Project Deliverable J: **Final Design Report**

GNG 1103 – Engineering Design

Team Alpaca (Construction 4)

By:

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Abstract:

We started our design by meeting with our client and discussing what problems she wished for our greenhouse to solve. Based on this discussion, we came up with this problem statement: The Algonquins of Lac Barrieres problem is that they need a greenhouse to grow crops because they don't have easy access to food in their area, and are unable to grow enough food for the year conventionally due to a short growing season, harsh winters with temperatures that reach -40, unsatisfactory soil and pests.

Once we had a problem statement, we looked at existing greenhouses to help determine what solutions we thought were most viable that we could build off of. After benchmarking, we decided to take borrow ideas mostly from the GrowIT 6x8 ft D Greenhouse.

Now that we had a problem statement and a design idea, we set a list of design specifications and design criteria that would solve the problems. This allowed us to create our first conceptual design sketches and begin planning our construction. We used these sketches to create our first cardboard prototype and present our solutions to our client for feedback. We were also able to create an estimated cost of our greenhouse and a basic project plan that was updated weekly.

At this point we started construction of our greenhouse. We updated our design weekly to keep up with problems that we faced in our design, as well as changing our project plan to incorporate these changes and problems and adding new tasks that came up.

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Introduction:

For our design project, we made a greenhouse for the Algonquins of Lac Barrieres, as they were having a problem with supplying food for themselves. This was due to a lack of access to grocery stores and poor crop growing conditions. Because of this our client Monique approached the university for help, and the project was presented to us.

To make our design solution unique, we added features that we believed would make our greenhouse better and set it apart from other groups. One of the features we included to do this was that we made our greenhouse's walls able to disassemble into smaller 2 ft x 4.5 ft panels that would be easy to take apart and transport. Another feature we added is windows that would swivel open and close that would allow the user to control the airflow in the greenhouse and allow in fresh air.

This report will go over the design process that our group went through in the design of our report, outlining key decisions that were made, and reflecting how they were or were not effective.

Needs Identification and Problem Statement:

The first step in the design process was to hold a meeting with the client and gather information on what problems our solution needed to solve. The meeting was held with the entire class, and the following requirements were discussed allowing us to formulate a problem statement.

The client requires a greenhouse that can grow crops for the whole year. This means that the greenhouse needs to be able to function through the winter. According to the client, it is common for temperatures to drop down to below -30℃ or -40℃. This means that some heating may be required. On top of this, the amount of snowfall will have to be taken into account. According to the stats Canada, there is lots of snowfall and ice fall during the winter. This means that the greenhouse needs to be low enough for the top to be easily cleared. As well, the greenhouse needs to be strong enough to withstand having snow on the roof during snowfall.

The client said that the ground was quite sandy, but that it should not be a concern about where the greenhouses are going to be place. The client also said that there would be a suitable amount sunlight for the project. The client also said that rainfall can be varied during the year. She also said that there would be some wind, but not an excessive amount.

According to the client, wild animals such as mice, squirrels, and chipmunks are a serious issue in these parts of Quebec. This could be an issue with animals burrowing under the greenhouse or chewing through the walls, and they pose a threat of eating the crops grown. Another concern that the client rose was that there were lots of bugs, worms and other pests. This could be a concern about how airtight the greenhouse needs to be to keep out these insects. This means that the greenhouse may need a floor or to be raised off of the ground

The provided budget for the project is $250. A transparent material is needed to allow sunlight into the greenhouse, and it needs to be low cost in order to satisfy the low budget. On top of this, another material is needed to build the frame. This needs to be low cost as well, and needs to be able to withstand the climate, forces and wildlife of the area. To be able to transport the greenhouse to the location, it will need to be disassemblable and be able to fit in the truck. This means that it needs to be built in smaller portions. The client did not specify a necessary size, so that is not a factor considered. However, an extra $10000 will be given to the winner of the design day. Insulation that can keep a greenhouse fairly warm during harsh winter conditions is required since sunlight is limited.

Limited solar panels are provided, which have to be utilized in order to produce required energy. The client didn't specify the need for any power, but it may be an option to keep the greenhouse warm in winter or to have a lighting system.

