Project Closeout

Team 18: Integrated Environmental Sensor

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1. Design Impact Statement

An important step in development of this project is analyzing the impact. By doing so, the team can be aware of potential side effects beyond the technical details and take steps to mitigate any negative consequences.

1.1. Public Health, Safety and Welfare Impact

Positive impacts related to public health, safety and welfare include reducing cost and promoting consumption of organic foods. If the sensor array performs as expected, the value of organic and biodynamic farming practices could be proven as more environmentally friendly, hopefully resulting in the expansion of organic farms and organic crops. According to US Davis, the lack of pesticides in organic foods is associated with health benefits [1]. Thus, more organic farms could increase the welfare of individuals around the world.

1.2. Cultural and Social Impacts

An important consideration for any project, but specifically in the humanitarian engineering sector, is the social context surrounding the product [2]. The context in which the product will be used is highly affected by cultural and societal components, and these heavily dictate how the product is used and interpreted. One potential cultural impact is the acceptance of the product. Using Hofstede's cultural indicators, Thailand is a highly collective society, with a tendency towards uncertainty avoidance [3]. This could mean that the results from determinations made with the integrated environmental sensor on best farming practices for environmental preservation, if believed, would likely be promoted because of the potential for widespread benefit. That being said, due to the uncertainty avoidance, the general population may be less willing to accept the data. This could lead to delays in action following the research collected for best farming practices.

1.3. Environmental Impacts

The impact of the use of solar energy is multifaceted. First, the use of solar energy matches the big picture objective of the project as a whole – proving that better farming practices yield more positive environmental impacts. Increasing the use of renewable energy sources contributes to the objective of taking steps to protect the environment.

In a broader sense, using solar energy in Thailand and other southeast Asian countries is becoming of increasingly high priority [4]. In Thailand specifically, the government has implemented plans including the Energy Efficiency Plan, Alternative Energy Development Plan, and the Power Development Plan, all evidence of the national agenda to increase reliance on renewable energy sources [5]. It is therefore important that we reflect this national approach in our project.

1.4. Economic Factors

In terms of economic impact, the cost of hosting the website is a primary concern that would mainly affect our project partner. The cost of a hosting service and a domain name is seven dollars per month. While self hosting is free, it is also associated with increased security vulnerabilities. Ports on the router must be open to receive requests [6]. This is not only dangerous but can comprise the service if any programs listening on those ports are exploitable [7]. The project partner's office network may slow down or result in loss of important information that ultimately costs more than the seven dollars per month that would have been spent on the more secure hosting service. This seven dollars can be thought of as an investment to avoid even more costs in the future.

1.5. Conclusion

Analyzing the impacts of this product encourages the identification of negative factors that may not have been considered in the original project development process. Many of the factors in this product are related to the product's implementation in Thailand. Most are inherent with the project itself but can be mitigated through communication with the Thai partner. That being said, there are likely going to be more factors that continue to come up and must be assessed. It is therefore extremely important for future groups who are continuing this project to maintain frequent contact with the Thai partner and ensure that updated designs reflect the partner's goals and needs with respect to Thailand to avoid unintended negative impacts

