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Team #3 - Team Mad Hatters
Test Date: October 11, 2014
Test Time & Location: 3 pm, Hammond Building & Surroundings
Greenhouse Gridding

The Cross Section Method

1) Test Results Summary: Prototype #1 (Table 1)

User Need/Feature/Requirement	Describe Test	What is "Pass"?	Materials/Tools needed to run tests	Pass or Fail?
1. Quick and easy setup (10 mins)	Setup of the greenhouse design in under 10 mins	Setup in under 10 mins with two people.	String, marker, measuring tape, nails, long paper	Fail, we were unable to finish the setup with 2 people within the 10 minute limit.
2. Stability/Wind Factor	Use of cardboard to put a lot of wind going onto the design of the greenhouse.	All pieces remain stable throughout wind power.	Cardboard	Fail, the pieces came undone and fell out of place.
3. Weather/Stability of ground (Rain)	Pouring of water onto the greenhouse design.	When foundation doesn't warp (become twisted out of shape) or change.	Water	Pass, the foundation didn't warp at all when water was put onto it.
4. Earthquake/Foundation stability	The vigorous shaking of the greenhouse design to test an earthquake's impact on the design.	Poles remain in the ground during and after earthquake.	2 people to shake the cardboard	Fail, the poles did not remain in place when the ground was shook.
5. Accurate and Precise Measurements	Using a protractor to check the angles at the corners of the design.	All angles are 90°.	Protractor	Pass, all of the angles remained 90 degrees due to the cross sections being placed correctly.
6. Durability/Impact	Use of hammers to hit the angles as well as the poles to act as falling objects.	If everything remains in place (angles, poles)	Hammers(2)	Fail, the angles came undone when hammers hit the sides and many of the poles came undone and fell out.

Prototype #1 Testing: September 22, 2014 (8 am, Hammond Building & Surroundings)

<u>Stability/Wind Factor Test</u>

In testing prototype #1, the prototype was unable to pass the Stability/Wind Factor test. The Stability/Wind Factor test consists of having two people hold cardboard pieces and flap them up and down so that they create the wind factor of the test (as shown in Figure 1). The prototype was unable to pass the test because a pass consisted of all pieces remaining stable throughout wind power. The prototype ended up having the pieces come undone and fall out of place. This was indeed a fail.

