Mission Statement:

Product Description: We have two different product designs. A ball joint design will be used to support the roof of the greenhouses in Rwanda. This design will consist of two beams that come together at a sphere. As another design to supplement the stress put on the glaze by the joints, wooden washers will be implemented to reinforce the glaze to the greenhouse itself.

Benefit Proposition: These designs will increase the durability of the greenhouse itself along with the glazing that surrounds the entire greenhouse. The designs focus on preserving the glazing by minimizing the friction and sharp edges that the glazing may come in contact with on the greenhouse. Preserving the glazing will allow the greenhouses to becoming cheaper to build and maintain.

Key Business Goals: There are some key goals that our newly designed products are being set up to meet. For example, durability, so that over time the joints will hold in a sturdy position without moving around or breaking. Coming up with the perfect way to make a well-developed greenhouse that can last over a long time is the main goal we are trying to achieve so it can save money, time, space, and un-skilled workers. With the newly engineered joints, we are also trying to make it so it is easy to assemble in little time and repairable. If the greenhouse is able to meet all of these goals or most of them, then we have achieved our key businesses goals.

Primary Market: These products is a supplementary accessory to the greenhouses, and its primary market will thus be the local communities where greenhouses will be established. The product is specifically designed for Rwanda, but it can also be used in other developing countries.
Secondary Market: These products can also be applied on other greenhouses, specifically those established in African countries. However, it can also be used for any greenhouses all over the world. If applied properly, it can also be used on any other tent-like structure for prevention of the tearing of the glazing/tent.

Assumptions: These product should be durable, easy to use, cheap, and made out of environmentally friendly material.

Stakeholders: Stakeholders who would want to be involved with these products are the villagers using the product and the companies that help produce the products.

Concept Development Summary: Our team gathered information about the country Rwanda by taking all the different aspects of the country (societal, economic, history, etc.) and splitting them up amongst our group. Rwanda is a small, poor, undeveloped country that has been devastated by civil wars and genocide. People all around the world are trying to come together to make this small Sub-Saharan African country a better home for the people who live there. The weather in Rwanda usually stays pretty consistent. The temperatures in Rwanda are between 59°F and 83°F, and will barely go below these temperatures throughout the year (Cedar Lake Ventures, Inc.). There are two rainy seasons that happen in Rwanda between the months of November and April, and cold air in the mountains produce snow or frost. Rwanda is a country in central Africa, to the east of Democratic Republic of the Congo, north of Burundi, west of Tanzania, and south of Uganda. Rwanda’s population is 12,337,138. Along with other countries in Africa, Rwanda has issues with its water and food supply. Chronic malnutrition affects 43% of people that reside in Rwanda. This also leads to the improper sanitation that plagues 4.2 million in Rwanda (WaterAid). Steel is not manufactured in Rwanda and so, it is not really used that much anywhere. Most of the construction materials used are made from soil, concrete, and cement.
One feature that we really wanted to test on Prototype #1 was a spherical type shape on the intersection of two joints. That was desired because we wanted to test how changing the shape of the part of the joint that comes in contact with the glazing would affect its overall function. We were also looking for our first prototype to be easily created and maintained so this would be a practical to use in greenhouses in Rwanda.

*Figure 1 Early Sketch Dimensions of Green House*  
*Figure 2 Early Sketch Concept Designs for Ball-Joint/ Washer*
Test Results Summary:

<table>
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<tr>
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<td>Permanence of Solution</td>
<td>Weight test: build prototype and put weights to stimulate different forces</td>
<td>Our prototype being able to hold over 3 pounds on a single joint</td>
<td>Weights, rope, materials to pull down on our prototype</td>
<td>Yes, it held up a hammer approximately 3.2 pounds</td>
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<td>Durability</td>
<td>Heat test: blow dry the material and see how it reacts to heat</td>
<td>Our joint doesn’t melt, catch fire, or fall down in up to 170 degrees Fahrenheit</td>
<td>Hair dryer, Heat Lamp, or concentrated heat source</td>
<td>Yes our prototype handled over a minute of concentrated heat from the hair dryer (180 degrees Fahrenheit)</td>
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<td>Cost</td>
<td>Add up all the costs associated with the joint</td>
<td>Each joint costing less than $2 totaling less than $8 between four joints</td>
<td>Calculator Internet</td>
<td>Yes, It was within the budget to be bought in a local store</td>
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<tr>
<td>Set Up Time</td>
<td>Time it takes to set up a joint</td>
<td>5 minutes to set up per joint</td>
<td>Prototype</td>
<td>No/Yes</td>
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<td>Environmentally Friendly Material</td>
<td>Research biodegradability of types of materials and recyclability</td>
<td>It doesn’t have a negative impact on the environment</td>
<td>Internet</td>
<td>Yes, our design only contains recycled wood and very few nails</td>
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<td>Easily Repairable</td>
<td>We’re going to break a joint that we’ve built ourselves and rebuild with raw materials</td>
<td>Repairable in less than 10 minutes</td>
<td>Dowel rods Elbow Grease</td>
<td>Yes, the design was simple enough to fit back together even after it snapped</td>
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Detailed Analysis of Tests

