Project Plan and Cost Estimate

Genius Troop

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Abstract

This document outlines a general design plan for the building of the purposed hydroponic system. The document outlines a list of materials, estimated cost, equipment needed for execution and a plan for the development of all 3 prototypes. Also, the document outlines contingency plans for potential areas of failure. The main purpose of this document is defining a plan for executing the conceptual design purposed in deliverable D.

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Detailed Design

Based on the chosen concept in deliverable D and the client feedback, we decided to go with a vertical hexagon shape for the structural system. The hexagon shape was chosen to allow easy construction of the prototype as opposed to a cylinder shape. The structure will be made from two materials wood and acrylic plastic. The base of the structure will be made out of wood lined with a thin sheet of acrylic plastic to water proof the wood. The top units that hold the plants will be strictly made form a quarter inch thick acrylic plastic. The overall dimensions of the structure is 24 inches wide by 80 inches tall. To increase the ease of construction the upper unit pieces were designed to fit in the makerspace laser cutter.

Figure 1: Structural System

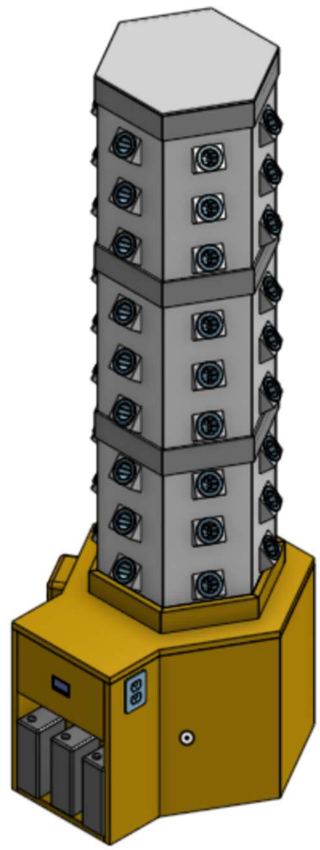
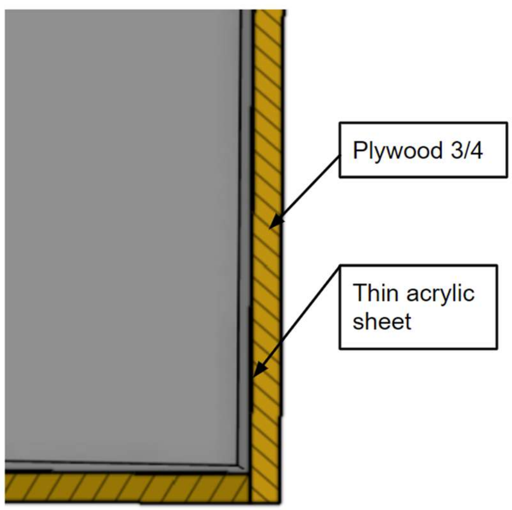


Figure 2: Base Materials



The plants are held by the structure through cups that sit in the frame of the body. All the cups are angles outward to increase growing space and sunlight exposer for the plants. The cups are easily pop in an out for harvesting, cleaning, or root inspection.

Figure 3: Plant Holders

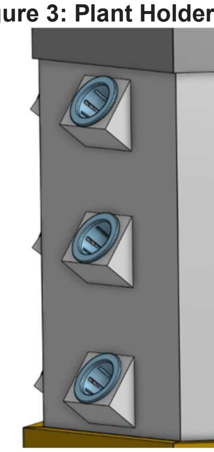


Figure 4: Inside view

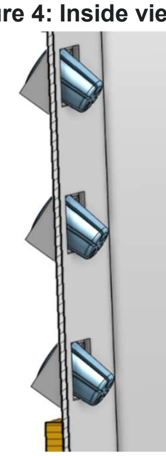
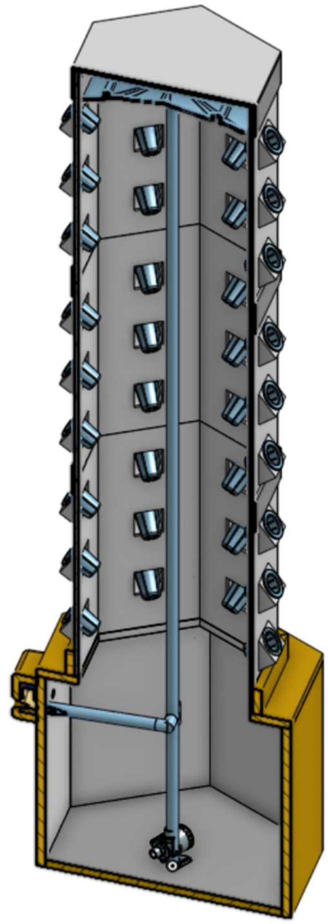


