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End of Project Documentation
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Smart Hydroponic Garden

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Elevator Pitch- We are creating an autonomous hydroponic system with minimal user interaction to help lessen food waste.

EXECUTIVE SUMMARY

A large portion of food waste comes from households, so our solution will bring food production into homes through an efficient hydroponic system. Our hydroponic system is unique because it requires minimal user interaction. The setup would fit in small spaces and can be used anywhere regardless of weather. Environmental data is collected using sensors and AI. We have plant growth cycles that tested our product and adjusted variables such as nutrients to water ratio and duration of when the artificial light is turned on. We worked to define all our assignments and tasks of the project. The tasks were broken down into smaller specific tasks that lead to a completed successful project. After the tasks of the project were defined, we set specific times for when these tasks were to be completed. The team created a clear timeline set as to where each team member should be week by week as well as where the team should be. This was done using a Gant Chart, and a PERT Chart outlining week by week the full duration of Senior Design between the two semesters. As part of a risk assessment, we looked at the potential risks that might be posed by our project. These risks came from unpredictable results of the project, and the goal of team is to minimize or reduce risks by accounting for potential issues. To achieve this, the team had to brainstorm all risks associated with project, list the probability and impact of each risk, and provide mitigation plans to resolve the risk. After close inspection of the project after a full semester of work, we reevaluated our societal problem. We concluded that a large portion of food is wasted in every step as it makes its way to households. Our solution remained the same in bringing food production into homes through an efficient hydroponic system. This will shorten the food distribution chain and eliminate waste throughout every link of the system. We built our prototype in our first semester of senior design. Following the creation of the prototype the team needed to develop a device test plan to ensure the prototype worked as intended. For Spring 2022, we were ready to test our product and make changes if necessary. We prepared the test plan to assess and correct the flaws that we encountered. We took our evaluation from the previous semester into consideration, and we put our prototype against a series of tests that will determine if the sensors, components, and other materials in our prototype need to be upgraded or changed. Outside of testing our prototype and documenting features the team needed to get a better understand of the market environment that our product competed in. To do so the team underwent a market review process. A market review is where we were able to identify our consumer and client of the prototype we made. This included a market analysis that shows how our product is unique and showed who would need or want this product. Towards the end of the project, we needed to finish the device test plan that we had laid out earlier in the second semester. Here we documented how every feature stacked up against the tests, in the end giving them a score of a pass or no pass. The prototype underwent extensive tests to see if the product would hold up to the consumer. We tested accuracy, longevity, and precision of each feature. We made sure that the hydroponic garden was able to deliver all the measurable metrics and performs as intended. In the concluding aspects of the project the team found that all the features passed our testing and delivered on what we had set out to accomplish.

Abstract - Food waste has been a problem for many years not only in United States but also globally. Among other problems, food waste is huge contributor to climate change as food end up in landfill and releases harmful gasses to our environment. Our team is attempting to address this issue by reducing the food production and therefore reducing food waste and its harmful effects. While food is discarded at every step of the food chain, households are known to be the main contributor. By bringing the source to the consumer's home, households can control their production and consumption of crops. Our solution is building a smart hydroponic system that will require minimal interaction with the users, to aid all households regardless of their gardening skill and space availability. This paper lays out the plans, execution, and results as we build and develop our prototype. First, we decided to create a list of features of our smart garden. Then, tasks to complete the project are listed within our work breakdown structure. A major factor for success in our project involved integrating all our sensors into the system. We also included risk assessment of changing factors as we proceed with our project. After building our prototype, all our measurable metrics were tested accordingly. The testing results thoroughly prove that each feature meets the predetermined goals. Within the market review section, we specified manufacturing strategy from prototype to production in a cost-efficient manner. Overall, our team is successful in creating a smart hydroponic garden and was able to grow healthy plants.

Keyword index – food waste, hydroponics, auto dosing, water sensor, ambient light, health monitoring camera, nutrient, fertilizer,

I. INTRODUCTION

A. Societal Problem

Food waste has been a dilemma for many years and overproduction of crops is one of the root causes. The entire globe including the U.S. play a major role in this societal problem and households are largest contributor of food waste. To tackle this problem, we will bring production into households through a hydroponic system.

B. Design Idea

The hydroponic garden will have smart features that will make the novice gardener a pro. We will have electrical conductivity sensors that will measure the conductivity of the water and add fertilizer when necessary. Similarly, we will have sensors for ambient light and pH that will supplement the ambient light with artificial lighting and adjust the pH as necessary. We will also have a camera that can time lapse the growth and monitor the health of the plants. With all these features the end user just must add water and seeds to the system.

C. Work Breakdown Structure

After establishing the features that the hydroponic system will have, we listed the tasks and steps we need to take for the success of the project. We listed each task and wrote specific details on what should be accomplished for Fall 2021 and Spring 2022 semesters. We distributed the tasks among the group and estimated the time that each step will be done. We also listed and described all assignments that are required throughout the course for both semesters.

D. Project Timeline

Since the team defined the tasks that are required to be completed so that the full feature set is fulfilled, the next part is to set a timeline for when these tasks will be completed. This timeline will include the full duration of Senior Design which will be the semesters of Fall 2021 and Spring 2022. We will set a timeframe week by week using a Gant Chart and a PERT Chart of where the team, and each team member should be with their respective tasks and assignments.

E. Risk Assessment

There are risks involved with our project that could cause our group to not be able to deliver a finished product. A risk evaluation and assessment are required so that our team can come up with mitigation plan. It is crucial to have a backup plan as our grades depend on this project. The risk evaluation will include not only parts and equipment failure but health and wellbeing of each member.

F. Problem Statement Revision

Our chosen societal problem in our first semester is food waste. After a semester of working with our senior project, we now have a better understanding of our problem statement. Food waste has been a societal problem around the world and substantial portion of food waste comes from households. Food is wasted in every step of the production process. Our solution will bring food production into homes through an efficient hydroponic system. By bringing food production to households, we can eliminate waste produced in the process and can encourage consumers to only plant and harvest what they need.

G. Device Test Plan

After the prototype is built and the major features of the project are functioning, the prototype must be tested. The team will highlight a variety of tests to ensure that the Deployable Prototype meets the measurable metrics. These tests are critical in determining the status of the prototype and ensuring that any possible improvements can be made with the knowledge acquired from the results of each test. A timeline and test plan will be established to allow the team to stay on track to meet the requirements outlined by the punch list and measurable metrics of every feature.

H. Market Review

Getting the product ready for the market is an essential part of the prototype process. Here the team developed a plan based on market research to get the product into the customer's hands. For this we needed to understand the environment that the product would compete in, which would allow us to make this strategic plan that put our prototype through the various reviews to empower our product to compete in market sector that it occupied.

I. Testing Results

For one of the final parts of the project itself the team followed the device test plan that was laid out earlier in the project timeline. Several tests were conducted so that the prototype itself met the measurable metrics that were created at the beginning of the project. After these tests were completed, the team was able to share the results of testing and determine whether each feature met these metrics being given a pass or a fail.

J. End of Project Documentation

For the last and final assignment, we will be turning in all our documentation we have done for the past two semesters. We will be sure to proofread and check the formatting. If deficiencies are found, we will fix them before submission and publication on the University's webpage.

II. SOCIETAL PROBLEM

A. First Semester Interpretation of the Societal Problem

1) Overview of Food Waste

Food waste has been a problem for a long time, and it continues to affect not only United States but also the whole world. Globally, 1/3 of produced food is wasted and 45% of wasted food are fruits and vegetable [1][7]. According to the Natural Resource Defense Council (NRDC), 40% of America's food from farm to fork end up in landfills [2]. In 2015, the U.S. Department of Agriculture (USDA) and the U.S. Environmental Protection Agency (EPA) set a national goal to cut food waste by 50 percent by 2030, aligning with similar targets set by United Nations [2]. Food waste should not be ignored anymore, as this is an issue with global consequences.

2) Impact of Food Waste

Food waste causes problems to the environment and to consumers. Food waste negatively impacts the environment, or ecosystem and our climate [8]. Resources such as water and land are wasted when food is wasted. Our climate is impacted by the process of food production: from energy used growing the plants to carbon emission produced when transporting them. The climate is greatly impacted by the gasses released when food waste ends up in landfills. Below are details on some of the impacts of food waste:

a) Natural Resources are wasted

Food and agriculture consume up to 16 percent of U.S. energy, almost half of all U.S. land and account for 67 percent of the nation’s freshwater use. When food is wasted, NRDC reported that about one-fifth of these resources are also wasted. For more detail, food production accounts for 80% of the country's freshwater consumption. The waste of food translates to 25% of our fresh water being wasted.

b) Contribution to Climate Change

Food waste is a significant contributor to climate change. Food waste accounts for at least 2.6 % of all U.S. greenhouse gas emissions. Most of those greenhouse gases are released by growing the food, though a portion is released as methane as food rot in landfills. According to Environmental Protection Agency (EPA), food waste contributes to 22% of municipal solid waste and is the number one contributor to landfills as seen on Figure 1 below [3].

3) Effects on Consumer

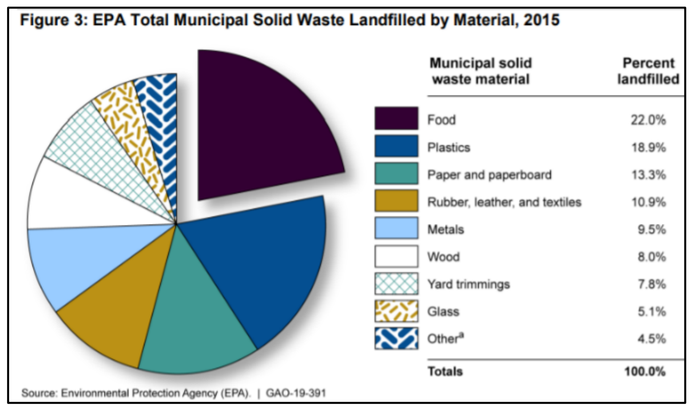


Figure 1: Municipal Solid Waste Statistics Reported by EPA; Image from United States Government Accountability Office (GAO) 2019 Report "FOOD LOSS AND WASTE: Building on Existing Federal Efforts Could Help to Achieve National Reduction Goal" [3]

As our environment is affected by food waste, our society also experience the impact of food waste in our daily lives. When we waste food, we waste our time and money that are used to acquire the food. In fact, a household of four loses on average $1800 per year on food that is wasted [2].

1. Where Food is Wasted

Food loss happens even in the beginning of production until the food ends up in the household. I wanted to suggest a solution that households can participate in because as shown in Figure 2 below, households are the greatest contributor in share of food waste.

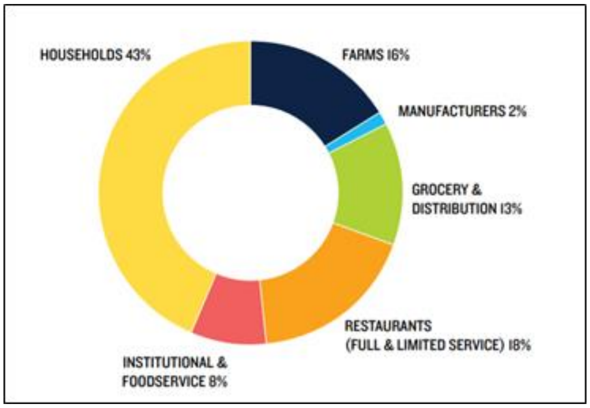


Figure 2: Breakdown of food waste by supply stage for 2015 from ReFED report (Rethink Food Waste Through Economics and Data); photo from NRDC Report [2]

2. *Proposed Solution to Lessen Food Waste*

There are many ways to reduce food waste. US Environmental Protection Agency (EPA) released a tiered system called "Food Recovery Hierarchy" that lists out the most preferable method in tackling food waste. Figure 3 shows that the priority in this system is to simply reduce the source [3]. If we produce and buy only what we need, there will be less waste. We agree with EPA that food reduction should be prioritized to solve food waste problem. Since most of the waste comes from households, and most of the wasted products are fruits and vegetables, we wanted to build a solution around these two factors. We are suggesting that persuading households to plant their own crop can lead to reduction of food waste. When people produce the goods right at their home, overproduction of crops can be lessened, and the food production chain is shortened [5]. Consumers can also control how much they want to produce and tailor the number of crops to their needs. We now face a new obstacle: gardening is not possible for everyone. Some reasons include small spaces and climate change. Some may also reason out that they do not know anything about gardening, so they rely on buying food at supermarkets.

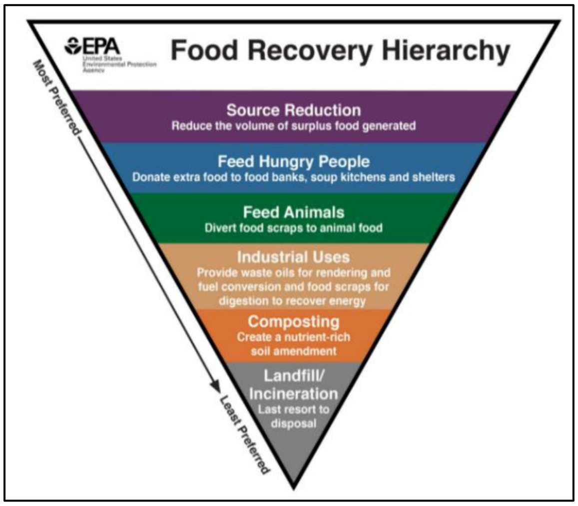


Figure 3: This inverted pyramid shows the different strategies to manage food waste from the most preferred ways to least. The hierarchy system provides the action that other organizations should prioritize [4]. Photo and system created by EPA.

B. Second Semester Improved Interpretation of the Societal Problem.

Food waste is a problem that needs to be addressed because it is wasteful on our resources. Resources like land and water are limited. This means that if we do not act on conserving food we may run out of water and land trying to feed everyone. In addition to wasting resources food waste creates pollution to our environment.

Food waste creates two types of pollution, greenhouse gasses and land. Decomposing food causes greenhouse gasses like methane and carbon dioxide. Landfills also pollute our land and thereby water supply from leachate, or toxic liquids leaching into land and water. The largest contributor to landfills is food waste and the largest contributor to food waste is households. A solution for this problem is to stop household food waste.

III. DESIGN IDEA

A. How does the design address the societal problem?

To stop food waste, the production of food must be addressed, and changes should be implemented in every stage of the food process [4]. Research shows that domestic households are greatest contributor to food waste. A large percentage of food waste are vegetables and fruits. We came to conclusion that an effective solution is changing the way domestic households are involved in the food waste process. When households are involved in growing or producing their own food, they can control the amount of food they eat, which can lead to reduction of food waste. Shortening the food production chain to eliminate waste.

Our team has decided that a solution to addressing this societal problem is to have an autonomous smart garden that consumers can operate within their homes. By having an autonomous garden system, food production will be right in customer's reach. Consumers can have control over the garden's environment, which will enable for year-round yield of products. Hydroponic system will be a practical gardening solution to use because it uses less water, emits less greenhouse gasses and is less wasteful than sourcing food from grocery stores.

We would like to build an autonomous hydroponic system that would require minimal user interaction. We will incorporate what we have learned from our engineering classes and explore using artificial intelligence (AI). The setup would be inside a grow tent or closed container so it can fit in small spaces. For the design, we would utilize sensors to collect environmental data including temperature, humidity, water level, the amount of light, nutrients, and other factors that the plants ideally need. We would use the feedback from the system so we can maintain or improve the environment of the plant so that the system can be automated to the point where there is little to no user interaction. AI would be compensation for some sensors and aid in monitoring the growth. One example is using camera to monitor the color of the leaves of the plant. For test purposes, we will pick a vegetable that can grow easily so we compare data when variables are changed. One of our goals is to have a growth cycle (from seedling to harvestable size) to prove that the system works. When the system becomes successful, this will encourage the user to grow their own vegetable and eventually lessen the food they waste.

There are a couple of alternative approaches to this problem. There is a possibility for a sorting waste or finding trash bot that removes food waste, however this doesn't lead to less food waste it just gets rid of the food that is wasted. Most designs or solutions that involve other stages in food waste process, such as the production of food on farms or the distribution of the food through stores, need approval by governing bodies to develop products. Lastly, other hydroponics solutions seem very effective in addressing the societal problem, but do not consider the obstacles that come with not providing feedback on the system and just monitoring sensors. Our solution is unique because it takes an out of the box path of attacking the societal problem by the root of the problem, households. We are enables users to grow food they need when they need it, thus advocating for the effort to reduce their own food waste. Also, the design idea is distinctive in that we are not only using sensors to monitor level in the system, but we are using this data as feedback which will allow the system to adjust to the desired criteria with little to no human intervention. What sets our group apart is monitoring the growth of the system, adjusting the pH of the system, the deficiency of nutrients via the programmed AI camera.

TABLE 1.
Punch List [11]

Topic	**Measurable Metric**
Water Level User will be alerted if water level is low.	When water reservoir is below a certain threshold, user will be alerted that system needs to be topped off.
Temperature User will be alerted if temperature reaches values that are non-optimal or harmful for plant growth.	The temperature will be monitored. This is for future expansion if we want to add venting for this unit to be placed outside.
pH Optimum pH for hydroponics is 5.5-6.5. Our system will maintain that acidic environment plants need for growth and nutrient absorption.	Optimum pH for hydroponics is 5.5-6.5. We plan to monitor the pH to the upper limit. If it is higher than the upper limit, we will be able to control a peristaltic pump to add pH down.
Coloration of plant leaves AI will track color of leaves and compare to healthy colors.	We will be able to track the coloration of the plants leaves by camera and raspberry pi to alert for possible nutrient deficiency.
Electrical conductivity After nutrients are added, water will be more conductive. If the electrical conductivity in water drops below a certain threshold, the system will be able to control a peristaltic pump to add fertilizers.	Nutrients present in a system will cause the water to be conductive. By measuring this using, a sensor, the system will be aware when nutrients are added and the lack thereof. Typical EC value is 1.2, or in ppm that is 800-1200.
Light System will be aware if correct amount of light is present. The system will monitor how much natural light the plants are getting and will add artificial lighting to make up for what the plant needs daily. System will be able to tell ambient light outside of system and inside of system.	System will turn off artificial lighting if ambient lighting is sufficient and conversely if ambient lighting is lacking, system will turn on the lights. For example, if we have 6 hours of strong natural light, we will supplement the system with an additional 4 hours of artificial lighting. If the system receives little/no ambient light system will turn on light for 10 hours.

