Long Duration Experiment Technical Report

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Abstract

NASA is preparing to send a greenhouse to Mars aboard the first mission to colonize the red planet. It will give astronauts the opportunity to study the potential of growing crops on Mars to support the astronauts instead of relying on shipments from Earth. They will study the soil composition to see if it contains the necessary nutrients to support plant life. If they succeed, this experiment will be the gateway to large-scale farming to sustain larger populations. If not, then NASA will know to focus on hydroponics-based farms and other methods to feed the astronauts. The experiment requires a greenhouse, soil testing equipment, data recording devices, and a specialized astronaut with a background in botany to maintain and oversee the experiment. The experiment does not require much additional power, as it mostly runs off preexisting life support functions that are already integrated into the main habitats, like lighting, pressurization, atmosphere regulation, etc. NASA expects to have crops growing within three months of setting up the greenhouse, definitive results by the six-month mark, and be actively pursuing larger agricultural infrastructure by the end of the first year.

Keywords: Mars, crops, soil composition, farming, greenhouse.

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One of the most fundamental necessities for survival is creating a sustainable food source. Here on Earth, we find it almost everywhere we go. Our planet is covered in lush greenery and wildlife that we can harvest and eat. The same cannot be said for Mars; the red planet is covered by a desolate, cold desert with no signs of life. For the initial mission to Mars, the astronauts will have three years’ worth of food to support themselves, but food takes up valuable space and weight that could be used for more pressing equipment or supplies to establish a permanent Martian base. The first astronauts to step foot on Mars must establish a reliable food source to survive and support future missions. The best option is a farm. Crops are being grown and tested in numerous harsh environments, like aboard the ISS and in simulated environments in Arizona, Hawaii, and Antarctica (Candanosa, 2017). Nobody has a sample of Martian soil on Earth, so everything NASA believes about the soil is based on information gathered by rovers and satellites. NASA does not know exactly how abundant the vital nutrients for plant growth are on Mars. One of the most important missions that the astronauts will be tasked with is to analyze the soil for those nutrients and test various species of vegetation, like potatoes and lettuce, to see how well they could potentially grow in Martian soil, and, if they can grow, what the optimal setting is for them to thrive and feed the astronauts. The experiment ties into MEPAG goal IV: preparing for human exploration. The information collected regarding this experiment will play a crucial role in designing future missions. If they can grow food, astronauts will be able to create large-scale greenhouses using the nutrients in the soil to grow produce. If they can’t, NASA will have to continue supplying the astronauts with enough food to last for the entire journey while they search for better alternatives, like hydroponic farming methods.

# Designing the Experiment

There are several different qualities about Mars’ environment that will define how NASA designs the systems that will go into the experiment that wouldn’t be an issue on Earth. While some are beneficial to the experiment, most will hinder the results and make the experiment extremely difficult. The first is size. The spacecraft has very limited space to transport the necessary equipment to Mars. The SLS rocket currently in development by NASA to carry astronauts to the Moon and Mars can carry 10,000 pounds of equipment, food, and supplies when it is in its Block 1B configuration, the one that is designed to Mars (Harbaugh, 2018). This means that the greenhouse will have to be compact and light in order to leave enough room for other vital supplies, like life support systems and habitats. Because of its small size, the greenhouse will be too small to support large crews of astronauts. Several greenhouses on subsequent missions will likely be necessary to produce a large enough crop yield to feed everyone. Student researchers at the University of Arizona, in collaboration with NASA, designed the Prototype Lunar/Mars Greenhouse for astronauts to be able to grow the necessary food to support themselves. To overcome the size issue, the greenhouse is an 18 foot long, eight-foot in diameter cylinder that can fold down to a four foot in diameter disk that can be easily stored aboard the spacecraft (Granath, 2017).

The next limiting factor is water supply. It has been proven by the MARSIS satellite that water does exist deep within Mars’ crust and under large ice caps (Mars Express detects liquid water hidden under planet's south pole, 2018). The problem is getting it to the surface in large enough quantity for the astronauts to drink and use for the greenhouse. If astronauts fail to harvest water, NASA will have to develop alternative methods to produce it. Water is a relatively dense substance that costs a fortune to ship on a spacecraft. To produce enough water to support large colonies of astronauts and large-scale greenhouses, astronauts would require large, power-intensive machinery. As the astronauts study soil composition, they will also be testing the water content of the soil to determine the potential for harvesting it.

One of the few beneficial factors present on Mars is the carbon dioxide-based atmosphere. At 95% CO2, the atmosphere is inhospitable to humans, but plants love it. The CO2 can be easily pumped into the greenhouse to help start photosynthesis and produce the ATP that will help them grow. While this means that specially designed systems have to be implemented to help control the flow of CO2 into the greenhouse as to not overexpose the habitat to the exterior environment, it is a major benefit that will become exponentially more useful as the greenhouse system expands.

