Polycrop Smart Drip Irrigation System

Team 17

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Hello Dr. Trombetta and to whom it may concern,

This report details our progress towards the completion of the Polycrop Smart Drip Irrigation System as of the middle of the Spring 2021 Semester. The objective for this semester is to complete the assembly of our system and verify the functionality through implementation in an outside environment.

In the following report, we will explain the purpose of our project, elaborate on the user analysis and product specifications, provide an overview diagram, detail the engineering specifications, explain our test plan, provide updates from our schedule and budget, and address our risk matrix and mitigation plans.

So far our team has developed plans on how to tackle the issues outlined by the previous teams, while also adding impactful updates to the system so that our smart-drip irrigation system helps the Nicaraguan farmers more effectively. The main feature of the design we seek to improve on is providing the capability of watering different types of crops, making our system a polycrop irrigation system.

In spite of the continuation of the pandemic, we are on track to deliver our finished product by the end of the Spring 2021 semester. Our team is thrilled to work on designing and producing this polycrop smart drip irrigation system. We are excited that our project will help farmers in Nicaragua!

Warm regards,
Team 17

Polycrop Smart Drip Irrigation System

Team 17

Third Progress Report

Presented to

The Department of Electrical and Computer Engineering

University of Houston

By

Diego Tolentino (Team Leader)- Applied Electromagnetics

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Project Manager: Dr. Steven Pei

Faculty Advisor: Dr. Leonard Trombetta

Sponsor: IEEE EDS, BioNica, and Universidad Nacional Agraria (UNA)

Purpose:

The purpose of this project is to provide an updated and improved smart drip irrigation system (SDIS) to low-income Nicaraguan farmers as part of a continuation project. The previous system is designed to irrigate a single type of crop - a monocrop system - while our team looks to design upgrades that will allow for the irrigation of multiple crops - a polycrop system - depending on soil moisture levels. Currently, the agricultural activity in Nicaragua accounts for roughly 17% of the nation's Gross Domestic Product with roughly 31% of the population being employed in the agricultural industry, and an estimated 24.9% of those people are living below the poverty line, meaning they are living with less than $3.20 per day [1][2][3]. The non-profit partnership of this project will look to provide economic and technological relief to farmers by providing a durable and easy-to-use irrigation system.

Overview Diagram:

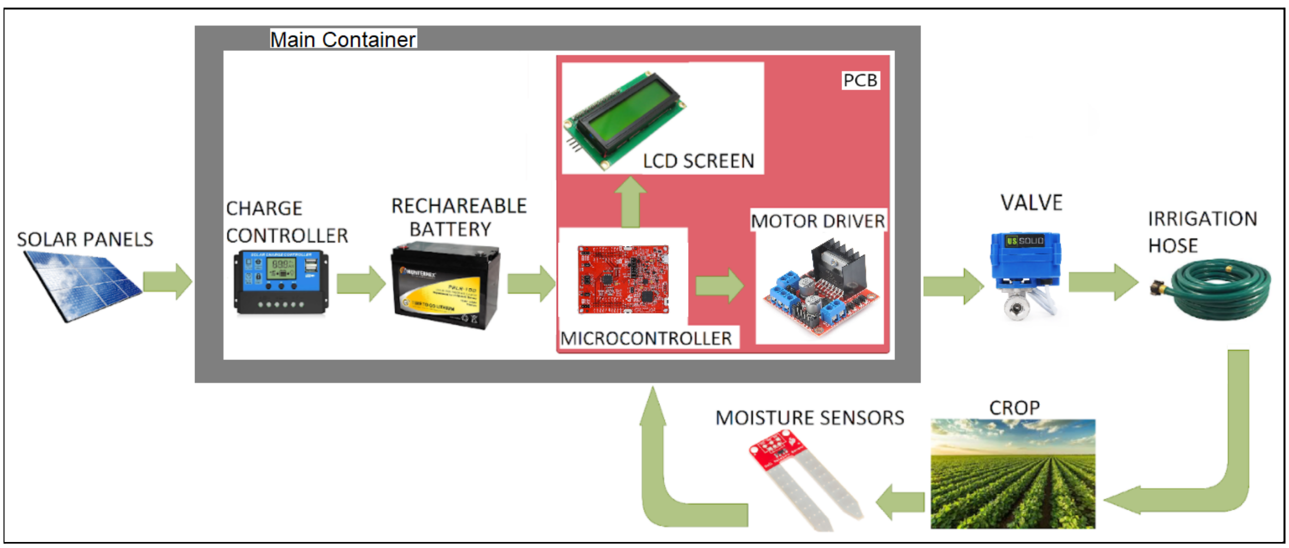

Figure 1. Overview diagram depicting how the Polycrop Smart Drip Irrigation System

Our system begins with the solar panels, which harness the solar energy and converts it into electrical energy. That is then inputted into the charge controller, which regulates the rate at which the electrical current is added or drawn from the battery. Our rechargeable lead-acid battery then provides voltage to the microcontroller, which functions as the brain of our system and is responsible for managing the status of the moisture sensors and opening and closing the valve.

The microcontroller will also control the entire irrigation process, control the LCD screen outputs, and will have different options for the farmers, allowing them to customize the smart-drip irrigation system. The LCD screen will be the way our system will communicate to the farmers. The motor driver will control the motor, so whenever the crops need water, the motor will turn the valve, which in return will give water to the system through an irrigation hose. Once the moisture sensor finds that the soil is no longer dry, it will give that feedback to the microcontroller, which will then tell the motor driver to turn the valve off. In order to protect our system from the harsh Nicaraguan climate, our team decided to keep our components in an IP67 rated container, with the capability of water and dust proof resistivity.

Patents and Standards:

Patents:

To ensure no intellectual property infringement with systems or processes intended to operate in a similar fashion to our proposed SDIS, the team evaluated the following patents. After careful consideration, a conclusion was derived that the system is not in violation of any patent law.

- S. . Bermudez Rodriguez, H. F. Hamann, L. Klein, and F. J. Marianno, “Automated Irrigation Control System,” 10 , 241 , 488 B2, 26-Mar-2019.
    - This patent by Bermudez, *et. al* seeks to use smart drip irrigation by taking into consideration the contrast of light for a designated crop. The system uses a photosensitive sensor to detect the contrast of light and send information to a central computer. After said data is collected the system then examines the

sensor's output and in addition to locally available weather information determines if the irrigation process should begin. Given our SDIS does not operate with either photosensitive sensors or a central computer, our proposed design is not in violation of Bermudez, *et. al* intellectual property.

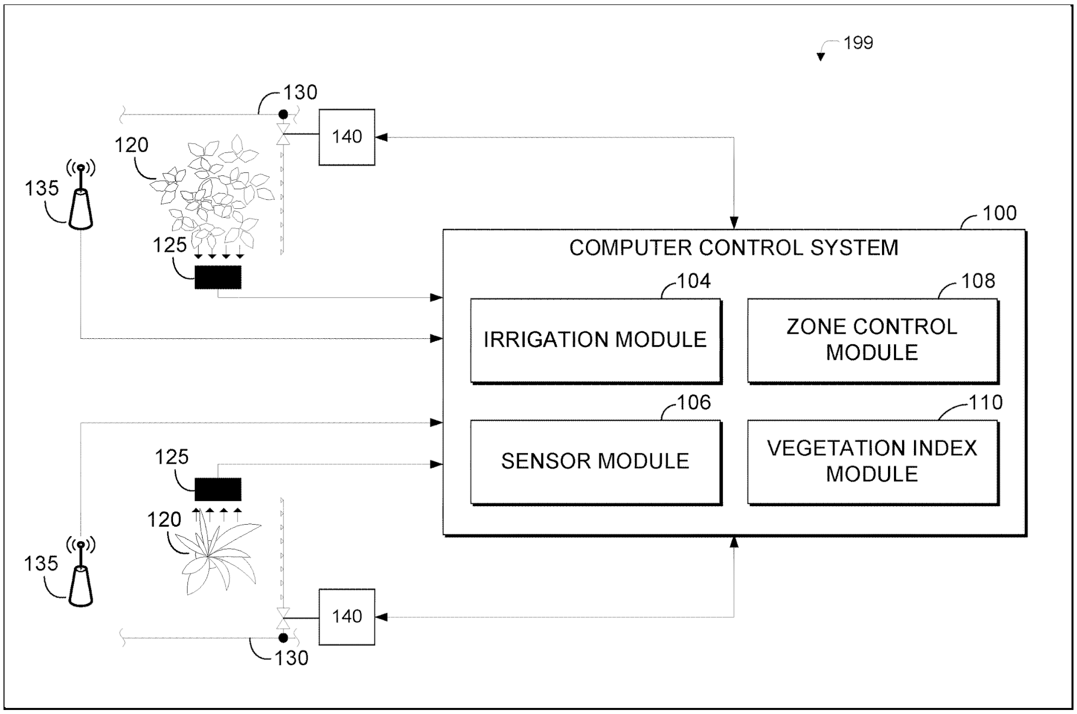

Figure 2(a): Irrigation system using photosensitivity sensors. [5]

- Richard W. Parod, C. H. M. (n.d.). "Solar Powered Irrigation Machine". *Patent No. 8517289B2. 9-28-2007*
    - This patent is for a mobile irrigation machine that waters crops as it slowly moves across a field. It also utilizes solar tracking to determine the times at which the machine is to turn on and begin irrigating. The approach for our project differs from this patent since we use our solar panels strictly for power, not for solar tracking. Furthermore, while our design uses a machine, it is valve operated rather than motor operated.