B. *Design Components*

1) *Hardware*

One of the first component we decided to use was the STM32F030R8T6. We went with this microcontroller because the plethora of connections available. This includes analog and digital input/output ports, multiple analog to digital converters, and communication interfaces of I^2C, UART, and Serial Peripheral Interface. Some of the added bonuses are the Arm 32-bit processor which is powerful but also energy efficient, the flexibility of the board for Arduino Uno connectivity, and the option to use STM32CubeIDE or the Arduino IDE. This will act as the driving force for adjusting system parameters based on the feedback we receive from our sensors.

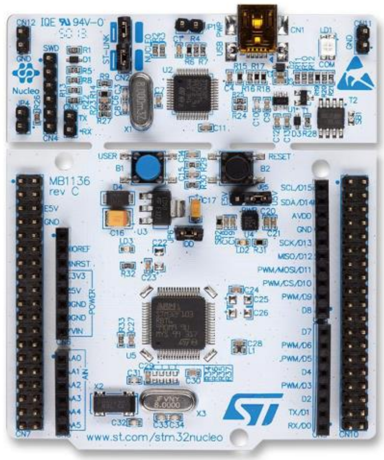


Figure 4: STM32F030R8T6 (64 pin) [15]

The next component we decided on was the Raspberry Pi Zero W. We chose this because we know that we will have to send alerts to the user while receiving input from either sensors or the microcontroller, which will be made easier by using this single board computer. There was the possibility to use one of the other boards in the Raspberry Pi lineup such as the Pi, Pi2, Pi3, or Pi4, however we chose the Pi Zero W based on the small formfactor and low power consumption. One of the main purposes of using this board was the ability to use and modify open-source software to control a camera to recognize plant nutrient deficiencies based on the coloration of the leaves.

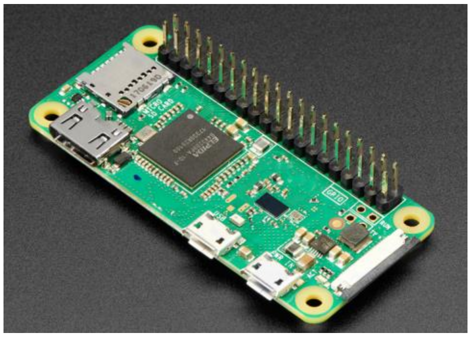


Figure 5: Raspberry Pi Zero W [13]

As referenced before a camera is needed for this design and the camera for this hydroponics system was determined to be the Raspberry Pi Camera Module 2. The main reason for this choice was both the easy connect and interface with the Raspberry Pi as well as the price and value the camera presented. For detecting the coloration of the leaves most cameras would do because we will be mainly relying on software, and the 8 megapixels that the camera boasts will give our system clarity it needs for this function. Along with monitoring the plant leaves the camera also supports 1080p 30 frames per second or 720p with 60 frames per second which allows us to create a timelapse of the system to see how much the plant has grown. Some additional used for this camera were the camera cable attachment for the Pi zero, and a case to protect the camera module.

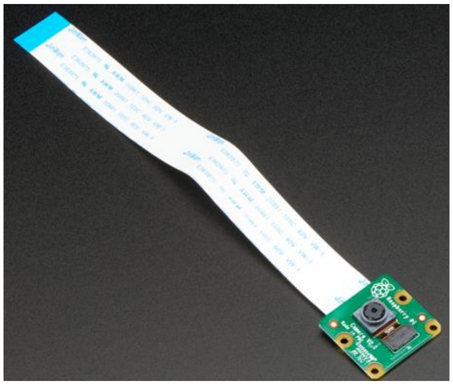


Figure 6: Raspberry Pi Camera Module 2 [13]

Another piece of hardware is an Ultrasonic Ranging Module that is used to determine the distances from objects to the sensor. We will be using this as a water level sensor in the hydroponics system to determine the amount of water we have left in our tank for the plants. After doing research on alternative options for a water level sensor we decided to use this part for the ease of integration with our microcontroller as well as not having to submerge the sensor which could become costly if the part starts malfunctioning due to the movement of water.

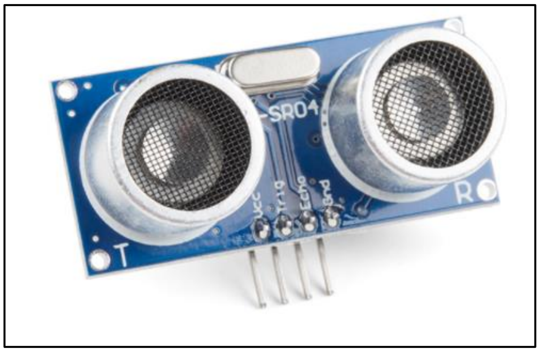


Figure 7: HC-SR04 Ultrasonic Module Distance Sensor; photo from Adafruit, a product manufacturer and distributor *[10]*

We decided to go with the Gravity pH sensor because it is compatible with our Arduino board. The sensor isn't the most expensive, so it doesn't come with calibration liquids that specify certain pH. We have liquid pH test kits that we can use to calibrate this system ourselves. We can test water at various acidities and calibrate the sensor. Using this sensor and the peristaltic pump we can adjust the pH as needed for the specific plants we are trying to grow.

Figure 8: Gravity analog pH sensor [14]

We decided to go with the Gravity Electrical conductivity sensor because it is compatible with our Arduino. The sensor isn't the most expensive. it does not come with calibration liquids that specify certain EC. We don't think we need that because for our project we can dose the fertilizer per
Some of the last pieces of hardware we used were a BH1750 Light Sensor to monitor and

manufacturer recommendations and measure the EC with this sensor. We will then have a baseline for how much nutrients are the maximum for the system. Paring this with the peristaltic pump we can add fertilizer to the system as needed.

Figure 9: Gravity EC sensor [16]

We decided to go with this dosing pump because it's capable of lifting our liquids into our hydroponic system. This pump is not submersed into the liquid itself, just the tubes are, and the motor will not be exposed to harsh chemicals. We thought about doing a gravity fed device that is powered via solenoid but decided against that because if the solenoid failed it would dump the whole bottle of chemicals into the hydroponic system. This would not only be wasteful but dangerous.

Figure 10: Peristaltic Dosing Pump [13]

control the ambient lighting of our system monitor any incoming light outside of the system.

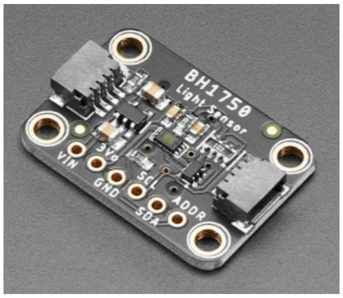


Figure 11: BH1750 Light Sensor [13]

We are also including and Temperature and Humidity Sensor to observe the temperature and humidity of the hydroponics system. These parts were chosen to give us a general understanding of the environment that the plants are in so that adjustments and refinements of the location of the plants can be made.

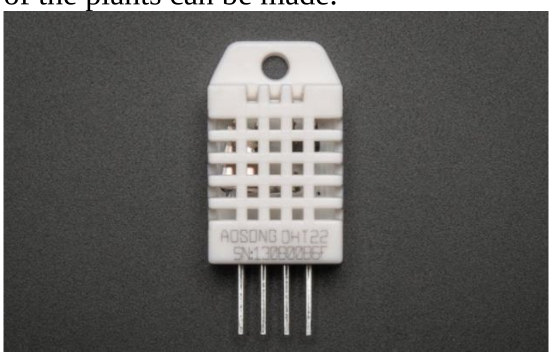


Figure 12: Temperature and Humidity Sensor [13]

2) *Software*

The software for this design idea was alluded to before in the hardware section. For the microcontroller we are using the STM32CUBE IDE in possible combination with the Arduino IDE to monitor and adjust the hydroponic system to meet our defined guidelines for pH, fertilizer (in form of electrical conductivity), an ambient lighting. Both IDEs use the C programming language to communicate with the microcontroller. The last pieces of software we will be using is for the Raspberry Pi one of which are the operating system that the Pi is ran on which is Linux, python to manipulate the information received from the sensors to alert the user accordingly, and source code from the OpenCV project which we will edit to fit the needs of our nutrient deficiency monitoring camera.

IV. FUNDING

The funding will be from the group and divided evenly amongst the team. Everyone will have an equal share of the cost.

TABLE 2.
Funding [11]

Part	*Unit price*	*Quantity*	*Price*
Raspberry Pi Camera	*30*	*1*	*30*
Raspberry Pi Zero	*14*	*1*	*14*
Camera Connector	*6*	*1*	*6*
Camera Case	*3*	*1*	*3*
Ultrasonic Ranging Module	*4*	*1*	*4*
Light Sensor	*4.4*	*1*	*4.4*
pH Sensor	*57*	*1*	*57*
EC Sensor	*36*	*1*	*36*
Peristaltic Pump x3	*11*	*3*	*33*
Temp Humidity Sensor x2	*4*	*2*	*8*
grow bed	*17*	*1*	*17*
materials for frame	*100*	*1*	*100*
Light	*50*	*1*	*50*
Subtotal:			*362.40*
Sales tax			*30.80*
Shipping			*0*
Total:			*393.20*

V. WORK BREAKDOWN STRUCTURE

A. Hydroponic System Features and Tasks Assignments

To fulfill the feature list of requirements outlined in the design idea there was a set of assignments that the team needed to complete. Below are those features that our system will have and the tasks it took to achieve each. Also laid out is the specific amount of time that the tasks will task and who was assigned to each task.

1) Water Level Alert

When water reservoir is below a certain threshold, user will be alerted that the tank needs to be topped off. We will be using the Ultrasonic Ranging Module, which determines the distances from objects to the sensor. We will be using this as a water level sensor in the hydroponics system to determine the amount of water we have left in our tank for the plants. The ultrasonic sensor can be integrated with our microcontroller and does not need to be submerged in water. One challenge for this sensor is that it measures the distance from the first object it sees and if the roots get in the way, the supposedly water level measurement will be inaccurate. For next semester, we will evaluate the accuracy of the sensor and might switch to other submergible sensors. We estimated 22 hours needed for this feature, not including the collection of data which should be throughout both semesters whenever we start a growth cycle of the plant. The following tasks for this feature are assigned to Gedie.

a) Setting up the Ultrasonic Sensor.

This task will take 12 hours. The following are needed to set up ultrasonic sensor: researching and understanding the datasheet, reviewing how STM32 board and pinout configuration work and coding. Part of this task is making sure that the sensor can measure distance from water and not the container. This task is assigned to Gedie.

b) Setting up and data gathering.

This task will take 1 hour. The team will brainstorm beforehand before placing the sensor in the system. We will gather data for the first time and compare if the values are the same as physical measured values. This task is assigned to Gedie.

c) Connecting to Raspberry pi for "alerting the user" feature.

This task is estimated to be done within 2 hours. When the ultrasonic sensor is reading acceptable values, we can now configure raspberry pi to alert the user when certain threshold is met. This task is assigned to Gedie and Stephen.

d) Evaluation of sensor and possibly changing the sensor.

For this task, the team would brainstorm and evaluate together if the ultrasonic sensor is the best for the system. We can opt to use a waterproof sensor later if we run into problems with simple ultrasonic sensor. If the ultrasonic sensor needs to be upgraded, we will have to pick another sensor and integrate that in the system. These steps are estimated to be done in 7 hours and is set for next semester. It is basically repeating step 1 but now we have more experience on what we are looking for. This task will require the effort of the team, but Gedie will lead and generate the code.

2) Temperature

Monitoring temperature is the first step to controlling temperature. While it is not our goal to control temperature this semester, we want to take the first step to monitor it. Temperature can have severe effects on the plants that will grow. While there are different ranges of temperature where plants will thrive, monitoring the temperature is required for each kind of plant. This setup is estimated to take 20 hours. This task was assigned to Joel.

a) Connect temperature sensor to the MCU (Micro-controller unit).

This involves knowing the correct pinout of the temperature sensor itself, which means looking up all the information in the corresponding data sheet. Knowing the correct pinout on the MCU is also required as not all pins serve the same purpose. Each pin on the MCU must also be configured. The MCU we are using is an STM32 model. We are also using an STM32 IDE to assist us in writing our code. When we configure the pins on the MCU, we can automatically generate the code necessary to drive those pins.

b) Debug any issues from step 1.

There are many nuances involved with connecting a sensor to the MCU. Especially a sensor you haven't worked with before and uses a different communication protocol. You can describe this process as trial and error. This step will most likely be the most time consuming.

c) Convert data retrieved from temp sensor into readable data.

Once there is actual raw data being received, some kind of manipulation of that data must be applied for it to be readable. What that manipulation looks like can vary, a few examples of what it could look like is a simple algebraic manipulation, or a more complex processing of the actual bits of data being received.

3) pH Control

Most hydroponic plants require a pH of 5.5 – 6.5. According to our local municipality, California American Water's 2020 annual water quality report, the water coming out of our tap has a pH of 7.4-8.1 with an average detected value of 7.8. We know that plants cannot absorb nutrients if the pH is too high so if we want to have healthy plants or any growth at all, we need to be able to measure the pH and add an acid as necessary. The following tasks are assigned to Victor and expected to take 30 hours total.

a) Setting up pH Sensor to be able to read pH from water.

This task requires setting up a pH Sensor using an ADC on the STM microcontroller to be able to read the pH. This task will be done concurrently with setting up the EC sensor because multi-channeling will be required for the ADC. This process should take 15 hours.

b) Being able to lower the pH as necessary based off readings from the sensor.

The microcontroller will switch a relay to turn on a 9V peristaltic pump to add acid to the water until ideal conditions are reached. This process will require calibrating the pH sensor and the peristaltic pump and the acid's strength to be able to lower the pH of our system. This process should take 15 hours.

4) Detecting Coloration of Hydroponic Plant Leaves

The coloration of the plant leaves is one of the tasks that allows the system to find the deficiencies in plant leaves. This comes in the form of nitrogen, phosphorus, and potassium deficiencies in the leaves of the plant. The Raspberry Pi will take pictures to monitor the system and through Python and the OpenCV project the camera will suggest as to what deficiency the system is experiencing so the user can calibrate as needed. Stephen will be working on this section of the project, with little help from teammates to configure or set up the Pi Zero with the camera. This task should take about 65 hours to complete and is assigned to Stephen.

a) Setting up the Raspberry Pi Zero and Camera.

This task is the basis of the main task in finding the coloration of the plant leaves. This involves installing the Raspbian OS on the Raspberry Pi Zero and making sure that the camera works on the system and can be controlled through software. The last part of this task would be adding it to the frame of the hydroponics system itself. Because this task involved installing a complete operating system and making sure that the system is up to date, the estimation of this task is about 10 hours to fully complete.

b) Configuring the Color Range of Deficiencies.

After the Raspberry Pi Zero is set up and the operating system is working with the camera, the next task to find the color ranges of the plant leaves that will be done by using Python scripts that incorporate the OpenCV project. Here the detection for which color values and ranges will be continuously tested and configured until the system can accurately tell what color range relates to deficiency that is in the system if any. This task will task approximately 25 hours to complete.

c) Finding the Deficiencies in Leaves.

The final part of this task is to find the deficiencies in the plants of the hydroponics system. After finding the color ranges that relate to the deficiencies the system will then analyze the image to detect for how many pixels match that color range to tell the deficiency. There must be a determined threshold for the number of pixels that signify a deficiency. This means that there is going to be several tests that must be conducted in the system to estimate the right number pixels that allow for accurate thresholds. This task should task take about 30 hours.

5) Electrical conductivity

Electrical conductivity measures the amounts of salts in the water by testing how conductive it is. Pure water has no electrical conductivity and water with more salts in it is more conductive. By using this measurement, we can tell how much fertilizer is in our system. If the water is too lean, we will add fertilizer to the system to make it ideal for plant growth per the fertilizer's recommended dosage. The following tasks are assigned to Victor and is anticipated to take 30 hours.

a) Setting up EC Sensor to be able to read EC from water.

This task requires setting up an EC Sensor using an ADC on the STM microcontroller to be able to read the electrical conductivity. This task will be done concurrently with setting up the pH sensor because multi-channeling will be required for the ADC. This process should take 15 hours.

b) Being able to increase the EC as necessary based off readings from the sensor.

The microcontroller will be able to turn on a peristaltic pump to add nutrients to the water until ideal conditions are reached. This process will require testing and calibration of the sensor to be able to input the right amount of fertilizer. This process should take 15 hours.

6) Light

Keeping track of the amount of light that the plants are receiving is a key task to ensure that the plants receive adequate light, either from natural ambient light or artificial lighting. While artificial lighting will always be available to the plants, using natural light will be more efficient in saving energy. We need to be aware when there is ambient light present. If we do not detect ambient light, then we know artificial light must be provided. With the light sensor, we will be able to retrieve values that are associated with the amount of light detected in the environment. To get any kind of information from the light sensor, we must connect it to an MCU (Micro-controller unit). The information that will be received are raw values that aren't immediately readable. We must additionally process these until we can convert them into values that we can read. This setup is estimated to take 20 hours and is assigned to Joel.

a) Connect light sensor to MCU (STM32).

As mentioned earlier with the temperature sensor, this step involves looking at data sheets of both the sensor, and the STM32 to know what the pinouts of each device are. Not all pins serve the same function and because of that, if you use a wrong pin and apply a high enough voltage, you can damage the electronic components such as the IC's or capacitors. So, this first step requires a lot of reading and understanding of how the sensor and MCU work.

b) Debug any issues that will arise with step number 1.

Again, this step will probably take the most time. Step 1 is rarely a straightforward step. There are many nuances involved with connecting a sensor to the MCU. Especially a sensor you haven't worked with before and that uses a different communication protocol. You can describe this process as trial and error.

c) Convert to readable data.

Converting the raw data into a readable format can vary from each sensor. Once there is actual raw data being received, some kind of manipulation of that data must be applied for it to be readable. What that manipulation looks like can vary, a few examples of what it could look like is a simple algebraic manipulation, or a more complex processing of the actual bits of data being received.

B. Fall Assignments

There were several assignments for the first part of Senior Design. All these assignments are worked on and completed by the whole team. The purpose of these assignments was to prepare the teams for the End of Project documentation of the entire project as well as to fulfill requirements of Senior Design.

1) Assignment 1 - Individual Problem Statement

The first of those assignments was the 'Assignment 1 - Individual Problem Statement.' This assignment is designed to start the brainstorming of project ideas that the team will potentially use for their senior project. Here each student was tasked with finding a societal problem that they felt was important that could be solved through a project. With supporting evidence from charts and statistics as well as references from creditable peer-reviewed articles.

2) Assignment 2 - Team Problem Statement

Next was the 'Assignment 2 – Team Problem Statement.' The purpose of this assignment was to create a discussion amongst the group as to what individual assignment interested the team more. It was also important to consider the skillset of the entire team and if they would be able to solve the societal problem. The other item to consider is that the team could design a whole project around this chosen societal problem. The format for this assignment was outlined in the previous individual assignment.