2. Project Timeline

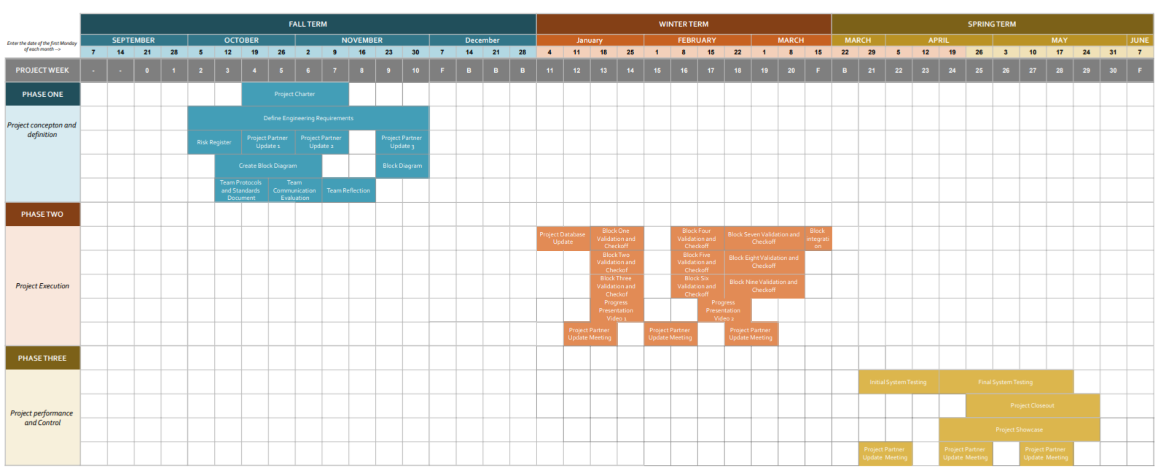

Figure 1: Year long project schedule

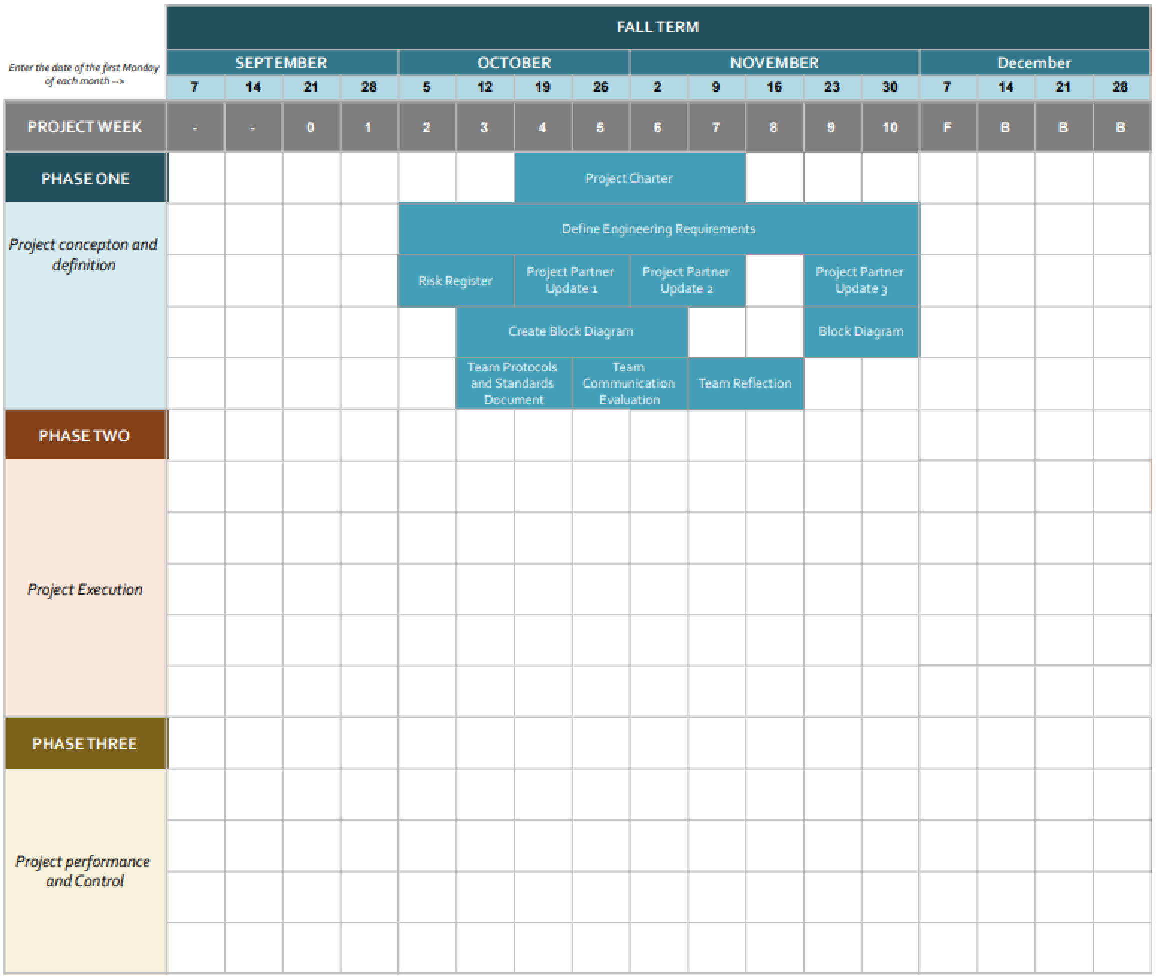

