Lunar Bamboo Greenhouse Questions and answers

1. I've been thinking of doing an aquaponic system which would involve having a tank underneath with a few fish to help produce natural fertilizers for the plants while also potentially being another source of food. Would that be something that would be good to peruse or is that something outside of what you're looking for?

I am open to the idea of aquaponic system and using fish unfortunately you are still going to be limited to the same volume. Besides fish you might also consider freshwater crawfish or other kinds of water bugs.

I've heard that tilapia is a good fish for aquaponics.

2. Also, I've been wondering how tall the green house would be. Height restrictions can play a major part in deciding which type of bamboo is possible to use and how best to grow it.

Since the structure is a hemisphere with a diameter of 20 ft, the height is 10ft in the middle. Because of the need for radiation and micrometeorite protection both for the crew and the plants, the shape is to help with preventing weak points in the structure both for keeping air in and the strength for supporting the regolith on top.

3. Would the greenhouse need to be strictly a spherical, dome shape, or could we change the shape of the greenhouse for more opportunities?

The shape is essentially a hemisphere. Part of the reasons are related to the inflation as well as the strength of the shape once the 3ft of regolith is added on top.

4. Would the power be supplied to the building already or will we have to think of a power source by ourselves?

The power will already be in the module but you could give direction of where you want outlets and if there are specific power requirements.

5. Are there other plants planned to accompany the bamboo, and if so, what are they?

You can help determine that. Some may be related to food production but is not the only concern. The main plants for you to worry about is the bamboo.

6. What is the material that will be used for the greenhouse?

There will be several layers of cloth and flexible materials—kevlar and Beta cloth (a fiber glass material) on the out side, layers of mylar for insulation, urethane as a pressure bladder, and an inner scratch material. You should be able to find more details on the internet. Search inflatable space craft materials—the modules on the moon will be very similar.

7. Finally, how and where would the water be stored for the greenhouse?

Some water may be stored outside but some should be inside. You can help determine that internal storage location and quantity.

8. Are there any details on the material and structural supports of the inflatable module we are working in?

If you do a Google search on materials for inflatable modules, you should expect that those materials will be very similar to what we sent to the moon. There should not be other supports as the dome structure should be very strong.

9. Is the 20ft diameter we are given a measurement to the inside of the inflatable or the outside?

Assume that to be the inside dimension for the dome

10. Is the bamboo being grown from seeds or are they being sent up as shoots?

I would like to let you be the judge of that. It seems to me that it may be more valuable for us to send small shoots to start the growth, but I'm open to ideas.

11. What are the dimensions of the entrance to the module?

Good question. Let's assume each hatchway to be 48 $in.^2$.

12. Can we put infrastructure (plumbing, electricity, etc...) underneath the floor or does it need to remain within the 20ft hemisphere?

There may be some that is in the walls and floor of the module, but there will be connections and cables inside as well

13. How much bamboo are we expected to be growing?

The purpose of the bamboo is to supplement the capabilities of the ECLSS racks, by removing carbon dioxide and providing carbon dioxide, but we don't expect it to take over the job of the ECLSS. I don't have a quantity that is required so I am depending on you to help determine how much to grow.

14. How much space do we need to allocate for other crops?

I'm not exactly sure. How about half. Again I am depending on you to help decide this.

15. A question regarding the ventilation system in the Greenhouse base. I've devised a diagram of a propeller system with the qualities of an air conditioner. However, we have no idea where that hot air will go. I thought that maybe there could be an insulation method that allows hot air to pass out the base, but any contact to the outside is highly dangerous. We would like your input on where the air would go, assuming there's plumbing underground with drainage holes that help with the ventilation.

This is a similar issue that we have on the space station. We can't vent hot air to the outside as that means we are losing air. this implies that we're going to have to have some kind of radiators that send heat without losing air.

If you look at a picture of the space station, you will see big large panels that are the solar panels and other sets of white panels that are the thermal radiators. The space station has a liquid cooling loop that circulates cold water to different cold plates in the space station. after the water is warmed up by being next to the electrical components, the water is circulated to a heat exchanger where the water is cooled again and recirculates inside the space station. As the water passes through the heat exchanger, the heat from the water is transferred to ammonia that circulates on the outside of the space station to the white thermal radiators.

Those thermal radiators eject heat only by radiation. Because space does not have air There is no convection like what we would use on earth. Therefore, it can only eject the heat by way of radiation.

I don't mean for you to have to design this thermal system for the lunar base. You should probably show a loop that goes outside somewhere to reject the heat and then comes back inside with cooler water.

16. Where will the excess water go after watering the plants?

Will it cycle back and be used for watering them again, or will the water be used for different purposes?

You can determine that. If it still has nutrients in the water, you should probably cycle it back past the plants.

17. Is the outer wall of the dome going to start curving immediately (when it connects directly to the floor/ground), or if there is a wall rising up from the floor/ground and the curve starts from there?

How tall are the walls before the curve if the latter is the case and how tall is the center? We don't want anything to be too uncomfortable and tight for anyone inside.

Just like an arch is considered the strongest structure by spreading the forces evenly through the arch, a hemisphere is a very strong structure because the forces are spread evenly through the whole hemisphere.

Initially I expected each module of the habitat to be just a hemisphere but after talking with some people I think it would be better if there is 1 ft of strait wall and then hemisphere.