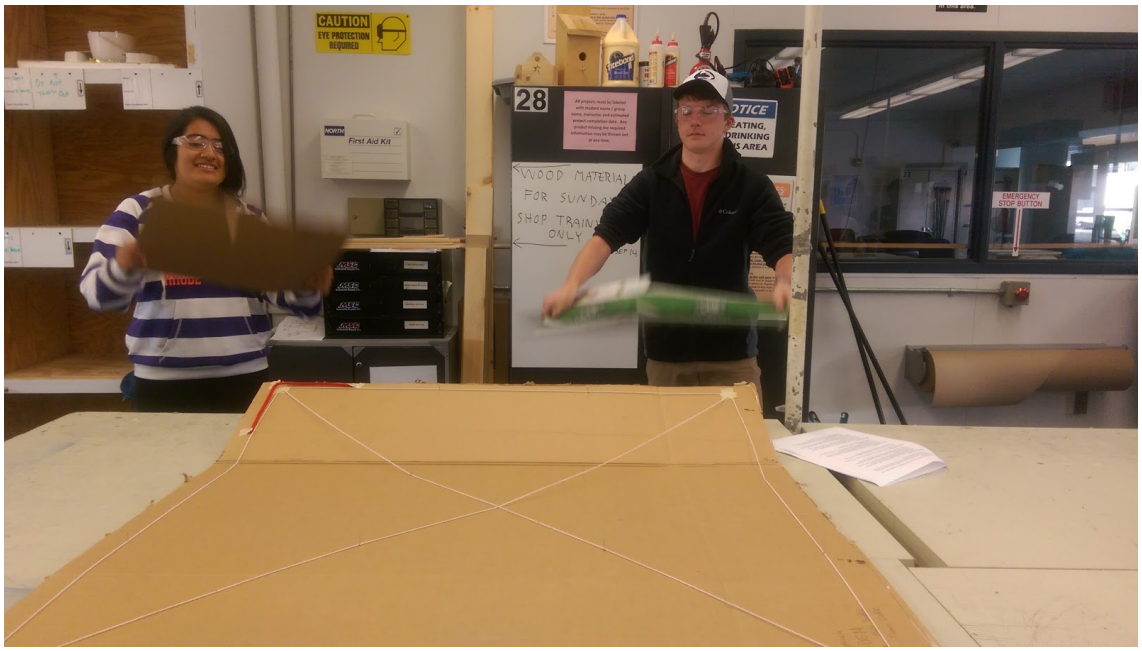


Figure 1: The group members are creating wind from flapping cardboard in the direction of where the grid layout is.

Weather/Stability of Ground (Rain)

Prototype #1 did pass the Weather/Stability of Ground test. The idea behind the test was to see how the grid would hold up against the rain since rain is a huge factor in Kenya. The test consists of one person pouring a bottle of water onto the cardboard foundation (the ground) to see if the foundation warps (become twisted out of shape). When water was poured out onto the cardboard foundation (shown in figure 2), the foundation did not warp at all. This was definitely a pass.

Figure 2: Water was poured on the foundation of the greenhouse by Natalie.

Earthquake/Foundation Stability

Prototype #1 failed the Earthquake/Foundation Stability test. The test consists of two people vigorously shaking the greenhouse design to test an earthquake's impact on the design (shown in Figure 3). A "pass" would consist of all the poles remaining in place before and after the earthquake test. This was a fail because the poles did not remain in place when the ground (cardboard) was shook.

Figure 3: The foundation for the greenhouse is being vigorously shaken to test the effect of an earthquake on the grid of the greenhouse.

Accurate and Precise Measurements

Prototype #1 passed the Accurate and Precise Measurements test. The test consists of using a protractor to check the angles at the corners of the design and make sure that they are precisely 90 degrees (shown in Figure 4B). When a protractor was used, the angles at the corners were all 90 degrees due to the Cross Section Method (shown in Figure 4A). This was a pass for sure.

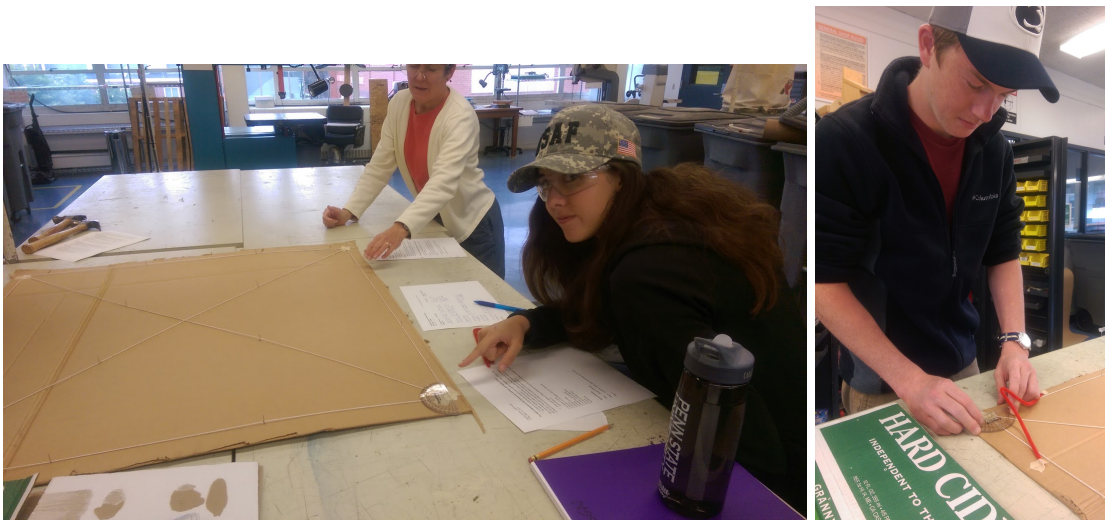


Figure 4: A.(left) Alex points out the measurement of the corner.
B.(right) Matt measures the angle for another corner to be sure that its 90 degrees.

