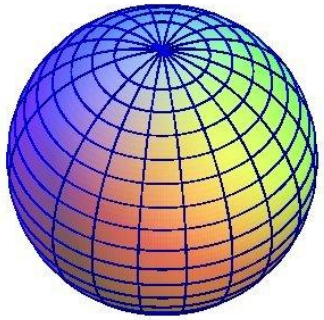
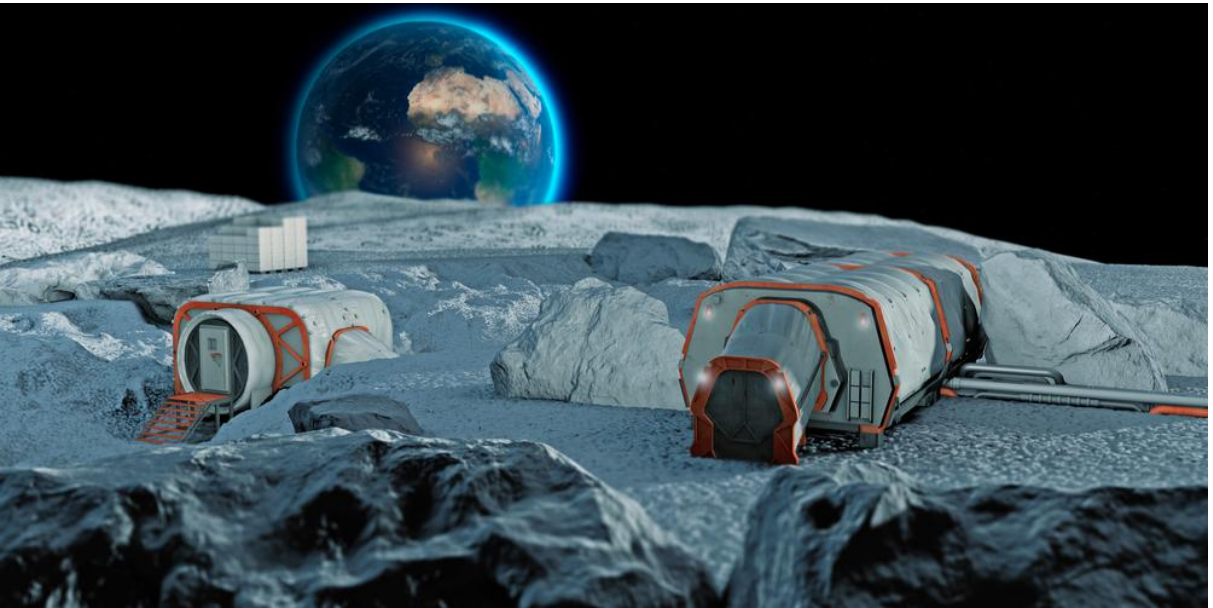


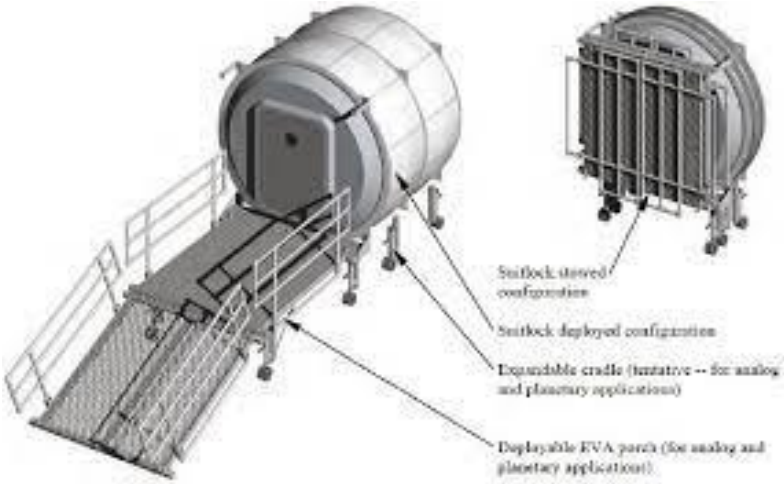
Supply Pod Airlock

by Glenn Johnson

In previous years, HUNCH students have designed Lunar Supply Pods that hit the lunar surface at high speeds and use friction with the lunar soil to slow down and bring durable materials (water, food, nuts, bolts, clothing,…) to the surface of the moon without bringing a lot of support structure and engines that would end up being wasted trash on the moon. HUNCH students have also designed Lunar Supply Pod Movers that will allow the astronauts to pick up the Lunar Supply Pods with the lunar rover and bring it back to the Habitat where it can be unloaded. Now HUNCH needs a safe place where the crew can unload the supplies. If the crew unloads them outside in the vacuum of the lunar surface, the space suits are going to be too big and bulky to be able to crawl into and out of the supply pods and dust would probably get on all of the supplies. The supply pod needs to be brought into a controlled environment to make it easy for the crew to unload the supplies and bring them into the habitat where they can be used.

Design a Lunar Airlock big enough for astronauts to unload supplies and equipment from a cylindrical or spherical Lunar Supply Pod along with any support equipment and tools needed for the job while being protected from the vacuum of space on the Moon. This airlock will need to have a large enough opening for the supply pod to either roll or be placed inside and be able to while able to handle dust.





Requirements for Lunar Supply Pod Airlock

Problem:

HUNCH needs a safe place where the crew can unload the Lunar Supply Pods. If the crew unloads them outside in the vacuum of the lunar surface, the space suits are going to be too big and bulky to be able to crawl into and out of the supply pods and dust would probably get on all of the supplies. The supply pod needs to be brought into a controlled environment to make it easy for the crew to unload the supplies and bring them into the habitat where they can be used.

Objective:

Build a scaled model (will fit on top of a desk)of an airlock big enough that can be used for emptying the contents of a supply pod. Use a baseball as the dimension of a spherical supply pod (2.8 in). Find a similar sized soup can to represent a cylindrical supply pod.

- Suggest construction materials. Show how these or similar materials will be put together.
- Provide ideas of how it will be delivered to the moon and attached to the smaller airlock
- What kind of hatches or sealing 'doors' would be used?
- How will it handle the lunar dust without leaking?
- What does the Lunar Supply Pod Mover need to be able to do for your airlock? You can impose requirements on both the supply pod and the mover (within reason).
- What kind of tools may be needed for unloading the supply pods?

Tips:

Be prepared to explain how the Supply Pod Mover gets the Supply Pod inside the airlock. (page 7 of presentation)

- What tools do the crew need to have for unloading the supply pod?
  - What needs to be in the airlock so the supply pod is accessible and doesn't move while being unloaded? (its round and can roll)
  - What kind of lighting is needed?
  - Once the airlock hatch is closed it may be important to clean up the dust so it doesn't get into everything that is unloaded. What kind of tools are needed?

Is there an orientation that could minimize the amount of dust that gets on the hatch or gets inside?

What methods could be used to remove dust that does gets inside? Air filters, sweepers? Is there a way to prevent the dust from getting inside?

Does the airlock have to be at 14.7 psi? Could it be at 10.2 psi or 4.0 psi to minimize stress on the airlock and air that might be lost to leaks? Can people breath at those lower pressures?

