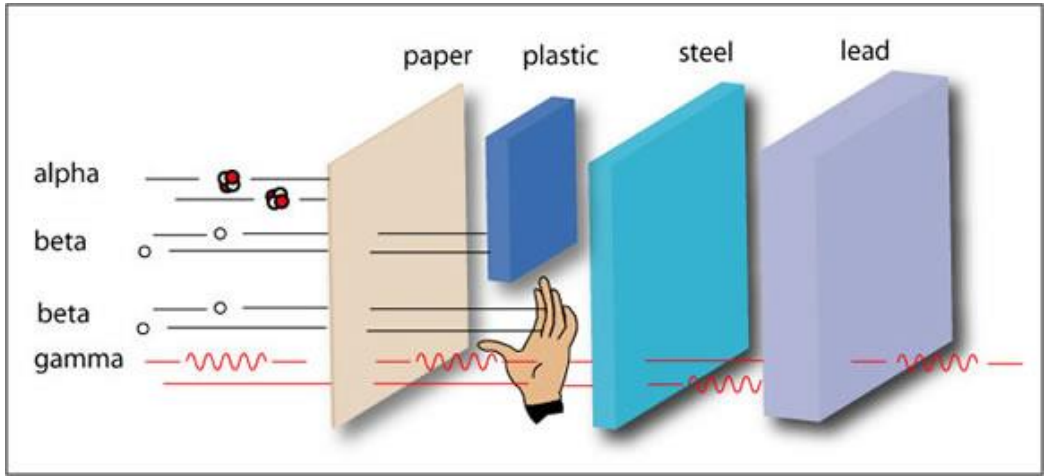
- Damage to humans—as particle and electromagnetic radiation passes through a person or other living plants and animals, the radiation can disrupt chemical processes, damage cells and even alter DNA that will cause cancers (no super powers yet).
- Earth's magnetic field and atmosphere are the main protection for life on earth from the radiation. Earth's magnetic field deflects a large portion of the particles from the sun before they get to the Earth's atmosphere. The magnetic field also curves the path of the charged particles so they are more likely to make contact with molecules in the atmosphere to slow them down. Some of this is seen as th Northern and southern lights.
- The moon does not have a magnetic field nor does it have an atmosphere. This means that the particles from the sun, solar flares, cosmic rays hit the surface of the moon and anything on it without being slowed down.
- Water and plastics are some of the best types of protection from radiation because of the number of hydrogen bonds that can absorb the energy of the different particles as they pass through. To protect the astronauts from the radiation using water or plastic it would require on the order of 2 or 3 feet thick o water or plastic. Unfortunately both are relatively heavy and could be cost prohibitive to send to the moon.
- Dirt--One of the other possible answers is to use some of the local soil and rocks from the moon or Mars to protect the crew. It takes more dirt and rocks to absorb radiation than it does water or plastics. But for the price of already being on the surface it is a good, cheap radiation shield which will also act as a thermal insulation and a micrometeorite shield. One of the many difficulties of designing a lunar base is how to put a significant amount of dirt for that protection on and around the lunar modules. Having crews shoveling dirt is time consuming and difficult but it uses the local surrounding material and could be more effective than many of the radiation materials that are being developed because of the amount of soil is available.

- **This is very basic information about radiation and students should continue looking up more information about conditions on the moon.**