Based on the criteria discussed above, the following problem statement was developed:

> The Algonquins of Lac Barrieres problem is that they need a greenhouse to grow crops because they don't have easy access to food in their area, and are unable to grow enough food for the year conventionally due to a short growing season, harsh winters with temperatures that reach -40, unsatisfactory soil and pests.

Benchmarking and Target Specifications:

After discussing the problem and making a problem statement, pre-existing solutions were looked at and compared to help decide the importance of each variable and our ability to provide a similar solution. Table 1 shows the process we went through, benchmarking three greenhouses that we found online.

Specifications	GrowIT 6x8 ft D Greenhouse	Palram Mythos 6 x 4 Greenhouse Twin Wall Green	Outsunny Portable 4-Tier Warm Pop up Plants And Flower Greenhouse with Shelves	Importance of specification
Shape	Triangle Roof	Triangle Roof	Triangle Roof	2
Cost	$242.99	$599.99	$99.99	4
Size	6'H by 6' 11/16" W by 8' D	6 ft by 4.1ft by 6.8ft	6.5 ft H x 4.6 ft L x 2.5 ft W	2
Weather resistance	yes	"Virtually unbreakable"	May be negatively affected by snow	5
Pest resistance	bad	good	bad	4
Size disassembled	Poratable	Disassemble into panels	Very Portable	1
Materials	Frame Material: Steel Panel Material: Polyethylene film	Polycarbonate panels Aluminium frame	Steel Plastic	3
Insulation	Little to none	Twin polycarbonate panels high thermal insulation	PE cloth	3
Score	49	60	38	

Table 1 Benchmarking

After benchmarking, the Palram Mythos 6 x 4 Greenhouse Twin Wall Green was determined to be the best. Unfortunately, it was unfeasible as it was way out of our price range. Instead, we chose to base our design more off of the more attainable GrowIT 6x8 ft D Greenhouse. Using this process and information gathered from our client meeting, we set a list of design specifications that needed to be met.

	Design Specifications	Relation	Value	Units	Verification Method
	Functional Requirements				
1	Keep out small mammals	=	yes	N/A	Test
2	Air ventilation	=	yes	N/A	Test
3	Allows Sunlight to enter	=	yes	N/A	Test
4	Strong Structure	>	697	lbs	Analysis, Test
5	Allows the house to stand on the sandy ground	=	yes	N/A	Analysis
6	Prevents water to leak from outside	=	yes	N/A	Test
	Constraints				
1	Cost	</=	250	$	Estimate, final test
2	Size when built	</+	6*8*6 rectangle 6*8*3 triangle roof	Ft^3	Analysis
3	Size disassembled	<	Trailer is 6x12	Ft	Analysis
4	Operating conditions: Temperature	=	-40 to +35	℃	Test
5	Operating conditions: Snow	>	50	cm	Analysis
6	Height of	<=	6	ft	Build it

	Greenhouse				under 6ft
	Non Functional Requirements				
1	Product Life	>=	5	years	Analysis
2	Safety: No sharp edges	=	yes	N/A	Test
3	aesthetics	=	somewhat	N/A	Test

Table 2 Target Specifications

Design Criteria:

Using these specifications and requirements, we came up with our design criteria solutions and put them in a table. As well, we further explained the design and functionality of each aspect and how it would work in our design.

	Need	Design Criteria
1	Last through the winter (-30 to -40 Celsius)	Roof is made of corrugated panels to withstand heavy snow Roof also has supports every 2 feet to provide extra support and aid in mounting corrugated panels
2	Wild animals like chipmunks, squirrels and bugs	Elevated off the ground, base is made 6 inches off the ground to keep rodents out and provide stability on the soft sand.
3	Air ventilation	Rotating window with a lock is used to allow for air circulation and to lower temperatures during the summer.
4	Growing plants	Walls and roof are made of transparent material that will aid in plants growth.
5	Ground is quite sandy	Rectangular base Floor or off ground
6	Rainfall can be varied during the year.	6 mill Waterproof polyethylene is

		used to keep the greenhouse waterproofed through storms.
7	Transporting the greenhouse	Built in panels that can be easily disassembled for transportation using nuts and bolts.
8	Low cost	Affordable materials were used such as wood, polyethylene, and corrugated roof panels.

