CubeSat Autonomous Plant Growing System for Weather Balloon Test

EE DESIGN 1 USF

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Team Members

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Introduction

In partnership with three Mechanical Engineering teams, our project seeks to design and implement an efficient, microprocessor-based system for plant life support and environmental data collection within an autonomous CubeSat.

A weather balloon test will be instrumental in evaluating the system's performance in challenging near-space conditions.

Driving Requirement 1

- This system will collect data on the environmental conditions inside the CubeSat. The environmental data our system will collect includes data on:
    - Temperature
    - Humidity
    - CO_2 and O_2 concentration
    - Ethylene concentration
    - Light intensity
    - Soil pH
    - Alcohol concentration
- The system will also take images of the roots and sprout zone of the plant, as well as a hyperspectral image of the sprout zone.

Driving Requirement 2

- This system will maintain the environmental conditions required for the plant to survive. These conditions include:
  - Temperature range within 18 - 22° C.
  - Humidity range within 60 % - 80% RH.
  - CO_2 concentration within 400 - 1500 ppm.
  - Ethylene concentration maintained below 100 ppb.
  - Constant air flow with air velocity between 0.3 - 0.5 m/s.
  - Growing light with an intensity range within 200 – 250 µmol/m2/s.
- These conditions will be maintained using an array of sensors and environmental controllers.

Driving Requirement 3

- This system will be able to wirelessly transmit images and data via an antenna to a ground station.
- The antenna will be able to operate at a range of 25 – 35 km, approximately the expected altitude of the weather balloon. The wireless communication components include:
  - Wireless communication module (Cellular or Satellite)
  - Antenna (Operating at 433MHz, 900MHz, or 1800MHz)
  - Sim Card
  - SD module for storage

The system is engineered to proficiently transmit comprehensive sensor and photographic data captured by the microcontroller. Furthermore, it possesses the capability to receive signals from the ground team, thereby facilitating prompt responsiveness for the implementation of emergency adjustments to optimize system performance.

Driving Requirement 4

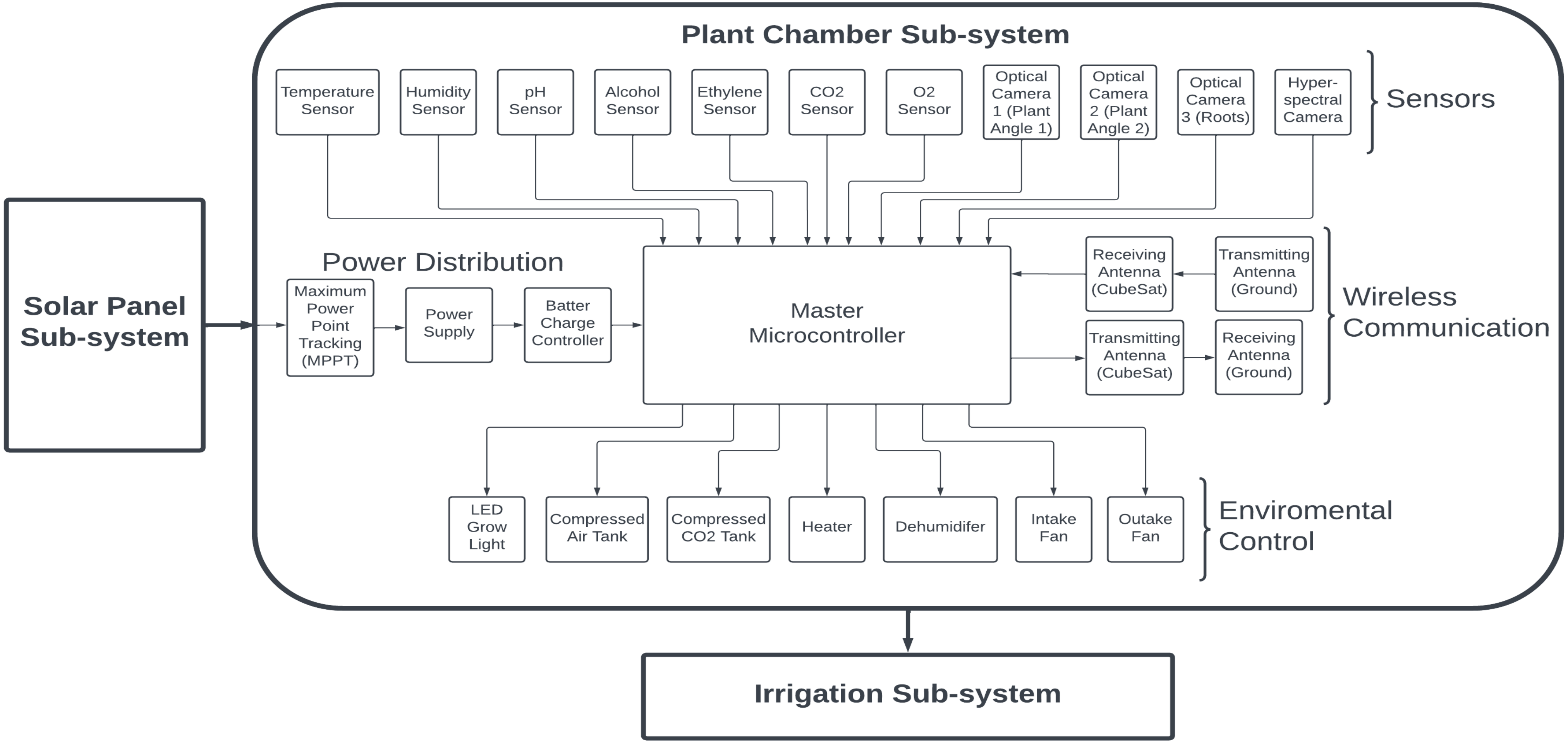
- This system will oversee and control the power output provided by the solar panels.
- This will include operations to ration the power to different components so that the CubeSat can complete its 30-day mission. The components in this section includes:
  - Solar Panels
  - Solar Panel Manager (MPPT)
  - 3.7V Lithium-Ion rechargeable Battery
  - 3.3V - 5V Relay