Figure 2: Zoomed fall term schedule

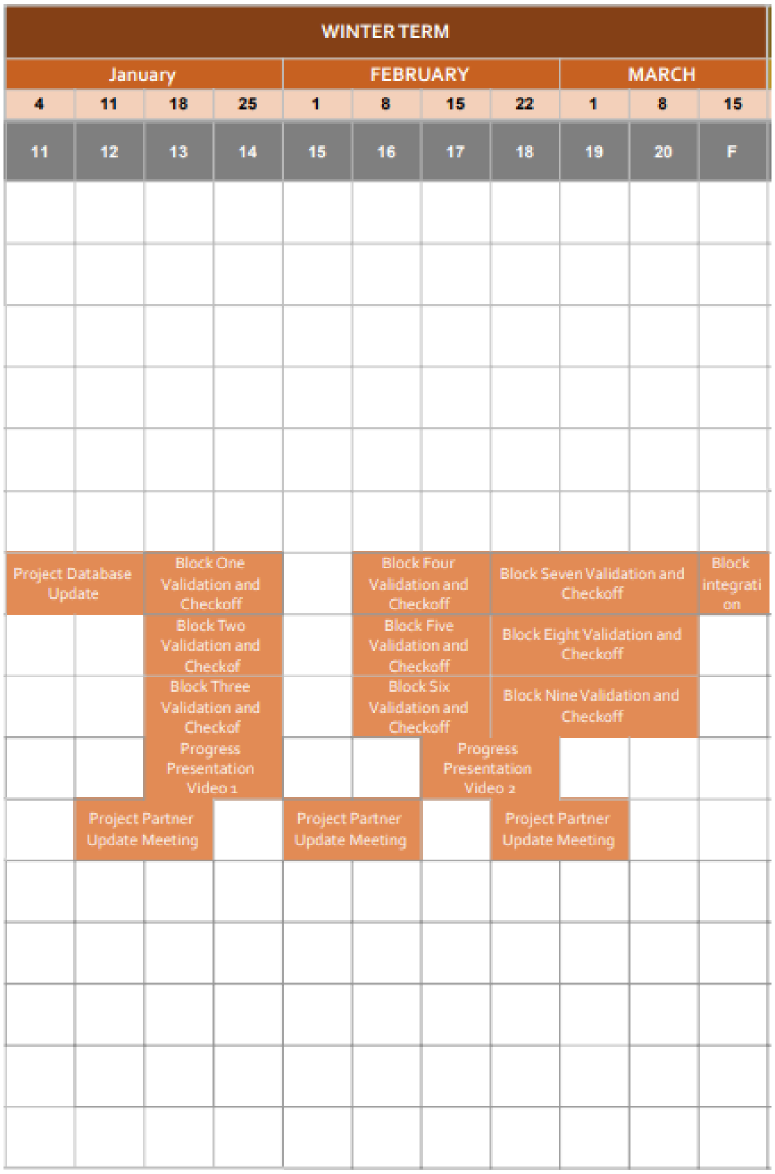

Figure 3: Zoomed winter term schedule.

