Plantmosphere Technologies

Plantmosphere

Post Mortem

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Figure 1: The Greenhouse Structure.

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1 Introduction

Our initial idea was to create a greenhouse that could be used in countries suffering from food shortages such as Sub-Saharan Africa. As we worked on this project we realized that our component costs are high, and regular maintenance would be required to service the current Plantmosphere. Therefore, in order for the Plantmosphere to become suitable enough for Sub-Saharan Africa, we would need to raise capital, and re-iterate our design to incorporate inexpensive components that may be available in developing countries. After much research we realized that there are many domestic markets that could assist in raising capital for further Plantmosphere development, including:

- Agencies assisting in disaster areas
- People who would like to grow their own vegetables
- People who feel grocery store vegetables are not healthy or organic enough
- Schools that would like to grow vegetables for student lunches

2 Product Overview

The Plantmosphere is a user-friendly, automated greenhouse system designed to manage a plant's environment for the duration of its growth cycle, with minimal user input. Our product's durability and focus on water recycling makes it an attractive option for the unpredictable Sub-Saharan Africa climate. The Plantmosphere's modular system design allows users to purchase optional modules that provide additional functionality, enhancing the gardening experience.

This project focuses on the critical automation systems to be incorporated in the prototype model, which include:

- Humidification
- Irrigation
- Lighting
- Ventilation
- Soil Heating
- Water Reservoir Control

3 System Overview

The Plantmosphere is comprised of several subsystems, which are controlled by an Arduino microcontroller. The subsystems include: irrigation and humidification, lighting, ventilation, and soil heating. The subsystems are controlled with different interconnected devices, which are detailed in Figure 2 below.

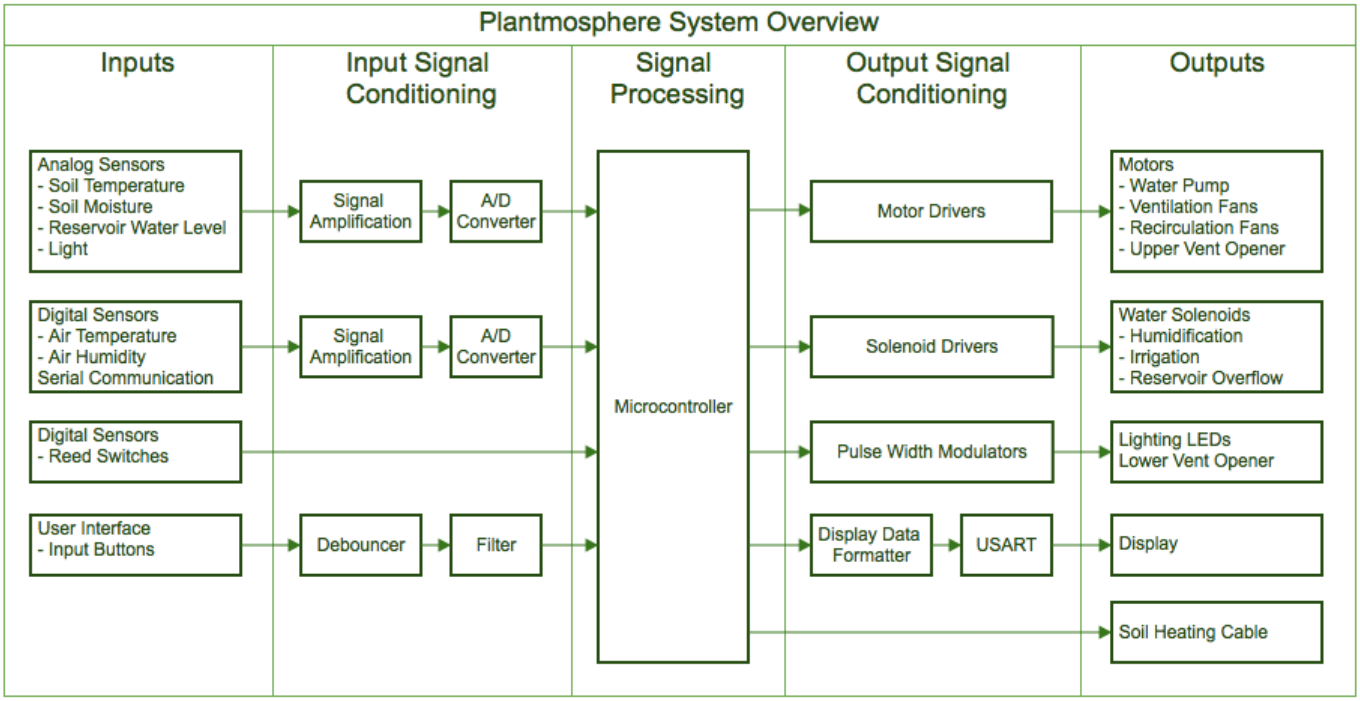

Figure 2: The system diagram and interconnections

Some of the devices are shared between the different subsystems. For example, the air temperature sensors are used by both the irrigation and humidification subsystem and the ventilation subsystem.

3.1 Irrigation and Humidification

The irrigation and humidification subsystem uses multiple sensors to determine when the Plantmosphere requires irrigation, humidification, or both. Figure 3 shows the devices used in this subsystem.

3.2 Lighting

To control the lighting subsystem, light sensors have been employed. Figure 4 presents this subsystem's components.

3.3 Ventilation

Temperature and humidity sensors control the Plantmosphere's ventilation devices. The devices used in this subsystem are presented in Figure 5 below.

3.4 Soil Heating

The soil heating subsystem uses many different sensors to control the soil temperature, as shown in Figure 6 below.

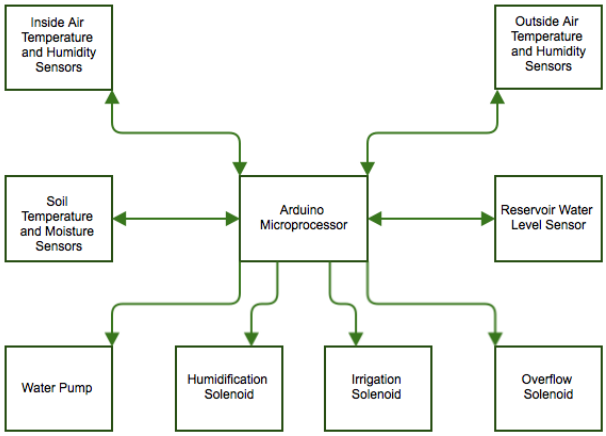

Figure 3: Irrigation and Humidification Subsystem

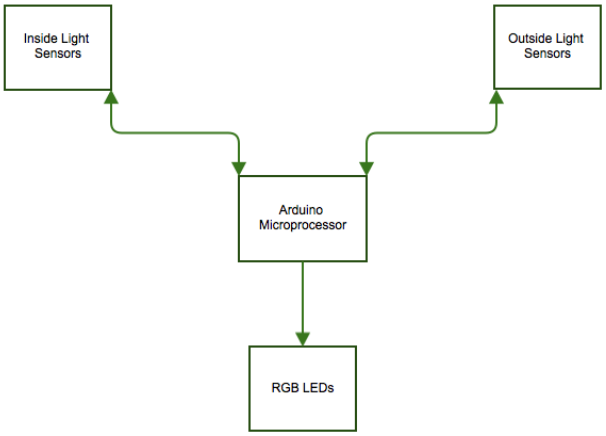

Figure 4: Lighting Subsystem

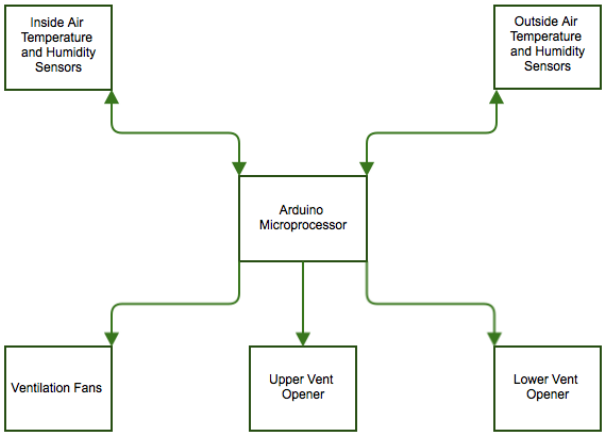

Figure 5: Ventilation Subsystem

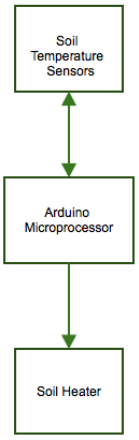

Figure 6: Soil Heating Subsystem

4 Initial and Final Cost

Table 1 displays the projected and actual cost for the project. Table 2 shows that the project ended up costing more than anticipated. This was due to several reasons including:

- Some parts were poorly made causing integration to require more parts.
- The required specs for some subsystems ended up being more than the parts could handle. This required either new parts or a re-design usually requiring more parts.
- Using scrap parts initially cost less but in some cases required more parts of integration and therefore ended up costing more.

Now that we have a better understanding of all of the parts required for this product the costs could easily be reduced.