Figure 5: Delivery System



The water delivery system is run off of a fountain pump that pumps approximately 9 gallons per minute. The water is pumped up a tube to the very top of the structure at which the water is disrupted evenly down the side of the structure by a distribution plate. The water falls back down into the tank and is then recycled back up the pump. To allow for the system to change its water automatically the pump is also connected to a solenoid which can be opened to allow the pump to pump the water out of the tank. Once the tank is dry another solenoid can be opened to fill the tank with fresh water.

Figure 6: Water In/Out

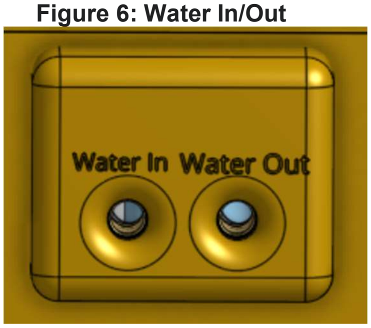
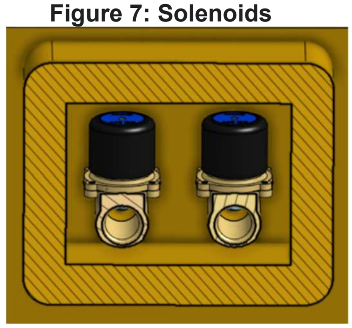


Figure 7: Solenoids



Finally, the nutrient system is located on one of the sides of the nutrient tank. The brains of the system are a mega Arduino. The power is supplied by a 120 AC V cord which is then converted into 5 V and 12 V DC current by a converter. The respective currents are then connected to a relay board controlled by the Arduino. The relay controls the water pump, the two solenoids, three peristaltic pumps, and the GFI plug.

Figure 8: Nutrient System

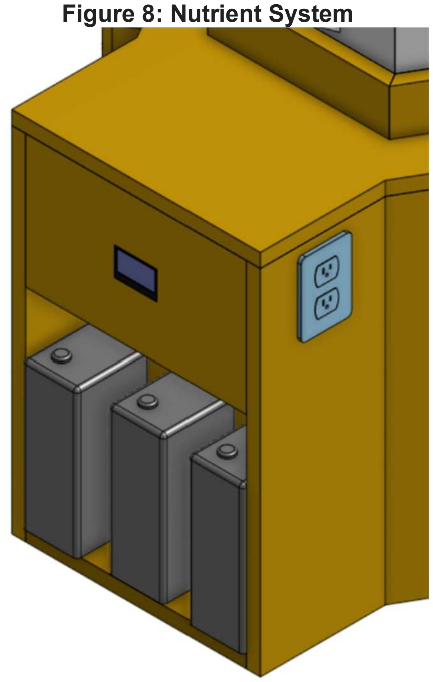
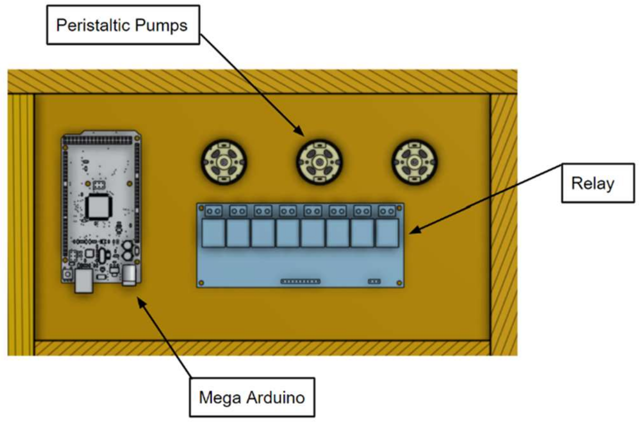


Figure 9: Electrical Components



The three peristaltic pumps are located at the top of the nutrient tank a pipe runs from them into the fertilizer tanks located at the bottom of the nutrient system. In addition, there is a GFI plug mounted on the side of the nutrient system which allows users to plug in grow lights if they wish. The plug is light sensitive meaning that it will not supply power when it is bright outside saving on electricity. To monitor the pH level of the nutrient solution there is a probe located at the bottom of the tank that take constant pH level measurements. Then, to determine the water level there is a water sensor located at the top of the tank. Finally, there is screen on the front of the nutrient system that allows the user to adjust the settings to their needs.