Could there be a multiple zipper hatch like those used on body bags?

Could there be air filled support beams to keep the roof up when the airlock doesn't have air in it? T

Are there specific shapes that would make it easier for the pod to be placed inside?

Are there specific shapes that make the volume easier to work in?

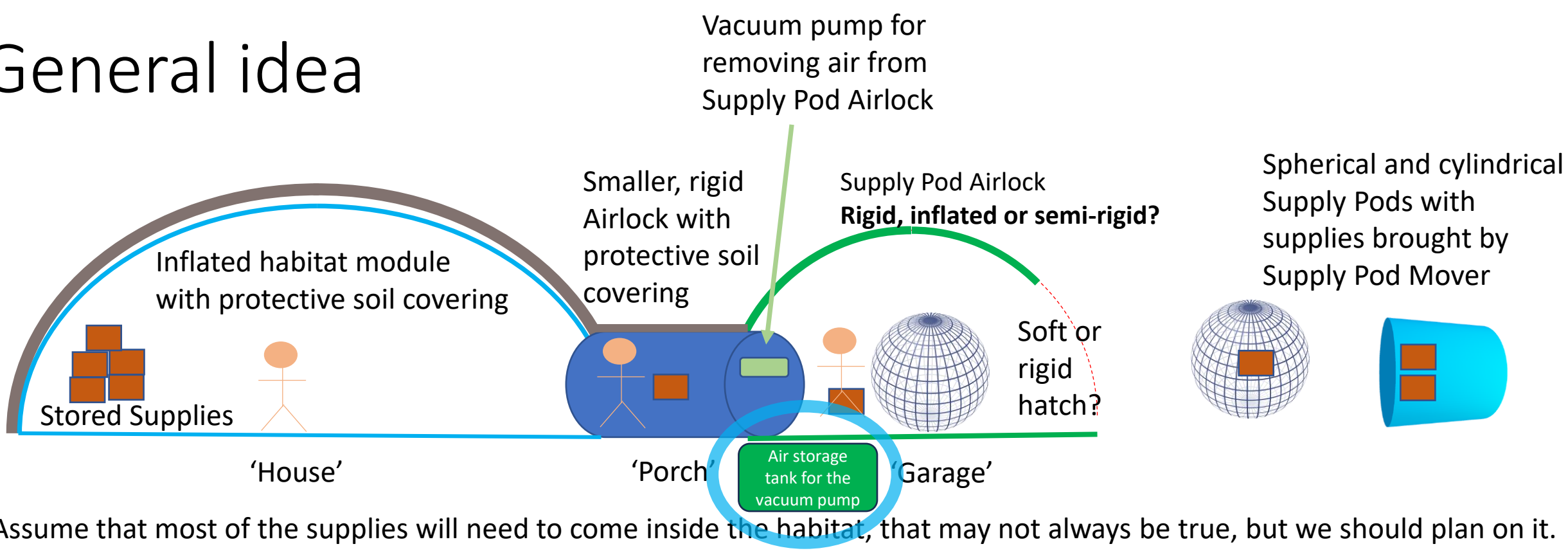
Are there specific shapes that are easy to construct with the materials you are choosing?

What kind of lifespan might it have?

How are you going to represent your ideas for how it is constructed? Cloth, inflatable materials, paper mache—the more accurate your model, the less imagination your reviewers need to have.

What all can your idea of a garage perform—removal of supplies, staging area for supplies, can the rover come inside (more dust)?

General idea



Assume that most of the supplies will need to come inside the habitat, that may not always be true, but we should plan on it. The biggest goal about airlocks is trying to not lose air every time it is opened and closed. Because the supply pod airlock is large enough to handle the supply pods we should plan on using it only when there are pods to be emptied and disassembled and/or filled with trash. Use of the smaller airlock will minimize the amount of air that is lost each time crew go in and out of the habitat.

Think of the habitat as the 'house', the smaller airlock as the 'porch' and the supply airlock as the 'garage'. Your job is to design the 'garage'. The supply pod airlock may also act as kind of a dust porch so that less stray lunar dust will get to the 'porch' airlock and even less will get inside the habitat.

What kind of flooring will the Supply Pod Airlock need? Can it still be flexible or does it need to be rigid?

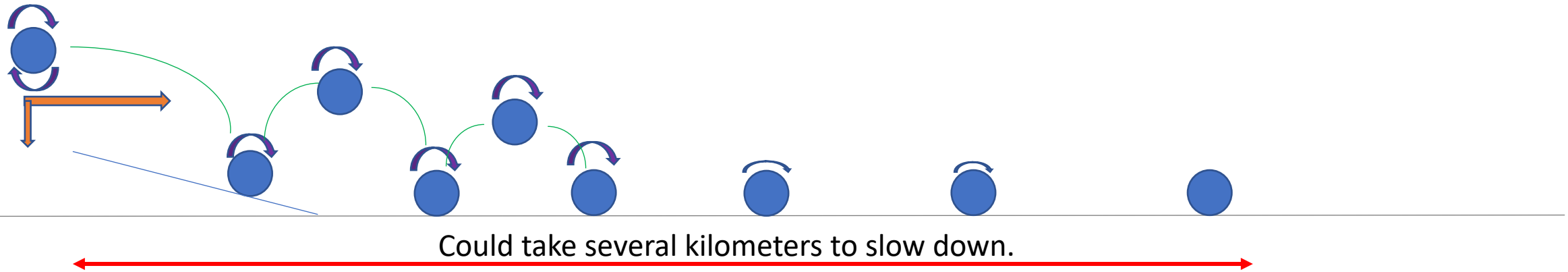
What is a Lunar Supply Pod:

Not all supplies to the moon need to be placed gently onto the surface. Water, food, nuts, bolts….supplies that are unlikely to get damaged by touching down harder and can handle a rougher delivery as long as the pod doesn't break open. Placing materials on the moon costs around $1.2 million per kilogram. If we can cut down on the amount of mass we have to send that isn't supplies (fuel, engines, landing gear), we will be able to send more supplies for less cost and have less trash on the moon.

The purpose of the supply pod is to decrease the **mass** used to get supplies to the Moon without breaking open:

- Minimize the amount of fuel needed to slow down the supplies
- Decrease the amount of landing gear
- Decrease the amount of materials left on the moon

Lunar Supply Pod bouncing and rolling to a stop on the moon before being picked up/transported by a SEV with some kind of tool.



We expect that, just like a golfer can aim a ball pretty close to a hole, NASA would be able to aim a supply pod within ½ mile radius of where the astronaut could pick it up. But this still means that it may be too far for astronauts to walk to and it will be too heavy for them to move by hand or foot. We will need to use the SEV to bring it back to the Lunar Base. This means we will need some kind of tool either on the front or the back of the SEV that could pick it up, drag it or roll it to the Lunar Base---This is another project.