3) Assignment 3 - Design Idea Contract

After deciding on the societal problem, the team now moves on to designing the solution. 'Assignment 3 – Design Idea Contract' was where the team could get creative. Here the team needed to detail the aspects of how their project was supposed to work, the required software, all the way down to the general components that they would be using. The purpose of the assignment was to connect the societal problem to a solution that the team committed to with a full feature list. The assignment was then reviewed by the corresponding instructor and treated as a contract on what the team would deliver at the end of senior design.

4) Assignment 4 - Work Breakdown Structure

The next deliverable was 'Assignment 4 – Work Breakdown Structure.' Following the detail of the full feature list that the team delivers at the end of senior project is a description on how this will get done. In this assignment the feature list gets broken down into several tasks that will fulfill the design idea contract guidelines. Here the team laid out the tasks throughout of all senior design, including who was doing what task, and how long each task would take roughly to complete. Completing this allows the team to move on to creating a timeline for when these tasks will be completed.

5) Assignment 5 - Project Timeline

As mentioned before the team needed to create a timeline of when the task laid out in the work breakdown structure would be completed. This came in 'Assignment 5 – Project Timeline' where the team created this time sequence. For this assignment the team created a Gant chart and PERT diagram that detailed the packages of tasks that each team will complete, what time these would be completed, and any significant milestones along the way. This assignment encompasses the totality of all deliverables from the start of senior design to the end in the following semester.

6) Assignment 6 - Risk Assessment Report

'Assignment 6 – Risk Assessment Report' is the next assignment where the team continued to look at future of the project. The purpose of this task was for the team to identify possible risks and events that might lead to the project not being completed on time. After identifying these risks, the team then laid out strategies that the team might take to overcome these events. The last part of the assignment was to create a risk assessment chart for what the team deemed as the most important to overcome by the end of senior design.

7) Assignment 7 - Laboratory Prototype Technical Evaluation

Getting close to the end of the first part of senior design the next deliverable was 'Assignment 7 - Laboratory Prototype Technical Evaluation.' This assignment was to showcase what the team has been working on the entire semester in the form of a prototype. Considering the feature list described in the Design Idea Contract, the team presents their protype to the instructor to display the progress the team has made thus far in senior design. The prototype included the integration of all the software and hardware required in the project.

8) Assignment 8 - Public Laboratory Prototype Presentation

The last assignment for the first part of senior design was 'Assignment 8 – Public Laboratory Prototype Presentation.' After displaying the progress of the team's prototype to the instructor the team was then tasked with presenting this publicly. This included a short video summary to highlight the feature set of the project, a large-scale poster, handout for the audience, and the actual presentation of the team. The purpose of the assignment was to demonstrate in a live format how the prototype works, fulfilling the team's feature set.

C. Spring Assignments

1) Assignment 1 - Problem Statement Revision, Design Idea Review, Timeline update

This assignment is to revise the first semester's problem statement. We should have gained extensive knowledge of the topic. We will show how we understand the problem and address the solution to our problem statement. If any changes are needed, we will need to submit a change order request which will need instructor approval.

2) Assignment 2 - Device Test Plan

We will need to develop a test plan that proves our prototype works as expected. The test site will be on campus at Riverside Hall 3001. We will need to show that it works in different factors and if it is unable to, we will need to make improvements to the project should all be working at the time of presentation. The presentation will be held during lab period and should last within the prototype.

3) Assignment 3 - Market Review Report and Presentation

We will be required to write a written report for the marketability forecast and present a short overview of the design. Consulting business majors or other experts is allowed. The market review should identify the consumer/clients of the product.

4) Assignment 4 - Feature presentation and report

The feature report is an individual assignment that is not in the end of project report. The individual report should show our technical features of the project and our specific contribution to the features. We can discuss how this project integrates with other members of the group's features. This report requires illustrations and must follow IEEE format. A six-minute presentation including visual aids is required for this assignment.

5)Assignment 5 - Testing Results Report

This is the results of our device test plan which should be included in the End of Project report. It should include test results and details of how they impact the project.

6) Assignment 6 - Engineering Ethics quiz

Each team member will take the quiz on engineering ethics.

7) Assignment 7 - Deployable Prototype Evaluation

For this assignment, we will demonstrate the complete deployable prototype. This means the features of the hydroponic system should be complete. The hardware and software of
30 minutes. One requirement for this assignment is that all team members should speak for at least two minutes.

8) Assignment 8 - End of Project Documentation

This assignment is the end of the documentation which means all aspects of the senior project are compiled. This assignment requires completion of the End of Project Report in pdf file, team picture and end of project video.

9) Assignment 9 – Public Deployable Prototype Presentation

For this assignment, we will present our final product in a Senior Design Showcase event. This event is tentatively virtual, we will receive more instructions as the semester progresses. We will give an overview of our project and demonstrate the functionality of our system.

VI. PROJECT MILESTONES AND TIMELINE

A. "Engineering Story"

The first assignment for us as a team was to develop individual problem statements. Our individual problem statements had a requirement that they had to solve a societal problem. We had different problems that varied from food waste, clean energy efficiency, waste management, and employee shortages due to coronavirus. We had solutions such as an autonomous hydroponic system that can detect diseases, a solar panel cleaning drone, a trash sorting robotic arm, and a robot food server. Ultimately our group decided to go with the hydroponic system because it best fit our skillset. We all have some gardening experience and some of us even had hydroponic experience.

Our problem we are addressing is food waste. We realize that food waste is a global problem and that throughout the food distribution chain there is food waste in every step of the process. Our solution would be bringing the food production into consumer's homes. This would shorten the food production chain and reduce food waste. The most important aspect of this group is that we automate everything. We want lighting to be automated to be able to augment natural sunlight with artificial lighting when the system does not receive enough light. We want the system to adjust the water conditions to input enough fertilizer and lower the pH to ideal conditions. The system will also alert the user that the water level is low alerting the user to top it off. The end goal is that the user only needs to plant the seeds and add water to be able to enjoy all the vegetables without all the labor. A problem we see is that maybe not everyone has a green thumb and that plants may get sick. We will be implementing a camera system connected to Raspberry Pi that will use machine vision to identify diseases.

This project required a lot of brainstorming. As a team we got together to identify problems and solutions. Collectively we decided on what grow bed will we use, how the light will be mounted to the frame and anything else we decided to add to the system. We started parts research and decided to go with median priced components. We did not want to go too expensive nor too cheap and we figured we can calibrate the sensors ourselves to be able to replicate more expensive components. This took some more time and programming on our side but in the end, we should be able to meet our goal.

After we have all the sensors working, we will need to fit them into our frame. By this point we have a "deployable prototype". We will start a growth cycle of lettuce and gather data. We will make note of all the fine details and be able to re-evaluate the project for improvement. During our re-evaluation we can see what features need to add to the parts list as well as refine existing features and parts. Ideally a second growth cycle can be started about this time. We will again gather data and compare it to our first growth cycle. After a few growth cycles and re-evaluation, we should have a finished prototype by the end of the Spring 2022 semester.

B. Milestones

In addition to Gantt Charts and PERT diagram seen in Appendix E, we also summarized our major milestones in Table 3 below. The project milestones are identified as objective or goal of the small tasks and will keep us in track for the completion of the project.

TABLE 3.
Milestone [11]

Team Problem Statement Established	September 2021
Design Idea	September 2021
Set Contract/Parameters	September 2021
Build frame	October 2021
Start of first grow cycle	October 2021
Integrate sensors to the system	November 2021
Prototype Progress Review (Presentation in person)	November 2021
First Harvest	December 2021
Laboratory Prototype Presentation (Presentation in person - tentative)	Future date: Dec 10
Assessment of First semester prototype	December 2021
Refine Components	January 2022
Integration of changes and new sensors	March 2022
Public Deployable Prototype Presentation	Future Date: 5/13/2022

VII. RISK ASSESSMENT

A. Sensors associated with the feature

Below are the risks associated with the sensors we are using for our system. The sensors are very important because they will make up the features of our project. We talked about mitigation strategies to implement when the risks happen and still have a successful project.

1) Water level sensor

a) Component not working

The probability of the sensor not working is very low. This can happen when we receive a non-working component that could be a manufacturer's fault or shipping damage. When this happens, we need to first confirm if it really is a damaged component or is the wiring is not correct. If we deemed this a manufacturer error, we would have to buy a new sensor. The impact of buying one very late can be catastrophic if there is a shortage in supply. By then, we will evaluate if we need to switch to a different sensor.

b) Water Damage

The ultrasonic sensor is not meant to be in contact with water. To minimize this risk, we would strategically place the sensor into the system where water can be avoided. If this is not possible to prevent, we will explore the possibly of changing sensor next semester and have a waterproof one. We will also explore making a waterproof case and compare the expenses that will incur and go with the cheaper and more effective solution.

c) Inaccurate data

This risk is likely to happen. This can be fixed by calibrating the sensor and modifying our code to adapt to the system. If we still cannot get a viable data, we would need to change our sensor.

2) Temperature sensor

a) Incorrect temperature reading

This could be caused by several reasons. Must troubleshoot software to see if the error is occurring because of inadequate code. If code is not the issue, then it could potentially be a hardware problem in which case best solution would be to replace the sensor itself.

b) No temperature reading

This could be a similar problem to incorrect temperature reading in that there might be some code that is inadequate to process and display temp reading. Could also be a hardware issue and best solution would be to replace the sensor. Replacing sensor is an option because of low cost and how easy it is to procure one.

c) Physical damage to sensor

In this case, best option would be to replace sensor if we are not able to retrieve data accurately from the sensor.

3) pH Control

a) Breaking the probe

This risk can be caused by dropping the pH probe or from something dropping on it. This risk can be mitigated by making sure the probe is clear from any bulky things that may drop on it. A backup plan would be to order another one on amazon which had them in stock at the original time of purchase, about 1 month ago. This probe breaking is low as the glass end is protected by a plastic coating that shields the probe from impact.

b) Inaccuracy of probe

The probe should be calibrated but the frequency we are unsure of. We have pH test kit that uses reagents and a color chart. Using this we can calibrate the sensor periodically, but the frequency of the calibration is unknown and the variance in the probe is also unknown. This risk is high as the sensor is only moderately accurate however the impact is extremely high if it were to be inaccurate it could kill all the plants. This risk is mitigated because the pH probe will be set to the high end of the spectrum plants like their pH to be. That gives us a safety factor of 1 pH. pH being a logarithmic scale means that we must add 10x more pH down to go from 6 to 5.

c) Peristaltic pump malfunction

The peristaltic pump can malfunction, and we unintentionally add too much pH down which may kill the plants. We can mitigate this risk by diluting the acid with some water so it's not as strong. Maybe once we get a feel for how much acid is being used, we will be able to calibrate the system further. We don't want the chemicals above the water level of the reservoir tank as this may cause a siphon to happen where all the chemicals are dumped into the tank even with the tank off. We can prevent this by having the chemicals below water level so that siphoning won't happen. A pump malfunction is very low probability, but the impact is high as it could kill all the plants.

4) Detecting Coloration of Hydroponic Plant Leaves

a) Change in temperature of light causes imprecise readings

This risk is created by changing the temperature of the light we are using to grow in the hydroponics system, which will result in incorrect deficiency detection. Due to this feature being based on coloration of the plant leaves, the only way to mitigate this risk is to maintain the same light temperature in the system that was used in testing.

b) Interfering colors leading to incorrect readings

Relating to the previous issue this risk is also due to the feature built on coloration of the plant leaves. If there are colors that match deficiencies within view of the camera, then the system will detect a false deficiency. The solution for this risk is to position the camera to a point where it can only see the plants in the system, with no outer coloration interference. Another solution is to train the camera to identify the leaves first and then use the coloration detection on each leaf itself

c) System timeout with no readings

This risk can happen if Raspberry Pi stalls when trying to filter the image. This is due to the weak processing power of the Raspberry Pi Zero. The workaround for if this issue is encountered is to optimize the code that is written to the Raspberry Pi Zero. Also, offloading some of the processing of the Raspberry Pi to the microcontroller can help in mitigating this issue. The last option would be to upgrade the Raspberry Pi from a zero to something like a Pi 3 or Pi 4.

5) Electrical conductivity

a) Breaking the probe

This risk can be caused by dropping the EC probe or from something dropping on it. This risk can be mitigated by making sure the probe is clear from any bulky things that may drop on it. A backup plan would be to order another one on amazon which had them in stock at the original time of purchase, about 1 month ago. This risk is high because the probe is made of extremely fragile glass that has no protective covering. The impact of this would be high if we cannot get a replacement in time. However, at the ordering of this part it was available online for quick delivery.

b) Inaccuracy of probe

The probe should be fairly accurate

as there is no way to calibrate it. What may throw off our readings is if some buildup or residue is on the probe head itself. This can be prevented by frequently checking and making sure the probe head is clean. This risk is low as the sensor is very accurate however the impact is extremely high if it were to be inaccurate it could kill all the plants.

c) Peristaltic pump malfunction

The peristaltic pump can malfunction and unintentionally add too much fertilizer which may kill the plants. A siphon may occur if the fertilizers are stored above the tank's water level. We can prevent this by having the chemicals below water level so that siphoning will not happen. A pump malfunction is very low probability, but the impact is high as it could kill all the plants.

6) Light sensor

a) Incorrect light reading

The light and temperature sensors are very similar in that the issues that could potentially arise with them have the same causes. For example, if we are reading an inaccurate light reading, it could be a problem with our code or with the light sensor itself. We'd need to troubleshoot the code to inspect this. If we have ruled out the code as the problem, then we'd need to move on to inspect the physical sensors itself. If this is causing the problem, then we can simply replace it.

b) No light reading

Again, this could be a problem caused by our code or by damaged physical components. If it's our code, we can re-write it to be adequate. If the sensor is damaged, we can replace it because of low cost and easy access to the sensor.

c. Physical damage

Low cost and ease of accessibility makes replacing the sensor the best option. We have extra light sensors ready.

B. Plants not growing or dying

1) Bad Seeds

The seeds might not germinate if we have bad seeds. We can prevent this by making sure we have fresh seeds that are stored in a cool dry place. Proper storage can ensure that we have high germination rates. This risk is very unlikely.

2) Poor Growth

Poor growth can happen by a variety of reasons such as improper light, fertilizer level, length of photo period, temperature, fertilizer, pH, or even not enough carbon in the air. We can mitigate these risks and prevent them from happening by trying to do our best growing plants per the plant's requirements.

Researching what the plant needs and then providing the ideal conditions will ensure us the best chance of success. We will be able to test our plants as get more growth cycles and make some changes to improve results. This risk is about medium as our group is not extremely experienced in hydroponics, but the plants should be forgiving so the impact should be low.

C. General component failure

1) Microcontroller

It is possible that microcontroller that we are using as the main part of the project fails one way or another. The first part of the mitigation is to see how bad the failure is. For any aspects of the microcontroller that are still operational we still use and salvage that part of the controller. Next for any parts that are not working the priority would then be to obtain a replacement for the microcontroller. The team is already prepared for this as we have 4 total units of the MCU, so if one fails, we do not have to order a new microcontroller. As worst-case scenario we can upgrade or use the Raspberry Pi we already have in the system and offload the work of the MCU to the GPIO of the Raspberry Pi.

2) Light

The lighting system that we have for the project in critical to the success of the project. In case our lighting system fails or one of the bulbs dies we have plan in place. As with the MCU we ordered extra lights for the system so if the lighting fails there is already an onsite replacement that could be assembled in less than a day. Due to the lighting being important to a few of our features, if our backup lights fail as well, we are stuck having to ordering replacements online which could set us back a week or two at most.

3) Pump

For the hydroponic system we have pumps to transfer liquid such as fertilizer or pH solution to our main grow tank. We have 3 pumps in place for the system and if any of this fail, we will be handicapped, but can keep the system fully operational. If more than one fails, then the only solution is to again order new pump parts. This creates a setback for the project of about 2 weeks maximum. If there are absolutely no pumps that are unavailable, then a potential solution of using gravity with these liquids would need to be created would also set the project back by an additional 2 weeks.

4) Raspberry Pi/SD card

As with the microcontroller it is entirely possible that the Raspberry Pi that is set up in the system fails. This possess more of an issue however than the microcontroller. We do indeed have a backup Raspberry Pi zero as well as a couple of 3's and 2's that we could use. So, there should be no issue in getting the parts as we have spares however, the issue comes to getting the Pi up and running. For this a failure of the SD card can be included, where a new SD card will need to be plugged into the replacement Raspberry Pi. To fully set up the new Raspberry Pi or SD card the project will be delayed by at most two days.

5) Power Supply

A failure of the power supply is one of the less severe of the components in the system. This is because the project is defined as using AC voltage/current to power the system. If the extension cords that we are using do indeed fail they will simply need to be replaced, and due to the wide availability of this component the delay of the project will be well under a day.

D. Transportation of prototype for presentation

1) Physical damage to parts

During transportation we can have issues with parts moving or shifting and breaking. There could be collisions with other vehicles or bad weather. We can mitigate these risks by and accelerating slower. Accelerating slower for both speeding up and slowing down will mean our parts wont shift as much while in transit. We can also tie these parts down so that they do not move. The individual sensors can be removed and reassembled on campus. Planning is also a way we can prevent damage. If there is bad weather on presentation day, we can bring in the project early so that there will be less chance of damage. Practicing defensive driving will prevent most collisions from occurring. Damage to parts due to transportation may have severe impact on our project as we might not have a spare if it is an expensive component. Also, if we are transporting parts on the day of presentation, we may not be able to get a replacement in time to present. The risk of any one of these happening is low if we drive safe and package everything separately to put together on campus.

E. General

1) *Lettuce seed, fluids, nutrients, and chemicals shortage*

While these risks could have severe impacts on our project, they also have a very low probability as all these items are readily available and in large quantities. If, however, they were to occur, our only option would be to propagate from an existing lettuce plant in one of our team member's garden. As far as the other items, we'd need to do in-depth research online to find vendors that have in stock items that we are looking for.

2) *Component shortage*

In the case of a component shortage, we would need to do in-depth research to find vendors who have stock of our required components. Because of the shortage however, this might cause the price to go up which would be something to consider itself. If we deemed the price too high, or if we could simply not find a vendor, our only option would be to wait, which could cause delays in our project. This can have mild to severe impacts on our project. We do currently have all the required components for our project, so this particular risk doesn't have a high probability this semester.

3) *Leakage, tip over*

The impact of this risk on our project would depend on a few factors. If our platform tips over and no structural damage or component damage is caused, it would have little to no impact on our project. If some damages were caused, then the impact would depend on the level of damage and to what part of our system was damaged. Possible solutions to this risk would involve replacing/repairing damaged components. We are taking preventative measures to this by having a low center of gravity, as well as ensuring our water tank is reinforced with 2x4 wooden planks.

