Conceptual Model of Autonomous Seed Germination Habitat for Mars Mission

Jonah Peter[1,2], Rodrigo Rene Rai Muñoz Abujder[1,2], Joseph Niko Vlastos[1,2], Parker Dubee[1,2], Luke Monhollon[1,2], Ivana Vasic[1,2], John Pfail[1,2]
Pantelis Solomides[1,2], Melissa Lokugamage[1,2], Iman Hamid[1,2], Alice Zhang[1,2], Jon Rask[2], and Robert Bowman[2]
[1] Space Life Sciences Training Program (SLSTP) [2]KBRwyle, Space Biosciences Division, NASA Ames Research Center, Moffett Field, CA 94035

INTRODUCTION

This poster summarizes the results of the Space Life Science Training Program (SLSTP) 2016 group project. The objective of the group project was to develop a habitat concept capable of germinating the first seeds on Mars. This study focuses on two preparatory measures regarding seed germination in spaceflight: analysis of seed surface sterilization protocols and the development of an autonomous seed germination habitat. The proposed habitat will require a compact, low wattage system to provide gas ventilation, artificial light, and water. A visualization system will also need to be developed to monitor seed germination remotely. To test the effects of seed storage durations on plant viability, we are also developing a ground study to monitor seed germination in seeds which have been dormant for three, six, nine, and twelve months. We will also compare the effects of different seed sterilization procedures. The results of this study will be instrumental in developing a viable procedure for transferring the first living plants to Mars.

PURPOSE

Our purpose is to develop a conceptual plan for an autonomous plant germination habitat that could be flown aboard a SpaceX Red Dragon vehicle in the 2018 timeframe, in order to grow *Brassica nigra*, or black mustard seeds, inside a spacecraft on Mars. In developing the conceptual plan, we have researched previous flight missions such as the Long Duration Exposure Facility (LDEF) and growth modules such as the BRIC and the European Module Cultivation System (EMCS). We seek to make a module more compact, durable, and capable of providing significant science return from Mars. In doing so, we have developed a seed germination ground study that uses flight-approved seed surface sterilization protocols, and Dr. Robert Bowman's proprietary lunar habitat module, which we adapted in our development of a remotely-controlled prototype for seed germination on Mars.

METHODS

Seed Dormancy Ground Study:

Objective: Examine current ISS seed sterilization protocol to understand long-term effects on Brassica seed viability.

- Viability of surface sterilized seeds has been shown to decrease after ~6 months of storage.

Experimental Design:

- Sterilize the surface of seeds using a standard ISS flight protocol
- Germinate surface-sterilized and unsterilized (control) seeds after 3, 6, 9, and 12 month intervals.
- Compare viability of sterilized and unsterilized seeds

Purpose: If seed viability of sterilized seeds is lower than control seeds, we may need to consider a different sterilization procedure if we want to send seeds to Mars as the seeds will be in stasis for more than 6 months in transit time.

FIGURE 1.
(Left) Top row displays sterilized seeds with unsterilized seeds in the bottom row. (Right) SLSTP Interns attaching *Brassica Negra* seeds to blot paper using Guar gum, or starch.

METHODS

Germination Ground Study:

Objective: Examine autonomous germination procedure and crucial factors using Dr. Robert Bowman's proprietary lunar growth module. Collect temperature, CO_2, Normalized Vegetation Difference Index or NVDI, and Imaging data to use as metadata in designing the conceptual model.

Experimental Design:

- Sterilize seeds using standard ISS protocol
- Germinate sterilized and unsterilized (control) seeds in 5 day periods.
  - Fluctuations in Temperature and CO_2 measurements taken once an hour for 10 minutes.
  - Imaging data was taken using an infrared sensitve Raspberry PI camera every minute.
- Compare viability and data of sterilized and unsterilized seeds and use data to model germination process for the conceptual module.

Conceptual Model Hardware Design

Objective: Using previous research and science data as a foundation, design the conceptual model with the following constraints:

- Voltage: ~5V-12V
- Sample Rate: 2.4 kilobits per second
- Weight: 1 Kg
- Consider previous cultivation systems such as the **BRIC-Petri Dish Fixation Unit (PDFU), EMCS, and Dr. Bowman's Lunar Module**
- **Consider** transport systems such as the SpaceX Red Dragon specifications, Astrobotic lunar transport specifications, and previous Mars scientific payloads.