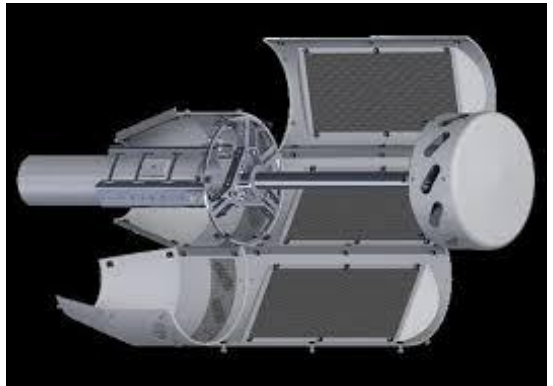
Lunar Supply Pods

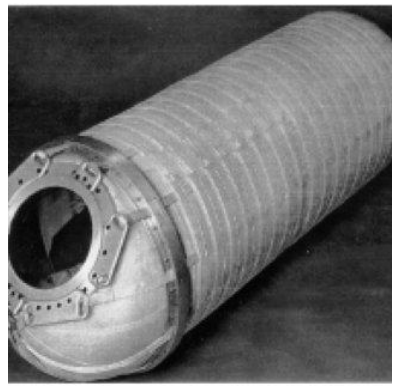
- Lunar Supply Pods are a project that were worked by HUNCH students in 2019 to 2020.
- In the same way that you wouldn't want to bring groceries to a house and leave the whole truck behind but instead just leave the bags of groceries, Lunar Supply Pods are the bags of groceries that are dropped off on the moon from orbit and allowed to bounce and roll to a stop using friction from the lunar soil and rocks to slow them down. We are planning for them to roll to a stop within a ½ mile radius from the Lunar Base. The exact design of the Pods have not been determined but we expect them to be either spherical and/or cylindrical so they can roll easily. They will have some kind of attachment points that can survive the touchdown and rolling without being damaged.

These are not Lunar Supply Pods but images of similar structures for different purposes. Expect the Lunar Supply pods to be either spherical or cylindrical with a diameter of 2m and a length of 4m(if cylindrical). Expect that there will be at least one hatch and probably a second hatch.

One of the teams from last year suggested the Supply Pod could be made of several tetrahedrons that come apart when the pod bounces down onto the surface to dissipate some of the kinetic energy. This a good idea that we are retaining partly because it would allow the use of the pod materials after the pod is emptied.

- It would be wise to look over the requirements for the Lunar Supply Pods so you know what you are designing for.
- http://www.hunchdesign.com/uploads/2/2/0/9/22093000/lunar_supply_pods_-_10-16.pdf
- You are welcome to look at how Finalists from last year designed the Supply Pods.
- http://www.hunchdesign.com/finalist-review-videos.html



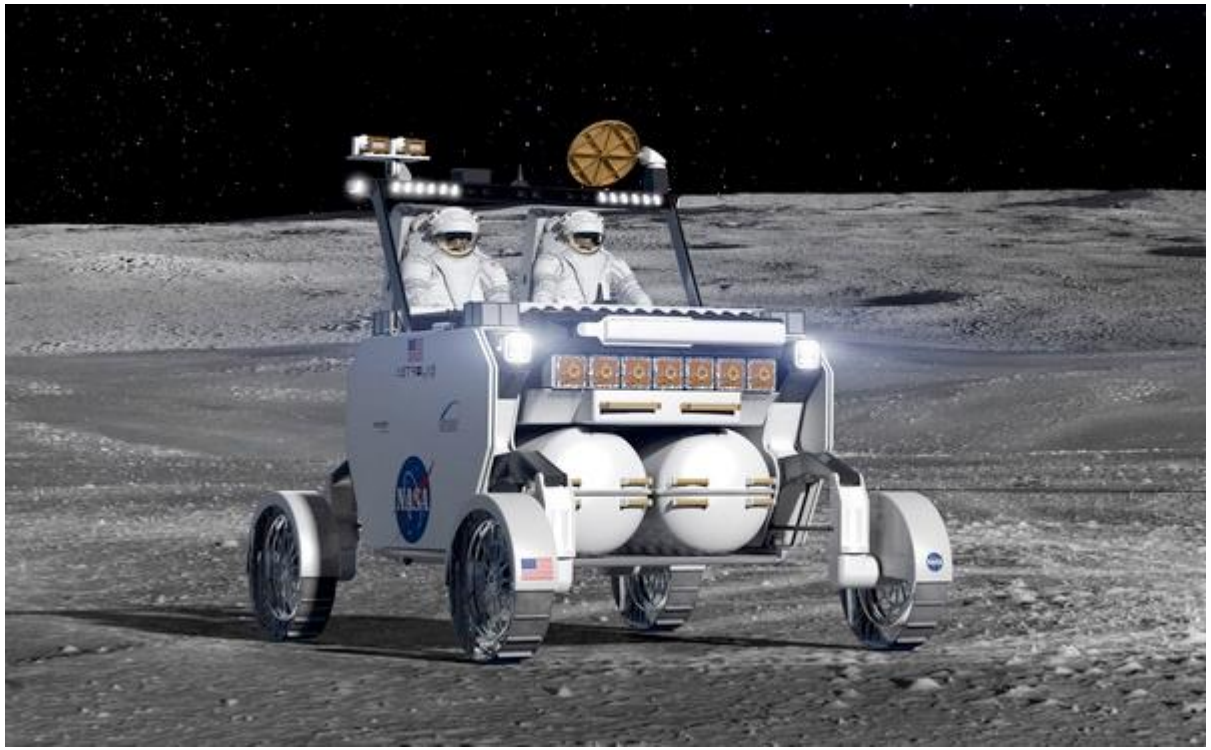


How are the Lunar Supply Pods brought back to the Habitat?

Space Exploration Vehicle (SEV)

- The point is that it would be wise for some of the first tools sent to the moon to be versatile. It is easier to send something like a 'lunar tractor' with several tools that can be powered by the 'tractor' or attached to the 'tractor' to get a job done. NASA has not built a 'lunar tractor' but they have built the Space Exploration Vehicle (SEV) also called the Lunar Electric Vehicle that has a lot of the aspects of a very high tech tractor.
- https://www.youtube.com/watch?v=nPSbOsOJ9Ro
- The base is kind of like the tractor. It has the motors, the batteries and the brains. It can be driven by people riding on top or controlled remotely. The 12 wheels allow it to drive up and down nearly any slope, rotate on its own axis, drive sideways or even diagonal (of course it can also drive like a normal car).
- https://www.youtube.com/watch?v=VtzR4iXY6vg
- You may also have seen it with a habitation module on it—kind of like putting a camping shell on a pick up truck. This allows the astronauts to drive around in a shirt sleeve environment to explore the lunar surface. There are space suits attached to the back so they can get in and out of their space suits without opening the hatch and losing air to go in and out.
- The first teams to the moon will be small since they don't have many resources and living quarters so the tools that are sent could all be powered off only one or two SEVs. The SEV will be the muscle for all the tools that would be needed for the job. Although there are times the astronauts might drive it, I expect it will also be robotic so people from the ground could program it to do some of the jobs before the people arrive and also after the crew is there.
- What kind of tools will they need for building a lunar base?
  - Box blade and/or bull dozer blade for smoothing out the soil
  - Auger for drilling holes
  - Front end loader for moving dirt
  - Tow bars for moving modules and other equipment to the desired locations.
  - Jack hammer for breaking up rocks that are in the way
  - etc.
- HUNCH job:
  - **Some kind of tool for lifting up/moving/transporting the Lunar Supply Pods that land on the moon.**