Selected Risks from Radiation Sickness



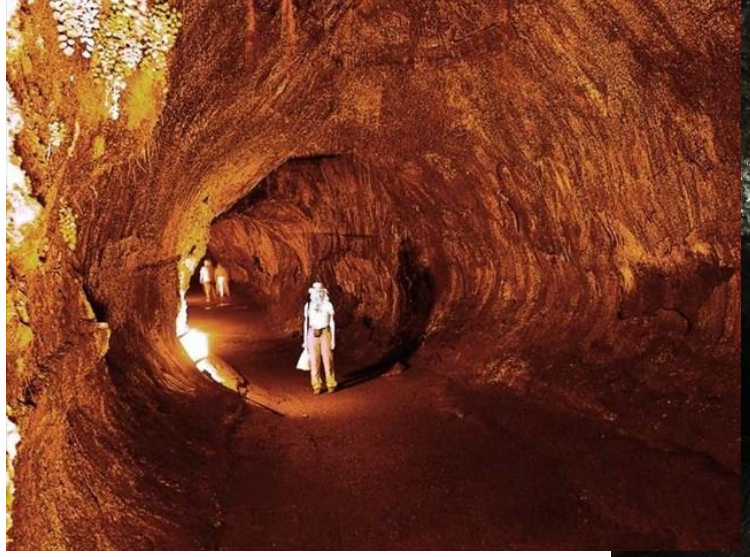


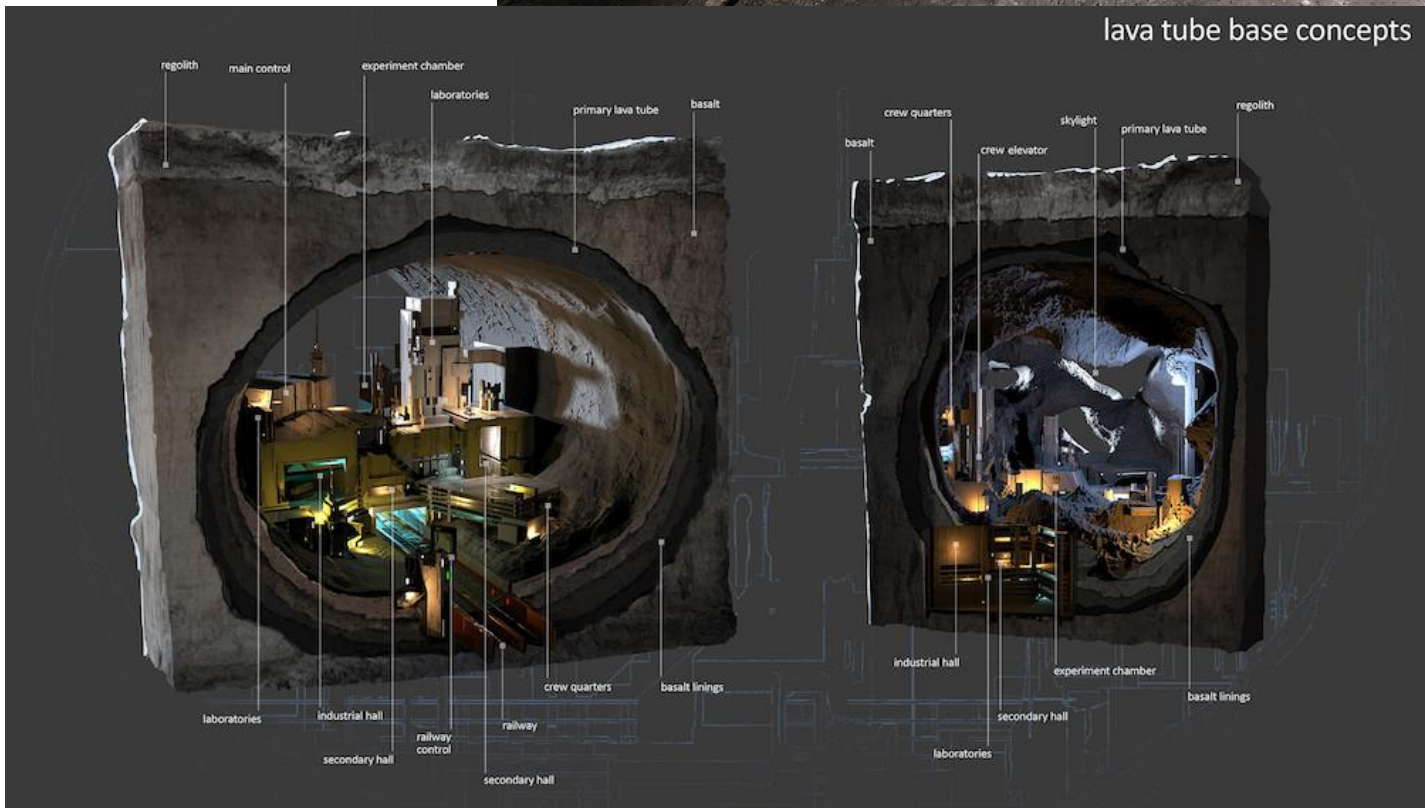
Radiation protection--5 ft is the goal

- The radiation scientists would like to have around 5 ft of lunar soil on top of the habitat to minimize the radiation the astronauts would receive during their stay on the moon. 5 ft of soil is a significant amount of weight on Earth but because this will be on the moon, it will be about 1/6th the amount of what it would be here on Earth. It will also be dry compared to most Earth's soil.
- 5 ft of soil going over the whole habitat is a significant amount of material to move. This would be the equivalent of several dump truck loads depending on the size of the habitat.