Table 1: Initial Estimate and Actual Cost

Category	Projected Cost	Actual Cost
Electronics	$150.00	$354.90

Hydration	$40.00	$328.92
Lighting	$90.00	$32.98
Soil Heating	$35.00	$49.06
Structure	$645.00	$897.87
Ventilation	$215.00	$207.67
Tools	$0.00	$17.89
Contingency	$125.00	$0.00
Total	$1,300.00	$1,889.29

Table 2: Overall Summary

Summary	Amount
Original Budget	$1,300.00
Actual Cost	$1,889.29
Overbudget (%)	45.33
Overbudget ($)	$589.29

5 Problems and Challenges

5.1 User Interface

The user interface required lots of testing a debugging the code. For installation, the largest challenge was routing the wires from the LCD and keypad through the greenhouse to the Arduino Mega. Upon learning the Arduino Mega did not supply power to the LCD and could not provide I2C pins to both the LCD and RTC to run them simultaneously, we decided to run the user interface separately on an Arduino Uno to display its functionality.

5.2 Structure

When designing the structure, we struggled with balancing time and cost. We started by designing a greenhouse to be built from scratch, following guidelines provided by the National Gardening Association. We created a bill of materials and calculated we could build a 8 X 10 foot greenhouse for around $300. However, we decided that the amount of time it would take to purchase the materials individually, organize a build location, and troubleshoot any problems that arose, it wasn't worth doing. We decided that it would be better to purchase a kit greenhouse and assemble it according to the instruction manual. This ended up costing us around $600, but it meant that we faced almost no problems with the structure itself. We found it very robust and easy to mount our components to.

5.3 Power

Initially, we had designed the Plantmosphere to run off of solar power and a battery. After calculating the estimated power requirements, however, we determined that the equipment would be far too expensive, and instead elected to use mains electricity. Additionally, Mike had an unused computer power supply unit, meaning that we wouldn’t need to spend any money on an elaborate power unit. The chosen unit was able to deliver much more current than required at standardized ATX voltages, which simplified our circuit design.

5.4 Humidification & Irrigation

We purchased the Gardena Micro-Drip System from Home Depot because it looked like it would integrate easily into our design and for the most part this subsystem worked perfectly. The main issue we had was due to a problem with the threading on the 2 water solenoids. Even though they were supposed to be standard threading we could not get any fitting to actually connect. We spent time at Home Depot and Rona and they could not help. We finally found someone at EMCO Corporation, a plumbing supply company, who could help. He was perplexed about the problem but found a connection that would work. This caused us to have to spend almost $50 for fittings. In the end this system worked well.

Another issue dealt with the connection to the relays. When everything was attached the solenoids would cause the relays would stop working correctly. After much research we realized that a snubber needed to be placed across the leads of the solenoids. Once that was completed the relay problems were fixed.

5.5 Lighting

Originally we had a design where we would solder LED's to a protoboard and hang the board from the roof of the ceiling until 10 inches above the plants. After the design specification we realized that it wasn't feasible to approach it this way and instead we purchased a roll of RGB LED's and cut them into strips and with an adhesive stuck them onto a board of plexiglass. The tough part in all this was calibrating with an Arduino board to emit our wanted 470nm wavelength of light. Also, calibrating the light sensors and coding them to work for a wanted light intensity was a difficult task. In the end, the lighting proved to be a much more challenging task than we had originally thought.

5.6 Ventilation

The initial design for the ventilation system always incorporated the greenhouse roof vent and a floor vent of some design. However, our search for an airtight louvered floor vent yielded only very costly results, and we decided to design our own vent. The initial design mimicked a roof ridge vent designed to make use of a pressure difference across a small opening created by high velocity wind. This design drew air through the vent but was not very effective, prompting us to redesign the floor vent. We settled on a design where a fan could be used as both an intake fan and a recirculation fan based on if the vent was open to the outside or to the inside. A stepper motor moving a flap is used to block one of the aforementioned openings, but testing showed that the fan was so powerful it would draw the flap towards it, no matter which position the flap was in. To hold the flap back, we installed a block to physically prevent the flap from moving once it was in position, and brought us to our final design for the floor vent. The fan placement was also adjusted based on where we needed to place the trough, water reservoir, and power enclosure.

5.7 Soil Heating

Initially we had planned to integrate an AC-powered soil heating cable with a relay module and feedback from soil temperature sensors into the Plantmosphere. The main obstacle with using our DHT11 temperature sensors in soil was figuring out how to waterproof them. We decided to use heat shrink (as it is thermally conductive) combined with silicone in order to keep water from damaging the sensor's internal electronic components. During testing of the soil temperature sensors, we logged stable data from them for several hours before both malfunctioned. Due to time constraints, and a lack of spare DHT11s, we made the decision

to cut out soil temperature controlled actuation of the soil heating cable. This did not eliminate soil heating functionality from our system since the cable already incorporates a built-in thermostat that activates the cable when it detects temperatures below 74˚F.

5.8 Rain Water Reservoir

The reservoir design went through many phases. We thought about making the reservoir out of rubbermaid containers, garbage bins, and constructing our own out of wood, similar to the final design of the trough. Each of these design options was found lacking, and we knew we needed to find something simpler like a rain barrel, but couldn't find any suppliers in the lower mainland. We finally were able to contact a reseller of food-safe rain barrels through a craigslist posting, and only spent $20 on the reservoir. Beyond that, the reservoir gave us very little trouble, once we managed to purchase it.

6 Timeline and deviations

Our original timeline and the actual timeline (shown in Figure 7) are similar. The main difference is in the end of the build and the planting of the vegetables and start of testing. There are many reasons why our timeline slipped. We purchased the greenhouse kit and quickly came to realize that it would not be easy to find a safe location to build it. We finally settled on the outside courtyard by the ENSC main office. The critical constraint being that we could only access it during office hours (9am until 4pm). This constraint delayed the project significantly.

The other delays to the timeline include:

- Parts acquisition took longer than expected
- Integration of some modules where more complex than originally thought
- Re-design of some sub-systems required due to unforeseen hardware limitations
- Design document took much longer to write and validate than planned
- Calibration of sensors was more work that realized

ID	Task Mode	Task Name	Duration	Start	Finish	Predecessors
1		Submit Proposal	0 days	Tue 23/09/14	Tue 23/09/14	34
2		Submit Functional Specification	0 days	Wed 15/10/14	Wed 15/10/14	47
3		Submit Design Specification	0 days	Tue 04/11/14	Tue 04/11/14	55
4		Submit Written Progress Report	0 days	Mon 17/11/14	Mon 17/11/14	56
5		Plant Vegetables	0 days	Mon 01/12/14	Mon 01/12/14	7
6		Demo	0 days	Fri 12/12/14	Fri 12/12/14	33,57,58
7		**Plan, Design, and Build Greenhouse**	**94 days**	**Mon 01/09/14**	**Sun 30/11/14**	
8		**Reseach**	**12.25 days**	**Mon 01/09/14**	**Fri 12/09/14**	
18		**Functional Design**	**33.25 days**	**Sat 13/09/14**	**Tue 14/10/14**	
21		**Detailed Design**	**23 days**	**Wed 15/10/14**	**Thu 06/11/14**	
24		**Purchase Parts**	**23.5 days**	**Fri 17/10/14**	**Sat 08/11/14**	
27		**Build**	**36 days**	**Mon 27/10/14**	**Sun 30/11/14**	
30		**Research Vegetables**	**12.25 days**	**Mon 01/09/14**	**Fri 12/09/14**	
32		**Plant Vegetables and Testing**	**13 days**	**Sun 30/11/14**	**Fri 12/12/14**	
34		**Write Proposal**	**10.5 days**	**Sat 13/09/14**	**Mon 22/09/14**	**16,14,9,10,17,1**
47		**Write Functional Specification**	**22.75 days**	**Tue 23/09/14**	**Tue 14/10/14**	**46,34**
55		Write Design Specification	20.75 days	Wed 15/10/14	Mon 03/11/14	54,47
56		Write Written Progress Report	14 days	Tue 04/11/14	Mon 17/11/14	55
57		Prepare Presentation and Demo	11 days	Mon 01/12/14	Thu 11/12/14	

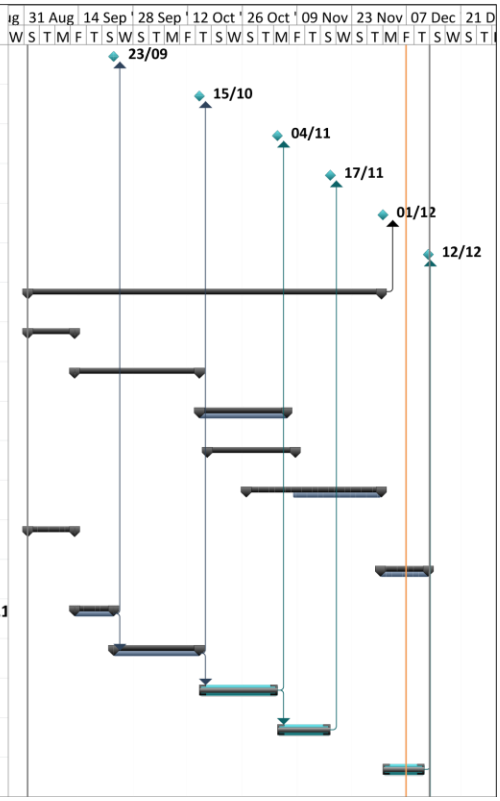

Figure 7: Project Tasks and Timeline

7 Workload Distribution

The work was distributed evenly among each member of the group. Table 3 summarizes each members contribution to the project.

