B.A.S.I.L.

Bio-Automated System for Indoor Life

Group 5

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1. Project Narrative

1.1 Motivation

As college students, we often find ourselves juggling a hectic schedule filled with classes, assignments, projects, and extracurricular activities. Amidst this busy lifestyle, many of us still desire to cultivate our own organic food, recognizing the benefits it offers in terms of health, freshness, and environmental sustainability. However, the time and effort required to maintain a traditional garden can be overwhelming, leading to neglected plants and suboptimal growth. In fact, studies have shown that up to 50% of home-grown basil plants die due to inadequate care and attention. This challenge served as the primary motivation behind our project: to develop an intelligent control system that simplifies the process of growing organic basil, even for those with demanding schedules.

Our project's motivation was further solidified when our photonics team member was approached by Dr. Michael Pape, an entrepreneurship professor with a Ph.D. in chemistry who had previously sold a company to Pfizer. Dr. Pape introduced a new technique for optimizing plant growth using electromagnetic field generators, which aligned with the photonics member's existing ideas for a similar setup. This serendipitous encounter not only validated our project's potential but also secured funding and support from Dr. Pape, who will serve as a sponsor and reviewer throughout the development process.

1.2 Background

The demand for fresh, locally-grown organic produce has been steadily increasing, with organic food sales in the U.S. reaching $50.1 billion in 2019 [1]. However, traditional gardening methods can be challenging, especially for college students with limited time and resources. In fact, a survey found that 31% of college students struggle to maintain a healthy diet due to time constraints [2].

Advances in photonics, electrical engineering, and computer science have opened up new possibilities for addressing these challenges. Smart greenhouses, equipped with intelligent control systems, have emerged as a promising solution, with the global smart greenhouse market expected to reach $2.1 billion by 2025 [3]. By applying our expertise in these fields, we aim to develop an intelligent greenhouse control system tailored specifically for herb cultivation, empowering college students and other busy individuals to successfully grow their own organic herbs. Through this project, we hope to contribute to the broader movement towards sustainable, locally-grown food production.

2. Existing Product / Prior Related Work

2.1 AeroGarden: Harvest Elite

The AeroGarden Harvest elite is a popular choice for automated indoor plant care. This product claims that it will grow six plants five times faster without the need for soil. AeroGarden Harvest Elite includes the following features:

- 20W full spectrum LED grow light
- Up to 12” plant height
- Stainless steel enclosure 17.4” H x 10.5” W x 6.25” D
- Digital display and push button controls
- Automatic reminders for water and plant food
- Vacation mode

AeroGarden is designed so that plant pods can be inserted into six different spots. The pods have holes in the bottom where the roots of the plants are able to grow into the water reservoir beneath to absorb the nutrient enriched water. Over-arching the plant's pods is an LED panel which emits lights that are specific frequencies to stimulate photosynthesis. They have also incorporated a control panel with a user interface which allows the user to set reminders and control the LEDs.

2.2 AquaSprouts Garden Bundle

AquaSprouts is a product kit that simplifies aquaponics in the home. Aquaponics is the combination of aquaculture (raising fish) and hydroponics (growing plants in water) into a symbiotic relationship where the fish waste provides nutrients to the plants while the plants filter and clean the water in a closed loop cycle. The AquaSprouts Garden Bundle includes the following features:

- Grow-bed: housing that fits any standard 10 gallon aquarium
- Light Bar: 2ft, 2640 lumen LED strip providing daylight white light
- Submersible LED light: Full range RGB LEDs for aesthetic purposes
- Pump and Timer: Submersible 160 gallon per hour pump and mechanical plug timer with 15 minute adjustable increments
- Grow Media: Allows for plant roots and fish waste to have a surface to combine

2.3 Botanium

Is a stylish but simple single plant hydroponics device that provides automated watering and nutrient delivery into a porous growing medium. Botanium is divided into a plant chamber with the porous growing medium and a nutrient rich water reservoir with a submerged pump.

2.4 Click and Grow Smart Garden 9

The Click & Grow Smart Garden 9, launched in 2020, is an indoor gardening system designed to simplify the process of growing fresh herbs, vegetables, and flowers in urban living spaces. Utilizing advanced hydroponic technology, energy-efficient LED lighting, and a self-watering system, the Smart Garden 9 ensures optimal plant growth with minimal user intervention. The companion mobile app offers personalized gardening tips, reminders, and inspiration, empowering users to cultivate fresh, healthy produce year-round and promote a sustainable lifestyle.