Figure 10: Peristaltic Pumps with GFI plug

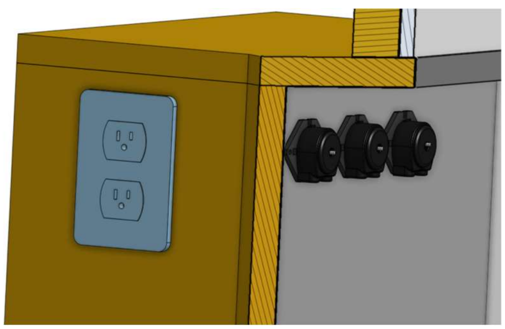
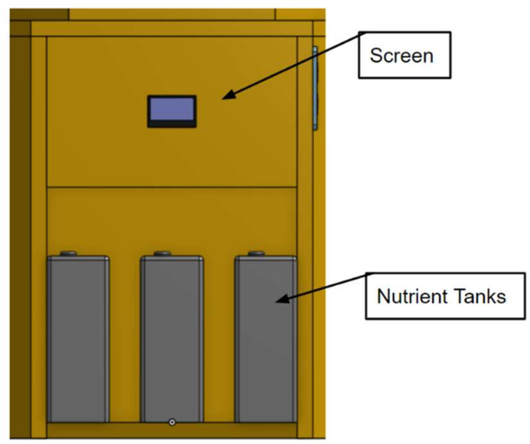


Figure 11: Nutrient System Front View



There were a variety of materials that were in the decision for our hydroponic that were not chosen. Each material provided huge problems that would not be ideal in the long run. Recycled plastic has poor resistance to ultraviolet radiation. Styrofoam is tough to shape, and is susceptible to rodents. Steel sheets would need a metal welding and lathing which is not provided in the manufacturing shop, and it has the potential of rust poisoning. In addition, multiple materials were not chosen due to the high expenses: ABS plastic sheeting, carbon fiber, and epoxy resin. Our final decision was to have the base constructed out of plywood that was lined with a thin acrylic while the top units would be made from acrylic plastic sheets that are ¼ inches thick. We have concluded that if the whole structure were made from acrylic plastic, it would go way over our budget therefore, using plywood for the base leaves us under the budget amount. Another issue for using acrylic plastic sheets would be that there would need to be a way to prevent sunlight from getting into the hydroponic and hitting the roots since the plastic is transparent. Our solution for this would be to have a sort of non-toxic spray paint or sticker that is applied to the outside of the structure. Acrylic plastic is a great option because it is UV resistant with as little as 3% degradation outdoors over a 10-year period. It can also be cut by a laser cutter allowing for precise cuts and 3D shaping. Lastly, acrylic plastic is a strong durable material that can be cleaned easily, heated up to bend in unique shapes and light to carry.

A full list of materials and equipment required to build the structure is listed in the attached excel sheet.

Project Risks

To ensure a successful execution of the design plans the following projects risks have been identified.

General system design

By nature, nutrient film systems have the main two risks being pump failure and root clogging. Due to the continual nutrient solution delivery method, in the scenario of pump failure, this can lead to the root drying and loss of all incorporated crops on the system. This is further compounded by the vertical delivery nature of the system where instead of the more traditional nutrient film system delivery water flow over a shallow incline, this system is straight vertical, meaning that water flow is faster and potentially not as consistent as the slower incline flow. The water flow is further complicated by overgrown root development, impeding the vertical progress of the nutrient flow and disrupting the smooth flow and thus path of the flow. This will lead to the same issue where the nutrient flow is disrupted, leading to rapid root drying and loss of crop. To address the latter point, due to the minimized use of pipes (only one main vertical pipe is utilized) and employing a wider pipe that will avoid clogging, this will address any potential pipe clogging. Clogging with the plant root systems will be minimized using special cup holders that will allow the fluid to bypass the roots in a smooth manner, as well as employing non-clogging nutrient supplements that avoid the utilization of more solid nutrient materials like soil or other particulates.