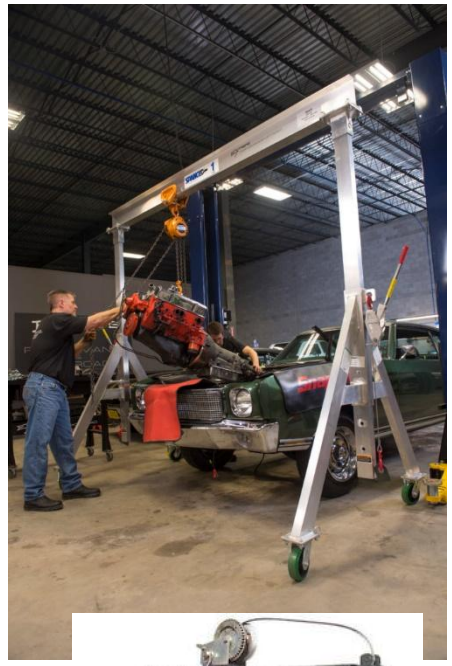
Artemis Lunar Rovers



https://www.youtube.com/watch?v=-uvdFO_Tj60

Lunar Supply Pod Mover

The Lunar Supply Pod Mover will either be some kind of trailor that is pulled by the SEV or some kind of winch/hoist that fits on the back of the SEV itself. The important thing about this Supply Pod Mover is that it has to bring the Supply Pod back to the Lunar base and be able to put the pod into the airlock with as little work from the astronauts as possible. Right now its easy to imagine people doing most of this job but there will probably be a time that it will be done robotically.

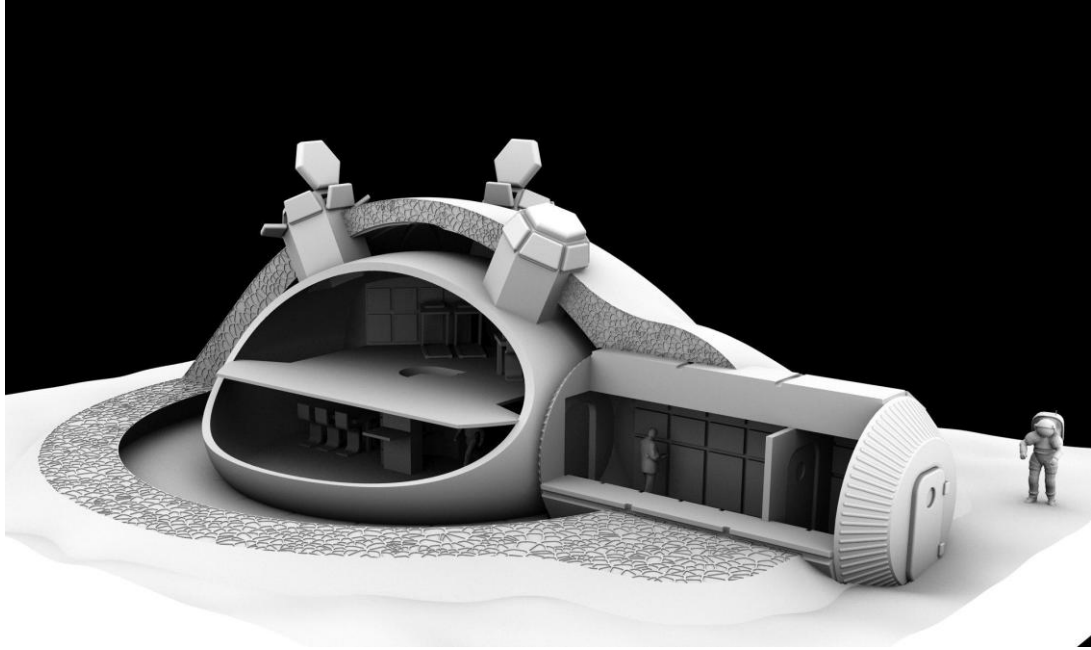


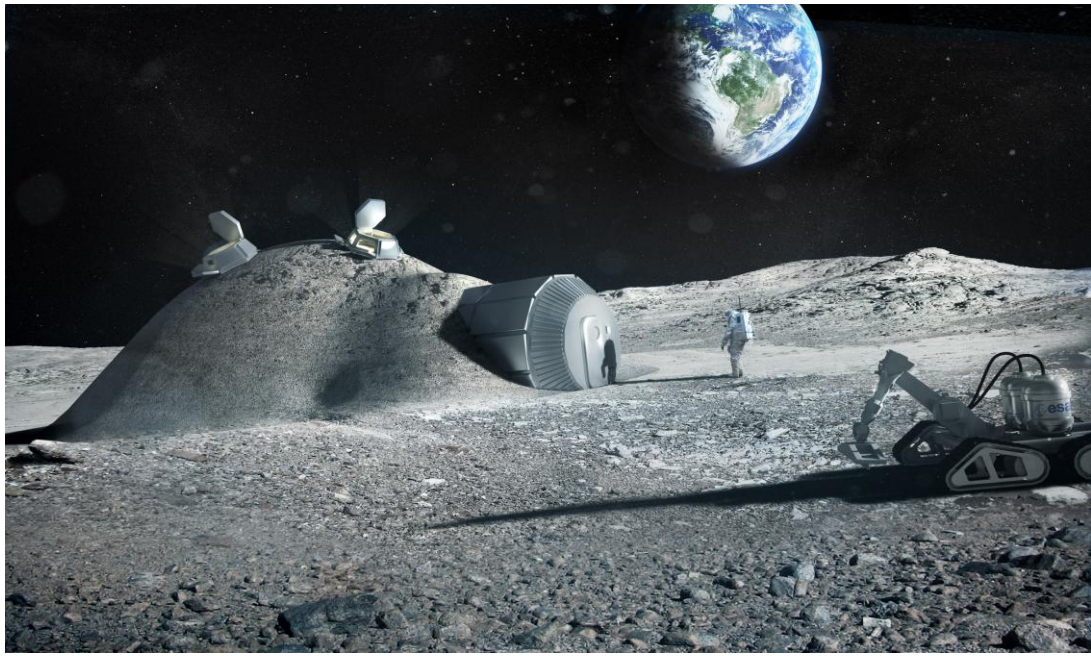
Rigid, semi-rigid, or Inflatable Airlock?