2.5 Summary

After taking a look into these commercially available products we got some reassurance and new ideas. The products already in circulation were using some ideas we had already thought of implementing so this was a good sign that we were on the right track of thinking to begin with. One major takeaway we realized when researching these products was that none of them were using soil which we were going to use originally. This led us to start doing some research into hydroponics and how we could benefit from also implementing a similar system into our product.

2.5.1 LEDs

One of the main ideas we had from the start of the project was to use LEDs instead of relying on natural sunlight. We received further justification for this idea once we noticed that most of the related work done for automated growing mediums utilized LEDs in their design as well. AeroGarden and Click and Grow Smart Garden both include an LED light hood which emits specific color frequencies in order to stimulate photosynthesis in the plants. Also, BASIL will similarly use a timer to naturally simulate daylight cycles.

2.5.2 Water Reservoir

We originally wanted to implement a self watering system but due to the benefits of integrating hydroponics we decided to change our approach. BASIL will utilize a water reservoir which will be placed under the herbs where the roots will be submerged in nutrient dense water. This idea came from AeroGarden, AquaSprouts, and Botanium as they all use a form of hydroponics. Similar to these products we will be implementing a pump to incorporate oxygen and disperse the nutrients in the water so that it reaches the roots. We plan on improving on these designs and implementing our own form of hydroponics that will cater to herbs specifically.

2.5.3 Sensors

BASIL will include sensors similar to those found in related products on the market. Comparable to AeroGarden, Botanium, and Click and Grow, BASIL will have a water sensor to ensure the reservoir is always filled to the appropriate capacity. Additionally, we will include a light sensor, like those in AeroGarden and Click and Grow, to determine if the plant is receiving enough light and adjust the LEDs accordingly. Our product will be unique by also providing a temperature sensor, pH sensor, humidity sensor, color sensor, and Gauss sensor. BASIL will use these readings to ensure the system operates safely and efficiently at all times. All data from these sensors will be available to the user on BASIL’s website.

2.5.4 EMF Generator

This is one of the biggest differences BASIL will have in comparison to the other products on the market. One of our main goals is to increase the yield from indoor growing so our consumers will always have a supply of their own fresh herbs. BASIL will utilize a specific threshold of frequencies that have been tested to increase the biomass accumulation in plants. These frequencies also stimulate root growth which is particularly helpful with herbs because a stronger root system will increase nutrient and water uptake.

No other products on the market utilize an EMF Generator.

2.5.5 External Connectivity

In order to include a component of software engineering into our design we knew that implementing a smart system capable of extrapolating data from our sensors and sending notifications was the best solution. Aerogarden and Click and Grow Smart Garden both utilize a pairable phone application designed to give the user control over the LEDs, send notifications, and provide specific plant information. In our design we plan on utilizing a website to handle these tasks and include some control over the EMF generator.

2.5.6 Conclusion

BASIL will be the accumulation of all of the previous works in this field. We will be taking the best parts of these previous works and building upon them to work efficiently in our design. The main differences in our design will be the implementation of the EMF Generator and the use of external connectivity to allow control. All of the components together will create a semi-autonomous herb cultivator with enhanced growing capabilities that allows for full user oversight.

3. Project Outline

3.1 Goals

Basic Goals:

- Ensure optimal growing conditions for the basil plant by accurately monitoring environmental factors.
- Implement a hydroponics-based system that efficiently circulates oxygen and nutrients to the roots of the basil plant.
- Implement a web application for data analysis and user-friendly interaction
- Design a portable and safe hardware setup that can be comfortably placed inside a home

Advanced Goals:

- Stimulate plant growth by integrating optimal LED lighting systems.
- Incorporate an EMF generator to disperse the most optimal waves for further growth stimulation.

Stretch Goals:

- Implement machine learning algorithms to detect plant health issues prior to leaves turning brown.
- Develop a mobile application for remote monitoring and control of the B.A.S.I.L. system.