4) *Conflicting schedules*

These can have severe impacts on our project as it takes all the team to build the project. The probability conflicting schedules as a risk is considered low because everyone on the team is highly motivated to successfully build this project as it is a requirement for graduation.

5) *Team health (burnout, flu, injuries)*

Burnout or health related issues are more likely to occur. While we don't really have solutions to those risks, we can prevent this from happening by practicing safe practices, keeping hygiene high, wearing personal protective equipment, and getting flu shots.

F. COVID-19 Restrictions

We started our senior project during a global pandemic. Some of the restrictions are lifted and people can meet indoors if we follow the CDC and county guidelines such as wearing a mask and complying to the maximum occupancy limits. One benefits of the lifted restriction is that we can go on campus and utilize the senior project laboratory. Physically attending class and laboratory is not mandatory and are held online. With many people being vaccinated, the chances of going back to campus for the second semester is high. Still, COVID-19 restrictions pose as risk to the completion of the project because we would need to adapt to the rules and regulations that can change at any time. The impact of those regulations and restrictions are very low but can still put some of the activities we planned on hold. When going on campus is restricted, there will be no in-person presentations. If this occurs, we will need to move our schedules to create a presentation, which may cause conflicts. For now, we can meet in person at one of the team member's homes to integrate the parts and components of our system. We plan to continue to do so for the duration of senior project unless guidelines change.

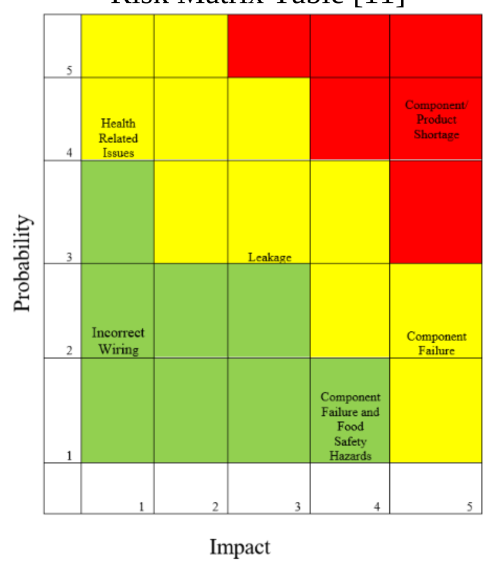
Table 4.

Risk Assessment [11]

Risk	**Impact (Ranked 1-5, 1 as lowest)**	**Probability (Ranked 1-5, 1 as lowest)**
Component Failure	5	2
Damage to Frame (Transportation)	4	1
Component/Product Shortage	5	4
Leakage	3	3
Health Related Issues	1	4
Food Safety Hazards	4	1
Incorrect Wiring	1	2

Table 5.

Risk Matrix Table [11]



VIII. DEPLOYABLE PROTOTYPE STATUS

A. Water Level Alert

For the water level feature, we would like to test the sensor's functionality while it is placed in the sensor and working with the components of the system. From last semester, we tested the sensor's capability of measuring the distance of the water from where the sensor is placed. Ultrasonic sensor HC-SR04 is not commonly used as water level sensor. We tested for issues before placing the sensor in the system.

1) Initial Test for implementation

Before the water level feature was integrated in the system, Gedie made sure that the feature will work independently and successfully. To account for penetration of ultrasonic waves in the water, Gedie has tested the sensor on top of a jar while filling up the water. The real and experimental values only varied for maximum of 0.2-inch differential. Overall, the average difference is about 0.1 inch. The result in Figure 13 shows that the sensor, even while measuring water, is within the accuracy range.

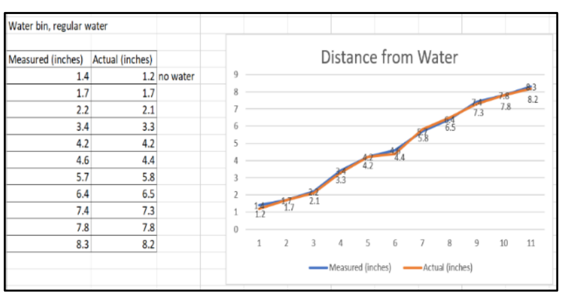


Figure 13: Water level test. Test results and screenshot by Team 8 [11].

The accuracy of the measurement is within the specification of the sensor based on datasheet, so we proceeded to use this sensor in our system. For second semester, we account for different scenarios and gather measurements given by the sensor versus manually measured values. Although the table below only shows three tests for the water level feature, each Test ID consists of a minimum of 10 viable test runs and should have acceptable values that are within accuracy range that is specified in the datasheet. The results will determine if we need to replace the sensor. Another option we can take after gathering data is to incorporate the average difference into the code to show calibration.

2) Troubleshooting

The group agreed to let the system run on its own during winter break. The first phase is complete, we will continue testing for Spring 2022 semester. When it's time for burn-in tests, Gedie found out that the first sensor failed because it was left alone in the system and used in prototype presentations. As a result, rust accumulated around the transducer and connectors. Gedie tested the sensor in different distances and the reading is constant with an average of 470 inches. To troubleshoot, we used other sensors to make sure that the microcontroller or connectors are not the issues.

3) Accuracy testing

After testing the second sensor, the readings are what we expected. To go above and beyond on testing the water level feature, Gedie tested another sensor. The last sensor has passed almost all the tests, so we did not have to calibrate. The test results details are found in Appendix A.

4) Results and status

After gathering data, Gedie concluded that the hardware and software for water level feature passed the critical conditions and burn-in tests. She also tested three sensors so we can calibrate and change the code if needed. Gedie implemented 3 test plans as seen in table below.

Table 6.
Water Level Feature Test Plan [11]

Test ID	Test Description	Expect Results	Actual Results	Pass/Fail (to Measurable metrics)
WaterlevelTest1	Gather and compare values from physically measure distance versus the distance shown in our display when user is topping off water while all the pumps inside the bin are turned off	<= 0.2-inch difference	Within 0.2-inch difference	Pass
WaterlevelTest2	Gather and compare values from physically measure distance versus the distance shown in our display when user is topping off water when pumps and air stone are on	<= 0.2-inch difference	Within 0.2-inch difference	Pass
WaterlevelTest3	Gather and compare values from physically measured distance versus the distance shown in our display when roots are present and possibly covering the line of sight of the ultrasonic sensor	<= 0.2-inch difference	Within 0.2-inch difference	Pass

B. Temperature

An external temperature sensor was placed near the system to provide a control reading to compare the system's temperature sensor. A total of 10 readings were compared and each reading was taken at least 5 mins apart. Out of the 10 measurements, 8 were the same. Two of the readings were within 1 degree of difference with the external temp sensor. Overall, the readings given by the systems temp sensor were well within a 10% range compared to the external sensor. Refer to Appendix A for more result information.

Table 7.
Temperature Test [11]

Test ID	Test Description	Expect Results	Actual Results	Pass/Fail (to Measurable metrics)
Temperature Test 1	Compare system reading of temperature to a more accurate temperature sensor	System reading of temp should be within a (+-)10% range of temp sensor	Compared to the reading of the external sensor, the systems sensor was giving readings well within 10% range.	Pass

C. pH Control

We want to be able to measure how accurate and precise the pH probe is. We can do this by verifying with a liquid pH test kit frequently and possibly recalibrating the probe if necessary. While there are better probes that do not need calibration as often, we were budget constrained to go with a slightly cheaper option. We will test how accurate and precise this probe is and possibly re-evaluate if a different probe is needed. When the pH is above 6.5 pH down should be added until it is below 6.5. There may be slight fluctuations throughout the day and this system would only be able to lower the pH so that it is below the upper limit.

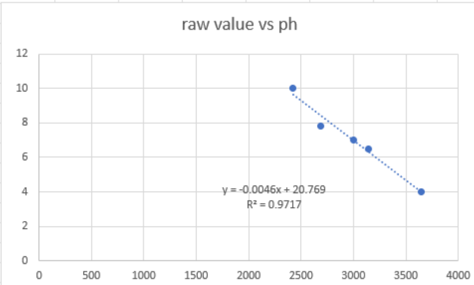
There was a slight fluctuation in the pH probe reading. It read 6.7 instead of 6.5 and pH down was added. This may have lowered the pH to 6.3 but the range is still within limits of 5.5-6.5 because by design we used the upper limit in case there are small fluctuations in the reading.

Table 8.
pH Test [11]

Test ID	Test Description	Expect Results	Actual Results	Pass/Fail (to Measurable metrics)
pH Test 1	The precision of the probe should be checked to make sure it is still working properly. This can be done by checking with a liquid pH tester or by testing with calibration solution.	Various, as the probe may need calibration	The pH probe displayed an inaccurate reading once and resulted in more pH down being added. This was still within 5.5-6.5 range though as we set the limit to 6.5 and it read 6.7.	Passed majority of tests and only failed once with no adverse effects
pH Test 2	pH is higher than threshold of 6.5. System will turn on peristaltic pump to add phosphoric acid to lower pH. When pH is adjusted to optimum levels the pump will stop and the pH will be continuously monitored.	If pH is above 6.5 pH down is added to solution until it is below threshold of 6.5.	pH reading was able to give microcontroller a value to compare and lower the pH to appropriate level.	Pass

TABLE 9.
pH Calibration [11]

raw	ph	raw
3650	4	3650
3140	6.5	3140
3000	7	3000
2690	7.8	2690
2425	10	2425



D. Detecting Coloration of Hydroponic Plant Leaves

For the feature of detecting the coloration of the plant leaves there are a variety of tests that must be implemented to ensure that it meets the measurable metrics. Then main metric that this feature is measured by is the ability to detect a possible deficiency in the plant. This is possible through a series of steps starting with creating the mask or filter to identify the color ranges, accurately finding the deficiency, and lastly alerting the user whether there is or is not a deficiency. Due to this there are 5 main tests that must be conducted. First, the prototype should be able to take a picture and apply a mask to it. Next, the system should be able to identify the 3 deficiencies of Nitrogen, Potassium, and Phosphorus somewhat accurately after the mask or filter is applied to the original image. Lastly, after the system has checked for the deficiencies, it needs to properly alert the user whether any of the deficiencies where detected. If the prototype can achieve a passing mark on these tests, then the feature set meets the measurable metrics.

After conducting numerous tests to configure and fine tweak the feature to meet the measurable metrics that were outlined before, there were a total of 30 tests to find the accuracy of deficiency detection. All these tests included the first and last coloration detection test ID's shown below, where these aspects received a 100% score. Moving on to the three main deficiencies, all of nitrogen, potassium, and phosphorus were tested 10 times each to see the accuracy of detection. Those results are seen below in the table. The reason for testing each feature 10 times was to see if different circumstances affected the feature's ability to work such as different lighting situations. The conclusion from testing was that the algorithm created was accurate with the lighting situation playing a major role in if the deficiency was detected or not. It was concluded that the feature did indeed meet the measurable metrics that were created by the team in an earlier part of the project. To get more of a visual of how these tests were conducted refer to Appendix B.

TABLE 10.
Coloration Detection Feature Test Plan [11]

Test ID	Test Description	Expect Results	Actual Results	Pass/Fail (to Measurable metrics)
Coloration Detection Test1	Conduct and confirm a test that a live image of the prototype was taken, and a mask was created	Up to date image, Mask/Filter populated with no errors	30 successful /30 attempted	Pass
Coloration Detection Test2	Apply the nitrogen mask/filter to the original image to detect for the said deficiency in the plant leaves	New masked image populates with pixels with deficiency present and does not populate with no deficiency present.	8.5 successful/10 attempted	Pass
Coloration Detection Test3	Apply the potassium mask/filter to the original image to detect for the said deficiency in the plant leaves	New masked image populates with pixels with deficiency present and does not populate with no deficiency present.	8 successful/10 attempted	Pass
Coloration Detection Test4	Apply the phosphorus mask/filter to the original image to detect for the said deficiency in the plant leaves	New masked image populates with pixels with deficiency present and does not populate with no deficiency present.	10 successful/10 attempted	Pass
Coloration Detection Test5	After gathering the information from the masks/filters applied to the original image to find the deficiency, the user is alerted of whether there is a deficiency or not.	LCD states any deficiency or states healthy	30 successful /30 attempted	Pass

E. Electrical conductivity

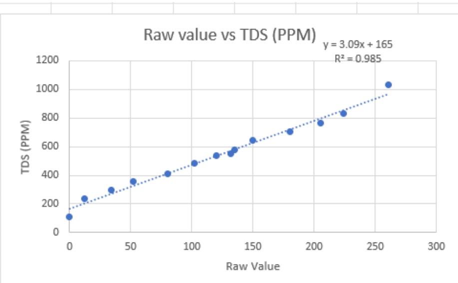
Electrical-Conductivity is the measurement of the salts in the water. Salts make water more conductive and since we are using a salts-based fertilizer, the more fertilizer added the more conductive the water will become. We have calibrated our probe to be able to read EC levels based on the manufacturer's recommended setting for dosing of fertilizer to water.

Table 11.
Electrical-conductivity Test [11]

Test ID	Test Description	Expect Results	Actual Results	Pass/Fail (to Measurable metrics)
Electrical Conductivity Test 1	The precision of the probe should be checked to make sure it is still working properly. This can be done by checking with a TDS meter or by testing with calibration solution. Calibrate as necessary	Various, as the probe may need calibration.	The probe is very precise and there was no observable debris or algae/film buildup on the sensor.	Pass
Electrical Conductivity Test 2	EC is adjusted by two peristaltic pumps pumping two fertilizers to system.	Within values set based on low or high fertilizer level. Either 214 for low or 244 for high.	The probe added fertilizer and increased the EC as intended	Pass

Table 12.
Electrical-conductivity Calibration

RAW	TDS (PPM)
0	111
261	1030
224	831
132	552
120	537
102	484
80	408
52	358
34	297
12	233
135	576
150	641
180	702
205	763



F. Light

The measurable metrics for our light source included an automated on/off function, depending on an arbitrary threshold quantity of lux and being able to provide an adequate amount of light for a period of at least 12 hours. Our light source does in fact meet these metrics.

For the automated on/off function, the flux threshold was toggled between low and high values for a total of 10 times. Each time, the light source responded accordingly by turning on or off depending on the amount of light that was present. For the second test, two counters were added to the code, the first one counted how long the light sensor recorded a lux value that was above 700 lux. That counter was set to reset after 16 hours. A second counter recorded the amount of time elapsed after the first counter reached 16 hours, in effect counting the "rest" period for our light source. This second counter was set to reset after 8 hours for a total of 24 hours (16 on, 8 rest).

For testing purposes, these counters were set to a maximum of 20 seconds to see how the system would react. After some debugging, the system reacted accordingly to the set metrics. The counters were lowered for the sake of performing multiple tests, but then they were raised back to the "16 hours on" and "8 hours rest". Once they were raised to these values, 2 tests were observed to confirm the system responded accordingly to provide more than the metric of 12 hours of supplemental light to the system turned off automatically for the rest of the day to conserve energy this 12-hour timeframe of more than 700 lux was achieved. Refer to Appendix A for more result information.

Table 13.
Light Tests [11]

Test ID	Test Description	Expect Results	Actual Results	Pass/Fail (to Measurable metrics)
Light Test 1 On/Off	Change lux values to higher and lower than the threshold to see the response of the light source	Light source should turn on when the lux value is below the threshold and turn off when lux value is more than 2x the threshold.	Our light source did in fact turn off and on 100% of the time when the system was reading lux values below and over the threshold.	Pass
Light Test 2 Total Time	Measure the total time that the correct amount of lux is present in a day	Correct amount of lux >700 should be directed towards the plants for more than 12 hours.	Our light source does turn on to provide light above 700 lux for 16 hrs which is above our required 12 hours and the light source turns off when this 16hr quota is met.	Pass

G. Humidity

An external humidity sensor was placed near the garden to compare to the system's sensor. Like the light sensor, the readings were given by the system's sensor were well within a 10% range when compared to the external humidity sensor. One important fact to note is that when initially comparing the readings of both the external and the system's sensor, there was a significant difference. This was because the external humidity sensor was inside a house before being brought out to the garden. It took at least 6 hours for the external sensor to acclimate to the system’s environment. Once this was achieved, both sensors were giving similar readings. Refer to Appendix A for more result information.

Table 14.
Humidity Test [11]

Test ID	Test Description	Expect Results	Actual Results	Pass/Fail (to Measurable metrics)
Humidity Test 1	Compare system reading of humidity to a more accurate humidity sensor	System reading of humidity should be within a (+-)10% range of humidity sensor	System humidity sensor gave readings that were within the 10% range of an external humidity sensor.	Pass

IX. MARKETABILITY FORECAST

Our smart hydroponic garden is built to help reduce food waste. Based on our research, food waste is created at every stage of food production and results to gas emission, leachate, and landfills. We would like to shorten the food production chain by moving the production of fruits & vegetables into the household. We picked household as our market target because based on our research, households are the largest contributor to food waste. By bringing the solution into homes, we attack multiple sources of food waste from farm, distribution, retail to households. As households get involved in being part of the solution, we hope that households will create better habits of not wasting food.

Our current situation creates a large market for hydroponic gardens. An unprecedented global pandemic has been around for more than two years, and people have adapted to the new styles of living. Most people stay at home because of lockdowns and work from home situations. During the pandemic, a lot of people started new hobbies. New hobbies are made possible because people started working from home temporarily. One of these hobbies are gardening. According to survey, during early stages of the pandemic, "55% of all U.S. adults spent time outdoors gardening and caring for their lawns" [9]. According to the same article, there 20 million first-time gardeners that started the hobby in 2020 [9]. When people go back to the workplace, which some people are already experiencing, our product will be very appealing. The features of our hydroponic garden will make it possible to leave the plants unattended for long period of time. Even when people are not home because if go on business trips and vacations, the garden is self-sufficient. The user will only make sure the water level is good and the fertilizer bottles are filled, and the rest of the system will automate the fertilizer, turn on the light when necessary and even monitor the health of the plant.

Households who are directly experiencing work from home options are not the only our only market target. Our product is also appealing to individuals who wants to practice healthy lifestyle. When people grow their own food, they are in control with the fertilizer they put and reduce the use or likely eliminate the use of pesticides.

We would also like to target people who do not have gardening skills and would like to start to grow their own plants. Because the garden is automated, the user can grow their own food even without having a green thumb or experience in gardening at all. This will open to possibilities of trying out other plants and being more aware of food that we eat.