Table 3 Design Criteria

Joining of panels with nuts and bolts:
A required aspect of the greenhouse is for it to be disassembled easily. Since our team is creating a scaled down version of the greenhouse we decided to make one wall panel disassembly to show our chosen mechanism even though it is not needed for our small scale greenhouse. The system used to join the panels panels together is drilling holes in the sides, top, and bottom of each 2 ft x 4.5 ft panel, and fasten the panels together with a 4 inch long bolt with a washer and nut. This can be done in multiple locations to ensure a tight seal and strong support between panels. This will reduce the panel size from 6 ft x 4.5 ft down to 2 ft x 4.5 ft which makes the disassembly much easier which in turn will satisfy the client.

Door:
The door is going to be 4 ft 2 in high and 1 ft 8 in wide. This is because the total height of the front structure will be 4 ft 6 in and total width of section will be 2 in, and you have to subtract the volume occupied by the 2 in x 4 in planks of the frame. The area of the door will be covered by polyethylene wrap, which will allow more sunlight to enter the greenhouse. The door will be attached to the frame of the greenhouse using two hinges, which will allow the door to swing outwards. There will also be a fence latch which will allow for the door to remain closed and let the user add a padlock if they wish.

Supports
Vertical supports were needed every 1.5 feet but could be extended to a maximum of 2 feet for side panels of the greenhouse. Also, a vertical support was placed two feet in, at the front and back of the greenhouse. This was done to improve vertical ridgidy and help support the weight of the roof. Moreover, 3 diagonal pieces of wood were added to to both sides of the greenhouse. 1 for each panel forming the letter “N” on a slight slant. This was done to add more stability to the structure to counteract outside forces such as wind. Furthermore, the “N” shaped reinforcement would help support the load of the roof plus the added weight of all the snow that piles up during winter. Lastly, the supports were put on a slant for the purpose of forming triangles within the side panels since, triangles are the strongest shape due to the fact that any force added is evenly spread through all three sides.

Base:
The base is required in order to keep the entire structure as stable as possible because it is said that the location where the greenhouse would be located is windy. The size of the base is 4 ft by 6 ft, which is the size of the greenhouse. It has to be mentioned that there are some supports what have to be put in order to increase the stability of the structure. The supports are going to be put in every 1.5 ft. Consequently, there will be 3 supports in overall. Additionally, the top of the base is going to be covered with plywood and it will be like floor.

Roof:
It was decided by the group that the roof will be a triangular roof for the greenhouse. At the front section, the roof is designed to have a roughly 37° angle between the span and the ridge in order to let the snow slide down from the roof during the winter. The height of the ridge is 1.5 ft, which will bring the total height of the greenhouse to 6 ft. A support beam will be placed in the middle of the front section at a 2 ft interval, which means that the hypotenuse of the triangle will be 2.5 ft. On the horizontal section of the roof, there are two connections spaced every 2 ft built between the length of each roof in order to increase its stability while the greenhouse is experiencing a heavy snow. Inside the greenhouse there will also be added support beams. There will be one 6 ft beam that goes from the front to the back, and at 2 ft horizontals two 2 ft beams will connect each side of the support beam to the side, as well as a 2 ft beam connecting it to the top.

Window:
We decided to put windows on the front side and back side of the greenhouse to allow the user to control air flow of the greenhouse. Each window has two parts, the frame and rotating section. The frame will be 2 ft x 1.5 ft, which will be built in as part of the support of the back frame. Also, we have a 2ft axis that connects opposite sides of the frame, which the window section will rotate around. The rotating section will be 1 ft 8 in x 1 ft 2 in to accomodate for the size of the frame. The frame has two stoppers on each corner at the bottom side. The stoppers will help the bottom of window cannot through the frame when we need close it. At the top of the frame, we have a lock for windows. The area window will be covered by polyethylene, which allow more sunlight to enter.