Durability/Impact

Prototype #1 failed to pass the Durability/Impact test. The test consisted of the use of hammers to hit the angles as well as the poles in order to act as falling objects. When the prototype was hit (as shown in Figure 5), the angles & poles came undone and fell out of place. This was definitely a fail since nothing remained in place after the test was done.

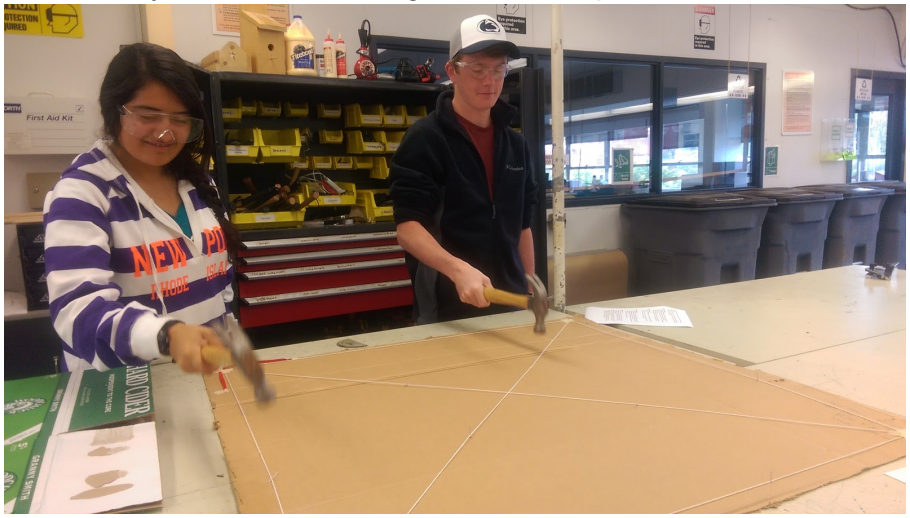


Figure 5: Hammers are being used by Matt & Natalie to show how durable the grid is.

2) Test Results Summary: Prototype #2 (Table 2)

User Need/Feature/Requirement	Describe Test	What is "Pass"?	Materials/Tools needed to run tests	Pass or Fail?
1. Quick and easy setup (10 mins)	Setup of the greenhouse design in under 10 mins	Setup in under 10 mins with two people.	String, marker, measuring tape, nails, long paper	Pass. It took us longer to measure out the strings, but since everything is pre-measured before we start the process, it can consistently be done in under 10 minutes.
2. Stability/Wind Factor	Set up the design outside on a windy day and observe to see if the string or blocks are affected or altered.	All pieces remain stable throughout the wind	String, wood, tape, measuring tape	Fail. When the wind is too strong, the string moves, which could keep us from being completely accurate. Also, the four wooden blocks are light and could be pushed over if wind levels got too high.
3. Weather/stability of ground (Rain)	Set up the grid using the prototype on a rainy/wet day to see if the strings become more flexible when wet	When the distance between the outer corners is still 6 meters even when the string is wet	Water	Pass. Our stakes weren't affected by the rain and the water did not change the flexibility of the string.
4. Accurate and Precise Measurements	Using measuring tape to check all sides of the square (that each is 6 meters) and check that the hole in each block of wood is in the same place for all pieces.	All sides are 6 meters and hole is in each block of wood in the same place.	Measuring tape, ruler	Pass. Since the sides were all 6 meters and the holes were in the same place in each block of wood.
5. Durability/Impact	Use of people to walk through the outside and see if they trip of the string.	If everything remains in place (angles, poles) and the structure does not come undone (the whole thing moves).	People	Fail. When we tested it outside people kept tripping over the string, the foundation would come undone.
6. Stake Placement	Measuring the placement of stakes using measuring tape to be sure that they are no more than one cm off.	If all stakes are no more than 1 cm off.	Measuring tape	Pass. All stakes were accurately placed. The string is clearly marked and the cross-section overlaps the inside strings precisely where the inside posts should be put.