The proposed system is designed to facilitate the provision and storage of energy, ensuring continuous operation of all components independent of the day cycle. This capability is integral to sustaining uninterrupted functionality throughout extended operational periods.

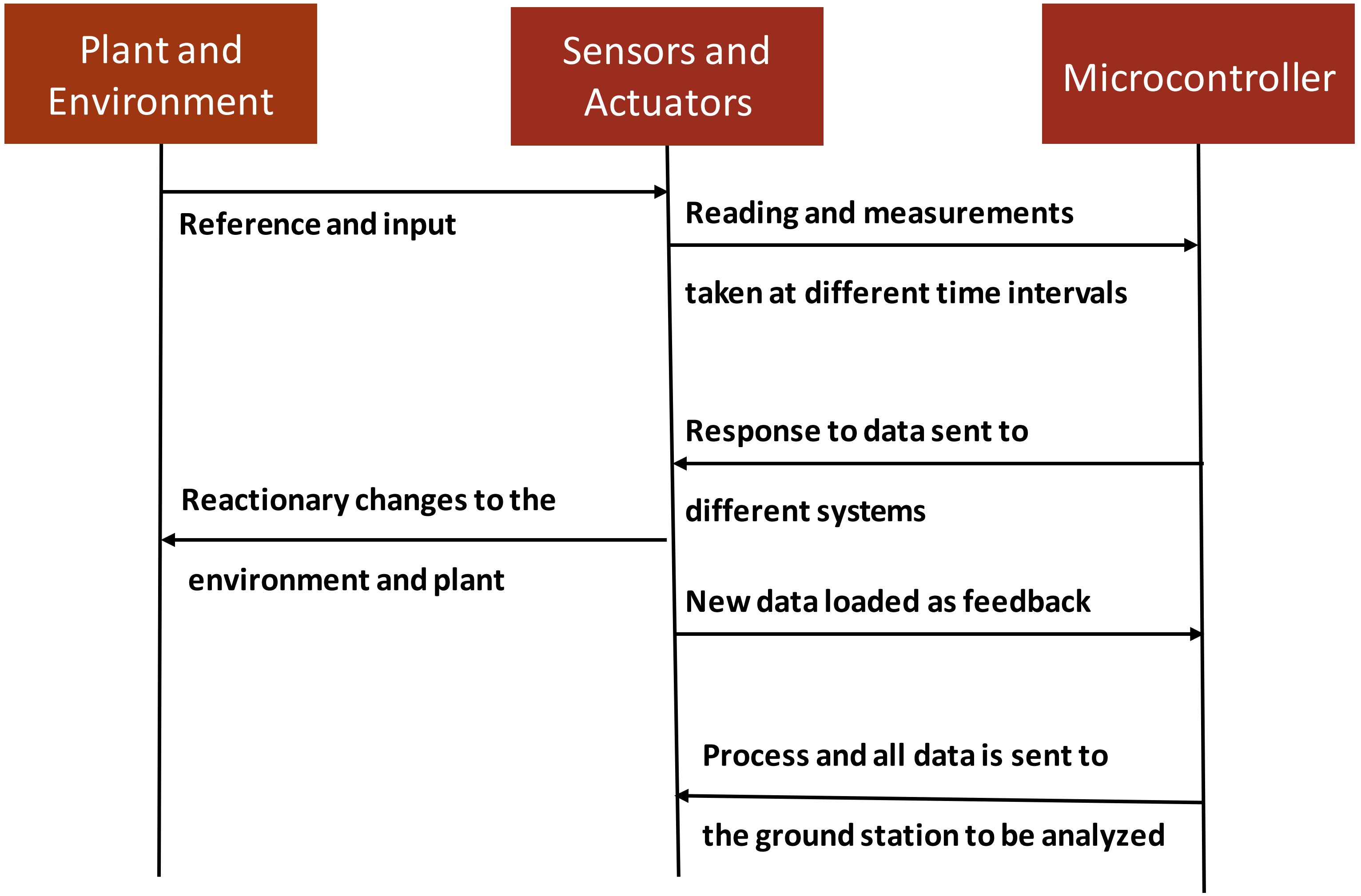
Driving Requirement 5

- This system will be entirely autonomous.
- For 30 days, the system will undergo a prescribed 'day in the life' cycle without any intervention.
- During this cycle, the CubeSat will:
  - Simulate daytime conditions for 8 hours.
  - Spend 90 minutes collecting and transmitting data.
  - Simulate daytime conditions for 8 more hours.
  - Simulate nighttime conditions for 4 hours.
  - Spend 90 minutes collecting and transmitting data.
  - Simulate nighttime conditions for 4 more hours.
- This cycle will repeat daily, all while the system maintains temperature and humidity conditions without additional human input.