We also made the following preliminary sketches of our greenhouse design to present to our client in our second meeting, this one with just our group present. We showed Monique our conceptual design and shared with her our plans for building the greenhouse. She was satisfied with our design, only raising questions about whether the 6 millimeter polyethylene would be warm enough through the winter. We discussed with her that we read that it has been recommended as a year round greenhouse material and decided that we would not change this aspect of our design.

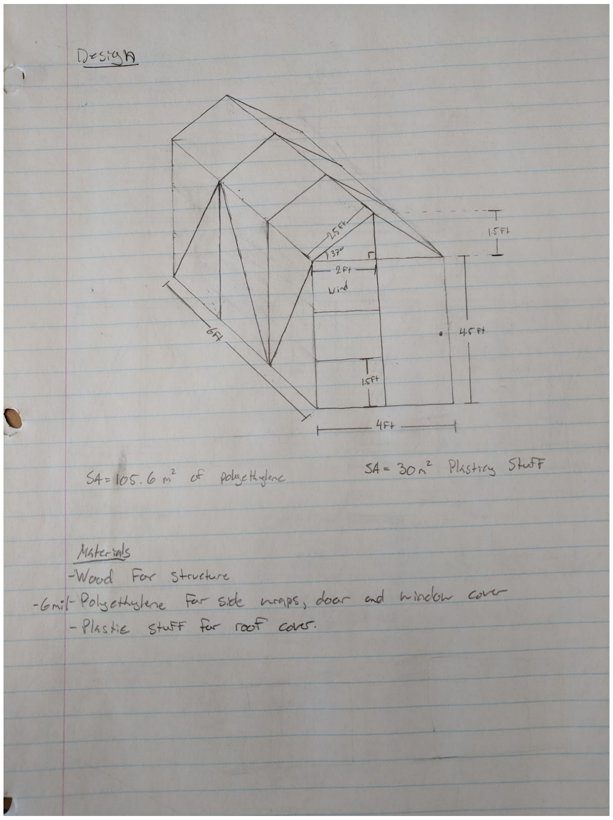

Figure 1 Original Concept

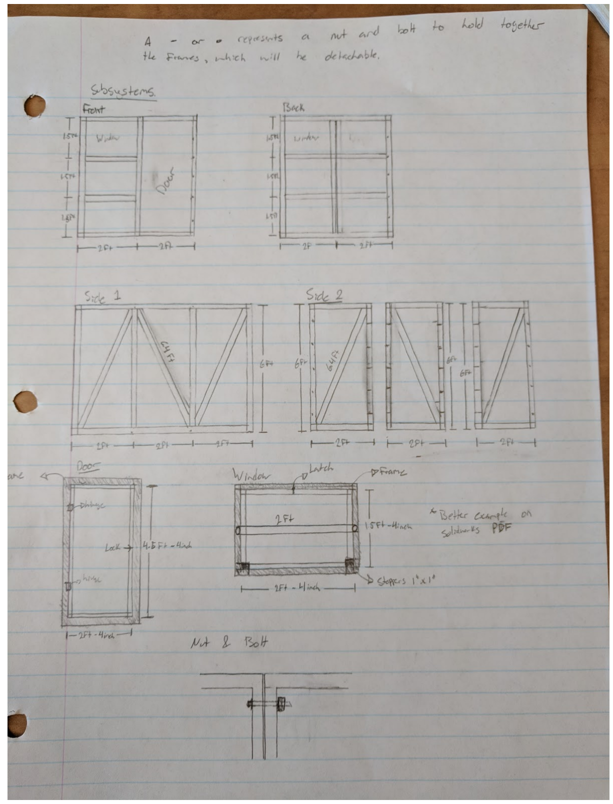

Figure 2 Original Concept Sketches

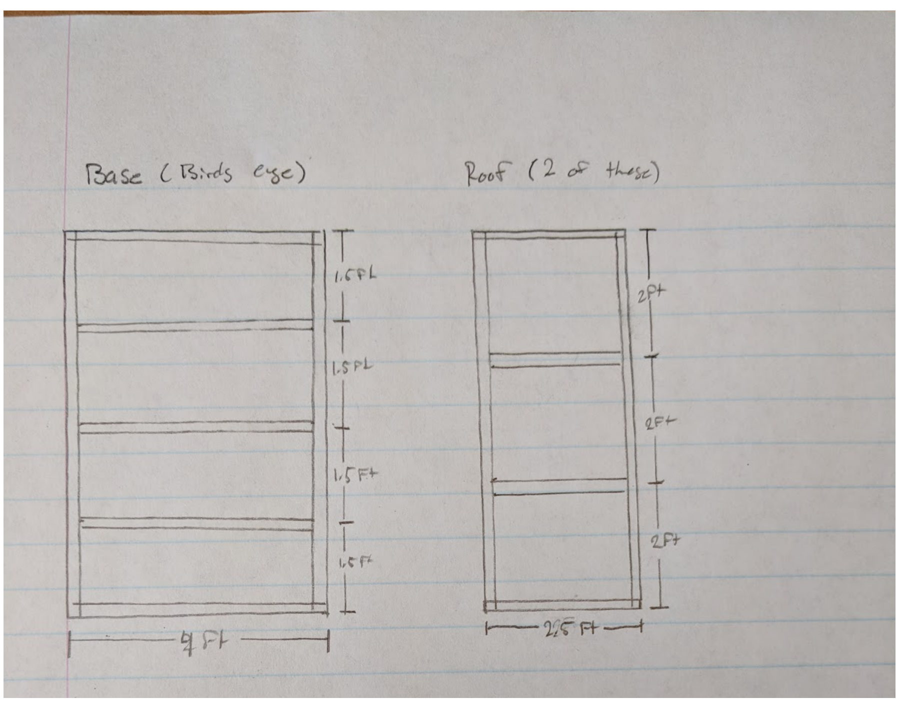

Figure 3 Original Concept Sketches two

Cost and Project Plan:

Once we had our design set, we set out a cost estimate. Unfortunately we came in slightly over budget. To cut back on costs, we used wood from old projects so as to not need to buy new, as well as deciding to 3D print some pieces.

Wood:
2x4x8: 33 boards @ 3.65 x 33 = $120.45
https://www.homedepot.ca/en/home/p.2x4x8-spf-dimension-lumber.1000112108.html
2x6x8: 5 boards @ 5.40 x 5 = $27