2) Observation Summary (what did the team observe and learn from the tests? Did the tests reveal important information? Were there any surprises?)

Prototype #2 Testing: October 11, 2014 (3 pm, Hammond Building & Surroundings)

Quick & Easy Setup

For this test we had our “kit” assembled in advance. Matt and Thomas were the two team members who would be responsible for creating the grid in under ten minutes, As soon as they began to extend the perimeter, the timing began. It took them around three minutes to adjust the perimeter to a perfect square. When the length between corners was the same length of the cross-section strings, it was known that the perimeter created the 6 meter by 6 meter square. Next, they laid out the vertical strings between the two outer sides, which took them an additional minute. Once the two vertical strings were placed in the correct locations, the used the intersecting lines to place the inner stakes. Placing all sixteen stakes took another minute. For the setup process, it seems that establishing the outer perimeter as a perfect square is the most time-consuming step, because it requires the two builders to do precise adjustments. Despite this, the team was still successful in creating the grid in under ten minutes, so the prototype passed the “Quick and Easy Setup” Test.

Figure 6: Here is the finished outline of prototype #2.

Stability/Wind Factor

The second prototype did not pass this test, as strong winds sometimes moved the string, especially the cross-sections. We saw this when we set up our design outside on a pretty windy day and it did not stay together as well as we would have hoped. If the wind were to get any stronger the blocks could potentially tip over as well. However, we could improve on this in a number of ways. Using stakes instead of blocks would greatly improve the stability of the blocks and keep better tension in the string. If we wanted to keep the blocks we could make them larger, so they would have a bigger base and be

less likely to tip. We could then incorporate a rebar in a third hole drilled through the top of the block to keep the string completely in place.

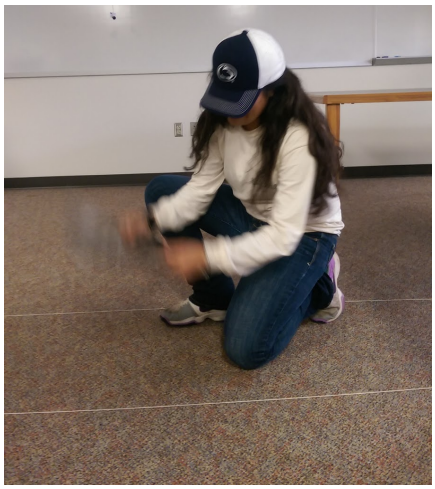


Figure 7: Natalie is creating wind by using a folder to test the wind factor on the string.

Weather (Rain)

There is a wet season in Kenya from November to May. The team wanted to test the prototype to see if it would still measure an accurate under wet conditions. In order to test this, Matt and Thomas set up the grid on a day when it was raining. The team observed how the water impacted the flexibility of the string, for it was possible the the string could absorb water that would allow it to stretch when it was pulled taut. The team measured the perimeter and noted that it was still 6 meters in length, so the rain did not impact the string. The prototype was still able to create a 6 meter by 6 meter grid in wet conditions, so the prototype passed the “Weather” test.

Figure #8: Thomas & Matt pose as the rain comes down on the prototype.

Accurate and Precise Measurements

The second prototype passed the accuracy and precision test. During the building processes, the team carefully measured 24 meters of string so there would be exactly 6 meters on each side of the square perimeter. When creating the wooden blocks for the corners, the team carefully measured the dimensions so the hole would be placed in the same location for each block. As a result of these careful measurements, the second prototype had sides that were 6 meters long and level, which indicated a pass for this test.

