

The Helio-Portal

A Connection From Lima to Philomath



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Objectives:

- Beautiful and effective structural elements.
- An emphasis on wood, instead of steel fasteners or other materials.
- Client feedback in Philomath indicated an arch, and a futuristic look that honors Philomath's past as a timber town.

Project Goal: Create an intriguing parametric form demonstrating the aesthetic and structural strengths of timber products. We designed a "Helio-Portal," a metaphorical connection and tunnel between Lima and Philomath.

Material and Fabrication Details

- We are limited to 20 4' x 8' $\frac{3}{4}$ " sheets of low-quality plywood
- Lima requires a 25mm minimum distance from the edge of the plywood - fabrication constraint
- Due to the depth of the plywood sheets ($\frac{3}{4}$ "), we designed our members to sit vertically (thin face-down), allowing for stability in our joint connections and overall structure

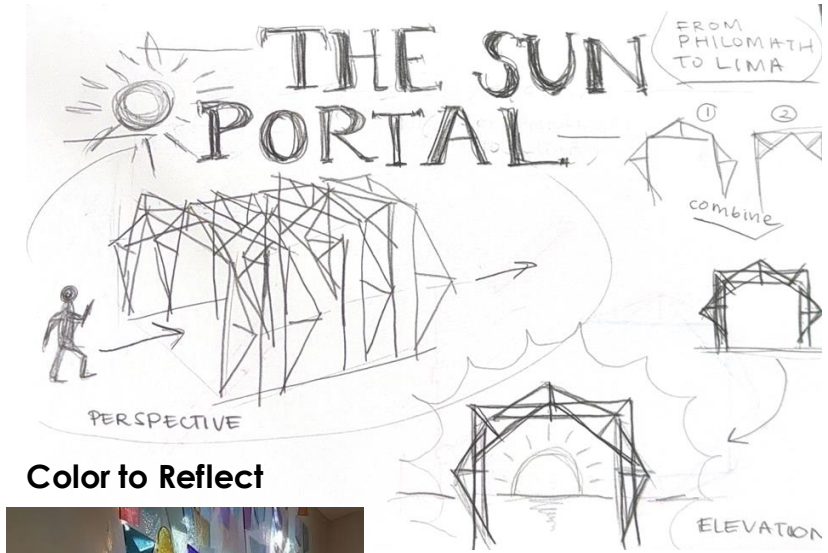
Inspiration and Precedents

- The Magnolia Restaurant used diagrid as its core aesthetic feature. It relied on wood and wood-colored copper sheets, with minimal visible steel in the connections.
- We explored regular, geometric patterns, and a shape like an arch or a building frame.
- Diagrid-oriented ideas were too plain and had constructability problems, so we settled on a truss system.
- Initial ideas involved movable chairs, and this concept was recycled into connections between frames that doubled as furniture.

