Soil Analyzer

ECE 445 Design Document

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1 Introduction

1.1 Objective

Throughout the last century, small farms have become far and few between, while corporate farms seem to continue to grow larger and larger[3]. The United States average farm acreage is 444 acres[13], but there are hundreds of farms that are triple this acerage. In addition to farms covering large amounts of land, they are all very unique. Farms can be placed in areas where there is either ample or limited amounts of water[8]. With such a large area to manage, there is no possible way for a farmer to know the condition of their entire field. With constant monitoring of soil moisture, a farmer can keep their crop at an effective moisture level. This prevents over watering, and can help conserve water in places where water usage is limited, which is important, especially since agriculture is responsible for 80-90% [11]of freshwater usage.

Our goal is to boost farming effectiveness, reduce water waste, and ensure that crops survive during uncertain weather patterns. We plan to first prove that it is possible to establish an array of devices throughout a field to record soil quality, and then communicate this data to a central hub to be analyzed. We initially hope to accomplish this with simple moisture sensors which will collect water content measurements of the soil. If we can accomplish having this very simple data collected and then analyzed, we hope that our design can be furthered by modularly adding more expensive and complex sensors to collect various other soil quality analytics.

1.2 Background/Visual Aid

An agriculture company called 360 Yield Center has created “360 SOILSCAN” [1], a device which can be fit in the back of a pickup truck. The soil samples then have to be collected by hand and then brought to the device in the truck to be tested. A very similar device, has also been made by Agrocares[2]. This device is instead handheld and requires the user to scan each quadrant of their field to test soil quality. Although these have all the expensive soil testing sensors, they don’t eliminate the hassle of checking soil quality throughout an entire field. It still requires the farmer to perform the laborious task of going into the field and checking every quadrant of land for its soil contents. This would have to be done every time the farmer would like their field soil quality surveyed.

Our device would ensure that no matter the size of the farm, or where these farms are located, it would enable the farmer to always have an idea of the soil moisture level. With this information, they could then make appropriate decisions for their field, whether that would be adding more nutrients to a certain quadrant, or adding an exact amount of water.

In Figure 1, you can see our vision for this device. We hope to have it be evenly spread into fields. From there we hope to establish a simple hub to receive data at a remote location the farmer can choose. These devices aren't intended to be too large so that deployment and collection, when necessary, is very easy. This would also facilitate ease of replacing devices for repair