Weight Test:
For this test, we tested how much weight each of the joints could hold up independently (refer to Figure 1). We performed this by laying our prototype on top of the graded shelves allowing it to rest flat. Next, we tied a rope to the joint we were testing and then tied a weight to the end of the joint. We used a metal hammer as the weight. We allowed the weight to hang freely and apply a constant downward force on the joint. We then removed the weight after a minute to see that it has passed the weight test of holding over 3 lbs per joint. Our prototype was able to hold 3.2 lbs per joint for over a minute.

Heat Test:
For this test, we tested the amount of heat each of the joints could withstand (refer to Figure 2). We performed this test by laying out our prototype on a flat surface so the heat could be evenly distributed through the whole joint. Next, we used a hair dryer to produce constant heat of around 180 degrees Fahrenheit on each joint. After a minute on each joint, our prototype was still standing so it passed this test.
Cost:
For this test, we tested if our joint falls into the budget of 2 dollars per joint and 8 dollars for 4 joints. Each joint only required about a quarter of a dowel rod (i.e., ¾ m) and only one circular knob. The dowel rods were less than $2 each and the knobs were less than $3 for about 12 knobs. Since this is less than $6 across 4 joints, it passed our cost test.

Setup Time:
For this test, we tested how long it takes to initially set up each joint (refer to Figure 3). Including the gluing and drying time, our time was above 5 minutes, our set goal for each joint. Since our original design called for nails, we can factor out the drying in the second prototype so this would allow the set up time to less than five minutes.

Environmental Friendliness:
For this test we tested biodegradability and recyclability of each of our compounds. We researched the composition of the wood for our dowel rods and knobs. The wood wasn’t treated with any harmful chemicals so it’s environmentally sound. Also, since our joint is only wood, it’s able to decompose naturally. All these elements allow our joints to pass the environmentally friendliness tests.
Repairability:
For this test, we tested how easily repairable our joints were by breaking one and seeing how long it would take to put back together (refer to Figure 4). Since our prototype was put together with glue instead of nails, it makes this test less reliable than the others. Even with these constraints, we still broke the joint and tested it anyway. It only took our joint roughly 8 minutes to be repaired (including drying time) so our joint has also passed the repairability test.

Figure 4: Repairability
Observation Summary
What our team observed from our tests is how practical our joint would be in an environment like Rwanda. Our tests have shown our group that our ball-joint design would be very successful in helping address the issue of the tearing of the glazing. Our team observed that our design was able to handle weight and the heat of a hair dryer, was repairable, and also was quickly set up. We didn’t physically observe but still noted the cost for each of the joints and how environmentally friendly the material is. Some surprises that came about during our testing was the amount of weight our joints were able to hold. It was surprising because our joints were barely staying together since we only had wood glue available. What was also surprising is how well our design actually trapped heat because we fully wrapped our joints with the glazing for optimal testing. Why this surprised us is because we only wrapped it with glazing to see if it would even say together with heat. It turns out it was not only able to stay together with heat, but also perform its duties by trapping the heat and humidity inside the greenhouse.

Re-Design Ideas/ Thoughts for Prototype #2
There are many aspects of our prototype that can be improved in the next prototype. For example, we would need to add a different set-up time test for the next prototype since we will be using nails instead of wood glue to keep the joints together. There are not any tests that we would remove for prototype two because our tests fully address all the needs and features required for our joints to perform for their purpose. The test results we didn’t receive were durability using the nail instead of glue, set-up time using nails, and also repair time using nails. This process of creating a prototype for a good cause is rewarding and makes the whole process much more enjoyable. In regards to feedback, we did not receive any from the HESE students personally.

