High Altitude Lettuce Seeds

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Abstract

This paper reports the experiment conducted by students of Arapahoe Community College to test plants' response to the extreme conditions found at an altitude of 100,000 feet. Four germinated lettuce seeds were divided in two groups: a positive control and the experimental group. The first group was placed inside of aluminum capsules with perforated aluminum lids and placed outside of the payload to experience the full effects of high altitude. The second group was placed inside of pressurized aluminum capsules and sealed with PVC caps; the capsules were then placed inside of the payload in an environment with a relatively constant temperature, which was maintained by heating pads. A third group, the negative control, remained on Earth. Once the payload was recovered, the capsules were opened, and all groups of seeds were transplanted following the same conditions. After two weeks of observation, the experiment was judged inconclusive, since none of the three groups sprouted; a bad batch of seeds is a potential explanation.

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Mission Overview

The purpose of our mission was to observe the effects of high altitude on germinated lettuce seeds at an elevation of 100,000 feet, while keeping the plants alive by controlling temperature and pressure inside of the payload. Our objective was to contribute data that could help humans grow food in the extreme conditions of space.

Requirements

- Sealed Sturdy Structure
  - Used foam board to build the payload using hot glue to secure the sides
  - Used aluminum pipe cut to 2.5 inches as plant capsules
  - Used epoxy/sealant to secure both ends of the two sets of capsules
    - Aluminum caps for the pair of capsules on the outside of the payload
    - PVC caps for the pair of capsules on the inside of the payload
- Implemented heating system
- Installed battery to payload
  - Connected heaters to the payload and then to the battery
- Kept entire payload weight under 1.0 kg
  - Foam Board Structure: 331 g
  - Battery: 192 g
  - Biological components: 400 g

Design

In order to have a positive control — which would allow us to observe the effects of high altitude on the plants — we needed an uncovered and uncontrolled exterior compartment to contain a set of germinated seeds. We wrote a list of requirements for the payload design in order to make sure that we met all of the goals for the payload. Our statements were as follows:

The payload ...

- Shall contain a plant with the goal to survive
- Shall contain a control plant that is exposed to the environment
- Shall contain any sensors or micro controllers that will be needed for data collection
- Shall contain a spot for the battery with easy access to allow us to plug it in.
- Shall be able to support the heating pads for the plants with the goal of survival
- Shall have a center of mass close to the middle of the payload

Optional statement (not required to be met but meeting the goal would be ideal)

- Shall be able to hold several of each type of plant in order to allow for redundancy

Our final design included four compartments (two on the inside and two on the outside) to house the plant casings that were spaced to ensure proper weight distribution. The control plants were placed on the opposite side of the payload from the test plants in order to move the center of mass towards the center (see Figures 3.1 and 3.2). The battery had its own bay to allow for a sturdy place for the battery. Using CAD we were able to achieve all of our statements along with the optional statement because we could place a design in a simulation and compare it to the statement goals and adjust the design accordingly. Without this we would have had to make many more prototypes.

To ensure we could properly test the effects of limited atmosphere, our design also included a second control group which would remain on the ground, so as to have another set of plants to compare to when we replanted the seeds that returned from the flight.