The last major factor is radiation. Because it lacks a magnetic field, like the one on Earth, Mars is prone to large doses of radiation that would be unhealthy for the plants in the greenhouse. This problem could be solved in a variety of ways, but it will come down to how the colony is developed. It is possible to create an underground shelter and use the soil above as a shield, or astronauts could use autonomous systems to help pile up soil over the habitats to protect them. Whatever way NASA chooses, it is crucial to protect the greenhouse from radiation. Large enough doses can cause seeds to stop sprouting, stunt growth, and deprive the soil of nutrients (Glenn, 2019).

# Materials and Equipment

The experiment will require some crucial supplies to make sure that NASA gets as much data as possible. The main piece of equipment is, of course, the greenhouse. It will be the centerpiece of the experiment and will provide NASA with the necessary information on how plants will grow with Martian soil and nutrients. The second piece of equipment is the soil analysis kit. This will allow the astronauts to test various samples from different locations for the necessary nutrients, like nitrogen, phosphorous, and potassium. It will help NASA determine whether it is feasible to create larger, more traditional farms that can use the soil to provide the nutrients necessary for the plants to thrive versus a system that relies on hydroponics or another nutrient surrogate. Other testing equipment and data recorders will be required to track the progress of the crops and make sure they are edible and have no negative side effects that could be averse to the astronauts. Machinery to produce fertilizer from human excrement would also help the plants grow and provide some of the nutrients lacking in the soil.

Many of the same parts that will go into the habitats will be required for the greenhouse, like life support systems, lighting, and pressurization. This requires some simple engineering to make sure that it will be sealed off from the exterior and accessible from the habitats. It will also require a larger water supply, hence a more effective water production system. The bottom line is that the greenhouse will just put a little more pressure on the support systems that are already in place to keep the astronauts alive. The greenhouse will be the most difficult part of the experiment to implement.

# Power

Power will be much harder to come by than on the moon. The near-constant dust storms that plague Mars will quickly cover any solar panels that are placed around the colony to provide power, so astronauts will have to develop a system to clean the panels off routinely or use a power source, like wind, that isn’t as prone to dust damage or lower efficiency. The greenhouse will require more power to keep the life support systems running, and the water production machinery will have to be upgraded to be more powerful, thus adding to the power requirements. Compared to the power requirements of the rest of the habitat, the greenhouse will not be a major investment and will only require a slight increase in power production. The greenhouse is not very power-dependent for anything beyond the typical life support present in the habitats. The soil sampling kits require little to no power. The habitat will not need the maximum power output from the power source, so it is feasible that the greenhouse will not require additional infrastructure beyond what is already present.

# Time Factors

The greenhouse will be a major part of the astronauts’ lives. They will have to keep daily tabs on the progress of crop growth, find the perfect setting for the crops, collect and analyze soil samples, and maintain the structure. It will require at least one of the astronauts to specialize in botany and it may be his or her main job to maintain the greenhouse and record data.

The structure will take little time to erect, as it folds onto itself for storage. The astronauts just have to connect wiring and life support systems to the main habitat before they start adding soil samples, seeds, and water. The experiment will be ongoing for as long as the information is relevant, and the crops are being produced. If the experiment is a success, it will be the first of many greenhouses constructed to help feed the colonists.

# Theoretical Results

The president of the company that produced the Prototype Lunar/Mars Greenhouse claims that plants can be growing inside of the greenhouse in 30 days (Staff, 2010). It is reasonable to assume that, by the three-month mark, the greenhouse should be producing crops under ideal circumstances. If the soil is not providing enough nutrients to the soil, crops could take much longer to grow. By the three-month mark, the astronauts should have analyzed dozens of soil samples and kept tabs on the nutrients in the greenhouse to identify whether the soil is usable or not for agricultural means.

By the six-month mark, NASA expects the astronauts to have come to a conclusion as to the effectiveness of Martian soil and the long-term effects on plant growth. If the plants require a large amount of surrogate nutrients from outside sources, it will be deemed too nutrient-deficient to pursue, and the astronauts will turn to hydroponic-heavy systems to carry out further agricultural development. If the plants show signs of being healthy and not needing too many more resources to fully grow, then the experiment will be deemed a success and NASA will begin designing and testing larger-scale farms that use the soil as the main source of nutrition for the plants.

At twelve months, the astronauts should be developing whichever method was determined to be the best at the six-month stage. This includes more greenhouses, larger infrastructure, and larger crop yields to feed the ever-growing population of colonists. Since the experiment is part of the vital life support systems for the colony, the experiment never truly ends. The original mission was to determine the potential for the use of Martian soil, but that was fulfilled at the six-month stage. During the later stages of the experiment, the astronauts are refining and testing the various methods to produce the crops necessary to support themselves at the highest efficiency possible.

# Conclusion

To fulfill the dream of creating a Martian settlement, NASA needs to be able to feed all their astronauts. This experiment will help provide valuable data to NASA scientists and engineers to help design future agricultural infrastructure to support the masses. The experiment will be the first stage of a large part of life on Mars. In the near future, greenhouses will dot the landscape and help feed all of those who venture to the red planet. MEPAG outlined the four most important areas of research regarding Mars, and this experiment is one of the biggest concerns regarding goal IV: preparation for human exploration. Without a sustainable food source, humans will never flourish on Mars. This is one of the first big steps toward securing our future as an interplanetary species.

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