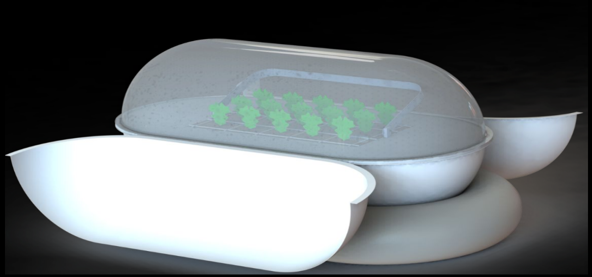
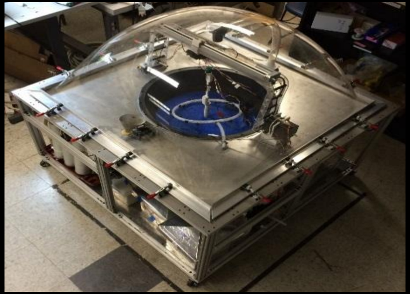
MARS OASIS

Mars Operational Agricultural System for In-Situ Specialization

An Autonomous Martian Greenhouse for Crop Production Research





National Space Grant Foundation

NASA

Semester Review

MarsOASIS Team Members:

- **Project Manager** – *Chris Tomso*
- **Systems Engineer** – *Noah McCreight*
- **Chief Financial Officer** – *Chris Tomso*
- **Mechanical Lead** – *Alex Lampe*
- **GUI Software Lead** – *Henrik Larsen*
- **Control Logic Lead** – *Jared Jolton*
- **Team Members**– *Brent Ruttle, Ryan Bohannon, Zack Allen*

Semester Review

Agenda:

1. System Overview
2. Growth Cycle #2 Recap
3. LabOASIS Modification Results
4. Conceptual Design Review
5. Proposed Changes to the Conceptual Design
6. Summary
7. Future Plans for LabOASIS

What is MarsOASIS?

Mars
Operational
Agricultural
System for
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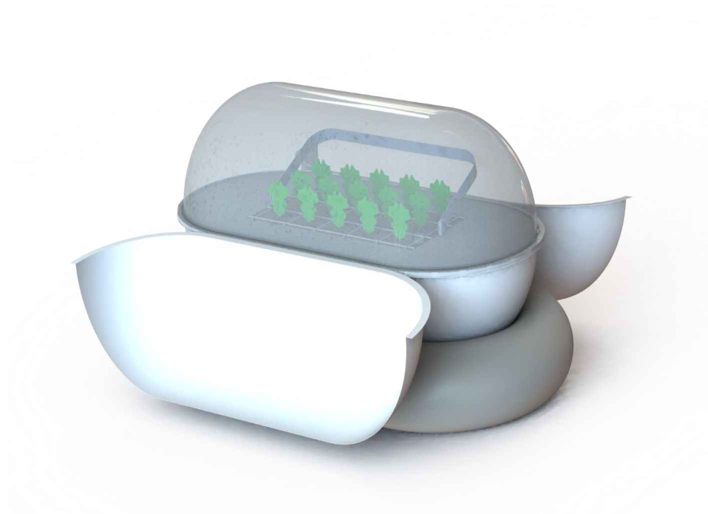
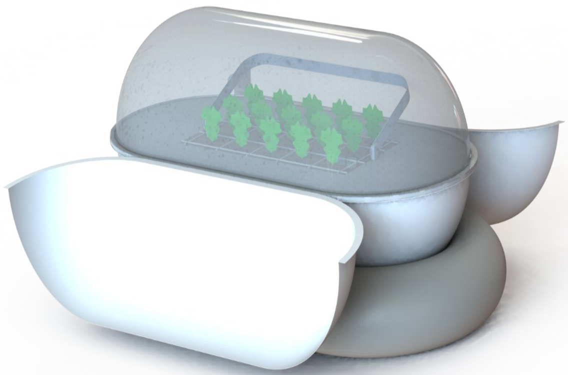
Specialization



A Pre-deployable Miniature Martian Greenhouse for Crop Production Research

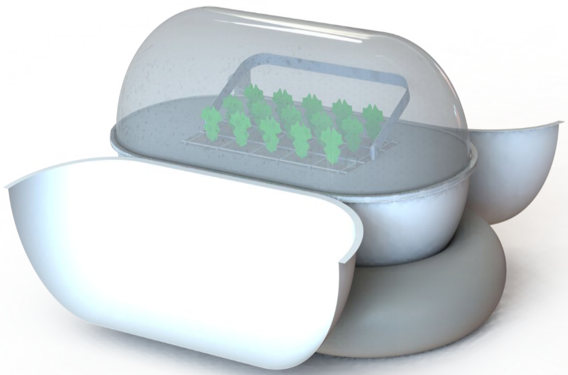
Introduction to MarsOASIS



Key Features of the Flight Concept:

- Transparent pressure vessel to capture natural sunlight
- Low internal pressure to minimize structural needs
- Ability to supplement sunlight with LEDs
- In-situ carbon dioxide capture from Martian atmosphere
- Deployable shield to protect system from dust storms and provide thermal insulation
- Water-recycling hydroponics system
- Internet-based GUI for teleoperation
- Movable camera for plant growth monitoring