Table 3: Workload Distribution

Category	Task	Alex	Faisal	Jane	Jeff	Mike	Terry
Research	Plants	X	X	X	X	X	X
	User needs	X	X	X	X	X	X
Discarded Design Solutions	Motor control	XXX	XX			XXX	
	Lower intake vent	XX			XX	XX	
	Roof vent	XX			XX	XX	
Design	Design trough					XXX	
	Lower intake vent	XXX			XXX	XX	
	Roof vent	XXX	XX			XX	
	Wiring plan	XXX				XXX	
	Soil moisture sensors			XXX		X	XXX
	Soil temperature sensors			XX			XX
	Air temperature/humidity sensors						
	Company logo	XX					
	User Interface	XX			XXX		
	Lighting	XX	XXX				

	Hydration					XX	XXX
Implementation, installation, calibration	Trough	XXX				XXX	
	Reservoir		XX			XX	
	Wiring installation	XX	XX	XXX	XX	XX	
	Wiring beautification			XXX			
	Air temperature/humidity sensors			XXX		XX	
	Greenhouse construction	XX	XX	XX	XX	XX	XX
	Irrigation					X	XXX
	Humidification					X	XXX
	Lights		XXX				
	Light sensors	XX	XXX				
	User Interface		XX		XXX		
Documentation	Proposal - writing	X	X	X	X	X	X
	Proposal - editing	XXX	XX	XXX	X	XX	X
	Functional spec - writing	X	X	X	X	X	X
	Functional spec - editing	XXX	XX	XXX	XX	XX	XX
	Design spec - writing	XXX	XXX	XXX	XXX	XXX	XXX
	Design spec - editing	XX	XX	XX	XX	XX	XX
	Post-mortem - writing	X	X	X	X	X	XXX
	Post-mortem - editing	X	X	X	X	X	X
	Project Management	X	X	XX	X	X	XXX
Calibration	Light sensors	XXX	XX			XX	
	Soil moisture sensors					XX	XXX
	Lights	XXX	XXX				
Testing	Ventilation	XXX		X	XXX		X
	Irrigation		X			X	XXX
	Humidification						XXX
	Soil Heating			XXX			XX
	Lighting	XX	XXX				
	Water Resevoir		XX			XX	
	User Interface	XX	XX		XXX		
	Arduino Code	XX	XX	XXX	XXX	XX	XXX

8 Group Dynamics

The Plantmosphere group worked incredibly well together. Everyone did what was necessary to get the job done. There were no conflicts or issues with any member.

Tasks were created and prioritized by Terry Hannon and placed onto Jira. The group would then take the tasks that they were more confortable with as lead and at least one other person would join the task as an assistant. The group determined the deadlines during weekly meetings and everyone was good about meeting and in most cases exceeding them.

Each member had primary functions but also had many secondary functions as well.

8.1 Faisal Emami
His main function was that of hardware engineer, but he also worked as lighting system designer and implementer along with overall design assistant.

8.2 Terry Hannon
His main function was that of project manager, but he also worked as irrigation & humidification designer, testing design assistant, and Arduino developer.

8.3 Jane Horton
Her main function was that of design and software support engineer, but she also worked as code base maintenance and algorithm development assistant, soil heating designer, and data logging designer.

8.4 Alex Naylor
His main function was that of design & hardware support engineer, but he also worked as power supply designer, ventilation design assistant, and lighting design assistant.

8.5 Jeffrey Shum
His main function was that of software engineer, but he also worked as ventilation system designer, user interface designer, and woodwork assistant.

8.6 Mike Thiem
His main function was that of structural designer, but he also worked as workshop technician, purchasing coordinator, and algorithm development assistant.

9 Individual Learning

9.1 Faisal Emami
When our group met in early August to plan and organize our Capstone project I had the intention that I would solely be focusing on the hardware and electronics components of the project. However, as the semester progressed I found myself working on mechanical, and software sides and getting involved in many aspects of the project design. I designed the lighting, helped out with the trough, building encasements for components to be housed in, water reservoir, user interface, and coding with the Arduino microcontroller. Altogether, these tasks provided a great learning experience and brought myself out of my comfort zone to explore new tasks and really appreciate what I had learned through my time in school and what I can still learn when I apply myself.

Selecting to design and implement the lighting subsystem for our project, I had little knowledge on the importance of the specific kind of light that optimizes plant growth. I learned about the complexity of the quantity and quality of light that plants require, as well as how to program a microcontroller to connected to sensors to control the lighting and provide the specific wavelength of light. Another great learning experience came in the workshop with the help of Mike Thiem, our experienced team member in woodworking, taught myself and the rest of the group techniques on how to approach building structures that were to be used for

our project. His help sped up the construction of our project and allowed me to add another skill to my repertoire.

Some of the few deceptions within our project were the vast size of it and the budget. When we planned the project and broke it down into subsystems as a group back in August, we didn't realize the enormous scope of our project until we wrote the design specification document. Our document was over ninety pages and we had to take a three day extension on it. The sheer size of the project hit myself and my group mates at that time and realizing that we weren't going to meet our original project deadlines sank in and caused the group to really buckle down and work even harder. Another misunderstanding was our budget. Our final tally was almost double our original estimate which included a thirty percent overestimate calculation. This had to do with a lot of the parts being more expensive than originally thought do to the sinking Canadian dollar, unexpected shipping fees, as well as parts breaking and having to purchase replacements. Also, we always found that we needed more and more of certain parts so we had to purchase additional items. Luckily, we were able salvage parts from Alex Naylors treadmill for use in our project otherwise our total cost would have been even more.

The best part of the project was working in a group of diverse individuals whom were hard working, very dependable, and had a strong passion for our project. All of our different skill sets combined enabled us to accomplish what we had set out to do in August. As a group, we worked hard together utilizing our capabilities the best we could and building a strong bond in the process. We learned a lot from each other as we did about the project and that is something I can cherish forever.

9.2 Terry Hannon

Coming into this course I was very nervous about how everyone would get along. I did not really know most of the group and did not know how they would or would not accept me. But from the first meeting I felt like I was in a group I could work with. Everyone was intelligent, eager, and passionate. Having a lot of work experience I have worked in good and bad teams and I have to say that this was the best team I have ever worked with.

My tasks started early, as I was the project manager. I needed to get the tasks organized, by entering them into Jira, and coordinated. I also need to determine the major milestones and deadlines. This information then was entered into a Gantt chart so that it could be easily communicated with the rest of the team.

I figured that with my programming background I would mainly focus on developing the code for the Arduino, but I ended up also designing and developing the irrigation and humidification system. I even helped to build a soil moisture sensor using 2 nails. I did not realize how much fun that would be. The hardest part about that task was calibrating the soil moisture sensor so that it would produce readings that we could use and understand.

Another aspect of the humidification and irrigation system that I learned was the proper use of relays to power the pump and 2 solenoids needed to control whether the humidification, irrigation or both were running. Splicing the extension cords to work with the relays seemed easy but I was a little nervous when I went to use them the first time even though I was sure there were no issues. . The only issue was with the

water solenoids. There was a problem with the threading. I realized then how important it is to ensure the products you buy are of good quality.

Being the project manager on this project was not that difficult. Everyone was eager to work on tasks and was already picking tasks before I had them all entered. It was a very good feeling. We also completed most of the documents at least a couple of days early, which we then used to ensure it was as well written and accurate as possible. The only exception to this was the design specification; I do not think any of us realized it would end up being 95 pages long. Even so, we were not really late as we could use the one free late for a 3-day extension in the deadline, which we met.

I think I learned the most inside the greenhouse when everything was coming together. It was interesting to see 3 or 4 people crowded in the greenhouse working on one item or another with such determination and confidence.

Lastly, I learned that having a good idea could be hampered when you cannot find a place to build it. It took a while before we could find a place to build the greenhouse and the only place we could find had access restrictions. These restrictions caused delays in completing the build so we ended up not getting as much grow-time as we would have liked.

In the end the project completed successfully and I think the group worked incredibly well together. I would work with any one of them again.

9.3 Jane Horton

Capstone was an incredible learning experience in many technical and social aspects. I was worried at first that a group of six people would be difficult to coordinate, but I am very fortunate to have been given the opportunity to collaborate with five very capable and easy-going individuals. Our project was extremely ambitious, and it seemed like no matter how much time we put in as a team, there was always more to do.

For the documentation portion of our project I learned that the time spent writing the document should be equivalent to the time spent editing it. The amount of weight placed on formatting, grammar, and spelling within all documentation was unexpectedly large. I learned that attention to detail reflects on the level of professionalism of the resulting document.

Taking on such a complex project challenged my skills as a problem-solver more than anything else. Constructing the design specifications forced every team member to consider the details of our project from so many angles we hadn't initially thought of. I learned about different device power requirements, cable management practices, algorithm development, and using science as a tool to reinforce engineering design decisions. As a team we decided to place a lot of importance on our system test plan and calibration. I learned how essential a comprehensive test plan can be, as it brought to light many aspects of our project that needed to be considered – such as how to test our sensors for functionality, or how to confirm that actuators were performing in accordance with the implemented software algorithm. Although our design document ate up so much time – such that we initially thought it was detrimentally detracting from development time - I think that every page of our 95 page design document contributed to our success.

A major portion of my learning experience involved consolidating our main code base. Ensuring consistent variable names, making sure everyone added changes they made to a changelog, and implementing best coding practices in general was a very involved task. When everyone is writing different code for the same project, consistent communication between teammates was essential. The detail contained in our design document was needed to make sure everyone was on the same page regarding the software algorithms that were decided on.

Another enlightening aspect of the project was the gross underestimation of the budget. Equipment often got lost or broken and needed replacement. Unforeseen items were required to build device enclosures, adaptors needed to be purchases for components that didn't fit together properly, and miscellaneous items such as glue, tape, and wire connectors added to our expenses. The budget, including our contingency fund didn't come close to the final cost of the project. I learned that a contingency fund should amount to at least 50% of the tentative budget.

