

University of Ottawa

Faculty of Engineering

# Final Design Report

## Project Deliverable J

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## **Abstract**

In this project we attempt to solve an aboriginal community's need for a hydroponics system to grow their own vegetables. As a country, Canada has many remote areas with difficulty accessing commercially grown vegetables, an effective solution to this problem could benefit many people. We approached this problem by comparing the ability of existing hydroponics techniques such as aeroponics and deep water culture to fulfill the client's desire for water efficiency, low electricity use, and low cost among other needs. Then we went through many physical prototypes to optimize our system's ease of use, efficiency and growing capacity. Our final system can support 12 plants by using only 33.6 watts of electricity, has a water reservoir of 38L and costs a total of 80.46\$. In conclusion, this system is an inexpensive way to grow plants and performs well in situations where water and electricity are scarce resources. As a result it could help lessen the issue of a lack of fresh vegetables in remote areas in Canada.

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## Introduction

Remote communities in northern regions of Canada face an uphill battle when referring to growing fresh fruits and vegetables. Often the communities face very short growing season which are not feasible for growing crops. These communities often must travel large distances to visit groceries stores with fruits and vegetables readily available which can be extremely expensive due to the remoteness. Many communities often can go long stretches without proper nutrition due to the lack of nutrients in their diets.

## Empathizing

A hydroponics system is a method of growing plants using water and a nutrient solution instead of soil. The tips of the roots will touch the water and absorb nutrients and oxygen. The client has informed the group that the supply of water is limited to spring water, lake water and rainwater.

The total budget to build the green house is \$350; \$250 for the structure and \$100 for the hydroponics system, respectively. The design should be easy to manufacture and maintain, in terms of the cost of materials and maintenance. It should be made with material of a certain quality that should not have to be replaced or tuned up often. Additionally, in order to keep the cost low, there will be limited automated parts that require power supply. Instead, it would be ideal to have members of community who would help maintain the greenhouse (ie. refilling, watering) and who would know how to fix it if it breaks in any way. The system should be composed of technical components that do not require specialists to repair. For example, if any tubes get clogged, the members of the community should have the tools and knowledge to be able to easily unclog the tubes and keep the system running.

On the topic of cost effective materials, the client also mentioned past issues with animals eating food that is around or chewing through pipes and wood. Animals such as squirrels, chipmunks, bugs and bears have ate their plants and other food items that were grown in the past. To address this issue, the design will avoid the use of soft materials and will shield vulnerable components such as wires. The client mentioned nearby resources for materials such as branches from trees, that the members of the community have used to build their cabins.

The client has also suggested that multiple types of plants will be grown in the greenhouse. This is important to keep in mind because different plants have different needs for survival (ie. different amounts

of nutrients, amount water, level of pH). Therefore, there must be an aspect of compartmentalisation and customization in the hydroponics system to meet those needs. Examples of the types of crops the client has requested to be accommodated are, hardy vegetables, such as sweet potatoes and onions, as well as green vegetables and sema.

In terms of temperature, the crops will need to be protected from cold temperatures, sometimes  $-30^{\circ}\text{C}$  or even  $-40^{\circ}\text{C}$ . It is essential that there is a system set up to heat the greenhouse during the winter months. If the water the crops are growing in is below a certain temperature, the plants will not survive. The client also mentioned issues with snow pile-up during the winter months, which could make the greenhouse hard to access or could block the sunlight from getting in through the roof. In response to this issue, the group will work closely with the construction team to find a solution.

Overall, the client would like a design that is cost effective, sustainable, weatherproof, animal-proof and that can supply the community with fresh fruits and vegetables. Table 1 and Table 2 outline the client needs in terms of specific design criteria and design specifications.