https://www.homedepot.ca/en/home/p.2x6x8-spf-dimension-lumber.1000117995.html
⅝ x 4 x 8 OSB @ $23.98
https://www.rona.ca/en/panel---osb-panel-0938046--1
Hardwood Dowel 7/8 In. x 48 In. @ $5.58
Polyethylene: 10ft x 25ft @ $24.98
https://www.homedepot.com/p/HDX-10-ft-x-25-ft-Clear-6-mil-Plastic-Sheeting-RSHD610-25C/204711657
Corrugated Roof Panels: 8ft x 26 inches (17.33 sqft) @21.97 x2 = $43.94
https://www.homedepot.ca/en/home/p.cor-pvc-8--feet--clear.1000412021.html
Corner Brackets @ 1.22 x 12= $14.64
https://www.homedepot.ca/en/home/p.2x2-corner-bracket.1000150430.html
Mending plate 4pk @ 2.14 x 2 = $4.28
https://www.homedepot.ca/en/home/p.2-inch--zinc-mending-plate-4pk.1000773678.html

Total(taxes in) = $299.28

Next we made our original project plan, which was updated weekly based on progress made during the lab construction as well as change to the designs. This was done to measure our progress, and make sure that we were able to complete everything before design day. We ran into a few problems, but were able to work during extra hours and completed everything on time. The following is our original schedule set before we started construction and our final schedule updated before our last construction setting.

