Lunar Ag Science and Food Lab

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Design and build a scaled model of an agriculture grow lab for the moon that will begin as an experiment growth lab with some food production but will eventually become solely for food production.

Problem:

- NASA along with International partners are planning on building a base on the moon for people to live for long periods of time that will eventually turn into a permanently crewed location. Currently it is very expensive to send materials to the moon—on the order of $1.2 million/kg. At that kind of expense, it would be valuable to grow some food on the moon if possible. It is not as easy as planting seeds and waiting for them to grow. There isn't any air on the moon and the soil is not very good for growing plants. There is also lots of radiation and it is very dry.
- The long-term goal for a lunar base is to develop mining and manufacturing capabilities. Making things that can be used on the moon and things that could be sent to space from the moon. Many people are hoping to mine ice from the dark segments of the moon and be able to use it for oxygen, and for fuel for spacecraft that could be launched from the moon.
- The less dependent on supplies from Earth the moon base can be, the cheaper it will be to operate the base and the cheaper the products coming from the moon will be. Food production is a significant portion of that calculation. Food will have to be grown inside since there isn't an atmosphere around the moon—no air. This means limited space and needing power to grow the plants.
- Lunar regolith is a low nutrient soil, that is like a fine-grained volcanic rock and pumice. Imagine volcanic rocks being broken up by meteors hitting the surface for the past 4 billion years. The grains are sharp and jagged not rounded like grains on Earth that have been weathered and tumbled. There isn't any organic material in the regolith since nothing has lived in the soil before. The lunar regolith is alkaline and has a pH of 9.0 to 10.5-- the pH for good soil on Earth is closer to 6.5 to 7.5. It is not required to use the regolith, but it is a resource that is already on the moon instead of shipping dirt from Earth.
- Not all plants have to be for food but they should have a value to the Lunar Base, the astronauts and the mission.

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Objective:

Design and build a scaled model of an agriculture grow lab for the moon that will begin as an experiment growth lab with some food production but will eventually become solely for food production.

- Depict in your model at least 3 different types of plants that could be grown in this growth lab and how it would be done.
- The plants should be grown in at least 2 or 3 styles or there could be different styles of growing the plants.
    - In ground planting
    - Hydroponics
    - Aeroponics
    - Hydroculture
- Demonstrate one of the plant growth styles your team plans to depict in the model with a real plant that you think would be a good plant to grow on the moon. Be prepared to explain why you chose this plant.
- The growth area on the moon will be 20ft diameter spherical dome with a 2ft cylindrical base. This allows for a 12ft high apex of the dome. Use the volume efficiently.
- Your model will demonstrate:
    - Watering and recycling systems
    - Lighting systems
    - Air circulation
    - Storage materials for experiment equipment and tools for the plant growth.
    - Worktable/area
    - Ability to change and reconfigure as the facility proceeds from experimentation to food production
- Describe the amount of power needed for growing the plants as well as needs for the crew that are working in the facility—lighting, fans for air circulation, water pumping/cleaning,…
- At least 25% of the plants should be intended for food production initially.
- Other plants may be for purposes other than food but should have a clear value to the astronauts or the mission or the moon base.
    - Medicine, Construction materials (rope, wood, bamboo), Oils, Paper, specific chemicals, …other

For Example:

In the scaled model, a team might show how they would grow

- one plant grown in dirt
- a different plant grown in hydroponics
- another plant grown in aeroponics