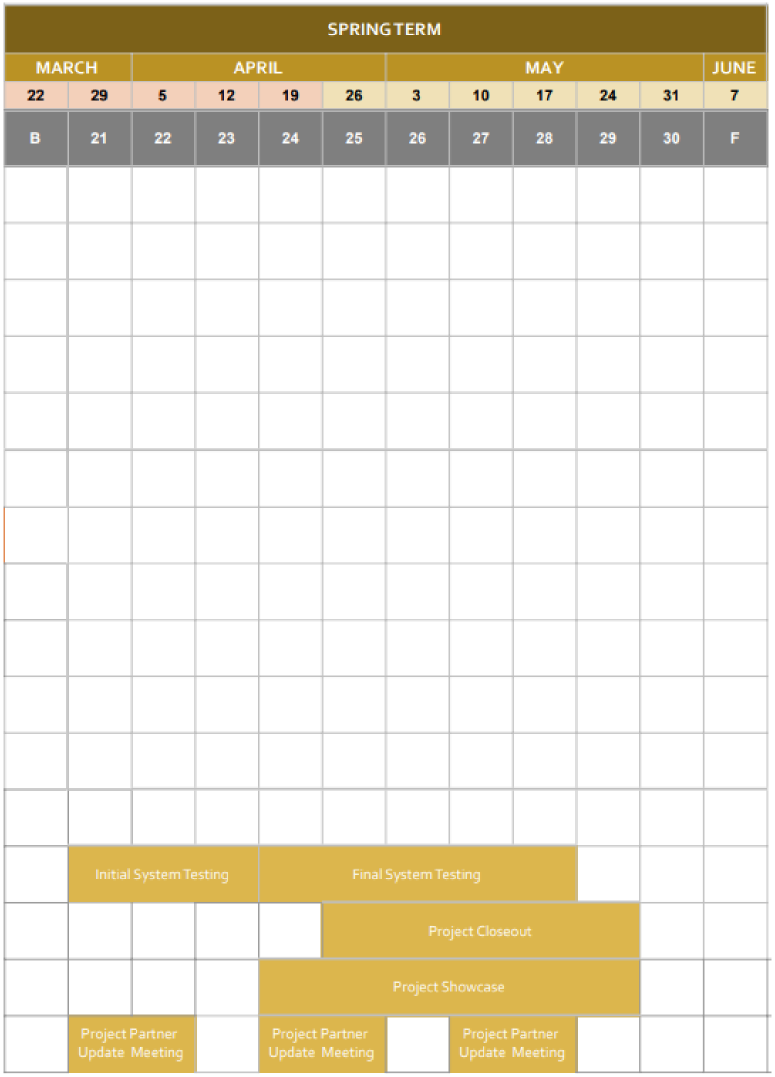

Figure 4: Zoomed spring term schedule

3. Scope and Engineering Requirements Summary

Table 1: engineering requirements summary.

Name	CR	ER	Verification Method	Test Process	Test Pass Condition	Evidence Link

Data Visualization	Data should be visible on the web.	9 out of 10 users can view a desired sensor graph and select a given time point in 2 minutes.	Test	1. Find 10 subjects 2. Give each subject a time point and graph to look for 3. Ask the subject to find their specific data points 4. Time the subject	9 out of 10 users can find the specific graph and time point in under 2 minutes then this condition passes.	https://drive.google.com/file/d/1xE9YI-9RzWobrhrbGyPOWufVPzzoTVWv/view?usp=sharing
Ease of Access	Final product should allow ease of access for simple maintenance such as cleaning	The system will allow 9 out of 10 users to open the enclosure without any tools that are not attached to the product, and using only what is provided in the enclosure to replace the battery in under 10 minutes.	Test	1. Find 10 subjects 2. Ask the subject to open the enclosure using only the tools attached to the product 3. Ask the subject to replace the battery with only the tools provided in the enclosure 4. Time the subject	9 out of 10 users can open the enclosure in under 10 minutes and replace the battery with no additional tools.	https://drive.google.com/file/d/1PJtwZZXKfc1Obq_7xZVtarxfIbBzPb2u/view?usp=sharing
Environmental Restrictions	Final product should withstand tough outdoor environments	The system will not allow water to enter the enclosure when sprayed with a stream of water from all angles for at least 300 seconds.	Test	1. Put paper inside enclosure 2. seal enclosure 3. spray with a stream of water from all angles for at least 300 seconds. 4. Bring it in and check if paper is wet.	If the system protects the paper and it is not wet, this requirement has been met.	https://drive.google.com/file/d/15JX-sMCILRSuJKzce9T6cPHEo3tfq3yI/view?usp=sharing