## Define

### Problem statement

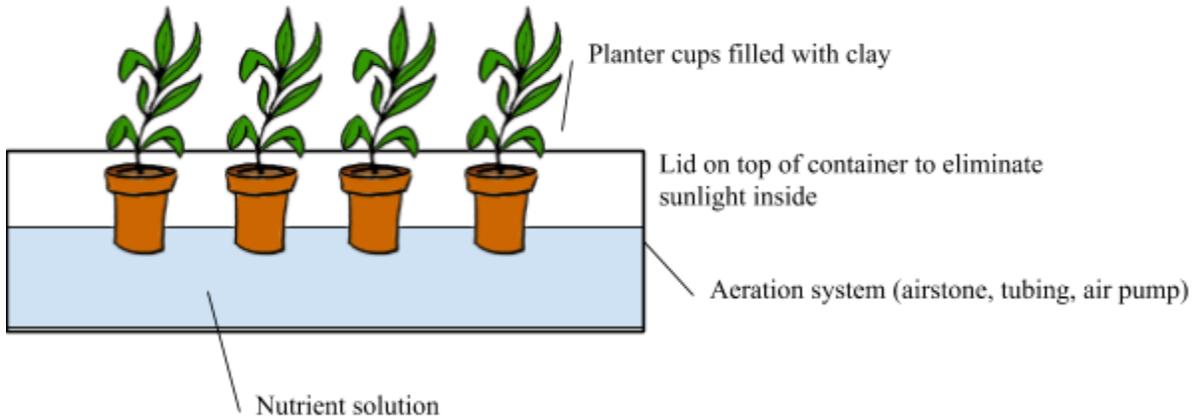
**The client, a representative of a small First Nations community near Barriere Lake, QC has mentioned that residents from her community do not have easy access to fresh fruits and vegetables. The 59-acre reserve does not have any running water or electricity and is located a couple hours away from the closest grocery store. In the past, the community has experienced difficulty growing crops due to poor conditions relating to the water quality, the temperature, the soil, and the surrounding wildlife. Therefore the client has requested the group to design and build a hydroponic greenhouse for growing plants year round. The greenhouse will be built on an airport strip, a centralized location for approximately 50 individuals.**

<b>Table 1: Specific Design Criteria</b>		
<u>Number</u>	<u>Need</u>	<u>Design Criteria</u>
1	The system can grow plants year round	Ability to withstand cold weather (-40°C)
2	The system requires low maintenance	Self-sustainability, sufficient material quality
3	The system is able to acquire water year-round	Rainwater collection method, snow-melting method
4	The system is low cost	Cost (\$)
5	The system can fit in the greenhouse structure	Volume (in m <sup>3</sup> )
6	Compact and transportable	Weight (kg), length, width, height (in m) and ability to take apart into smaller pieces
7	The system can grow a variety of different produce and herbs etc.	Nutrient control, control of the pH of the water, temperature control

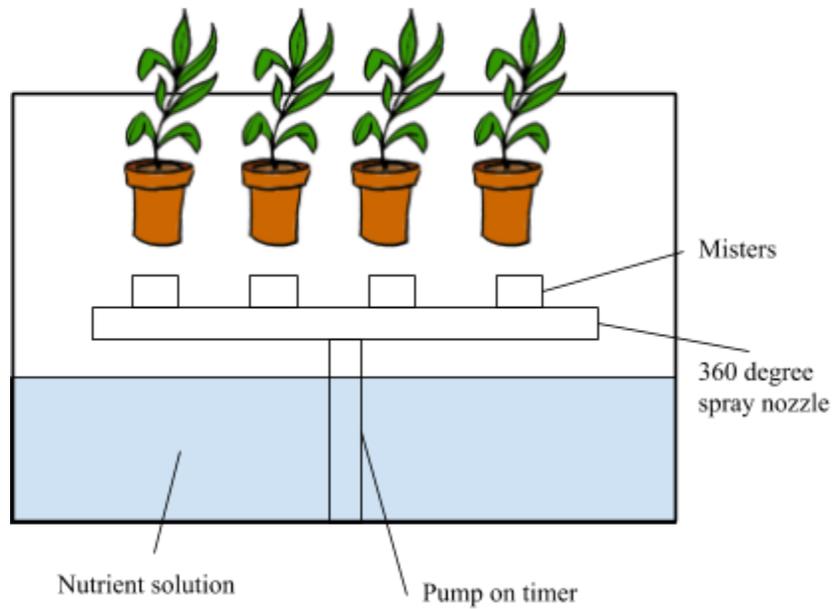
<b>Table 2: Engineering Design Specifications (EDS)</b>					
	<u>Design Specifications</u>	<u>Relation</u> (=, < or >)	<u>Value</u>	<u>Units</u>	<u>Verification Method</u>
	<b>Functional Requirements</b>				
1	Feed community members	$\geq$	50	People	Test
2	Meet different growing needs	=	yes	N/A	Test
3	Withstand all weather conditions	=	yes	N/A	Test
4	Easy to use and maintain	=	yes	N/A	Test
5	Variety of produce can be grown	=	yes	N/A	Test
	<b>Constraints</b>				
1	Animals	=	yes	N/A	Test
2	Cost	$\leq$	100	\$	Estimate, final check
3	Size (panels)	$\leq$	4x8	ft	Analysis
4	Electricity	=	?	?	Analysis
5	Rain/Snow Water Availability	$\leq$	980.0	mm	Analysis and Test
	<b>Non-Functional Requirements</b>				
1	Product Life	$>$	10	Years	Test
2	Aesthetics	=	yes	N/A	Test
3	Corrosion and UV resistance	=	yes	n/a	Test
4	Safety: minimal pinch points	=	yes	n/a	Test
5	Reliability	=	yes	n/a	Test