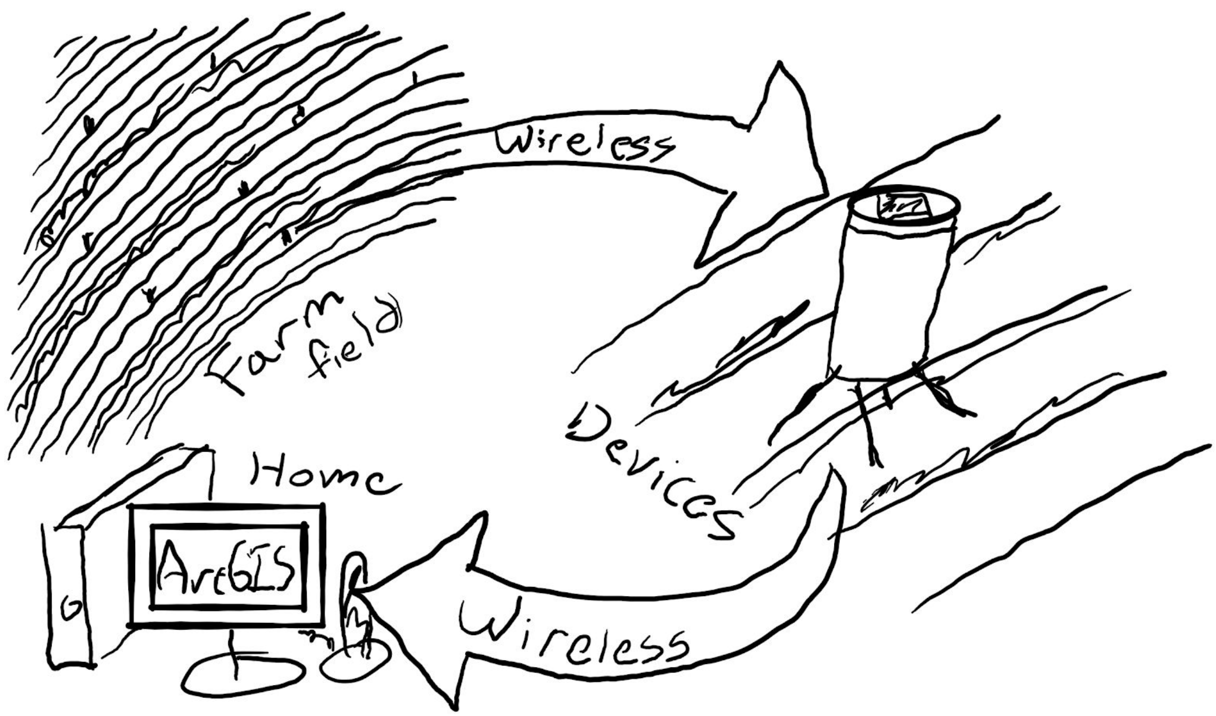

Figure 1.

1.3 High-Level Requirements

- The system will be able to communicate wirelessly either as a relay system through 3 separate nodes or directly to the main hub.

- Each node must have a minimum data broadcast range of at least 5ft.

- Each individual node will be able to be powered on at any moment from a battery large enough to store adequate charge for 24hr — recharged daily by solar panels.

- Soil moisture sensors will be able to differentiate between 3 different moisture levels: Dry, Moist, and Saturated.

2 Design

To have a fully functioning design, we have separated our design into five sections: a power supply, a control unit, a RF communicator, moisture sensors, and a hub. Our power supply should be able to provide a continuous 3.3V to our devices during their standby and data collection modes. The control unit will be able to manage sensor data, data transfer, and 32GB of memory storage. The RF module will be able to send and receive data using RF signals to transmit data radially at least 5ft. Data should be able to be transferred at about .04Mbps. The moisture sensor should be able to record real time data from the soil at least once a day and report it to the control unit. We will be creating three of these devices, and placing them a distance of up to 5 feet away from each other. The hub will be placed within 5 feet of one of these devices. The hub will be equipped with its own RF receiver, and will be able to collate the data into an ArcGIS map.