I also realized during the busy stages of the project that there is no way we could have completed it without all six members of the team working full-time. The project would not have been successful without the unique skills and work ethic that each person contributed to the Plantmosphere. Not only were technical skills essential, but since the team worked well as a unit, we were able to become a well-oiled machine that generated quality documentation and design work efficiently. I would consider myself very fortunate to work with such a harmonious team in my future engineering career.

9.4 Alex Naylor

Coming into this project, I intended on focusing mainly on electronics, but I ended up getting involved in quite a bit more. I helped my team members to make the trough for our plants, build a fixture for our user interface box, write code for both actuation and decision-making, and create an intake vent, among other tasks.

My greatest learning happened in the workshop, where Mike used his vast woodworking knowledge to teach myself and other group members how to use many tools, along with some basic strategies. Much of my construction progress would have come to a halt without his guidance.

Creating a realistic budget was a difficult task. When we were interviewed for ESSEF funding, the estimate we came up with ended up being three quarters of what we actually spent in the end, even with the thirty percent overestimate. Furthermore, the figure we ended with would have been a lot larger had we not salvaged many of our more expensive parts. Occasionally, parts will break, designs won't work, or lengthy shipping times might necessitate spending more for express delivery. In larger projects, it seems to be a miracle to be able to budget finances properly as most designs are in flux between the beginning of the course and the time the proposal is due.

After a shocking revelation that our design specification document was due three days earlier than we'd expected, I learned two things. First, it is **incredibly** important to check deadlines for every document. Second, the design specification is one of the most useful tools for determining what will and will not work in your project. Over the week that we spent on ours, we discovered that some of the designs we had chosen were either flawed or that they were missing crucial elements. For example, the upper vent reed switch

configuration was completely reorganized after it was concluded that the initial setup would have been unreliable. The design specification is also useful for determining an inventory of the parts required to complete the project.

I also noticed that progress can be quite deceptive depending on the size of the project. For almost two straight months before the presentation and demo deadline, we were making strides almost daily. We documented all of our electronic and mechanical progress with pictures and video, totaling over one hundred items four days before our presentation. Snags were rarely hit, but when they were, their resolutions were typically quick and easy. But despite the constant leaps and bounds we were making, there was always so much more to do: more needed to be built, installed, coded, and optimized. It is paramount to not let progress cloud your perception of how much is left to do. Moreover, weekly meetings are an asset for ensuring that everyone knows what is left to do and when it needs to be completed.

Lastly, group dynamics are a large aspect of the Capstone project and have a large influence over its success. I was lucky enough to work with a group that was passionate about the project and knew what they were doing. It was easy to trust that everything would get done properly and in a timely manner. Further, every member brought something different to the table, allowing each to specialize in his or her own strengths. As we worked together, we were able to try and learn new things, so that everyone was able to help one another on multiple systems. I believe that our diverse skill set was ideal for the project that we undertook.

9.5 Jeffrey Shum

Being a part of Plantmosphere Technologies, I have learned more unexpected than expected aspects of this project during the past four months. From the beginning, I knew to expect to learn about the technical side of design with circuitry and coding. However, I surprised myself at how involved I was in the physical design and construction of many of our modules. The amount of documentation required also exceeded my expectations, especially for our design specifications document.

Most of my time was spent on designing and building the ventilation system from the ground up. This included learning about the need for airflow and the different strategies for implementation. The process forced us to be creative in generating the desired airflow through long periods of trial and error of vent and fan placement. In the end, our final vent was completely different from our initial design. Construction was also time-consuming because I first needed to learn about the basics of woodworking. However, I gained dexterity and confidence in using the many tools. More importantly, I learned about the importance of planning ahead before diving into construction by taking into account the physical constraints of every component individually and together as a module, envisioning the required order of steps, and carefully marking and measuring before every precise cut or drill.

Designing the User Interface (UI) was another primary task. The initial challenges were finding the required existing libraries for the operation of the Liquid Crystal Display (LCD) and learning how to interface a keypad. However, once I obtained a basic sample code for turning on the LCD and learned about the wiring behind a keypad, I was able to individually interface them with the Arduino and gain a better understanding of how each component interacted with code. My creativity was once again driven during the coding process of the UI as a whole, in thinking about how to display our desired outputs dynamically in a continuous loop.

The biggest eye-opener in the entire creation process of the Plantmosphere is the amount of administrative work and documentation required before any progress can be made. The compilation of our budget was really an ongoing task as we frequently encountered issues or changes which warranted the purchase of additional parts. Needless to say, our initial budget was greatly under-projected. The management of individual tasks was paramount in the success of progress as it kept the entire group organized and on the same page for exactly what needed to be completed.

Our group dynamics were very good as a result of my excellent team members. They were able to instill confidence in each other, lend a helping hand, and each of them taught me many skills and helped me develop as a team member. It was easy to put my trust in this group, and I am privileged to have been able to call myself a part of such a diverse and passionate team.

9.6 Mike Thiem

This class has been the single most educational and enjoyable class of my entire degree so far. By forming a group early and having a diverse skillset amongst the members, we were able to start trying different approaches to solving the problems of greenhouse design and control. For example, when learning how best to control AC-powered devices, I experimented with other designs before deciding on using solid-state relays, such as the triac. After weeks of experimenting with different circuit configurations, we decided that for the sake of safety and reliability, that we would buy a relay module instead, and control those with the Arduino. This sort of decision making process was common throughout the semester: we would always start by trying to design a particular subsystem from circuit components, and quickly realized that, because of the massive scope of our project, we just wouldn't have time to do the due diligence, ie testing and proving the safety and reliability of our home-made solution.

The most useful thing I was able to learn and practice during this project was my general problem solving ability. For the majority of the term, the problems we faced with the individual subsystems were straightforward to understand and fix. However, when we began integrating the systems together, we were faced with an onslaught of errors, misbehaving actuators, and indecipherable test results. My approach to this chaotic, frustrating and stressful situation was to take a methodical approach to each problem. When we were faced with an error or malfunction we didn't understand, I started by suggesting all the possible components that could be causing the problem, and why, and helped to delegate quick tests that would confirm or refute these assumed causes. I had us write simplified versions of our code to isolate problems, use the DMM to check the connectivity of our circuits, and used the intuition for circuit behavior I developed throughout my degree.

More importantly than learning and honing technical skills, I've gotten the opportunity to learn some very important leadership skills. With a project as ambitious as this, we found ourselves needing all six members to contribute at all stages throughout the project in order to get things done on time. We struggled through the beginning of the semester, with some members feeling like others weren't putting in the necessary (or equal) amount of effort. We had a very constructive discussion and managed to make this known, and the entire group dynamic changed. Everyone was able to work together, communicate effectively, and we started all

actually contributing. I couldn't be happier with this group and how far we've come, and how much we've learned in the process of creating the Plantmosphere.

10 Conclusion

This project was very exciting and rewarding as well as an incredible learning experience. Even though it was challenging at times it was also a lot of fun and the group worked very well together bringing out the best in all of us.

Plantmosphere Technologies will be looking at continuing this project even further with the following new objectives:

- Solar power
- Water runoff reclamation
- Water filtration
- CO_2 sensor
- Automatic fertilization with pH sensor
- Modular design
- Hydroponics support
- Sunlight filtering or blocking
- Water reservoir and greenhouse heating
- Mobile device integration
- More options for different type of plants

11 Appendix

MINUTES

September 02, 2014

10:30-11:30

Present: Alex Naylor, Faisal Emami, Jane Horton, Jeff Shum, Terry Hannon

Absent: Mike Thiem

Purpose of Meeting: To decide what to do over the next few days

Minutes:

Group called the meeting to order at 10:30.

A. Sensor research delegation

- Research delegates are as follows:
  - Alex Naylor: Light sensors
  - Faisal Emami: Chemical sensors
  - Jane Horton: Temperature Sensor
  - Jeff Shum: CO_2 & O_2 sensor
  - Mike Thiem: Soil moisture level sensor
  - Terry Hannon: Humidity sensor
- Deadline: Friday, September 6, 2014

B. Power generation

- Initially, we want to start out using a generator, but eventually would want to use solar panels if we had more funding and time

C. Mobility

- The product will not be fastened to the ground itself, but will rest on a platform so it is more mobile

Meeting was adjourned early at 11:00 (all items discussed).

[Unnamed company]

MINUTES

September 02, 2014

20:00-21:00

Present: Alex Naylor, Faisal Emami, Jane Horton, Jeff Shum, Mike Thiem, Terry Hannon

Absent: None

Purpose of Meeting: Mike wants to give some updates

Minutes:

Alex called the meeting to order late at 20:30 due to technical difficulties.

D. Mike's ideas

- Might lose light through opposing wall
  - Lose lots of heat, so maybe try to use the light to recapture more heat
  - Use a black sheet with perforated holes to let some light in, but to also keep light in from other sources
  - Alternatively, we could use an electric heater
    1. Most likely requires a lot of power
- Structural stuff
  - Simplified building process: no special tools or materials
  - Materials should be easy to find and ideally the assembly should be tool-less
  - Pressure-treated wood for frame
    1. At joints, drill a hole and insert a bolt and wing nuts
  - For holding it together, use something similar to the casing on desktop computers
    1. Possible issue could be thermal insulation
- Use of racks so that plants can be stacked vertically
  - Needs lighting for each rack
  - Adjustable heights for each rack to accommodate tall plants

E. JIRA

- Terry added more tasks
  - The tasks need to be broken down further
  - Plant research task added

Meeting was adjourned early at 20:45 (all items discussed).