Magnolia Restaurant



Inter-Lattice Diagrid System



Color to Reflect



Magnolia Connection

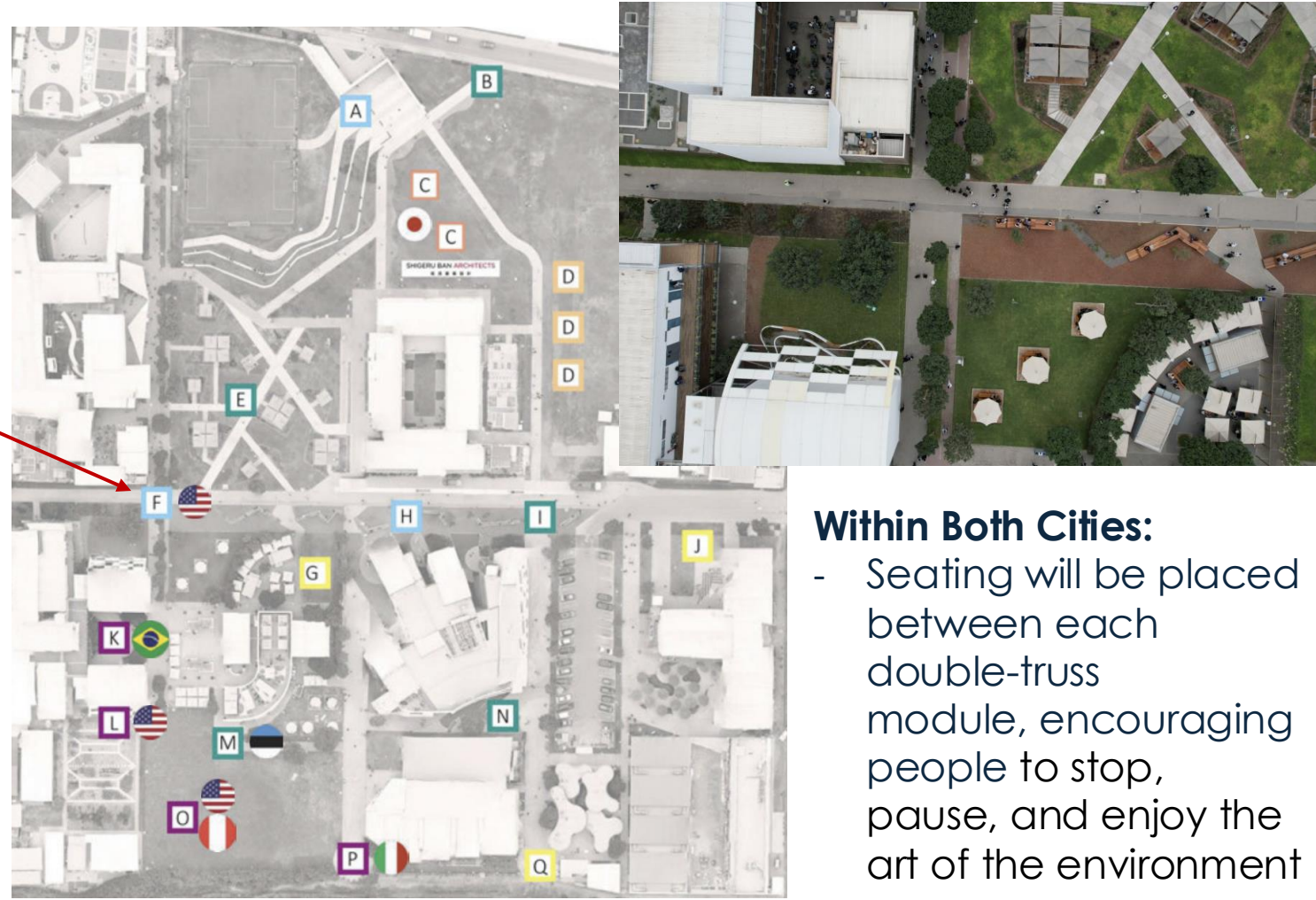
Site Application: To Lima and Philomath

Philomath:

- The overall height of our structure is **8' 6"** to ensure it fits within the Philomath council chambers.
- Trusses will be pre-assembled to cater to the request for a quick building process

Lima:

- The existing east-west orientation of the Lima Site **F** walkway correlates directly with our main concept: a sun portal
- Structure can be placed just shy of the intersection to avoid limiting bidirectional movement + behind the tree on the North end of the walkway



Within Both Cities:

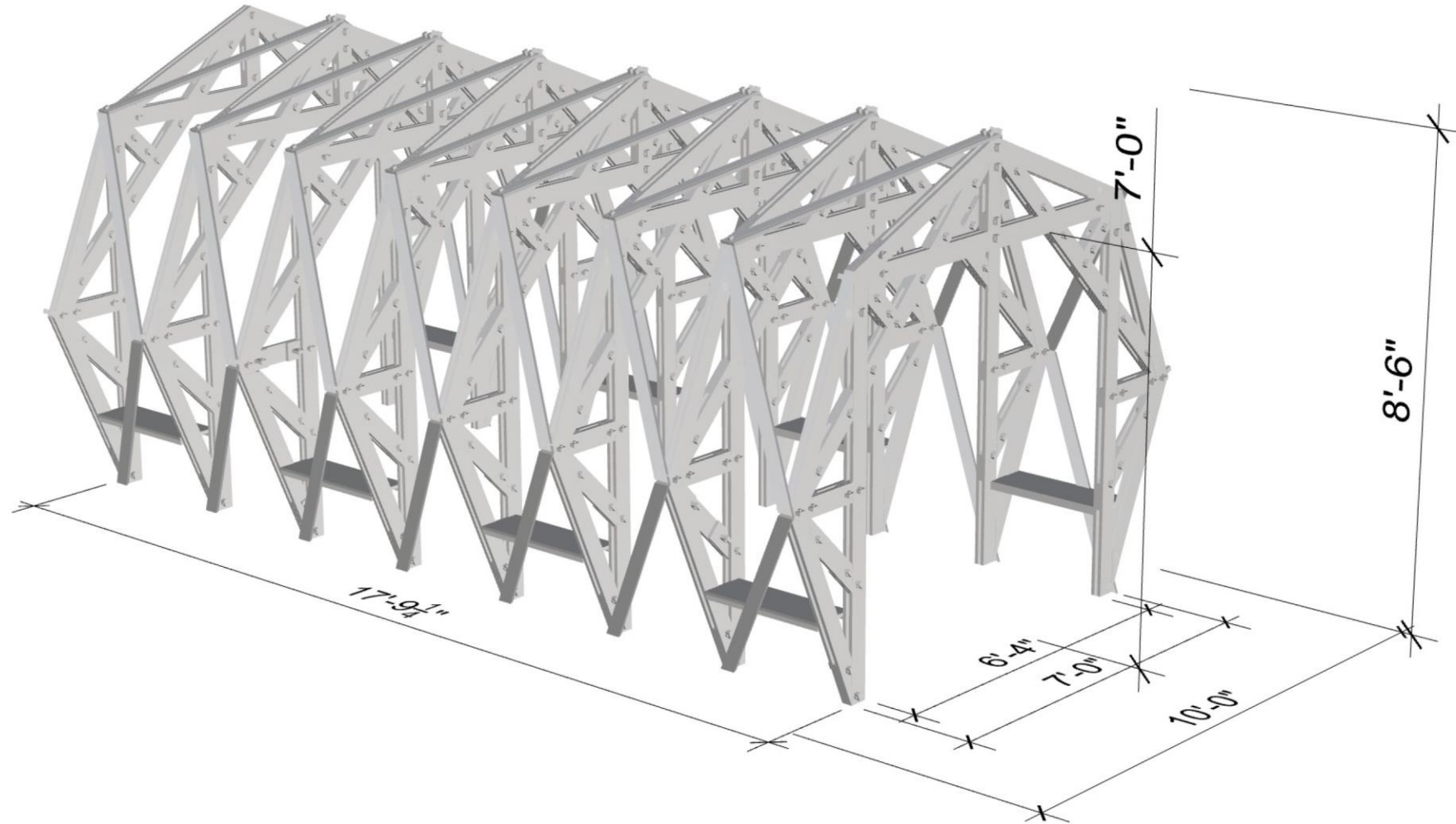
- Seating will be placed between each double-truss module, encouraging people to stop, pause, and enjoy the art of the environment