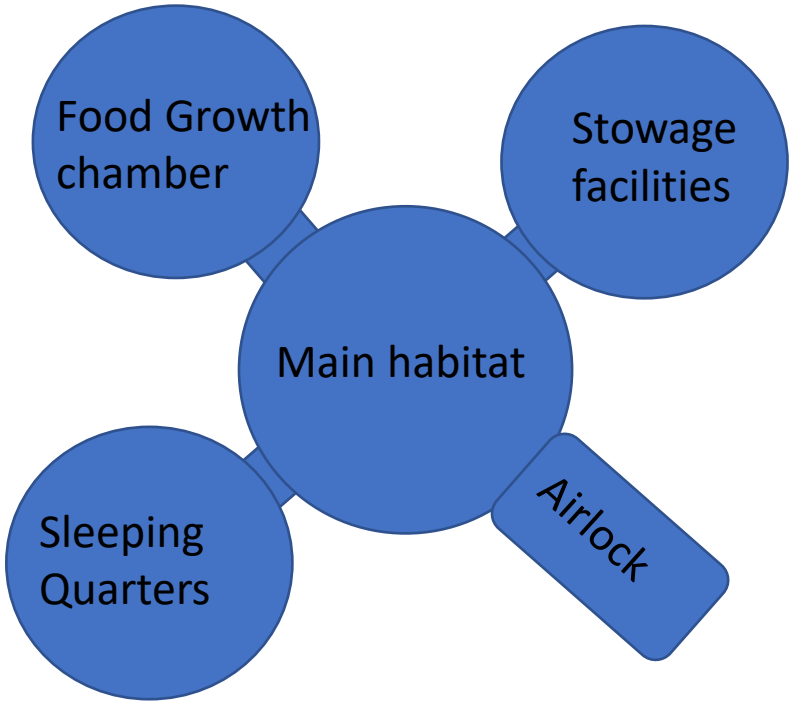
Some plants will grow better in one type of system than another. The team's model shows how the crew will be able to access all of the plants for maintenance and harvesting.

- The team chooses to grow strawberries in hydroponics as their demonstration.

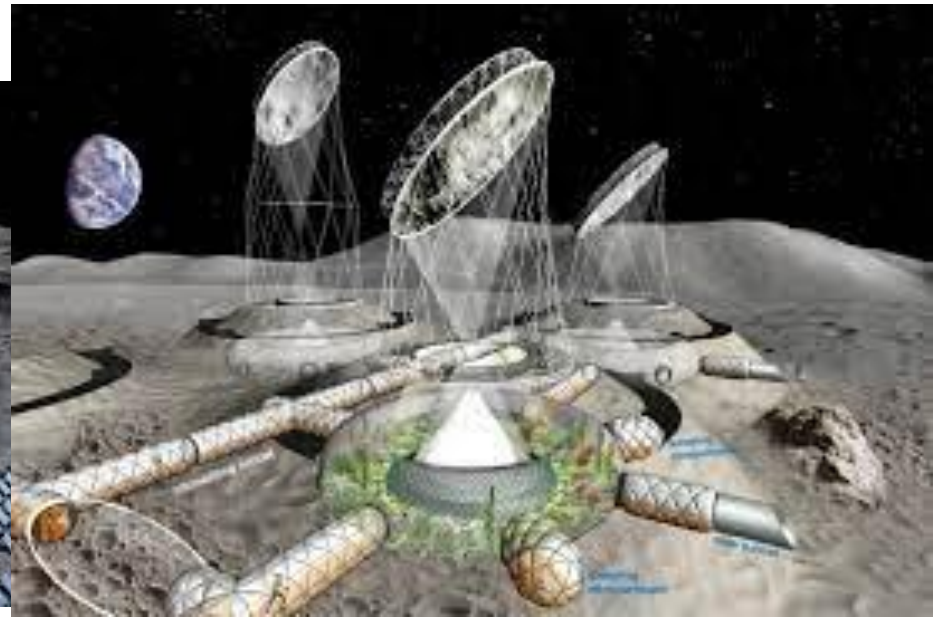
Lunar Greenhouse

What should a Lunar Greenhouse look like?