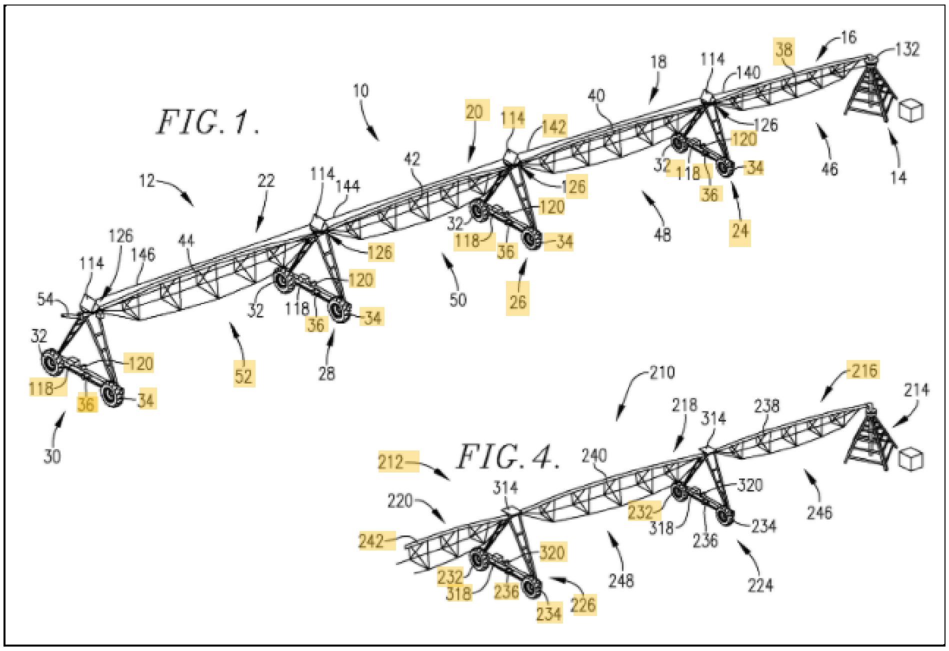

Figure 2(b): Solar Powered Irrigation Machine [6]

- Paul, M. F. (2020). “WATERTIGHT ELECTRICAL COMPARTMENT FOR USE IN IRRIGATION DEVICES AND METHODS OF USE,” 10,965,109, 30-Mar-2021.
    - This patent covers the creation of a water tight compartment to be used for an irrigation system. The purpose of this compartment is to have a watertight environment to house the various components that go into making an irrigation system. This system is designed to avoid the need to have AC power wiring to be run into it as the electronics held within are assumed to be wireless and have battery power within the enclosure. Although this patent is designed to improve automatic irrigation systems, we are not designing or building our own enclosure.
    - This patent also makes claims on certains methods used to make the compartment

watertight such as using O-rings and sealing caps in a certain manner. The patent also gives descriptions of how each compartment of the enclosure can be used such as the description of compartment 30 being able to be used to house wireless flow sensors.

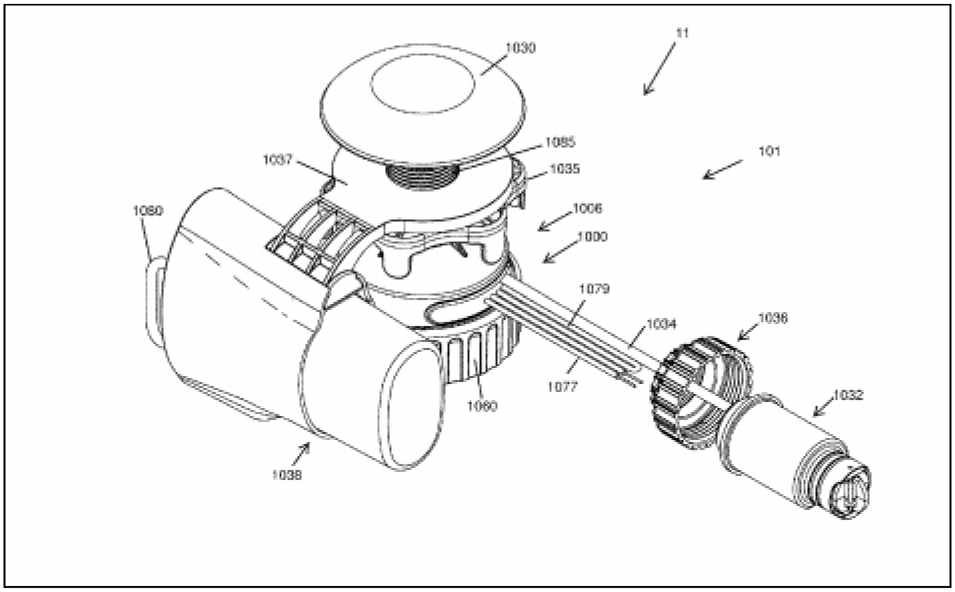

Figure 2(c): Patent #10,965,109 Drawing [7]

- D. Lankford, “Crop-specific Automated Irrigation and Nutrient Management,” 10,512,226 B2, 24-Dec-2019.
  - In this patented system the user is responsible for initiating the irrigation process after the system alerts the user of detected dry soil. In addition to user data, the system operates by taking into account geographical location and weather data to further determine if irrigation is needed at that time. Unlike Lankford’s system, our proposed design focuses on a completely automated irrigation based on soil moisture data and excluding local weather data. After evaluation, our proposed SDIS is not in violation of Lankford’s patent.

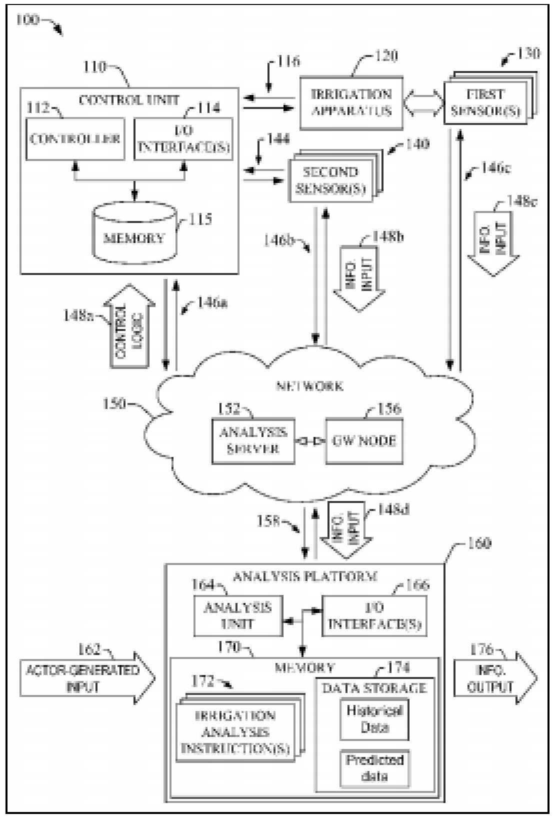

Figure 2(d): Patent #10,512,226 B2 Drawing [8]

Standards:

In compliance with industry and professional boards standards, we have consulted the following standards to be compliant with performance and data standards set by recognized institutions. The consulted standards for this system are as follows:

- IEEE Standard for Sensor Performance Parameter Definitions [9]
  - This IEEE standard sets the parameters and limitations for sensor performance. This standar assures the performance of humidity and moisture sensors across different disciplines. Furthermore, the aforementioned standard is specifically constructed for systems with an input/output (I/O) system. The proposed SDIS meets these standards as the capacitive sensors used operate within the minimum and maximum parameters of said standard.

