VR Lunar Habitat Project

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What will it look like living in a habitat on the Moon?
What kind of space will they have?
How much privacy with the astronauts have?
What can we do to make it more comfortable?

Objective:
Develop a Virtual Reality, multi-room, lunar habitat that allows viewers to see the dirt covered outside and the inside of the habitat with its assortment of equipment and supplies. This will help engineers and astronauts visualize the kind of work that needs to be done for this future living space.

This habitat will reflect a stage that will take a few years for NASA and its partners to attain and will draw from HUNCH students from previous years. You are encouraged to pull some of the look and feel from existing artwork from the internet but some portions will be beyond what is currently available and will require some of your own research and creativity.

https://www.youtube.com/watch?v=Od_E2O-YHN8

https://www.youtube.com/watch?v=uAbjAkXmLXE

This project can be developed using any type of software that will allow the user to record a video of the user walking around the exterior of the habitat to see the construction, entering through the airlock and around the inside of each module to see details of the equipment and supplies inside the habitat. For example, this could be done on **Autodesk Inventor using the steering wheel**. Other CAD software should also have some options for looking around inside and around a part or assembly. Initially, the development of the environment is more important than using a headset and goggles.
https://www.youtube.com/watch?v=gUCM56x8TL0

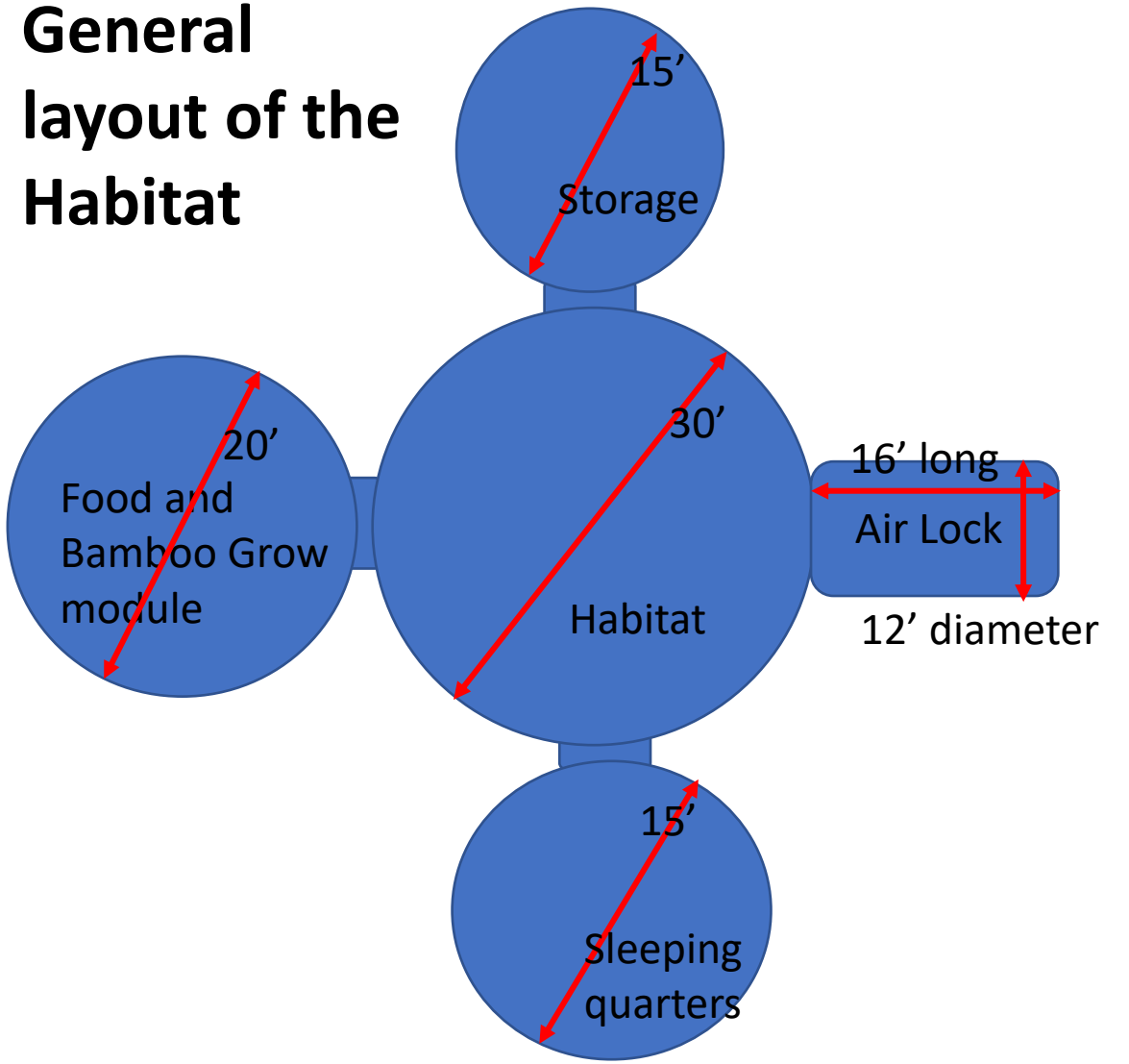
This is an artist's rendition of what some of the early modules may look like on the moon. You can see some robots that are bringing regolith up the side of the habitat to eventually protect the astronauts and structure from radiation and micrometeorites with several feet of dirt.