Overall Design

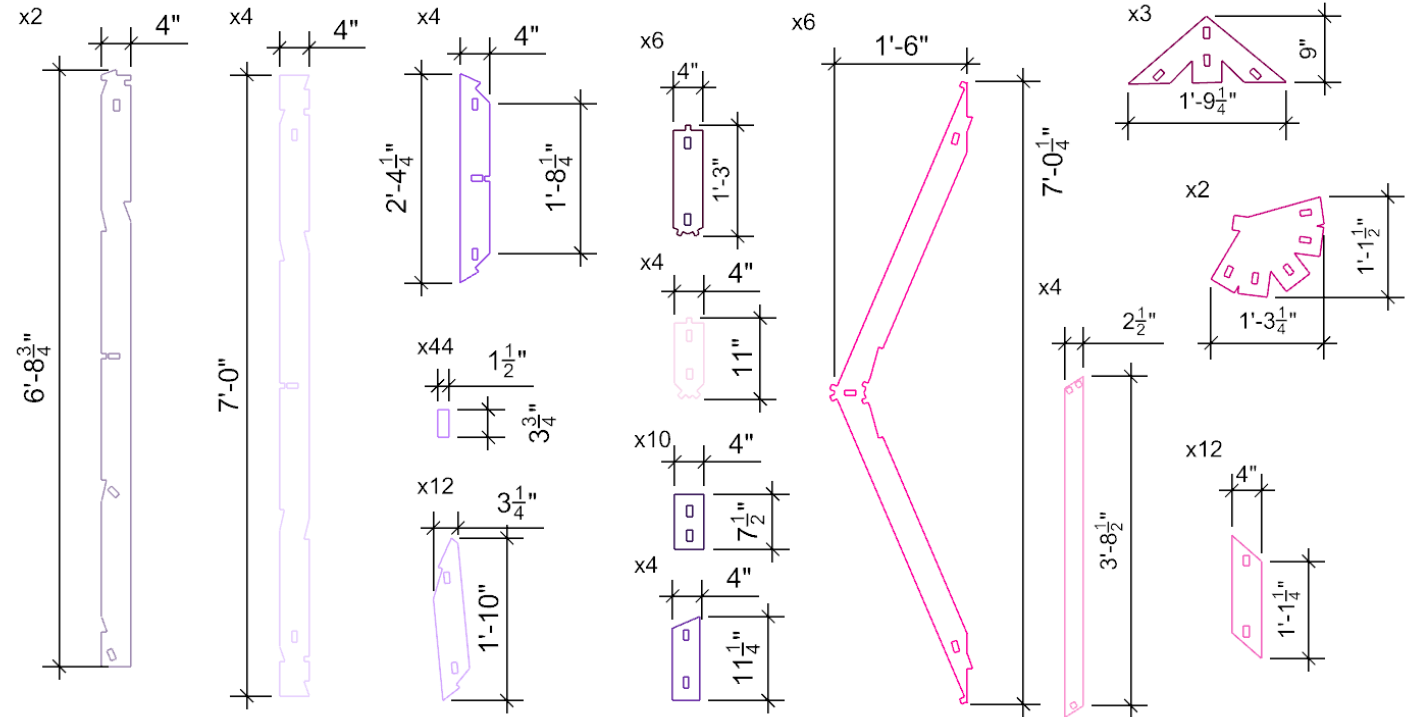
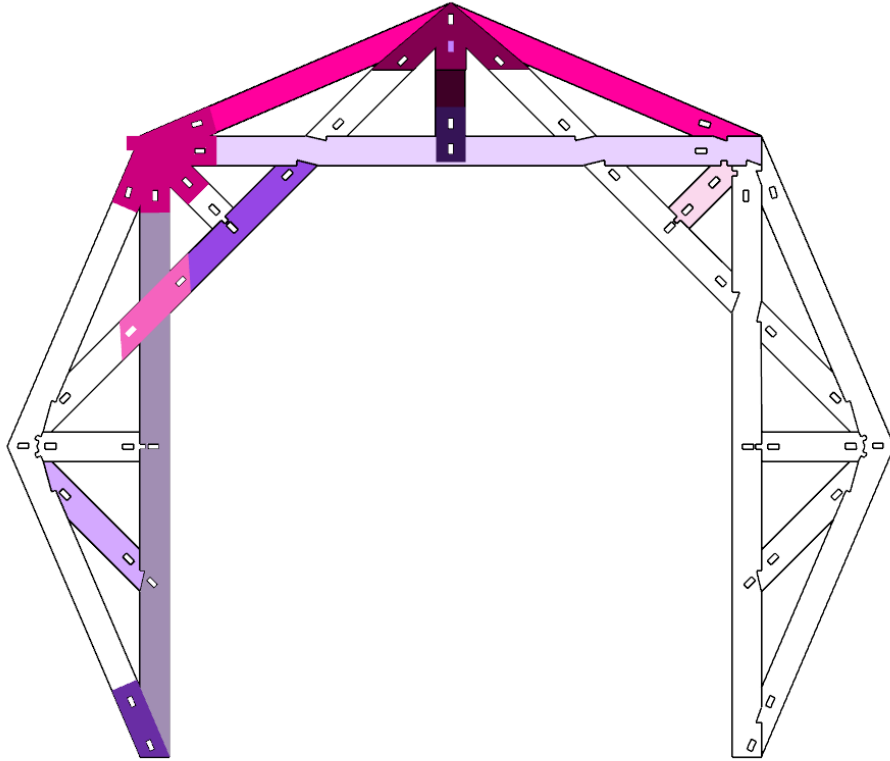
The Helio-Portal connects 8 star-shaped frames to create a tunnel, symbolically connecting Philomath to Lima.
Connections between frames provide seating for pedestrians.