Local Recording	Data should be stored on device incase wireless link is lost.	The system will have onboard storage that must record at least 1Mb of data.	Test	1. Start recording 2. Wait for 10 minutes 3. retrieve data and check the storage 4. repeat if needed to get up to 1Mb	1Mb of data was gathered and stored on device.	https://drive.google.com/file/d/1LwyI85y6je6JooTd1BHMHyZnuo1Dm6DJ/view?usp=sharing
Location and Time	Product should have accurate location and time information	The system will report time with no more than 1 second error and it will report location with no more than 3 meter error	Test	1. Turn on device and wait for device to initialize 2. Query device for location and time 3. Compare time to official UTC time reported from time.gov 4. Compare location with latitude and longitude determined by map 5. Validate device reported value of location to be no more than 3 meter error and the reported time to be no more than 1 second error	If the system reports location within 3 meter of actual location and time is within 1 second of actual time this condition passes.	https://drive.google.com/file/d/1JYanm5WCek4KcwHf1ie-ImcVZxa_n_H9/view?usp=sharing

Off-Grid Power	Sensor array must be off the grid using a solar panel	The system must run for 24 hours with out external power connections off of at most 2 5000mAh battery packs.	Test	1. Place at most both 5000mAh battery packs on the system. 2. Run system for 24 hours. 3. Verify the system is operational after 24 hours.	If the system runs for 24 hours with out external power connections off of at most 2 5000mAh battery packs then the test passes.	https://drive.google.com/file/d/1GYwdvOzgy8Z3-KY-RBUM2SkOnLUbAHNU/view?usp=sharing

Sensor Integration	Must be able to measure different sensor data that is useful for a farm.	The system will measure temperature , humidity, and air pressure with no more than a 5% error at full range values.	Test	1. If the system is off turn on device and wait for device to initialize 2. Measure a low temperature of at most 48 degrees F and a high temperature of at least 80 degrees F 3. Measure a low humidity of at most 45%RH and a high humidity of at least 80%RH 4. Measure a low air pressure of at most 999hPa and a high air pressure of at least 1004hPA 5. Compare temperature values with thermometer 6. Compare humidity values with hydrometer 7. Compare air pressure values with barometer 8. Validate measured values within 5% of expected value	If the system reports temperature, humidity, and air pressure values with no more than 5% error compared to their respective actual values measured by a thermometer, hydrometer, and barometer, then this condition passes.	https://drive.google.com/file/d/1pzjeWjhJGZ8ElGLZ4tCzOkIUePfxyYNk/view?usp=sharing

Wireless Transmission	Sensor data should be wirelessly transmitted from farm to a office.	The system will send data wirelessly for at least 400m without line of sight.	Test	1. Bring transmitter at least 400m away from the receiver 2. Setup the system and make sure there is no line of sight between the receiver and transmitter 3. Send a predetermined data value 4. Check if data at the receiver is the same as the data being transmitted	If the system reports the same data sent as the data received at the receiver from at least 400 meters away then this condition passes.	https://drive.google.com/file/d/1RwF1OEmAVFN4LzhQxR0MD643dfqqJ2MP/view?usp=sharing

4. Risk Register

Table 2: Risk register overview summary.