One possible solution

One possible option that is being discussed is to find a lava tube like those found in Hawaii and place the habitat inside. These are formed when lava is flowing out of a volcano where the outside of the lava flow cools and allows the center of the flow to remain liquid. At some point the liquid flows out of the tube and the inner walls are able to cool into solid rock. Finding a large, natural structure like this could be a terrific time saver and provide several feet of radiation protection and might even have a source of lunar ice inside (never sees the light of day). Unfortunately we don't know where to find any lava tubes yet and once found, the location of any lava tube may severely limit where the lunar base can be set up. It also may be difficult to clean out the lava tube if there is any debris from the ceiling collapsing. No two lava tubes are the same size or dimension so it may be hard to plan a habitat to fit inside. There may be sharp edges inside that would need to be smoothed out before it would be safe for the habitat or even space suits.





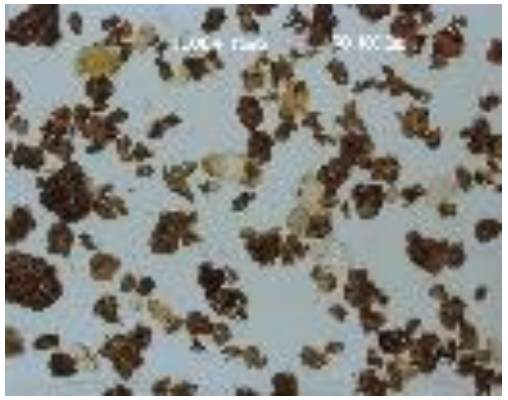
Alternate solution-- Placing lunar soil on top of the lunar habitat.

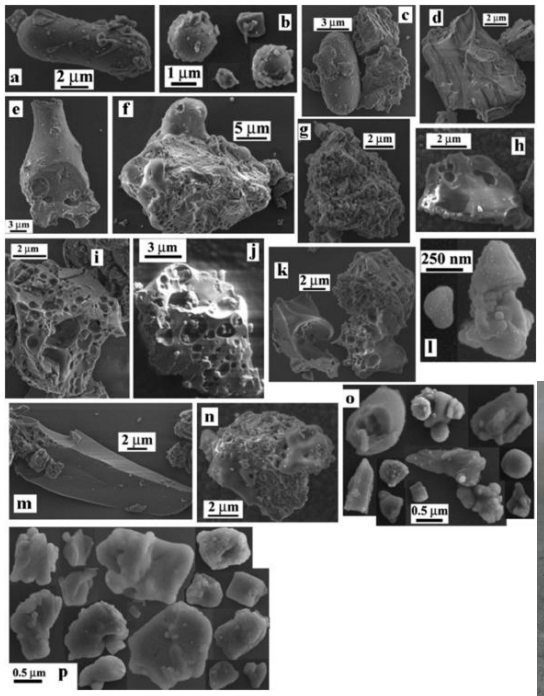
If you can't have an already built lava tube in the desired location, it would make sense to pile dirt on top of the lunar modules to the desired thickness. As long as there is loose soil surrounding the area, the base could be placed nearly anywhere.

- Difficulties—
  - Piling the dirt up on the sides is helpful but the majority of the radiation will be coming through the roof.
  - Large, sharp rocks could damage metal and inflatable modules.
  - Will need to move large amounts of soil
  - Limit the weight of the machine that places the soil on top of the module
  - Need to prevent the soil from sliding off the module
  - Minimize astronaut labor time and effort.
  - How much can be automated?
  - May need to bring soil from further away.