- For this stage of the Lunar base, the habitat will be composed of 4 inflatable modules and one rigid, aluminum airlock. Where one of the modules is for the growth chamber for growing food and experiments with plants.
- Each of the modules for lunar habitat is an inflated dome so the roof and walls will be curved. The floor is also part of the sealed structure so there can't be holes in the floor to access the regolith. To protect the astronauts and the plants from the cosmic and solar radiation, the dome will be covered with a few feet of regolith (lunar dirt).
- Your team's layout must be designed to allow people access for maintenance of the plants and the chamber itself (incase of damage).
- The layout needs to be designed to make cultivation of mature plants easy to do.
- Your prototype should be a scaled model with all the structural requirements represented. You should also have detailed renderings of the full-size growth chamber, including a list of recommended materials (power, lights, water system, etc.)
- You should conduct research on the type of plants you recommend by growing a one of them and monitoring growth variables. Consider using an old aquarium or some other analog for your growth chamber. Maybe even a something that allows viewing of the growth of the root system.



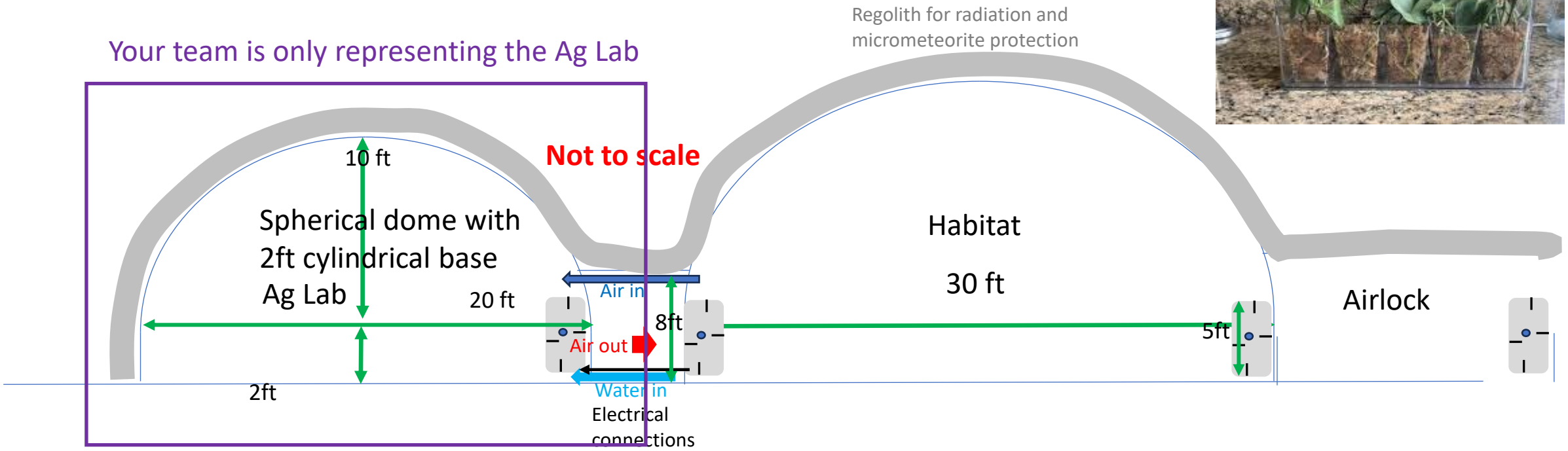
All these domes will have to be covered in dirt to minimize the radiation exposure to the plants and people as well as helping to regulate the internal temperature through the 28 day/night cycle.