- We expect many of the habitat modules will be inflated and covered (mostly) with a few feet of lunar soil to protect the people from radiation and micrometeorites. Since we never plan to release the air from the habitats, the internal air pressure would support the weight of the soil on top of the habitats.
- There are advantages and disadvantages to having a rigid airlock or an inflated soft airlock. You can evaluate and decide which you think is better.
- If the airlock is decided to be inflatable then we won't be able to put soil on top for protection and insulation since the soil would be relatively heavy (even though it is the moon) and the soil would collapse the airlock every time air was removed.
- If you decide to go with a rigid airlock, you will have to come up with a plan for getting it to the moon and set into the needed location. It is also possible that some components will be rigid and other components are soft.
- https://houstonpbs.pbslearningmedia.org/resource/npe11.sci.engin.design.moonhabitat/inflatable-moon-habitat/
- https://www.youtube.com/watch?v=FEmoqRp8_dw
- https://www.youtube.com/watch?v=Od_E2O-YHN8

Rigid airlock

- Could be a large, rigid airlock with a big hatch that would allow the supply pod to be brought inside. Being rigid would allow the airlock to be covered by dirt to protect the crew from radiation and potential micro meteorites. The moon has a gravity about 1/6th that of Earth so it won't be as heavy on the Moon as it is here.
  - Rigid hatches are easier to seal. They can also be heavy.
  - A rigid airlock would need to be landed gently—may be difficult because of the size.
  - Could it be assembled on the moon in space suits (big thick gloves) with lots of dust around?
  - How would you get the parts there?
  - Some of the current designs for airlocks on the moon include a ramp that allows the hatch to be off the ground and the astronaut to knock off some of the dust before going inside. This is great if they are not bringing in lots of supplies.
  - Even though it won't be as heavy on the moon, it will still be heavy to get off the Earth.
  - Although there are some definite advantages to having a large rigid airlock, there are several complications to getting it to the moon, getting it put in location and the potentials difficulties to any assembly.





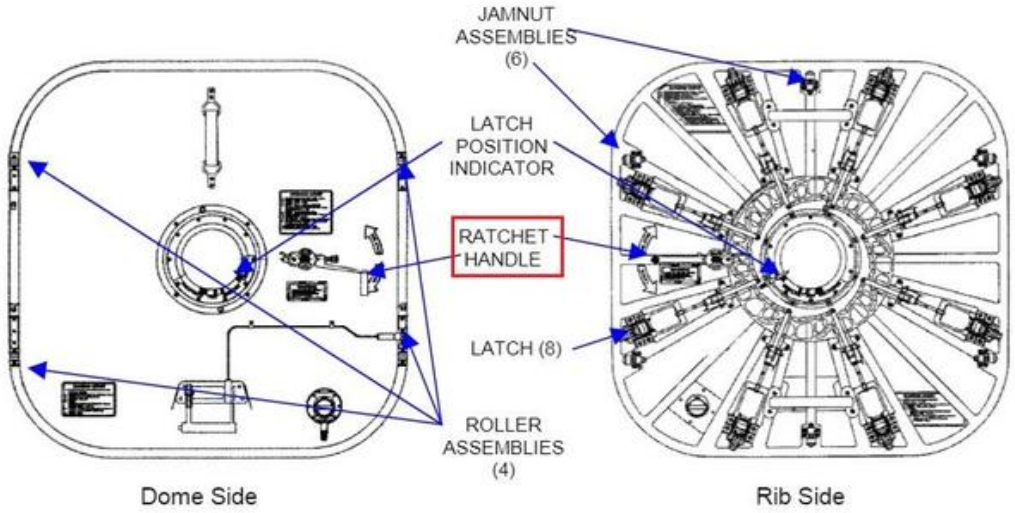
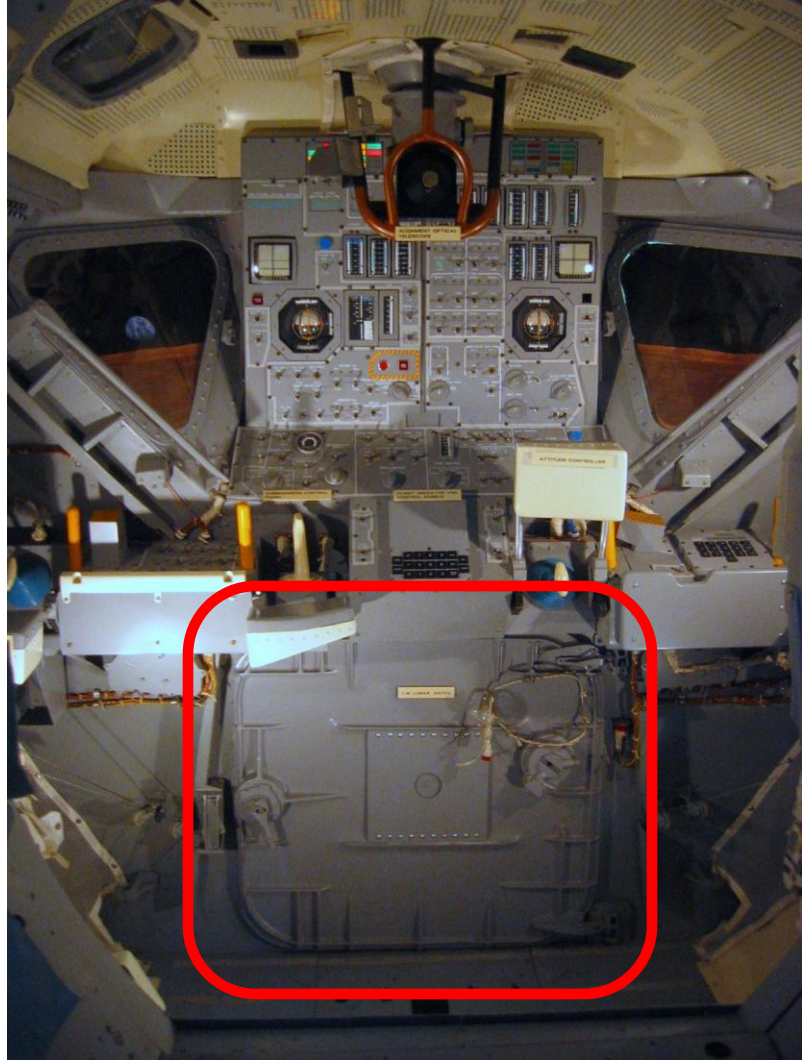
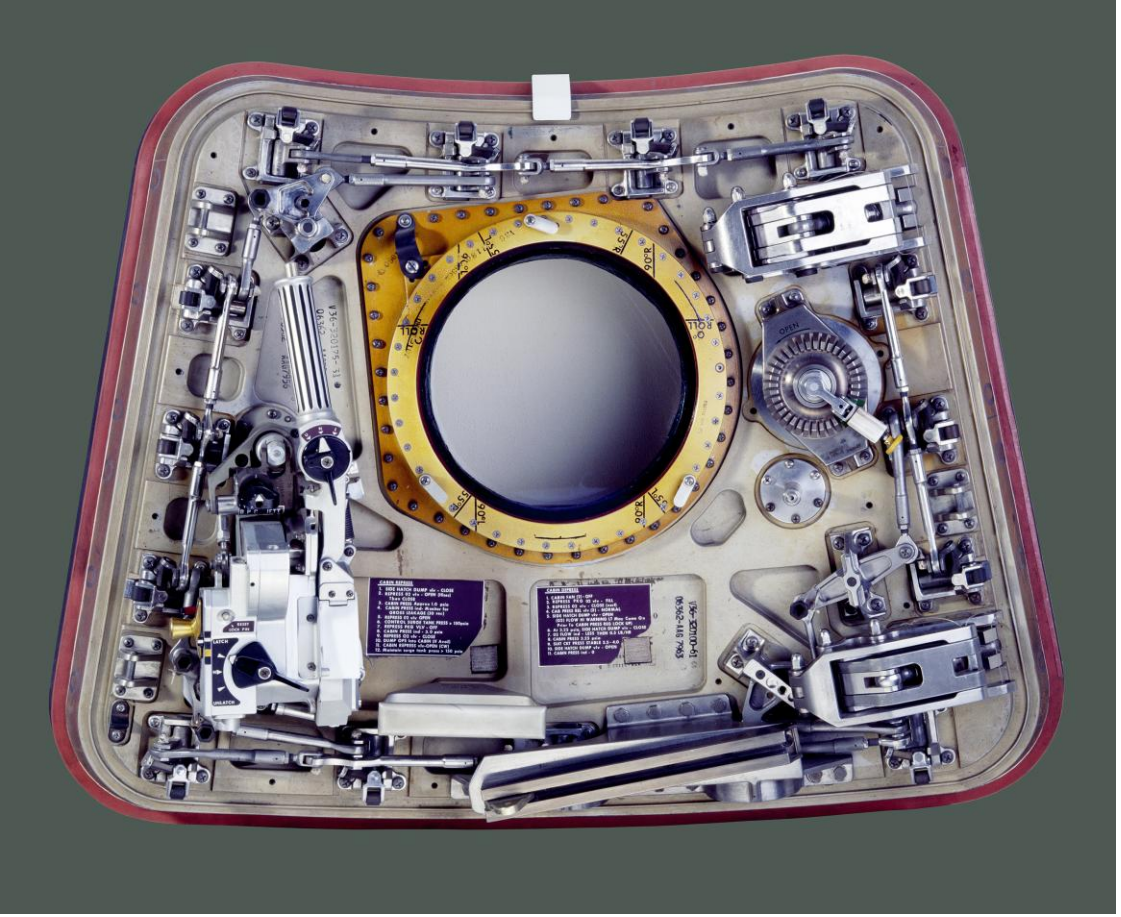