- IPC J-STD-001**, "**Requirements for Soldered Electrical and Electronic Assemblies." [10]
    - Also known as the J-Standard, it covered the entire soldering process and the working environment to be performed in. The standard is important, particularly the guidelines for soldering through plated holes, since this is how connections are made on the PCB. It also details the effects of electrostatic discharge, which is crucial to understand since if we are not properly grounded before working on the electronic components in the PCB, could potentially damage them, rendering them inoperable.
- Recommended C Style and Coding Guidelines - Texas Instruments [11]
    - Standards created by Texas Instruments in 2013 for their C coding standards. These guidelines describe their preferred use of comments, formatting, and certain structuring of functions like "if" and "else" statements.
    - This document gives templates for function headers, file headers, and more to be able to give good descriptions on what your code is doing and how to use it. This is necessary as if the current code and data were to be passed onto another team they would be able to easily continue development of the code rather than having to spend time figuring out what each function or block of code does and test its application.
    - These standards reduce time used on unnecessary debugging and testing and allow for code to be easily updated since the programmer would know what to look for and where and make things much easier.
- IPC-2152 —Standard for PCB Trace Width [12]
    - This IPC Certified standard dictates what the Trace Width should be in regards to a PCB. Trace width is the width assigned for the connections of the PCB. Different operations require different currents, and the net width needs to accommodate these currents. For most smaller PCBs, like the one we are using, it is recommended to provide a 0.010" width. However, if there is more than .3A through the connection, the trace width should be larger. Most modern 3D CAD Softwares takes this into consideration automatically, such as the one used for the

PCB design.

Constraints:

Lack of Feedback Data:

The previous iteration of this project was intended to be fully assembled by an engineering team from the Universidad Nacional Agraria no later than October, 2020. However, due to the country experiencing two major hurricanes all efforts to assemble the system came to a halt until further notice. The new expected timeline for the assembly of the monocrop system is scheduled for February, 2021. As a result, no data on the previous system is available at this time thus resulting in our team being limited to the number of adjustments that can be carried out to further ensure the lifetime of the final system.

Unable to Establish Contact with UNA:

Through the previous months, our team has made several attempts to establish a proper communication channel with BioNica. However, all efforts have yielded unsuccessful results. Our faculty advisor has become our main point of communication between our sponsors and the team. We remain optimistic that proper communication will occur in the upcoming days to finalize the delivery timeline of this project.

Deliverables:

By the end of the semester we will have a fully operational Smart Drip Irrigation System. This system will have the ability to allow the user to select among predetermined saturation levels. If our saturation levels are not sufficient for the crop that is being grown in the plot of land, there will be a manual bypass that allows the user to open the valve and dispense more water. Our system will operate on 12 [V] DC which will be supplied by an array of solar panels which will be configured to have a voltage of 20 [V] DC. Our system will be housed in an IP67 rated enclosure. By that standard the enclosure will be waterproof, dustproof, and heat resistant which will allow it to survive the Nicaraguan weather since this system is to be operated outside. The electronics inside the container are rated to operate in temperature not to exceed 113°F, or 45°C, which is more than sufficient in the Nicaraguan environment. The system will have the ability to irrigate a maximum area of to 9 [m] x 16 [m] as this is the area of the plot of land the previous team installed in Nicaragua. Our system will periodically check if we need to open the valve every two hours currently, but this is subject to change as further testing continues. This contrasts what the previous team planned which was to water at night as that can cause a growth of mold on the crops. Our system will also have a new interface to display system information such as current saturation, current mode, and any errors occurring. This interface will consist of an LCD and buttons to make selections and display the mentioned system information.

Test Plan:

When the system is powered the user will be prompted to select the desired saturation level setting. This choice will be between a low, medium, and high level of saturation. Once the saturation point has been set the system will go into an idle state waiting for the moisture sensors to detect that the soil saturation is dry for our set saturation level. Once this occurs the microcontroller comes out of its idle state and starts the motor on the ball valve so that it will be in the open position. This will allow water to flow through the plumbing of the system and irrigate the crops. Once the sensors detect that the soil has reached the proper saturation threshold, the motor to the ball valve is triggered, closing the valve, and thus stopping the water from flowing. While this is occurring the LCD output will be displaying the saturation and current mode so that the user can ensure the system is working properly. Additionally, there will be a manual trigger that will open the ball valve should the system fail or if the highest saturation level is still not able to saturate the type of crop as needed.

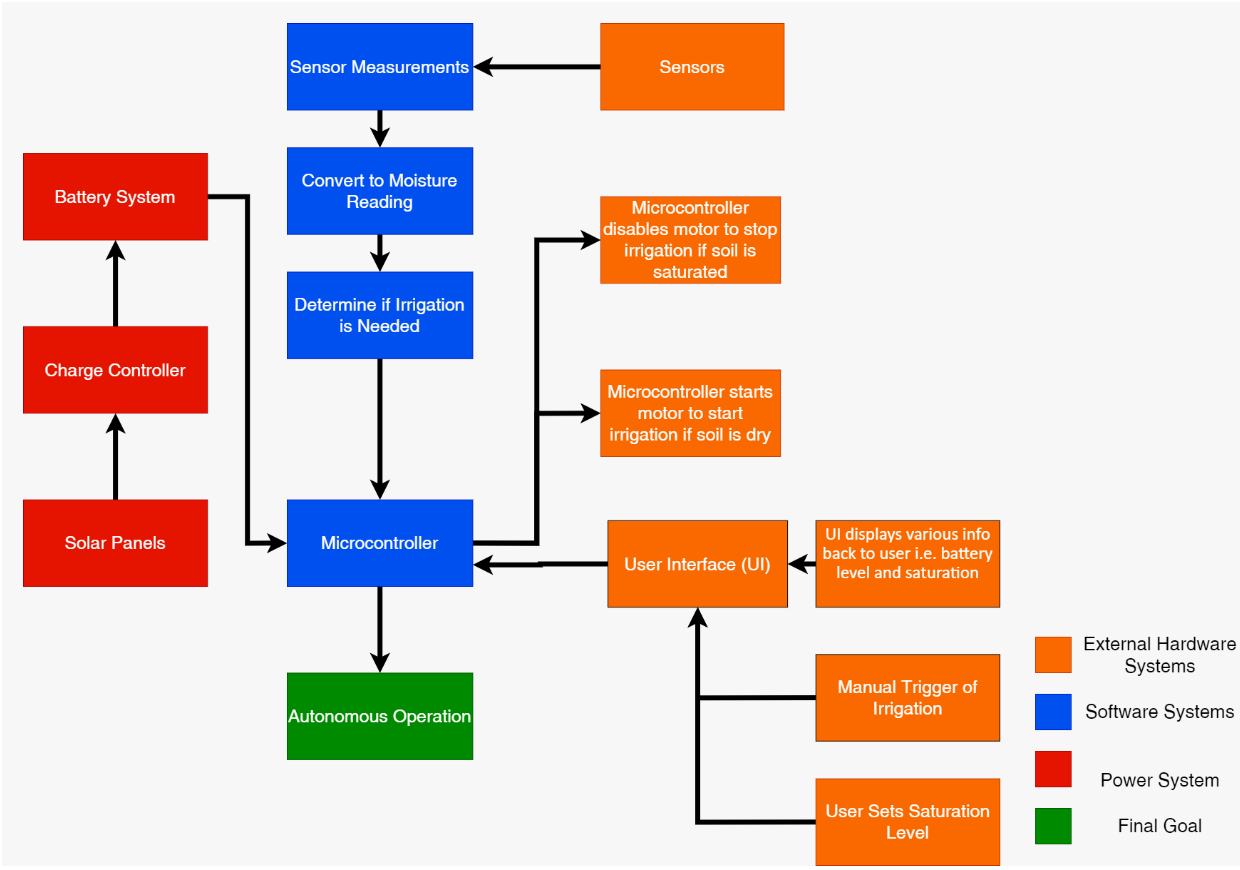

Figure 3: Goal Analysis Diagram

In order to analyze the goals of our deliverables, we need to explore the features and behaviors of our system. In this section of the report, we analyze the sections of the system that are measurable and observable. Further, we provide Table 1, which contains our parameters, target values and tolerances needed to validate the product specs and engineering specs, and a description of how the testing will be conducted. Table 1 describes the relation between the input of the moisture sensors and what is expected to be outputted to the user interface (UI) and activate or deactivate the motor depending on the saturation. We have also provided our test plan for the main components of our system to verify their functionality.