Functional Diagram



Sequence Diagram



Swap and Performance

Component	Voltage	Current	Time Usage	Max expected Current Draw
Solar Panels	10V	2A	N/A	N/A
Battery	3.7V	6Ah	N/A	N/A
Temperature, Humid VOC Sensor	3.3V	2mA	2 ms	2mA
Oxygen Sensor	3.3V - 5V	6.5mA	1 min	6.5mA
Carbon Dioxide Sensor	3.3V - 5V	4mA	1 min	4mA
Alcohol Sensor	3.3V - 5V	10mA	5 mins	10mA
Light Sensor	3.3V	2uA - 45uA	24hr	45uA
pH Sensor	3.3V - 5V	57mA - 87mA	1 min (not shown)	87mA
Heater	5V	200mA	As needed	200mA
LED	3.3V - 5V	16mA(per light)	24hr	16mA
ESP32	5V	10mA (Sleep) 180mA (On)	24hr (sleep)	10mA
OV7470	2.75V	20mA	Depends	20mA
Antenna	TBA	N/A	N/A	N/A
Antenna Module	TBA	N/A	N/A	N/A
Total				345.45mA

Technical Trade and Path

Design Drivers

Key factors and requirements that determine project decisions

- **Cost**
  - Budget of $750 between all electrical subsystems
- **Partnership with Mechanical Engineering Teams**
  - Consideration to power and available space inside the CubeSat needed to be compromised on between the teams
- **Technology Availability**
  - The amount of environmental sensors were reduced due to size, cost, or necessity
  - CubeSat or near-space antennas are scarce because of both the little availability and their cost

Alternative Components

This includes any components that were considered and why they were not used

- **Power**
  - Typical store-bought batteries could be used in use with an exterior arduino module for power supply. These batteries and module do not have all the features that other batteries come with.
- **Sensors**
  - For a dehumidifier the available components were bulky, they would take up most of the space inside the CubeSat. There is a ventilation system already in place, which will regulate any unwanted moisture.
  - The pH sensor was expensive and would give other components information to regulate the environment. The data would be interesting, but we would not be able to do anything with the information.
- **Microcontroller**
  - The Raspberry Pie does not have the low power consumption necessary for this system which has a limited amount of power generation.
  - The MKR Zero Arduino was not used for the same reason.
- **Communication**
  - The available near-space or antennas designed for CubeSats were extraordinarily out of the price range.
  - Designing our own antenna would call for a lengthy testing process. Before the testing, there are protocols and licenses that are needed to ensure compliance. These take month to clear with the appropriate associations.

Course Plan for Open Studies

This is a plan that outlines future studies and how past issues may be resolved

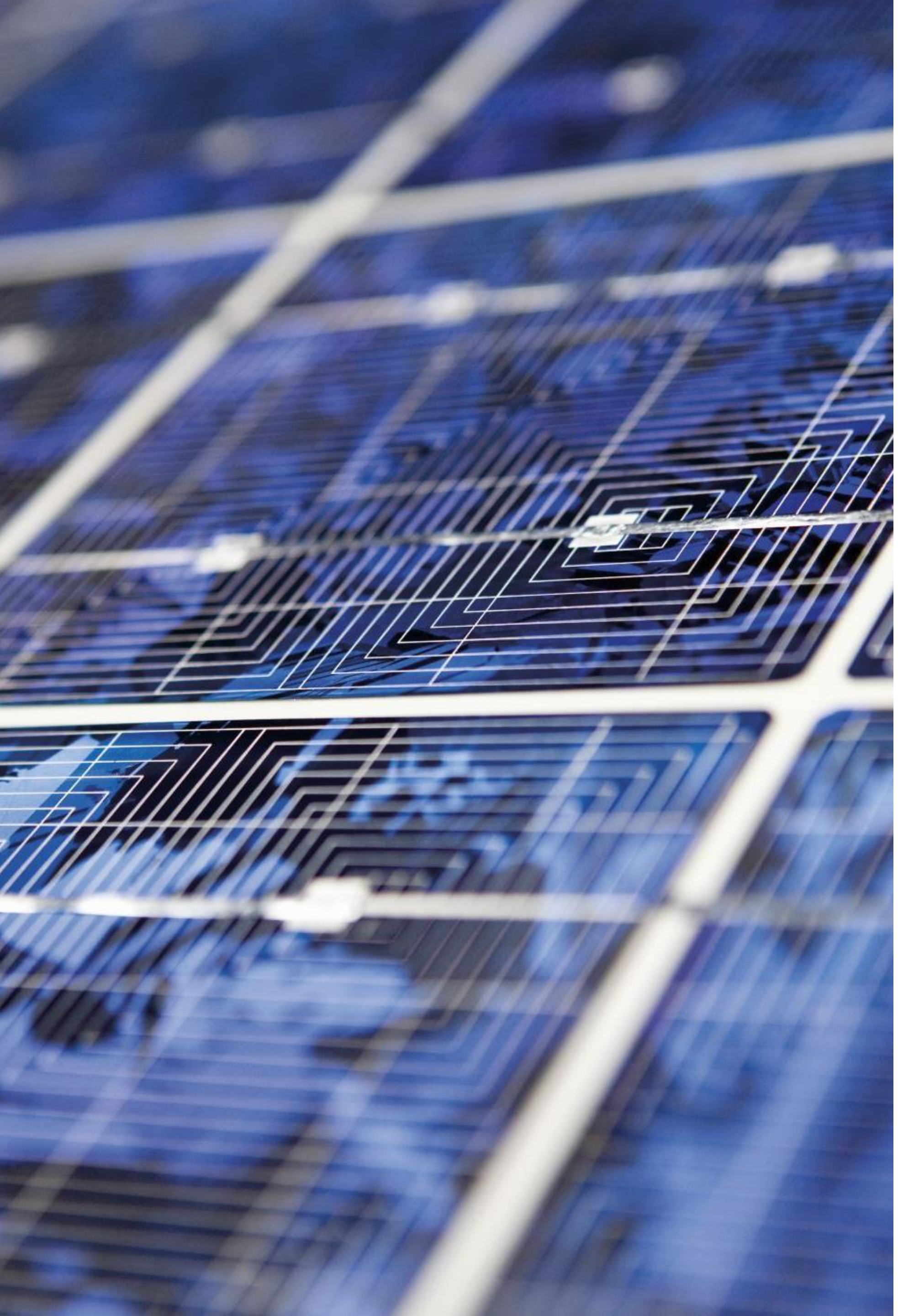
- **Subsystem testing**
  - Each component will undergo testing to ensure reliable data.
  - Further parts lists may be written in response to faulty products or insufficient data
- **Programming**
  - Codes that are compatible to the system will be written and tested
- **Wiring**
  - The full system will be built and tested