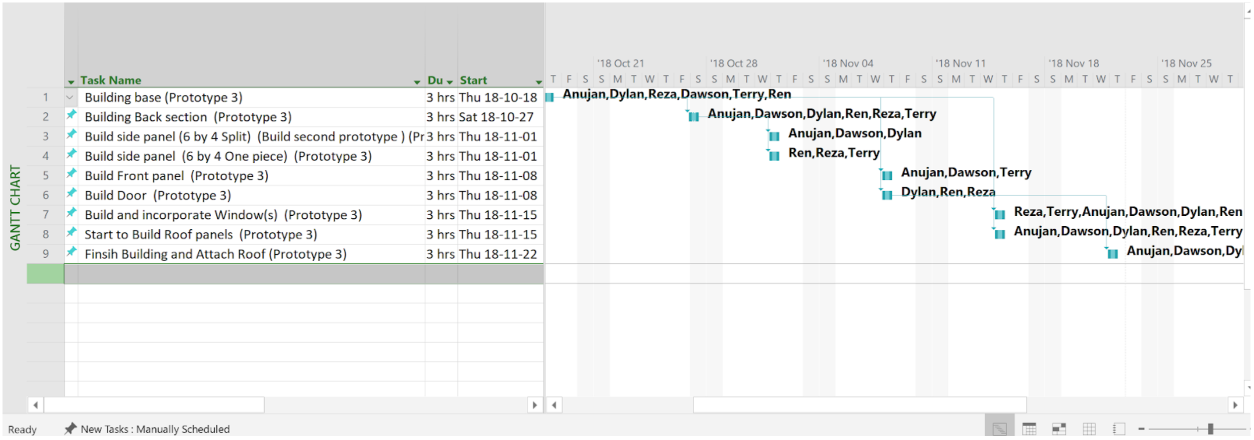

Figure 4 Original Construction Schedule

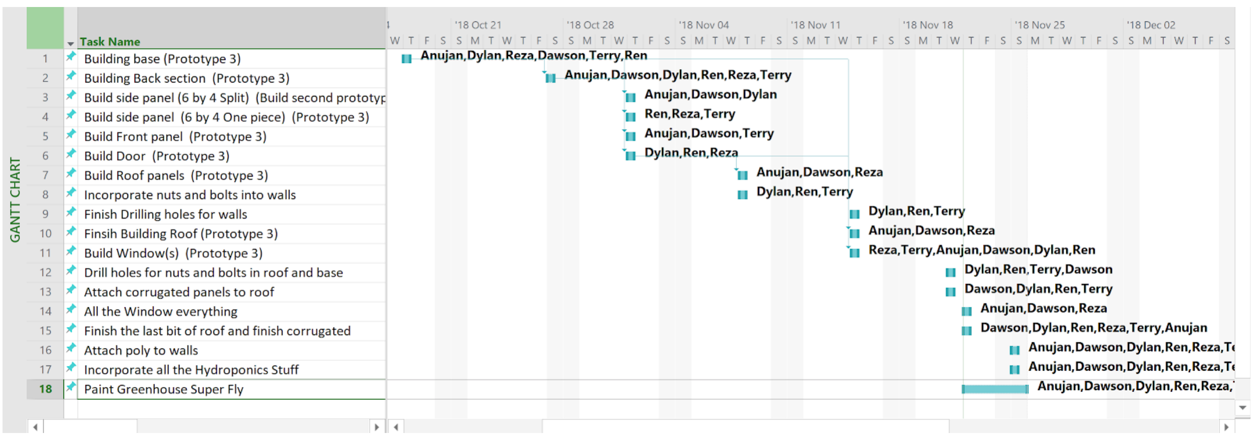

Figure 5 Final Construction Schedule

As you can see, there were many changes to the schedule. Once construction began, we realized that there were a lot more tasks than originally thought, and we decided to add some extra ideas to our greenhouse. For example, many tasks such as drilling the holes for the nuts and bolts took much longer than anticipated and ended up being done in parts over multiple weeks. As well, tasks that we realized needed to be added made their way onto the schedule such as incorporating nuts and bolts, attaching the poly, corrugated panels, and painting the greenhouse, which was done just for fun rather than being necessary.

Prototype I and Customer Feedback

Once we had a schedule and plan, we made a simple cardboard prototype to help us imagine the feasibility of our project and help us change our design for the better. The following is an image of our greenhouse as well as changes it helped us make.

The prototype was useful in showing possibilities of how we will be able to incorporate hydroponics into our greenhouse construction. Assembling the pieces showed us where we would have trusses and walls, and where hydroponics would be able to attach wires or pipes. The prototype will also allow us to easier communicate our ideas to hydroponics and allow us to describe and offer solutions easier.