# Ideate

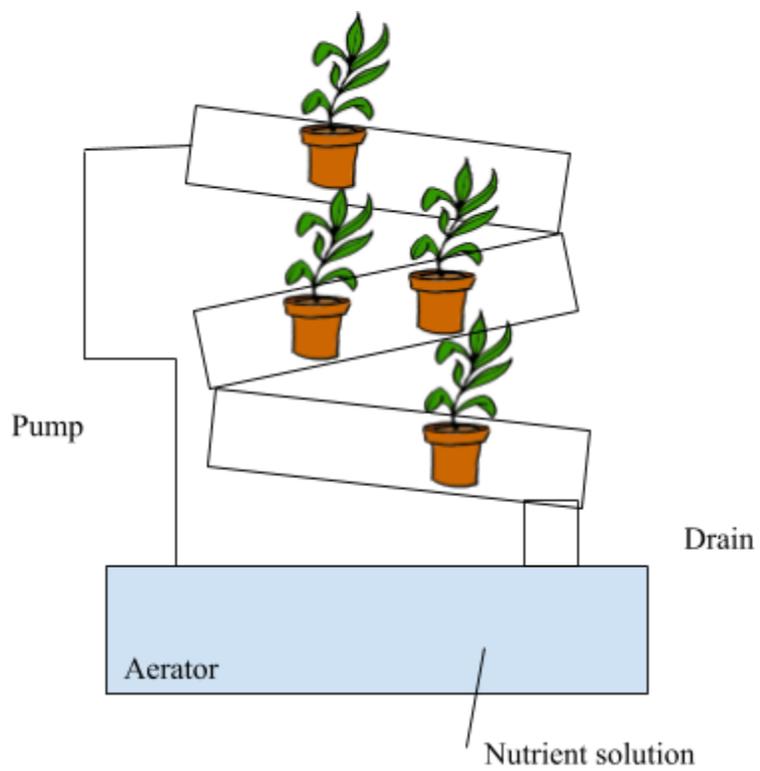
## Preliminary Design Ideas



*Image 1: Deep water system*



*Image 2: Aeroponics system*



*Image 3: Nutrient film system*

Benchmarking

<b>Table 3: Benchmarking the Overall Design Ideas</b>				
<u>Specifications</u>	<u>Importance (weight)</u>	<u>Deep water</u>	<u>Aeroponics</u>	<u>Nutrient film</u>
Cost	2	3	3	1
Water efficiency	3	1	3	2
Maintenance	1	3	2	1
Ability to grow a variety of plants	3	1	3	2
Electricity use	2	3	1	1
Size	1	1	2	1
Total		22	30	18