To hit our target audience for the product we must enable these users to garden in the easiest way possible. As we mentioned automating this process is what the purpose of the prototype was. To distribute this to customers we need to make the manufacturing and assembly of the product much simpler. For this the product can be broken down into two parts, the building of the frame and assembling of the components. Starting with the frame, this part is simple as the manufacturing process with resemble that of IKEA. There will be precut and predrilled holes for the frame with sticker labels to identify the different parts. We would also include a booklet to show customers how to assemble the frame step by step. This cuts costs for us and the customer, while allowing the customer to either put the product together themselves or hire someone else to do it for cheap.

Next moving on to the electrical components. This becomes extremely hard to manufacture because we cannot allow the end user to assemble these components out of safety and limited experience. This means that we as the sellers of the product must use PCB’s and solder as much of the components as possible to create a compact board for the customer to attach to the frame. We can automate this process by having machines assemble these electronic components to be ready to ship out to the customers for their product.

Lastly are the consumables that the customer needs for the product like fertilizers, seeds, and replacement parts. For fertilizers it would be wise to direct the customer to external sites or stores where they can purchase the parts they need for the product, more than likely including this in the initial purchase of our product. For replacement parts we should be as transparent as possible allowing the customer to buy parts if anything breaks and allow them to assemble it themselves. If they do not feel like doing so, we can offer a service to have the customer ship it back to us and have us repair the broken parts at a cost which will generate some revenue for us.

Our product is not restricted by geographic location and zones which makes it easier to market. Since the hydroponic garden is suited indoor use, crops can grow anywhere, wherever the user is. Our target market for the product is households. This product can be broken down for shipping and set up at the end destination. Ideally the target sell price for this should be around 500 USD including lights, frame, electrical components, starter seeds and fertilizer. As the popularity of hydroponic gardens increases, we can see that the market can be expanded to community centers, dormitories, restaurants and even offices.

We have also conducted a SWOT analysis of both our team and the product. This analysis allows the team to understand the environment that the product competes in, so that well-grounded business decisions can be made. Refer to the figure below on this information.

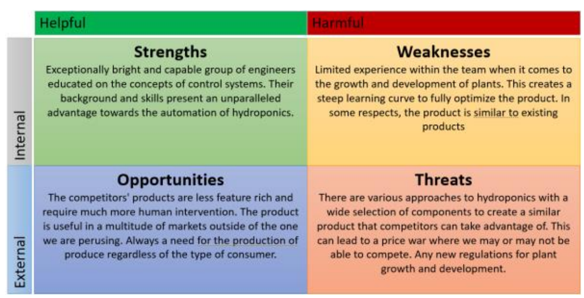


Figure 14: SWOT Matrix [11]

X. CONCLUSION

A. Societal Problem

As a summary we talked about the impact of food waste. Climate is negatively affected and when we waste food, we also waste the resources. This problem is global, and United States plays a major role. Food waste occurs in every stage of the supply chain and domestic households are the greatest contributor. We are tackling this problem by bringing the production of food in the consumer's home which will be done effectively through a hydroponic system.

B. Design Idea

We would build an autonomous hydroponic system that would require minimal user interaction. We will use artificial intelligence (AI) and feedback from the sensors to collect the data, maintain and adjust the environmental factors including temperature, humidity, water level, the amount of light, nutrients, and other components that the plants ideally need. We have a goal of having growth cycles to test our system.

C. Work Breakdown Structure

After deciding on the hydroponics features, we listed assignments and tasks to work on for the two semesters. We estimated the hours to complete the task and the overall hours to complete the feature. We also assigned the tasks to the team members.

D. Project Timeline

There are features on our system that we wish to integrate. These features are broken down into tasks and subtasks to give a step-by-step work breakdown of what will be required to accomplish these features in our system. In the project timeline, we associate a timeframe with these tasks. That timeframe includes when a task begins and what is the expected end date. Most of the timeframes are led by our deadlines which were assigned to us by our instructors. The way we keep track of these timeframes is by using a Gant chart and a PERT chart. These are useful tools that give us visual aids to help keep the project on track to being completed within the allotted time.

E. Risk Assessment

In any project, risk assessment is necessary. For our hydroponic system project, we carefully considered several environmental, technical and safety risks before we proceed into making the prototype. Potential risks, albeit big or small, are discussed among the team and resulted to strategic plans if these risks happen. One big impact risk we talked about is when our sensors do not work when we come together to integrate. The probability of this is very low but has one of the highest impacts to our project. To avoid this, we would need to integrate ahead of demonstration time to make sure we do not waste time by making a major change such as possibly using multiple microcontrollers.

F. Problem Statement Revision

After a full semester's worth of experience, we obtained a clearer understanding of our project as a whole. From this the team revisited our previous problem statement and made the necessary revisions to highlight our improved understanding of the societal problem. Through this knowledge gained we clearly defined our project's objective to create a direct and focused path for the completion of the project itself.

G. Device Test Plan

Every key aspect of this project needs to be tested to ensure it is functioning properly. A test plan is devised to test this project. We will spend the next 8 weeks testing. We will have step by step procedures and criteria on what is a passing or failing test.

H. Market Review

Our product is built on the idea of bringing food production right in consumer's home. While households are our main target market, we can see our product expand to other areas such as community center, dormitories, offices and even classrooms. Right now, the popularity of non-traditional farming such as hydroponic garden is increasing. Because of this demand, we can see our product thriving in the market as we can offer cheaper and effective product.

I. Testing Results

After testing every feature (which includes software and hardware) of our hydroponic system, we were able to gather data to prove that our components are functioning properly. Several test plans were planned beforehand, and we were given ample time to have these burn-in tests implemented. The tests and results are different among features, but overall, calibration was made if needed.

J. End of Project Documentation

This is the final assignment for the project. The purpose of this assignment is to have a cohesive and correctly formatted assignment to turn in. We as a group will read through the documentation and fix any deficiencies we find. The end goal is to have a finished presentable project documentation that is presented to not only future senior designers but potential employers as well.

REFERENCES

[1] Food and Agriculture Organization of the United Nations. (2011). The state of the world's land and water resources for food and agriculture (SOLAW) – Managing systems at risk. Rome and Earthscan, London. [Online]. Available: http://www.fao.org/3/i1688e/i1688e.pdf, [Accessed January 12, 2022].

[2] Dana Gunders, Jonathon Bloom. (2017, August) Wasted: How America is losing up to 40 percent of its food from Farm to Fork to Landfill. Natural Resources Defense Company. New York, New York. [Online]. Available: https://www.nrdc.org/sites/default/files/wasted-2017-report.pdf, [Accessed January 26, 2022].

[3] United States Government Accountability Office. (2019, June). FOOD LOSS AND WASTE – Building on Existing Federal Efforts Could Help to Achieve National Reduction Goal. United States. [Online]. Available: https://www.gao.gov/assets/gao-19-391.pdf, [Accessed August 26, 2022].

[4] United States Environmental Protection Agency. (2014). A Guide to Conducting and Analyzing a Food Waste Assessment. United States. [Online]. Available: https://www.epa.gov/sites/default/files/2015-08/documents/r5_fd_wste_guidebk_020615.pdf, [Accessed August 26, 2022].

[5] S. K. Panda, A. Blome, L. Wisniewski and A. Meyer, "IoT Retrofitting Approach for the Food Industry," 2019 24th IEEE International Conference on Emerging Technologies and Factory Automation (ETFA), 2019, pp. 1639-1642, doi: 10.1109/ETFA.2019.8869093. [Accessed September 26, 2022].

[6] Paz, M., P.R. Fisher, and C. Gomez. 2019. Minimum light requirements for indoor gardening of lettuce. Urban Agric. Reg. Food Syst. [Online]. Available: https://acsess.onlinelibrary.wiley.com/doi/epdf/10.2134/urbanag2019.03.0001 [Accessed September 26, 2021]

[7] K. Dobernig, B. Gözet and K. Schanes, "Food waste matters - A systematic review of household food waste practices and their policy implications," *Journal of Cleaner Production*, vol. 182, 2018. [Online serial]. Available: https://doi.org/10.1016/j.jclepro.2018.02.030. [Accessed Jan. 25, 2022].

[8] R. Ishangulyyev, S. Kim, and S.H. Lee, "Understanding Food Loss and Waste—Why Are We Losing and Wasting Food?," Foods. vol. 8, no. 8, p. 297, 2019. [Online serial]. Available: https://doi.org/10.3390/foods8080297. [Accessed Jan. 25, 2022].

[9] K. Jackson, "Survey finds many turned to gardening during the pandemic". Alabama News center. [Online]. Available: https://alabamanewscenter.com/2021/06/01/survey-finds-many-turned-to-gardening-during-the-pandemic/ , June 1, 2021. [Accessed: Feb. 19, 2022].

[10] Adafruit. Ultrasonic Sonar Distance Sensors. [Online]. Available: https://learn.adafruit.com/ultrasonic-sonar-distance-sensors [Accessed: Aug. 1, 2021].

[11] CSUS Senior Project Fall 2021 to Spring 2022 Team 8: Stephen Arnett, Joel Barrios, Victor Le, Gedie May Licaycay, [Online]. Available: https://mysacstate.sharepoint.com/:x:/r/sites/CSUSacramento2021-2022SeniorDesign-

Team8, [Accessed June 20, 2022].

[12] “Simple Gantt Chart”, Vertex42.Com, United States. [Online]. Available: https://www.vertex42.com/ExcelTemplates/simple-gantt-chart.html?utm_source=ms., [Accessed: Aug. 1, 2021].

[13] Adafruit Industries, “Adafruit Industries, Unique & fun DIY electronics and kits,” Adafruit.com, 2019. [Online]. Available: https://www.adafruit.com/, [Accessed August 26, 2022].

[14]“DFRobot industrial pH sensor for arduino - SEN0169 | DFRobot Electronics,” [Online]. Available: *www.dfrobot.com.* https://www.dfrobot.com/product-1110.html [Accessed August 26, 2021]

[15] Mouser, “STMicroelectronics NUCLEO-L010RB,” Mouser Electronics, 2022. [Online]. Available: https://www.mouser.com/ProductDetail/STMicroelectronics/NUCLEO-L010RB?qs=l7cgNqFNU1g9%2FPXCFtRNRQ%3D%3D [Accessed August 26, 2021]

[16] “Ec meter - DFR0300 - Gravity: Analog Electrical Conductivity Sensor | DFRobot Electronics,” [Online]. Available: *www.dfrobot.com.* https://www.dfrobot.com/product-1123.html, [Accessed August 26, 2022].

GLOSSARY

AI – Artificial Intelligence, computer systems used to perform tasks that normally require human intelligence.

Ambient light - Available light in an environment.

Auto dosing - An automatic dosing mechanism to feed nutrients into the system.

ADC - Analog digital converter. Converts analog signals to digital signals.

Deep Water Culture - is a hydroponic method of plant production by means of suspending the plant roots in a solution of nutrient-rich, oxygenated water.

Environmental Protection Agency (EPA) – Independent executive agency of the United States that sets and enforces laws to protect the environment and control pollution.

Fertilizer - A chemical or natural substance added to soil or land to increase its fertility.

Food and Agriculture Organization of the United Nations (FAO) - a specialized agency of United Nations that works with over 130 countries and promotes end of world hunger [1].

Food waste - Refers to food that completes the food supply chain up to a final product, of good quality and fit for consumption, but still doesn't get consumed because it is discarded, whether after it is left to spoil or expire.

Frame – Structure used to hold our grow system. We fabricated ours out of wood.

Health monitoring camera – Camera using AI to analyze the color of the plant to ensure optimal coloring on the leaves.

Hydroponics - the process of growing plants in sand, gravel, or liquid, with added nutrients but without soil.

MobaXterm – Program used for Serial Terminal to test print statements of STM.

Natural Resource Defense Council (NRDC) – Non-profit international environmental advocacy group.

Nutrients - Chemical elements and compounds necessary for plant growth, plant metabolism and their external supply.

OpenCV - Open Computer Vision; An open-source library of real time computer vision function that were originally developed by Intel Corporation.

STM – STMicroelectronics, a brand of microcontroller.

United States Department of Agriculture (USDA) – Federal department responsible for developing laws related to farming, forestry, rural economic development, and food.

Water sensor - Used to measure the water level in the system.

Appendix A. Hardware

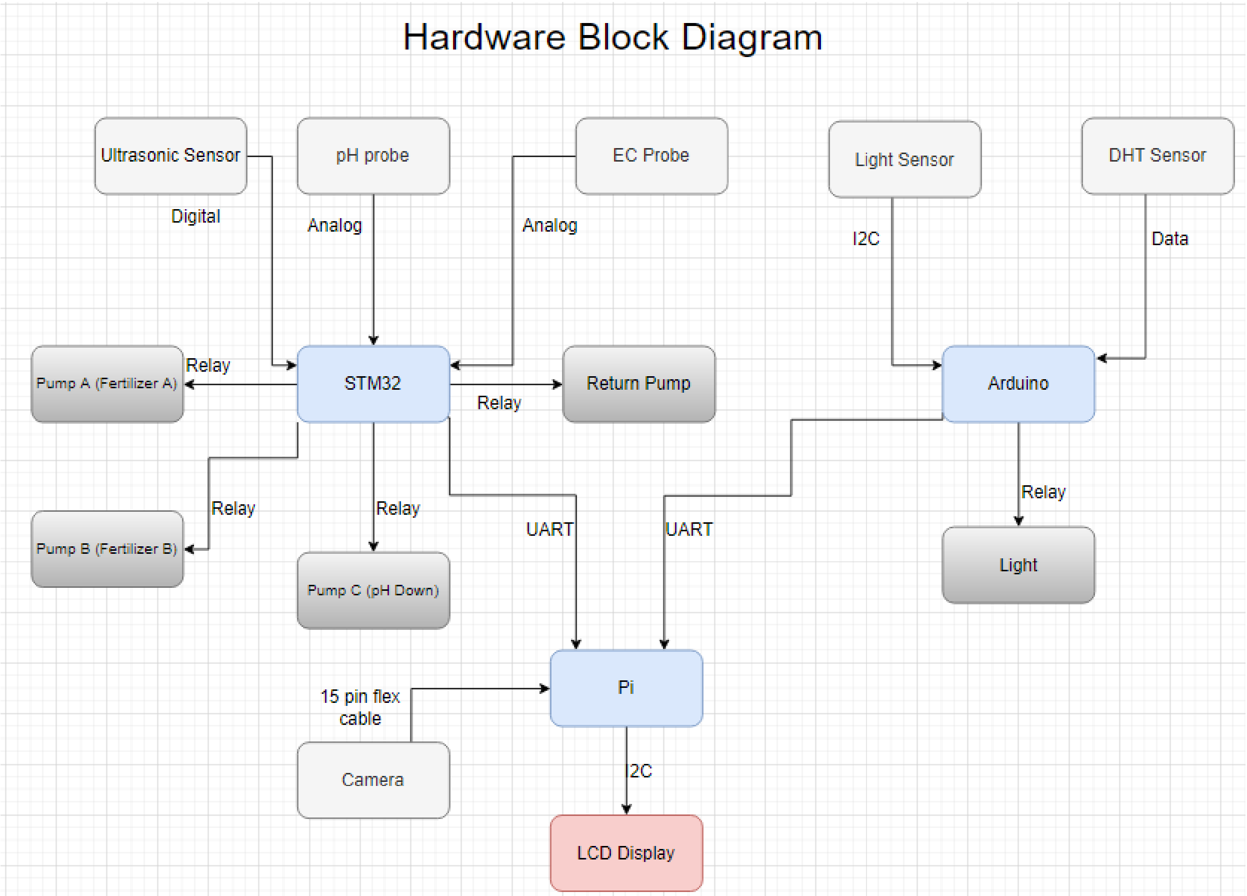


Figure A1: Hardware Block Diagram [12]

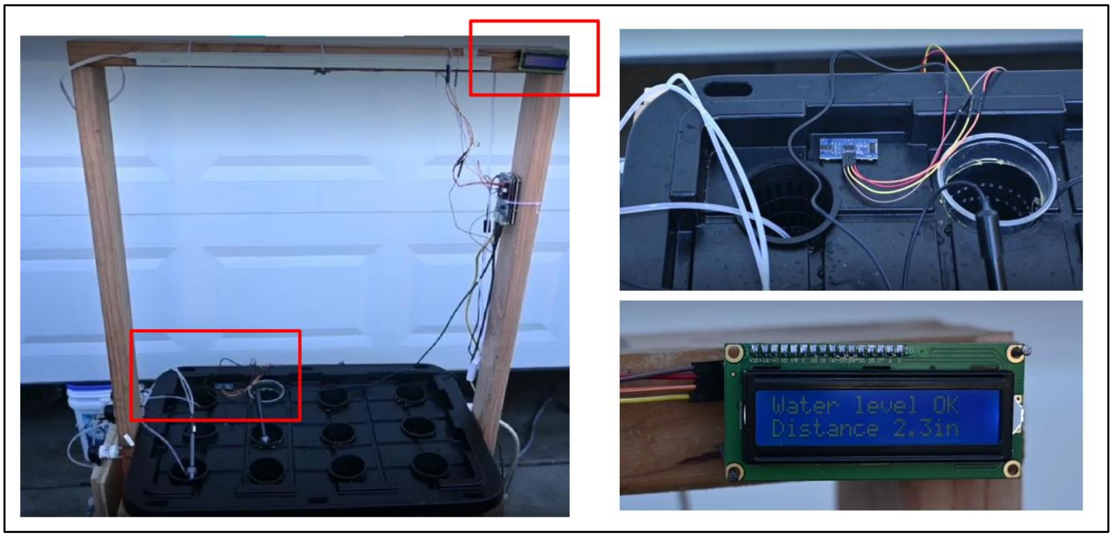


Figure A2: Water Level Sensor Integration [12]

Test 1: Pumps off

Sensor 2:

Physical 3.5

Moba Reading:

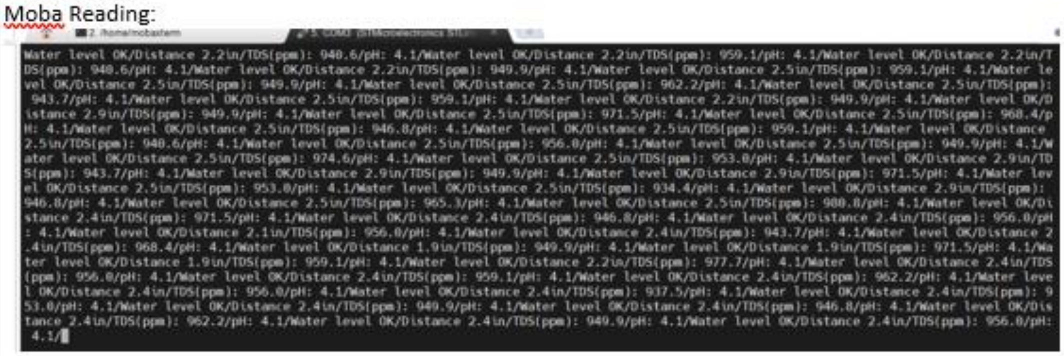
Physical: 3.7

Moba Reading:

Sensor 3:

Physical: 2.25

Moba Reading:



Physical: 2.875 inches

Moba Reading:

Physical 3.5

Moba Reading:

Figure A3: Water Level Feature MobaXterm Reading [11]

Table A1.
Water Level Feature Test 1 Results [11]

Test ID: WaterlevelTest1
Test Description: Pumps off
Summary: Tested 1 rusted sensor and 2 new ones
Result: Rusted Sensor _ fail

Test Numb	Sensor Measurem	Physical Measure	Difference	Pass/Fail	Comments/Changes	Date
1	2.5	2.13	0.37	Fail	Sensor 1 (from last semester)	2/19/2022
2	3	2.75	0.25	Fail		2/19/2022
3	4.4	4.125	0.275	Fail		2/19/2022
4	475.1	1	474.1	Fail		3/5/2022
5	475.3	1	474.3	Fail		3/5/2022
6	475.3	1	474.3	Fail		3/5/2022
7	475.3	1	474.3	Fail		3/5/2022
8	475.4	1	474.4	Fail		3/5/2022
9	475.4	1	474.4	Fail		3/5/2022
10	475.4	1	474.5	Fail		3/5/2022
11	475.5	1	473.4	Fail		3/5/2022
12	474.4	1	473.5	Fail		3/9/2022
13	474.5	1	473.1	Fail		3/9/2022
14	474.1	1	474.5	Fail		3/9/2022
15	475.5	1	474.4	Fail		3/9/2022
16	475.4	1	474.1	Fail		3/9/2022
17	475.1	1	474.1	Fail		3/9/2022
18	475.1	1	474.2	Fail		3/9/2022
19	475.2	1	472.4	Fail		3/9/2022
20	473.4	1	472.1	Fail		3/9/2022
21	473.1	1	472.6	Fail		3/9/2022
22	473.6	1	472.6	Fail		3/9/2022
23	473.6	1	472.5	Fail		3/9/2022
24	473.5	1	472.3	Fail		3/9/2022
25	473.3	1	471.8	Fail		3/9/2022
26	472.8	11.25	461.55	Fail		3/9/2022
27	472.8	11.25	461.55	Fail		3/9/2022
28	472.8	11.25	461.65	Fail		3/9/2022
29	472.9	11.25	461.55	Fail		3/9/2022
30	472.8	11.25	461.55	Fail		3/9/2022
31	472.8	11.25	461.65	Fail		3/9/2022
32	472.9	11.25	462.15	Fail		3/9/2022
33	473.4	11.25	462.15	Fail	Rust accumulated in sensor, re	3/9/2022
34	4.2	3.5	0.7	Fail	Sensor 2	3/10/2022
35	3.8	3.5	0.3	Fail		3/10/2022
36	3.8	3.5	0.3	Fail		3/10/2022
37	3.8	3.5	0.3	Fail		3/10/2022
38	3.8	3.5	0.3	Fail		3/10/2022
39	3.8	3.5	0.3	Fail		3/10/2022
40	3.8	3.5	0.3	Fail		3/10/2022
41	3.8	3.5	0.3	Fail		3/10/2022
42	3.8	3.5	0.3	Fail		3/10/2022
43	3.8	3.5	0.3	Fail		3/10/2022
44	3.8	3.5	0.3	Fail		3/10/2022
45	3.8	3.5	0.3	Fail		3/10/2022
46	3.8	3.5	0.3	Fail		3/10/2022
47	4.2	3.5	0.7	Fail		3/10/2022
48	4.2	3.5	0.7	Fail		3/10/2022
49	4.2	3.5	0.7	Fail		3/10/2022
50	3.7	3.7	0	Pass		3/10/2022
51	3.7	3.7	0	Pass		3/10/2022
52	3.7	3.7	0	Pass		3/10/2022
53	3.7	3.7	0	Pass		3/10/2022
54	3.7	3.7	0	Pass		3/10/2022
55	3.7	3.7	0	Pass		3/10/2022
56	3.7	3.7	0	Pass		3/10/2022
57	3.7	3.7	0	Pass		3/10/2022
58	3.7	3.7	0	Pass		3/10/2022
59	3.7	3.7	0	Pass		3/10/2022
60	3.7	3.7	0	Pass		3/10/2022
61	3.7	3.7	0	Pass		3/10/2022
62	5.2	3.7	1.5	Fail		3/10/2022
63	3.8	3.7	0.1	Pass		3/10/2022
64	3.8	3.7	0.1	Pass		3/10/2022
65	3.8	3.7	0.1	Pass		3/10/2022
66	3.8	3.7	0.1	Pass		3/10/2022
67	3.8	3.7	0.1	Pass		3/10/2022
68	3.8	3.7	0.1	Pass		3/10/2022
69	3.8	3.7	0.1	Pass		3/10/2022
70	4.2	3.7	0.5	Fail		3/10/2022
71	4.2	3.7	0.5	Fail		3/10/2022
	3.8	3.7	0.1	Pass		3/10/2022
72	2.2	2.25	-0.05	Pass	Sensor 3	3/10/2022
73	2.2	2.25	-0.05	Pass		3/10/2022
74	2.2	2.25	-0.05	Pass		3/10/2022
75	2.2	2.25	-0.05	Pass		3/10/2022
76	2.5	2.25	0.25	Fail		3/10/2022
77	2.5	2.25	0.25	Fail		3/10/2022
78	2.5	2.25	0.25	Fail		3/10/2022
79	2.2	2.25	-0.05	Pass		3/10/2022
80	2.9	2.25	0.65	Fail		3/10/2022
81	2.5	2.25	0.25	Fail		3/10/2022
82	2.5	2.25	0.25	Fail		3/10/2022
83	2.5	2.25	0.25	Fail		3/10/2022
84	2.5	2.25	0.25	Fail		3/10/2022
85	2.9	2.25	0.65	Fail		3/10/2022
86	2.9	2.25	0.65	Fail		3/10/2022
87	2.9	2.25	0.65	Fail		3/10/2022
88	2.5	2.25	0.25	Fail		3/10/2022
89	2.4	2.25	0.15	Pass		3/10/2022
90	2.4	2.25	0.15	Pass		3/10/2022
91	2.4	2.25	0.15	Pass		3/10/2022
92	2.4	2.25	0.15	Pass		3/10/2022
93	2.1	2.25	-0.15	Pass		3/10/2022
94	2.4	2.25	0.15	Pass		3/10/2022
95	2.4	2.25	0.15	Pass		3/10/2022
96	2.4	2.25	0.15	Pass		3/10/2022
97	1.9	2.25	-0.35	Pass		3/10/2022
98	1.9	2.25	-0.35	Pass		3/10/2022
99	1.9	2.25	-0.35	Pass		3/10/2022
100	2.2	2.25	-0.05	Pass		3/10/2022
101	2.4	2.25	0.15	Pass		3/10/2022
102	2.4	2.25	0.15	Pass		3/10/2022
103	2.4	2.25	0.15	Pass		3/10/2022
104	2.4	2.25	0.15	Pass		3/10/2022
105	2.4	2.25	0.15	Pass		3/10/2022
106	2.4	2.25	0.15	Pass		3/9/2022
107	2.4	2.25	0.15	Pass		3/9/2022
108	2.4	2.25	0.15	Pass		3/9/2022
109	2.4	2.25	0.15	Pass		3/9/2022
110	3	2.875	0.125	Pass		3/9/2022
111	3	2.875	0.125	Pass		3/9/2022
112	3	2.875	0.125	Pass		3/9/2022
113	3	2.875	0.125	Pass		3/9/2022
114	3	2.875	0.125	Pass		3/9/2022
115	3	2.875	0.125	Pass		3/9/2022

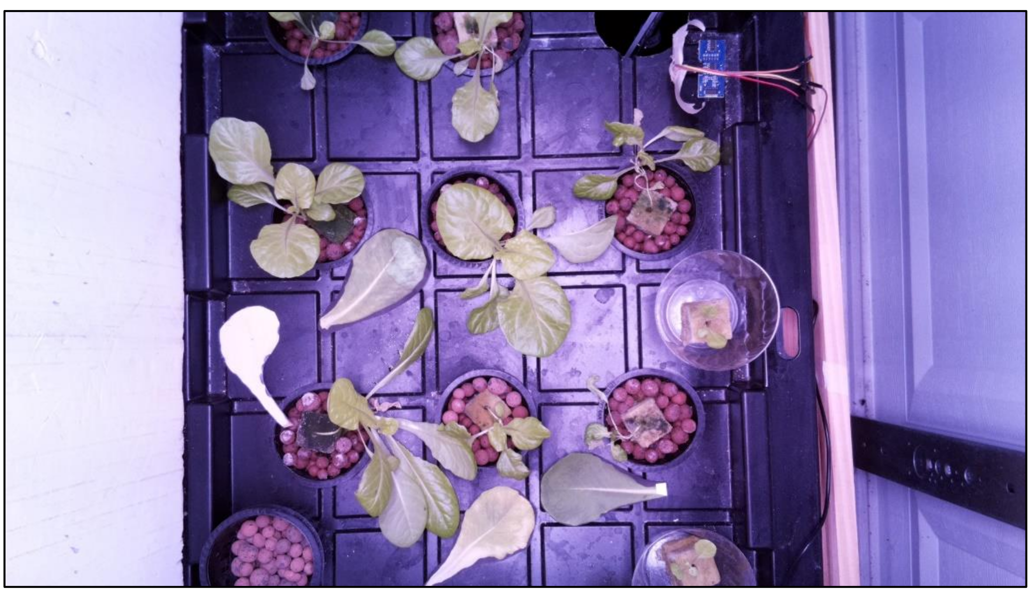


Figure A4: Top-down camera view of the hydroponic system [12]

Table A2.
Temperature Test Results

	Temp Test 1	
	Temp sensor reading (F)	External sensor(F)
1	70	70
2	70	70
3	69	70
4	70	70
5	70	71
6	70	70
7	70	70
8	70	70
9	70	70
10	70	70

Table A3.
Humidity Test Results

	Humidity Test 1	
	Humidity Sensor	External Sensor
1	65%	66%
2	65%	65%
3	65%	65%
4	65%	65%
5	65%	65%
6	65%	65%
7	65%	65%
8	65%	65%
9	65%	65%
10	65%	65%

Table A4.
Light Test Results

	Light Test 1	1= True, 0 = False		
	Lux > Threshold	Lux < Threshold	Light Source On	Pass/Fail
1	1	0	Off	Pass
2	1	0	Off	Pass
3	1	0	Off	Pass
4	1	0	Off	Pass
5	1	0	Off	Pass
6	0	1	On	Pass
7	0	1	On	Pass
8	0	1	On	Pass
9	0	1	On	Pass
10	0	1	On	Pass

Appendix B. Software

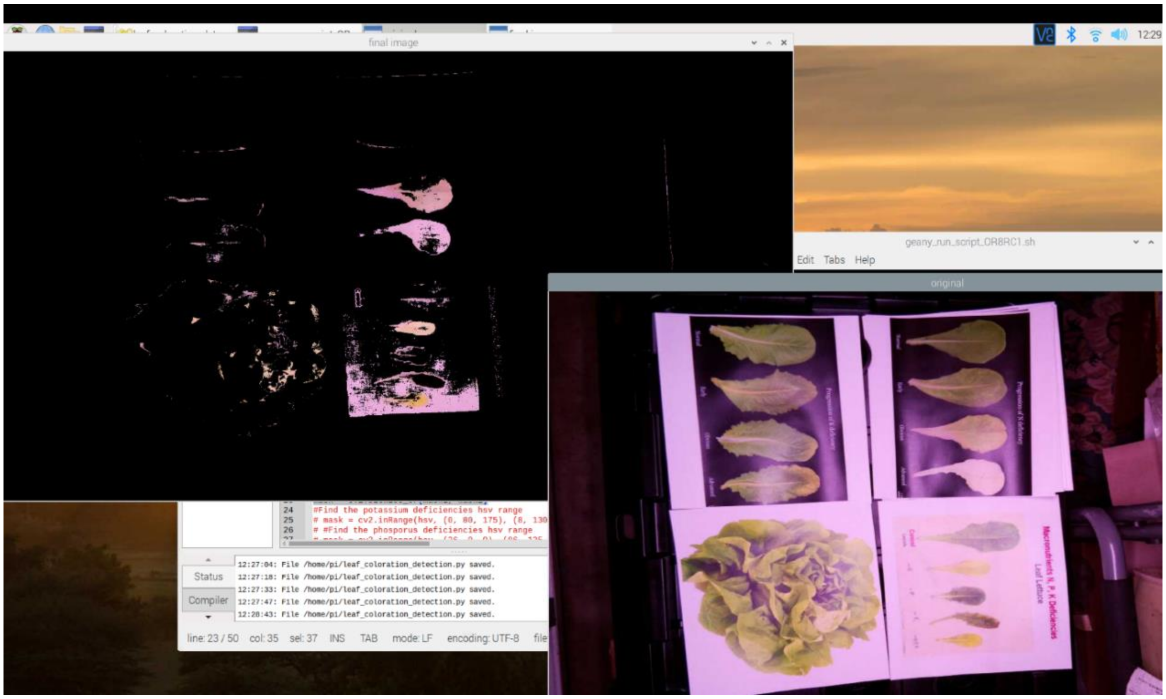


Figure B1: Nitrogen Testing Images [11]

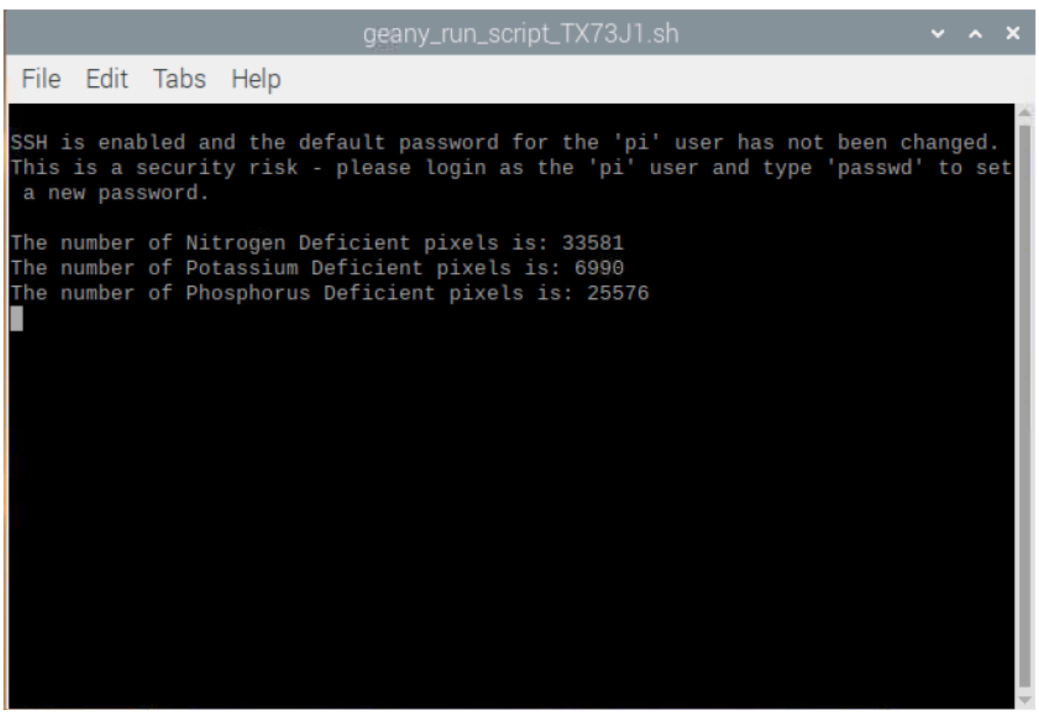


Figure B2: Nitrogen Testing Pixel Count [11]

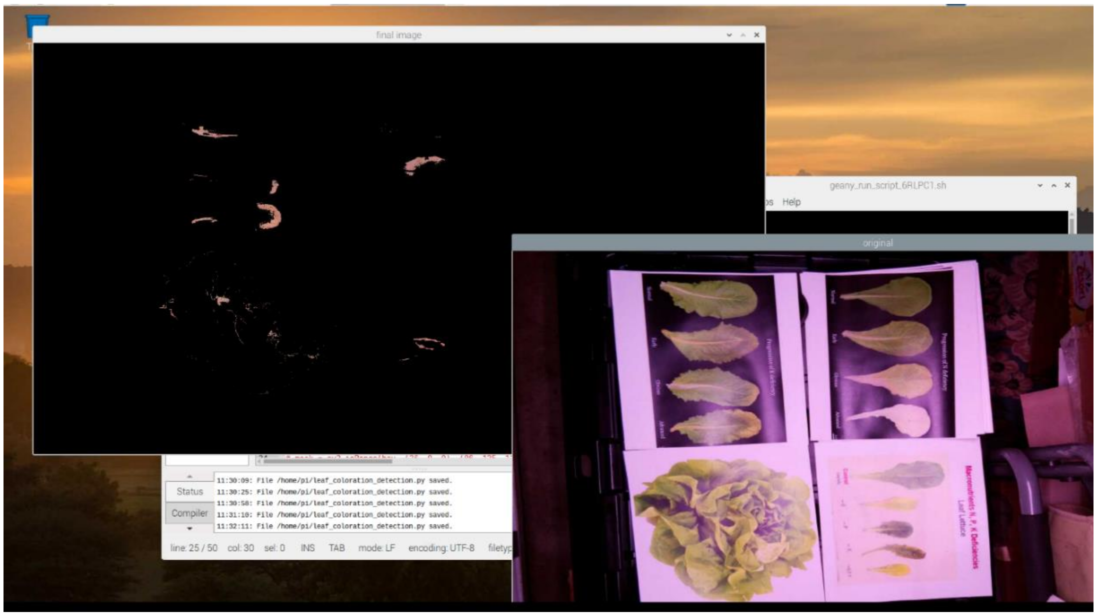


Figure B3: Potassium Testing Images [11]