2.1 Block Diagram

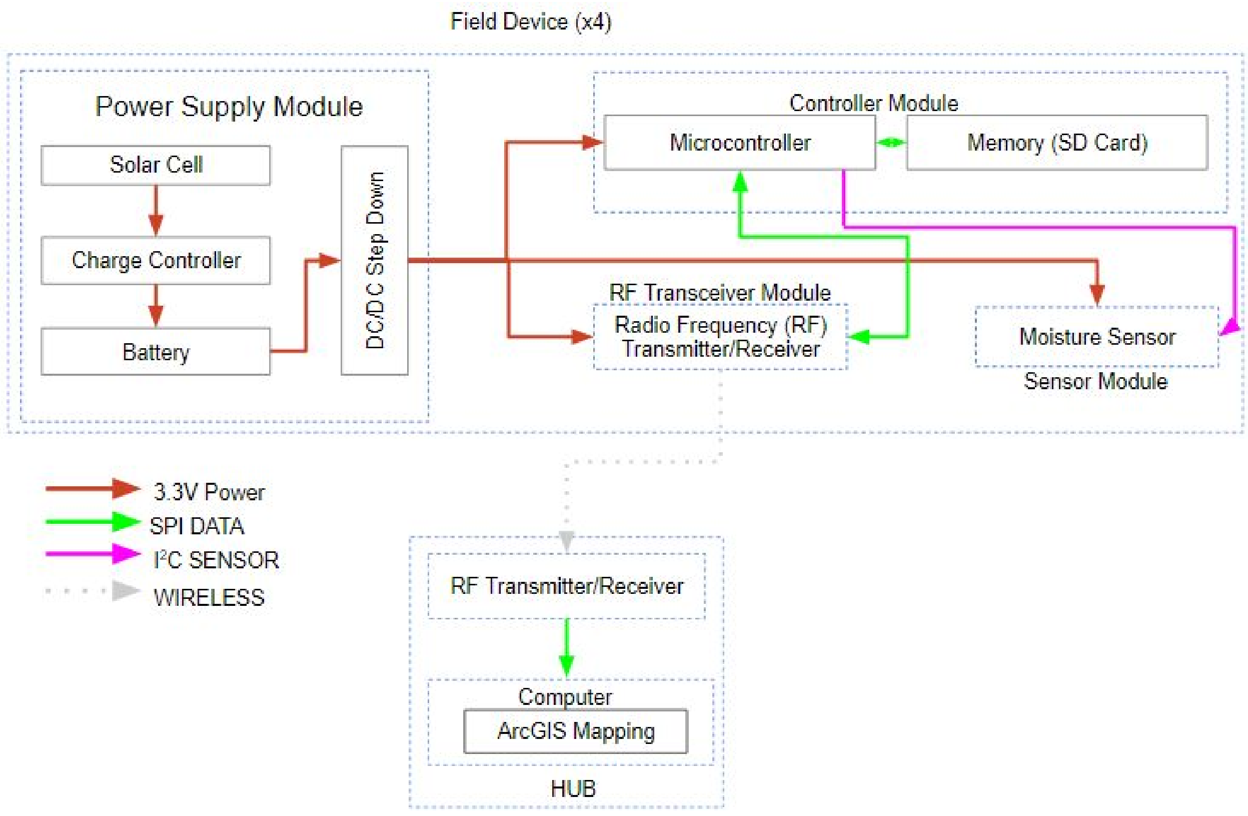

Figure 2.

2.2 Physical Design:

In figure 3 you can see our vision for our physical design. It will have all electronics encased in a waterproof tube. The solar panels will be underneath a clear waterproof layer of plastic at the top of the tube. The bottom of the waterproof tube will have a three legs that will be inserted into the dirt to hold the device upright. The moisture sensor will be placed in the center of the bottom of the device.

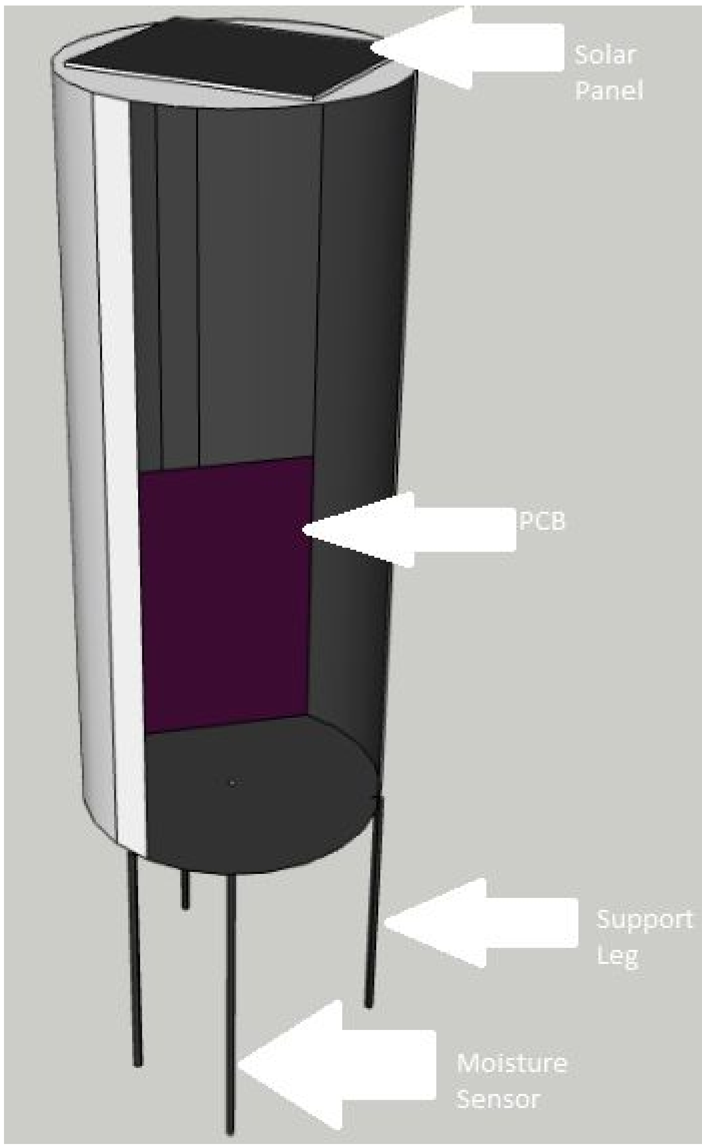

Figure 3.