Required materials inside the modules

- Hatches between modules
- Toilet
- ECLSS racks
- Tables
- Chairs
- Communications center
- Computers
- Lighting
- Exercise equipment
  - Treadmill
  - All in one home gym (like bowflex)
  - Stationary bicycle
- Hygiene area
- Beds
- Raised porch area for entering the airlock (allows dust to fall off suits before entering)
- Inside of airlock and relevant chairs and stowage materials for 4 space suits

The 4 circular modules are inflated structures with 3 ft of lunar regolith covering exterior of all modules. The Air Lock is a rigid, aluminum, cylindrical structure that is mostly covered with regolith but not close to the entrance hatch.

General layout of the Habitat



Add ons

Shelves
Containers
Storage for personal materials
Clothing
utensils
Tool box
Dishes
Lab
Com center
Medical
Shower
Fire extinguisher
Fire blanket
Spare parts
Sewing machine
Climate controls
Oven/cook top
Water dispenser

Setting the mood

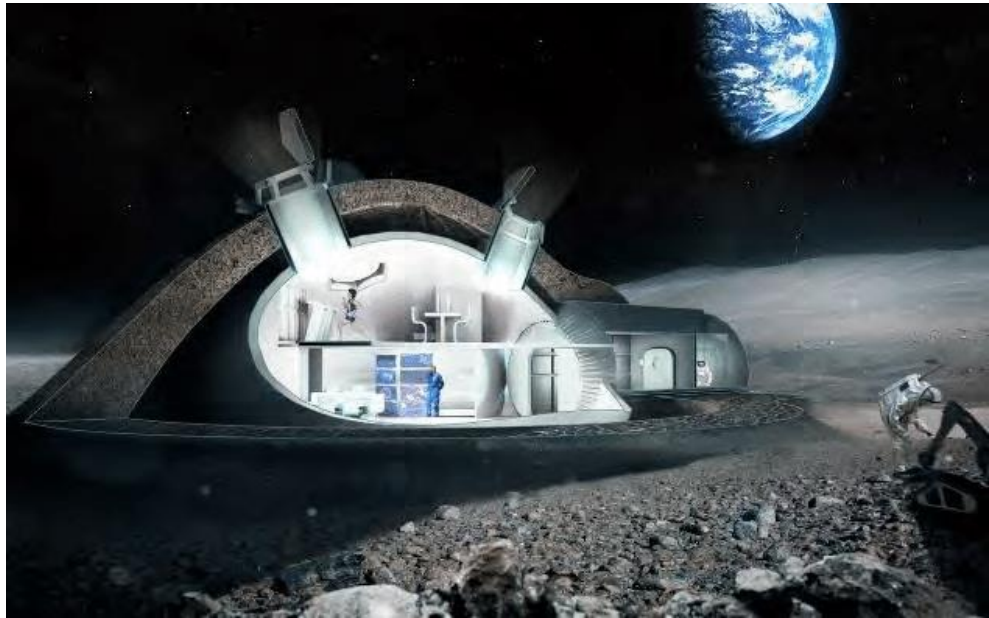
When people return to the moon, there will be dirt and rocks….nothing except what the astronauts bring with them. (kind of like camping but no air to breath) Their first trips will be to determine if it is possible to collect ice from the craters and how they might do it. After a few trips they will have left some supplies so they can start building a small base so they don't have to sleep in the Lunar Landers. This will initially include one or two rovers for driving around, tools, …. Over a few trips they will have some inflatable habitats will be covered with dirt to protect the astronauts from radiation and micrometeors and as well as to act as insulation to regulate the heat. At first equipment and vehicles may be placed a little randomly for convenience but eventually it will be important to plan out the surrounding area where they want to set up their base of operations.