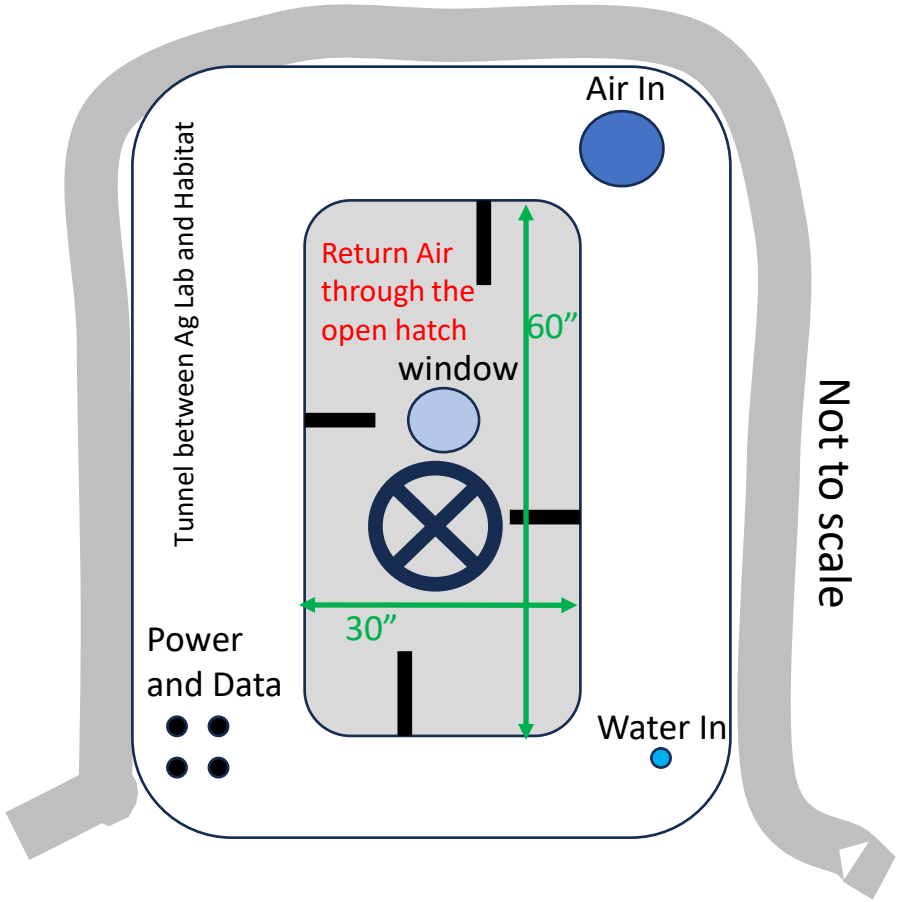
Determine at least 3 types of plants that would be the most beneficial for a lunar base and grow one of them to demonstrate that it can be grown using artificial lighting and your choice of growth media.

Make a scaled model that will fit in a 24” x 24” space on a table to demonstrate how food items could be grown in a 20’ diameter, lunar inflatable module that allows for people to tend and harvest the materials from the greenhouse. It should include:

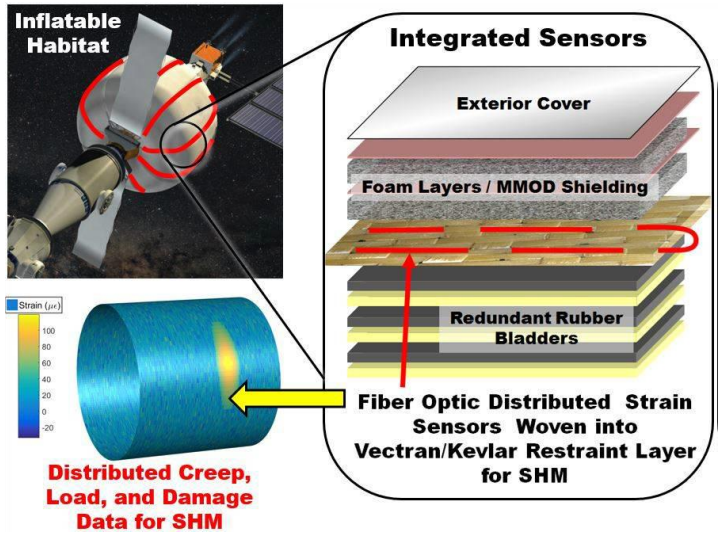
- Grow beds
- Lighting
- Plumbing—in and out
- Mixture of air from other modules
- Walkways and work areas



Structure Safety



No blocking of the hatch with cables or hoses. In the event of a depressurization or fire, all connections need to go through the bulkhead and can not go through the hatchway. All connections have valves that can be shut to prevent loss of air and water. This isn’t science fiction with automatic doors--hatches are closed manually.