2.3.1 Power Supply

The power supply will provide each individual node with ~3Volts through a power rail that will be accessed by all other modules within the design. To accomplish this, a solar panel will collect energy from the sun, and pass it onto a battery charging controller at 5V. The charge controller will accept this voltage and charge the battery safely, while using a maximum power point tracking controller to optimize power from the solar panel. The rechargeable battery must be large enough to provide power to the circuit even when the solar panels are unable to collect energy from the sun. To transfer power from our batteries, a DC-DC step down converter will be used to sufficiently supply ~3 volts of power to the rest of our circuit at ~500mA.This stepped down voltage must be available 24/7 in order to supplement other modules of each node.

Requirement	Verifications
1. Batteries provided charge by solar power 2. Provides enough battery power to run device in 12 hour periods of darkness 3. Provides ~500mA at ~3V.	1. Measure output power from charge controller to battery to ensure 5V are being output to battery 2. Discharge batteries for 12 hours after being charged by solar panel 3. a. Measure open-circuit voltage after step down, must be within 5% of 3V b. Measure current with ammeter after the step down circuit, must be at least 500mA.

2.3.2 Control Unit

The control unit is in charge of handling the overall protocols for each of our soil analyzer nodes. With a microcontroller, the control unit will communicate with the soil-moisture sensor using the I^2C serial protocol. This communication includes both receiving moisture levels from the soil moisture sensor and sending a control signal to the sensor to initiate a power saving deep sleep. The control unit will also be using the SPI synchronous serial communication interface to successfully store and transmit data within and between nodes. With SPI, our control unit will be able to store data from both the soil moisture sensor and RF receiver onto an SD Card. Within each of our SD cards, the nodes geographical location will be pre programmed upon installation. To complete the communication array, the control unit will use the same SPI to pull data from the Secure Digital Card and transmit the data through our RF Transceiver Module.

Requirement	Verification
1. Must be I^2C compatible with a SCL of 100kHz 2. Must be able to receive and transmit data at ~.01Mbps through SPI protocol 3. Must be able to analyze sensor data, and categorize its state based on data collected.	1. Use oscilloscope to measure SCL off microcontroller 2. We will use a Tektronix MDO Demo 1 Board to break out the SPI signals and verify if the data transmitted and received from the microcontroller can run at ~.01Mbps. 3. Verify that the state stored in the SD card matches that of the current soil condition.

2.3.3 RF Transceiver Module

Data will be sent between devices and the hub by using RF signals. It will be used to make an array out of the devices so that the devices can be spread out across a field to maximize data collection. Will extend the effective range of each transceiver to accomplish the necessary 5ft minimum. Data will be sent between devices and the hub by using RF signals. The devices will be spread across a field to maximize data collection. Be able to receive and transmit ~1GB of data that contain moisture levels and position. It should also be able to receive and send data at the same time. This chip will control the data communication, and memory access of this device. We would also like to have it responsible for accessing the data output of the probe.