Your job is to help this multi-national coalition of countries and companies visualize what this new Lunar location will look like and help with planning something that will prepare us for doing it right. You will find that there is not a lot of space for all of the listed necessities. Some of the areas will need to be dual purpose. For example, the galley table will also be a work table and maybe even an operation table in the event of an emergency. Look carefully for how you can save space and volume. Just like on a submarine or a space station, every bit of space will be utilized for some purpose—food storage, tools, spare parts, trash storage, …. Like on the ISS, all 7 or 10 crewmembers need to exercise but there isn't room for a full gym and one piece of hardware will need to be able to do multiple exercises. It will be similar on the moon.

There will probably not be any windows (except maybe on the airlock) since we will be trying to protect from radiation. This also means that all of the lighting will be artificial and probably LEDs.

Inflatable modules
https://www.youtube.com/watch?v=Od_E2O-YHN8&t=10s

This habitat is an interesting representation with lunar regolith covering the majority of the structure and part of the airlock but it seems to be missing some of the internal equipment for life support and less likely that they will have windows the crew can't access.



Teasing out advantages of the new environment

Submarine quarters

The intention of the VR Lunar Habitat and the VR Lunar City is to help NASA plan out locations and hardware that have never been built and never been seen by human eyes before. This is obviously not easy to be the first. The other possibility is that your ideas will help develop video games about the moon that will be more realistic because of your innovations.

One of the things I'm hoping students will help out with is teasing out how to use the 1/6th gravity of the moon to our advantage. For example, the International Space Station was built with micro-gravity in mind—the floors and ceiling are used for stowage and experiments the same as the walls. Some of the stowage racks are just made of cloth. This would not be possible on Earth.

- If I can jump 18" here on Earth, how high can I jump on the moon?
- If I jump 18" high and land a few inches to the left or right on Earth, how far off to the side will I be when jumping on the moon?
- The 'super strength' of being on the moon will make the astronauts clumsy until they get use to the gravity difference. This will happen for every team that arrives. Your design needs to allow for this adaptation time and also once they are adapted.
- It typically takes around two weeks for people to get their "space legs" when they get to the moon. Will it be the same on the moon?
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- What could be done on the moon with 1/6th gravity that can't be done on Earth?
- What kind of stowage is possible there but not here?
- Do they need the same number of rungs of a ladder or steps on the stairs as we do on Earth?
- All of the supplies and equipment will have to be sized so they can be brought through the hatches.

It may be helpful to layout some of the dimensions on the floor in tape so you can arrange things visually and experience a little of the volume available. Put 4 people in the space and see how you would feel being that close for sleeping, eating, working and cleaning up.

Some added thoughts to help.

- Strength of the inflated structure-- A basketball is inflated to only 7.5 to 8.5 psi but that is plenty strong enough that someone can stand on it and it not be deformed much and it is plenty strong. If you wanted to bury a basketball it could be under a lot of dirt before it would pop—right. The habitats will be at 14.7 psi and will be under 3 ft of lunar regolith. Since that regolith will be 1/6th the weight of 3ft of dirt on Earth (equivalent to about 6" of earth dirt), I expect that the habitats will be plenty strong enough to support the weight of the regolith and even hanging some things from the ceiling. The arch is a very strong structure and this is a dome which should be very sturdy.
- https://www.youtube.com/watch?v=2AuaMpxcTAw
- Be creative about how you make space for your astronauts. I think it might be better to have 2 beds and stowage in one module and 2 beds and stowage in another module (less snoring in one space). Your choice. Are there other options?
- Plan your stowage for the materials that might be used the most to be the easiest to access.
- On the space station, the air flow originates in the Russian segment where the air is pushed through ducting to all the modules and then returns back to the Russian segment through the open hatches. How will you distribute the air flow with ducting from the habitat with the ECLSS to the other modules? These systems can be noisy with the fans moving air around. The cloth of the module and the regolith on the structure may help make it quieter than on the space station. Can your ducting be partially included with the structure of the habitats?
- What can you do with the higher ceiling in the main habitat? Is that where the air ducting could start? Can there be stowage or other useable space up there?
- The whole space station was designed around the lack of gravity and floating around. There are experiment racks on the walls, ceiling and floor. There are module that go up, down and on either side without ladders. Stowage in any little nook and cranny. The racks are shaped to fit to the curved side of the module. How can you use the 'mini-g' of the moon and the shape of the structure to the crew's advantage in outfitting the modules?
- There will have to be a hatch in the main habitat for each module and a hatch in each module so it can be inflated independent of the other modules. Hatches can be heavy—keep them small to save on mass but keep them useful for moving supplies going back and forth. You will probably have to step over the threshold to go through. Look up hatches on boats and the space station for a reference.