Table 1: LCD Output Dependent on Probe Voltage

Probe Voltage	Soil Status	LCD Message
0 - $V_{SAT\ LOW}$ V	Dry	“Under Saturated”
$V_{SAT\ LOW}$ - $V_{SAT\ HIGH}$ V	Sufficiently Saturated	“Saturated”
>$V_{SAT\ HIGH}$ V	Over Saturated	“Over Saturated”

Task 2.5-Moisture Sensors:

The sensors will be tested using three different soil samples that are representative of the soil conditions where the system is to be implemented. These soil samples were obtained from our project sponsor BioNica to accurately test the sensors and overall system. We will then attach the sensors to the microcontroller and take readings on test soil and output these readings to a computer terminal using a UART communication protocol. This will work with the user interface to test variable moisture settings. Different water levels will be added to each sample to attempt to replicate weather conditions.

Task 1.5-Printed Circuit Board (PCB) Connections:

In order to check if the connections of the PCB proper, we will have a two step plan. First, before ordering the physical PCB, we will run software simulations to check if the PCB will work as intended. EasyEDA, the software used to design the PCB, has a button which allows the software to run an analysis on the PCB. Once this analysis is complete, it will recommend any changes or incomplete connections it spots. After that, we can also check how the system will look in a 3D rendering. This is the time we can test if everything is good and as intended. Finally, once everything is complete and we order the designed PCB, we will commence physical testing. Using the lab at the University of Houston, we will send a voltage through connection paths using a bench power supply. Then, using the multimeter, we will measure the voltages and verify traces are pathed correctly. Once everything is functional, we will solder on the components. In case anything happens during testing, we will have duplicate PCBs as a precaution.

Task 2.3-Power Delivery:

Our power delivery system's functionality will be verified by connecting the battery and solar panels to the charge controller. The charge controller's user interface will display the voltages of each. While connected, the solar panels will be toggled from exposure to sunlight and darkness. Through observation, the charge controller should show that the solar panel voltage is displayed to match the voltage of the battery. The battery voltage will also be displayed on the charge controller, and should display an average of 12 [V] when connected.

Task 3.1-User Interface:

Our user interface consists of a Liquid Crystal Display (LCD) and three buttons that have certain functions like scrolling up/down and select. We will assemble the buttons and LCD and attempt printing various messages to the LCD and ensure that our buttons allow us to scroll up, scroll down, and make a selection. We will ensure that when a selection of the saturation level is made in the interface that it is properly adjusted within the microcontroller and the saturation points are adjusted as well.

Task 3-Assembled System:

Once the system is fully assembled, the team will first verify the functionality of the ball valve by activating the system while the moisture sensor is dry. This should prompt the ball valve to open, which would allow water to flow through and irrigate the crops. The moisture sensor would then be dipped in water, shutting off power to the ball valve and closing it. For a final test, the design will be installed at a member's house and tested in a 4 [ft] x 10 [ft] garden.

Schedule:

Table 2 depicts the intended schedule based on the Fall 2020 semester predictions. However, due to some circumstances our project schedule has changed from our first proposed schedule. Part of the code needed to test proper communication with the sensors is currently not yielding the proper output and therefore adjustments need to be made. Furthermore, because more sensors are going to be added prior than intended, the team will need to reassess how the wiring that will lead connect back to the main enclosure. Although the team has been delayed in some parts, progress and an early start has been made in other areas. These areas include the design of the PCB board, code to output the system's message and warning to the users, and early developments on the user manual. Together, these changes are reflected in the schedule, which can be seen in Figure 4.

Table 2: Proposed schedule during Fall 2020.

Assignment	Due Date	Assigned Member
Phase 1: Research		
Analysis Written Report	September 18th, 2020	All
Oral Reort	October 1st, 2020	All
Individual Written Report	October 9th, 2020	All
Previous Team Meeting	October 15th, 2020	All
Sensor Research	October 16th, 2020	Diego
Power Unit Research	October 16th, 2020	Vedant & Josh
Protective Casing Research	October 16th, 2020	Vedant
Microcontroller Research	October 16th, 2020	Victor
Budget Proposal	October 22nd, 2020	All
Design Written Report	October 23rd, 2020	All
Contact Nicaruguan Team/Sponsors	October 26th, 2020	Diego
Duo Presentation (Team 1)	October 29th, 2020	Vedant & Victor
Individual Evaluation Report	November 6th, 2020	All
Duo Presentation (Team 2)	November 19th, 2020	Victor and Diego
Final Individual Written Report	November 20th, 2020	All
Phase 2: Building and Testing		
Order Parts	January 15th, 2021	All
Minimal User Interfance	January 29th, 2021	Victor
Build/Test Solar Panel System	February 1st, 2021	Vedant & Josh
Complete User Interface	February 26th, 2021	Victor
Complete Polycrop Code	February 17th, 2021	Victor
Integrated Power Supply	March 10th, 2021	Josh and Vedant
Print 3D Casings	March 10th, 2021	Vedant
Complete System Assembly	March 20th, 2021	All
Phase 3: Documentation & Shipping		
3D Models	March 21st, 2021	Vedant
Write Assembly Manual (English and Spanish)	March 24th, 2021	Diego & Victor
Complete Propotype	March 31st, 2021	All
Ship tp Nicaragua	April 1st, 2021	Diego

The current schedule of the project can best be represented by the Gantt Chart below. This chart focuses on the second and third phases of our project - the assembly and testing phase. Currently, we are at week 33 of our project with more tasks than anticipated being completed before the intended deadlines. The team will focus on finalizing the electrical wiring, 3D printed enclosures, and sensor testing. With this task outstanding, the is projected to finish the complete system testing and assembling phases earlier than the proposed dates.

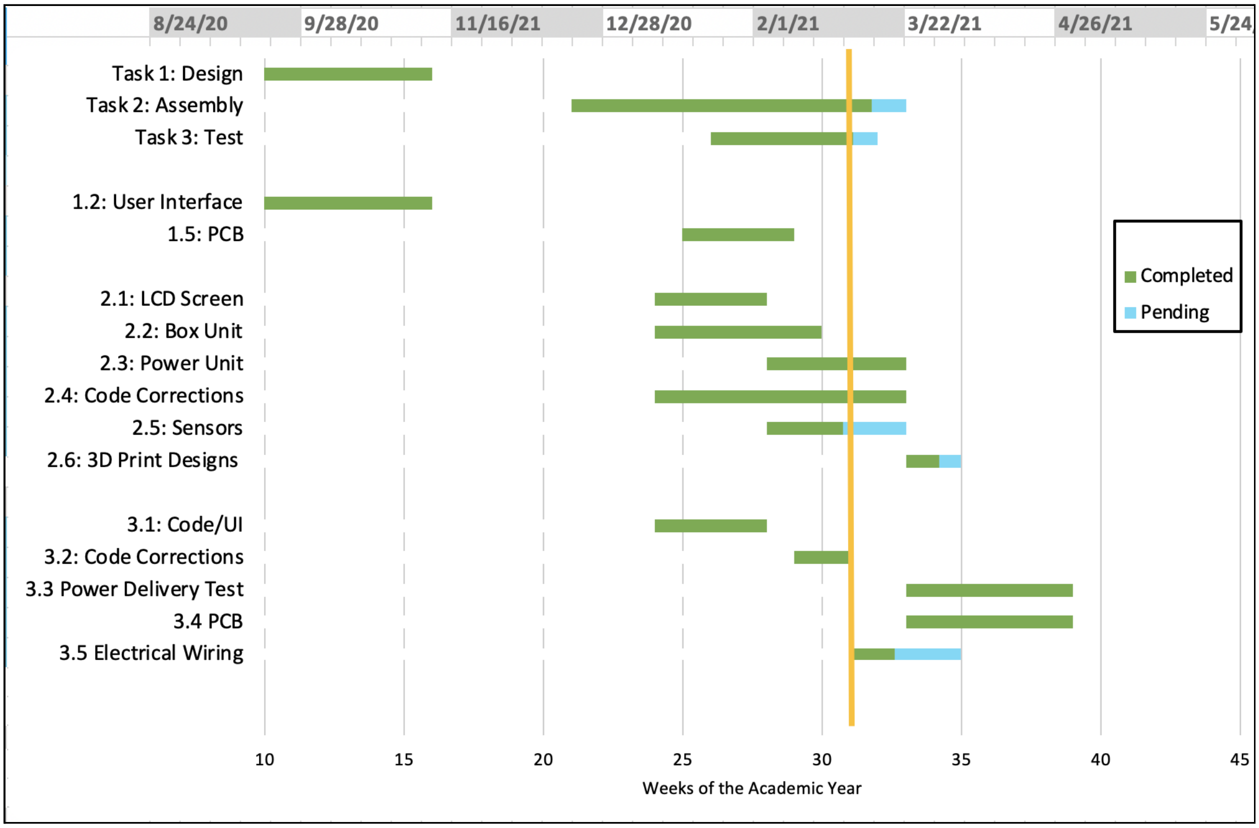

Figure 4: Schedule with completion and progress of tasks.