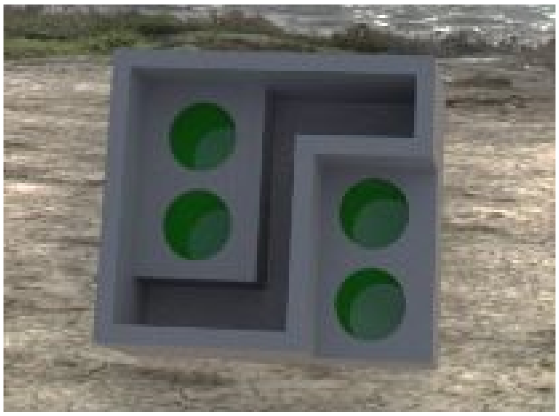

Figure 1: Shape of Design

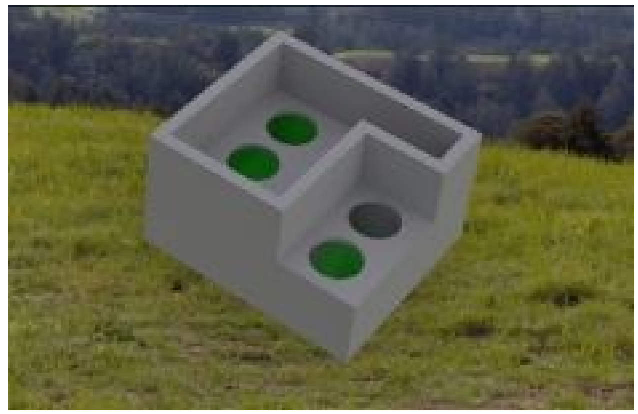

Figure 2: Side-view of Design

Figure 3: Payload day of the launch

Figure 4: Payload day of launch

Budget

For this experiment we used the following materials:

Materials	Cost in USD ($)
Romaine lettuce seeds	3.40
Mini-rockwool blocks	14.95
Foam board	12.99
Sensors	65.15
Battery	35.99
Heating pads	10.00
Micro SD card 32 GB	15.00
Soil	4.99
Capsules (Pipe and caps)	25.00
Total	187.47

Test Plan and Results

- Vacuum Test

We tested the aluminum capsules in a vacuum bell jar to ensure that they would withstand the change in pressure during flight. We tested capsules with both the aluminum caps, and PVC caps. The capsule test with aluminum caps failed the pressure test, but with the PVC caps, the test was successful, and held under pressure. We chose to use the PVC caps on the capsules that were inside the payload to maintain the pressure, but we used the aluminum caps for the capsules

on the outside of the payload so as to keep the overall mass closer to the 1 kg requirement.

- Cold Test

We tested the payload materials in a cooler filled with dry ice for two hours. The payload and the adhesive held together well, and we concluded that the payload would be able to withstand the cold temperatures of the launch. The plants were not included in the cold test, as they had not been grown at this point in time.

- Drop Test

The drop test was simulated in SolidWorks. The simulation showed that the payload would withstand impacts greater than needed.

- Whip Test

After the payload was assembled with all the mass that would be present in the payload during launch, we attached the payload to a string similar to that which would be used during flight, and conducted a whip test. The paper clip that was included in the flight integration tube failed, resulting in the payload flying off the flight string. To ensure that the payload would remain in place during flight, we replaced the washers with ones of a smaller size on the flight integration tube, as well as arranged the paper clip so that it intersected the flight integration tube on a bend.

- Sensor Test

The infrared heat sensors functioned properly but during assembly a pin broke on the SD card reader. As a result, we removed the sensors from the payload.

Expected Results

We expected the plants in the pressurized canisters to continue to grow after the launch, having been somewhat protected from the harsh elements of high altitude. On the other hand, we expected the control plants in the canisters on the outside of the payload to not continue growth at all, as they were exposed to immensely cold temperatures, solar radiation, and low pressure. We also had control plants on the ground, grown from the same batch of seeds as those in flight. We predicted that this set of control plants would continue growth as normal, as they were kept in their normal environment.

Ready for Flight

We had some logistic problems with our lettuce seeds and canisters in the week of the launch due to the loss of some members who had personal issues; we dealt with that by calling an emergency meeting to put all the payload components together and performed the last tests and became ready for flight. Unfortunately, while our sensors were operating correctly, we had a mishap involving the SD card reader. This meant that we were unable to collect any data throughout the launch, and as a result, decided to forgo the sensors entirely. Fortunately, however, we were able to successfully complete everything else as required and had the payload ready for flight at 5pm on the Friday before launch.