3.2 Objectives

Basic Objectives:

- Integrate sensors into the hardware setup with the following accuracy ranges:
  - Temperature sensor accurate within ±2°C
  - Humidity sensor accurate within ±5% RH
  - Light intensity sensor accurate within ±5% of the full-scale range
- Design and integrate a hydroponics system into the B.A.S.I.L. setup that includes:
  - A water reservoir with a capacity of at least ½ gallon to ensure an adequate supply of nutrient solution
  - A submersible water pump capable of circulating the nutrient solution at a rate of 1-2 liters per minute to maintain optimal oxygen levels and nutrient distribution
  - A network of pipes and tubing to direct the nutrient solution from the reservoir to the plant's roots and back, ensuring continuous circulation
- Develop a user-friendly web application that includes:
  - An intuitive user interface for displaying real-time sensor data and plant growth metrics
  - A backend system that efficiently processes and stores sensor data
  - Deployed on an AWS cloud instance
- Design and construct a hardware enclosure that meets the following criteria:
  - Dimensions not exceeding 24 inches in length, width, or height to ensure portability
  - Made from durable, food-safe, and water-resistant materials to ensure longevity and safety

Advanced Objectives:

- Integrate an adjustable LED lighting system into the hardware setup that includes:
  - LED lights with a spectrum optimized for basil growth, focusing on wavelengths between 450-480 nm (blue)
  - A control system that allows users to adjust light intensity and duration based on the plant's growth stage
- Develop and integrate an EMF generator into the B.A.S.I.L. system that includes:
  - An EMF generator capable of producing frequencies between 0.1 Hz and 30 Hz, which are believed to have potential effects on plant growth

Stretch Objectives:

- Develop a machine learning-based plant health detection system that includes:

    - Integration of a high-resolution camera into the B.A.S.I.L. system to capture images of the basil plant at regular intervals
    - Creation of a comprehensive dataset of basil plant images, including healthy plants and those exhibiting early signs of stress, such as leaf curling or discoloration
    - Development and training of a machine learning model using the collected dataset to accurately identify early symptoms of plant stress or disease
- Develop a feature-rich mobile application for the B.A.S.I.L. system that includes:
    - A user-friendly interface that displays real-time sensor data, plant growth metrics, and system status
    - Secure user authentication and authorization to ensure data privacy and system security
    - Remote control capabilities, allowing users to adjust lighting, watering, and EMF settings from their mobile devices

3.3 Features

- Sensors that obtain accurate readings of the light intensity, pH, temperature, and humidity
- A web application that shows data analysis on the measurements of the plant and have the information available in a user friendly environment
- An automated water circulation system
- A EMF generator to disperse the most optimal waves to further stimulate growth
- Portable design which can be placed comfortably inside a home
- LED lighting system which stimulates the plants to further increase growth
- Safe and user-friendly hardware design

3.4 Product Description

BASIL will be designed to make indoor plant care simpler and more efficient. With the integration of multiple sensors we will be able to accurately track a few environmental factors such as the pH levels, temperature, and humidity. The goal is to keep the herbs at their most optimal level for these readings to ensure the plant is always primed for growth. There will also be a nutrient rich water reservoir which will eliminate the need for soil and having to water the plant manually. Our design will additionally include LED grow lights which will be emitting the optimal spectrum to stimulate the plants growth further. All this data will be available on a web application so the user is able to track their plants health and receive real-time updates. BASIL will overall reduce the amount and time and effort normally required when it comes to growing herbs so even the busiest individuals will be able to enjoy fresh, organic herbs year-round.