Finding existing models of hardware

- The objective of this project is for students to help figure out how to fit all of these important components for living on the moon into the limited space of the habitat.
- Here is one place that might give you some of the hardware you need for the inside of the habitat. Check out the Mark III space suit.
- https://nasa3d.arc.nasa.gov/models
- I am sure there are more if you can find them on the internet. Check Thingiverse also.

Environment Control and Life Support Systems (ECLSS)

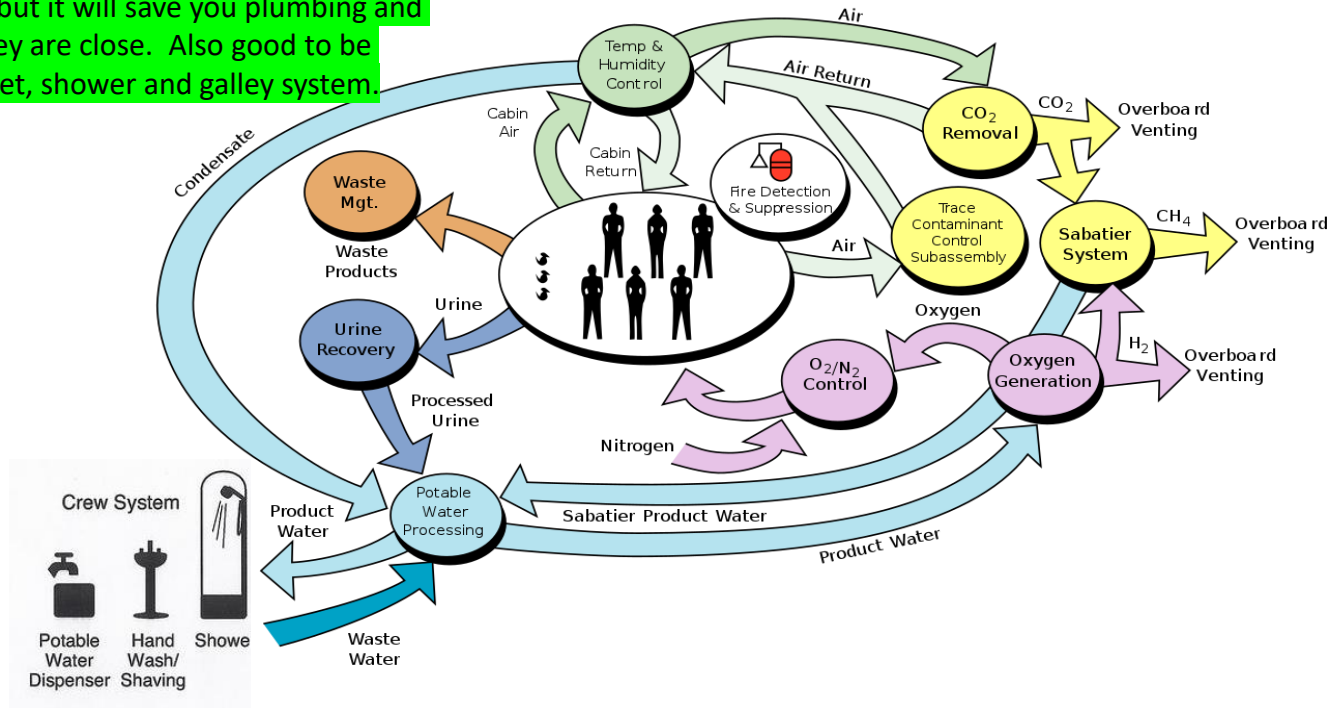
One of the most important parts of a habitat is going to be the ECLSS equipment. On the Space Station it was composed of 4 racks—the CDRA (Carbon dioxide Removal Assembly), WRS 1 and 2 (Water Reclamation System, and the OGS—(Oxygen Generating System). Water is a necessity for people to live. People need between 2.7 and 3.7 liters of water per day which means the people on the Space Station would use about 26 Liters per day for the 7 people that are always on the ISS. This would be 777 Liters per month. That is a lot of water to send up on a regular basis. On the Space Station NASA is able to recycle around 95 to 98% of the water. This saves NASA from sending up a lot of water.
Some of these originated from similar equipment that is on a submarine and used for the same purposes. Thanks to advancements in technology, some of these have gotten smaller and more compact since the start of the ISS program. You will also need to add shower so people can get clean, a potable water dispenser for injecting water into freeze dried food packets and drinks, and you will need a toilet (yesterdays coffee becomes todays coffee). It will be necessary to have a tank (or multiple tanks) of about 80 gal. total for the clean water that is ready for use.