Prototype Development



Flight Concept: **MarsOASIS**

Prototype: **LabOASIS**

MarsOASIS to LabOASIS

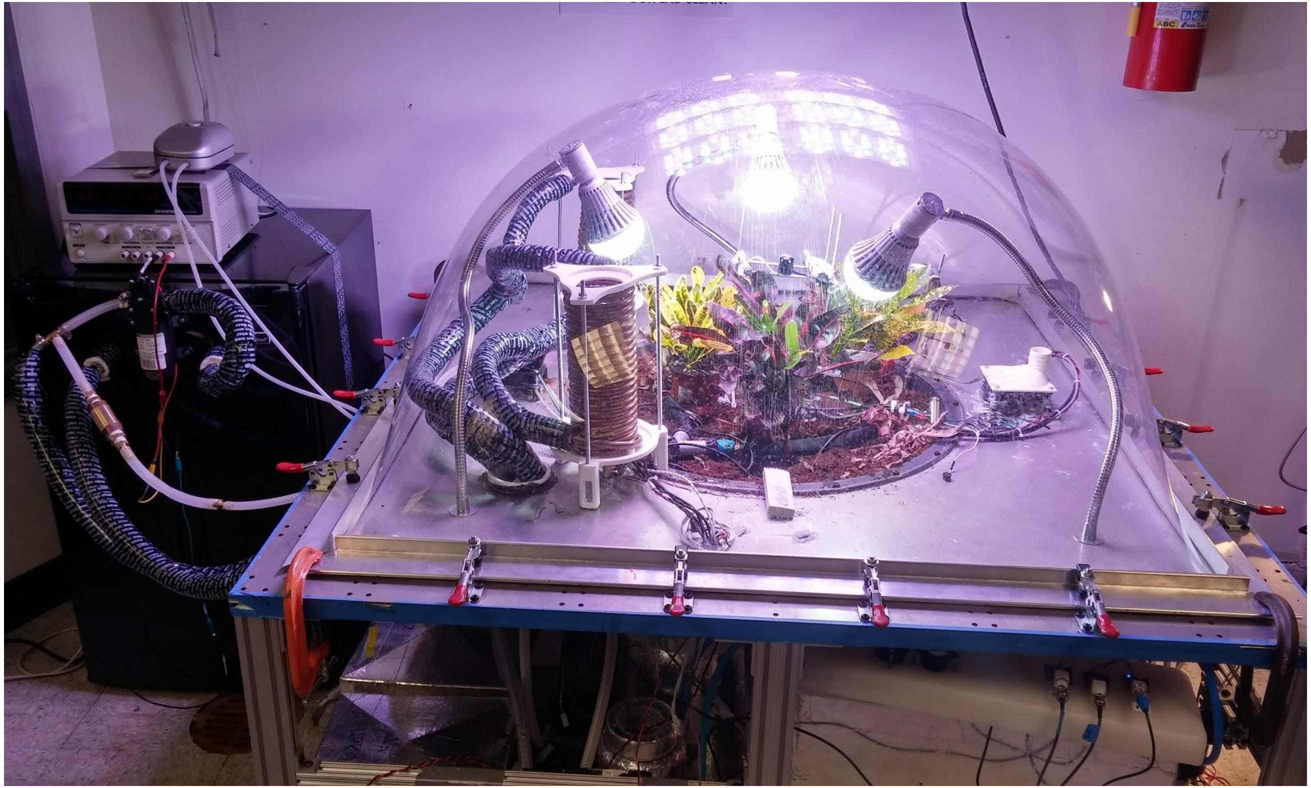
Prototype is similar to Flight Concept…..

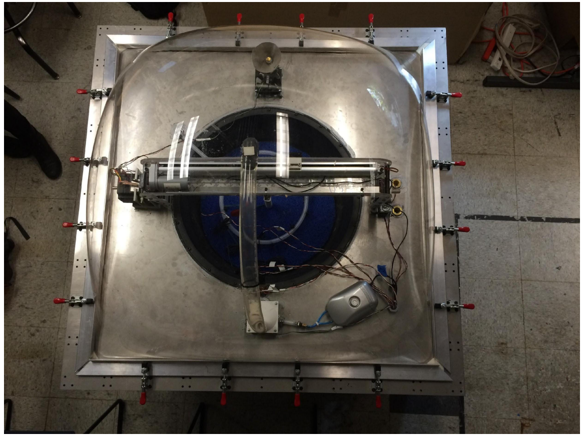
- Hybrid Lighting
- Autonomous control
- Internet-based GUI for teleoperation
- Water recycling
- Moveable Camera

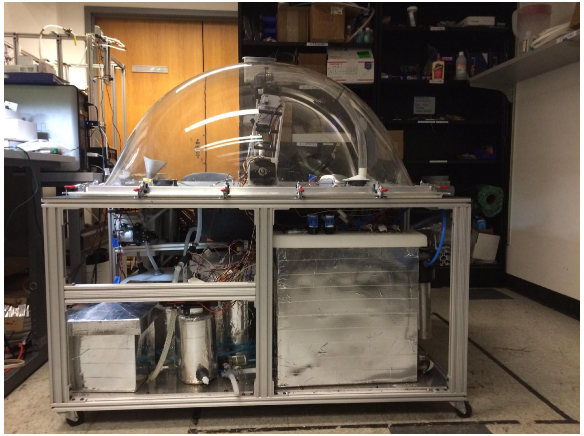
But differs on the following key points:

- Simulated natural Martian light
- Supplied CO2
- No volume/mass constraints
- Standard lab internal pressure
- No deployable cover
- Minimal thermal control
- Reduced-scope system requirements list