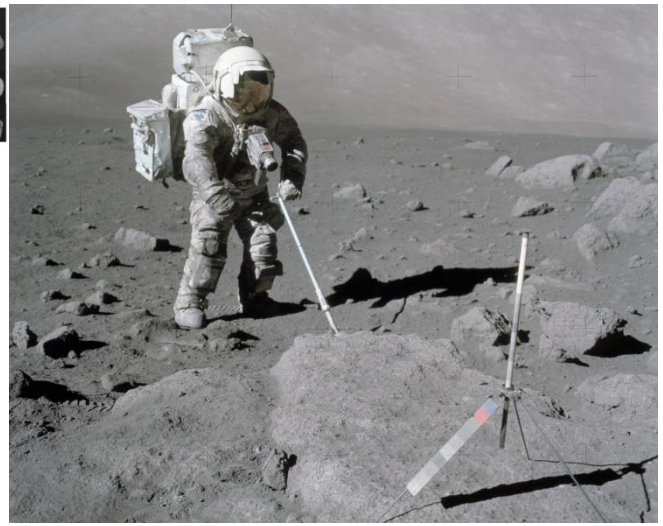
Lunar Soil problems

- Most lunar soil that came back from the Apollo missions was a fine powder. Because there isn't wind or water to move the soil around the moon, the grains are like tiny, sharp shards of glass. In some areas the soil was only a few inches deep and in others it may have been a foot or more. When the astronauts came back into the lunar module, the air was very dry and the little dust particles on the suits were susceptible to static electricity so they would stick to the walls and equipment or they might float in the air since there wasn't as much gravity. This meant they could be inhaled or get into eyes.
- Last year we found that this jaggedness of the particles makes them cling together different than our soil. Imagine the difference between sticking your hand in jar of marbles or sticking your hand in a jar of Jacks (like the game with the ball). The marbles will roll past each other and allow your hand to push in easily. The jacks will lock together and prevents your hand from going very deep into the jar.
- There are also areas that have larger particles like pebbles, gravel and rocks but they would all be fairly angular and sharp edged since there aren't streams to roll down or dust storms to smooth them out.





Very fine powder. Feels kind of like powdered concrete.

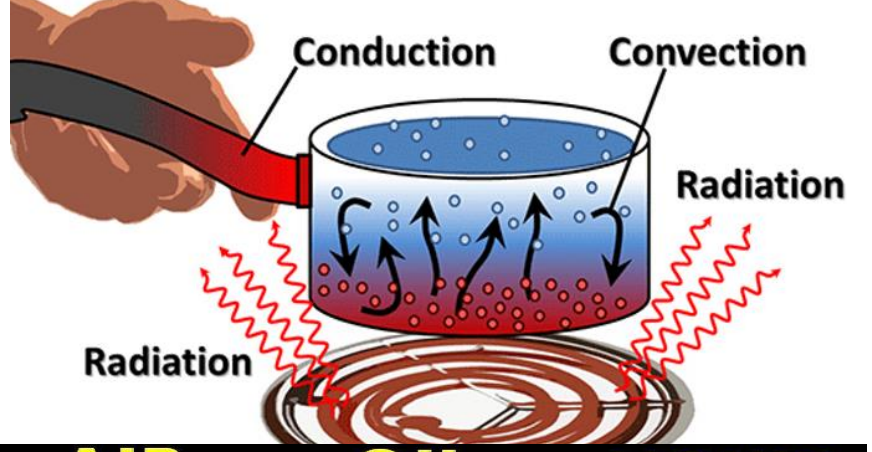


Notice the fine dust on the white suit.

Cooling of motor

- This lunar dust blower will need to run for longer periods of time without stopping in order to put the amount of dirt on the habitats. Realistically, they can start and stop to cool off as needed but the longer they can operate, the faster the habitats can be made safe. Cooling a motor in space can be tricky since there are very different conditions between the Earth, on the moon and in space.
- There are 3 kinds of transmission of heat—conduction, convection, radiation. Conduction is transfer of heat by contact. Convection is transfer of heat by flow of air or fluid. Radiation is transfer of heat by way of infrared light.

https://www.machinedesign.com/learning-resources/whats-the-difference-between/document/21834474/whats-the-difference-between-conduction-convection-and-radiation

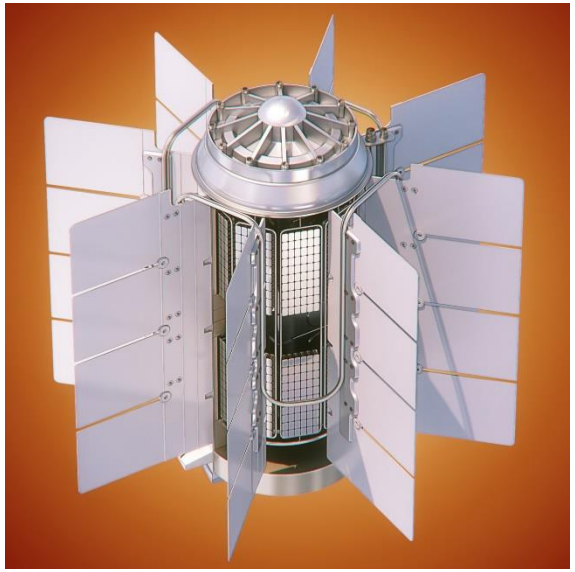


Motor cycle engines are known for using various cooling methods to keep the engines from over heating