What kind of ducting is needed to circulate air effectively so the air smells and feels fresh when 4 people are all eating, exercising and living in the same couple of rooms?
Is there a need for circulation fans?

1. **OGS—**produces oxygen by using electrolysis to separate water into O2 and H2
2. **CDRA—**removes carbon dioxide from the air
3. **WRS1—**removes water from urine by evaporating the water and condensing it back to fairly clean water
4. **WRS2—**cleans the water further by running it through filters—water is cleaner than what you drink at home.

A space station rack has dimensions similar to a refrigerator—42” wide x 72” tall x 36” deep at the biggest part of the curve. You don’t have to preserve the dimensions but you should try to keep the volume if you break it into smaller pieces.

This equipment does not need to be next to each other but it will save you plumbing and hosing if they are close. Also good to be close to toilet, shower and galley system.



Water tank

Both the Habitat and the Bamboo Greenhouse will need water storage. The crew need to have water that can be cleaned and waiting for use for drinking, food rehydration and hygiene activities. The bamboo and other plants need water with the appropriate minerals added to help them grow. As water evaporates from the plants, soil, drying towels and clothing, steaming food, sweating people, … the condensing water will be cleaned and made available to both tanks of water.

The ECLSS system should have at least 100 gal of extra water to work with.

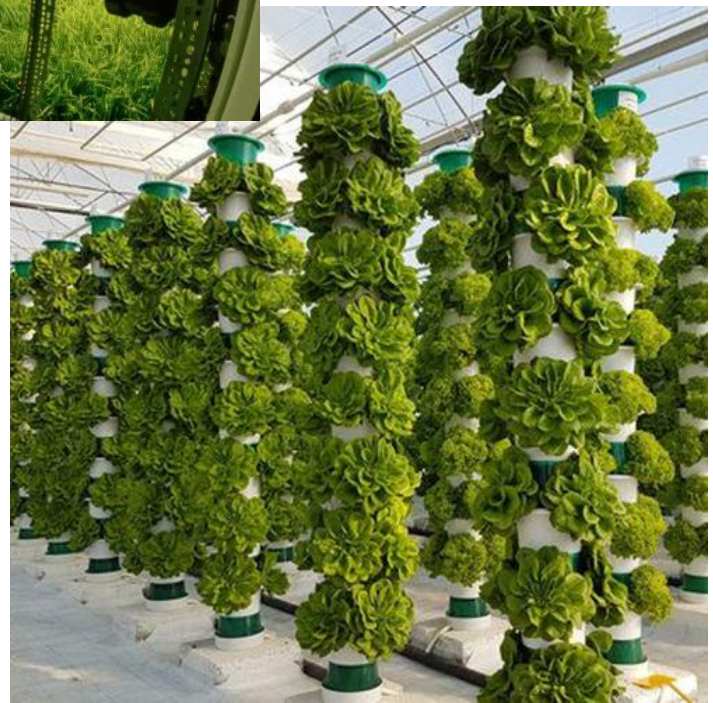
The bamboo and plants should also have around 100 gal of extra water to pull from.

Is it better to have one tank for each location or should there be multiple smaller tanks for separation and safety?

Several 50 gal tanks or two 100 gal tanks?

Growing bamboo and food in the Lunar Greenhouse

Other HUNCH students are developing the details for what a Lunar greenhouse will look like. Your job is to show things growing in the greenhouse but your representation doesn't need to be as detailed as what the Greenhouse team is developing. You are welcome to work with a Greenhouse team but it is not required.



Sleeping Quarters

- I don’t see any examples of what people think the Lunar bedroom will look like so you will have to use some imagination and take inspiration from what other designers have done with small spaces.