Test Requirements

Req#	Function	Requirement	Test Method	Brief Test description
1	ME	Plant chamber shall be capable of fitting within a 3U space	Inspection	The plant chamber can be measured using a tape measure or similar tool
2	EE	Circulate air through chamber at a velocity of 0.3-0.5 m/s using fans	Inspection	Use fan manual to show the settings and speed of the blades
3	EE	The grow light shall be capable of providing an intensity of 200-250 umol/m2/s with a light wavelength of 400-700 nm for 16-18 hours a day	Inspection	Can see if the lights are on and switch the different intensity and wavelengths are see if there a change with sight
4	EE	Microcontroller should have at the minimum same number of I/O pins as sensors with room for expansion boards	Test	Test I/O by sending signal or receive signal and add expansion board and see if data can be sent
5	EE	Antenna must communicate from weather balloon to ground station distance about 25km-35km	Demonstration	The launch of the weather balloon will be the opportunity see if communication reaches the required distance
6	EE	Temperature sensor to measure desired range of 50-80 degrees F	Test	Put the temperature in different ranges using thermostat to control environment
7	EE	Humidity sensor to measure range of 40%-80% RH	Test	Change environment using humidifier and dehumidifier and measure change

Test Requirements Cont.

8	**EE**	**CO_2 sensor measure range of 400-1500ppm**	**Test**	**Move sensor to different environments with higher and lower CO_2**
9	EE	O_2 sensor measure range of 160,000 - 209,000 ppm	Test	Move sensor to different environments with higher and lower O_2
10	EE	Ethylene sensor measure range of 0-100ppb	Test	Move sensor to different environments with higher and lower ethylene levels
11	EE	The solar panels and battery will generate/store enough power to allow the CubeSat to operate autonomously	Test	Use datasheets of each individual component and come up with power budget and see if device is powered during operation
12	EE	Optical/fisheye camera imaging on root zone and sprout zone	Test	Take multiple images in different orientations and positions
13	EE	Payload shall include hyperspectral camera imaging on leaf zone	Test	Take multiple images in different orientations and positions