The Basic Dimensions



Kit-of-Parts

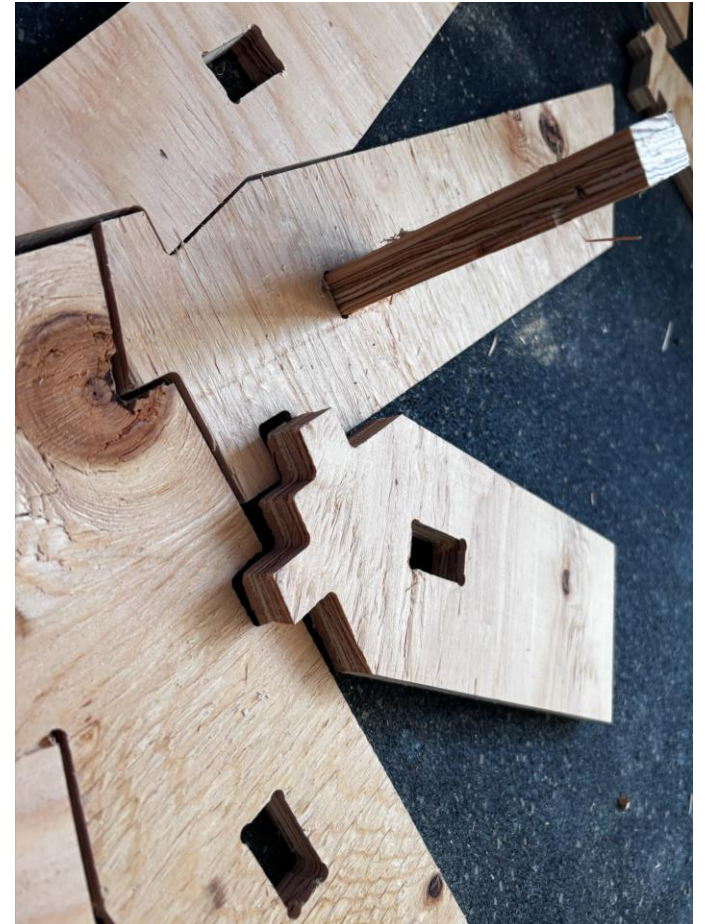


Connections at 1/8" Scale

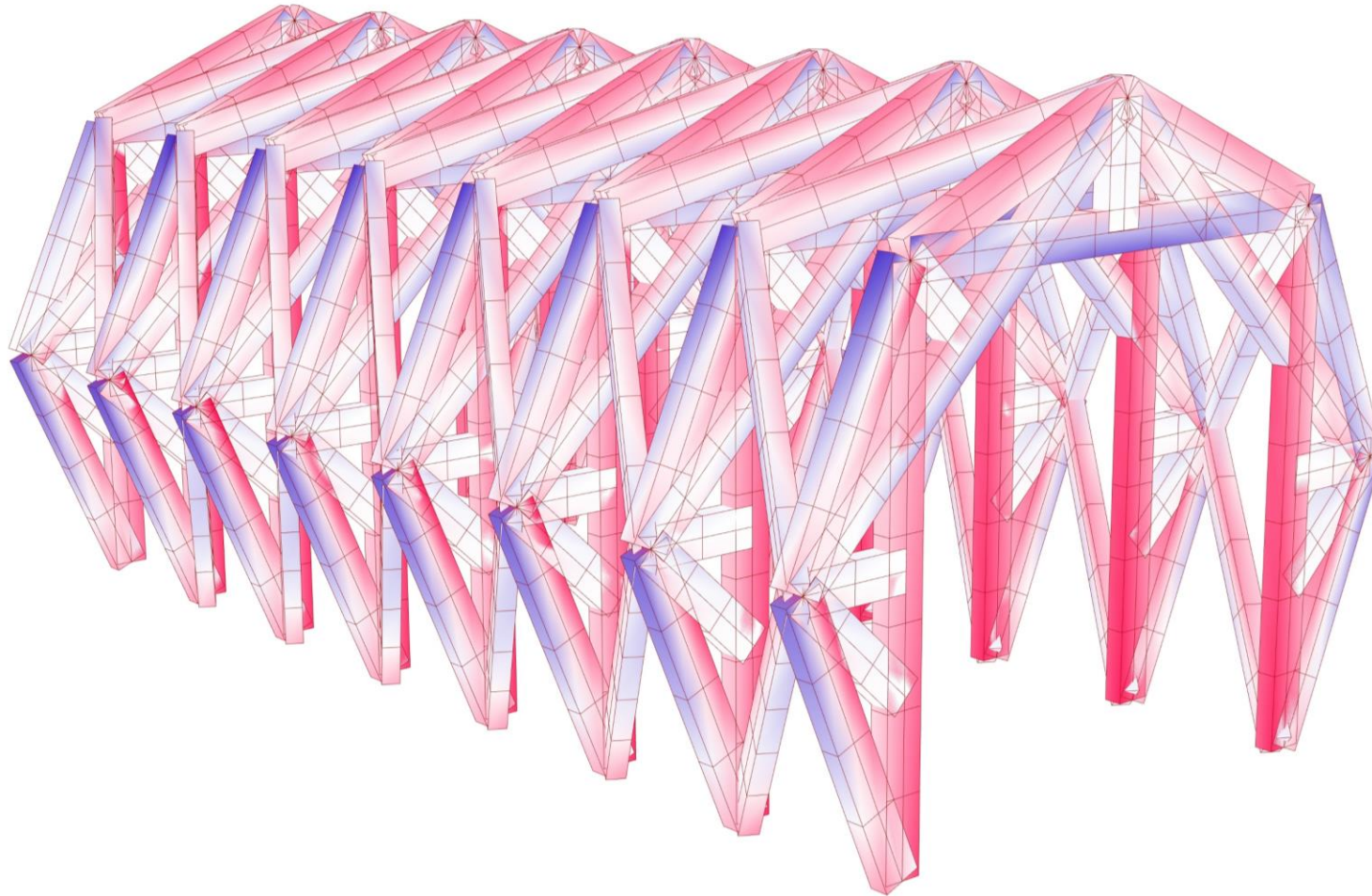
- Structure uses square dowels to connect specially fitted parts, transferring live and dead loads into the 16 contact points
- Seat and diagonal connectors between modules help distribute the live load and resulting bending moments