Because these are inflatable modules, the air pressure is what is holding up the ceiling. The interior layers are only loosely attached to the pressure bladder so as to minimize chances of puncture to the bladder. This means objects can not be attached and hung from the ceiling or the walls—potential damage to the pressure bladder.

It is important to mix the air around in each of the modules. Even though there is some gravity, it is possible to have pockets of carbon dioxide which could be hazardous to the people. Also, with a higher humidity level than in the ISS, there could be moisture build up in cool areas that would allow for mold or fungus to grow. Mixing of the air can be done with a few large fans or several smaller fans. Higher speed fans are typically noisier than larger slower moving fans.

Pros and Cons of Plants

Consider the following as you think about the kind of plants you might send to the moon.

Plants have several potential purposes in a Lunar base:

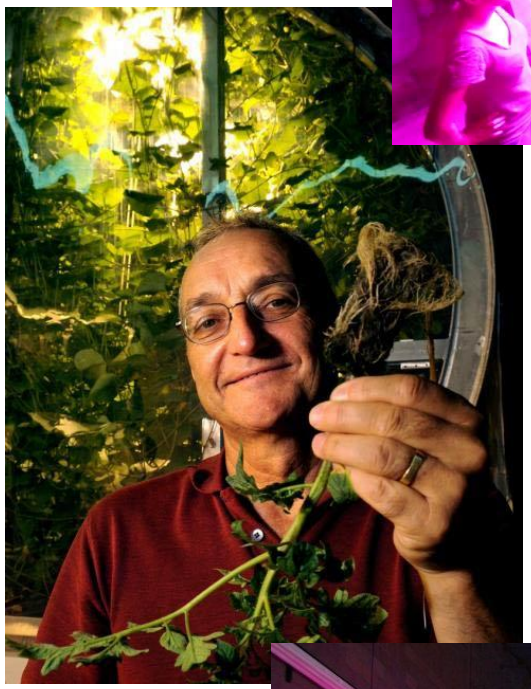
- Take in CO2—Plants absorb carbon dioxide and turn it into leaves, stems, roots and sometimes fruits.
- Make O2—photosynthesis is the process of turning water and carbon dioxide into glucose includes making oxygen
- Food production—Any food produced on the moon will help decrease the amount of food supplies that are needed to be sent from Earth.
- Uses some of human waste for fertilizer—people produce a significant amount of waste products but some could be used to aid in the plant growth.
- Mental health of the crew—having green plants growing and having something to take care may be calming for the crew.

Plants could also have some drawbacks:

- Take lots of astronaut time—we definitely need to know how to grow food in space but it does take a significant amount of time to cultivate crops. Is this how we want to spend astronaut time on the moon?
- Pollen—Allergies for the crew.
- Higher Humidity--Growing plants inside will increase the humidity level inside the Lunar Habitat. Could that cause problems for other equipment or the comfort of the crew?
- Bacteria growth—bacteria from human waste used for fertilizer or bacteria on either the plants or in the growth media could be problems for the crew
- Fungal growth—if plants are sent from Earth, they may arrive with some fungus either on the plant or in the soil that could cause health issues for the crew.
- Fertilizer smells—any fertilizer from humans could also make the humans sick
- Organic matter—Organic matter doesn't degrade into dirt without fungus and bacteria and bugs to break them down. Can we help degrade
- Where does all that plant waste go after growing the fruit or vegetables the crew wanted?

There are some plants that will take nitrogen from the atmosphere and put it into the soil. NASA is having to supply the nitrogen for the air. Is it more important to pull the nitrogen from the air with specific plants or is it better to send the nitrogen compounds we want to put in the soil? Which plants are used for nitrogen fixing?