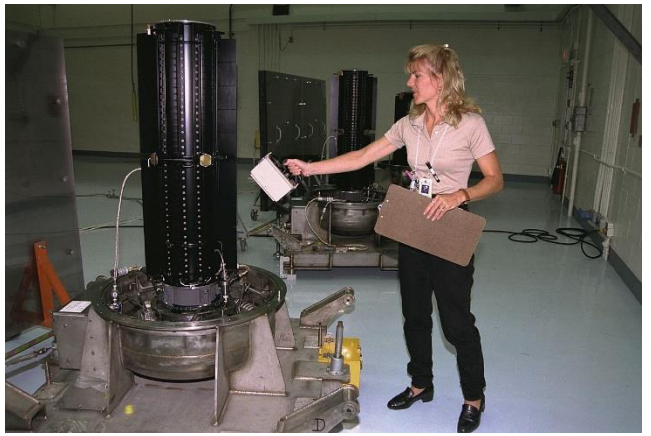
The Pistol Grip Tool used on the ISS by Ann McClain during a space walk is made out of aluminum to act as a heat sink for the motor but is not usually used for more than a few minutes at a time.

Heat sinks

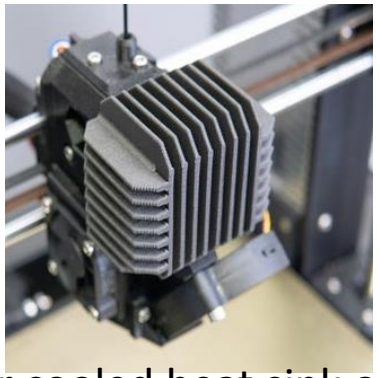
- On Earth, electric motors and gas powered engines are cooled by liquid or air flowing across hot sections. The liquid (water, radiator fluid, oil) on these engines is usually cooled by air flowing through some kind of radiator to take the heat away. In space or on the moon there isn't any air to blow across the motor or to blow through a radiator. They will have to depend on heat sinks and radiative cooling. On the International Space Station there are lots of motors that cycle on and off and some that run continuously at low speeds. Some of the cycling and low speeds are to prevent over heating of the motors.
- A heat sink is a larger object (usually a good conductor of heat like metal) that is put in contact with the hot motor. The heat sink conducts and spreads the heat away from the motor. Fins cut into the heat sink allows more surface area for convection and radiation to take the heat away.
- On Earth the motor is losing its heat to the heat sink by conduction. The heat sink loses its heat to the air with convection and a little bit by radiation. However, in space the motor still conducts its heat to the heat sink but the heat sink can only radiate that heat away by infrared light. There won't be any convection so it loses its heat much slower. More fins and bigger fins can assist in helping dissipating the heat faster. Dirt can act as an insulator if it gets on the heat sink. It will be important to keep the dirt away from motor if possible to prevent additional heat build up.



Radioisotope Thermoelctric Generators depend on heat sinks and cooling fins to dissipate heat from plutonium for generating power on deep space satellite missions.



This RTG was for use on the Cassini space craft going to Saturn



Air cooled heat sink on stepper motor on 3D printer

Requirements for Dust Blower

Problem:

Lunar soil is a cheap radiation and impact protective cover for lunar habitats. The habitats are expected to be inflated and over 15 feet tall. Dirt can be pushed up to the sides of the habitat with a bulldozer type of blade but the most radiation will be coming straight down through the top of the habitat where it will be difficult to get the soil up to and just as difficult to keep it from sliding down. We need a simple method of getting the soil up on top of the habitat without damaging the outer covering—don't pop the house. The sliding down of the soil will be handled by the Lunar Soil Waffles/baffles team. Fortunately for us, engineers in northern climates have already developed snow blowers that could scoop up light weight lunar soil and throw it up on top of the inflatable structures. The soil on the moon is similar to the mass of soil on Earth but is has less weight because it is on the moon. Snow blowers are designed for snow on Earth not lunar soil with rocks and abrasive grains.