[Unnamed company]

MINUTES

September 05, 2014

17:00-18:00

Present: Alex Naylor, Faisal Emami, Jane Horton, Jeff Shum, Mike Thiem, Terry Hannon

Absent: None

Purpose of Meeting: Have everyone discuss their research on their assigned sensors among other things

Minutes:

Alex called the meeting to order late at 16:45 due to pre-meeting discussions.

F. Sensor research

- Alex: Light sensor
  - Found code and a list of parts needed here and here
  - Want to sense when it's daytime or nighttime; if it's night, we want the LEDs off, but if it's day and too dark, we want the LEDs on
- Faisal: Chemical sensor
  - Need different chemicals for different plants, so focusing on pH sensors
    1. Don't seem to be chemicals for some essential nutrients
  - Need a pH probe, which comes in a pH kit
    1. ~$105
  - pH level should be between 5-7; otherwise it's toxic to the plants
  - pH sensor is useful for letting the user know not to over- or under-fertilize their plants
  - For now, we aren't going to use it because of the price, but we'll keep track of the part
- Jeff: CO_2 sensor
  - There's a sensor, or a sensor module
    1. Sensor is ~$35 and module is ~$50
    2. We'd prefer to get the module over the sensor itself for reliability and easier incorporation
  - Ideally, we'll put the entire module in the same PVC pipe as the rest of the instruments at the top of the greenhouse as air is pulled into it
- Jane: Temperature and humidity sensor
  - Found humidity and temperature sensor combination on Lee's Electronics
    1. ~$5, ~$8
  - Looking into waterproofing
  - Want to know temperature inside and outside greenhouse
- Mike: Soil moisture level
  - Use Jane's sensor, can just cover it in silicon and bury it
- **NOTE: MAKE SURE ALL PARTS ARE RoHS COMPLIANT**

G. Assign people to different tasks

- Waiting on JIRA issues to be online; should be up tomorrow

H. Decide on team name

- Diverted to next meeting; not all members present at time of discussion

I. What foods and other plants to grow for our demo

- Radishes seem to be the best bet
  - Easy to grow
  - Grow better in cold temperatures
  - Grows fast
- Green onions might be an option as well
  - Grows at a similar rate as radishes

Meeting was adjourned late at 17:25 (not all items complete; diverted to next meeting).

[Unnamed company]

MINUTES

September 08, 2014

20:00-21:00

Present: Alex Naylor, Faisal Emami, Jane Horton, Jeff Shum, Mike Thiem, Terry Hannon

Absent: None

Purpose of Meeting: Clarifying our audience and choosing our team name

Minutes:

Alex called the meeting to order late at 20:15 due to him not being prepared.

J. Audience clarification

- Cameras only for our benefit; not in final product
  - Jeff and Faisal might have some webcams
  - Mike has an old camera
- Third world means more focus on cost reduction and making the greenhouse work in all climates
  - We'd need to talk to people from third-world countries to find out their needs
- Jane visiting grandpa on weekend and will ask about growing stuff
- First world means we can put more in it and charge more; want to make it as easy as possible to use
  - Again, need to talk to other people to find out their needs
  - Talk to people with greenhouses about issues they have with them
    1. Talk to Mike Henry about issues with greenhouses and agriculture
    2. Find other people that have been to the third world
  - Also possibly Engineers Without Borders
    1. Might be more "talk than walk", so possibly avoid
- Should look into how much money we're willing to spend if we have to
  - Ideally, we should aim to get as much funding as possible to avoid having to spend our own money
    1. Have to be wary of whether or not the funding changes ownership
    2. Wighton Fund should reimburse us in the end
- Let's focus on making the bare minimum work; if it does, then we can focus on adding more to it at a later date
- **FOCUS ON THIRD WORLD!**
  - This means focusing on retaining as much water as possible
    1. Once this is complete, we could add even more with more money and time
  - pH, CO_2 sensor; not necessary for now
  - Light, temperature, humidity sensors; important
  - Irrigation: most important for this audience
    1. Drip irrigation might be easiest; can turn off by dropping pressure
  - It would be nice to keep the whole system modular so that we can add more in the future easily

K. Choose team name

- Candidates:
  - Greenhouse Solutions
    1. Name of a book and a company

- Fight Hungry Nations
- Greenhouse Food Service **OR** Greenhouse Food Solutions
- Agri-Tech Industries
    1. **Product Name:** Plantmosphere
    2. Company name already exists
- Greenhouses Yielding Never-Ending Opportunity (GYNO)
- Get Your New Ownage Solution (GYNOS)
- Greenhouse Automation
- [Smart] Green Systems
- Green Harvest Systems
- Green Harvest Solutions
- Plantmosphere Industries
- Plantmosphere Greenhouses
- Plantmosphere Solutions
- Plantmosphere Technologies

- **Team Name:** Plantmosphere Technologies (A.K.A. Plant-Tech)
- **Product Name:** Plantmosphere

L. Discuss AG-25: Explanation of Key Elements

- Based on the "Proposals and Progress Reports" lecture, slide 10
- Relates to the Scope/Risks/Benefits section

M. Other items

- Jane found a greenhouse, but it's ~$500
- Jane found polyethylene sheets on Craigslist
    - Need to look into retail price, although we could get a discount buying in bulk (this is for the future)

Meeting was adjourned late at 20:20 (Discussed additional items).

Plantmosphere Technologies

MINUTES

September 09, 2014

19:00-20:00

Present: Alex Naylor, Faisal Emami, Jane Horton, Jeff Shum, Mike Thiem, Terry Hannon

Absent: None

Purpose of Meeting: Discussing tasks on JIRA

Minutes:

Alex called the meeting to order late at 19:45 due to miscommunication.

N. Discussing tasks on JIRA
- Note there's a page limit for each section in the proposal
- For the "Research Sensors" task (**AG-15**), everyone add in their own research as a comment on JIRA
- Faisal: add in your research as a comment on your task (**AG-22**)
- **EVERYONE ADD YOUR RESEARCH TO ITS RESPECTIVE JIRA TASK**
- Order of tasks for proposal:
  - **1)** AG-24, AG-25, AG-26, AG-27, AG-28; **2)** AG-23; **3)** AG-29

O. Go over team roles
- Can ask Steve if we need CEO, Marketing, etc.
- Probably doesn't matter

P. Proposal draft due date
- Draft deadline will be for **Wednesday, September 17th, 2014**

Q. Optional Items
- **User interface:**
  - Very simple for proof of concept
  - In the future, might want to add a touch panel
    1. Touch screen arduino module?
  - Buttons to turn off the various functions
- **Generic environment for growing plants (less user input)**
  - Nice to use as a pre-set
  - Minimizes user input
  - Grow a variety of plants in one enclosure

R. Other items
- **EVERYONE GET "MPP VIEWER" TO SEE THE GANTT CHART (.mpp file)**
- **Airflow pipe; how does it stay heated at night**
  - It won't
    1. This just means that the temperature readings are less accurate

Meeting was adjourned late at 20:30 (Due to late start and discussed additional items).

Plantmosphere Technologies

MINUTES

September 12, 2014

16:30-17:30

Present: Alex Naylor, Faisal Emami, Jane Horton, Jeff Shum, Mike Thiem, Terry Hannon

Absent: None

Purpose of Meeting: Various items (nothing specific)

Minutes

Alex called the meeting to order early at 16:15.

S. Have a schedule made that superimposes everyone's schedules

- Mike posted everyone's schedules on Dropbox
- Fridays are group meetings and other days are individual teams
  - Tuesday 11:30 – Faisal, Jeff, Alex meeting
  - Tuesday 7:00 – Jane Mike, Terry
- Everyone add their proposal writing to Dropbox and everyone read everyone else's sections

T. Discuss our research and have it posted on the respective task

- Mike:
  - Foundation:
    1. Materials, reservoir inside its, water reclamation
    2. If water in base, use gutter (as discussed in the previous meeting)
    3. Cheapest $/gallon are garbage bins, rubbermaid containers (54 gallons, $27)
    4. Elevated foundation:
       - **a.** Deck underneath foundation, raise greenhouse on platform with stilts
         - **i.** Issue: could get drafts underneath
    5. Dig ditch in soil:
       - **a.** Put it in the ground
  - Structure:
    1. Buy a kit:
       - **a.** See JIRA
       - b. Find out how to order it, where it's coming from, where to ship it
       - c. There's also one at Home Depot (6x4 feet)
  - Watering:
    1. Submersible pumps
    2. Drip irrigation:
       a. Snake tubing around all the plants, then poke holes where the plants are, add some more tubing, and add an "emitter"
       b. Make a block diagram
    3. Humidity sprayer:
       a. Kit with PVC, clamps and stuff
    4. Irrigation/Humidity combo kit as well
    5. Arduino should just turn the pump on and off
- Jeff:
  - Airflow systems:
    1. Natural ventilation; no power needed

2. Roof and sidewall vents
    a. Hot air at roof vent, cold air at side vent
    b. 3 meter height difference between the two vents
        i. Might be too large a difference for our greenhouse
        ii. Need fans if we can't achieve this height difference
        iii. Instead of height difference, manually heat the air at the top with some black coating?
    c. For just airflow movement, we can use the pipes discussed earlier
    d. If there's enough airflow, we won't need to worry about a CO_2 sensor
    e. Determine number of fans required in place of this vent, where to put them, and what kind of fan
    f. If we use side vents, we'll need a % of the wall to be a side vent (~15% - 40%; depends on climate)

U. Discuss proposal progress

- Delay to next week

V. **Other items**

- Jeff can read over other's proposal sections until he has to write the executive summary
- Make a document we can all edit about questions for Jane's dad
- Jane can apply to ESSEF grant
    - Interview…
- ******APPLY TO FUNDING SOON******

Meeting was adjourned early at 17:00 (All items discussed).