If people are serious about exploring further into solar system and further, there is no doubt that we need to learn to grow our own food off the planet. Just because we are adamant about growing plants and food, doesn't mean we get to ignore the drawbacks of growing plants. It means we have to account for those problems. Be aware these difficulties as your team is working on your project. These may be questions you will be asked about.



Things to Think about

Which plants:

- take in the most CO_2?
- produce the most O_2?
- make products that could be use for construction
- make food that would be the most nutritious?
- make medicines or oils that could be valuable to the astronauts?
- Least biomass
- Need the least nitrogen
- Least water
- Most carbon (biomass or producing sugars)

How many plants are needed to equal the amount of O_2 needed for 1 person for 1 day?

Are any of these plants also aesthetically pleasing to help with being away from Earth?

Are there any plants that need:

- Less water?
- Less light?
- Less care?
- Cause less allergies?

- Make sure you start your experimental evaluation of growing your plant species as soon as possible. We want to see quantifiable data on the parameters you have measured -such as:
  - optimal water requirements, nutrients, optimal light
  - hydroponics/aeroponics/hydroculture-vs-soil.
  - How do we turn sterile lunar regolith into a viable growth medium?
- Can you make your design modular. The purpose of the greenhouse is learn what is needed to grow plants on the moon, and over time we need to change and/or rearrange the configuration to grow more crops. Design your system so that reconfiguring growing areas can meet these requirements. Think racks/shelves that can easily be modified to meet multiple needs.
- The gravity is only $1/6^{th}$ that of Earth. Could plants grow faster and taller in the lower gravity? What pressure will water pumps need to effectively deliver water to the plants? Are there other modifications to consider?

Scaled model for how it will be done on the moon

We are not designing the dome—that is done. Teams are designing the interior layout with plant growth equipment that can be changed as the needs change.

Your design might be represented using a paper mache dome or poster board or 3D printed skeleton dome. Another option could be building a wire frame dome so it is transparent and can see your layout. You might build one half of the dome so the interior is visible – similar to a child's doll house

The chamber must be separated from the main living areas but provide for exchange of gasses (oxygen and carbon dioxide) with the rest of the lunar habitat.

Your presentation needs to include detailed drawings of electrical and plumbing as well as testing data with plants grown in the lunar regolith.

What can you show and represent in your model?
- lighting system that optimizes plant growth.
- efficient watering system
- mixing of air
- Work space for astronauts
- Tools and storage
- Access to mature and young plants
- Don't walk on your hoses and cables
- You are not able to attach equipment to the walls and ceiling so you may need to incorporate some of the support equipment into the structures for the plants.

Water Tank

Both the Habitat and the Agriculture Lab will need separate water storage. The crew need to have water that can be cleaned and waiting for use for drinking, food rehydration and hygiene activities. The 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 Habitat will have at least 100 gal of extra water to work with. The Habitat resevour will top off the water for the Ag module at a maximum of 150 gal. of water per day.

<u>This is an important distinction.</u>

As a plant grows, it uses the water to make its stalk, leaves, roots,… When the fruit or stalk or leaves are harvested and eaten, the water is then transferred into the person. Then the water leaves the person as urine and fecal material. The urine and moisture from the fecal material are recycled through Water Reclamation System and some water must return to the Agriculture Lab.

As the air is circulated through the Ag Lab and back into the other modules, humidity will be pulled from the Ag Lab and spread out to the other modules and is condensed to be recycled.

Although this sounds a little complicated, this is a much shorter water cycle than we see on Earth.

Three 50 gal tanks or two 75 gal tanks?

Hydroponics/Vertical Farming

- There are a variety of new types of indoor farming some of which are inspired by the drive to go to the moon and beyond. Some of them use some regolith others use less or none. The question we need to answer is if it can be done with a variety of plants. Many types of plants can be killed by having too much water and need to be in a sandy soil to allow for good percolation of water past the roots.
- Aquaponics that utilizes fish might sound like a good idea here on Earth but it would require a lot of water, fish food and maintenance that could be difficult on the moon. This means there would be a lot of challenges on the moon that I don't want you to have to demonstrate for this project. Therefore, NO FISH. Maybe on a later project.

https://www.youtube.com/watch?v=suYcri3FzcI

Demonstration/Testing

Your ideas for growing should be tested in your own grow chamber and then represented in a scaled model that depicts the building on the moon. You should start this early in the year so you have relevant information about how the plants grow. If you have problems, you will have time to make changes.