During the creation of our first prototype, it was discovered that when building the 4 walls, two walls must be built smaller than 4 feet to accompany for the thickness of the wood used on the other 2 sides. It was also discovered that when building the roof it will be much easier to build the roof as a subsystem then attach the roof to the 4 walls after, as opposed to attaching each side of the roof to the wall beneath it. The prototype also offered us more information on our subsystems, and how they will be incorporated into our greenhouse. For example, it was noticed that the door and windows would need to be scaled down to fit inside the frames, as well as that it could be more difficult to implement them into our design.

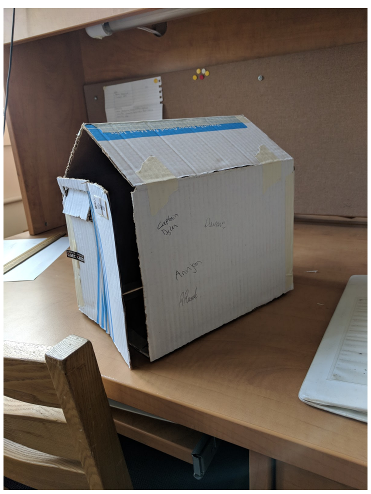

Figure 6 Prototype 1

Prototype II and Customer Feedback

Once we started construction, we ran into a few more problems. First, we decided to scale down our greenhouse to a more reasonable size. We reduced the dimensions of the walls of the greenhouse from 6 ft wide x 6 ft high x 8 ft long to 4 ft wide x 4.5 ft high x 6 ft long. Including the roof, the greenhouse will be a total of 6 ft high. This was done to cut down on costs, use less materials and make it more manageable to build. Another change is that we decided to make every wall able to be disassembled using the nuts and bolts system. Originally only one wall was supposed to be disassemblable, but during construction it was easier to build each wall by making smaller sections, and it was decided that we should implement our portability feature into every wall. As well, it has been decided that for the roof we will be using corrugated panels made from pvc. In the original plans 6 mil polyethylene was planned on being used over the whole greenhouse to save on costs, but in order to support the necessary weight we are now using the corrugated roof panels. To help keep the structure sturdy two layers of wood will be added to the top and bottom of every panel. This will link the back, front and two sides panels to the foundation and roof allowing for a more rigid structure overall. Whereas connecting every panel to the foundation and roof with nails and screws would not suffice as the link would not be as strong as using an intermediate layer of wood, which could cause structural failure if a nail, screw, or bolt breaks under pressure from the weight of the roof and anything on top that such as snow.

Prototype III and Customer Feedback

Nearing completion of our prototype, the only real change in our design was to our roof. We decided to not use two panels, and instead our roof panels will be a series of triangular supports (trusses) that will be placed every 2 feet on top of our walls. This will make the portability of our greenhouse roof more difficult, but it will still easily transported by two people. The triangle supports will be roughly 2 feet high, and will be connected at the tops by plywood sections to hold them together more effectively. Small square gouges will be taken out of the angled section, and will allow the beams to sit on wood support while hanging off slightly for the gutters to easily be connected. Our roof will still be attachable by nuts and bolts, as there will be a layer of wood along the edge of the roof that will allow lay flat against the top of the walls. This will let the nuts and bolts go perpendicular to both panels and hold the walls and roof together when tightened. This was chosen because it was determined that the panels method would not be able to safely support the necessary weight that will be required.

Conclusion

Over the course of our design project, we learned many valuable lessons. One such lesson was that we need to communicate more during group projects. During our project, especially in the pre-design stage, there was not a lot of communication within the group about ideas and there was even less discussion with the hydroponics team. As the project progressed, we did begin to communicate more and the project went much smoother and was done more effectively. We also learned that it is much more difficult to incorporate conceptual designs into the final product. For example, our windows did not work as well as intended and created lots of problems, and the disassembling using nuts and bolts made for a lot of extra work that did not exactly go as planned. Going forward on future projects, communication should be set and encouraged early on, as well as more effort and feasibility concerns in conceptual designs.