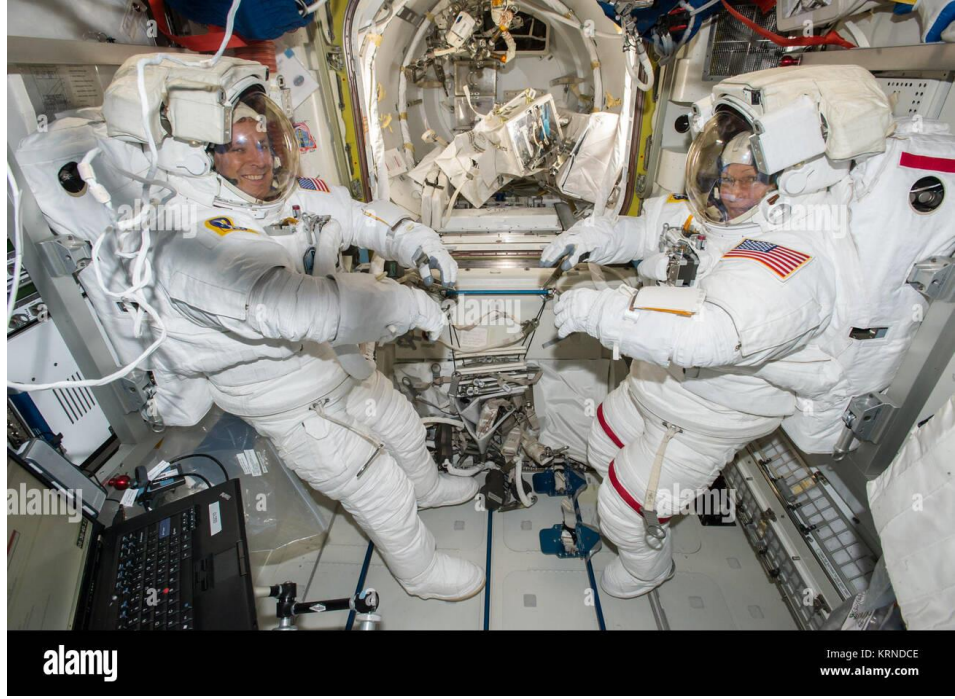
- What will the module for the Sleeping Quarters look like? Assume there are sleeping stations for 6 people.
- The maximum height will only be about 7 ½ ft because of the curvature of the inflatable habitat. How will you use the space efficiently?
- What will the beds look like when there is only 1/6th the gravity of Earth?
- How much privacy does each individual get?
- Can the sleeping space double for another activity in the day when people are not sleeping?
- Is there room for some exercise equipment?
- Could there be office space with a few computers?
- Could the beds fold away in the daytime?
- What kind of things might they store in the Sleeping Quarters—clothing, personal items, food, …?

Bedroom in the Hindenburg

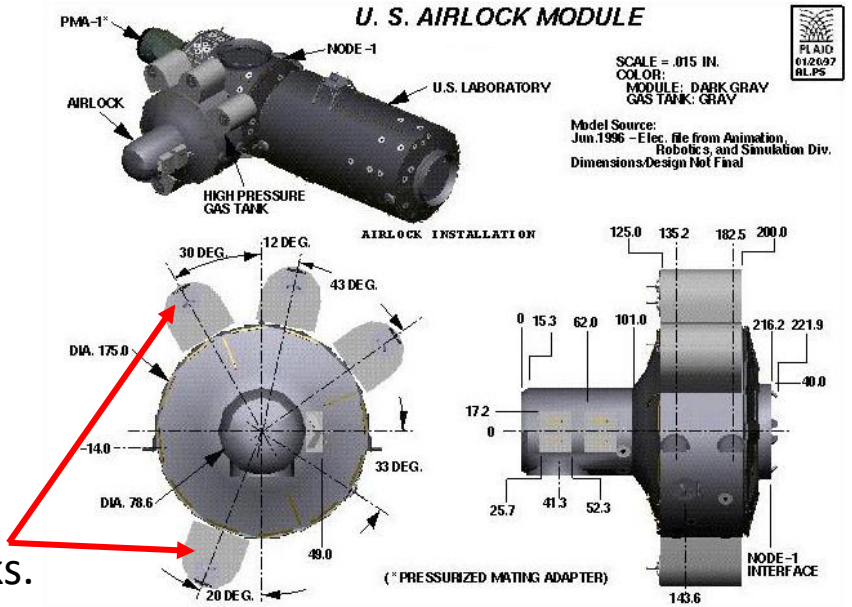
Bunk space in a submarine

Airlock

The airlock will need two hatches—one that leads outside and one that lets you inside the habitat.
There will need to be communication panels in the airlock
Places for each of the 4 suits to hang on the wall for maintenance.
Tools for working on the suits.
Tanks for recharging the suits with air
A small oven for baking the carbon dioxide out of their CO2 removal canisters after a moon walk.
A bench for them to sit on while they are putting their suits on.
A vacuum cleaner for collecting lunar dust.
There will also need to be some 3 oxygen and 3 nitrogen tanks on the outside of the airlock for repressurizing after going out and coming back into the habitat.