This allows the total height of each module to be 1ft taller than half the diameter.
Main Hab—1ft + 30/2 = 16ft at the center
Stowage—1 ft + 15/2 = 8.5ft at the center
Bamboo Greenhouse—1 ft + 20/2 = 11ft at center
Sleeping Quarters--1 ft + 15/2 = 8.5ft at the center
Air Lock is a metal cylinder so this doesn't change

18. One question I have for you… with the bamboo greenhouse project can we use other plants for the prototype? Thinking wheat, grass, or another small grain that will grow fast and be a better size for a scaled model? We have some bamboo and seeds ordered but just wanted to see if grasses would be a nice substitute.

The lunar bamboo greenhouse project has two main "deliverables", as shown on page 4 of the project description

1. A scaled model of the lunar inflatable module
2. A demonstration that the bamboo species you've chosen can be grown in lunar regolith (or other conditions that your lunar bamboo greenhouse can support) (if your type of bamboo is not available, grow some kind of bamboo to help you understand what bamboo needs)

Although scaling the bamboo with grass is a cool idea, the scaled model does not need to use any real plants. Keeping plants alive while transporting can be difficult. Having some scaled plastic plants or other representations would be fine. The growing of the bamboo is to help the students understand the needs of different kinds of bamboo. I'm hoping that understanding some of the bamboos' needs will influence the greenhouse requirements.

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19. For example, what type of power would the habitat be using? Would it be AC or DC?

All space craft except the ISS use 28V DC. The ISS uses 120V DC. They were trying to minimize power losses due to the length of the cables but it has cost us lots of power converters all over the space station. I expect the Lunar Habitats will also use 28 Volt DC.

20. We have researched that the 1/6th gravity of the moon does affect the trajectory of air particles so, does that mean if we were to use vents/pumps (to ventilate the air of carbon dioxide from other modules or bring oxygen in) would we have to pressurize the air or work in the ability to suck air in to make it work on the moon?

All the airflow will need to be circulated and mixed. Having a good mix in the green house will be especially important since the bamboo and other plants will be removing CO2 and providing O2.

21. Our final question is on the Q & A. It's stated that we can assume the entrance is 48 square inches, to us this seems far too small and would only function as a vent so is there another measurement we'd be able to use?

The dimensions of the hatches have not been determined so I am going off what is currently used on the ISS. Part of the difficulty is that hatches are made of fairly thick aluminum so they are not warped from the pressure when a vacuum is on one side and there is pressure on the other.

These hatches allow the refrigerator size racks to float through them on the ISS but with $1/6^{th}$ g that may still be difficult. If you look at hatches on a ship, they are also relatively small and also require that people step over the threshold.

If you have a specific reason for the dimensions of a hatch, you can suggest it but you should have very good reasoning to back it up.

22. With the Bamboo growth chamber- do we need to design a floor or could it grow directly in the lunar soil. Could we dig in the soil to add water lines, drainage, and electricity lines so we don't have to count this in the height of the structure?

Because this is an inflatable structure, the floor is also holding the air pressure inside and keeping the structure sturdy. Any soil you bring in needs to be placed on top of the floor. You may choose to have a raised floor to place air ducting and hosing underneath.

23. To what extent do you want the scale model to be detailed? We have designs for a basic ribbed dome, but do we need to deeply consider the forces and strains on the model? Regardless, we will have the necessary additions like the lighting and plumbing. Also, does the dome need to be smooth? I have seen many domed buildings designed to have flat panels sealed to a frame. I think the transportation of materials would be easier and more efficient if we used that concept.

The inflatable module is mostly smooth inside. The more detail you can put into your model, the more we will understand your ideas. Before NASA will build the modules, we will have every detail determined—right down to the Velcro patches on the wall. I am hoping you will tease out some of the details that will make NASA engineers think hard about what is needed. No one has built these yet so the air ducting, water hoses, electrical wiring and lighting are just concepts until you place them.

It costs $1.2 million per pound to get something to the moon. We need to minimize the weight of materials we send but retaining good strength. The dome structure is like a lot of arches—very strong.

Consider---A basket ball has a pressure of about 7 or 8 psi and can withstand someone standing on it with only some deflection. It could be buried pretty deep before it would pop. The habitats will have 14.7 psi inside (about 2x a basket ball). The habitats will be buried with about 3 ft of lunar regolith but at 1/6th gravity, it will be like 6 inches of Earth dirt. I am confident that the habitats will be sturdy without ribbing.

24. Will the vent system that will transfer fresh air to each and every module need to be done within the base, or will it be an attachment on the exterior part of the base?

All of the ducting for the habitat needs to be internal to the modules. The regolith that is put on the outside may damage the ducting or micrometeorites could puncture them without getting to the pressure bladder of the habitat.

We have learned a lot about bamboo recently thanks to the people from Bamboo Garden.

Lucky Bamboo is not really bamboo—it is really a tropical water lily and is not a good simulation for growing real bamboo.

Bamboo seeds are very difficult to get to germinate and could take several weeks or even months to sprout. Some may never sprout.

If you are already trying to or have succeeded in sprouting bamboo from seeds, keep it going but realize that it may not produce much growth data for you. If you can get some bamboo from a green house,

you will probably have much more luck. This doesn't mean you can't send bamboo seeds to the moon, we will just have to change our expectations for when it will produce. I have seen some good bamboo growth experiments. GOOD JOB—KEEP IT UP!!!

Another thing to think about with the greenhouse is the importance of the green. Many of you are finding that there are color ranges of light the bamboo grows best in that doesn't include green—this will leave the bamboo and other plants appearing black because it is absorbing most of the other colors. The astronauts may want to see the green when they go into the greenhouse to remind them of home.