Task Updates:

With the time that has passed, the control system for our device is complete. The controls system gives the ball valve an opportunity to open every two hours if conditions are met. We monitor six soil sensors and once four of the sensors are detected as being dry then we queue our valve waiting for the next two hour cycle to begin irrigation. Once our sensors have been satisfied the valve is closed and irrigation is stopped. Now that all software has been completed we can finish assembly and begin testing our full system soon. In the testing phase we will determine our tolerances for measurements and check for any bugs. We will also have the opportunity to adjust our saturation levels should we determine that there needs to be any adjustments.

Task 2.3: Power Unit

The power delivery system has been assembled and wired correctly. The solar panels were set out in cloudy weather conditions and read an output of 19 [V], which is more than sufficient for our system, as it needs to charge a 12 [V] battery. The solar panels, battery, and charge controller were then connected together to test, and the charge controller utilized voltage regulation to match the voltage from the solar panels to the voltage of the battery. This verifies that the solar panels were properly charging the batteries, through the charge controller.

Task 2.6: 3D Designs

Our team has completed the 3D design for the Battery Platform. Our team decided to contain the battery in a custom 3D printed platform so that we can hold the battery in place. It will also allow mounting the battery to the back panel of the main container.A lip was added to keep the battery from slipping, and zip-ties will hold the battery in place. Using TinkerCad, the Battery Platform design was completed. The 3D model was then 3D printed using PLA plastics. Our resulting printed platform has a slight deformity, but it still functions correctly.

Our team also decided to make a Shield to hold our delicate, interactive components in place — charge controller, LCD screen, buttons, trigger, and potentiometer. We needed this Shield as it also helps make the layout of our interactive components for the user. Further, this Shield will cover our PCB while also hiding the wiring so that it remains protected from outside influences. The 3D designing aspect of this build is done, and our team is in the process of printing the design.

Task 3.4: PCB Testing

In order to test the integrity of our PCB, our team conducted a test to check the terminals. By doing this, our team could decide if every component in the PCB was connected properly. Using the ohmmeter at the electronics lab, we checked if the measured resistance was approximately resources. If the measured resistance was approximately 0, we know that the connection is clear and ready to use. Everything is perfectly connected, and is ready for use.

Risk Matrix and Mitigation Plans

Below are Figures depicting our risk matrix and our mitigation plans. On our risk matrix we can see Tasks 1.2, 1.5, 2.1-2.3, 2.4, 2.5, and 3.4. Task 1.2:User Interface Design, because of where we are in the project design the likelihood of this having a malfunction is low as it has been tested with test code and seems to be working. Though if we were unable to get a UI designed properly it would mean that we would be losing lots of the additions we aimed to add like the ability to set saturation modes and display system info. Task 1.5: PCB Design, is a medium risk task because if we were unable to design and create our PCB then we would lose the goal of making more permanent and secure connections but we would be able to work around this by using protoboard. Tasks 2.1-2.3:LCD, Box Unit, and Sensor Assembly, are high risk tasks as if we are unable to connect these systems together then we would lose most of our system functionality. The likelihood that this occurs is not too high but if it does it would be devastating to our project. Task 2.4: Code Corrections: this task is a medium risk task as if an error does occur our system would not operate properly as this system manages the sensor readings, UI, and ball valve. The probability is low that this occurs as we are building off the code from the previous group which had an operational system. Furthermore, Task 2.5: Sensors is identified as a risk since obtaining wrong results from testing the moisture sensors will cause improper irrigation when is not needed. Failure in sensor testing is categorized as a high and probable risk because it will show that the main purpose of the system to irrigate on soil moisture readings has not been met. To overcome this obstacle, we will test all sensors independently with different level of water content in the soil to ensure that the output generated from the sensors are reflective if there is a need to irrigate or not.Task 3.4: Electrical Wiring:, is a high risk task as this task is essential to deliver power to our system and without power nothing would operate, the likelihood of this occurring is low as we are not completely redesigning the power system but rather improving it.

Furthermore, with the current completion of task denoted above in Figure 4, the completed tasks are denoted with a grey circle on the bottom right hand corner of the completed task cell. Properly finishing these tasks on time, have allowed for the team to carry on with the project ahead of schedule without needing to overcome delays caused by failures due to equipment or component failures.

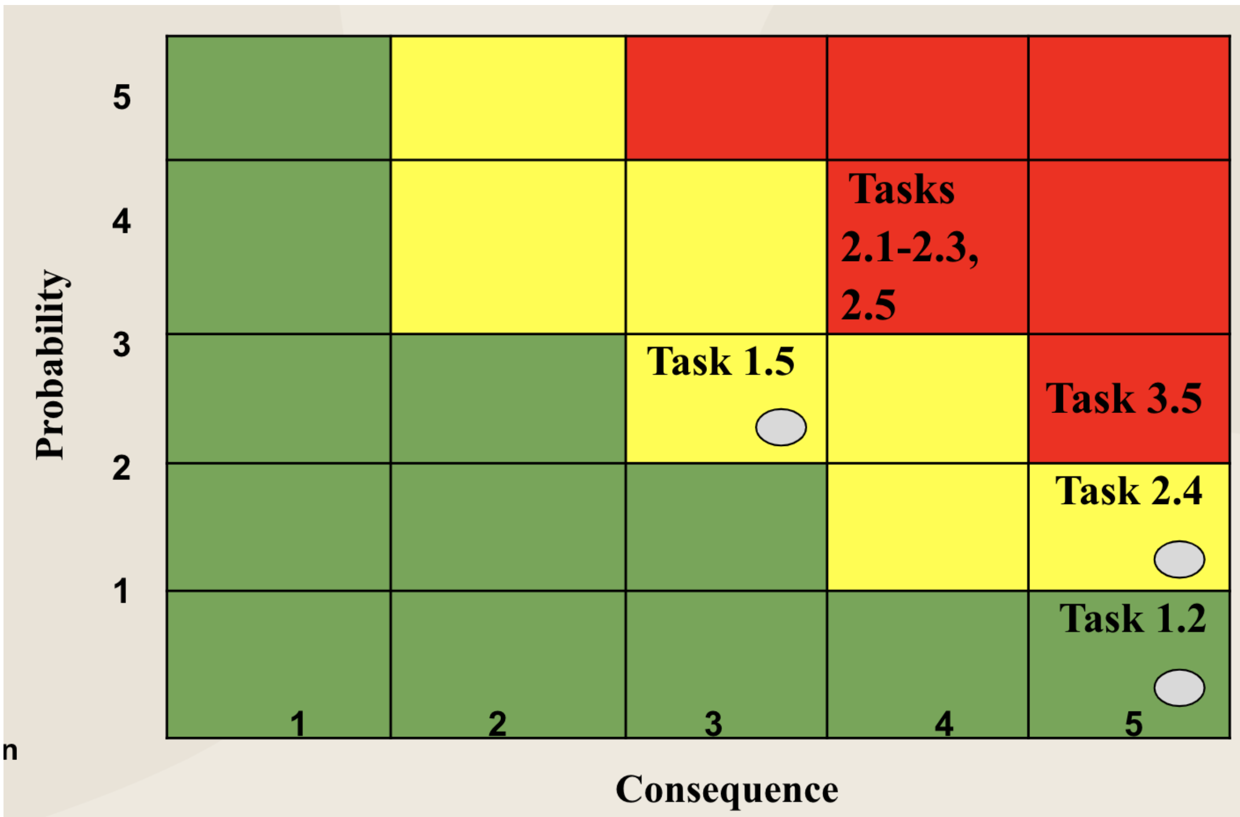

Figure 5: Risk matrix for project design tasks

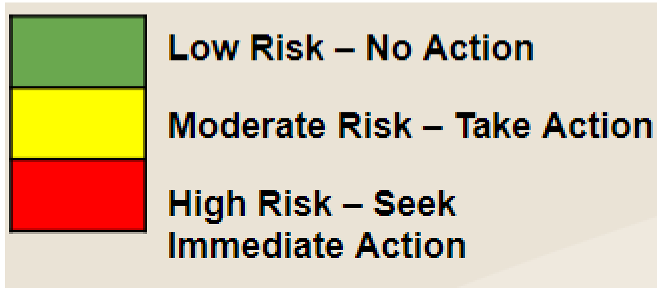

Figure 6: Risk matrix legend

Table 3 below highlights the mitigations plans for the tasks specified in the Risk Matrix.