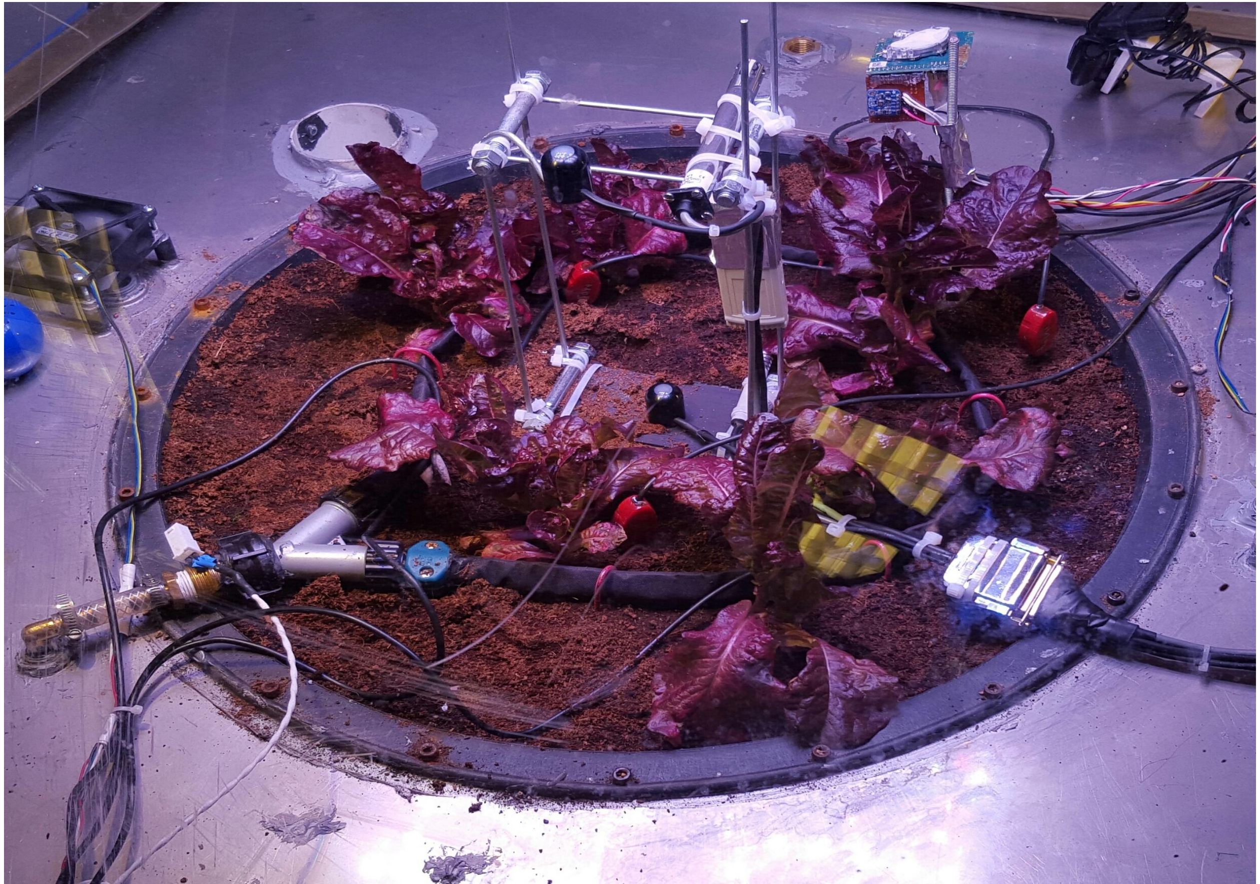
LabOASIS Photos







Growth Test #2 Recap

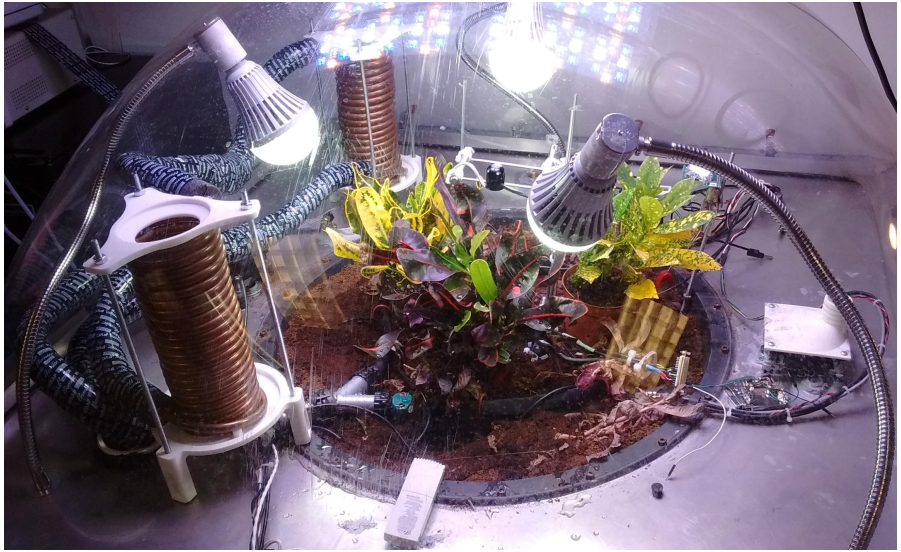


LabOASIS System Update

LabOASIS System Update

Lighting System Status

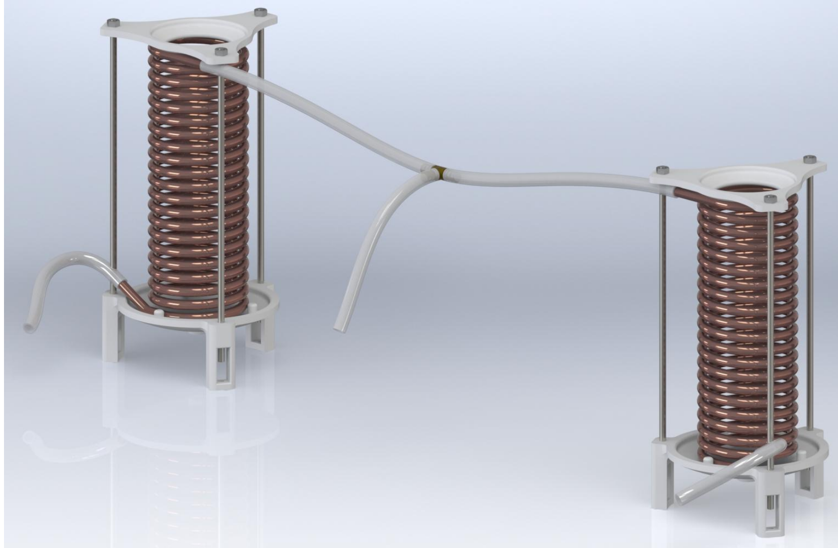
- Wide angle (180 degree), 5700 K, 3200 Lumens bulbs provide equal coverage over entire growth bed of minimum 170 +/- 30 micromoles/m^2 s^2, maximum 400 +/- 30 micromoles/m^2 s^2, depending on light pole geometry



LabOASIS System Update

Dehumidification System Concept

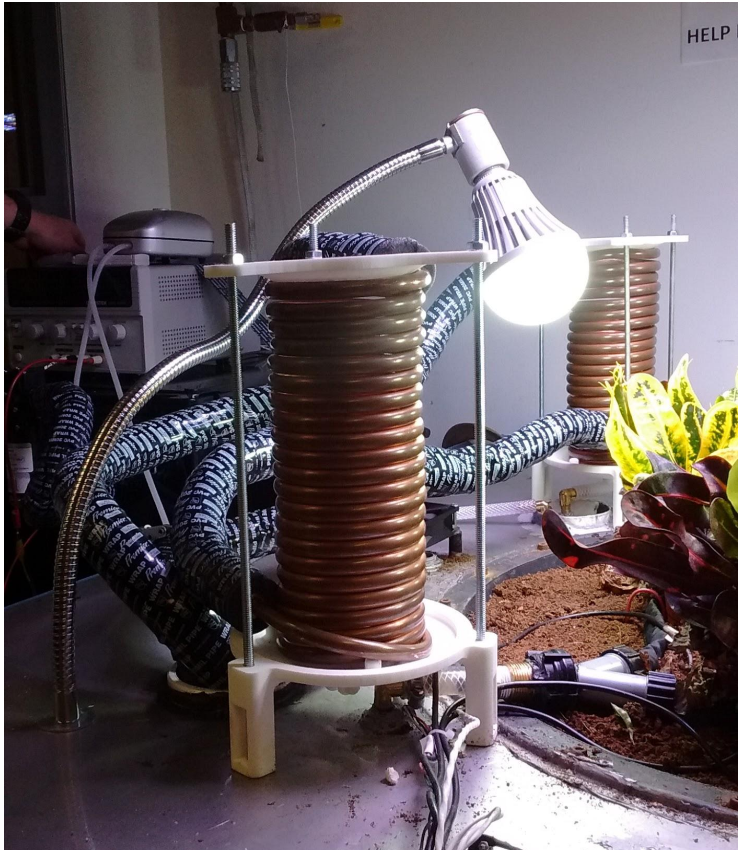
- Thermodynamic sizing calculations indicated the need for 29 Watts cooling capacity to condense 1 Liter of water per day via cooling coils
- Cold water reservoir (set to 39 degrees F) is located in a fridge external to the LabOASIS system to more closely mimic the flight concept



LabOASIS System Update

Dehumidification System Status:

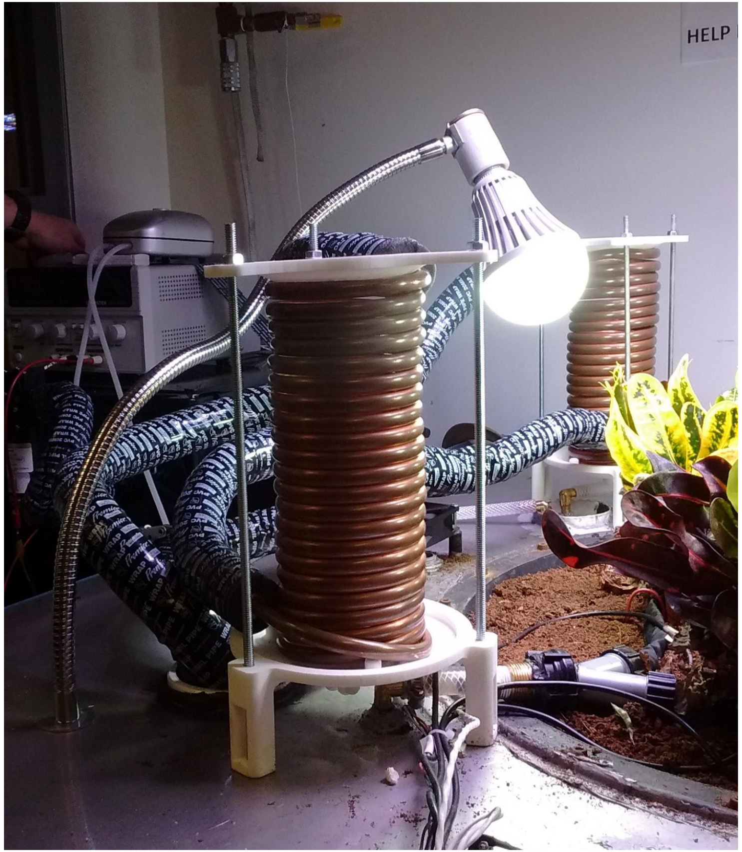
- Air pump spliced into water line via one-way check valve; allows residual water to be cleared from coils after main pump has shut off
- Insulation added to all water lines in order to prevent residual heat loss
- Coils mounted on 3D printed stands to allow efficient drainage



LabOASIS System Update

Dehumidification Test Results:

- Extra plants added to increase test fidelity, 1 gallon of water added to soil
- System is capable of reducing humidity from 83 to 65 %RH in 15 minutes @ 75 degrees F atmosphere; water reservoir temperature increased by 4 degrees F during this time
- Humidity returned to 83% in 25 minutes, refrigerator lowered water temperature by 4 degrees F in 15 minutes

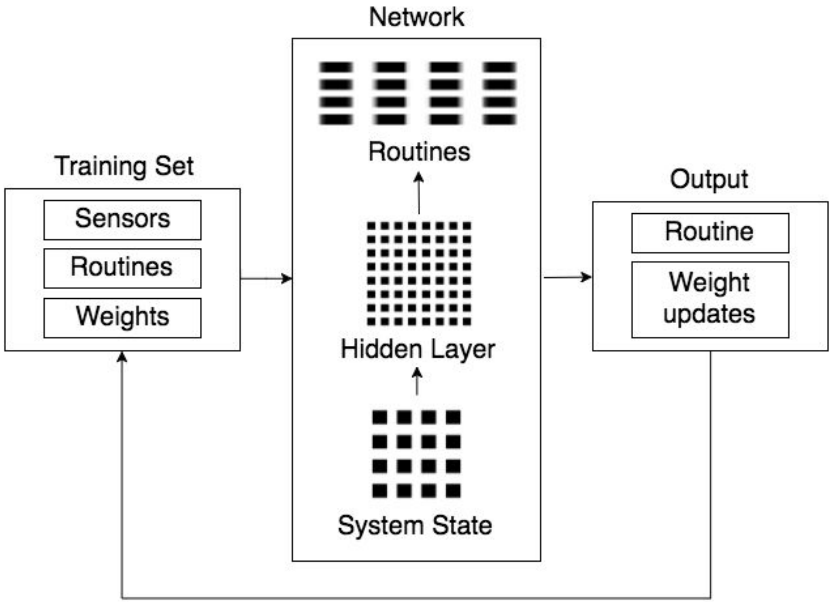


LabOASIS System Update

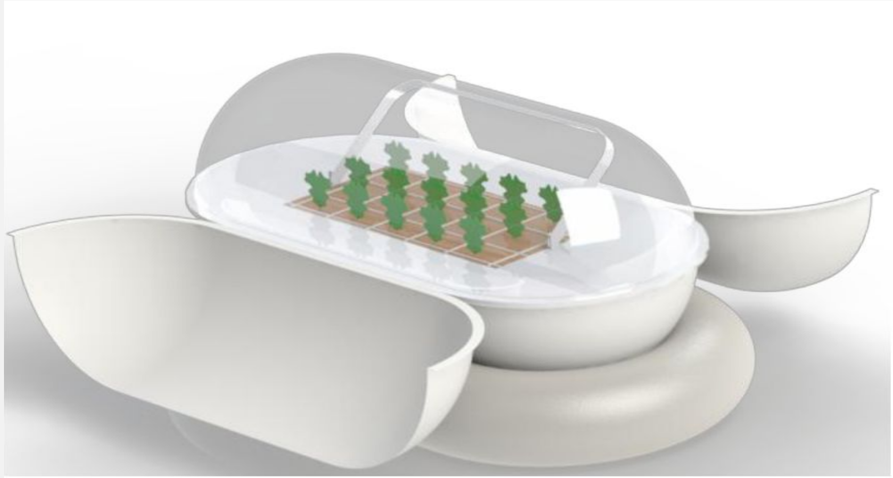
Machine Learning System Status:

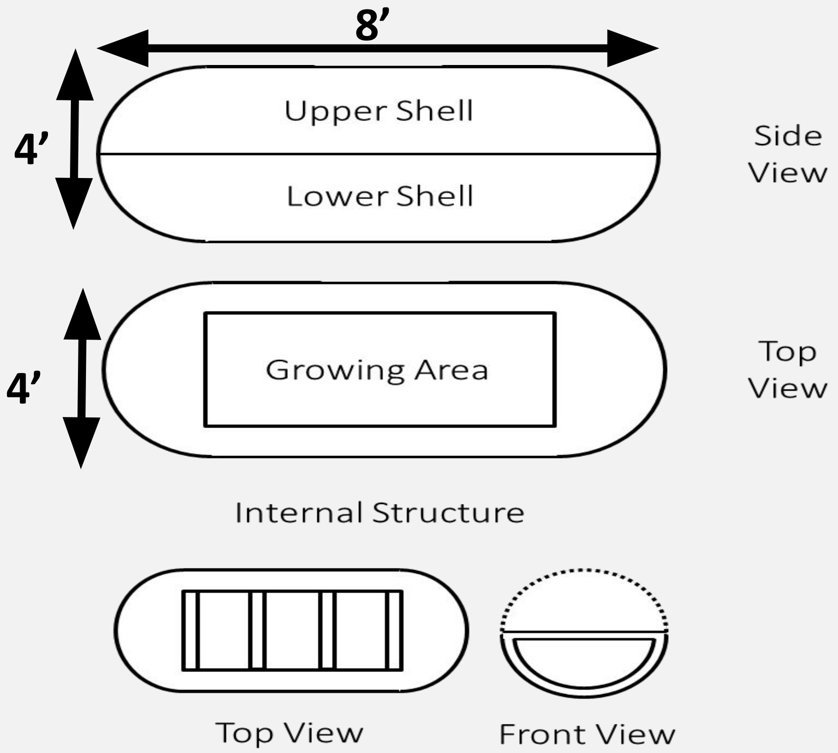
- Implemented a neural network that uses a metacognitive weighting scheme for decision making