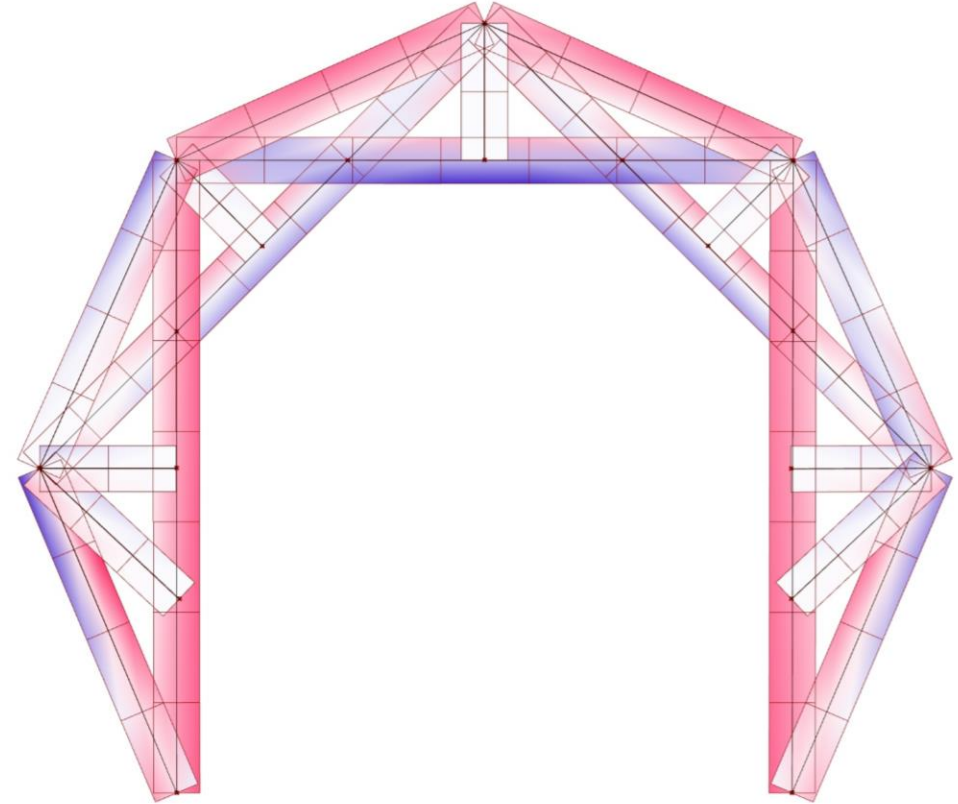
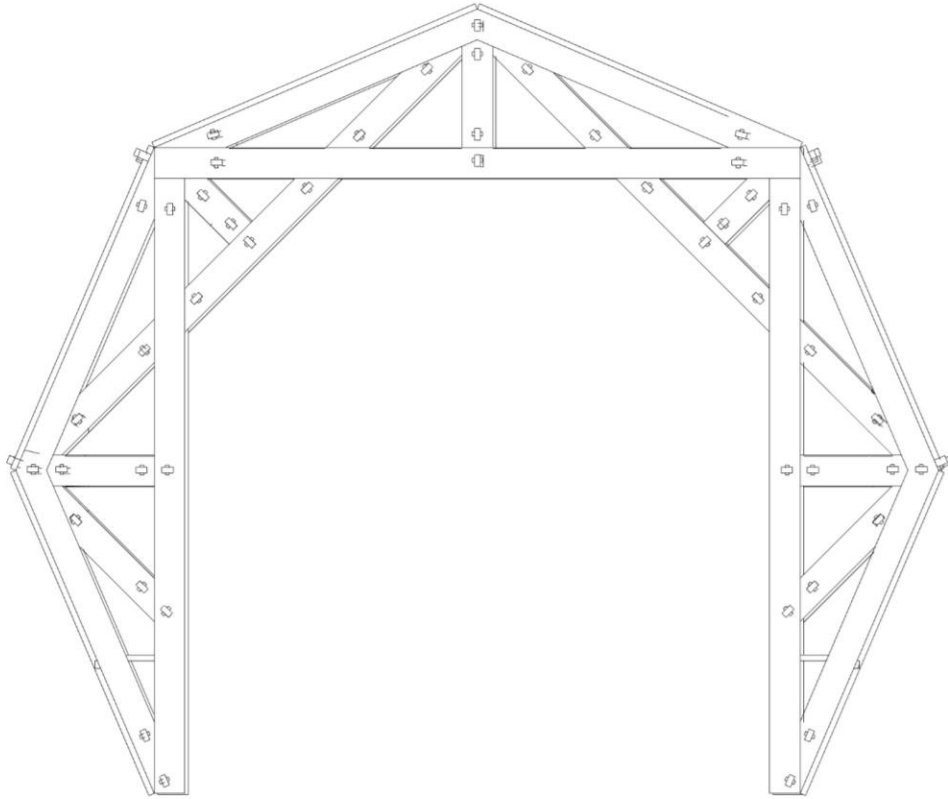
Modular Connection 1:1 Scale



Structural Analysis: Overall Structure



Structural Analysis: Typical Module



Hand Calculations

- Compression strength of plywood against the grain is very high.
- Most likely failure would result from bending (main structure) or shear (the seat).
- Worst case scenario calculated using length of an 11 ft beam (approximate total length of the beam with a bend in it.) Beam can sustain a 140lb point load without bending rupture, much more than the weight of a single frame. Seats should mostly transfer compressive force, not bending moment – low position helps. Assume up to 400lb from people sitting on either side.
- Strength and MOR data are from the University of Oklahoma.
- At 900psi sheer strength, the seats are structurally sound.
- All factors of safety exceed two.