4. Project Specifications

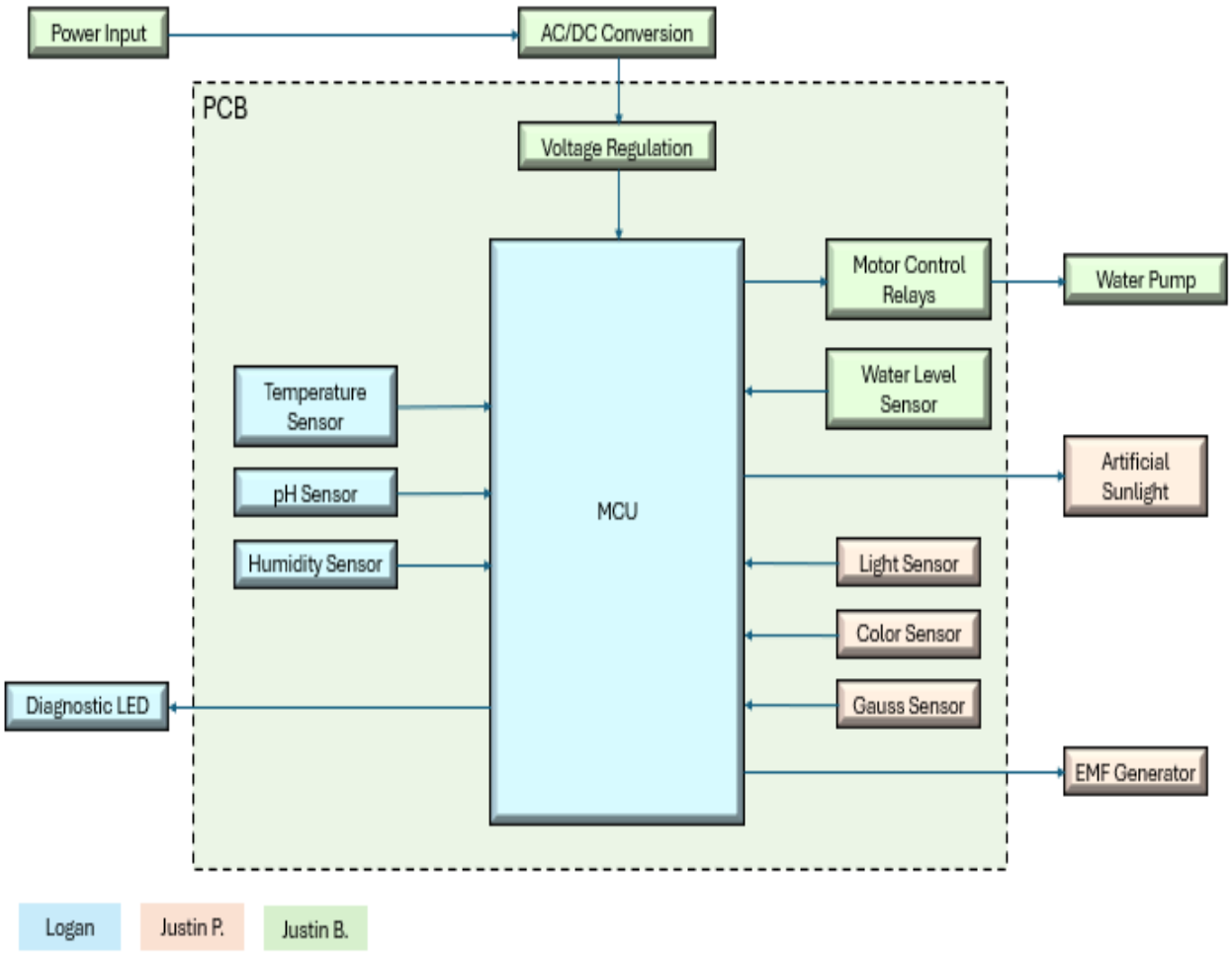
4.1 Hardware Specifications

Item	Type	Specification Description
1	Physical	Enclosure to have no dimension greater than 24 inches Enclosure total weight less than 30 lbs Allow for at least 1 plant that is 12” in height
2	Power	Entire device power input supplied from a single wall outlet 120VAC
3	Sensors	Temperature sensor accurate within ±2°C Humidity sensor accurate within ±5% RH Light intensity sensor accurate within ±5% of the full-scale range pH sensor accurate within ±0.5 pH Color sensor capable of accuracy within ±5% FSR
4	Water system	Water reservoir containing at least 0.5 gallon Water pump capable of at least 1 Liter per minute
5	Growth Acceleration	LED lights covering full spectrum to mimic sunlight EMF emitter adjustable from 0.1 to 30Hz