RESULTS

Seed Germination Ground Study Results:

Using the Raspberry Pi IR sensitive camera, Temperature, and CO_2 sensors, 27 sterilized and 34 unsterilized seeds were germinated over a 5 day period in Dr. Bowman's proprietary habitat. Temperature, RGB, and NVDI images were taken every minute while ten CO_2 readings are taken every 6 hours. The daily average of the Temperature and CO_2 were taken to examine the germination process.

Temperature and CO_2 Readings

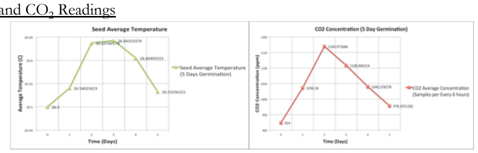

Figure 2.
(Left) Habitat Average Growth Seed Temperatures (°C) and (Right) CO_2 concentrations (ppm) of Germination over 5 days.

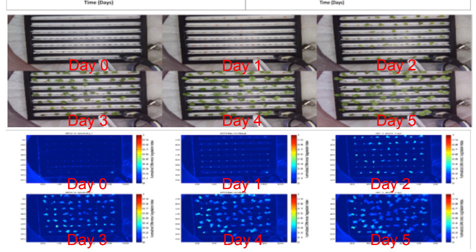

Figure 3.
(Top) 5 day germination RGB and (Bottom) Normalized Vegetation Difference Index, NVDI Habitat Growth Images (top 3 sterilized seeds |bottom 3 rows unsterilized) seeds over 5 days.

Conceptual Hardware Model Design:

Using the ground study results and research conducted, a preliminary AutoCAD autonomous germination model has been made and 3D printed using PLA with the specifications mentioned as well as a basic telemetry unit using a custom designed Android application connected with an Arduino to receive live Temperature, Humidity and CO_2 measurements and plays the recorded germination video.

Figure 4.
(Top Left) Overview of Preliminary Germination Module, (Top Right) Components view of Germination Module, (Left Bottom) Basic telemetry unit with Android, Arduino, Raspberry Pi, and corresponding sensors, and (Right Bottom) Component view of 3D small scaled module print.

Seed Dormancy Ground Study Results:

Currently, 36 seeds have been prepared and properly stored for each sterilized and unsterilized set per 3, 6, 9, and 12 month trial. Once the time interval is reached, each seed set will be germinated in a controlled environment. The table below shows the designated times for germination.

Seed Set/Storage timeline	3 Months	6 Months	9 Months	12 Months
Sterilized	11/2/16	2/2/17	5/2/17	8/2/17
Un-Sterilized	11/3/16	2/3/17	5/3/17	8/3/17

DISCUSSION

In the seed germination ground study, the process has the carbon dioxide and temperature values in the chamber climb steadily and then increase drastically to their respective peaks at 1169.97ppm and 26.64°C on the third day. It can be presumed this is when the brassica begin to sprout and require a larger amount of the available module resources as these resources begin to decrease due to activities such as CO2 drawdown and micronutations. In the video analysis, the unsterilized brassica display faster micronutations than the sterilized brassica. In the NVDI image analysis, a majority of the seeds absorb equal amounts of light until the third day. Afterwards, a larger amount of unsterilized seeds begin to absorb light, but only towards the outer regions of the seed cassette. Further analysis and test runs on the seed storage ground study sets will be needed along with video analysis on the brassica leaf diameter measurements using pixel to distance estimation. As for the conceptual design, the framework for a biocompatible germination habitat weighs approximately 600 grams and uses insulating material such as aerogels to make a passive, yet efficient system. Further investigation will be required in designing compact power, sensors, data compression, and telemetry systems.

CONCLUSIONS

The preliminary milestones and foundation have been completed in designing a conceptual germination module with the biocompatibility and ability to grow seeds inside habitat-like environment on Mars. This project was undertaken to leave a legacy and inspire for future SLSTP cohorts in pursuing capable plant life on Mars.

ACKNOWLEDGMENTS

Supported by the Space Life Sciences Training Program (SLSTP) at NASA Ames Research Center, Jon Rask, Robert Bowman, Wyle Laboratories, and our other collaborators.