Table 3: Mitigation plan for potential risks

Task	Identified Risk(s)	Mitigation Plan
#2.1-2.3, 2.5 System Assembly	Error made during assembly of the system	• Handle Components Carefully • Store in a safe area
#2.4 Original Code Edits	Improper System Operation	• Redesign system operation • Reduce number of sensors • Remove time constraints on system
#1.5 PCB Design	Improper Connections made during design phase	• Create Connections on piece of perf board • Connections will not be as robust, but will be more reliable than jumper cables
#3.4 Electrical Wiring	Faulty wiring connections made during assembly phase	• Follow PCB Schematic • Troubleshoot system step by step to find errors

Budget:

For this project, we've set the budget to be $325. From the time of the last report, mounting materials and connectors have been purchased, totaling our amount spent to $389.34. All hardware for the project has been purchased, and our only future expenditures will be the invoice for 3D printing materials. Observing Figure 3 below, our team has gone over budget with our project, and so future expenditures will be donated through our team members. However, our faculty advisor, Dr. Trombetta, has informed us that a proposal has been issued to IEEE to get more funding in support of future projects with Bionica, and if approved, would allow us to delegate more funding to improve the infrastructure of our design.

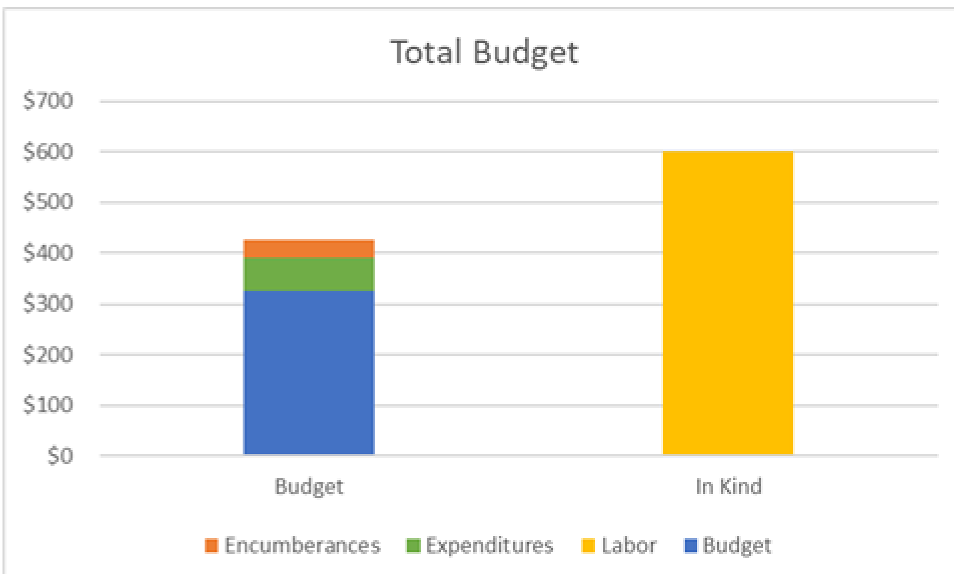

Figure 7. Current Expenditures and Total Budget

Conclusion:

We, Team 17, the Polycrop Smart-Drip Irrigation team, are on track for completing the project by the end of the 2021 Spring semester. So far, we have accomplished creating an appealing design with important upgrades, purchased parts, completed most of the programming, and most of the PCB design. After carefully considering our schedule and current expenditures, we have decided to move on and build the physical system. Further, we also have arranged a lab bench so that we can test our system and have arranged multiple tests to ensure our system works. Due to the current COVID-19 pandemic, our team will have issues with meeting up in person, but we are successfully getting important work done with frequent Microsoft Team calls. Our goal is to have our system work perfectly, in spite of the restrictions placed on us. With our combined teamwork, we are excited to build an excellent smart-drip irrigation system and help improve Nicaraguan farmers' lives.

Sources:

[1] *Worldbank.org*. [Online]. Available: http://documents1.worldbank.org/curated/en/532131485440242670/pdf/102989-WP-P152101-Box394848B-OUO-9.pdf. [Accessed: 08-Dec-2020].

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[4] Maloney, I., Woelfel, C., Lawal, A. and Serrano, C., 2020. SMART DRIP IRRIGATION.

[5] S. . Bermudez Rodriguez, H. F. . Hamann, L. Klein, and F. J. . Marianno, "Automated Irrigation Control System," 10 , 241 , 488 B2, 26-Mar-2019.

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<u>Appendix A:</u>

Design Specifications

Table AA: Critical Voltage Thresholds

Saturation Mode	**High**	**Medium**	**Low**	**Manual Trigger**
Irrigation Needed Voltage	1.61 [V]	2.25 [V]	3.22 [V]	**None**
Satisfied Voltage	0.966 [V]	1.61 [V]	2.25 [V]	**None**
Tolerance	+- 0.1 [V]	+- 0.1 [V]	+- 0.1 [V]	**None**

Improvement From Previous Group

Table AB: Improvements From Previous Group

Previous Group	**Our Group**
Single Crop Design	Polycrop Design
One Moisture Sensor	Six Moisture Sensors
Loose Wiring	Printed Circuit Board
Used LEDs to Communicate	Using LCD Screen to Communicate
Three Solar Panels	Four Solar Panels
IP65 Container	IP67 Container
Normal User Manual	Video User Manual