System Design Based

Expanding on the difference between this vertical system and the tradition inclined nutrient film system, the issue of water flow has further potential complications. Since the flow of water is not guided by an incline but rather a sort of waterfall system, the flow needs to be contained and properly administered to each of the plants in the grow column. As such, the flow will be guided using specially shaped guide funnels between each column unit. The risks involved in this are whether all the lower crop cups receive an appropriate level of nutrient solution, and potential spillage between units due to the irregular water flow due to contact with crop roots. Practical tests are still to come, but the specially designed guide funnels will be tested to verify proper fluid funneling and delivery of nutrient solution between each column unit. The rate of water flow will also need to be tested and made to ensure that there is no overflow and thus waste in the delivery system.

Another risk involved in this system is the diverting of nutrient flow to the 6 columns of crops. The nutrient solution is piped via a single main vertical pipe, and then via a custom-made plate, the solution is pooled then directed towards each of the columns for delivery. However, there is a balance involved in the pumping, solution pooling accumulation, and ensuing delivery that needs to be established and has not been practically tested yet. Thus, there is a risk of the diverting of nutrient flow and ensuring that the flow to each column is the same. Again, prototype testing will be employed with timed measurements of nutrient delivery. The custom-made diverting plate at the top is open to be changed depending on results and further researching regarding fluid mechanics.

Pumping system

The pumping system of this system is very simple, as there is only one main vertical pipe to deliver nutrient solution to the top of the system for drainage, and no auxiliary side piping as the system utilizes guide channels to deliver the solution to each crop cup. However, there are associated risks. First, if there ever arises some leakage or clogging in the main pipe, the system dies since it is dependent entirely on that single main pipe. There are also issues in theory about the detachable unit design of the system. Since it is advertised as being able to remove and separate units easily for cleanup, it is still undetermined how exactly the main pipe that goes through the center of the system is going to interact with the different units. To address the later issue, a variety of solutions can be applied. First, the main pipe could be independent of the units, meaning that each unit is simply placed on top of the pipe, running vertically independent of the stacked units. Variable heights mean variable main pipe length, but this can be installed separately. An alternative would be for there to be a smaller incorporated pipe in each unit but stacking them gives risk to sealing issues and leakage problems. Further testing is required but the former solution seems to be the most practical.

Structural system

Since the crop cups are stacked in columns, there is a risk that the bottom cups will not receive the same amount of light as the top ones due to blockage and shade. This is more dependent on greenhouse design and the application of lights in that regard. This is being addressed by adjusting the design so that the cups are spaced out from each other in a way that should allow for adequate light to be delivered to each cup. Further discussion with the greenhouse project group may be needed to fully address this problem. Another risk due to the tall and relatively narrow column like structure, is just the risk of toppling over. Since the nutrient reservoirs is stored at the bottom, it is evidently very bottom-heavy, meaning that it is possible to tip over due to the taller overall height of the system. A wider based could be considered or employing some method to anchor the system to the ground. It is further also important to consider the type of flooring that the system stands on, another topic to discuss with the greenhouse group.

Nutrient system

Depending on whether the team remains firm on using organic nutrient solution and the type, it could cause clogging in the crop cups due to debris, soil, and other particulates, or potentially just smell really bad if organic fish-based nutrients are used. The straightforward solution is to employ mineral-based nutrient solution, but this may conflict with the standards expected from the client. Further client communication and testing with both different types of organic nutrient solutions and mineral systems will be considered.

Contingencies

Our system is entirely dependent upon the pump's ability to circulate water and nutrients through the structure. Therefore, a failure or malfunction of the pump would greatly impact the entire system. The pump may fail due to debris entering the pump itself or due to regular 'wear and tear'. To prevent debris such as root pieces, dirt, and leaves from draining down into the reservoir in the pump unit, we are considering placing a mesh screen between the top of the pump unit and the bottom of the first growing unit. This screen could easily be removed and cleaned as a part of the system's regular maintenance. In this way, low amount of debris will be able to interfere with the internal components of the pump. We will not be able to prevent natural wear on the pump during regular operation, so replacing the pump must be easy to do. With the modular nature of our tower system, the user can simply separate the grow units from the pump unit, disconnect the pump from the central pipe, and install a new pump in its place.

Our team must also ensure that there is an even distribution of nutrients solution between the each of the 6 faces of our system. To ensure there is an even distribution of nutrients between each face, the nutrient/water solution must be well- mixed in the pump reservoir, and the top face of the tower must divert an equal volume of nutrient/water solution to each of the 6 streams. We will ensure that the inside of the central pipe and the part responsible for diverting the flow into 6 streams is smooth by having a circular pump on the distributor disk. The distributor disk allows water to build up and then leaks once overfilled.