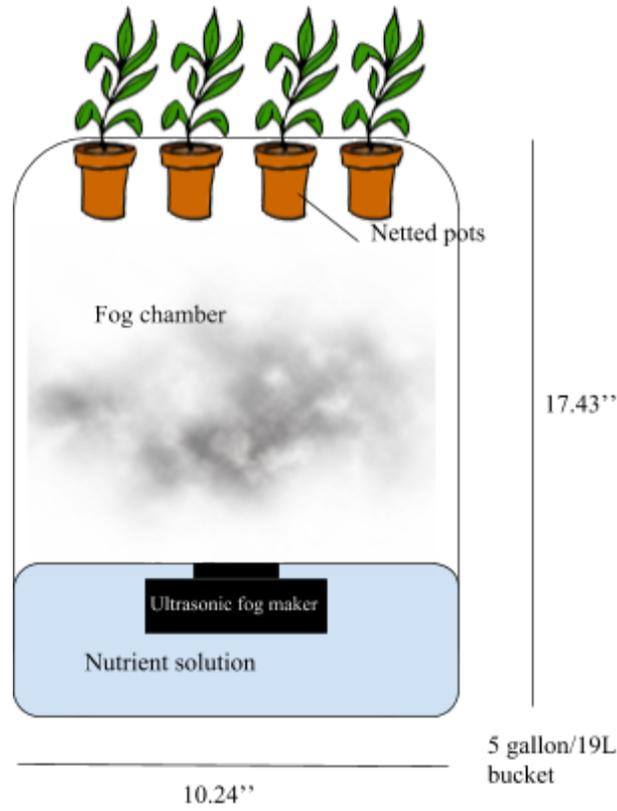
**Table 4: Pros and Cons of Different Methods**

<u>Category</u>	<u>Method</u>	<u>Pros</u>	<u>Cons</u>
Growing Medium	Kratky Method -growing your plants in a container without needing electricity, air stones, pumps, or anything else.	-Extremely cheap (only part is a bucket)  -Easy to compartmentalise, if you need a different nutrient solution for a different plant just put it in a separate bucket.  -Easy to maintain and clean (no small or moving parts)	-Can only really support crops which grow above ground and grow despite low dissolved oxygen levels (lettuce does very well but other plants could fail)
	Nutrient Film Method -a trickle of water containing nutrient solution is circulated past the roots of the plants.	-Expandable in the future with the addition of more pvc plant trays  -Trays can be arranged vertically or horizontally making its arrangement flexible for optimal space usage	-Difficult to set up, the slope of the trays must be measured carefully to ensure that the water flow doesn't stall  -Expensive, it requires both a pump for water and a pump for air  -Reliant on electricity, if the power goes out for a few hours the plants will starve because the water must be delivered by electric pump.
Plant Placement	Multi level shelving system	-Good use of wall space  -Not great use of whole greenhouse	-May block sunlight for lower plants
	On the ground		-Wasted space as anything put on top would block its sunlight
	Combination of hanging plants and put on ground	-Effective use of space	- Some sunlight blockage  - Tough to run piping

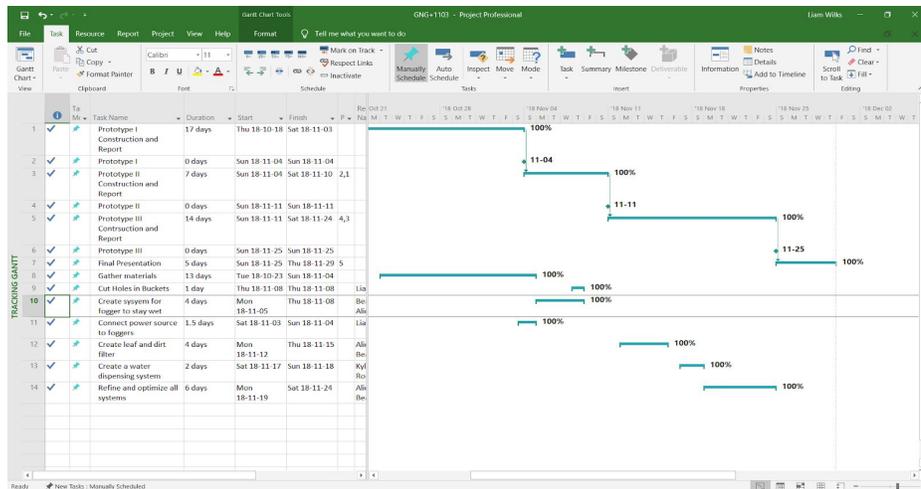
Tank placement	On the same vertical level with gutters	- No need for electricity as gravity will move the water	-Tank must be well supported -No recycling of water
	On the ground and use a electric pump to recycle water	-All possible water is used - No need to support tank	-Will require electricity
Growing Medium	Perlite	-Good water drainage	-Dust can be hazardous if inhaled  -Low water retention
	Expanded clay	-Good water retention  -Lightweight  -The clay has a neutral pH, which also makes mold and fungus less likely to grow	
Volume of Water	Use large bodies of water, rather than a “trickle” system	-easier to maintain the temperature of the water	
Initializing the Growth	Have a plant nursery	-will allow for bigger plants to have a chance to grow	-will take up space and require more specific needs