Figure 1.- Hatch Dome/Rib.

ISS Hatch between modules. Notice that there are 8 latches that hold it closed and they have to all move at the same time pulling the hatch tight against the opening. Hatches are positioned so that the pressure of the module is pushing the hatch closed. This is both a safety measure and an engineering value. Hatches can be made lighter and less robust with fewer latches if the pressure is keeping the hatch closed. Notice the two orange colored hatch seals facing us. NASA typically likes to have two seals for safety reasons. Sometimes one is on the hatch and the other is on the hatch opening depending on the configuration and needs of the hardware.



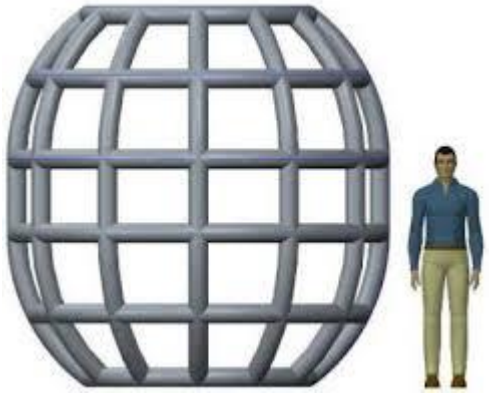
This is the hatch for the Apollo Lunar Module. Notice that it also opens inward. In general it is easier to seal a hatch where the pressure is pushing it closed. This one appears to only have one latch and two hinges.



Inside view of an Apollo Capsule hatch. Most hatches are designed so that the air pressure pushes them closed. This hatch had to hold pressure into the capsule and also open outward. This means that it had to have more latches to hold it shut. I count 14 latches.

This is the side hatch of the Space Shuttle. This one also had to open outward and hold pressure inside.

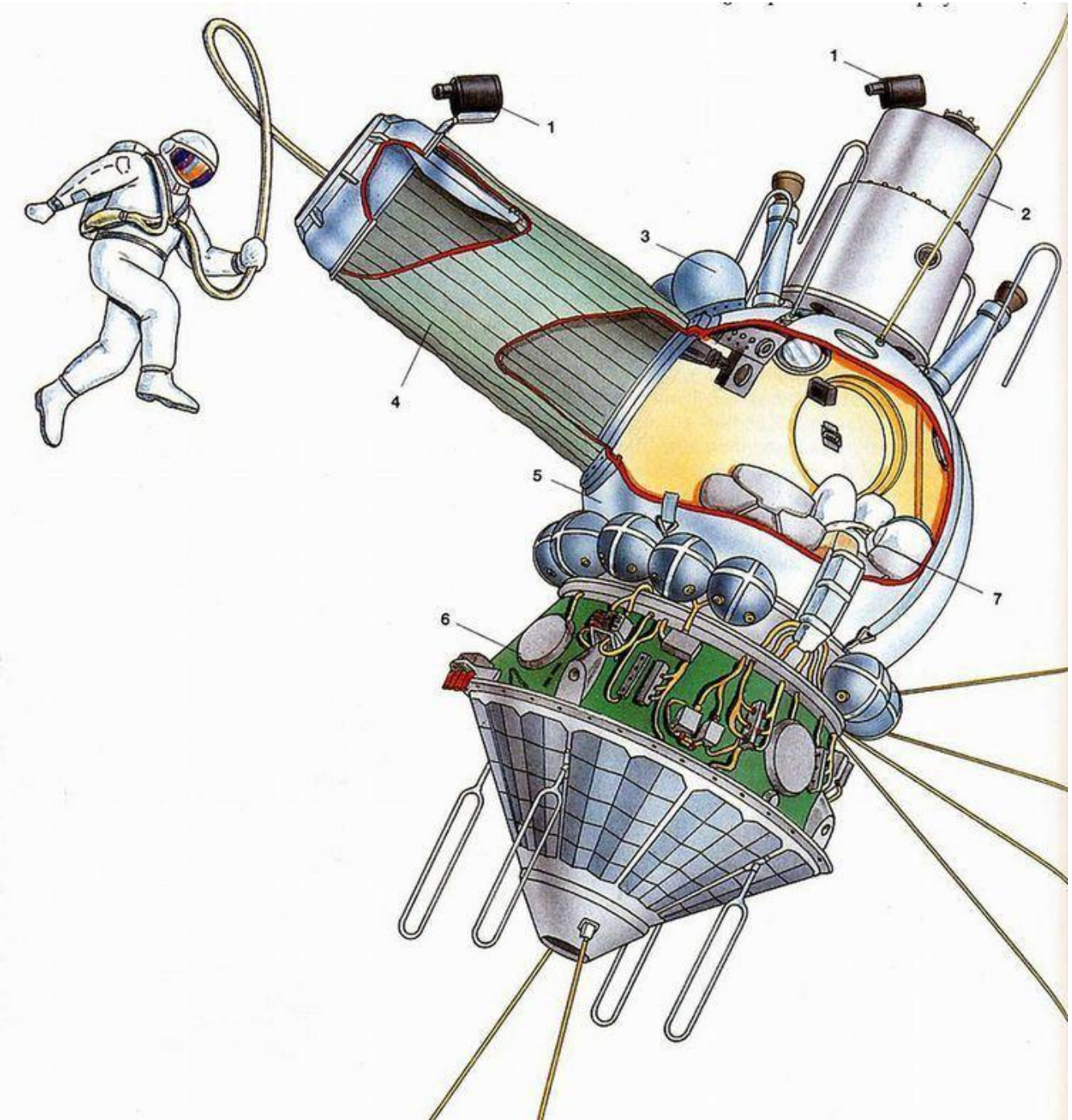
Inflatable airlock



NASA has been working on an inflatable airlock for on orbit as well as on the moon but only for people to go in and out of. Developing one for supplies has not been in their plans yet. This will be necessary for bringing in large and bulk supplies.