Plantmosphere Technologies

MINUTES

September 15, 2014

20:00 – 21:00

Present: Alex Naylor, Faisal Emami, Jane Horton, Jeff Shum, Mike Thiem, Terry Hannon

Absent: None

Purpose of Meeting: Discuss proposal and funding

Minutes:

Alex called the meeting to order early at 20:15.

A. Decide company logo
- Alex will attempt to use the font and format of Jane's logo with the "P" logo instead
- Deferred to next meeting

B. Discuss the proposal template
- Match heading colour to logo colour
- Font stuff
  - **Font size:**
    1. Main header: 18 pt.
    2. Sub header: 13 pt.
    3. Body: 12 pt.
  - **Font type**
    1. Calibri
- Do not use the text boxes; just write it in as normal
- Will add spacing as part of the template, not ad hoc spacing
- Add in title page as in example proposal

C. Discuss how to split AG-25: Proposal – Explanation of Key Elements
- See the notes about the example proposal in "Other Items" below

D. Discuss funding
- ESSEF due on Monday, September 22nd
  - Jane is handling it
- Sustainable SFU has a grant
  - Submitted by Terry
- Wighton Fund
  - Find out more about it (talk to Andrew)

E. Discuss whether or not to have everyone write their own bios for the "Company Profile"
- Everyone read and edit their own

F. **Other items**
- We will be following the sections as they are presented in the example proposal:
  - **Complete:**
    1. 1 – Jane
    2. 8, 9, 10 – Alex
  - **Incomplete:**
    1. 2 – Jane
    2. 3 – Jeff
    3. 4 – Mike

4. 5, 6 – Faisal
5. 7 – Terry
6. 11 – All
7. Executive Summary – Jeff
8. Letter of Transmittal – Jeff

- Update JIRA tasks based on this

- Jeff's ventilation stuff
  - Has numbers for the required surface area of the intake and exhaust vents
  - Ventilation varies by season (ie. difference in temperature)
    1. More ventilation in hot months
    2. Design for worst case (hotter environment)
  - Look at the greenhouse we're going to purchase and design around it
  - How many vents do we **need**
    1. If we remove a panel, we lose some thermal insulation
- **READ EVERYONE'S DRAFTS BEFORE FRIDAY'S**

Meeting was adjourned late at 21:30 (Additional items discussed).

Plantmosphere Technologies

MINUTES

September 19, 2014

14:30 – 16:30

Present: Alex Naylor, Faisal Emami, Jane Horton, Jeff Shum, Mike Thiem, Terry Hannon

Absent: None

Purpose of Meeting: Evaluate and revise the first draft of the proposal

Minutes

Alex called the meeting to order late at 14:45 (technical difficulties).

G. Revise first draft of proposal
- Remove the "Sources of Information" section
- Tell the group if you're making changes to a document
- Jane and Alex will edit the document Monday at noon for flow
- Comments done by Saturday night
- Edits done Sunday, brief meeting at night
- Discuss comment issues with people **BEFORE THE MEETING**
- Use the commenting system in MS Word:
  - "Review" tab > Highlight what you want to comment on > click "New Comment"
- When you go to add edits and comments to other peoples' sections, **SEND A MESSAGE ON WHAT'S APP WHEN YOU START AND END EDITING**

H. Decide company logo
- Done

I. Mike wants to discuss a new water reservoir
- Could use hot water to heat the soil (when the sun is hot enough)

J. Jeff wants to discuss air flow
- Need to close vents for thermal insulation
- Use the vent at the top of the greenhouse as well as maybe intake fans?
- Change the fan's polarity

K. **Other items**
- None

Meeting was adjourned early at 15:45 (All items discussed).

Plantmosphere Technologies

MINUTES

September 21, 2014

21:30 – 22:30

Present: Alex Naylor, Faisal Emami, Jane Horton, Jeff Shum, Mike Thiem, Terry Hannon

Absent: None

Purpose of Meeting: Discuss the edits we've made to our respective proposal sections

Minutes:

Alex called the meeting to order late at 21:35 (technical difficulties).

L. **Go over the edits made to each member's section of the proposal**
- Executive Summary:
  - Everyone needs to edit this

M. **Other items**
- None

Meeting was adjourned early at 21:45 (All items discussed).

Plantmosphere Technologies

MINUTES

September 22, 2014

20:30 – 21:30

Present: Alex Naylor, Faisal Emami, Jane Horton, Jeff Shum, Mike Thiem, Terry Hannon

Absent: None

Purpose of Meeting: Discuss the final draft of the proposal

Minutes:

Alex called the meeting to late order at 20:50 (technical difficulties).

N. Go over the final edit of the proposal

- Terry:
  - Change Terry's title (ie. Design Engineer and Project Manager)
  - Change "Third world" to "developing nation"
  - Change "Engineers" to "Engineering students"
  - **Executive Summary:**
    1. End of P1: Remove "simply"
    2. P2: Tense issues; change to "generate" and "reduce" and add a "therefore"
    3. P2: Put "subsequently" at the beginning of the sentence
    4. P4: Change "engineers" to "engineering students"
    5. P4: Change "ensures" to "increases the likelihood" or something similar
  - **Introduction:**
    1. P2: Both sentences 1 and 2 use reference one; add reference one to the end of each sentence
  - **Project Overview:**
    1. P2: Change to "select the plant"; remove "category"
  - 3 goals:
    1. 1) Sustainable solution for sub-Saharan Africa
    2. 2) First world residents can use it
       a. Remove "first world"
    3. 3) Gardeners of all skills can use it
  - Add a heading for both risks and benefits
    1. Climate stuff is both a risk and benefit
  - **Possible design solutions:**
    1. "food and water distribution **are** resource…"
  - **Proposed design solitution:**
    1. P1: Intro sentence is the perfect goal statement
       a. Add to introduction, P3
       b. Fix the intro of "proposed design solution" accordingly
    2. P3: "Proceeding" to "Following"
    3. P3: "emulate" to "strive to maintain"
    4. Diagram: Add in something to show that the microcontroller is redundant
       a. Not a big deal, but Mike's changing it
  - **Budget:**
    1. Remove "x1"
    2. Unbold components

3. Bold "total"
4. Maybe bold or highlight the row?
5. Capital "B" in table caption

- **Team Organization:**
  1. "Engineering students" again
  2. Name the person leading the meetings (ie. Alex)
- **Company Profile:**
  1. Fix Mike's sentence "in charge of"
- Change Jeff's name to Jeff (not Jeffrey)
- **Conclusion:**
  1. "Modular design" and "open source code"
     a. Mention these in the proposed design solutions sections
  2. P3: Change "required" to "necessary"
- **ADD STUDENT IDs!!!**

O. Discuss tomorrow's ESSEF presentation (ie. powerpoint, info)

- **Attire:**
  - Dark blue/black jeans, or dress pants
  - Button up shirt
- **Presentation:**
  - 5 minutes focused on cost breakdown
    1. Mike will make a graphic for this
  - Don't bother with a powerpoint
  - Other 5 minutes for product
    1. Exec summary, intro, etc.
  - Our project with stay at SFU, bring that up
  - Meet tomorrow from 9:30 AM – 10 AM

P. Discuss example documents

- **DO NOT USE THE 1999 EXAMPLES AS EXAMPLES FOR CONTENT!!!**
- Make a list of documents we want to use that are exceptional

Q. **Other items**

- How to break up functional design

Meeting was adjourned late at 22:30 (edited proposal further).

Plantmosphere Technologies

MINUTES

September 23, 2014

09:30 – 10:30

Present: Alex Naylor, Faisal Emami, Jane Horton, Jeff Shum, Mike Thiem, Terry Hannon

Absent: None

Purpose of Meeting: Discuss the ESSEF presentation

Minutes:

Alex called the meeting to late order at 09:35 (Jeff was late).

R. Discuss items for the ESSEF presentation

- 5 minutes discussing project and specifically budget
  1. Intro: say company name and our names and job title (everyone say their own name and title)
  2. Opening: goal line from P3 of introduction
  3. Next: Using an Arduino, mention Sustainable SFU and that we're donating it to them
     - At the very least, the greenhouse itself can be donated
  4. Next: budget
  5. Closing: Reiterate the project management software, that we've been working since July, ie. that we are very organized
- 5 minutes for questions

S. **Other items**

- How to break up functional design

Meeting was adjourned early at 09:55 (all items discussed).

Plantmosphere Technologies

MINUTES

September 25, 2014

13:45 – 14:45

Present: Alex Naylor, Faisal Emami, Jane Horton, Jeff Shum, Mike Thiem, Terry Hannon

Absent: None

Purpose of Meeting: Discuss our next steps

Minutes:

Alex called the meeting at 15:45.