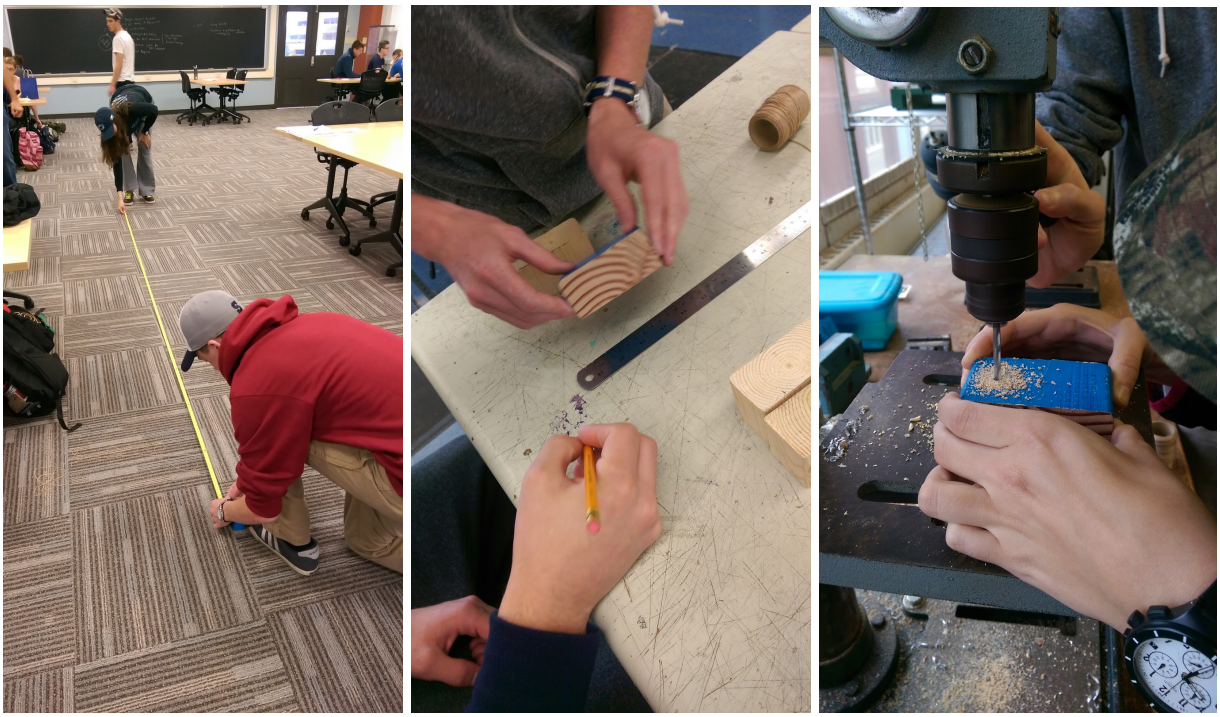


Figure #9: A. Matt & Alex measure the distance between wooden blocks with a measuring tape. When drilling the holes in the corner wooden blocks, the team was careful to measure the hole location so it was identical for each block.

Durability/Impact

During the initial setup of the prototype, the string was causing a hazard to the pedestrians. On multiple occasions, a person would not see the string on the ground, so they would walk into it. This not only created a dangerous tripping hazard for the people walking by, but the impact would alter the location of the prototype. The prototype was unable to maintain its structure after these impacts, indicating a failure for the “Impact” test. This issue could potentially be fixed if the four corners had wooden stakes instead of just blocks. This would keep the prototype tethered into the ground and more resistant to changes. Also, more visually stunning string would make it easier to notice, which would reduce the amount of impact it had to withstand from people passing by.

Figure #10: Alex walks through into the string to the team can observe how little impact is require to alter the measurements of the prototype.

Stake Placement

After the all the stakes were placed to create the grid, the group evaluated the accuracy of the stake locations to determine if they were within one centimeter of where they were supposed to be. First, we used a tape measure to measure the total length of the four outer sides. All four sides were six meters long, so we knew the perimeter was the correct size. We then measured the length between the corner stakes and the stakes located along the sides of the perimeter. As expected, the stakes were no more than one centimeter longer or shorter than two meters from each other. Next, we measured the length between the outer stakes and the four inner stakes. All measured lengths were around 2 meters, fluxuating no more than one centimeter, which is the