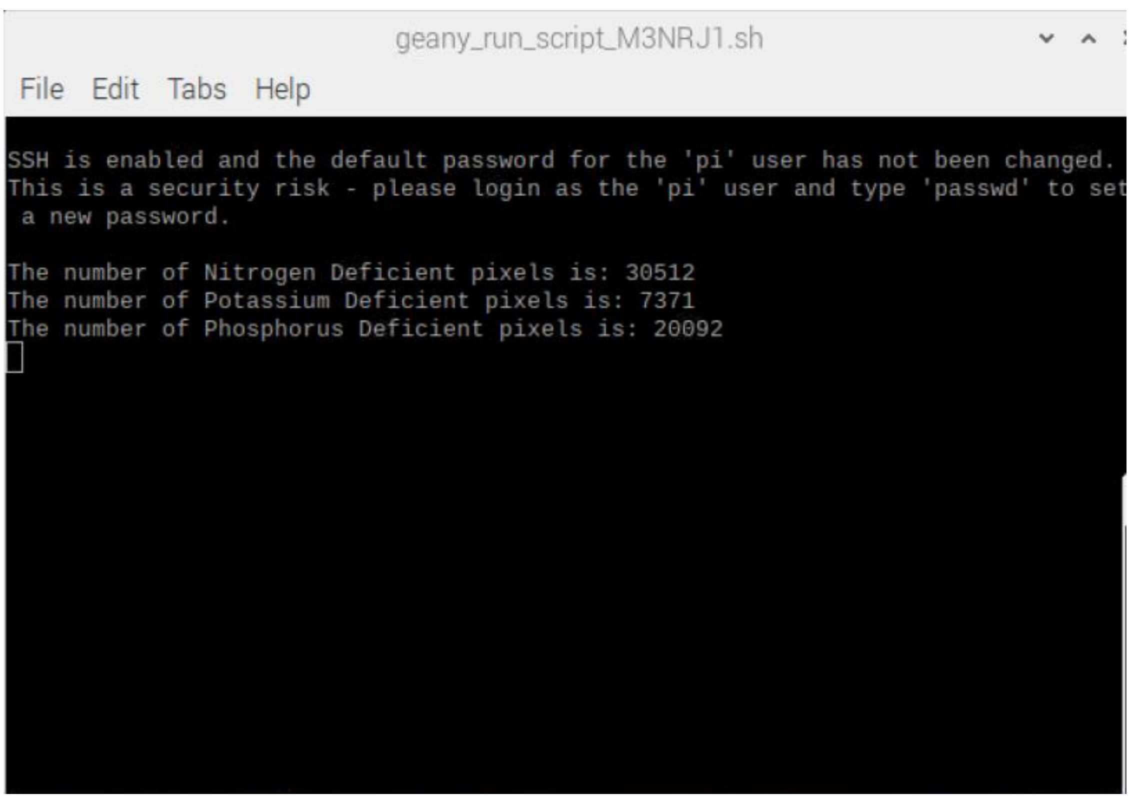


Figure B4: Potassium Testing Pixel Count [11]

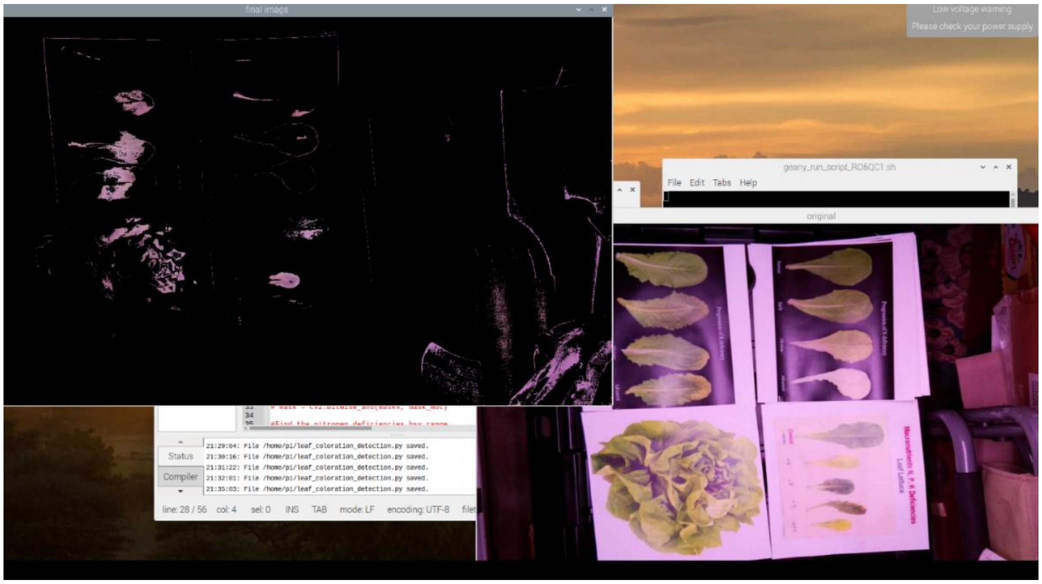


Figure B5: Phosphorus Testing Images [11]

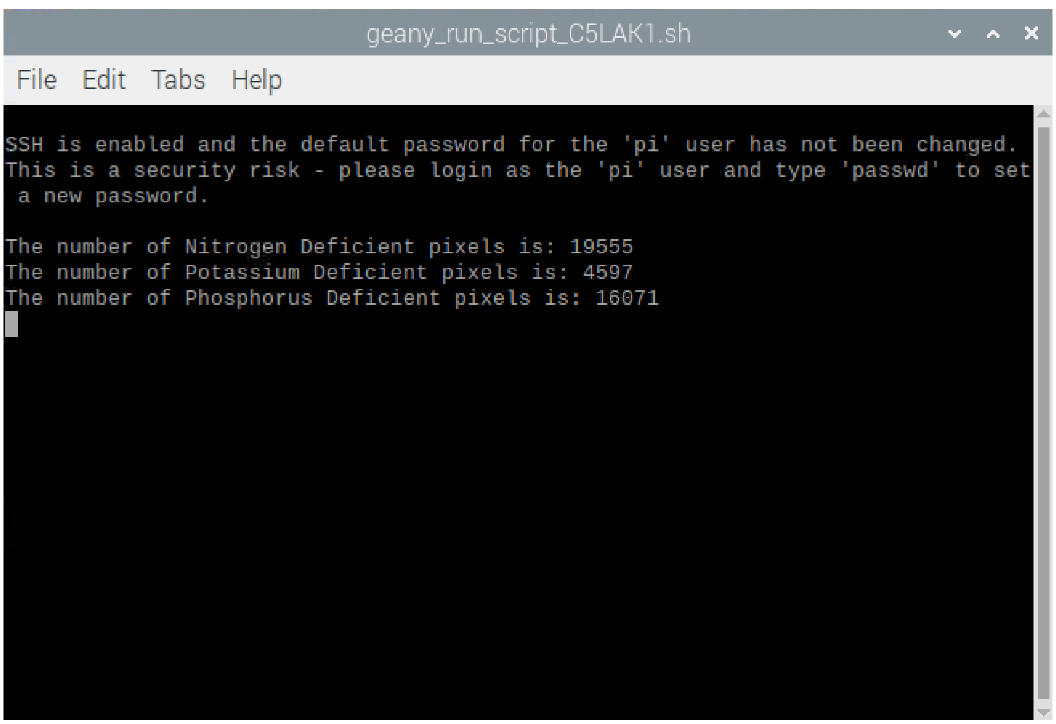


Figure B6: Phosphorus Testing Pixel Count [11]

Below is the link to our code for the entire project:

https://bitbucket.org/dwss-smart-garden/

Appendix C. Mechanical Aspects

Figure C1: Frame sideview [12]

Figure C2: Frame Front view [12]

Appendix D. Work Breakdown Structure

Table D1.
Fall 2021 Work Breakdown Structure [11]

Fall 2021 Semester				
Week Number*	Hardware	Software	Collaboration/Integration	Assignments (Team)
7 to 15	All 4 members are assigned at least 1 sensor: Joel - Light, Temperature/Humidity Victor - EC and pH Stephen - Camera Gedie - Water Level	Everyone is assigned to work on the software/coding of their sensor	Initial sensor setup	
9 to 12			Placement of lights and other components of the hydroponic system	
9				Senior Design Project Assessment Form
9				Assignment 4 - Work Breakdown Structure
10				Assignment 5 - Project Timeline
11				Assignment 6 - Risk Assessment
12			tentative start of growth cycle (planting seed in the system)	Prototype Progress Review (in person demo)
11 to 15	Board Assembly		Sensor testing and data gathering	-
15				Assignment 7 - Project Technical Evaluation
15				Assignment 8 - Laboratory Prototype Presentation
14				Teamwork, and Team Member Evaluations
4 to 13				Team Activity report

*Week Number according to canvas page

Table D2.
Spring 2022 Work Breakdown Structure [11]

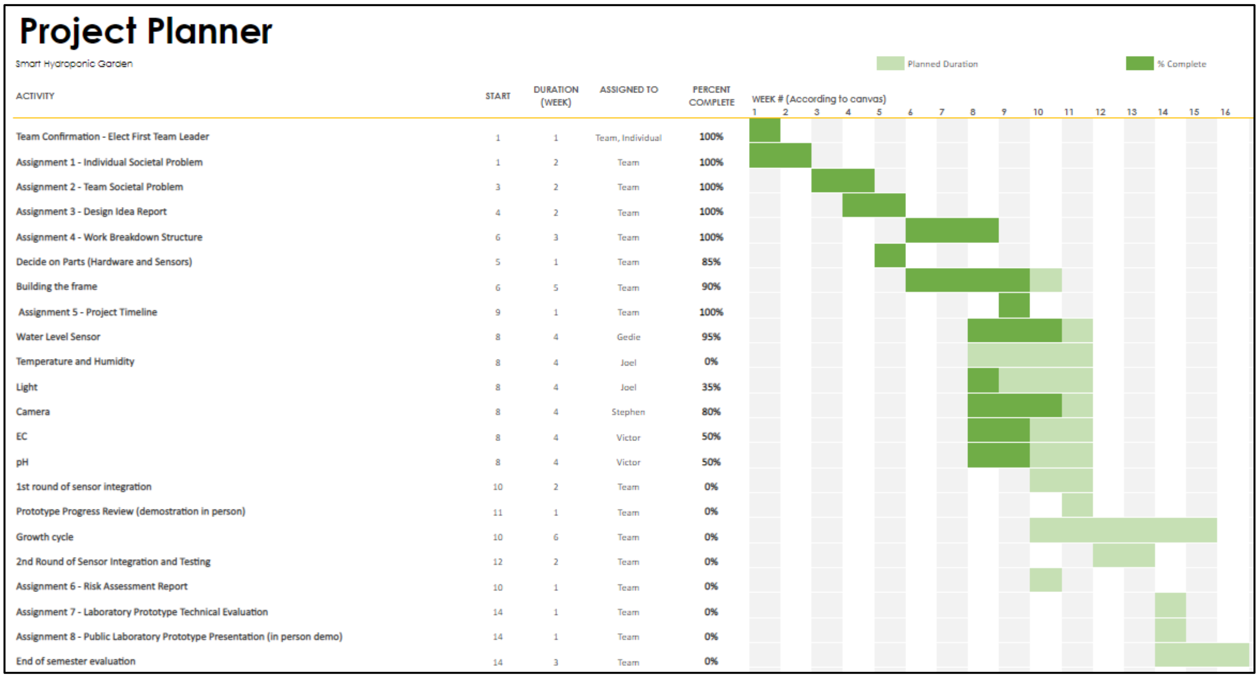
Spring 2022 Semester				
Week Number*	Hardware	Software	Collaboration/Integration	Assignments (Team)
1 to 4	Each team member will evaluate the hardware assigned to them: Joel - Light, Temperature/Humidity Victor - EC and pH Stephen - Camera Gedie - Water Level	Each team member will evaluate the software for the assigned sensor	The team will set a clear plan to finish individual parts and the entire project through the scope of the coursework.	
1 to 13				Team Activity report
2			start of growth cycle	
2				Assign 1: Revised Problem Statement
3			start growth cycle staggering	
3				Assign 2: Device Test Plan Report
4 to 10	Each team member will have made the necessary changes to their respective hardware	Each team member will have made the necessary changes to their respective software	The team will help assist others within the team towards completion of their individual parts	
4,10				Prototype Progress Review
6				Assign 3: Market Review
7				Assign 4: Feature Report
7,12				Teamwork, and Team Member Evaluations
6	Re-evaluate sensors	Finalize codes, upload to bitbucket		
10				Prototype Progress Review
11				Assign 5: Testing Results Report

12 to 14			In person team meetings to prepare the Deployable Prototype material	
13				Assignment 6 - Engineering Ethics quiz
14				Assign 7: Deployable Prototype Eval
15				Assign 8: End of Project Report
16				Assign: 9: Deployable Prototype Public Presentation

*Week Number according to canvas page

Appendix E. Timeline Charts and PERT Diagrams

Below are the Gantt charts for Fall 2021 and Spring 2022 semesters.



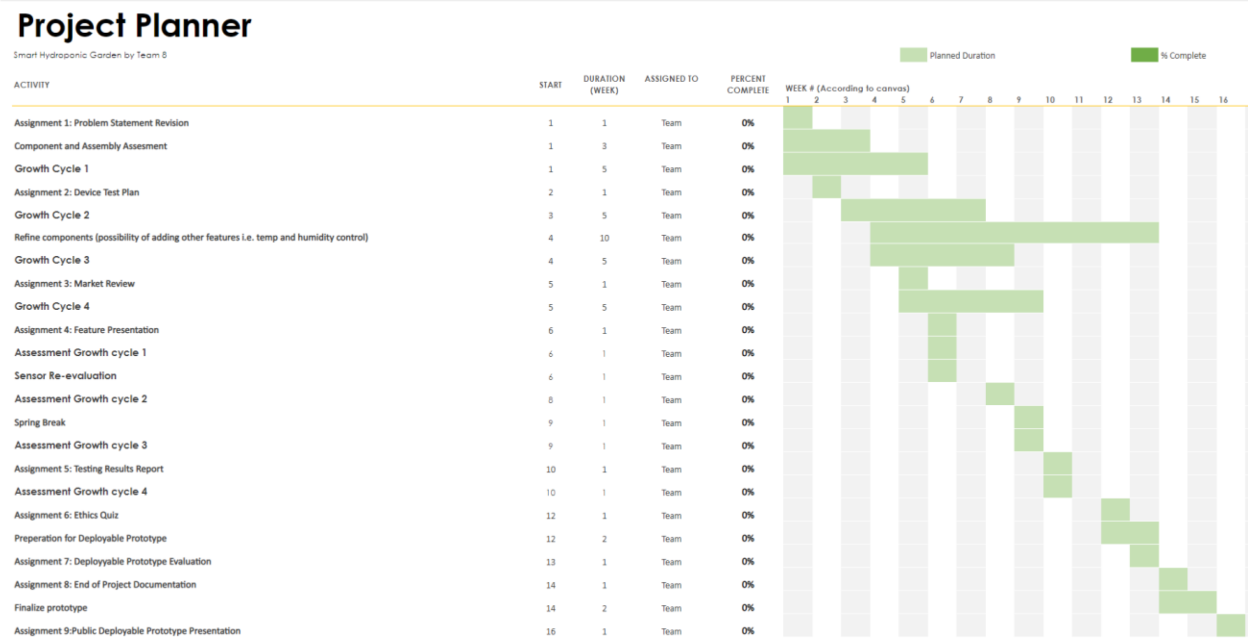
Project Planner

Smart Hydroponic Garden

Planned Duration · % Complete

ACTIVITY	START	DURATION (WEEK)	ASSIGNED TO	PERCENT COMPLETE
Team Confirmation - Elect First Team Leader	1	1	Team, Individual	100%
Assignment 1 - Individual Societal Problem	1	2	Team	100%
Assignment 2 - Team Societal Problem	3	2	Team	100%
Assignment 3 - Design Idea Report	4	2	Team	100%
Assignment 4 - Work Breakdown Structure	6	3	Team	100%
Decide on Parts (Hardware and Sensors)	5	1	Team	85%
Building the frame	6	5	Team	90%
Assignment 5 - Project Timeline	9	1	Team	100%
Water Level Sensor	8	4	Gedie	95%
Temperature and Humidity	8	4	Joel	0%
Light	8	4	Joel	35%
Camera	8	4	Stephen	80%
EC	8	4	Victor	50%
pH	8	4	Victor	50%
1st round of sensor integration	10	2	Team	0%
Prototype Progress Review (demostration in person)	11	1	Team	0%
Growth cycle	10	6	Team	0%
2nd Round of Sensor Integration and Testing	12	2	Team	0%
Assignment 6 - Risk Assessment Report	10	1	Team	0%
Assignment 7 - Laboratory Prototype Technical Evaluation	14	1	Team	0%
Assignment 8 - Public Laboratory Prototype Presentation (in person demo)	14	1	Team	0%
End of semester evaluation	14	3	Team	0%

Figure E1: Fall 2021 Gantt Chart [12]



Project Planner

Smart Hydroponic Garden by Team 8

Planned Duration · % Complete

ACTIVITY	START	DURATION (WEEK)	ASSIGNED TO	PERCENT COMPLETE
Assignment 1: Problem Statement Revision	1	1	Team	0%
Component and Assembly Assesment	1	3	Team	0%
Growth Cycle 1	1	5	Team	0%
Assignment 2: Device Test Plan	2	1	Team	0%
Growth Cycle 2	3	5	Team	0%
Refine components (possibility of adding other features i.e. temp and humidity control)	4	10	Team	0%
Growth Cycle 3	4	5	Team	0%
Assignment 3: Market Review	5	1	Team	0%
Growth Cycle 4	5	5	Team	0%
Assignment 4: Feature Presentation	6	1	Team	0%
Assessment Growth cycle 1	6	1	Team	0%
Sensor Re-evaluation	6	1	Team	0%
Assessment Growth cycle 2	8	1	Team	0%
Spring Break	9	1	Team	0%
Assessment Growth cycle 3	9	1	Team	0%
Assignment 5: Testing Results Report	10	1	Team	0%
Assessment Growth cycle 4	10	1	Team	0%
Assignment 6: Ethics Quiz	12	1	Team	0%
Preperation for Deployable Prototype	12	2	Team	0%
Assignment 7: Deployyable Prototype Evaluation	13	1	Team	0%
Assignment 8: End of Project Documentation	14	1	Team	0%
Finalize prototype	14	2	Team	0%
Assignment 9:Public Deployable Prototype Presentation	16	1	Team	0%

Figure E2: Spring 2022 Gantt Chart [11][12]