Safety Check:

From APA-Plywood: $Wt = 2.2 \text{ psf}$ $4\frac{1}{2}/24 \text{ PF}$

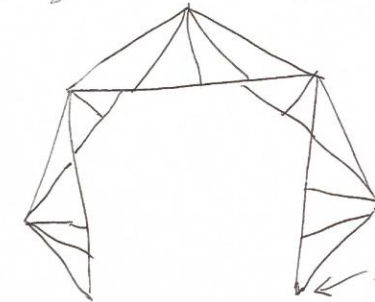
Area of ~~one~~ one frame:

$$3 \times \text{red} : 4'' \cdot (12.6 + 8)'' \Rightarrow 296 \text{ in}^2$$

$$5 \times \text{green} : 1'2'' \cdot 4'' \Rightarrow 280 \text{ in}^2$$

$$3 \times \text{purple} : 10' \cdot 4'' \Rightarrow 480 \text{ in}^2$$

$$8 \times \text{yellow} : 2' - 4.25'' \cdot 4'' \Rightarrow 904 \text{ in}^2$$



$$\leq \approx 1640 \text{ in}^2 \cdot 14 \text{ ft}^2$$

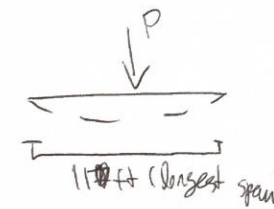
$$Wt : 30.8 \text{ lb}$$

$$\text{Safety check: } 4.8 \cdot \frac{4}{16} \cdot 2.2 \text{ psf} = 17.6 \text{ lb} \checkmark$$

$$\text{base: } 4'' \cdot \frac{3}{4}'' = 3 \text{ in}^2$$

$$\text{Bearing capacity} = 3000 \text{ psi} \cdot 3 \text{ in}^2 = 9000 \text{ lb} \checkmark$$

MOR: ~~12400~~ 8600 psi, (source: Oklahoma State University Strength properties of wood for practical applications)