Concept Refinement Summary
After the construction of Prototype #1, we needed new ideas to refine the first prototype and so we did some research on the reason that caused the tearing of the glazing. One common reason was that the glazing was directly nailed onto the wooden logs, and the nails were tearing the glazing when the wind applies too strong of a force on the glazing/greenhouse. We looked back into the brainstorming phase of the designing process and found a design that will theoretically substantially decrease the likelihood of the nail tearing the glazing, and that was the wooden washer design. No feature of the first prototype was changed, and we built a “Prototype 2” that is the first prototype of the wooden washer design. This wooden washer will simply be a thin cylinder with a radius around one inches, and it is supposed to increase the contact area between the nails and the glazing, hence reducing the friction felt by the glazing.
## Test Report Summary for Prototype #2

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<td>Yes, the design was simple enough to sand and nail back together even after it snapped</td>
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<td><strong>Washers Tearing Tests</strong></td>
<td>We are going to nail the washer to a wooden board with glazing in between and stretch the glazing until it tears</td>
<td>the washer makes the glazing tear ¼ less than the nail</td>
<td>Wooden Washer (round piece of wood) boards nails glazing</td>
<td>Yes, it held 18.3 pound compared to the nail that held 5.6 pounds before they tore</td>
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Since the wooden washer is a solid piece of wood, we dropped the heat, drop and weight test, because the data obtained will be similar to that of the standard wood. Instead of testing the durability of the design, which we have strong confidence in, we devised a new test to experiment the actual efficiency of the wooden washer in solving the glazing-tearing problem.

*Figure 1: Prototype #2*

In the lab, we nailed two sheets of glazing on a flat piece of wood, one sheet nailed with plain nail, and the other nailed with washers applied (refer to *Figure 1*). Then we clamped this piece of wood to the table and clamped the lower part of the glazing in between two smaller piece of wood to experiment on the maximum weight that the nails can hold.
The glazing that was nailed with just nails held only a couple of weights, meanwhile the glazing with the washers applied held significantly more weight (refer to Figure 2&3). We then took off the weights and put them on a balance to acquire the mass. The weights that the plain nails held was 5.6 pounds, and the weights that the nails with washers held was 18.3 pounds, which was more than 327% of the weight held by the original nails. This experiment apparently proves the efficiency and utility of the wooden washers.

**Cost Analysis:**
For greenhouse joint protection teams: Prototype #2 would be able to meet the goal of under <$2 because all it requires is a little bit of cutting, sanding, and nails. The joints are assembled by cutting the pieces that will come together at a certain degree, and then from there sand it out to make a smooth edge. Really what the best ideal triangle to build at the triangular joints should be an isosceles triangle because the base of it needs to be bigger than the sides. The estimated cost of the final prototype would be however much the saw, nails, and sand paper would cost. Nails and sand paper will be fairly cheap so it wouldn’t cost that much, and no need to buy a saw because the assemblers should already have one. In total the estimated cost should be no more than $20 to cover all the joints of their cost. The expected cost of the final project should be no more than $100. The reason why it would cost around $100 is that $20 for the nails and

*Figure 2&3: efficiency test of the wooden washers*
sandpaper, and then the workers should already have a saw, they will be getting wood from surrounding areas trees, and then the main portion of the cost will be the glazing to go over top the final assembled greenhouse. So, a cost of $100 for one greenhouse multiplied by the 250 that will be built equals a grand total of $25,000.

**User Guides:**

Greenhouse teams:

Ball joint:

**Step 1:** (make the triangles for the top twice as an isosceles triangle)

![Diagram](image1)

**Step 2:** (connect the triangles with long pieces of wood on the sides and top)

![Diagram](image2)
Step 3: (Assemble the middle piece to the sides to help hold it together)

Step 4: (Put two pieces of wood from the side to the top middle on both sides at a slant)

Step 5: (Put the glazing over top of the structure at fit and cut to size)
Wooden Washer:

**Step 1:** (find a relatively flat surface, and nail the glazing to the greenhouse with wooden washers over the nails, apply one washer approximately every 10 inches)

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**Re-design ideas/thoughts**

The HESE students gave us a lot of helpful advice and criticisms about our design. They all really liked the idea of the ball joint, but were concerned about the amount of time it would take to make the ball joint out in the field. They asked if the amount of time needed to make the round ball joint was worth the extra time the greenhouse went without tearing the glazing. After each one of the HESE students gave us some feedback, we thought about some extra ideas we could use to improve the design of the ball joint. One thing we thought of to conserve time is to have a mold of some sort in a cone-like shape that could help the carpenter make the round shape easier in the field. Another thing is have the ball joint come to the setup already pre made, kind of like a kit that someone brings in on the scene to build the greenhouse.
Works Cited


https://www.wfp.org/nod0000000e/3566/3984/399837