T. Decide when to start purchasing materials (some items may take a while to ship)
- After designing the system
- Discuss next meeting (September 26th, 2014)
- Can use just the ATMega chip rather than the entire Arduino to save money (see link)
- Some things we may want to buy sooner (ie. the Greenhouse)

U. Decide how to break up the functional specification document
- Need to split by components or function
- Add glossary terms when needed
  - Have a glossary document; maybe use Google Docs for updating
- Split the functional spec. up in terms of research sections for now
- **Rubric:**
  - Process Details: split up
  - Engineering Standards: could influence purchasing decisions
  -
- Flow charts will be good
  - Jane and Terry have experience with this (ie. Visio)
- **FOR SATURDAY 7 PM:** Everyone suggest structure for the tasks; upload to Dropbox (Alex will make a folder)

V. Close off the proposal and research JIRA tasks
- Do not close the research tasks
  - We could also close the old ones and make newer, more specific ones

W. Discuss making our own greenhouse
- Not enough time; ventilation, structural integrity, and air-tight issues
  - Making a greenhouse isn't the focus of the greenhouse; the automation is the crux
- The Home Depot greenhouse doesn't seem to be double-walled
  - Need this for thermal insulation
    1. The air gaps are required for this
  - The craigslist one was double-walled
- For now, we're getting the Home Depot one
  - **FOR SATURDAY 7 PM:** Decide if we can use this one
    1. Jane, Mike, Terry, and Alex will go to the Brentwood Home Depot at noon
    2. We'll take pictures for Faisal and Jeff
  - If it doesn't work out, everyone should look for alternatives

X. Discuss issues with reliability, redundancy, etc.
- Need to determine how to switch to an alternate Arduino or component

        - Keep one off and have it activate in the event that the other is off
        - Need to research how Arduino's fail (ie. in scenarios where the y don't turn off, but start outputting wrong values, etc.)

Y. **Discuss receipts for purchased items**
    - Give all of your paper receipts to Alex
    - If sellers give you an option for an emailed receipt, do that and forward it to Alex
    - Forward any email receipts to Alex

Z. **Other items**
    - **Google Drive Migration:**
        - Use this for future documents rather than the "capture/release" of MS Word documents

Meeting was adjourned early at 16:35 (All items discussed).

Plantmosphere Technologies

MINUTES

September 25, 2014

18:30 – 19:30

Present: Alex Naylor, Faisal Emami, Jane Horton, Jeff Shum, Mike Thiem, Terry Hannon

Absent: None

Purpose of Meeting: Discuss the functional specification sections

Minutes:

Alex called the meeting to order late at 18:45 (Jane and Mike late).

AA. Decide how to break up the functional specification document

- Can talk about greenhouse in the "structural requirements" section
- **Hardware Overview:**
  - Talk about Arduino connections
- **Software Overview:**
  - Need a process flow diagram to explain what the software will do
  - Talk about testing the software
  - Software standards – need it to be well-commented and modular
  - Talk about the Arduino stuff
- Meeting for General Standards Tuesday, September 28th, 9:30 – 11:00 AM
- Drafts due Monday, October 6th, 11:59 PM
- Meetings about drafts Tuesday, October 7th
  - Two meetings; Mike will attend both
- Comments due Wednesday, October 8th, 11:59 PM (tentative)

BB. Discuss what we should be doing this week

- Functional spec.; start writing (see above for due dates)
- Greenhouse is ~$650 total
  - Terry ordering it tomorrow
  - We'll give ESSEF cheque to Terry when it comes
- Go over research sections and decide what parts we need
  - As much as possible, use Digikey and remember **RoHS COMPLIANCY!!!**
  - Air ventilation incomplete
    1. Mike, Jeff, and Alex will meet Monday, September 29th, 1:00 PM (Sunny Room)
  - Look into LED stuff
    1. Use RGB LEDs?
       a. Color changes with voltage
    2. Alex and Faisal will meet about this this week
- Make a JIRA task to finalize components to buy
  - Don't worry about parts quite yet; worry moreso once we're done with the functional spec

CC. When to order greenhouse

- Terry ordering tomorrow (see above)

DD. **Other items**

- None

Meeting was adjourned late at 19:40 (due to late start).

Plantmosphere Technologies

MINUTES

September 30, 2014

09:30 – 10:30

Present: Alex Naylor, Faisal Emami, Jane Horton, Jeff Shum, Mike Thiem, Terry Hannon

Absent: None

Purpose of Meeting: Discuss the functional specification standards

Minutes:

Alex called the meeting to order late at 10:00 (Jeff late).

EE. Discuss the functional specification standards

- **System Overview:**
  - High-level diagrams
    1. Ideally, let's make a system overview overall
  - Description
  - Redundant requirements (ie. ones that fit into multiple requirement sections)
- Number requirements
  - For referencing purposes
  - Group requirements by section, then number them inside (ie. ventilation has requirements R1.1, R1.2, R1.3, etc.)
  - In each section, number your requirements starting at 1
- For classifications
  - **A –** Essential product requirements
  - **B –** Non-essential product requirements
    1. Might want to rename
  - **C –** Refinements
  - **D –** Out of scope (**TENTATIVE**)
- Use the word "will" when describing requirements
- For functional requirements, **NOTHING SHOULD BE TECHNICAL**
  - ie. "The vent will open when the temperature is too high", "all outputs will be appropriately labelled", "there will be an on/off switch"
  - A functional requirement could turn into a list of technical requirements
- Non-functional requirements are things that don't physically do anything
  - ie. "There will be a backup power source", "the data will be backed up"
- To distinguish between functional and non-functional, use **F** or **NF**
- Performance requirements: "the plants can't die"
  - Let's talk about this one more
- Physical requirements
  - ie. "The electronics must be enclosed"
- Add rationale for each requirement as a sub-bullet, and we can delete obvious ones later
  - Sort this out later (formatting)
- Make sure requirements you write go under appropriate header
- If you think a requirement might fit in another section, contact the person who has that requirement section
- For any redundant requirements, we might want to add them to **System Overview** section

FF. **Other items**

- None

Meeting was adjourned early at 10:20 (Alex had to go to tutorial).

Plantmosphere TechnologieS

MINUTES

October 2nd, 2014

20:30 – 21:30

Present: Alex Naylor, Faisal Emami, Jane Horton, Jeff Shum, Mike Thiem, Terry Hannon

Absent: None

Purpose of Meeting: Discuss possible example functional specifications from previous years

Minutes:

Alex called the meeting to order at 20:30.

GG. Discuss possible example functional specifications from previous years

- **Faisal:**
  - Electroaudio [2014]
  - Cycle Bright Solutions [2014]
  - VisuAid [2014]
- **Jeff:**
  - Smart Light Solutions [2012]
  - Urban Wheel [2013]
  - Arimus Audio [2014]
- **Mike:**
  - Arimus Audio [2014]
  - ScribeWare [2012]
  - Dimension Tech [2012]
  - **DO NOT USE AUTOMATIC SHOPPING CART**
- **Jane:**
  - Electroaudio [2014]
  - Urban Wheel [2013]
  - CapsulCorp [2013]
- **Alex:**
  - RefriEco [2014]
  - Easy Way Inc. [2014]
  - PresTrack [2014]
  - Arimus Audio [2014]
- We'll use point form (like VisuAid's)
  - If you need justification, add it in as an extra bullet
- Ex.
  - [REQ 1-A|B|C|D]
    1. The letters denote project phase
- No concrete values
  - Don't write things you don't have evidence for
  - Regarding power consumption in the functional document, only mention that it'll minimize it
  - Example of lighting section requirement good VS bad
    1. Bad: "The LEDs will emit 770nm wavelength light"
    2. Good: "The lighting system's emission spectrum will be optimized for the absorption spectrum of the plants."

        - Can use numbers only if it's for conforming to a standard (eg. "The wireless transmitter must operate with a frequency of 2.4GHz as per standard *X*")
    - Complete sentences
        - No fluff
        - Each sentence needs an object and subject
        - Start each sentence with "the" where needed
    - Write for content first; we'll edit for readability later
    - Use the word "will" only; we can change it in editing if needed
    - Write a rationale for each requirement, and we can remove the unnecessary ones
    - Use "not" rather than "never"
    -
    - **ADD IN A SECTION FOR USER INTERFACE**

HH. **Other items**

- None

Meeting was adjourned late at 22:30 (lots of discussion).

Plantmosphere Technologies

MINUTES

October 13th, 2014

20:30 – 21:30

Present: Alex Naylor, Faisal Emami, Jane Horton, Jeffrey Shum, Mike Thiem, Terry Hannon

Absent: None

Purpose of Meeting: Decide on parts to purchase

Minutes:

Alex called the meeting to order at 20:30.

II. **Decide on parts to purchase**

- **Lighting:**
  - LEDs:
    1. Do math and revisit
  - Photoresistors:
    1. http://www.digikey.ca/product-detail/en/PDV-P8104/PDV-P8104-ND/480611 **(x10)**
  -
- **Ventilation:**
  - Fans:
    1. Use Mike and Faisal's fans for now, will buy others as needed
  - Lower vent: **Re-evaluate**
  - Motors to open vents:
    1. Upper vent: **Mike wants to do more research**
    2. Lower vent: **Try out Alex's first**
- **Humidity/Temperature combination:**
  - http://www.amazon.com/Digital-Humidity-Temperature-Sensor-Arudino/dp/B007YE0SB6/ref=sr_1_2?ie=UTF8&qid=1413263285&sr=8-2&keywords=dht11+sensor#customerReviews **(x3)**
- **Solder:**
  - Lead-free solder: http://www.digikey.ca/product-detail/en/SMDSWLF.031%201OZ/SMDSWLF.031%201OZ-ND/2177055
  - Solder wick: http://www.digikey.ca/product-detail/en/LF-A-10AS/EB1193-ND/1638346
- **Soil Temperature sensor:**
  - Use the DHT11s listed in "Humidity/Temperature combination"
- **Soil Moisture sensor:**
  - Use this method: http://gardenbot.org/howTo/soilMoisture/
- **Electrical Enclosures:**
  - Leave that until later
- **Power:**
  - Use peoples' own adapters, will buy others as needed
- **Arduino:**
  - Everyone is buying their own Arduino UNOs

JJ. **Other items**

- Terry; send Alex the greenhouse receipts
- Greenhouse locations:
    - Mike's landlord has a place in PoCo
    - Talk to sustainable SFU this week

Meeting was adjourned late at 22:30 (lots of discussion).