A concern that our team had was that the roughly 6 feet structure could be knocked down causing immense damage to the whole mechanism and plants. Our solution was to make the base heavy enough that there would have no chance of it tipping over. It is also in the shape of a hexagon which allows steadier structure due to the many sides it has. Possibly add a strong metal rope attached by the side of the hydroponic, depending on the location and size of the greenhouse, the cable would be attached to the interior side of the greenhouse.

The lighting source would need to be deeply discussed with the construction group; however, our solution for the hydroponic to receive equal lighting opportunity would that the plants are staggered and spread apart preventing competition to receive a main necessity in growth. Another solution would be to add grow lights on the side of the hydroponic.

Finally, we have concluded as a team that the central pipe connection would cause multiple problems with leakage. Since our structure has 3 detachable units that are roughly 2 feet each, having one central pipe would reduce the risk of leakage. However, 3 attachable units cause different overall structural height. Our solution was to have 3 different size pipes, small for one unit, medium for two units and large for three units. With this solution, the issue would be that the cost is more expensive, and the bottom base would need a male/female adapter connecting the pipes to prevent leakage. A cheaper solution would be to have one central pipe that is detachable from each other at each unit level. This causes a higher chance for leakage in 3 other locations as of the other solution with only 1 location of leakage and a higher maintenance.

Prototyping Plan 1

The first prototype of this design we will be proving the concept of our delivery system and basic electrical components. To test the delivery system, we will first run a computer simulation of on the CAD design to see how the water will flow down the wall. If the results from the computer simulation look promising, we will then go to a physical model. For prove of concept we could make a cardboard model of one of the units and pour water down the sides in a way the mimics the pump to identify potential design flaws.

Also, for prototype one we need to test the bonding strength of quarter inch think acrylic plastic to ensure that our final prototype will have structural stability. This can be done by taking two pieces of scrap quarter inch acrylic glue them together. Once the two pieces have dried, we can test to see how must force the bond can take before it breaks.

Finally, for the electronics of the nutrient system we can do the basic wiring on a breadboard. We can use an arduino, a screen, and relays to write some basic code for opening and closing the relays and getting it to show the results on the screen.

Prototyping Plan 2 and 3

For the prototype two we will do more testing on the delivery system and electrical components of the nutrient system. For prototype two we will have bought the pump and piping. A general test should be conducted the ensures that the pump can pump to the desired heigh of 7ft with a minimal flow rate of 6 GPM. A rough protype of the distributor plate should also be made to ensure that the water is distributed even down the six sides of the hexagon.

For the nutrient system the pH sensor, water sensor, photoresistor should be added to breadboard circuit made in prototype one. The pH sensor should be tested for reliability and accuracy based on by using standardized pH solutions. All three sensors should be tested to ensure that when the appropriate conditions are met that the arduino will turn on the corresponding relay.

The construction of the body of the hydroponic should be started to get a feel for the amount of time needed for the overall construction.

Finally, for prototype three the overall construction of the structure will be completed as well as the delivery system. The nutrient system electronics will be transferred to a protype board and wired into place in the hydroponic structure. All the pumps and will be connected to the relays and will be tested.

Once the all three systems are built, we will run a series of test to ensure that the system is working properly. See table 1 for test objectives.

Test ID	***Test Objective (Why)***	***Description of Prototype used and of Basic Test Method (What)***	***Description of Results to be Recorded and how these results will be used (How)***
1	Testing Main Vertical Pump	Reservoir prototype with installed pump is activated and pumps fluid up pipe column Pump is activated and regulated by Arduino unit	Analyzing arduino output and water output, understanding what code needs to be modified and how to control water pressure and output amount
2	Testing Column Unit Assembly	Stacking and assembling column units Testing connection security, and ensuring that the middle pipe is properly incorporated	Taking observation notes on the unit fasteners and need for any design changes
3	Testing Water Directing by Top Plate	Pumping water up central pipe and observing water distribution to the 6 column sides	Measuring volume of water being distributed to each plant column to ensure that each column gets the same amount of nutrient solution
4	Testing Water Delivery to Growth Cups		
5	Testing Water Delivery Through Root System		
6	Testing pH System and other Electronics		
7	Testing Nutrient Level Maintenance		
8	Testing Unit Disassembly and Cleaning		