- Several distinct phases of operation
    - Initialize weight matrix for routines
    - Train the network using HSST as oracle
    - Check sensors and implement a solution
    - Check the efficacy of the solution
    - Update the weights and re-train



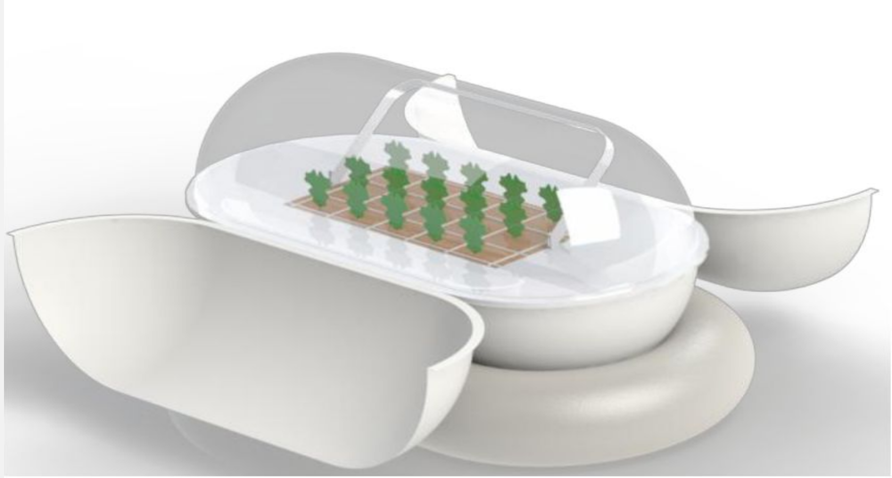
Original Conceptual Design

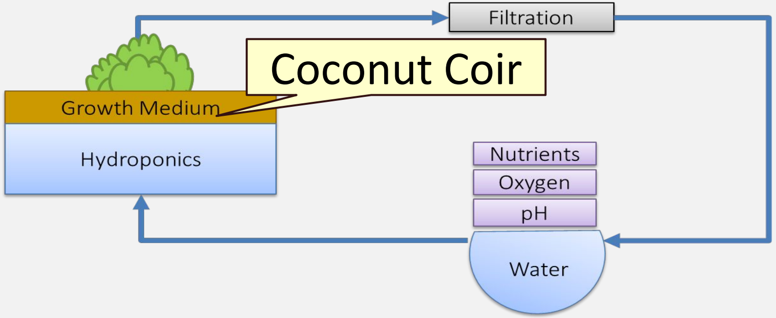


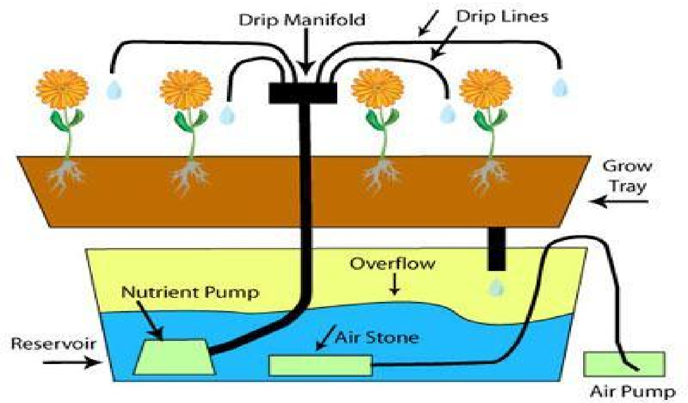


Pill shaped structure:
- Pill shaped to withstand pressure deltas
- Strong, low mass PEEK lower shell
- Strong, low mass Polycarbonate upper shell, allowing light transmission
- Aerogel, multi-layer insulation, & clamshell lid for thermal protection

Original Conceptual Design





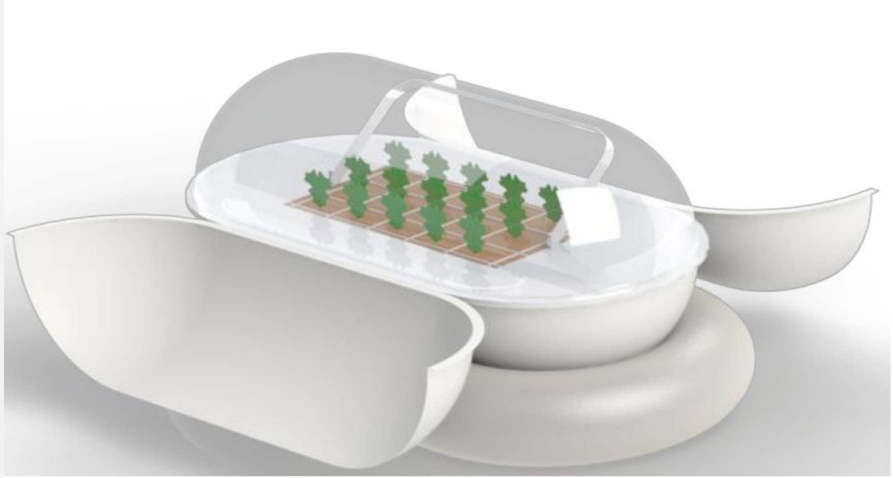


http://shop.hannainst.com/hydroponics-drip-growing-system

Closed Water Loop:

- Hydroponic, continuous drip & recovery
- Water conditioning in buffer reservoir (nutrients, pH, DO, and water temperature)
- Micro-filter for particulate removal and In-situ UV-C light for pathogens control
- Coconut Coir growth medium