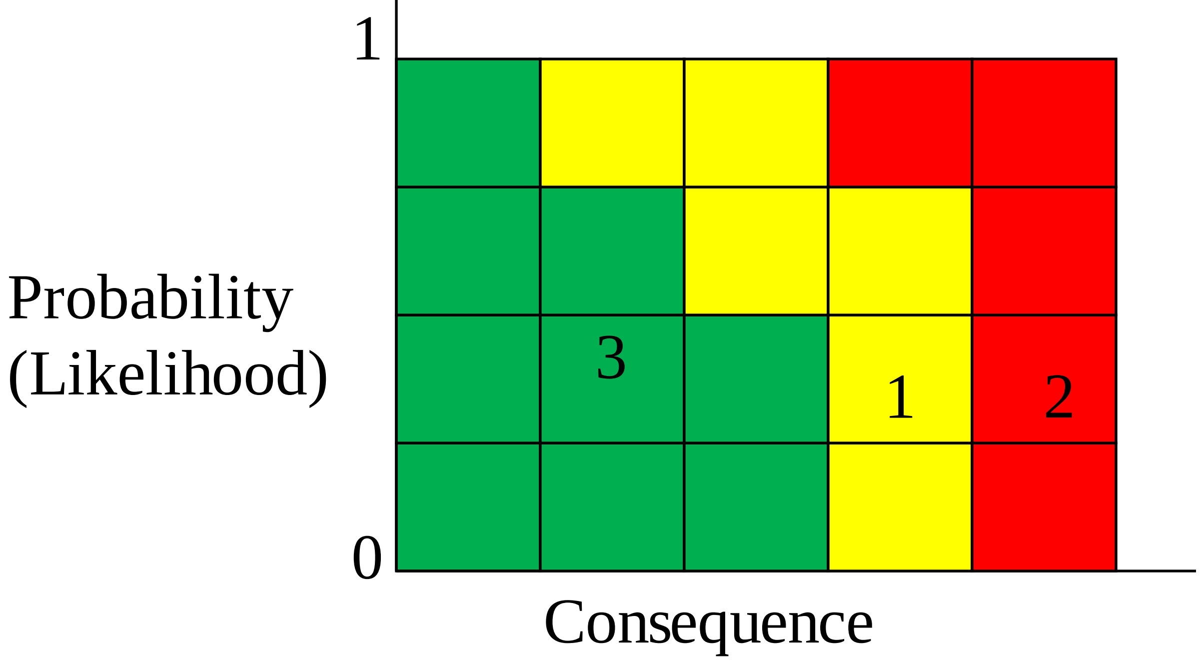


Test Plan

- How are we going to successfully integrate our requirements into our CubeSat?
  - Conduct a power analysis to ensure that the 10V power source, represented by the solar panel, is effectively supplying power to our system, with a seamless mechanism to redirect any surplus energy generated towards the charging of the battery.
  - Conduct a comprehensive verification process to ascertain that the printed circuit board (PCB) is effectively governing all sensors, while concurrently providing requisite feedback mechanisms to sustain optimal control over temperature, humidity, air concentration, light intensity, and pH levels.
  - Ensuring the operational integrity of all sensors, validating their precision in capturing data within the predefined margin of error.
  - Verify the system's capacity to bi-directionally transmit and receive data with the ground team, facilitating the measurement of data and enabling close to real-time adjustments as deemed necessary.
  - Validate the self-sufficiency of our system, ensuring its seamless operation without necessitating any human interaction, thereby exemplifying a state of complete autonomy and independence in its functioning.