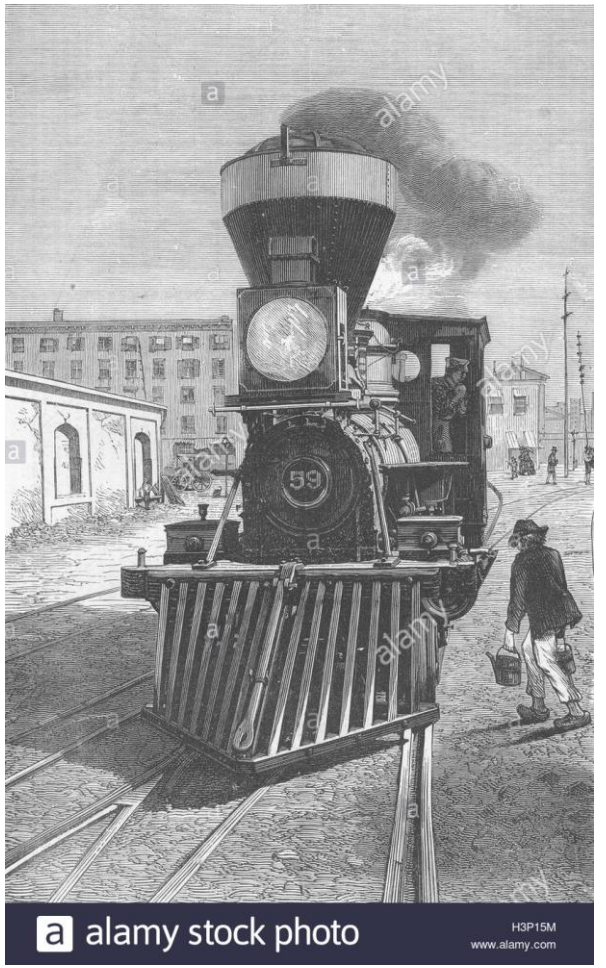
Objective:

Modify a snow blower to be used on the moon to blow lunar dust onto the inflatable lunar habitats to shield the crews from radiation and micrometeorites. To be clear, you are not redesigning a snow blower. Snow blower technology is already developed.

- Must be electric
- Don't throw rocks bigger than 1"
- Mitigate overheating of the motor
- Good wheels for the moon (talk to last year's Lunar Wheels teams)
- Easy to control with heavy gloves and bulky space suits
- Directional shooter of the dust
- Easy to push and maneuver through dust
- Variable speed motor (don't throw it hard when close to the enclosure)
- (This may be something that could also be automated in the future)

Tips and thoughts on snow blowers

- Temperatures range from +250 degrees F to -250 degrees F
- Pneumatic tires can not handle that kind of temperature changes nor can most plastics
- Think about materials that can handle both very cold and very hot
- Snow blowers are already set up to operate with gloves but make sure you keep it in mind as you make changes
- Keep in mind that the lunar soil will be more abrasive than snow or ice.
- Saw dust is often used for testing of snow blowers.
- Small, light weight, powerful
- It costs over $1.2 million per pound to get something on the moon—keep it light weight.
- Grill for rocks, wheels, account for abrasiveness of dust
- Cattle guard on a train, sieve, lunar rake




NASA-Apollo 16 photograph.

Requirements for soil baffles

Problem:

Lunar soil is a cheap radiation and impact protective cover for lunar habitats. The habitats are expected to be inflated and very smooth which would allow the dry, powdery dirt to slide down the sides with little coverage on the top where it is most needed. We need some method of keeping the dirt that is placed on top from sliding down the sides and being retained on top.