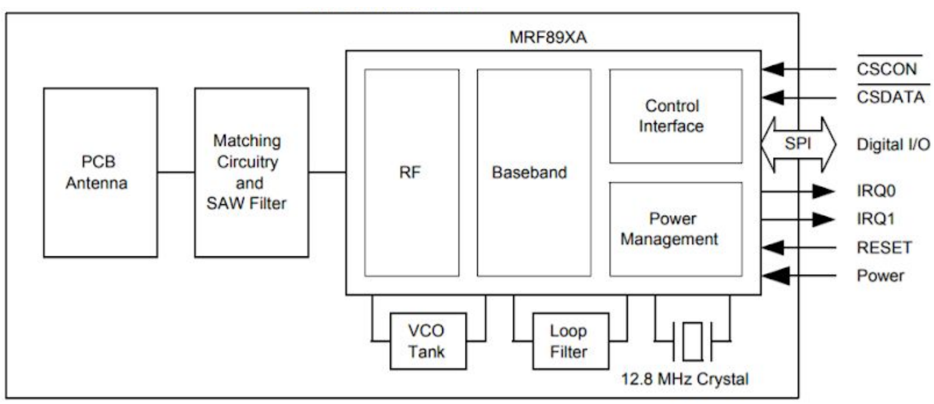

Figure 4:RF Module Block Diagram

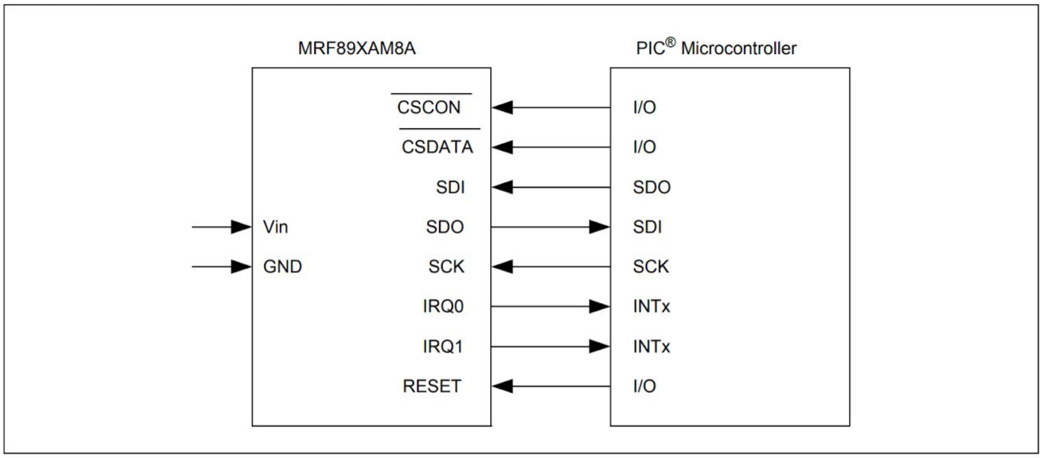

Figure 5:Microcontroller to RF Module Interface

Requirement	Verification
1. Must be able to transmit and receive data at .01Mbps 2. Must be able to transmit and receive data at a minimum of 5ft 3. Must be able to transfer 6 bytes of data at a time	1. We will send 4 Megabits from one node to another 5 feet away and ensure the data is transferred between nodes in 100 seconds 2. Send data from one node to another node 5 ft away and verify the same data was received 3. Send 6 bytes of data from one node, and verify the same 6 bytes were received by another node

2.3.4 Moisture Sensor

The Moisture Sensor will be in charge of differentiating between multiple moisture levels within a designated patch of soil. To be integrated into our control unit and power supply the moisture sensor must be I^2C compatible and have an operating voltage of ~3Volts. The Moisture Sensor must also have a deep sleep state that will be activated when the sensor is not needed i.e. during the night. Due to the nature of moisture sensors, there will not be an accuracy threshold requirement for our sensor. Instead, the moisture sensor is required to provide enough data to the control unit to easily determine which of three states the soil is in. These states being: Dry, Moist, and Saturated. The goal of determining between these states is to provide detail on what the soil needs to prosper. The meaning of each state is: Dry=Soil requires water, Moist=Ideal moisture level, Saturated=Soil has been overwatered.

Requirement	Verification
1. Must provide a moisture reading range from ~200 to ~2000	1. We can verify the range of the moisture sensor by checking values from the I^2C bus when the sensor is completely dry compared to completely saturated

2.3.5 Central Hub

The central hub will consist of a PC, RF to USB receiver, and ArcGIS software. This module will collect all data from the node array and display the moisture levels and allocated location of each node on a viewable map. The ArGIS map data values are required to update once a day to provide an accurate daily report.