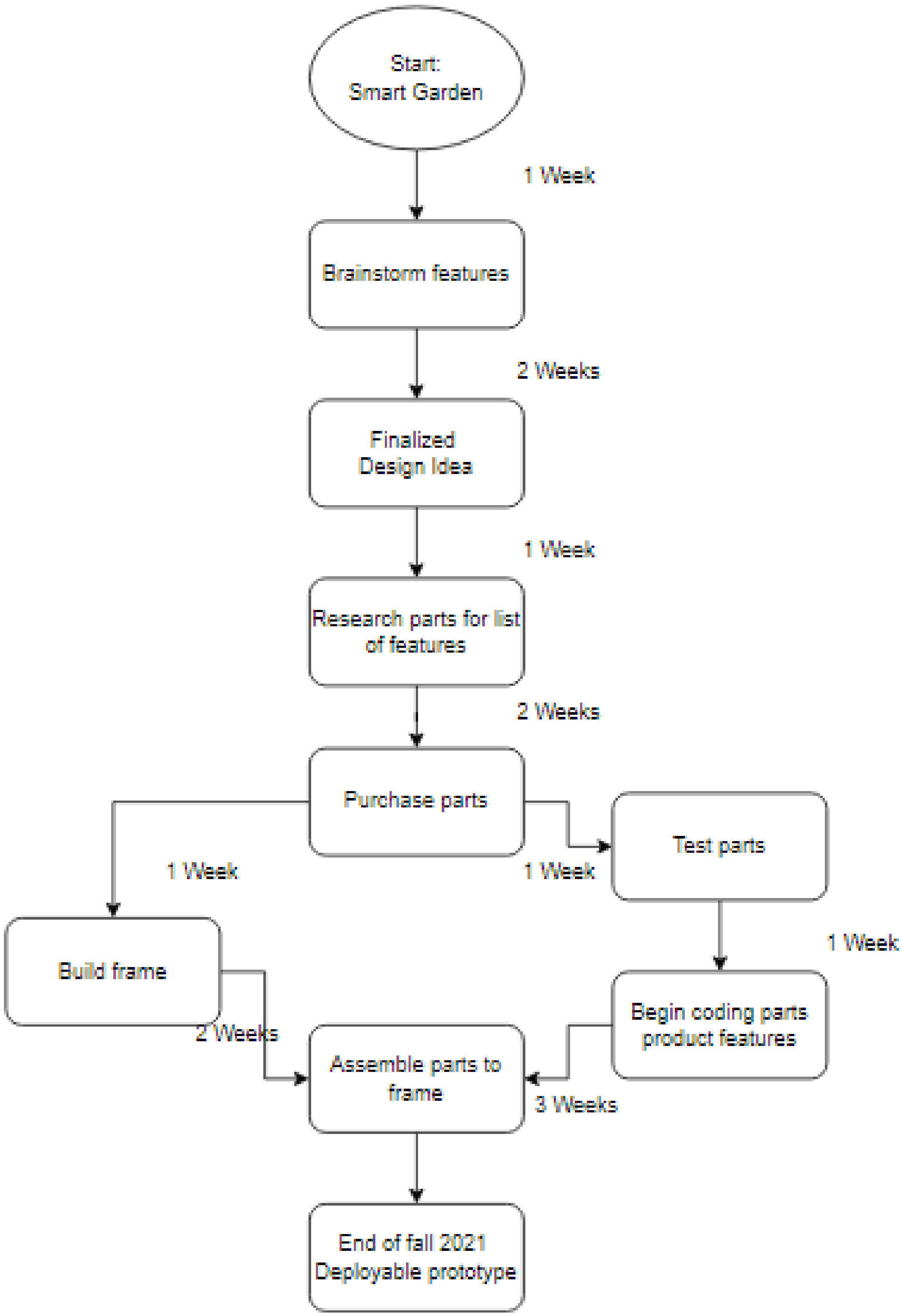


Figure E3: Fall 2021 PERT Diagram [11]

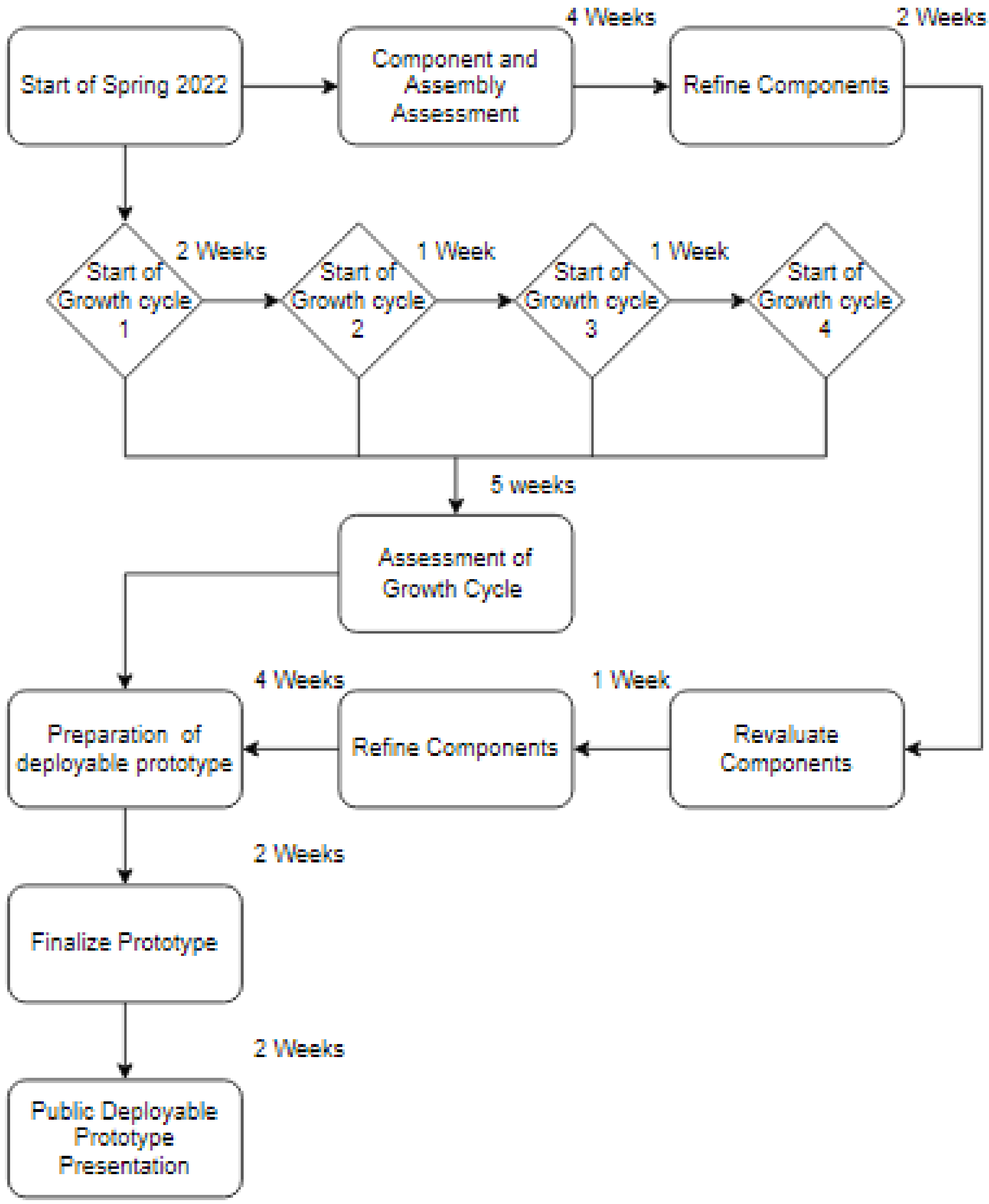
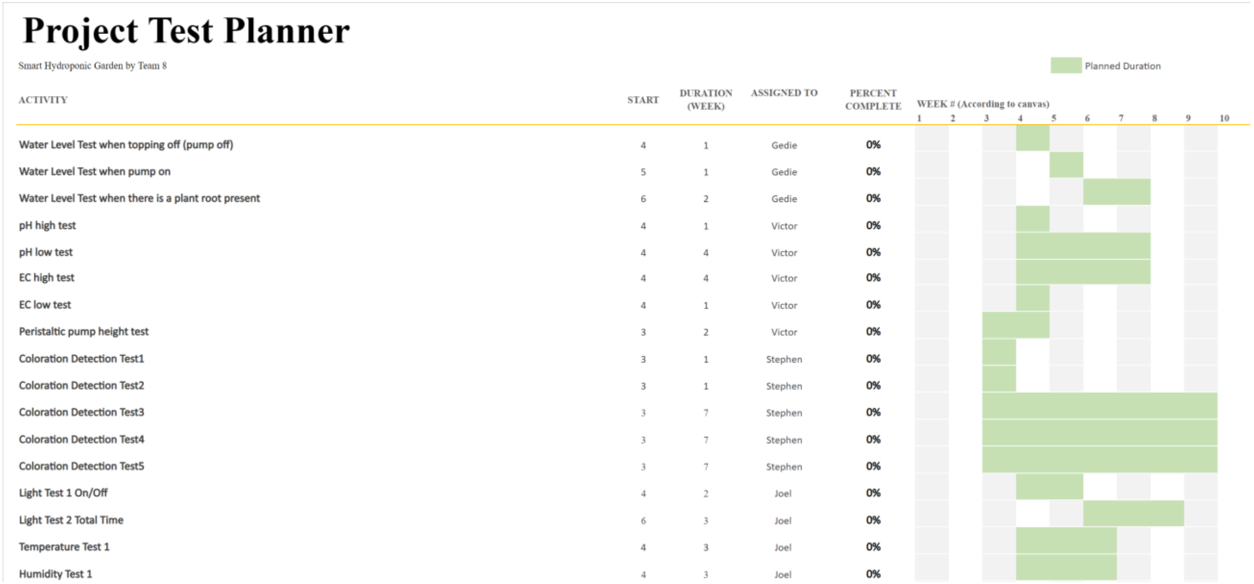


Figure E4: Spring 2022 PERT Diagram [11]



Project Test Planner

Smart Hydroponic Garden by Team 8

Planned Duration

WEEK # (According to canvas) 1 2 3 4 5 6 7 8 9 10

ACTIVITY	START	DURATION (WEEK)	ASSIGNED TO	PERCENT COMPLETE
Water Level Test when topping off (pump off)	4	1	Gedie	0%
Water Level Test when pump on	5	1	Gedie	0%
Water Level Test when there is a plant root present	6	2	Gedie	0%
pH high test	4	1	Victor	0%
pH low test	4	4	Victor	0%
EC high test	4	4	Victor	0%
EC low test	4	1	Victor	0%
Peristaltic pump height test	3	2	Victor	0%
Coloration Detection Test1	3	1	Stephen	0%
Coloration Detection Test2	3	1	Stephen	0%
Coloration Detection Test3	3	7	Stephen	0%
Coloration Detection Test4	3	7	Stephen	0%
Coloration Detection Test5	3	7	Stephen	0%
Light Test 1 On/Off	4	2	Joel	0%
Light Test 2 Total Time	6	3	Joel	0%
Temperature Test 1	4	3	Joel	0%
Humidity Test 1	4	3	Joel	0%

Figure E5: Device Test Plan Timeline [12]

Figure E6: First Growth Cycle in Spring 2022 [12]

Appendix F. Resumes

Gedie May Licaycay

Software

Microsoft Excel
(VLOOKUP, Pivot tables, Conditional Formatting)
Microsoft PowerPoint
Microsoft Outlook
Microsoft Access

Adobe Applications

- Acrobat Pro DC
- Photoshop
- Illustrator

Windows 8, 10
Mac O/S and Applications
Advance Design System (ADS)
OrCAD Pspice
MATLAB
Multisim
C++ (Programming Language)
Verilog (Programming Language)
Python (Programming Language)

Skills

Team Management
Conflict Resolution
Adaptability
Communication
Problem-solving
Organization

Experience

Sacramento Municipal Utility District (SMUD)
March 2021-May 2022
STEM Student Intern

- Assisting engineers in substation, distribution and transmission maintenance planning
- Utilizing multiple software applications such as SAP, GIS and databases to create cable replacement, Avian Protection and Trip saver projects.
- Tracking underground cable fault and entering into database.
- Creating notification and job packages for linemen and design team

Volt Workforce Solutions (Pegatron)
March 2014 - November 2018
Electronic Technician

- Diagnosed cell phone problems by identifying issues, running tests, and assessing functionality
- Performed cell phone repairs (Apple iPhone products) by replacing parts, assembling logic boards, LCD, and receivers, and performing function tests
- Calibrated equipment to meet project requirements

Production Assistant

- Promoted from entry-level position to production line manager
- Assisted engineers in the development of repair processes and procedures
- Managed and trained a group of workers to produce at the utmost efficiency
- Assisted the supervisor with various tasks

Education

California State University, Sacramento
College of Engineering & Computer Science
Majoring in Electrical & Electronic Engineering
GPA: 3.884

Relevant Courses:
Applied Electromagnetics, Network Analysis, Engineering Economics, Signals and Systems, Probability and Random Signals, Logic Design, Calculus, Physics, C++ Programming

Relevant Projects:
ADS (Applied Electromagnetics)

- Built and simulated transmission line circuits

Multisim (Logic Design)

- Designed analog and digital circuits using online simulator
- Used field-programmable gate array (FPGA)

Verilog (Logic Design)

- Designed codes and verified simulated circuits using binary number system, combinational and sequential logic
- Used Quartus from Altera for Verilog compilation

Joel Barrios

Electrical Engineer

Contact

E-mail
elbarrjo83@gmail.com

LinkedIn
https://www.linkedin.com/in/joel-barrios-39954b40/

Skills

Analog and digital circuitry

Microsoft software suite (Word, Excel, Outlook)

Specifications understanding

Software/Coding

Python

Matlab

C

VHDL

PSPICE

Multisim

ADS

Languages

Spanish

Engineering Student with 10+ months experience assisting in CCA hardware design in the Aerospace and Defense Industry. Motivated, self-disciplined, and eager to continue learning and add value to projects.

Work History

2021-05 - Current

Engineering Technical Aide

Sierra Nevada Corporation, Folsom, CA

- Gathered relevant data from various sources and developed comprehensive reports for leadership review
- Handled parallel assignments to support multiple projects
- Lab work using oscilloscopes to verify signal integrity
- Read and interpreted technical drawings, schematics and computer-generated reports

Projects

Smart Hydroponics System (Senior Project)

- Features include: temp,humidity, light, pH, EC, water-level, plant health
- Monitored all features listed above using sensors connected to an STM32 Microcontroller and Arduino Uno
- Automated our light source to turn on when there wasn't enough sunlight

Robotic Car

- Built car and programmed it using Arduino IDE to complete a set of given tasks
- Incorporated sensors, such as an ultrasonic sensor, to measure distance from the car to objects

Education

2020-01 - 2022-05

Bachelor of Science: Electrical And Electronic Engineering

California State University - Sacramento

- Dean's Honor List - [Spring 2020 - Spring 2022]
- Member of Tau Beta Pi (Engineering Honor's Society)
- Member of IEEE

Interests

Running, Biking, Kayaking, DIY Projects

Victor Le

Electrical Engineering student with varied work experience looking to increase experience and skills. Experience in both fast paced and self-driven work environment. U.S. Citizen and first-generation college student.

Skills

Windows OS, VPN software
Programming: **C, Matlab, Python,** asm
Simulation Software: Advanced Design System **(ADS)**, **Multisim**, **PSpice, AutoCad**
Google Workspace: Docs, Drive, Calendar, Meets
Microsoft Office: **Word, Excel,** Outlook, Powerpoint, Access, Teams

Education

CALIFORNIA STATE UNIVERSITY, SACRAMENTO — Expected Graduation May 2022
3.80 GPA

Electrical & Electronics Engineering, emphasis in Analog/Digital Controls

Clubs

- Mesa Engineering Program (MEP)
- Institute of Electrical and Electronics Engineers (iEEE)
- Tau Beta Pi Upsilon - Fall 2021 Recording Secretary

Employment History

SMUD ELECTRICAL ENGINEERING INTERN — May 2020 - Present
Sacramento, CA

- Assist engineers on a variety of engineering related assignments
- Drafting underground cable replacement projects on GIS using various criteria such as cost benefit analysis
- Underground cable fault tracking and database entry on Microsoft Access.
- Enterprise asset management (SAP EAM) for substation equipment.
- Gathered information off of high-level technical documents for Principal Engineers.

MAINTENANCE TECHNICIAN — November 2017 - Present
Sacramento, CA

- Performed interior & exterior repairs including electrical and plumbing
- Performed repairs to rental houses following tenant vacating property. Including woodwork, doors, walls, painting, rekeying locks, reprogramming garage doors
- Flexible Hours, availability for emergency service

Foreign Languages

- Native Cantonese; Graduated from private Cantonese School
- Mandarin; Graduated from private Cantonese School which had Mandarin aspect
- Spanish; 2 semesters of College Spanish

STEPHEN **ARNETT-ROBINSON**

U.S. Citizen

www.linkedin.com/in/stephen-arnett-robinson-a32636194

OBJECTIVE

To obtain an entry-level position in the field of Electrical Engineering

EDUCATION

CALIFORNIA STATE UNIVERSITY SACRAMENTO, *SACRAMENTO, CA* ***EXPECTED GRADUATION: MAY 2022***

BACHELOR OF SCIENCE IN ELECTRICAL & ELECTRONICS ENGINEERING GPA: 3.84

KNOWLEDGE AND SKILLS

- Spice/Multisim, MATLAB, Microsoft Office, C/C++, Autodesk Inventor, Linux OS, AutoCAD
- Knowledge of Electrical components and circuits, Electrical Wiring, Soldering
- Problem solving, Professionalism, Efficient worker, Team-oriented

PROJECTS

Self-Driven:

- Assembled personal computer from the ground up
- Recreationally inspected Arduino and built several circuits
- Researching smart home sensor, to monitor the temperature, humidity, noise, and light level for any room

Course-Related:

- Put together and programmed motorized robot to navigate course
- Assembled Hydrogen/Solar powered toy car
- Designed and built Hoverboard
- Experimented with IC's to display different properties of AND/OR gates
- Created hydroponics system to grow plants in not ideal environment
- Assembled water filter out of natural products like rocks

EXPERIENCE

JUN 2021 – PRESENT

DCPAE ENGINEERING INTERN, INTEL CORPORATION, *FOLSOM, CA*

- Composed documentation to enable customers to use the most important Server CPU within the company
- Refined essential CAD schematics on electronic circuits
- Reviewed key design changes and briefed organization of said changes in presentation format

ACTIVITIES

- Member of CSUS IEEE
- Member of Mesa Engineering Program

Appendix G. Vendor Contacts

For the scope of the project there were no vendor contacts that were used. The project itself was fully funded and evenly distributed by the team.

The following are sites and stores we purchased from:

- Amazon
- DFRobot
- Digikey
- Green Thumb Hydroponics
- Home Depot
- Lowes