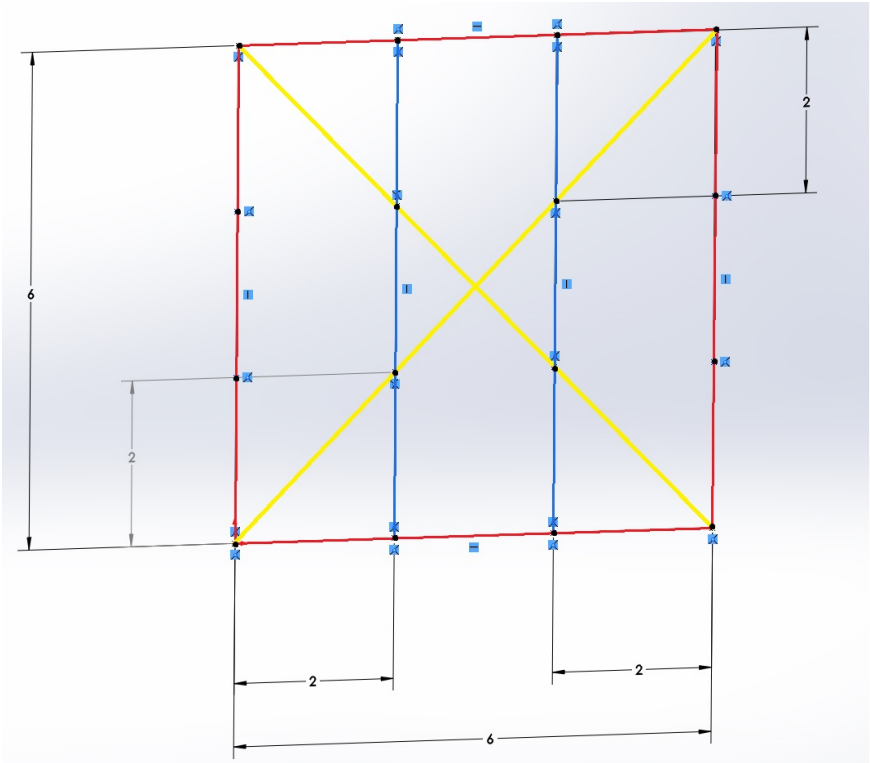
length we expected. Due to the accuracy of the lengths between the stakes, we determined this test was passed.

Figure #11: Thomas places the sixteenth wooden stake into the upper right grid corner.

Explanation of the Kit that will be taken to Kenya

We are taking a kit to Kenya with us when we go to build the greenhouse. The kit will consist of 4 blocks of wood that are equal in size as well as some extra blocks of wood just in case. These blocks of wood will all have a small hole in the center of them (all the same measurements). Then the blocks will have a 24 meter piece of string running through them to form a square, with side lengths of 6 meters and the entire string marked every 2 meters. This kit will also consist of two pieces of 6 meter string and two pieces of 8.50 meter string (for cross sections). The kit is then complete and ready for use when taken to Kenya. Basically all that will need to be done with the kit is to put the wood in the ground and then place the cross sections along opposite corners of the square then place the two 6 meter pieces of string vertically across the square. After that the stakes are placed and everything is all set!

The Cross Section Method



The cross-section utilizes simple geometry to accurately find where the posts will be located. Since some of our kit is already pre-made and the strings are measured out , the process of putting it together is relatively simple. The first step we took was to measure out and collect all the materials. From there, we marked the 24 m string every two meters and then thread it through 4 wooden blocks with equally sized holes. These holes are in the same spot on each block, which is very helpful to keep our string level, even when the ground might not completely be. The string will have tension and be elevated off the ground, so if the ground is bumpy or slightly slanted, we can still be accurate. We then taped the string on the outside of the blocks so each side length was exactly 6m and each wooden block was a corner of the square. This is our basic kit, a 24 m string with wooden blocks at each corner, making it a square. Next we laid down two cross-sectional pieces of string, each measured to be roughly 8.5 m. These allow us to see if the square is exact or not and helps us fix it if something is off. After this, we lay down two vertical strings, connecting the inner top posts to the inner bottom ones. These strings will overlap with the cross-sections, revealing the location of the remaining posts. The location of every wooden post is now accurately gridded with a marking or overlap of string, and they are ready to be put into the ground.