- Could be like a tent that uses some kind of rigid, semirigid support or inflatable supports to hold it open (tent poles or inflated struts), then once they roll or place the supply pod inside they could ‘zip’ it closed (double or triple zippers?), add the air they need for a working environment and remove the supplies from the pod.
- It would be attached to a smaller air lock that would be used all the time.
  - Crew would not be protected from radiation and micro meteorites. May need to be replaced after xxx number of times of use. Could be very cold or hot inside while removing supplies—crew may need to wear warm clothing.

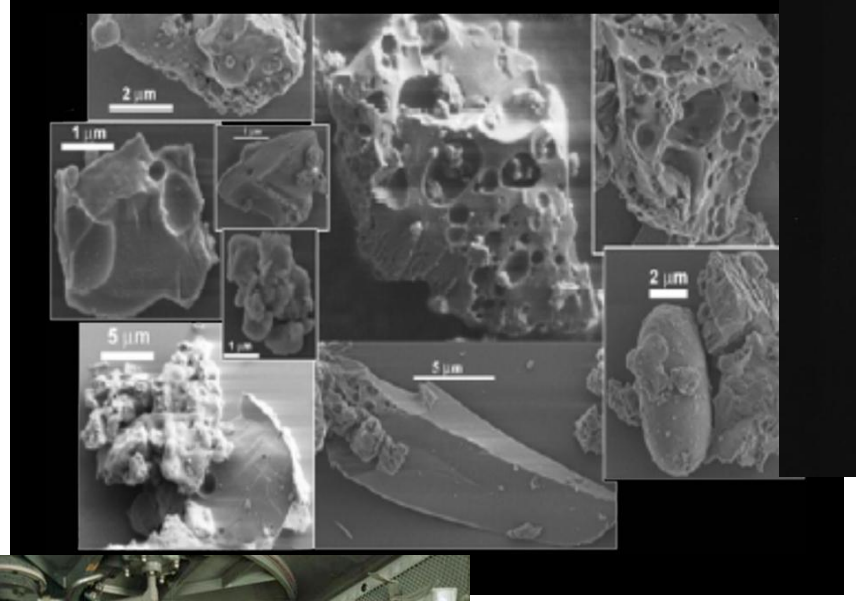
Inflated structures typically have bladders to hold the pressure inside and sturdier, abrasion resistant materials on the outside —like a soccer ball or a zodiac.



The very first EVA ever was done by the Soviet Union using an inflatable airlock on the side of their Vostok space craft. One cosmonaut stayed inside and the other took the first space walk. The airlock was ejected after use and the crew returned in the spherical portion of the space craft.

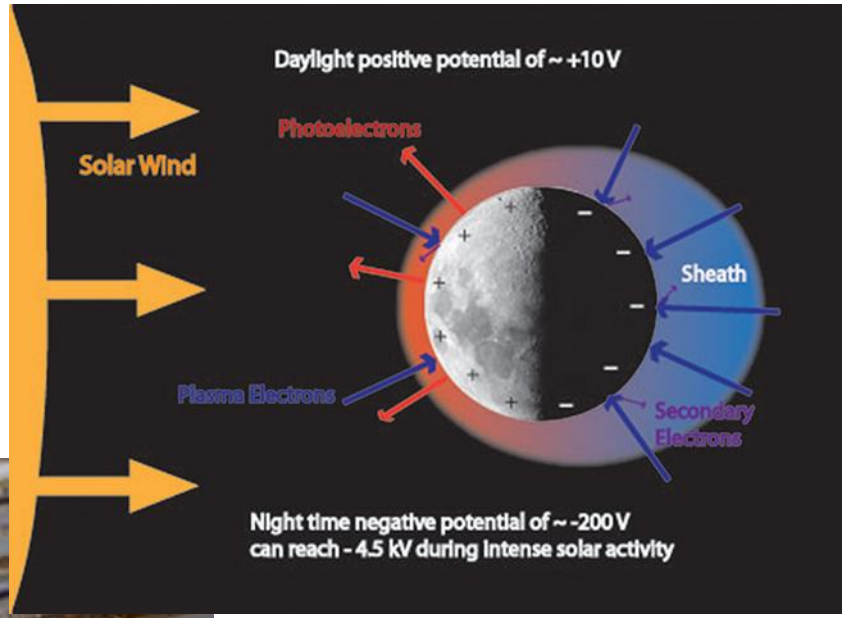
Lunar Dust problems

- Without wind and water on the moon to abrade the dust particles generated from meteor strikes, lunar dust can be very small and sharp like glass shards. The 1/6th gravity means that walking around on the moon can kick up lots of little dust clouds around you and get dust in places you wouldn't expect. Without moisture, the dust can also build up static electricity both from walking and also from the solar radiation knocking the electrons off the dust and making some of the dust float off the ground. This makes it difficult to avoid bringing dust into an airlock and even the habitat as well.
- One of the biggest issues with any hatch on the lunar surface is keeping the dust out of the hatch so that any mechanisms don't get bound up with dust and the seals are kept clean enough that they are able to provide a good seal.



Dust floating off the lunar surface near the terminus as photographed by Apollo crew.

Dusty Apollo space suits-- usually white.



Zippers?

- Would it be possible to use zippers instead of a large heavy hatch?
- Zippers have been used on the first space suits as well as all of the modern space suits. They are used in dry suits for scuba diving to keep cold water out and also in body bags to keep smells in. They are not impervious to dust, dirt and debris but it may be possible to come up with cleaning methods.

Could multiple zippers work as a good seal against the vacuum of space?

Tent zipper doors

The zippers used in dry suits for scuba diving are similar to the ones use on space suits and body bags.

- How big of doorways can be sealed with zippers?
- How do you keep the zipper from being over stressed and ripping out from the air pressure?
- Can zippers handle the lunar dust? Can they be cleaned once they get dusty?
- Is there an orientation for a zipper that would minimize the amount of dust that would get into it?

Combination of rigid and softgoods

- I am certain that all airlocks will have some rigid components on them. The question will be how much, how big of parts and what the purpose of the rigid parts will be. This airlock concept seems to be semi-rigid, meaning that it has some components that are rigid metal support structure (hatches) and other parts that are inflated and softgoods (internal volume). This one is small compared to what is needed for a Supply Pod but has good ideas for the first airlock on the moon. The elevated and metal grating of the EVA porch would allow astronauts to leave much of the dirt outside instead of bringing it into the habitat.