## Fogponic System

After many different designs and lots of research, we have confirmed that the best design for the greenhouse hydroponics system is the fogponics design. The fogponics design uses water vapour to hydrate and deliver the plants essential nutrients and as the plants are suspended in air, oxygen is constantly supplied to the plants. It works by implementing an ultrasonic fog machine into a bucket of nutrient solution. The plants will be in their own separate pots, filled with a growing medium, that sit in the lid. The vapour caused by the fog machine will keep the air inside the bucket moist and full of nutrients. This method is one of the most efficient ways to grow plants since there is no need for flowing water or aeration of the water and the plants will intake the maximum amount of nutrients allowing to grow much faster compared to other hydroponic designs. This also requires very little maintenance because there are no pipes, pumps, valves or other small pieces to clean out, it only requires a bucket and one fog machine. This makes it very ideal for our project because the community would need to have their system be very low maintenance and easy to fix if anything breaks. For the situation of our project, low water usage is very important and this system is perfect for that. This system uses very little water since the vapour in the bucket does not go to waste and all the nutrient solution is used by the plant.



**Image 4: Fogponics system**



**Image 5: Gantt Chart**

# Prototype

## Prototype I

The first prototype of the hydroponics system was created using a combination of cardboard and tape. The model is a 3D representation of the bucket fogponics system at a slightly smaller scale. This rough prototype aids in visualizing how the system and its many subsystems will function and allows for a more detailed critique of the design.

Some considerations after analysing the first prototype are:

1. The tracing and cutting of the holes in the bucket lid was challenging while building this prototype because in order for the cups to fit in the holes, which were not a perfect circle as they were formed by bending cardboard, they had to be forced. As a result, there were gaps in some spots surrounding the cups as well as spots that were too snug (as seen in Images 5 and 7). If the circle cutout for the cup does not match the shape of the cup, light could come in and support unwanted algae growth if the fit is too loose and it could be difficult to put the cup in/take it out if the overall fit is too tight. The addition of “wings” to the plant cups might be necessary to stop them from falling through the holes in the lid. Overall, it will be important to carefully measure, trace and cut the holes for the plant cups while building the model, as many faults were displayed from the prototype.
2. The holes within the bottom of the planting cups may cause problems if they are too wide because some of the growing medium could fall out. On the prototype, the size of these openings (seen in Image 9) could be easily controlled and it will be important to keep the diameter/density of the growing medium in mind when creating these openings on the model.
3. After viewing videos of the strength of the foggers, a high water level in the bucket will be necessary to have enough water reach the plant roots and allow for growth. When the bucket is filled with water, the fogger will be floating at water level, however in prototype I this design feature is not shown as no water was used in this prototype (in Image 6 the fogger can be seen sitting in the bottom of the bucket).

4. Cages may need to be added to the one or more of the fogponics systems in order to grow vine plants including tomatoes. This suggestion was provided by the client during the first client meeting.
5. As seen in Image 6, the wire to the fogger machine is simply taped to the side of the bucket. In future prototypes where water will be added, taping the wire out of the way will not be possible therefore another method would need to be established to control where the wire will fit and its path to the outside of the bucket.