Cost Analysis

At the Home Depot, a 2 inches by 4 inches by 96 inches cut of lumber would cost **$3.06**. These dimensions would provide more than enough wood to create the four corner blocks needed for the kit. The corner blocks for the design have dimensions 2 inches by 4 inches by 4 inches, so a single cut of this lumber would be enough to create six kits. As for the string, a 420 foot spool of twine only costs **$2.57** from the Home Depot. This would be enough twine for two kits, including 24 meter perimeter, the cross-section string, and the vertical string. Purchasing these two products together is only **$5.63**, and offers more than enough material to make a kit to be sent to Kenya. Additionally, wood is a readily available resource in Kenya. This means if anything were to happen to the kit and the wooden blocks, they could inexpensively be replaced. This is comforting because it would be difficult to keep the kit from ever getting altered. Based on this, it is safe to say that this design is under the material price goal of $10.

Wood - http://www.homedepot.com/p/Unbranded-2-in-x-4-in-x-96-in-Premium-Kiln-Dried-Whitewood-Stud-161640/202091220
String - http://www.homedepot.com/p/9-x-420-ft-Household-Twine-White-18007/202079625

Re-Design Ideas / Thoughts

One of the problems that occurred during testing was a result of the corner blocks used in the prototype. There was nothing keeping the blocks tethered to the ground, so they could easily be relocated, especially when a person trips over the string. To solve this, it is recommended that the third prototype uses a method to keep the corner blocks planted into the ground. This could be solved by using stakes to place into the ground instead of just blocks. It is important that the corner stakes still have a square shape, allowing them to create the 90 degree angles that ensure the string outlines a square. The issue of untethered corner blocks could also be solved by drilling a third hole through the top of the block. A piece of rebar could be placed through this hole when creating the greenhouse perimeter, keeping the corners firmly in place. Prototype #3 should also include a method of storing the kit so that the strings do not get tangled. To prevent this issue with prototype #2, the string is kept together with tape when it is not in use. This is not an effective solution, though, because a new piece of tape is needed each time the prototype is extended to create the perimeter. The third prototype could include so type of tool to keep the string together and untangled. A slender cylindrical piece of wood could be effective, for the string could be wrapped around the cylinder for prevent tangling while remaining compact and portable. Other than these two issues, I would not make any further changes to the prototype in its third design.

User Guide

Prototype

#2

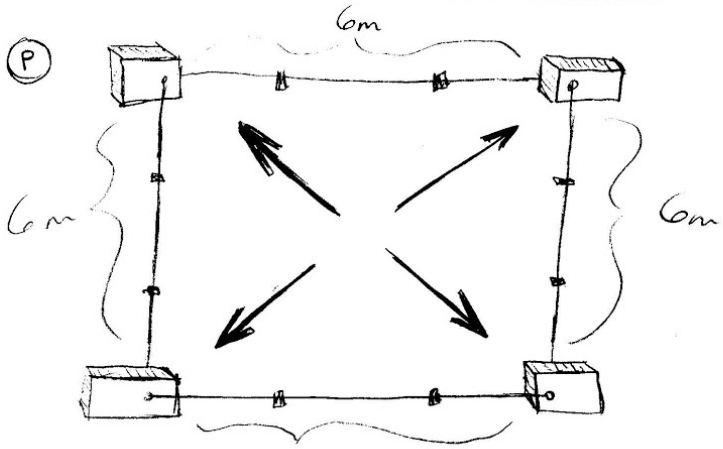
Cross Section Method

"Instruction Manual"

