Critical Assessment Document:
CubeSat Size Growing Autonomous System

Design Team:

Abigail Wittenbrook, Christopher Serrano

Joseph Moore, Phillip Cornett

University of South Florida

Electrical Engineering Department

Advisor: Arash Takshi

Abstract

This document details a collaborative effort between the University of South Florida's Mechanical Engineering team and our organization to develop a CubeSat-based system designed to advance the cultivation of edible plants in space. By utilizing a microprocessor-controlled environment within a CubeSat, the project aims to provide optimal conditions for plant growth, integrating essential life support mechanisms and data collection capabilities for space agriculture research. The purpose of this document is to outline the testing plans and their outcomes to date, discussing the changes and improvements made following these tests.

Test 1: Power Consumption

Our power budget is the foundation that will allow us to complete this mission. Since our mission revolves around creating an autonomous plant growing chamber, not only our system must be able to properly take care of the plant and collect data, but it must also be able to be self-sustaining and be capable of powering itself for its entire life cycle. Without proper power analysis of each component in our system, we would not be capable of carrying out this mission. After concluding our final component for our plant system, we searched for a high-capacity lithium-ion battery capable of being recharged over a 30-day mission. Additionally, we had to work closely with the mechanical engineers in finding a solar panel that will provide enough energy to power our system along with providing enough additional power to maintain the battery's charge for when the panels aren't generating power. Furthermore, we also must find a solar panel power controller that will properly allocate the power efficiently between the battery, solar panels, and our devices being powered. This will prevent events such as overcharging, overcurrent, and other harmful damage that could arise from an uncontrolled system. Lastly, we also incorporated controllable relays in our system that will allow us to cut off devices that aren't being used to save power even more.

Power Budget

Component	Voltage	Current	Time usage	Max Expected Current Draw	Power Draw
Solar Panels	10V	2A	N/A	N/A	20W
Battery	3.7V	6Ah	N/A	N/A	22.2WH
Temp and VOC Sensor	3.3V	2mA	2 ms	2mA	6.6mW
O2 Sensor	3.3V - 5V	6.5mA	1 min	6.5mA	21.45mW
CO2 Sensor	3.3V - 5V	4mA	1 min	4mA	13.2mW
Alcohol Sensor	3.3V - 5V	10mA	5 mins	10mA	33mW
Light Sensor	3.3V	2uA - 45uA	24hr	45uA	148.5uW
Heater	5V	200mA	As needed	200mA	1W
Fan	5.5V	.03A	As needed	73mA	.4W
LED	3.3V - 5V	16mA(per light)	24hr	320mA	1.056W
OV2640	2.75V	50mA 600uA (Stand-by)	Depends	20mA	140mW
GPS	3.6V	10mA 100mA	N/A	N/A	360mW 36mW
Receiver	2V	8mA	N/A		16mW
Wireless Module	3.6V	Transmit (215mA) Receive (29mA) Sleep (2.5uA)	N/A	N/A	774mW 104.4mW
SD Card Module	5V	.2mA 200mA	N/A	N/A	1mW 1W

Test 2: Individual Sensors

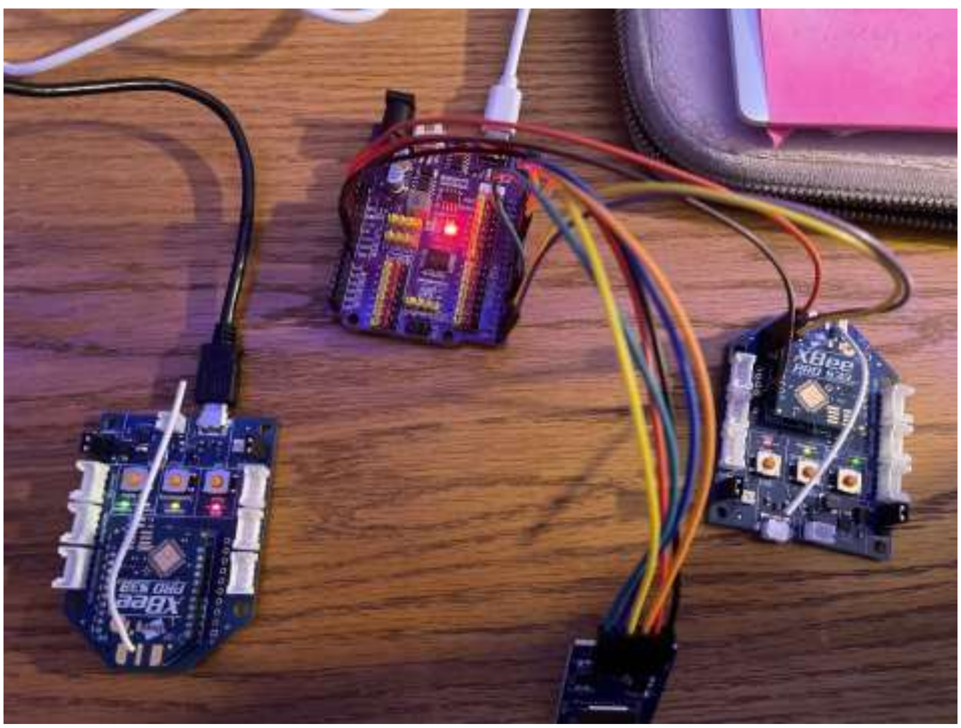
In developing the CubeSat chamber, the reliability and accuracy of data collected from individual sensors assume paramount significance. Each sensor within the system fulfills a pivotal role in monitoring the environmental conditions within the chamber indispensable for understanding how a plant reacts to an extreme near-space environment. Therefore, rigorous testing and evaluation of these sensors are imperative to validate their performance and ensure the success of the mission. The sensor array encompasses a diverse range of parameters crucial for plant growth, including temperature, humidity, VOC concentration, alcohol concentration, CO_2 concentration, oxygen concentration, and light intensity. This system will also capture periodic pictures of the plant's leaf zone and root zone, as well as a hyperspectral image of the leaf zone. Each sensor is required to exhibit high precision and sensitivity to accurately capture fluctuations and long-term changes in these parameters, thereby enabling informed decisions concerning environmental adjustments within the plant chamber. To attain this objective, only sensors with a high degree of precision and accuracy were selected for this mission. Prior to integration into the autonomous system, each sensor undergoes comprehensive testing to assess its performance under various environmental conditions and validate its calibration against reference standards. This testing phase serves to ensure the functionality of individual sensors and enables the identification of potential issues or discrepancies that may arise during operation.