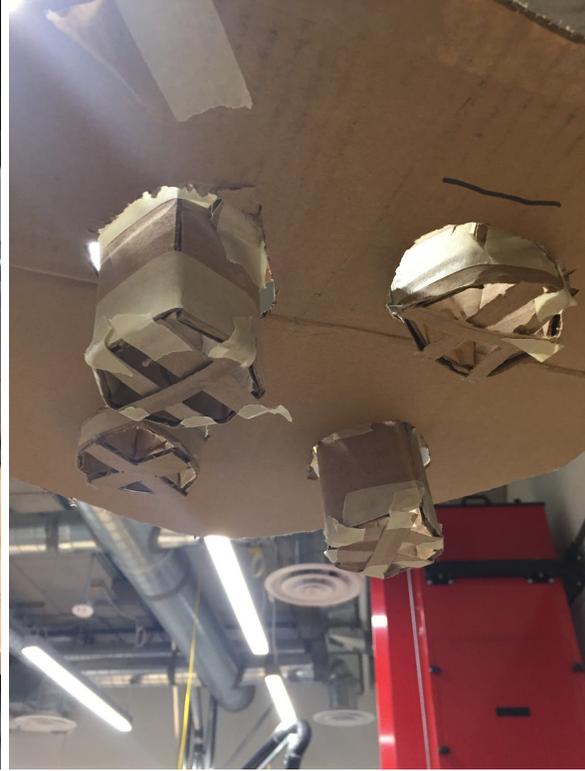
*Image 6: Prototype I, full model*



*Image 7: Inside bucket*



*Image 8: Top view of lid*



*Image 9: Bottom view of lid*

## Prototype II

- No new modifications were added to prototype I.
- Materials such as the paint bucket (Image 9), the leaf filter (Image 10) and the ultrasonic fogger (Image 11) have been gathered and tested.
- After testing the ultrasonic fogger in the bucket, it was determined that the fogger produces the most fog while slightly tilted to the side and only a few millimeters underwater. With this information, a system to keep the fogger underwater can now be designed in order to optimize fog dispersion within the bucket.
- It was also noted that a fan might be needed to optimize the fog dispersion within the bucket, as during testing, most of it gathered at the bottom. The addition of a fan would require power, therefore recalculating the power needs for the fogponics system.



***Image 10: Bucket (19L; diameter 11.80"; height 21.63")***



*Image 11: Leaf filter*



*Image 12: Ultrasonic fogger (diameter 1.75"; height 1.75")*

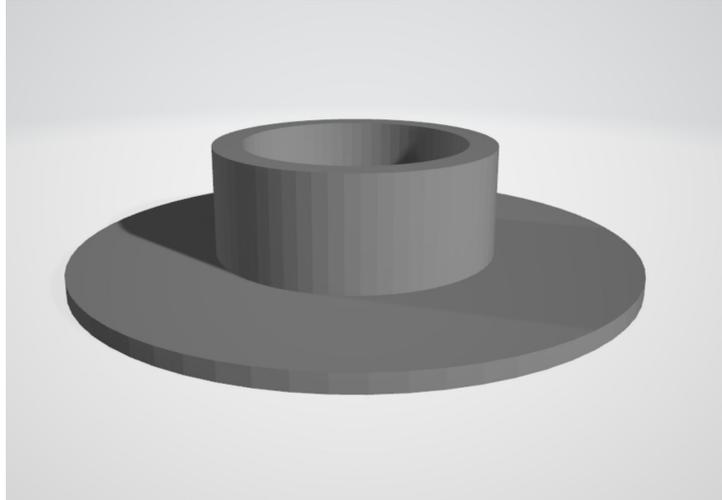
## Prototype II.V

List of changes since prototype II:

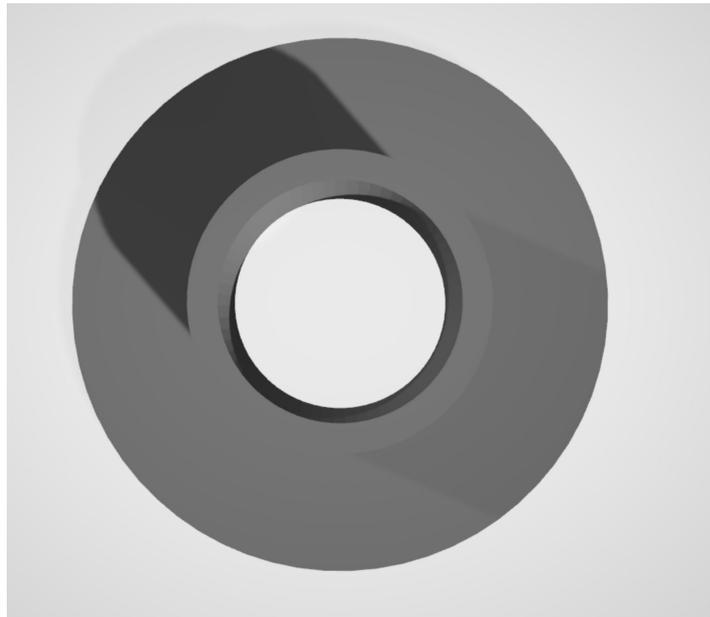
1. Holes were cut in the lid of the buck in order to accommodate for the plant holders (Image 12).  
The initial 2 seen were cut with a drill bit too small for the plant holders. This task has postponed until a larger drill bit can be obtained in order to obtain the correct diameter holes.
2. A flotation device that will be capable of floating the fogger on the surface of the water has been designed and will be printed within the next week. (see Image 13 and Image 14)
3. A paper test was conducted in order to test the strength of the fogger. This test involved placing a piece of paper along the side of the bucket and running the fogger. The paper continued to get wet at every level of the bucket proving that the fogger is capable of spraying water vapour to the roots of the plants.