Original Conceptual Design



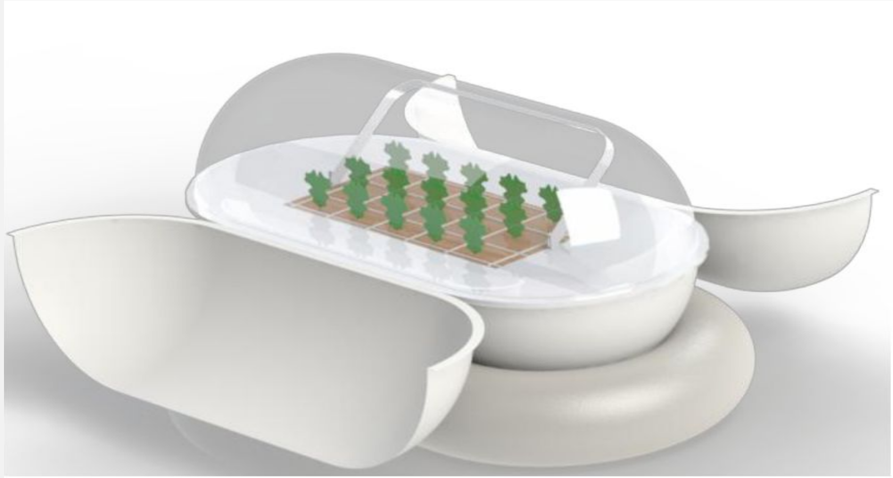
Atmospheric Constituents

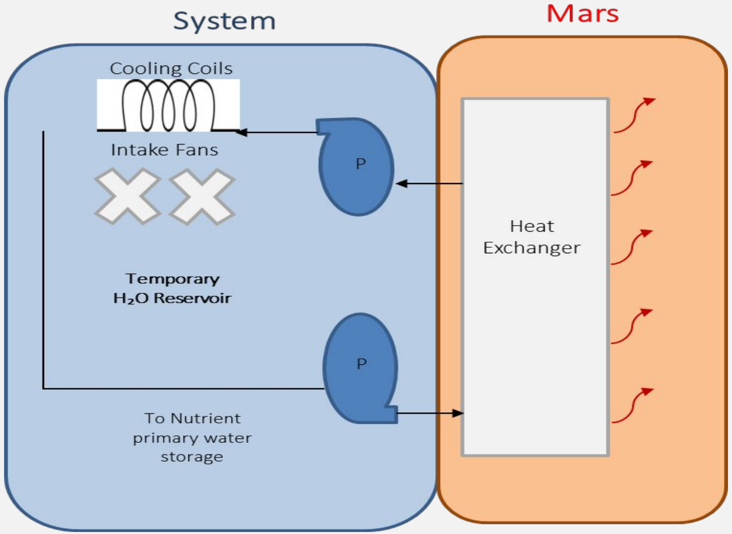
Atmospheric Constituent	Partial Pressure (kPa)
O_2	10.5
CO_2	0.2
N_2	24.3
TOTAL:	35

Atmosphere Revitalization:

- External CO_2 filtered, compressed, & stored
- Pressure swing adsorption and zeolite molecular sieve beds to adsorb/desorb CO_2 and N_2, separating O_2 for storage in tanks.
- Small fan to provide vertical air flow
- Total pressure maintained w/ on-board supply of N_2 inert gas (minimize deltas)
- Zeolite sorbers for toxic ethylene removal

Original Conceptual Design



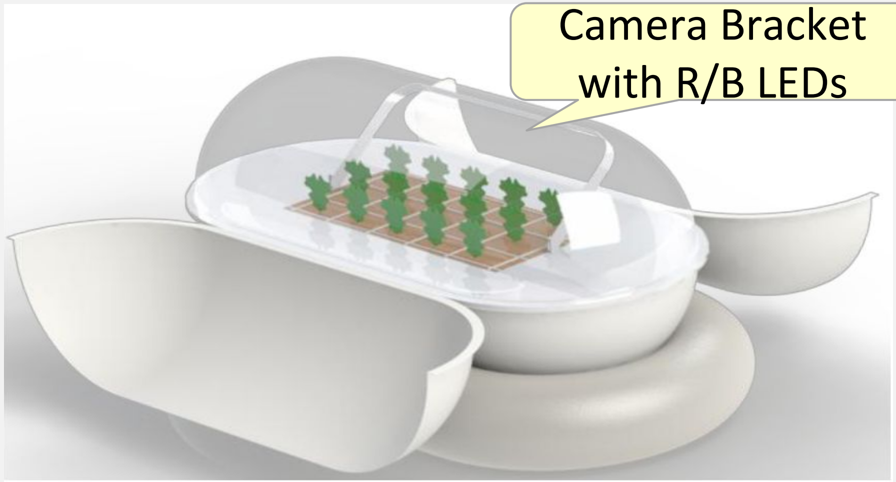


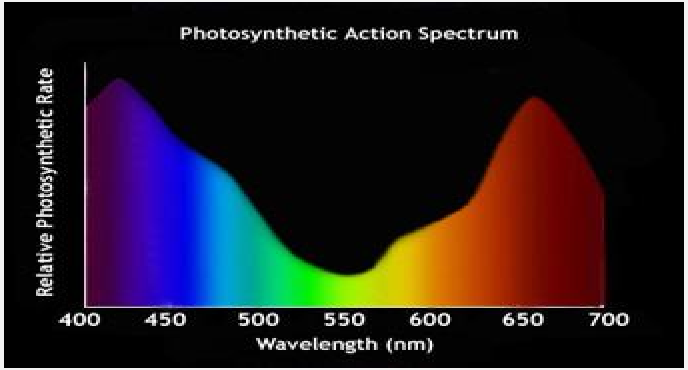
Dehumidification Loop

Relative Humidity & Thermal Control:

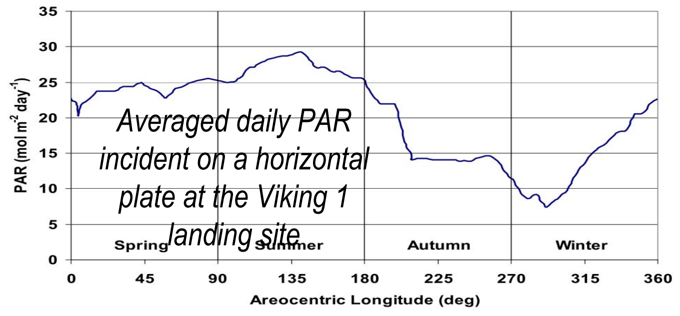
- **Humidification:** Use foggers, or increase internal temperature for increased evapotranspiration
- **Dehumidification:** Air pumped over coils cooled by outside air, to condense water
- Passive thermal protection system to insulate (fully closed at night)
- Internal patch heaters to raise temperature