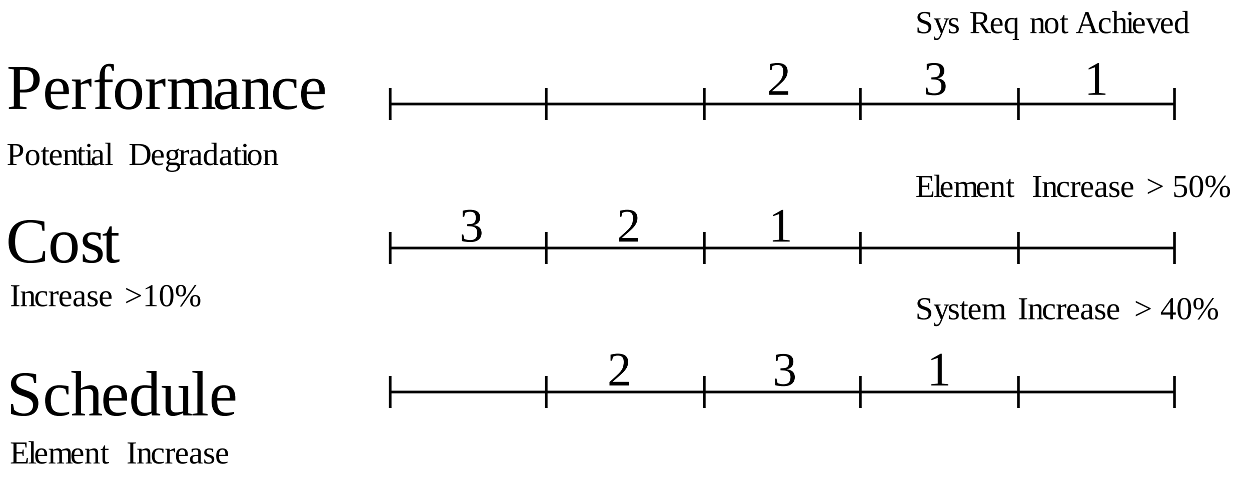
Risk Analysis

1. Wireless communication failure
2. Power generation from solar panels
3. Weather interference



Mitigation Plan

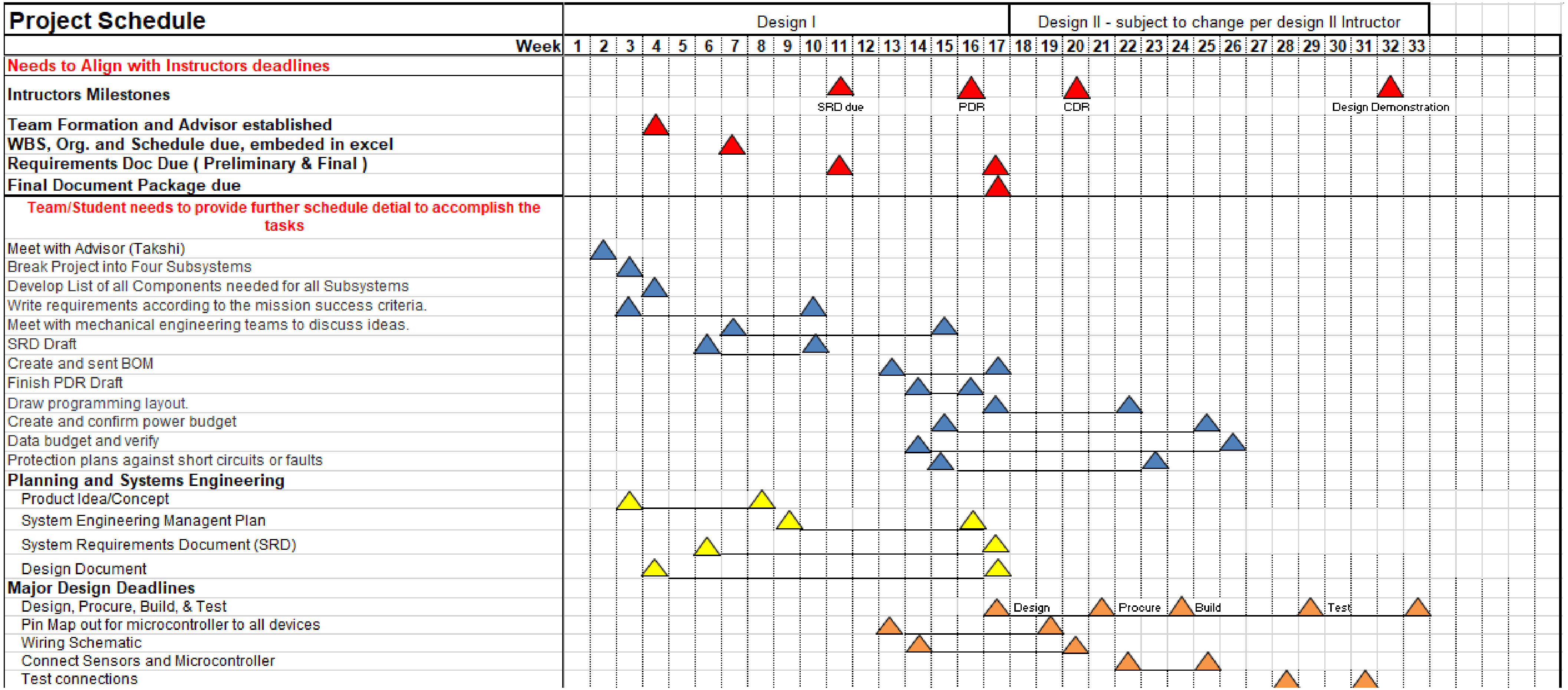
1. Wireless communication failure
    1. Multiple testing rounds from similar distance
2. Power generation from solar panels
    1. High capacitance battery
3. Weather interference
    1. Finding day with least harsh conditions
    2. Have multiple day slots for testing



Bill of Materials (BOM)

BOM			
Component	**Type**	**Price**	**Link**
BME680	Temp/Humidity/VOC Sensor	$10.76	https://www.digikey.com/en/products/detail/bosch-sensortec/BME680/7401317
ZMOD4410	Alcohol Sensor	$4.79	https://www.digikey.com/en/products/detail/renesas-electronics-america-inc/ZMOD4410AI1R/8823799
SEN0536	CO2 Sensor	$58.90	https://www.digikey.com/en/products/detail/dfrobot/SEN0536/18069280?s=N4IgTCBcDaIM4FMB2AGArAZgGwgLoF8g
VEML7700	Light Sensor	$1.88	https://www.digikey.com/en/products/detail/vishay-semiconductor-opto-division/VEML7700-TT/6210690
SEN0496	O2 Sensor	$95.90	https://www.digikey.com/en/products/detail/dfrobot/SEN0496/16678690?s=N4IgTCBcDaIM4FMB2AGALATgGwgLoF8g
4 PCS Flexible Heater Film	Heater	$15.99	https://www.amazon.com/dp/B0727X2DGC?th=1&language=en_US
5V Relay 6 Channel	Relay	$11.99	https://www.amazon.com/ANMBEST-Optocoupler-Trigger-Arduino-Channel/dp/B08RRTHTYQ/ref=sr_1_3?keywords=5v%2B6%2Bchannel%2Brelay%2Bmodule%2Barduino&s=industrial&sr=1-3&th=1
AFB0405LA-A	Fan	$11.66	https://www.digikey.com/en/products/detail/delta-electronics/AFB0405LA-A/5799904
WS2812B-2020	LED Strip	$9.99	https://www.amazon.com/BTF-LIGHTING-Flexible-Individually-Addressable-Non-waterproof/dp/B01CDTED80/ref=asc_df_B01CDTEJBG/?tag=hyprod-20&linkCode=df0&hvadid=242074984067&hvpos=&hvnetw=g&hvrand=5539641265872613748&hvpone=&hvptwo=&hvqmt=&hvdev=c&hvdvcmdl=&hvlocint=&hvlocphy=9012104&hvtargid=pla-372649960034&mcid=739debde9fe33d6e8e3329040e950334&th=1
TCA9548APWR	I2C Bus	$1.67	https://www.digikey.com/en/products/detail/texas-instruments/TCA9548APWR/3615458
Solar Power Manager	Solar Power Manager	$38.90	https://www.dfrobot.com/product-1714.html
Arducam with OV2640	Camera **(BUY 3)**	$77.97	https://www.amazon.com/Arducam-Module-Megapixels-Arduino-Mega2560/dp/B012UXNDOY/ref=sr_1_1?keywords=Arducam+Mini+Module+Camera+Shield+with+OV2640+2+Megapixels+Lens+for+Arduino+UNO+Mega2560+Board+%26+Raspberry+Pi+Pico&s=industrial&sr=1-1