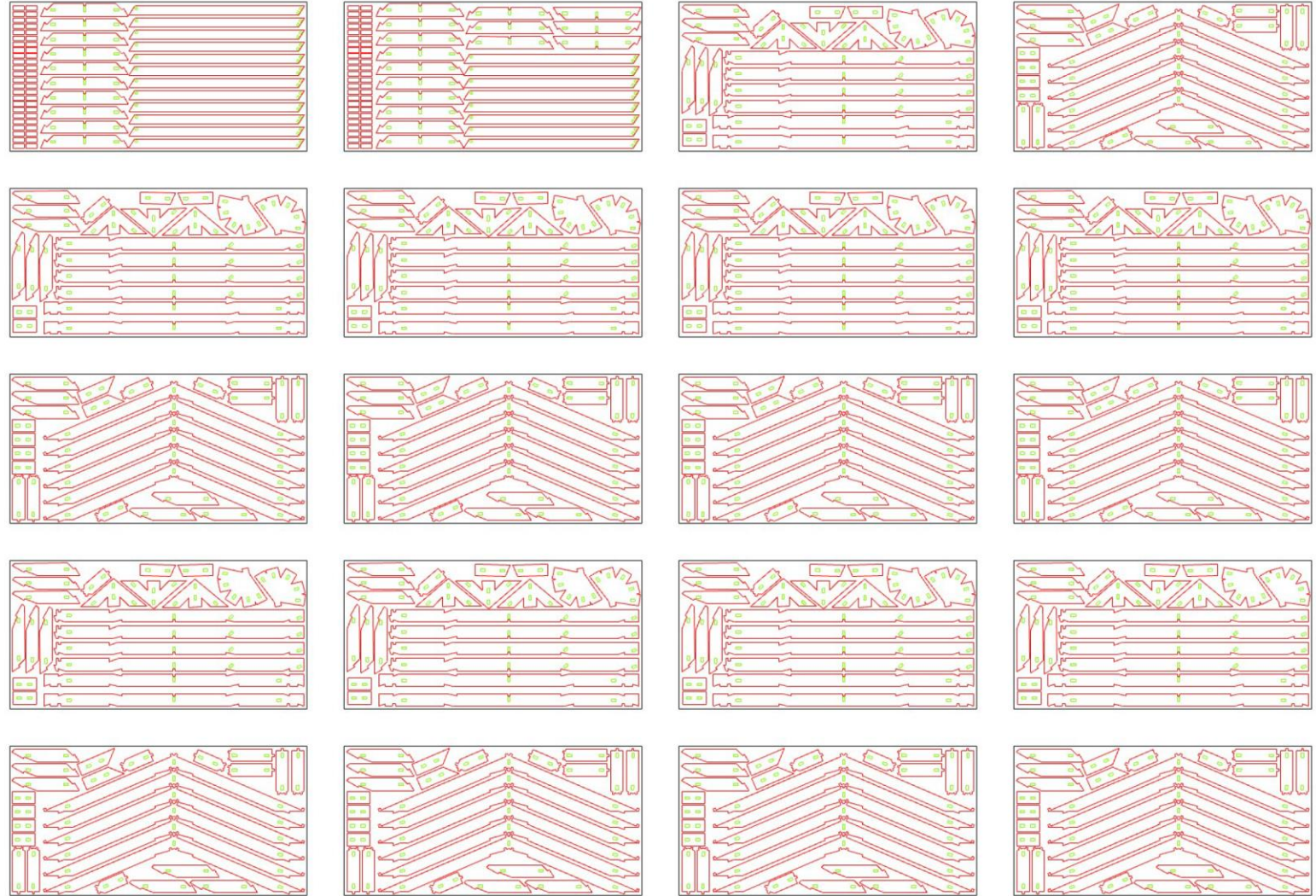


$$MOR = \frac{P_{max}}{bd^2 MOR}$$

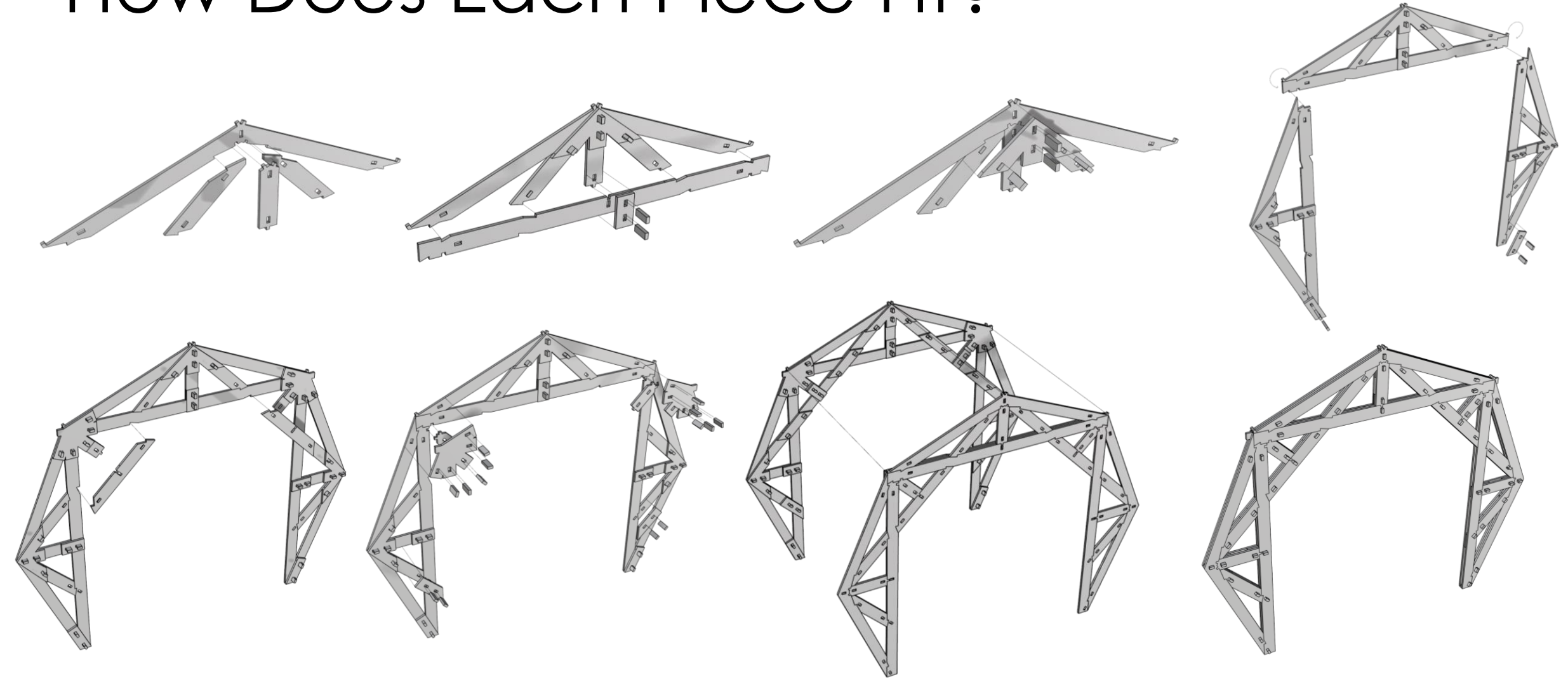
$$P_{max} = 147 \text{ lb} \checkmark$$

Nesting Plan

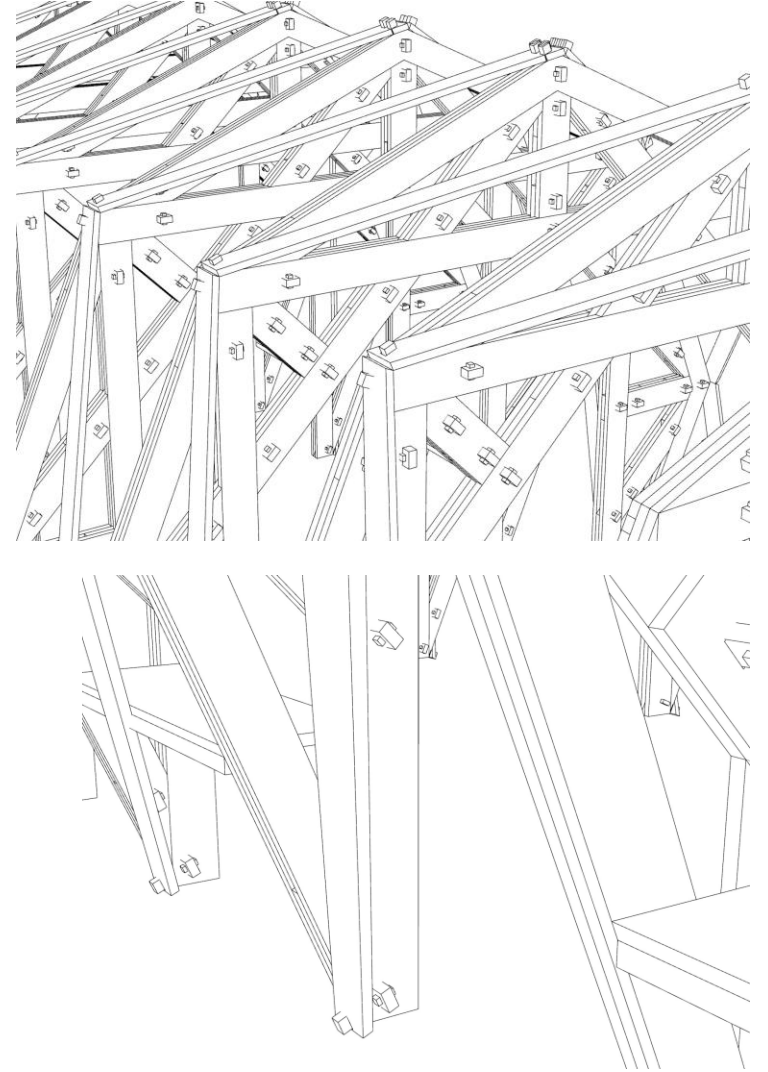
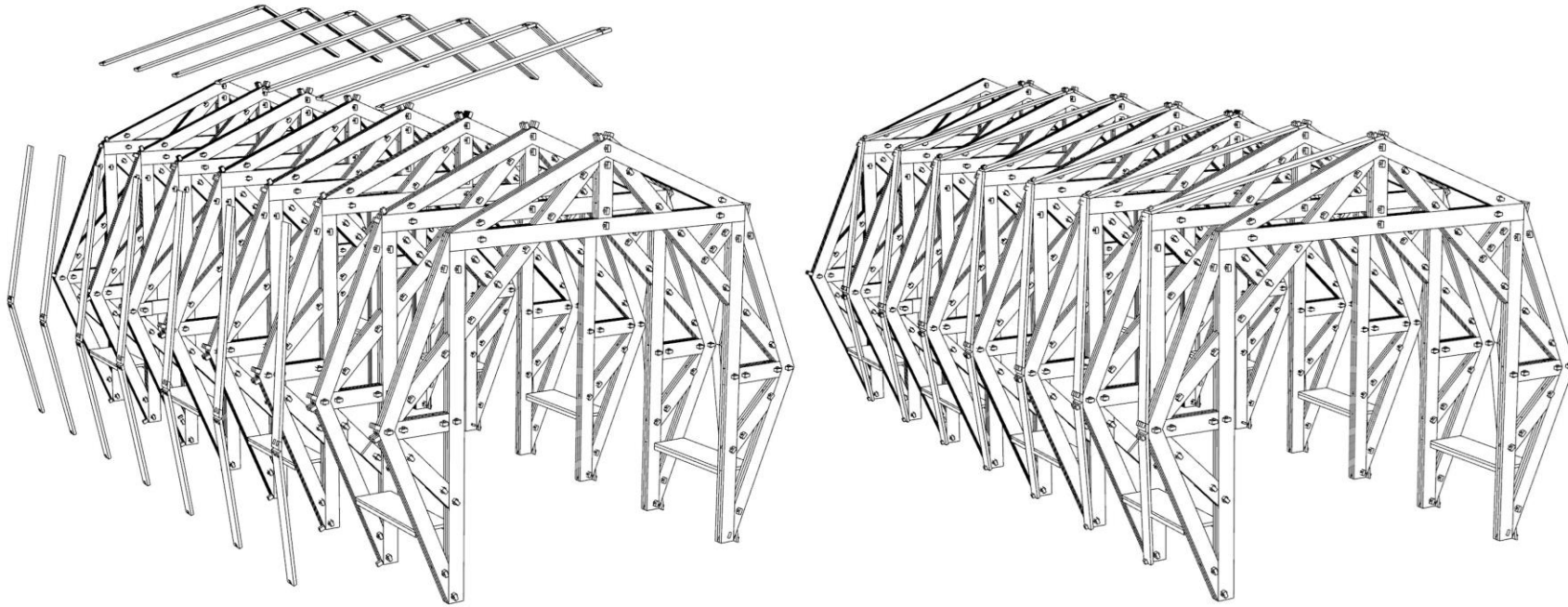
- Unfortunately, our pieces do not quite fit on the 20 sheets of plywood.
- Our initial iteration represented 2 sets of connections, paired with 1 set of members per system.
- Although doubling the members adds structural stability, it increases the weight of the structure and would require a 21st sheet of plywood.
- For a future iteration, we would consider our first idea to save material and reduce the overall weight of the overall structure.



How Does Each Piece Fit?



Side Panel Connections



Achievements So Far!



Weighed several design alternatives - and went from designing a diagrid to a truss - with an eye on aesthetics and client buy-in.



Designed strong connections that hold well by balancing our load both laterally and longitudinally.



Designed a solid, modular kit of parts; trusses can be added or taken away to fit the Philomath City Hall and walking path in Lima, Peru



Conducted a safety analysis via Karamba and hand calculation while evaluating shear, MOR, deformation, and compression strength.



We had fun!



What We've Learned

Structural Characteristics:

- Plywood is weakest to point loads in the middle of a long structural member. Making the structure double as a set of chairs creates vulnerability, but keeping chair connectors well below the beam's midpoint prevents excessive shear and bending moments.
- Plywood is a surprisingly light and strong material!

Construction Challenges:

- Considering a 2-point arch would have given us more stability, but we stuck with a 3-point arch for time constraint and interior height purposes
- Our system relies on certain pieces to be attached, otherwise it will fall. This could lead to difficulty assembling; we have many little dowels that could get lost, but are needed for construction

Further Developments:

- We really liked the idea of adding some more fluid elements, such as fabric to the structure to contrast the stiffness of the plywood. Ribbons?
- Additional diagonal elements could add robustness when dealing with live loads.
- An interactive, fluid element like mesh would move with the wind and with the movement of people and even help distribute loads across the structure.