Original Conceptual Design





www.bio.miami.edu

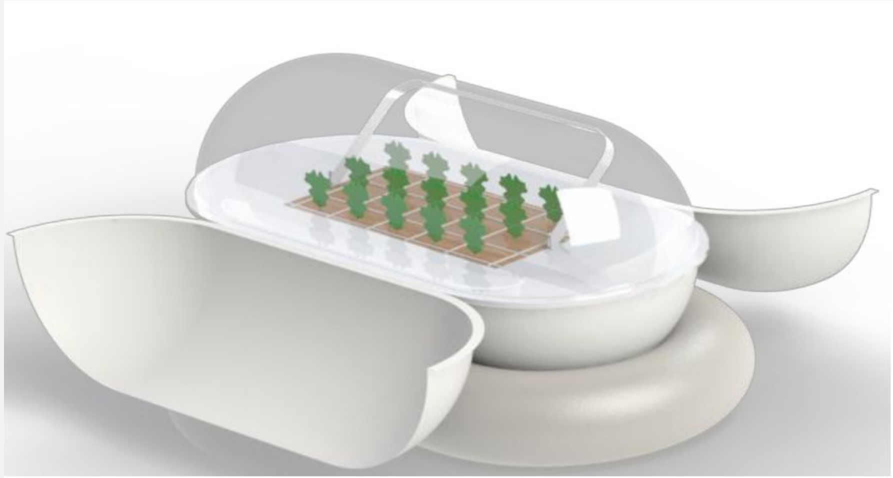


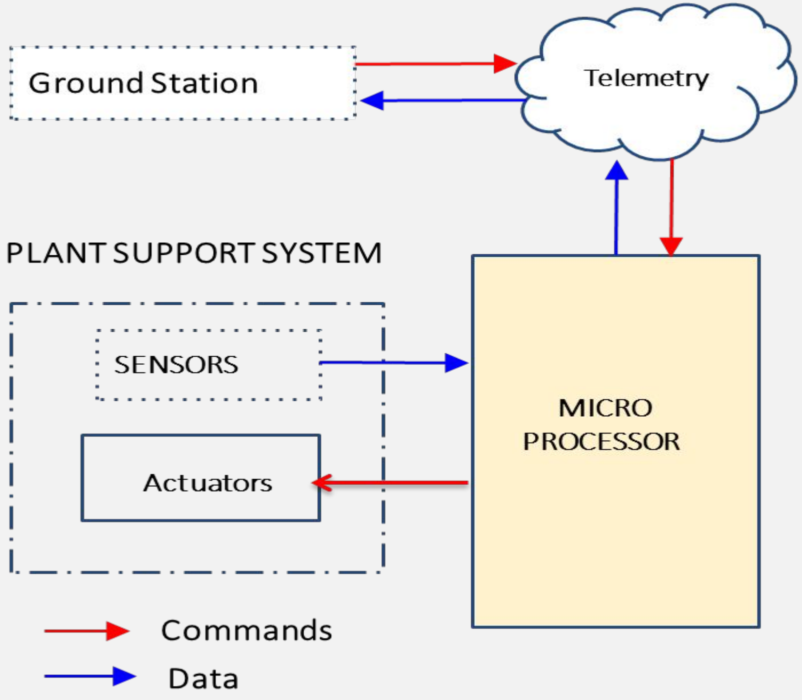
Clawson et al., 2005

Hybrid Lighting System:

- Sunlight primary source of light through dome
- Artificial red & blue LEDs to supplement in dust storms & enhance spectrum for plant growth
- LEDs line rotating bracket across length of vessel
- Bracket also include camera mount for imagery

Original Conceptual Design





Data, Software, and Power:

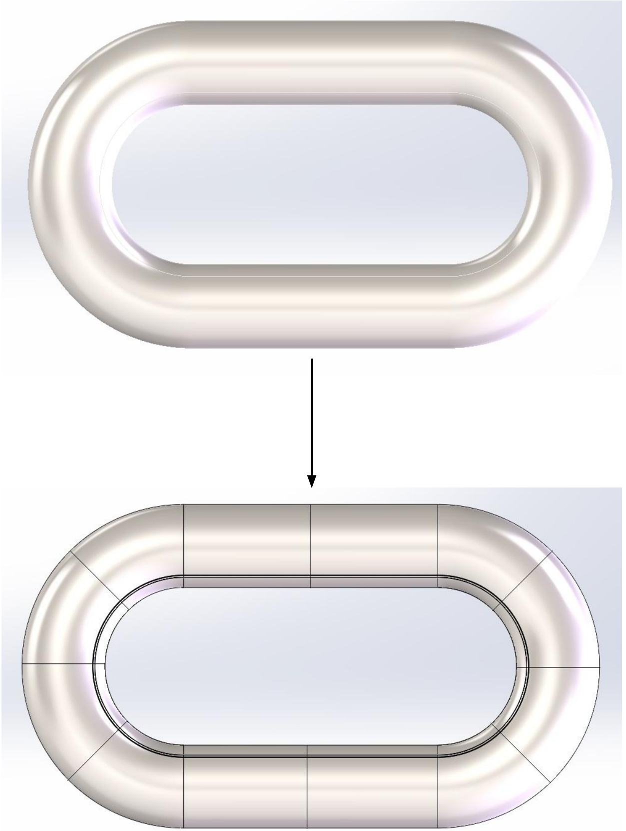
- RAD6000 processor for sensor data, control algorithms, actuator commands, communication
- Data compressed and uplinked to Mars orbiters from 35 sensors at ~1 sample/min (1/hr for images)
- Flexible photovotaic power on inside of clam shell lid with lithium ion battery for storage

Proposed Concept Update

LabOASIS Challenge: Water pooling on one side of the growth bed due to 1-2 degree tilt in the system.

MarsOASIS Solution: Compartmentalizing the inflatable structure at the base of the MarsOASIS system. Individually controlled compartments would adjust to uneven terrain.

Things to Consider: Would increase the weight and complexity of the system. Another potential solution would be a gravity-driven gimbaled growth bed, a trade study should be conducted between these options.

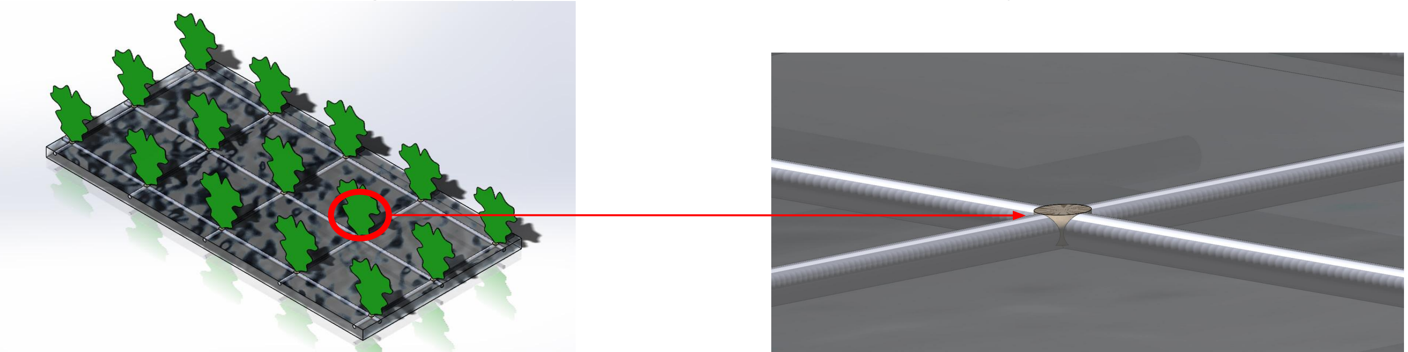


Proposed Concept Update

LabOASIS Challenge: Salts were building up in the coco coir growth medium. The medium also posed a challenge for achieving an even watering distribution.