For a baseline understanding, there should be some plants grown in regular potting soil to demonstrate that your team knows how to grow plants and you will be able to compare between potting soil and your other option. How does your method of growing your choice of plants compare to growing it in potting soil?
If you choose to do 'in ground planting' using regolith as your demonstration, limit your demonstration to 1 kg of regolith simulant. 1 kg of simulant sells for $45. If it doesn't grow something the first time, try growing it again because you are adding organic materials to the soil. Does it grow consistently through its grow cycle or does it shoot up at different times?

I was at the Houston Museum of Natural Science where they had an experiment going and were growing different plants (radishes, purslane, mung bean) in potting soil, Lunar regolith simulant and a Mars simulant. Lunar regolith is mostly crushed rocks so it doesn't have organic materials in it but does have lots of minerals. Mars soil is also different from potting soil.

Radishes, mung beans, purslane grown in Lunar Regolith simulant and Mars regolith simulant.

Lunar Regolith Simulant

- Regolith—Lunar regolith is a very specific term and is composed of broken up basaltic rock. This would be similar to the lava rock in Hawaii but broken up into a mixture of fine powder and gravel from being hit by meteors. Because there isn't any flowing water or air on the moon, the particles are very sharp and jagged unlike sand on Earth.
- Soil—a mixture of organic material from decomposed plants and animals, clay, and rock particles that have been decomposed by both chemical and mechanical weathering.
- Dirt—a very generic term that often refers to cleanliness (or the lack of) and can include mud, organic materials, inorganic materials, …
- As you might guess, there is a very limited amount of Lunar regolith on the Earth and very little of it has been used for trying to grow plants.
- It is possible to buy Lunar Regolith simulant but it can be expensive (around $50 per kilogram). It can also be made fairly cheaply if you are willing to put some effort into it.
- If you are growing only a few plants, you may not need very much lunar regolith simulant.
- Get some lava rock or granite from the garden center. There may be some of the sand and dust from the rocks on the floor or in a bag. It will probably still need to be crushed more.
- Because it is a fine powder, the lunar regolith will need to be kept moist so it sticks together and doesn't get kicked all over.

It is important to start with a regolith that has

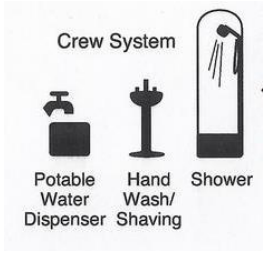
- Sandy to fine grain
- High mineral content
- pH is between 9.0 and 10.5
- **No organics**—it is valuable to bake your regolith at around 400F for an hour to kill off any organic in it.