Requirement	Verification
1. Must be able to receive data at .01Mbps 2. Must be able to receive data at a minimum of 5ft 3. Must be able to transfer 6 bytes of data at a time 4. The ArcGIS software must display a crop map, and host data points from each node.	1. We will send 4 Megabits from one node to the central hub 5 feet away and ensure the data is transferred between nodes in 100 seconds 2. Send data from one node to the central hub 5 ft away and verify the same data was received 3. Send 6 bytes of data from one node, and verify the same 6 bytes were received by the central hub 4. Verify that the specific points sent from are nodes are viewable and updated accordingly

2.4 Tolerance Analysis

One of the biggest requirements necessary for the success of this project is that the antenna within the RF module are able to transmit data to the specified range. Our target distance sits at a minimum of 5ft. When calculating the distance an RF signal may travel, a few variables need to be considered first. RF power refers to the output power of antenna in dBs referenced to 1mW(dBm).The relationship between power supplied to the antenna and the RF power is seen in this equation $P(dBm) = 10 \cdot \log10(P(mW))$. Using this equation, we can see an RF power of

3dBm is equivalent to about 2 times the output power. Path loss is the amount the power density decreases as a wave propagates over a distance. The power density proportionally decreases by the inverse square of the distance traveled. So, if my distance were to double, I would only receive 1/4th of the power from that signal. Although we cannot simply rely on this relationship, when implementing this calculation in a real world design. To truly receive an accurate estimate of propagation loss, the receiver sensitivity must also be considered.
Therefore:

Maximum path loss = transmit power – receiver sensitivity + gains – losses

In this equation, gains refer to any gain provided by the transmitting or receiving antenna, while losses refer to any cable attenuation or filters tied into the circuit. This is a close estimate, but we must also consider obstacles our signal may encounter like plants or bad weather. To account for this, manufacturers provide customers with a fade margin that accounts for most minor losses in signal from a specific antenna due to signal blockages. The higher the fade margin the better.
If we include this into our equation we get:

Maximum path loss = transmit power – receiver sensitivity + gains – losses – fade margin

Based on our current design, our RF IC assumes a transmit power of 10 dBm and losses to be negligible. To simplify the equation, we are assuming the receiver/transmitter antennas have gains of 6dBi each. We are making this assumption from the compatibility range within the datasheet of our RF module. This leaves us with the equation:

Maximum path loss=10+12-receiver sensitivity - fade margin

To determine the characteristics we are looking for in our antennas, we must plug this into the distance equation:

Distance (km) = (10(maximum path loss – 32.44 – 20log(f))/20)

In this equation f is the operating frequency of our signal, which based on our RF module is 868 Mhz. We are also looking for a distance of 5f, which is equal to .001524. From doing the calculation, we have determined that -(receiver sensitivity + fade margin)>=69.21. Given that our receiver sensitivity is about -100dBm and our fade margin is about 12dBm, we are well within our margin.

3 Cost

Our labor cost per hour is set at $35/hour with an estimated work week for about 10 hours per person. Including design, assembly, and presentation time, we estimate our work period to be the entire 16 weeks. For 2 people, this would lead to a total cost of 2 x 35 x 10 x 16 = $28,000.

Description	Qty.	Unit Price	Total Cost
Labor Cost	2	$14,000	$28,000
Excellway 5V 10W Portable Solar Panel Slim	3	$13.19	$39.57
TI SM72442 Charge Controller	3	$5.58	$16.74
LP 9V Rechargeable Battery Charger Set	2	$21.00	$42.00
TI-LM2717MT/NOPB DC/DC Converter	3	$6.66	$19.98
Mouser Electronics 579-MRF89XAM8A-I/RM RF Module	3	$6.67	$20.01
Mouser Electronics 595-TMS320F28035PNT Microcontroller	3	$13.07	$39.21
Banggood-Capacitive Soil Moisture Sensor	3	$4.86	$14.58
Pull Up Resistors	1	$10.50	$10.50
3D Printed External Case	3	$5.00	$15.00
PCB Board	3	$1.00	$3.00
Adafruit-MicroSD Card Breakout Board	3	$7.50	$22.50
SanDisk SDSQUNS-032G-GN3MN 32GB SD	3	$7.04	$21.12
Total Part Cost		-	$264.21