System Diagram

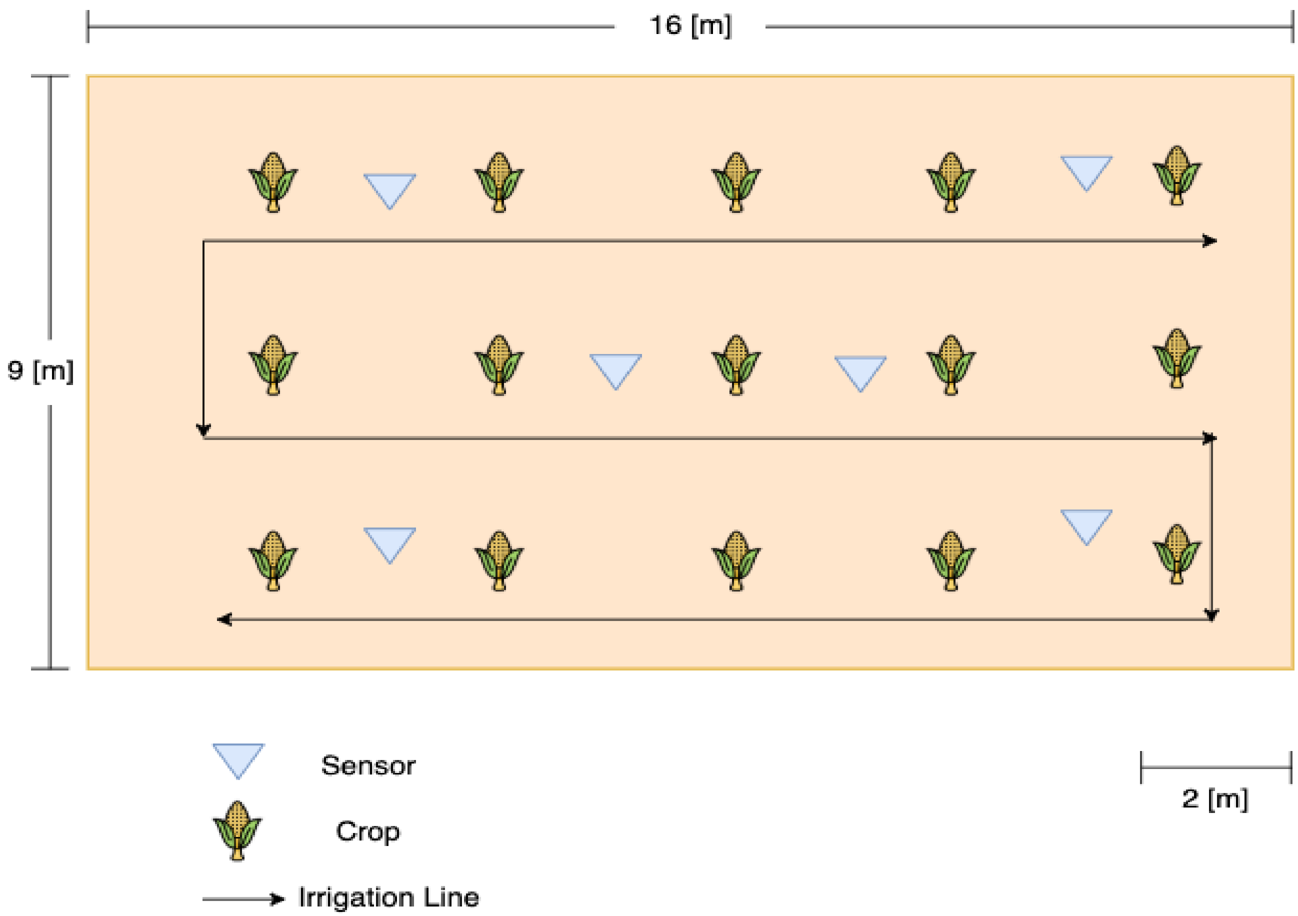


Figure AA: Diagram of Sensor Placements

PCB Design

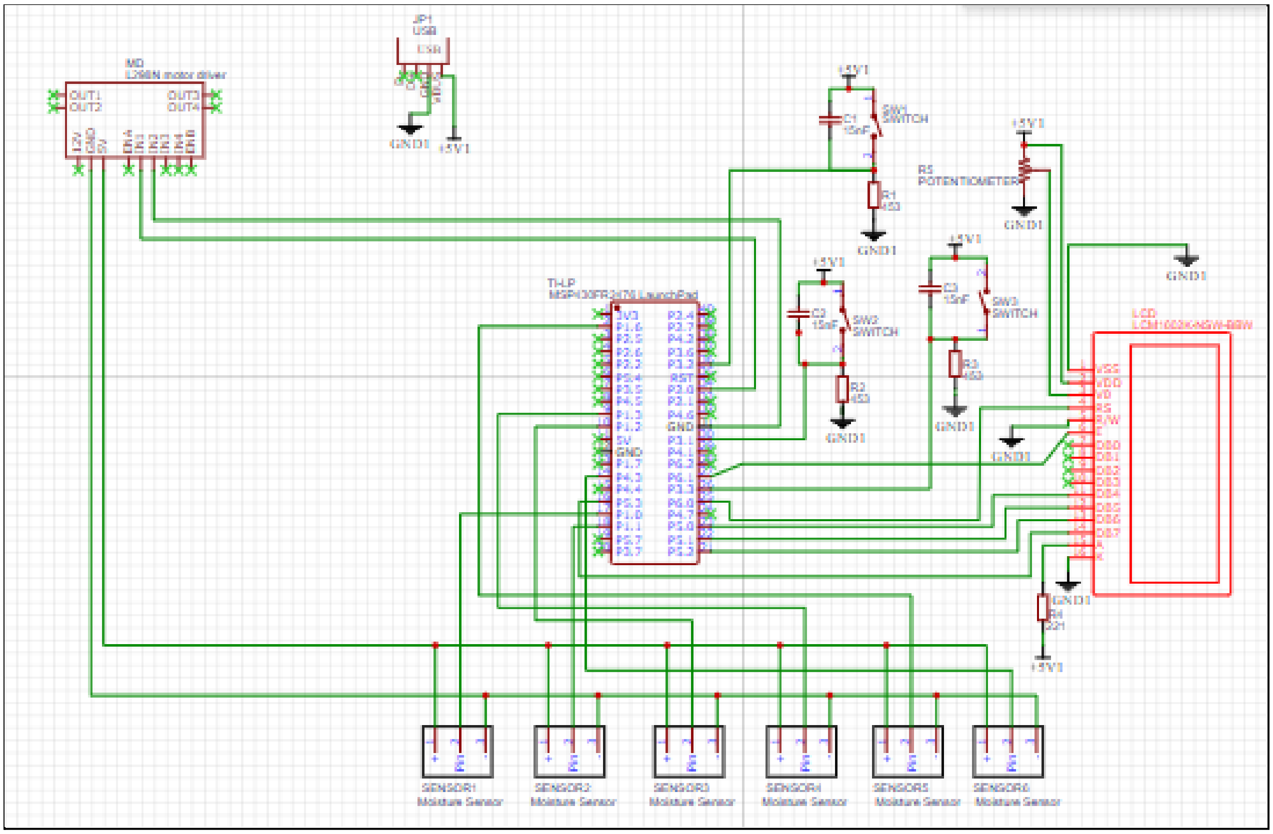


Figure AB: PCB Design Schematic

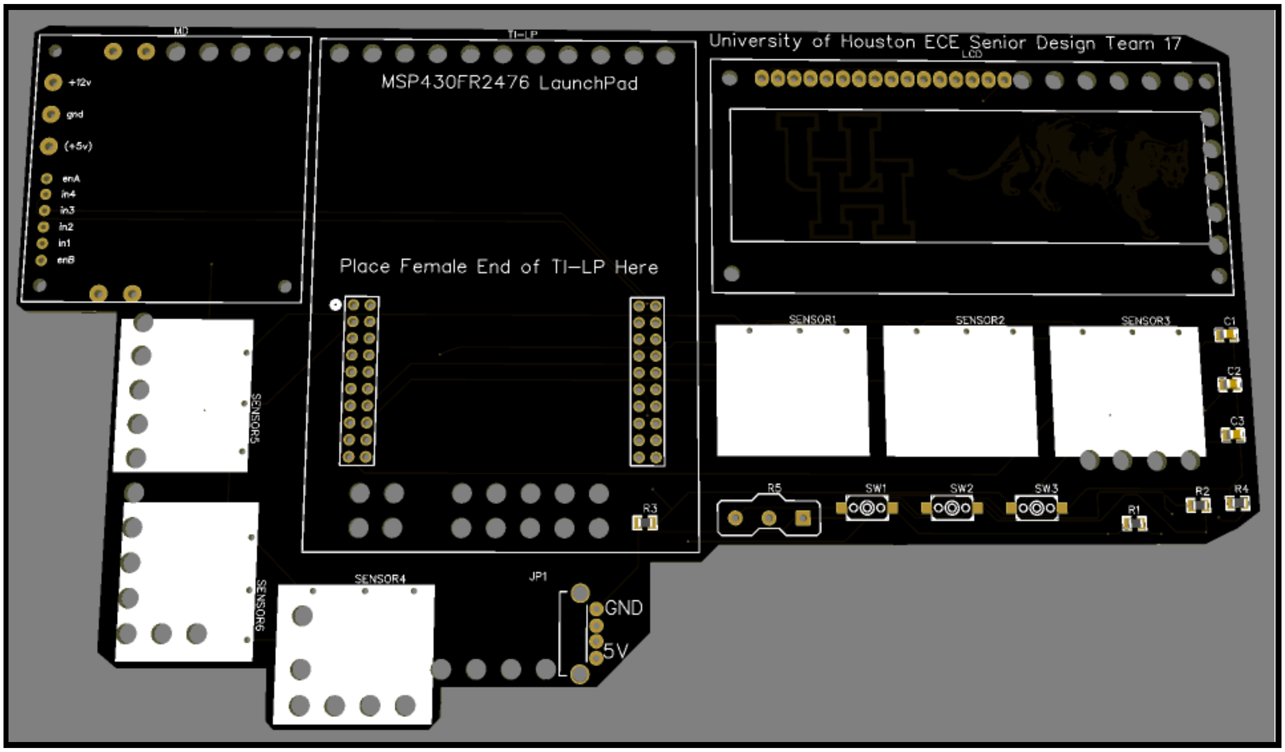


Figure AC: Final PCB Design

<u>3D Design for Battery Platform</u>:

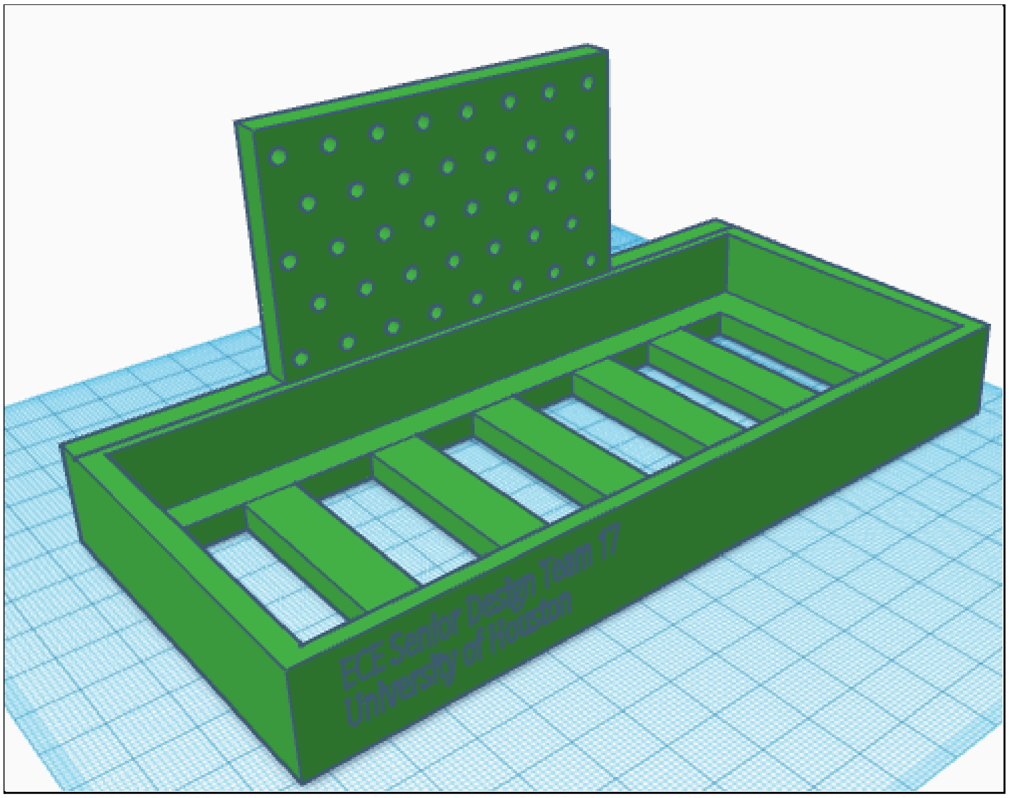


Figure AD: Battery Platform

3D Design for Shield Platform:

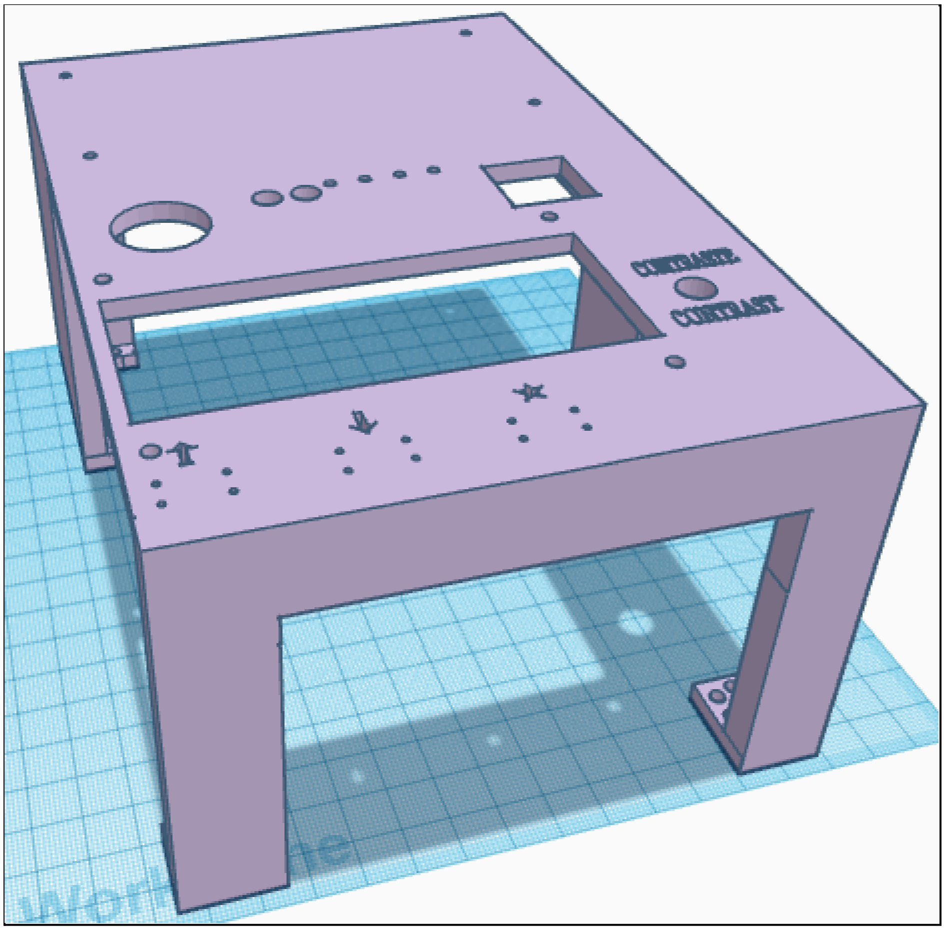


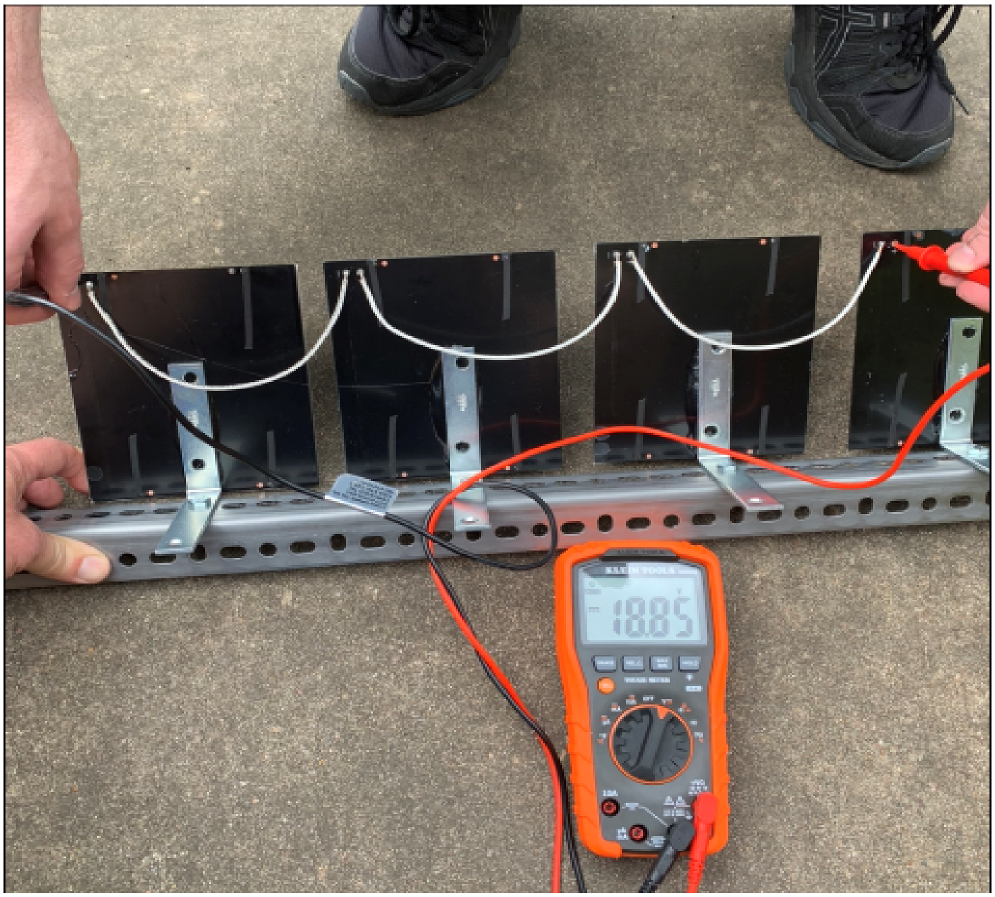
Figure AE: Shield Platform

<u>Appendix B:</u>

Testing references

<u>Power Delivery System:</u>

Solar Panels:



Materials:
-soldering wire
-epoxy for hardware
18-gauge wire
#8 ½” screws

Directions:
-mount the solar panels on the rail using screws and epoxy
Solder the panels in series, from the positive to negative terminals
(more detailed assembly processes will be covered in the final report)