The astronauts will enter and exit the new space suits through the back of the suit so the suits will probably face the wall when not being used or worked on.



Oxygen and Nitrogen tanks.

Stowage module

- Astronauts on the moon will not be resupplied every week, probably not even every month, maybe every two or 3 months. Which means they will need to keep a lot of supplies for repairs, food, batteries, trash containers, spar parts, clothing, … they will also need racks to hold the supplies that fit in the round inflated module. It needs to be arranged in a way that they will be able to access the supplies as easily as possible.
- What kind of racks will you make?
- How will they be arranged and leave space for walking and access for the people?
- Represent different kinds, styles and sizes of containers that might hold some of the materials that they will need.
- How would you organize the supplies?
- What kind of lighting do you need to be able to see in the corners of the room and shelves?
- Would it help if some of the shelves were movable?

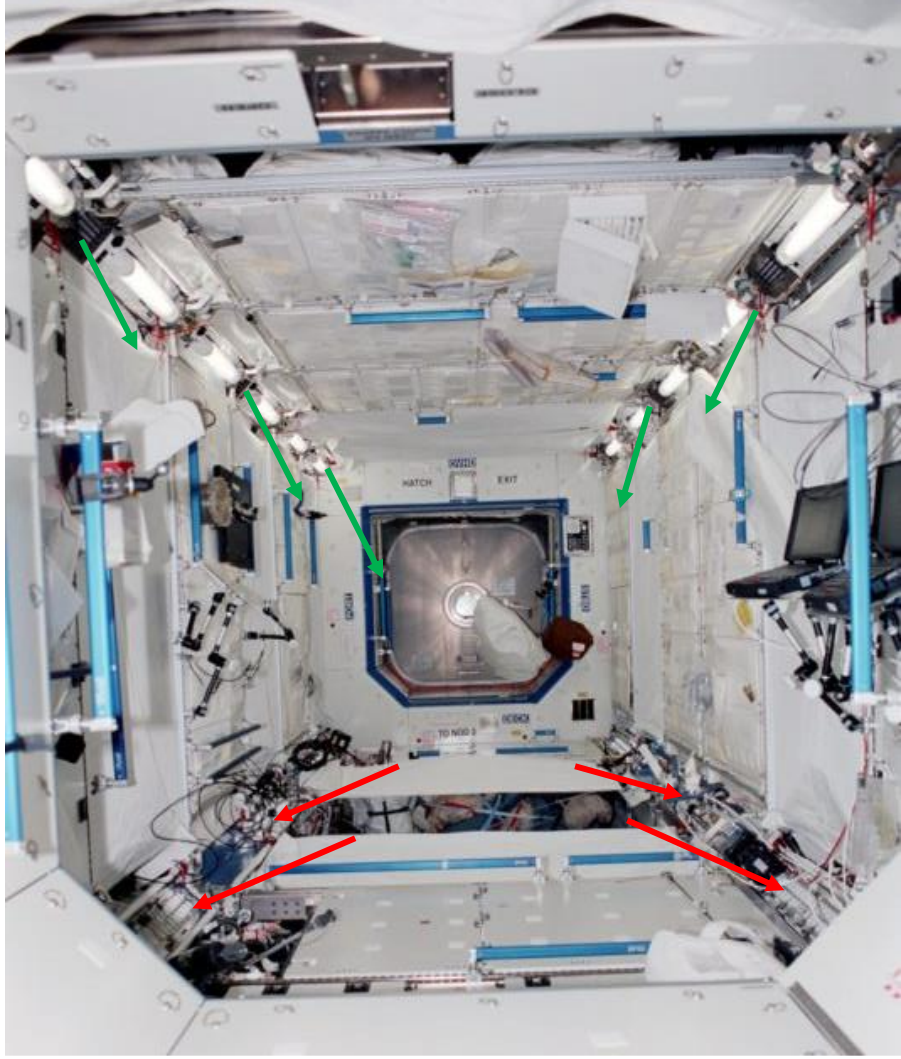
Mixing of air in Micro-G


S121E07401

Air is being pushed from the Space Shuttle that was docked to the Space Station through the hose and air is flowing back from the Station into the Shuttle through the hatch.


S129E009490

Once the hose from the Shuttle comes into the Space Station, the hoses pushing air from the shuttle pass through connections to the sides of the hatch with valves that can open and close so the hoses don't obstruct the ability to close the hatch.

