# A 3U Cubesat Platform for Plant Growth Experiments

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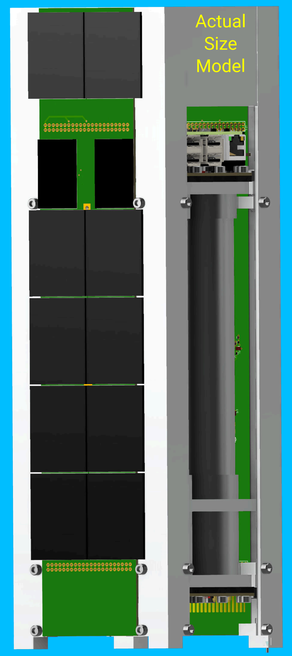
## System Overview

Four Sealed Independent Cylindrical Plant Chambers
Provides Enclosed Local Environment for Plants
Two Cubic Inches of Soil per Chamber
6.5" Tall x 1.25" Diameter Plant Space per Chamber
Top Board with RGB Grow Lights For Plants
Chamber Environment Monitoring Sensors
Raspberry Pi v2 Cameras for Observing Plant Growth
Raspberry Pi 3B+ for Logging Sensor and Camera Data
Side Power Boards with Solar Panels and Batteries
Bottom Board with Soil Moisture and pH Sensors
Expandable to include a future Attitude Control System
Limited Wire Harnesses Needed
Off-the-Shelf Materials

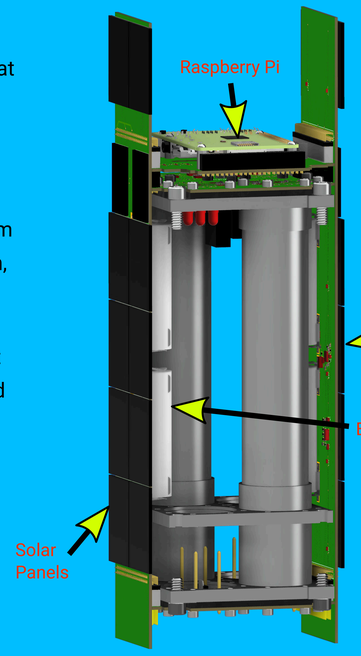



## Scientific Goals

Study the interactions of soil microbes and plants to understand what the optimal concentration of beneficial microbes is when in space conditions, that maximizes nutrient uptake in plant roots and increases overall plant fitness.

Changes in the environment and microbiome community health stem from the interplay between soil and plant properties such as growth, death, mutation rates, and metabolism of each microbe species.

The cubesat design gives the opportunity to investigate the impact of physical factors such as pressure, temperature, microgravity, and space radiation on the soil bacteria and overall plant health.

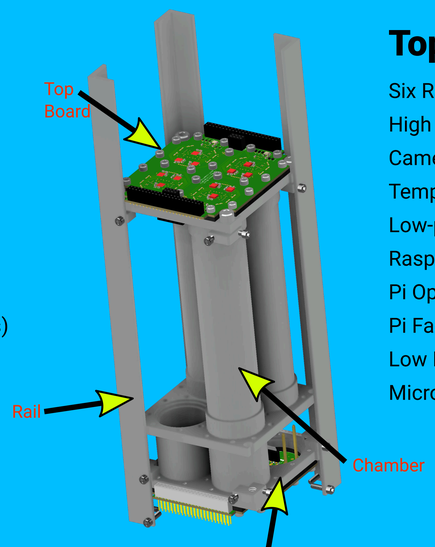



## Platform Power

Four Total Power Boards (One on Each Long Side)
Boards Provide Connections Between Other Boards
Design Uses ~4.5W Continuous Power Draw
Eight 3.7V 18650 Lithium Ion Batteries Total
~3.3W Solar Panels Per Side Under Full Illumination
Maximum Power Point Tracking (MPPT) per Side
Electronics mostly use 5V and 3.3V Power Rails

## General Structure

Complies with the CubeSat Standard
Aluminum 6061 Used in Majority of Structure
90° Angle Pieces and Metal Plates Define 3U CubeSat
O-Rings Seal Cylindrical Sections to Holes in Plates
1/4" Screws used to Compress Cylindrical Seals
Gaskets Seal Printed Circuit Board to Surface of Plates
Epoxy used to Seal PCB Electrical Vias
Basic Manufacturing Process Followed (Mills and Lathes)
Seals Provide Chamber resistance to External Vacuum




## Top Electronics

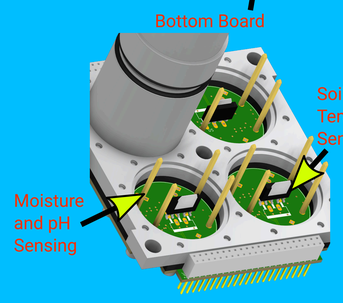
Six RGB LEDs Provide 18 Hour On Red and Blue Grow Lighting
High Resolution Color and Infrared Pictures Taken By Camera
Camera Lighting Provided By White and Infrared LEDs
Temperature, Relative Humidity, and Chamber Pressure Sensors
Low-power Infrared $CO_2$ Sensor Attached
Raspberry Pi 3B+ Computer Multiplexes Between Chambers
Pi Optimized in Hardware and Software to Utilize Low Power
Pi Fast Startup and Error Resettable with a Microcontroller
Low Power Microcontroller is Radiation Fault Resistant
Microcontroller Manages Radio Communications

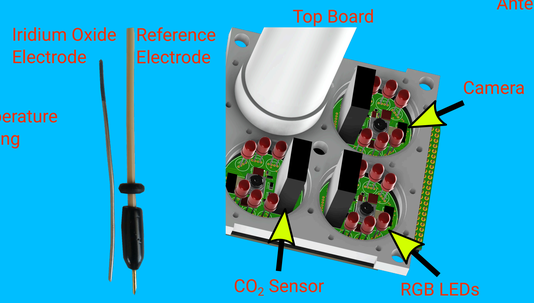

## Conducted Testing

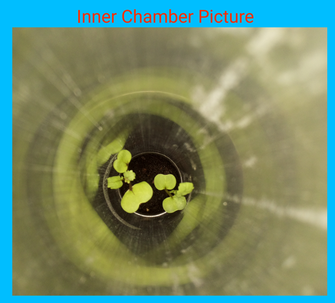
Grew Fast Plants and Bean Plants in Contained Chamber
Determined Appropriate Water and Soil Content Levels
Fast Plants need 4-6 weeks to Flower
Sensor Information Logged at 15 min Intervals
Pictures Logged Every Hour
Live Viewable Data via Web Browser for Ground Testing
Sealing Tests were Performed with Pressure Gauges
Iterated Intensities of Grow Lights to Maximize Biomass
Biome Cultures were collected and will be DNA sequenced

## Bottom Electronics

Digital Soil Temperature Readings
Capacitive Soil Moisture Measurements
Silver - Silver/Chloride Reference Electrode
pH Iridium Oxide on Stainless Steel Working Electrode
pH Electrode Created by Electrodeposition
Nafion Ionomer Coating Applied to pH Electrode




## Future Enhancements

Radio Communications on Amateur 2m and 70cm Bands
Frequency Shift Keying Used to Transmit at >200kbps
Extendable Antenna that Matches Necessary Bands
High Altitude Balloon Tests will include an APRS Module
Attitude Detection and Control System
Next Versions of Design Elements after Testing