Risk ID	Risk Description	Risk category	Risk probability	Risk Impact	Performance indicator	Responsible Party	Action Plan
R1	Part vendor is unable to ship a required part.	Timeline	10%	M	Vendor imposes 1wk+ lead time for a required part.	Alec will monitor part lead times.	Reduce
R2	PCB does not function as expected.	Technical	25%	H	Testing exposes problems in PCB design.	Ichen will do PCB testing	Retain
R3	COVID restrictions stop us from using ECE 44X reserved lab time for assembly.	Timeline	50%	L	Communication for OSU authorities indicates that we are no-longer allowed in buildings on campus.	Marley will watch OSU news for restrictions	Retain

R4	Software and hardware cannot communicate effectively.	Technical	25%	H	Testing exposes problems with hardware/software communication	Alec will preform software/hardware testing	Reduce
R5	Group member falls behind on work leaving the group one member short with unfinished work.	Timeline	15%	H	Regular communication with group members shows one party not responding to communication	Marley will take attendance at group meetings	Avoid
R6	Weather prevents outdoor radio testing for cellular network.	Timeline	35%	L	Cold weather and rain forecast could prevent outdoor testing.	Ichen will watch the weather before any outdoor test	Reduce
R7	COVID restrictions stop group members from meeting for final integration testing.	Technical	75%	M	Every group member's preference will determine if we can meet for a final integration stage of this project.	Ichen will poll everyone's COVID comfort level	Retain
R8	Group members are unable to deliver the final product to the project partner in Thailand.	Technical	95%	L	OSU sponsored travel and international travel restrictions will indicate if we can travel out of the country.	Marley will watch OSU and international news for restrictions.	Transfer

Much of our large risk came from the restrictions imposed on shipping and travel. Or original plan involved traveling to Thailand to implement and test our system. Clearly, international travel is still restricted. This meant we could not finish the implementation of our project. To combat this, our project partner worked with us to create detailed transition documents that will be passed to the next group to work on this project. Shipping restrictions were caused by chip shortages and high demand. Once we learned of the longer shipping times, we made sure to order items much sooner than they would be needed in our project. This created other challenges like requiring that our designs were finalized sooner. Shipping and travel risk was inevitable, but they were especially challenging during COVID.

Our risk register shows our anticipated risk and how it would be mitigated in our project. During the course of our project there was other, unanticipated, risk that arose. The most challenging was distributed testing. We did not anticipate how challenging it wo ld be to test our project from our homes. To overcome this risk, we spent extra time planning, designed extra communication channels into our project, and made our evidence video's format more flexible. As a team, we learned that not all risk can be anticipated. It is important to communicate and remain flexible to deal with any risk that may occur.

5. Future Recommendations

Table 3: future recommendations for continued project success.

Recommendation	Reason and start point
Focus system testing towards Thai people.	In an ideal world this sensor array would be delivered to Thailand for use by local farmers. Since our testing was done in the states, we did not have access to a reasonable population of Thai people to test our instructions, methods, and assumptions. This may have led to some unintentional bias within our system. Unfortunately, bias like this is very common in all technology built by one group of people that is intended for another. To create the most inclusive system, we believe Thai people must be consulted Some starting points include seeking out a club of Thai people, working closely with the overseas project partner, and producing multiple prototypes that can be sent to Thailand before the final delivery is made. Most importantly, we believe that assumptions cannot be made based on our American culture, methods, and bias.
Simplify the path sensor information must flow within.	The sensor data in this iteration of the system must travel through a complex data path. This was due to our desire to conduct distributed testing during the COVID pandemic. Currently, sensor data is gathered on multiple microcontrollers and synced through the internet to a singular database. In an ideal design, we believe that a single simple microcontroller would be in charge of all data collection. However, even though a backend database is a very good option for storing all of the data this sensor array generates, having multiple sources for data complicates the design. To start with an updated design, we think it would be best to adapt our chosen sensors to work with a single microcontroller unit. Our chosen Nordic Semiconductor nRF9160 has plenty of spare processing power and IO to gather all of the data that is necessary. To connect our sensors to this microcontroller it would be necessary to adapt their driver code and determine the correct IO schemes for the sensor's electrical signals.
Data to Cloud VM	The collected data currently directly connects with the database on the cloud VM and the data is then displayed by a web server on that same cloud VM. This design of directly connecting to the