Launch and Recovery

The payload was launched successfully at 7:06 am on November 11, 2017 outside of Windsor, Colorado. The payload reached an altitude of 107,830 feet above sea level. The payload traveled east and landed in Haxtun, Colorado, 128 miles from the launch site. It landed in a field that was surrounded by an electric fence. The payloads were retrieved by the Edge of Space Sciences (EOSS) team.

Figure 5: Capsules on the outside of the payload

Results and Analysis

After we retrieved our payload, we immediately pulled the seed pods from their designated canisters and put the pods into the farm to be taken care of by one of our members. Unfortunately, one of the pods sealed in our canister had fallen apart; it was extremely difficult to gather all of the soil, much less the seed that was launched. After the launch, it took several days for any of the seeds to show signs of germination. We had 12 pods planted with seeds in each, but after five days, only three of the 12 had germinated. The three that had germinated were not part of the launch; they were our control plants left on the ground. So unfortunately our results are completely inconclusive. While our payload plants did not germinate after the launch, neither did five of the other control plants. We suspect that we had received a bad batch of seeds, but it is also possible that the method of planting was just not conducive for these particular lettuce seeds to be planted in. If this experiment could be repeated, testing the planting of the lettuce seeds well before the payload is launched would guarantee conclusive results as to whether or not our efforts to enhance the survival of the lettuce plants yielded any results.

Figure 6: Control group 5 days post launch

Conclusion

Our original objective was to find out what it takes to keep any sort of plant life alive in the extreme conditions involved in our high altitude balloon launch. We made many mistakes along the way, but we now have a good grip on what it takes to have lettuce seeds survive the extreme conditions of our launch. Unfortunately, we yielded no conclusive results on what it takes to have these seeds survive the pressure, heat, cold, impact, and several other variables that could have prevented the seeds from fully germinating. We suspect that our batch of seeds were "bad", because so few of the seeds had germinated. Another possibility is that our batch was not planted properly. In the future, we know we will need much more extensive testing of the plants themselves, rather than the payload. The seeds' soil container came apart due to the force of the drop, so finding a more effective way of containing the plants without damaging the contents will also be needed for conclusive results. Furthermore, we did not achieve our major goal of finding out the differences between plants that survived such extreme conditions and those that did not, but we did successfully promote some control over the conditions inside of the payload. This was confirmed by the condition of the seeds immediately after the payload recovery; while the positive control seeds were completely dried, those in the containers inside of the payload were still moist -- which means that humidity, crucial for plants' survival, was contained. The experiment also taught us about what it takes to get good results from our payload. We aimed very high for our goal this semester, but we trust that if this experiment was done again, we would get good results and find out what is necessary to sustain biological life in such extreme environments.

Advice for Next Year

- Spending too much time planning leaves little time to actually build the payload, and even less time to solve the inevitable problems that will arise during production and testing.
- Designating one person to track the progress of individual deadlines ensures that everyone is doing something productive, nobody forgets a deadline, and that everything is properly documented.
    - Try to keep deadlines realistic, and space work out evenly.
    - A designated project manager is integral to ensuring a steady workflow, especially once the semester is in full swing.
    - Having a backup manager would mitigate any damage done by one of the managers leaving.
- Construct your payload and start testing as soon as possible. If something goes wrong and launch is scheduled for the next day, there will not be much you can do.
- Have back-ups. If something breaks, you might not always have enough time to wait for Amazon to send you another one, and parts needed in a payload might be very hard to find in local stores.
    - Having two people in charge of important aspects of the experiment will mitigate the damage of someone losing it, or leaving the project.
- Make sure everyone is communicating outside of the allotted meetings. Some people may not be able to make it to every meeting, and they need to be kept in the loop.

    - Having everyone exchange contact information, or having every member download Basecamp, or other group messaging applications onto their phones, will vastly improve communication.
- Be aware of what materials are already provided for you. There is no point in spending money and waiting for a sensor that the school already has.
- Take lots of pictures! They are useful for documentation.

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