4 Schedule

Week	Joseph	Paul
10/7/2019	Design schematic for each module/Order all module components	Design PCB
10/14/2019	Design I2C protocol for Soil Moisture Sensor/Test performance results	Submit PCB Design SPI for memory alloc
10/21/2019	Assemble Power Supply Module/Analyze Output of Power Supply Module	Design SPI for RF module/ Redesign and submit PCB if necessary
10/28/2019	Solder/Test Prototype PCB	Test RF module antenna range/data accuracy Redesign and submit PCB if necessary
11/4/2019	Verify correct assembly of modules	Design hub module/test data collection via computer Redesign and submit PCB if necessary
11/11/2019	Test overall prototype performance compared to High Level Requirements Finish Debugging	Establish/Verify Node-Node Communication Protocol
11/18/2019	Design ArcGIS map from collected data	Design 3D CAD case/Print 3D CAD case Design
11/25/2019 Fall Break	Catch up if not on schedule	Catch up if not on schedule
12/2/2019	Begin Final Report/Fix Bugs	Test fit components in case/Fix Bugs
12/9/2019	Finish Final Report/Prepare for Final Presentation	Finish Final Report/Prepare for Final Presentation

5 Ethics and Safety

We plan to use a device case that is made from plastic. Our finished devices for the final presentation will only be constructed by using 3D printer filaments. However, we are aware that if our final project were to be mass produced, it would have to be made from non toxic plastics that are safe for the environment and consumer. Since this device will be used in fields to grow produce, we plan to use plastics that wouldn't leech any toxins into the soil/water table. According to the California Proposition 65 common 3D printing filaments are known to cause cancer[6]. To ensure that plastic toxicity would not be a concern, we would create our final product from a safe plastic composite material.

In addition to plastic toxicity, we are concerned about combustibility of our device case. We are worried that if a module would happen to short unexpectedly, it would be a great risk to all the combustible crop around it. To ensure that our device wouldn't cause a field fire, we would advise that our final, mass produced product, be made from a plastic that meets the standard of V-0 Flame-Retardant standards[5].

We have also considered the construction of the case, in addition to the materials used. During the design of the case, we will keep in mind that these devices will be outdoors and should be waterproofed. In order to do this, we will design a case that has a screw top with a lip to prevent any liquids from entering the case. We believe that this is important to prevent any electrical hazards when water is introduced to a circuit. This will make it safe for the end user to handle and eliminate any chance of the device shorting unexpectedly. We believe that having our case rated IP65 will be more than enough protection against water[9]. IP65 states that the case would be able to resist water jets emitting 12.5 litres of water onto the device per minute. The average amount of rainfall per .5m^2 is about 4 liters/minute.[12] This is less than the IP65 rating, and would mean the device would be protected.

When considering the type of sensor to use we found that there are two types of moisture sensors, resistive and capacitive. By using resistive sensor you have the possibility to electrocute the plants and other living organisms since they have to pass a current through a substance to calculate the moisture level[10]. By using capacitive sensors we eliminate this risk, making it safe for all living organisms in the proximity of our devices.

It is always important to exercise caution when using power sources. We have carefully chosen the battery used for the field devices so that they are safe to be charged and discharged regularly. In addition to the hazards that come from regularly charging and discharging a battery, we considered the event that a battery may leak toxic material. Lead acid batteries inherently need a vent to allow for environmentally unfriendly gases to escape[7]. The option to use LiPo batteries was also ruled out because of their price, and their usage characteristics when it gets colder. When it gets colder, these specific batteries become harder to use. In the end, we decided to use a set of specifically rechargeable batteries. These batteries are sized like 9V form factor batteries.

Finally, when assembling this device we have to follow correct procedure to protect ourselves and those around us. In the lab we will take proper cautions when soldering to make sure that we have moving air over the soldering area. Prior to being in the lab we will have attended some type of lab training to help us stay safe. In addition to this we will test each module individually to ensure that the modules will connect safely.

By following these strict safety guidelines, we believe we strongly align with the IEEE Code of Ethics in both the development and the consumer end of the project. We are taking extra precautions to ensure the safety of not only those in the vicinity of our device, but also anyone who may be a consumer of the crops our device is used on. This alone represents what IEEE Code of Ethics #1 underlines as paramount. By taking the extra steps to protect the farmers crops i.e. his property, the implementation of IEEE Code of Ethics #9 is clearly visible as well. Overall, our team believes we are taking the property steps to keep safety as our top priority, as well as strictly abiding by the IEEE Code of Ethics.

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