***Image 13: Prototype II.V, lid with cup holes***



*Image 14: 3D design of fogger flotation device, side view*



*Image 15: Top view (diameter of 10cm)*

Prototype III, The Final Design

<b>Table 5: Final Budget</b>		
<u>Item</u>	<u>Quantity</u>	<u>Price</u>
Buckets	\$3.97x5	\$20.00
Lids	\$2.97x2	\$5.94
Fogger	\$17.99x2	\$35.98
Leaf Filter	\$0.50	\$0.50
Cups	\$0.17x12	\$2.04
Clay Pebbles	\$10.00	\$10.00
	Total before tax	\$74.46
	Total with tax	\$84.14



***Image 16: Prototype III, cup with holes***



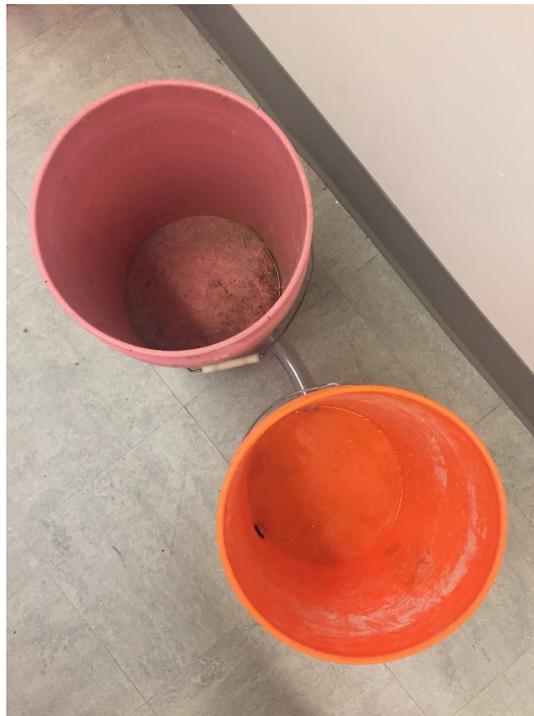
*Image 17: Cups with growing medium, in the bucket*



*Image 18: Fogger inside the bucket*



*Image 19: Tap on the water reservoir*



*Image 20: Tube connecting the two water reservoir buckets*

## Test

The final design was tested at the design day fall 2018, where it was connected to a battery power source and placed in the greenhouse. Live plants were placed in the cups with expanded clay pebbles and the foggers were turned on (Image 21). We found that the fog did reach the roots of the plants, as we observed water droplets on the roots of the plants. The water reservoirs were also placed in the greenhouse and integrated with the water collection system of the greenhouse roof. The gutters were aligned to fit to the placement of the collection buckets (Image 22).



*Image 21: The ultrasonic foggers are connected to the power source and produce fog.*



*Image 22: The two water reservoir buckets integrated into the greenhouse structure design*

## Future Work

In the end, there were some features of our design that were missing and others that were not needed. For example, we required a heater to maintain the temperature of the water in the reservoirs to ensure the plants would not freeze. A heater could have been accommodated, given we were under budget and therefore in the future, a heater would have been added to make the design more sustainable, especially in the winter months for the client.

Moreover, one feature of the design that was not needed would be the LED's on the second fogger. In the future we would have purchased the same plain black fogger as the first, instead of the one with LED's. This did not have any effect on the budget, therefore we included this component to enhance the aesthetics of the design. We did not realise that the light could have a negative effect on the plant's roots and so in the end, the LED's should not have been included in the final design.

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