Objective:

Develop a foldable waffle/baffle system that attaches to the out side of an inflatable habitat module that will hold the lunar dust and prevent it from sliding down the sides of the habitat. The dust is expected to be deposited onto the top by way of Lunar Dust Blower

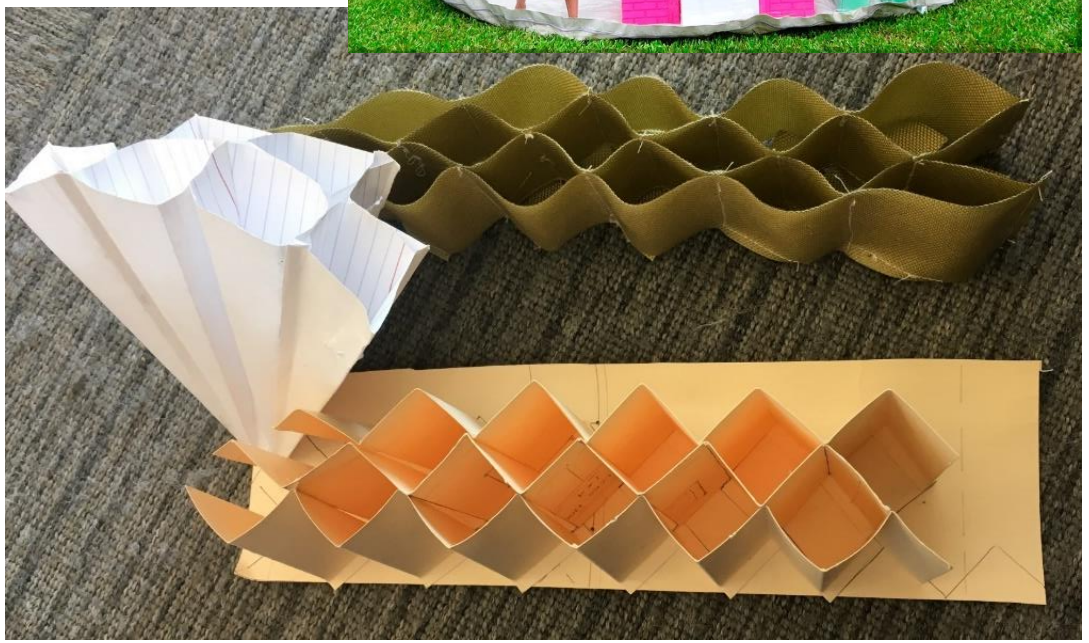
- Lighter weight is better
- Scale your prototype to a 24” diameter model (needs to fit on the demonstration table)
- Collapses into small space for transport to the moon
- Must fold out as the enclosure inflates.
- Attaches to the outer covering of the inflatable habitat
- The main goal is to keep the soil from sliding off the top of an inflated module. Once some minimum amount of soil is held in place, the soil on top of that should pile up and remain.
- There may be other cloth/flexible material based methods besides waffles/baffles.

This cylindrical cloth wrapper is what is inside some types of mattresses to separate the springs. Would this kind of cylindrical cloth wrapper be a good model for being collapsed for transportation and expanded open to hold dirt?

This is a woven or knitted waffle pattern in the cloth.

Tips and thoughts on waffle/baffles

- Saw dust (not wood shavings) may be a good simulant for this.
- Not all of the waffles/baffles have to be the same. The ones on the very top may not have to be as big as the ones on the sides since the dust would slide less where it is more flat and slide more where the slope of the habitat is greater.
- We don't want the soil to be sliding down over time, it needs to be fairly stable.
- The cloth does not need to be overly strong but it needs to be able to add structure to the soil so that the soil isn't shifting when people bump into the inside walls of the habitat.
- You might use something like a an inflated beach ball as the structure to model around. Or you might need to use something rigid like a mixing bowl to hold the needed shape and still be slippery to the soil.



These are cloth and paper waffle/baffles I made that might be folded up for transportation and then expanded out by the inflation of the hab module to hold soil. Each of these has value but also has difficulties that need to be worked out for implementation.

- https://segd.org/content/billboard-earthbag-project

Other proposed methods

- If you do a search for lunar habitats, you will find that there are many other competing ideas for how to use lunar soil for making radiation barriers and structures on the moon. Some are using heat to melt the lunar soil or epoxy to hold the soil in place or some other option. Many or all of them have good reasons to be used. However, no single method is good all the time in every location. Just like on Earth, there are many options for construction and times to use many of them depending on the location and the conditions of the area or even the needs of the time. On the moon there may be reasons to use all of these methods for different locations. Cold temperatures in some areas may not allow epoxy to flow or to cure properly. Lack of sun in some areas may not allow for using solar rays to be concentrated and melt the soil.
- This waffle/baffle project is one way of supplying the structure for the loose, deposited soil before leaving Earth and it being incorporated into the inflatable engineered product. I expect there may be times this method of holding the soil is not as desirable as another but that is part of the need for options.