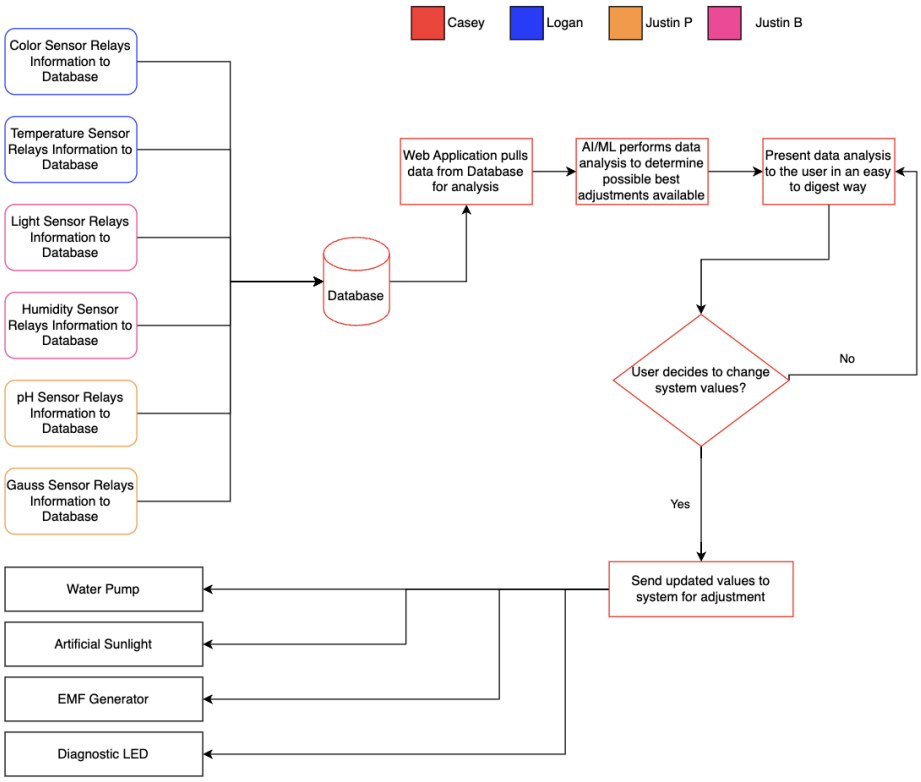
4.2 Software Specifications

Description
Deploy web application on the cloud
See real time data from plant on web application UI
Present data as the plant grows so users can see the rate of growth over time.
Use ML and AI for data reporting to give the user suggestions on what to change with how they are caring for the plant
Accessible website with easy to digest UI
Export user actions to adjust values in hardware (lights) (<5000ms response time)
Export data wirelessly (<5000ms response time)

4.3 Hardware Block Diagram



4.4 Software Block Diagram



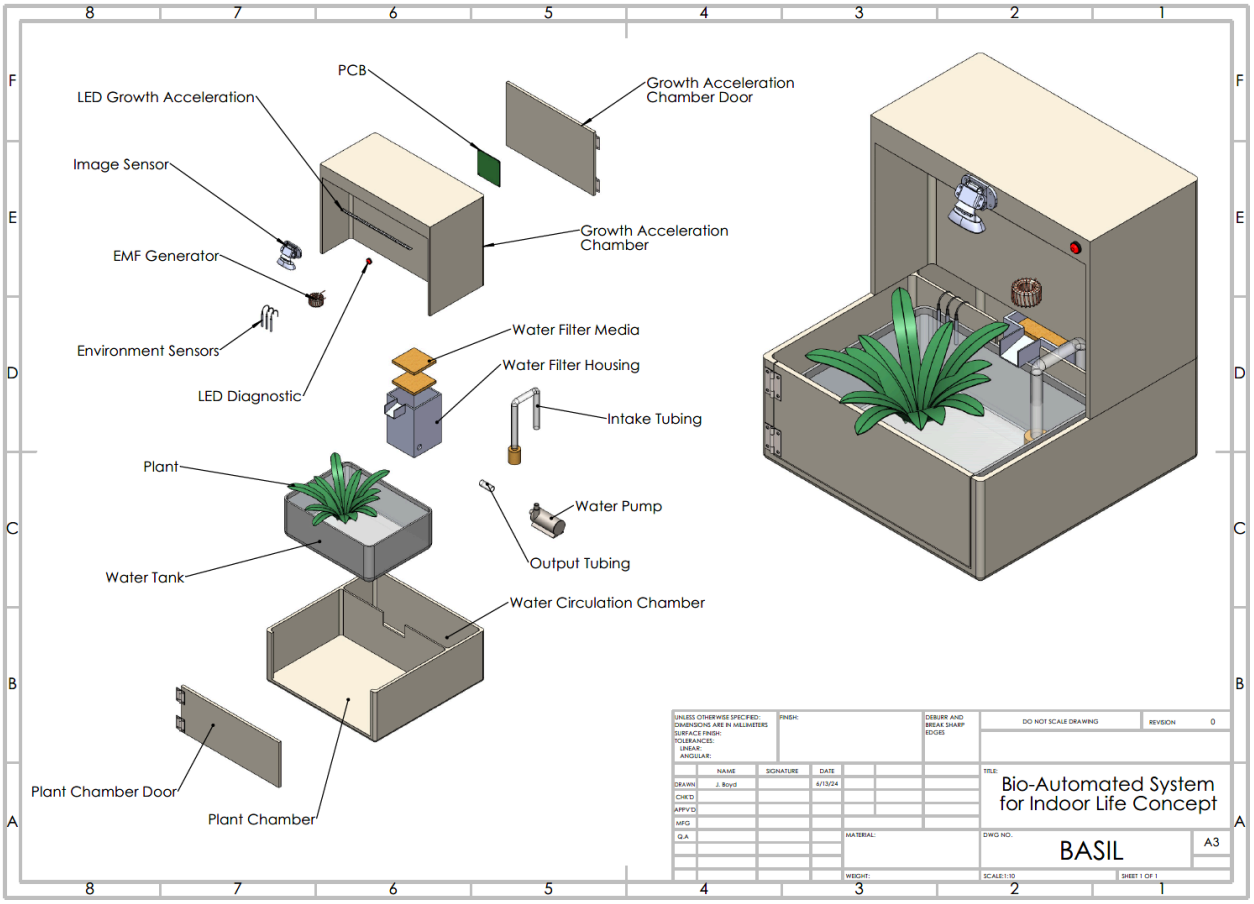
The software block diagram above implements an approach that updates our database with new values periodically. This data is then leveraged in our web application and is then analyzed by AI to then recommend to the user what to do in their system. Then it is up to the user to actually update those values in the web application, if they decide to do so, those values are then sent back to the system to be updated. We wanted to create the web app to be a one stop shop for all of the users needs for their system, this goes back on one of our main objectives of being convenient for users.