MarsOASIS Solution: Utilize a deep water bubbleponics system. Seeds will be implanted into soil plugs held in place during flight by a grid. Once in place on Mars, the bed will be filled with water.

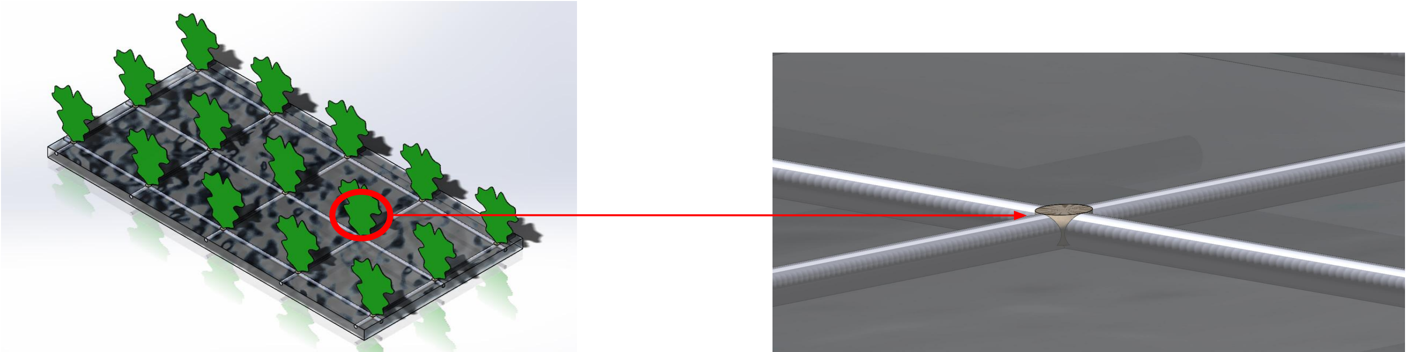
Things to Consider: Bubbleponics tank will minimize system mass. Condensate water will be used for flushing the system, supplemented by a small reserve of fresh water.



Proposed Concept Update

More Things to Consider:

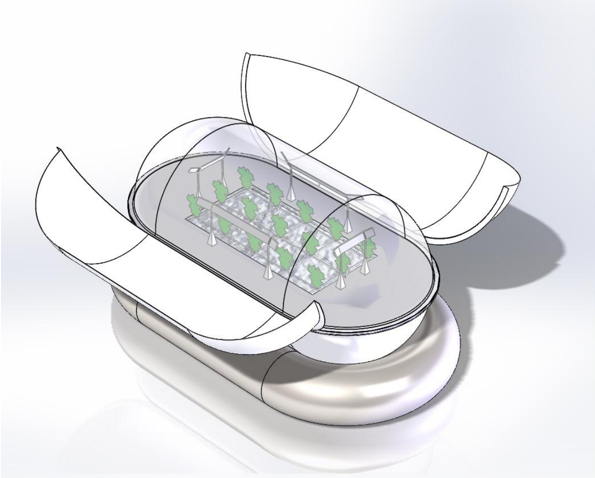
- Dissolved oxygen levels in water exposed to a low pressure environment may be at risk of dropping below 2 ppm. Bubbling oxygen captured by the concentrator could mitigate this risk.
- Bubbleponics system has potential to remove need for pH and nutrient control, further reducing mass and complexity.



Proposed Concept Update

LabOASIS Challenge: Previous lighting bracket did not output enough PAR and the bracket itself suffered from vibration modes.

MarsOASIS Solution: In order to reduce complexity, cost, and single point failures system will use structurally fixed LED lights & camera mounts.



Things to Consider: Added shadowing from the fixed lights may require increased reliance on internal lighting.

Proposed Concept Update

LabOASIS Challenge: Humidity control.

MarsOASIS Solution: Remove all primary systems for humidity addition. Put the stainless steel cooling coils at the growth bed rather than using an air intake loop. Two growth cycle tests have shown that there is no need for humidity addition.

Things to Consider: Putting the cooling coils in the growth chamber could cause temperature fluctuations. Condensation could still accumulate on the dome due to the extreme cold of the Martian atmosphere, a solution needs to be put in place to make sure this is collected (slant panels towards the grow tank, etc.)

Concept Update Summary

- Compartmentalized inflatable support structure for dynamic terrain correction
- Deep Water/Bubbleponics hydroponics system to avoid the problems of a solid medium
- Fixed lighting for structural integrity and failure mitigation
- Remove humidification subsystem from concept
- **Additionally:** Conduct future trade studies into eliminating hybrid lighting in order to increase thermal insulation while making sure to include the human factor of growing plants in Martian sun.

Lessons Learned

- Humidity control is a primary requirement for a sealed chamber environment
- Traditional solid-medium cultures present significant design challenges
- A high complexity lighting solution does not seem necessary or optimal in terms of flight-ruggedness
- Utilizing a machine learning algorithm instead of conventional control logic may improve overall processor performance

Future Plans for MarsOASIS

- Final documentation will be submitted to NASA
- Pending summer personnel resources, we will attempt to continue work on machine learning algorithms
- Pending NASA’s approval, we would like to retain the LabOASIS prototype for use by Christine Chamberlain in her doctoral research

Acknowledgements

The MarsOASIS Team would like to thank:

Professor Joe Tanner, Dr. Bill Liggett, Dr. Ray Wheeler, Kimberly Simpson, Tracy Gill, Eirik Holbert, Gioia Massa, Morgan Simpson, Charlie Quincy, Dr. David Klaus, Dr. James Nabity, Christine Chamberlain, Adam Escobar, Sairam Muttavarapu, Rishabh Berlia, Heather Hava, Daniel Zukowski, Michael Horowitz

Conclusions

Any Questions?

Conclusions

Thank you for your time!

Backup

Learning in the Autonomous System

- Routine vs. Sensor-Effect Matrix
  - Learns from routines implemented on the system
  - Learning speed controlled by changing matrix:
    - $M_{new} = (1-e)*M_{old} + e*M_{exp}$
      - e - proportion of experimental results included
      - e = 1: entire history controlled by current experiment
      - e = 0: current experiment has no effect on weights.

- Additional functionality to consider:
  1. Autonomously controlled routine implementation times
     - The implementation time is currently fixed
     - Allows system to develop more precise control