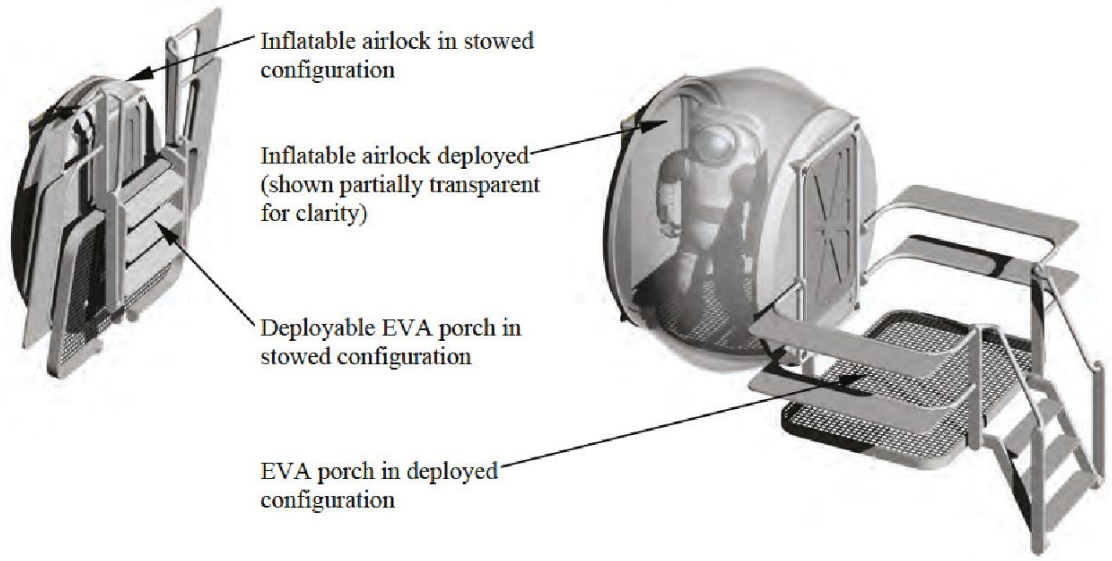
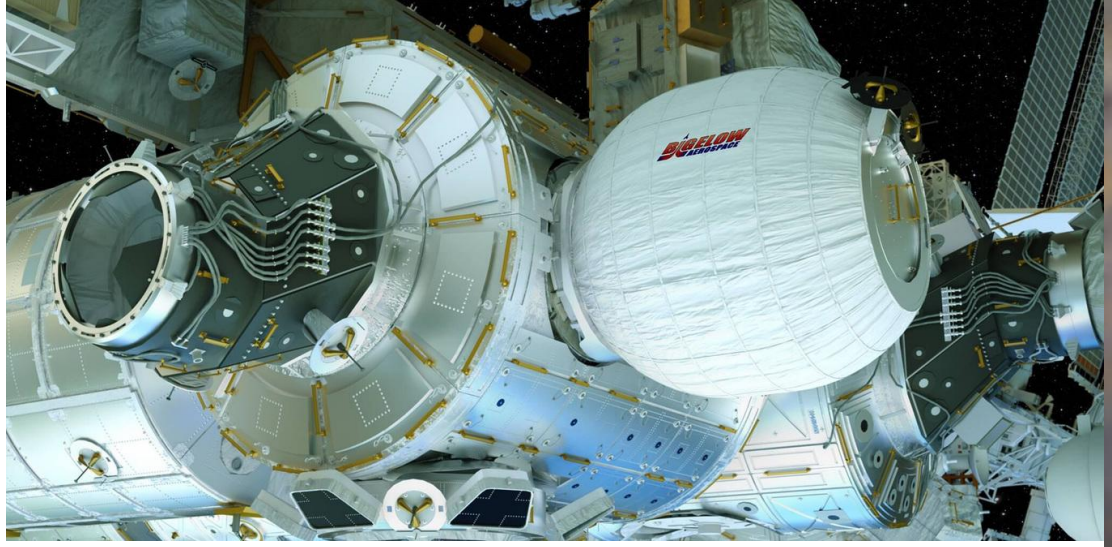


Figure 2: LSS Scenario 12.1 deployable arlock and EVA porch

Softgoods Engineering

- NASA has been designing and building space suits and even space craft out of softgoods since the beginning of the space program. NASA and the space industry has many specialists working on making everything from Cargo Transfer Bags and trash bags to inflatable airlocks, space suits and space craft modules out of flexible cloth and sealable plastics.
- Engineering and designing in softgoods is different from engineering with rigid materials. There aren't any CAD programs that can design flexible materials like cloth. Some things may be done in sheet metal but that isn't the same. You will need to pattern your designs in paper (which still isn't as flexible as cloth)
- Don't be afraid to use the sewing machine, it isn't that hard but you may need instruction to get the settings right. (I'm getting better.)



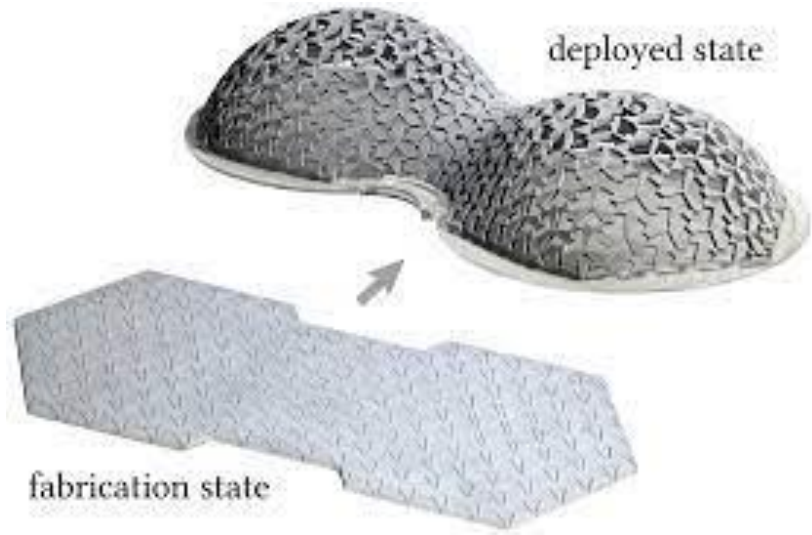
HUNCH students in Fashion Design classes make equipment for NASA training and for flight.

Karen Nyberg worked as a space suit engineer on thermal control systems before becoming an astronaut. She also did quilting while on orbit—challenging in zero-g.

Other options?

- Expanding paper
- https://www.youtube.com/watch?v=BxVGLdMR_8A

- Auxetic materials
- https://www.youtube.com/watch?v=vrOjy-v5JgQ&t=31s



This one is 3D printed but it could also be done by cutting a flat material, maybe even laser cut.

- Kiragami
- https://www.youtube.com/watch?v=4SBtXsG3ClU

Requirements for Supply Pod Garage

1. Show how the garage will arrive on the moon and be assembled/inflated/erected once on the moon (as little work for astronauts as possible)
2. Show how your garage attaches to the “porch”
3. Show how your garage hatch will work
4. Show how your hatch will be protected or cleaned when the supply pod is brought inside.
5. Show how much space is available for removing materials from the supply pod
6. Show how your garage will keep most of its internal volume (structure) when loading in the supply pod
7. It may be valuable to have
    a. a model that shows the inside
    b. a model that shows assembly
    c. a sample or description of the construction materials