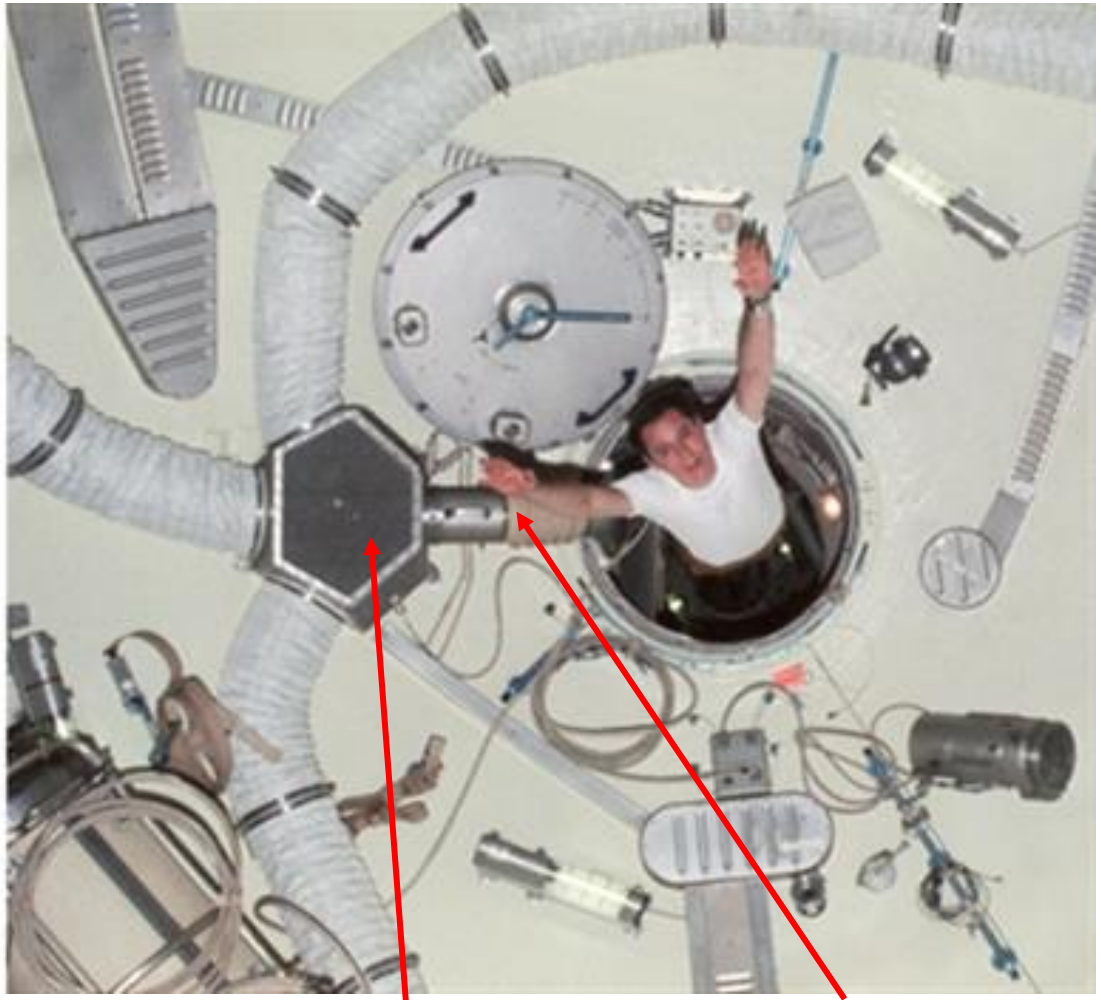


This is an early photo of the US Lab on the International Space Station. Notice the lights are on the overhead stand-offs. Air vents exhaust cool clean air from between the lights and inlet vents pull in air in the stand-offs at the deck with filters that collect the dust.

These are pictures from Skylab, NASA's space station in the early 1970s. Notice the gray ducting for helping circulate air through the space station.

When a Space Shuttle is not connected to the ISS, air is pushed through ducting from the Russian side of the Space Station to the other side of the Space Station from one module to the next. All of the air returns back to the Russian side through the hatches with lots of mixing in each module before it returns.

Without gravity there isn't any natural convection (hot air rises, cold air sinks) so it is very important to have forced mixing of the air. The moon has some gravity so there will be some convection which will help mix the air but it will still need to have good mixing and air flow.



The air ducts don't need to be as big as these but the larger the air duct, the easier it is to mix lots of air. Small fans turn faster and are louder. Big fans can turn slower and be quieter.

In-line fan

Air inlet with filter for capturing dust. This gets vacuumed every week

Ducting going through a hatch that pulls air from another section of the space station