Team 3:- Alex Bowers, Matt Bunker, Thomas Cadle, Natalie Jaren

Step #1

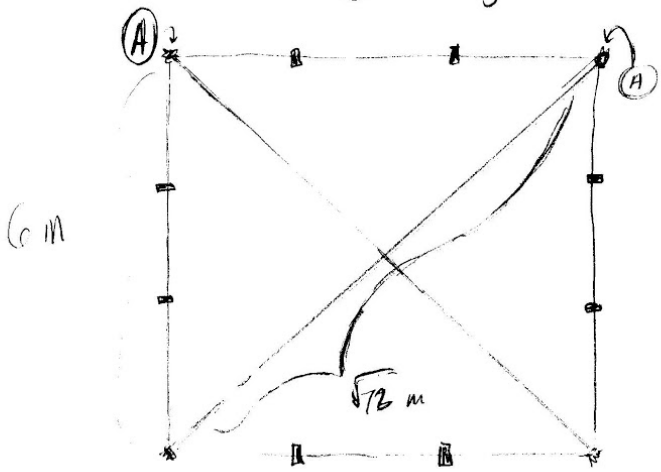
- Stretch out the 4 corner blocks of the Perimeter Layout (P) to their limit.



Each side will be 6m when fully extended.

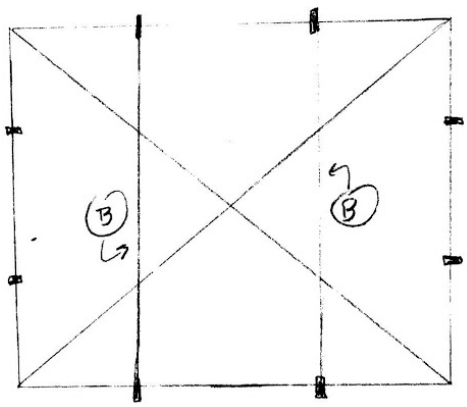
Step #2

- Use the two longest strings (A) to create a Cross Section



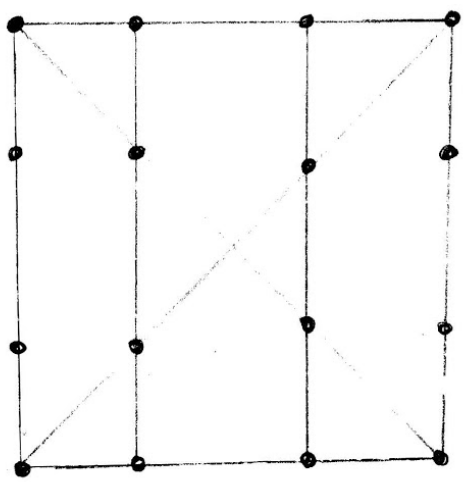
Step # 3

- Attach the two separate 6 meter strings (B) to the markings on Perimeter Layout (P)



Step # 4

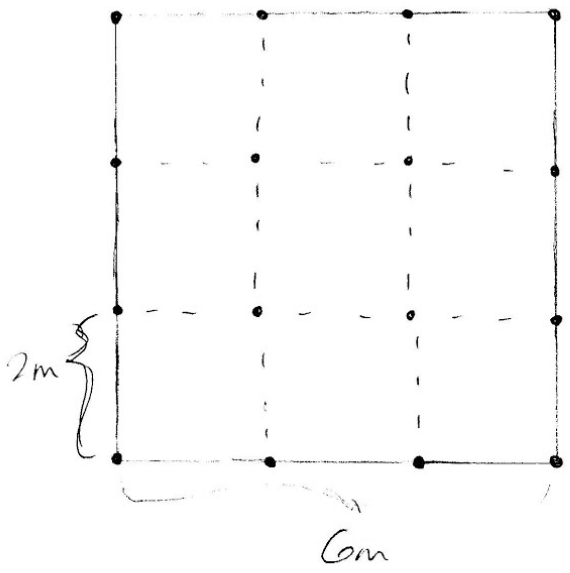
- Enter Stakes (S) in
  - the 4 corners
  - the 8 side markings
  - the 4 locations where the inner strings intersect



• indicates a Stake (S)

Step #5

- Remove inner strings (A) and (B) and Perimeter Layout (P)



Now your greenhouse grid is complete! ✓

Enjoy!