Plantmosphere Technologies

MINUTES

October 17th, 2014

16:00 – 17:00

Present: Alex Naylor, Faisal Emami, Jane Horton, Jeff Shum, Mike Thiem, Terry Hannon

Absent: None

Purpose of Meeting: Discuss what we need to do next

Minutes:

Alex called the meeting to order at 16:00.

KK. Discuss what we need to do next

- **Design Specification:**
  - Electroaudio's is a good reference
  - Background describes the component and explains why we chose it
    1. For LEDs, we can show the spectrum
    2. Maybe compare each component with others
  - Each person will choose one subsystem to head, as well as 2 or 3 other subsystems to help with (add a comment to the JIRA task)
  - See Google Drive: CAPTSONE > Official Documents > 3 – Design Spec > Task Assignment.docx
  - Control algorithm development should be parallel to hardware development
  - Assign tasks tomorrow

LL. **Other items**

- None

Meeting was adjourned at 17:00.

Plantmosphere Technologies

MINUTES

November 7th, 2014

16:30 – 17:30

Present: Alex Naylor, Faisal Emami, Jane Horton, Jeff Shum, Mike Thiem, Terry Hannon

Absent: None

Purpose of Meeting: Discuss our build priorities

Minutes:

Alex called the meeting to order at 16:30.

MM. Discuss build priorities

- **List of Tasks:**
  - **Enclosures:**
    1. Electrical Enclosure
    2. UI Enclosure
    3. Stepper Motor Enclosure
    4. Linear Actuator Enclosure
    5. LED Board Enclosure
    6. Waterproofing
  - **Power:**
    1. Prepare extension cords (wiring, Arduino code, etc.)
    2. Test PSU connections
    3. Testing
    4. Waterproofing
  - **Ventilation:**
    1. Intake manifold
    2. Upper vent configuration
    3. Mounting the fans
    4. Motor installation and programming
    5. Testing
    6. Waterproofing
  - **Sensors:**
    1. Sensor installation
    2. Calibration
       a. See design spec for specific calibration methods
       b. Go to biology and physics departments for thermometers, hygrometers, and photometer
          i. See Leslie Dodd in the bio department
    3. Programming and data logging
    4. Waterproofing
  - **Lighting:**
    1. Protoboard installation and soldering
    2. Wavelength calibration
       a. See physics department for spectrometer
    3. Testing
    4. Waterproofing

- **Water Reservoir:**
    1. Installation:
        a. Cut lid off of barrel
        b. Install pump and water level sensor
        c. Seal lid with plastic epoxy
    2. Water level sensor calibration
- **Humidification and Irrigation:**
    1. Writing the software
        a. Solenoid control
        b. Pump control
        c. Correct code once we actually test it
    2. Installation of Gardena kit, pump, and solenoids
    3. Testing
- **Trough**:
    1. Construction
    2. Installation
    3. Pipe fitting

NN. **Other items**

- **Shopping List:**
    - Caulking gun (Mike)
    - Barrel (Dude in Abbotsford)
    - Thicker diameter heat shrink (RP Electronics)
    - Pump (Home Depot)
    - More TIP41Cs (RP Electronics)
    - Reed switches (SPST-NO, Lee's Electronics)
    - Surge protector (Staples)
    - Breakers (RP Electronics)
    - Opto-isolators (Fred lab)
    - Ultrasonic Distance Measuring Module (Amazon)
    - NPT fittings (Home Depot)

Meeting was adjourned at 17:00.

Plantmosphere Technologies

MINUTES

December 1, 2014

09:00 – 11:00

Present: Alex Naylor, Faisal Emami, Jane Horton, Jeff Shum, Mike Thiem, Terry Hannon

Absent: None

Purpose of Meeting: Discuss what we have left to do according to JIRA

Minutes:

Alex called the meeting to order late at 09:45 (Alex, Mike, and Jane late)

Here's a color code for the items in this meeting. Each item also says who it's assigned to. Also notice that some JIRA tasks are still unassigned.

Green: Complete

Yellow: In progress

Red: Not started

Magenta: Might not be needed

Cyan: Not needed

Gray: I don't know

OO. Enclosures

- **Electrical Enclosure (AN):** Acquired, but not yet installed. Let's put it inside
- **UI Enclosure (AN):** Haven't seen Jane's electrical box yet; Jane will bring it up
- **Stepper Motor Enclosure (MT):** Not made yet, but should be easy. Blocked by lower vent completion
- **Linear Actuator Enclosure (MT):** Built; just needs to be waterproofed later
- **LED Board Enclosure (***UNASSIGNED***):** Not needed; everything is already waterproof for the most part
- **Waterproofing (MT):** Can't be done until the enclosures are complete

PP. Power

- **Prepare Extension Cords (TH):** Terry's are done (soil heating, solenoids (DC), and pump) we need to see who else's are needed (linear actuator)
- **Test PSU Connections (AN):** The connections work. I would prefer to make more reliable connectors, however
- **Waterproofing (AN):** Blocked by the enclosure
- **Testing (AN):** Individual subsystems have been tested; have yet to perform an overall system test

QQ. Ventilation

- **Intake Manifold (JS):** About halfway complete
- **Upper Vent Configuration (JS):** Has been designed, but needs to be installed and tested
- **Mounting the Fans (JS):** We haven't looked at this in a long time, or in any real depth. Use some sort of wooden wedge to angle them. Blocked by other subsystem installation

- **Motor Installation and Programming (JS):** The programming is nearly done, but the vents have not yet been installed
- **Waterproofing (JS):** Blocked by subsystem completion
- **Testing (JS):** Mechanical and code testing in progress

RR. Sensors

- **Air Temperature and Humidity Sensor Installation (JS):** In progress as of today
- **Soil Temperature Sensor Installation (JH):** To my knowledge, the sensor has been prepared, but has not yet been installed (blocked by trough completion)
- **Soil Moisture Sensor Installation (JH):** In progress as of today
- **Light Sensor Installation (FE):** This is blocked by calibration
- **Water Reservoir Level Sensor Installation (MT):** In progress as of today
- **Air Temperature and Humidity Sensor Calibration (JS):** Not required; pre-calibrated
- **Soil Temperature Sensor Calibration (JS):** Not needed as the DHT11 is pre-calibrated; adjust the soil temperature readings based on soil moisture in code
- **Soil Moisture Sensor Calibration (TH):** No response from Bio lady, Terry will look around for her
- **Light Sensor Calibration (AN):** LEDs have been calibrated to the proper wavelength and we have a voltage to energy map up to the intensity of the LEDs. We need to map the sun's power values to the photoresistors next, which I will need to discuss with Neha further. Faisal will talk to Neha further, or we can talk to Glenn Chapman. Terry will look into the image processing
- **Water Reservoir Level Sensor Calibration (MT):** This is part of installation
- **Air Temperature and Humidity Sensor Programming (JS):** Need to discuss further, but currently in progress
- **Soil Temperature Sensor Programming (JH):** Completed and unit tested
- **Soil Moisture Sensor Programming (TH):** Numbers need to be set based on calibration
- **Light Sensor Programming (FE):** This has been started, but we need to add a calibration lookup table
- **Water Reservoir Level Sensor Programming (MT):** No longer required as we're using a float switch
- **Air Temperature and Humidity Sensor Testing (JS):** Unit testing complete, but integration testing is not
    - Need to test the sensors at sub-zero temperatures
- **Soil Temperature Sensor Testing (JH):** Completed
- **Soil Moisture Sensor Testing (TH):** Initial testing good, just need to test with calibration numbers
- **Light Sensor Testing (FE):** Unit testing complete, but code testing is not
- **Water Reservoir Level Sensor Testing (MT):** Blocked by installation
- **Waterproofing (JH):** In progress, can be done before installation

SS. Water Reservoir

- **Installation (AN):** Need to discuss with Mike how we want to do the piping; also the location will be decided upon today. Need a garden hose for piping
- **Overflow Installation (MT):** This has not yet started. Small diameter PVC pipe from home should work, but we need a way to suspend it
- **Pump Installation (MT):** Hole needs to be cut in lid for power cables

TT. Humidification and Irrigation

- **Gardena Kit Installation (TH):** Halfway done; needs to be secured in place
- **Solenoid Installation (TH):** Will be done with the gardena kit
- **Pump Control Programming (TH):** Completed and unit tested
- **Solenoid Control Programming (TH):** Completed and unit tested
- **Testing (TH):** In progress; blocked by installation and calibration

UU. Trough

- **Build Trough (AN):** Needs cable channel
- **Install in Greenhouse (MT):** To my knowledge, this is in progress.
- **Plastic Wrap (MT):** In progress as of today

VV. UI

- Jeff has nearly completed the UI, including the error messages; needs to test one more thing
  - Flag for each error
  - Multiple errors get scrolled

WW. Other Items

- Discuss deadlines for the aforementioned items
  - Prioritize items
    1. Figure out the water reservoir location
    2. Power needs to be out there first
- Presentation Progress
- Ditch trough water reclamation
  - We have enough on our plates as it is
  - Trough water reclamation is negligible compared to rain water reclamation **FOR THE DEMO**
  - **AXED**
- Let's talk to Steve about the length of our presentation
- Fix motors to plywood, and fix plywood to the greenhouse. Use plywood strips to offset height change

Meeting was adjourned late at 11:48 (Additional items discussed and started late).