Project Schedule



Review of Action Plan

#	Date Create	Originato	Description	Assigne	Original Due Date	Status	Updated Due Da	Status and Closure Comments	Aging
1	9/5/23	Team	Develop Contact with Faculty Advisor and Arrange weekly meeetings.	**Chris**	9/7/23	**Closed**	9/7/23	Successful in contacting advisor and creating weekly meetings.	0
2	9/6/23	Team	Write draft for project proprosal to Kennedy Space Center (KSC)	**Phillip**	9/8/23	**Closed**	9/8/23	Draft finished and ready for editing.	0
3	9/6/23	Team	Edit proprosal draft and create final version.	**Abigail**	9/9/23	**Closed**	9/9/23	Final draft of proprosal finished and sent to Dr. Takshi.	0
4	9/11/23	Team	Write Tri-weekly report for first week.	**Joseph**	9/11/23	**Closed**	9/11/23	Coordinated with team to get all first week assignments into the report.	0
5	9/13/23	Team	Attended the team meeting with the ME teams and advisors	**Everyone**	9/13/23	**Closed**	9/13/23	Did introductions with the mechanical engineering team along with establishing a line of communication across teams	0
6	9/18/23	Team	Took notes on weekly meeting with advisor	**Abigail**	N/A	**Closed**	9/28/23	Take notes on meetings with Dr. Takshi and share them with the team	0
7	**9/18/2023**	Team	Assign rolls for each member	**Chris**	**9/21/2023**	**Closed**	**9/21/2023**	Assign each member a subsystem to lead, based on their academic focus and experience.	0
8	**9/19/2023**	Team	Supported the creation of sub-systems and became the the lead on one	**Joseph**	**9/19/2023**	**Closed**	**9/19/2023**	Helped disccuss and create the sub systems where we will divide tasks and took my the lead of my own	0
9	**9/25/2023**	Team	Create a materials schematic	**Phillip**	**9/25/2023**	**Closed**	**9/25/2023**	Create a schematic that shows the components of each subsystem and how they work together to form the system.	0
10	**9/26/2023**	Team	Meet with Mechanical Engineering team to discuss cubesat and plant chamber	**Chris/Philip**	**9/28/2023**	**Closed**	**9/28/2023**	Met with Mechanical teams and discussed design for the plant chamber and cubesat, will be communicating closely to allocate space for all components.	0
11	**9/27/23**	Team	Researched plant growing conditions and the sensor ranges required to observe these conditions	**Chris/Philip**	**10/1/23**	**Closed**	**10/1/23**	Plant information required for choosing correct sensors to monitor plant health.	0
12	**9/29/2023**	Team	Started and opened the SRD document to begin editing	**Joseph**	**9/28/2023**	**Closed**	**9/28/2023**	Downloaded and started editing the template. Opened it up to sharing to begin work for upcoming deadline	0
13	**10/2/2023**	Team	Submitted the tri-weekly report	**Abigail**	**10/2/2023**	**Closed**	**10/2/2023**	Organized with the team to make sure the deadline for this assignment was completed on time	0

Review of Action Plan

#	Date Create	Originato	Description	Assigne	Original Due Date	Status	Updated Due Da	Status and Closure Comments	Aging
14	10/2/2023	Team	Developed requirements for the antenna	Abigail	10/9/2023	Closed	10/15/2023	Created a standard for future antenna based on near space atmospheric conditions and connected subsystems	0
15	10/5/2023	Team	Worked on requirements for sensors and microcontroller	Abigail	10/9/2023	Closed	10/15/2023	Worked on the requirements for the microntroller and sensor like voltage	0
16	10/9/2023	Team	Create short list for antenna.	Abigail	10/23/2023	Closed	10/19/2023	Researched potential candidated for antenna purchase.	0
17	10/9/2023	Team	Gantt Chart	Abigail	10/23/2023	Closed	10/17/2023	In progress to develop a Gaunnt chart that will encompass individual and team efforts. Assigning subtsks and due dates allow the team to structure their time and focus.	0
18	10/9/23	Team	SRD	Joey	10/24/23	Closed	10/24/23	Worked on subsections within three and testing matrix	0
19	10/10/23	Team	SRD	Phillip	10/24/23	Closed	10/24/23	Writing the introduction and sections 3.17 and 3.17 of the SRD	0
20	10/11/23	Team	Researching requirements for additional light sensor added by advisor.	Phillip	10/18/23	Closed	10/18/23	Sensor added to project by advidsor. Requirments for the light sensor needed to collate short list.	0
21	10/13/23	Team	Power analysis for power generation and distribution	Chris	10/13/23	Closed	10/13/23	Went over estimated power generation along with calculated total power usage for all devices	
22	10/16/2023	Team	SRD	Abigail	10/19/2023	Closed	10/19/2023	Completed the required subtasks assigned to me for the SDR.	0
23	10/18/23	Team	Create short list for microcontroller	Joey	10/24/23	Closed	10/31/23	Narrowing down a list of possible microcontrollers to use given the requirements	0
24	10/18/23	Team	Creating shorlists for sensors	Phillip	10/31/23	Closed	10/31/23	Collating lists of candiates for each of our sensors. Does not include the cameras.	0
25	10/18/23	Team	SRD`	Chris	10/18/23	Closed	10/18/23	Finished section assigned by team	0
26	10/21/23	Team	Shortlist on power and assistance on wireless communication and sensors	Chris	10/21/23	Closed	10/21/23	Finding components that could work for CubeSat and the microcontroller	0
27	10/28/23	Team	Looked for Camera and LED lights	Chris	10/28/23	Closed	10/28/23	Finalized camera and LED components	0