	database allows for easier data transfer to the website from the microcontroller but this type of connection is not secure. To start, the system would be better designed and more secure if there was a secondary web server such as apache to receive that data and then have that data sent to the database. This allows for a more secure data transfer between the microcontroller and the cloud.
Explore wireless transmission in a more pragmatic way.	Since this year's project ended up being more focused on research we choose to use cellular for our wireless communication method. This choice was not based in fact but rather convenience. Cellular has a wide reach and minimal barriers to entry. It did not require that we set up any base station, maintained no complex antennas, and did not have to adapt packets to travel over the internet. Approaching the problem pragmatically, it may be better to explore other options for wireless including LoRa, ZigBee, or some other low band radio. This would require some more overhead, but save our project partner from the burden of a cellular bill every month. Some other wireless options could be simpler to implement in hardware and cheaper to support over a long period of time. Since the data rate is very low for this application, we think it would be possible to get away with a slow and cheap wireless link. Some ideas to get started include researching wireless modules, carefully identifying the project partner's needs, and determining the geographic layout of the wireless network. The project partner requires that the network be easy to maintain and cheap to run. While cellular is easy to maintain it is not cheap to run. Other options including LoRa would remove the economic burden of wireless communication from our project partner. Geography is challenging in Thailand. The farms are distributed with many small plots. These plots are often obstructed from one another by houses and barns. Choosing a wireless protocol that is able to travel a long distance through obstructions is very critical to the success of the project. To get around some of the geographic challenges, future teams may find it advantageous to explore mesh networking to allow information to travel around obstructions.
Data matching of local storage with cloud storage	The system has a local storage that stores the same data as the cloud storage since the local storage is used as a support just in case the cloud storage goes down our we lose WiFi connection for a bit. From there the local storage can be extracted and the local storage will have all the data regardless of cloud connection loss. To start, the local storage is not currently matched with the cloud storage so a future work could be to send out some data from the

	microcontroller then query a web server to query the database to send the same data back down to the microcontroller. If the query comes back the same then the data is the same if it is not then the microcontroller resends that data.
Send soil moisture data to data visualization webpage	Currently soil moisture data is being collected on the Arduino but is not being sent to the data visualization webpage. This should be a minimal improvement, but is important nonetheless. It may also take additional consideration to determine the best method to display the soil moisture data. A good starting point would be to look at how the weather sensor data is being sent, and mimic that approach.
Development of robust enclosure	While an enclosure was developed for this project, it deserves attention to make sure it fully meets the needs of the system. The electrical junction box used this year was waterproof, but did not provide sufficient ventilation to house electronic parts, especially in Thailand where the temperatures are consistently high. One solution to this is replacing part of the box with a metal mesh to allow for heat regulation. This would expose the electronic pieces to rain, however, so more consideration would have to be placed on a roof of some sort. There should be additional discussions with Bryan to work through the different possible solutions, and advantages and disadvantages of each.
Implementation of gas sensors	One of the most important features for the ultimate success of this device is the integration of gas sensors. Sensors monitoring methane, nitrous oxide, and ammonia will allow for more robust measurements of climate impact due to farming practices. Implementation of gas sensors will likely be very challenging and costly. We chose not to implement them this year due to the time required -- we expect an entire capstone could be dedicated to just gas sensor integration. First steps to accomplishing this task would be to talk to Chet Udell who leads the OSU Sensor Lab (OPEnS).

6. References

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