Test 3: Sensor Array

Expanding upon the groundwork laid during individual sensor testing, the integration and optimization of the sensor array become crucial steps in achieving comprehensive environmental monitoring within CubeSat. The sensor array's coordination with the environmental control system ensures the maintenance of optimal heating and lighting conditions inside the chamber. This synchronization extends to LED grow lights, which work in tandem with the cameras to capture images of the leaf zone under various light spectrums of red, green, and blue light to take hyperspectral images. Sensors play a pivotal role by feeding their data to an SD card, which serves as a repository for subsequent transmission. Efficient data management is paramount, with the SD card enabling organized storage of environmental data and preparing it for transmission to the ground station for analysis. Through seamless integration and meticulous coordination, we establish a robust framework for exhaustive environmental monitoring. This integrated approach not only enhances data precision and reliability but also empowers real-time adaptation to dynamic environmental fluctuations.

Test 4: Communication Foundation

Fulfilment of communication requirements is necessary for access to the plant's growth and the satellite's health. Without a functioning, regulated communication system, this project will not have measurable data, and therefore, be obsolete. Sensor data transmission is scheduled to occur at predefined intervals daily. The day and night cycle will define these exact times. The data received must be comparable to the current testing we are producing. The testing data we currently have is being modeled in MATLAB, which will then be used later for analyzing the performance. The transmission side uses Arduino to read the saved bytes from the SD card to then be sent during the specified times. The use of API mode in XCTU has been particularly advantageous, allowing us to streamline the communication process by reducing data packet size and transmission duration, thereby enhancing the efficiency of our data management in accordance with our project's specifications. The Zigbee protocol has been instrumental in this process, providing a simplified yet precise approach to information modulation. The successful preliminary tests have allowed for the integration of the communication subsystem into the master code, giving course to the tests of high gain antennas necessary for extended range communication. Range testing stands as the final validation step, ensuring that our system's frequency, gain, and configuration adhere to the optimal parameters, thus guaranteeing the integrity and reliability of long-distance space communication.



Test 5: Integrated System Test

In this phase, we will conduct a comprehensive validation of our integrated subsystems to ensure cohesive functionality. The benchmarks established during the individual testing of each subsystem are expected to be maintained when these components function interdependently. Autonomy within our context is defined as the capacity for self-governance, free from external control. Previously, each subsystem's adherence to this principle was assessed in isolation. Our objective now is to affirm the collective autonomy of the system, ensuring that it operates reliably and without external intervention. To this end, we will replicate the original tests, in a real time environment. This will include at least a fraction of the real distance testing of the communication protocol and the sensor system inside a chamber in an outdoor environment.

Summary:

The collaborative effort between the University of South Florida's Mechanical Engineering team and our organization has resulted in the development of an innovative CubeSat-based system designed to advance the cultivation of edible plants in space. By focusing on creating a microprocessor-controlled environment optimized for plant growth, this project integrates essential life support mechanisms and data collection capabilities essential for space agriculture research. Through a series of detailed tests—ranging from power consumption, sensor accuracy, sensor array integration, communication protocols, to an integrated system functionality—the document outlines the project's approach to ensuring sustainability, precision, and efficiency. Each phase of testing has been crucial for refining the system, highlighting the advancements made towards achieving a fully autonomous plant growth environment capable of operating within the challenging conditions of space.