Review of Action Plan

#	Date Created	Originator	Description	Assignee	Original Due Date	Status	Updated Due Date	Status and Closure Comments	Aging
27	**10/28/23**	Team	Looked for Camera and LED lights	**Chris**	**10/28/23**	**Closed**	**10/28/23**	Finalized camera and LED components	**0**
28	**10/28/23**	Team	Look for microcontrollers and modules	**Joey**	**10/28/23**	**Closed**	**10/28/23**	Have a list with two microcontrollers and make pros and cons of each and look for any addional modules like sd card or i2c bus	**0**
29	**11/7/23**	Team	Start looking at pin outs of the microcontroller and look for weather balloon solutions	**Joey**	**11/7/23**	**Closed**	**11/7/23**	Started to build a list of connections to microcontroller and start looking on how the cubesat will be deployed	**0**
30	**11/8/23**	Team	Group Meeting with Mechanical Engineering teams	**Everyone**	11/8/23	**Closed**	11/8/23	Discussed with Mechanical engineering teams in regard to power generation along with irrgation design layout	**0**
31	**11/12/23**	Team	Finished microcontroller hunt and pin out	**Joey**	11/12/23	**Closed**	**11/12/23**	Found the microcontroller used for the project and the output of the pins and libraries for coding purposes	**0**
32	**11/13/23**	Team	Assisted In finding means of wireless communication	**Chris**	11/13/23	**Closed**	11/22/23	Assisted in finding different ways of being able to communicate with our CubeSat wirelessly	**0**
33	**11/8/23**	Team	Wrote Preliminary Bill of Materials	**Phillip**	11/15/23	**Closed**	11/15/23	Preliminary BOM for sensors and evironmental components.	**0**
34	**11/8/23**	Team	Assisted with mapping sensor pins to microcontroller.	**Phillip**	11/15/23	**Closed**	11/15/23	Assisting Joey so that our chosen microcontroller fits our sensor requirements.	**0**
35	**11/8/23**	Team	Looking for a new low power option for a dehumidifer.	**Phillip**	11/15/23	**Closed**	11/15/23	The current dehumidifier is to power power-heavy, and needs to reduce the power drain or be removed entirely from the project.	**0**

Review of Action Plan

#	Date Create	Originator	Description	Assigne	Original Due Date	Status	Updated Due Da	Status and Closure Comments	Aging
36	**11/23/23**		Map connections to microcontroller	**Joey**	11/15/23	**Closed**	11/15/23	Advisor instructed to map each port in a table of the micontroller to the required sensors or devices	**0**
37	**10/23/23**	Team	Researched CubeSat antennas	**Abigail**	10/30/23	**Closed**	11/20/23	There are antennas specifically designed for CubeSats. I looked into their specifications to compare to those more affordable on the market.	**0**
38	**10/30/23**	Team	Market search	**Abigail**	11/15/23	**Closed**	11/22/23	The market for affordable near space antennas that can communicate at the distances needed is sparce.	**0**
39	**11/30/23**		Schematic diagram	**Joey**	11/20/23	**Closed**	11/27/23	Started and finish the schematic wiring diagram of the different component and their respective connections	**0**
40	**11/6/23**	Team	Design referral	**Abigail**	11/22/23	**Closed**	11/22/23	After speaking with my advisors, designing and making an antenna may be the best option for this project.	**0**
41	**11/15/23**		Meeting with Peter Jorgenson	**Chris**	11/15/23	**Closed**	11/15/23	Meeting with Jorgenson to go over wireless communication feasibility.	**0**
42	**11/15/23**	Team	Meeting with proffessional	**Abigail**	11/15/23	**Closed**	11/15/23	Chris, me, and the ME teams met with Dr. Jorgensen to discuss the feasibility of the communication of this project. He was able to put this subsystem into perspective.	**0**
43	**11/20/23**	Team	Break for thanksgiving	**Abigail**	11/20/23	**Closed**	11/24/23		**0**
44	**11/27/23**	Team	PDR Slides	**Abigial**	11/28/23	**Closed**	11/28/23	Complete my slides for the PDR	**0**
45	**11/27/23**	Team	PDR Slides	**Joey**	11/28/203	**Closed**	11/28/23	Finsihed updating my slides for the PDR presentation	**0**
46	**11/27/23**	Team	PDR Slides	**Chris**	11/28/203	**Closed**	11/28/203	Complete assigned section for PDR	**0**
47	**11/27/23**	Team	PDR Slides	**Phillip**	11/28/23	**Closed**	11/28/23	Complete assigned section for PDR	**0**