5. Projected Expenses

Item	Quantity	Price
Color Sensor	x1	$30.00
Gravity Analog pH Sensor Kit	x1	$30.00
Digital Temperature Sensor	x1	$5.00
Addressable RGB LED Strip (1 Meter)	x1	$15.00
Humidity Sensor	x1	$3.00
Microcontroller with wireless communication capabilities	x1	$30.00
PCB	x1	$45.00
Motor	x1	$10.00
Enclosure	x1	$50.00
Water Filtration	x1	$5.00
Tubing	x1	$5.00
Basil Seeds	x5	$3.00
EM Field Generator	x1	$30.00
Reservoir	x1	$10.00
Bluetooth Module	x1	$15.00
Gauss Sensor	x1	$3.00
Cloud Hosting	x1	$10.00 per month
Team Bonding	x4	$5.00
Total		**≈$320.00**

This total leaves our group about $630 under the budget that we have been allotted. This allows us the liberty of ordering extra parts for testing as well as not having to worry if certain parts end up being slightly higher than what we initially anticipated.

6. Prototype


PCB
Growth Acceleration Chamber Door
LED Growth Acceleration
Image Sensor
Growth Acceleration Chamber
EMF Generator
Environment Sensors
LED Diagnostic
Water Filter Media
Water Filter Housing
Intake Tubing
Plant
Water Pump
Output Tubing
Water Tank
Water Circulation Chamber
Plant Chamber Door
Plant Chamber
Bio-Automated System for Indoor Life Concept
BASIL
A3

7. Project Timeline

7.1 Senior Design I

Task	Timeline	Status
Pick Project Idea	05/14/24 - 05/17/24	Complete
Project Research and Writing 10 Page D&C Assignment	05/18/24 - 05/31/24	Complete
Research Components	06/01/24 - 06/06/24	Complete
Review and Upload D&C Report - Start Draft for 60 Page Report - Meet with SD Professors, Sponsor and Reviewers - Start Ordering Parts for Testing	06/07/24 - 06/20/24	IP
Research, Testing Parts, and Finishing 60 Page Report	06/21/24 - 07/07/24	N/A
Review and Upload 60 Page Report	07/08/24 - 07/12/24	N/A
Finish 120 Page Report and Film Mini Demo Video	07/13/24 -07/23/24	N/A

7.2 Senior Design II

Task	Timeline	Status
Review and Revise 120 Page Document and Start Working on PCB	08/19/24 - 08/26/24	N/A
Finish Custom PCB and Begin Building Prototype	08/27/24 - 09/15/24	N/A
Finish Building Prototype and Work on Presentation	09/16/24 - 10/15/24	N/A
Test Prototype and Work out Problems	10/16/24 - 11/03/24	N/A
Finish Final Product and Practice Presentation	11/04/24 - 11/19/24	N/A
Finalize Report and Upload Everything on Website	11/20/24 - 11/25/24	N/A
Final Presentation	TBD	N/A

References

[1] Organic Trade Association. (2020). U.S. Organic Industry Survey 2020.

[2] American College Health Association. (2019). National College Health Assessment II: Reference Group Executive Summary Spring 2019.

[3] MarketsandMarkets. (2020). Smart Greenhouse Market by Technology, Type, Component, and Region - Global Forecast to 2025.