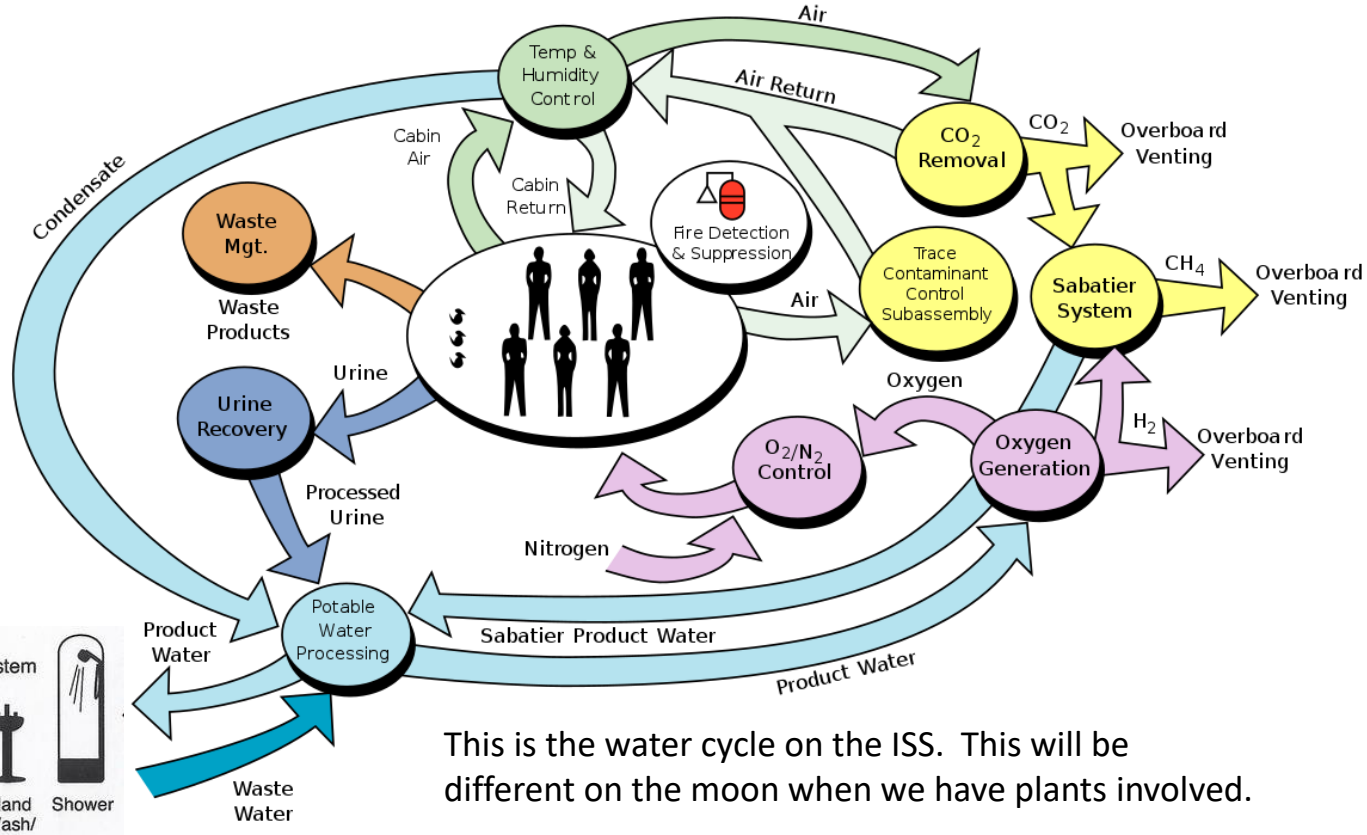
If you are dealing with Lunar Regolith simulant, you need to use N95 masks, eye protection and gloves. The particles are very tiny and sharp and you don't want to get it in your eyes or nose by accident.

Humidity and Temperature

- Many types of plants grow well in temperatures of around 80 to 90 degrees F but most people want to live in temperatures around 69 to 72. The humidity on the ISS is kept around 40% which is relatively dry (especially for Houston). When an Agriculture Lab is added to Lunar habitat, the humidity will probably go up to around 70% to 80%.

- One of the many reasons for sending a variety of plants to the moon is to help remove CO_2 from the atmosphere and provide some O_2, that can only be done by circulating air between all the modules with the Ag Lab. But that also means you are spreading humidity and temperature between modules as well. If the habitat is much cooler than the Ag Lab, the water will condense in the habitat on the equipment, and the plants will be sending their warmer air and moisture to the other modules. This means your attached greenhouse will be fighting with your habitat for both temperature and humidity. You will have to come up with some kind of compromise where your plants may not be growing at its optimum rate and/or your people may be dealing with a warmer temperature than they would prefer.





This is the water cycle on the ISS. This will be different on the moon when we have plants involved.