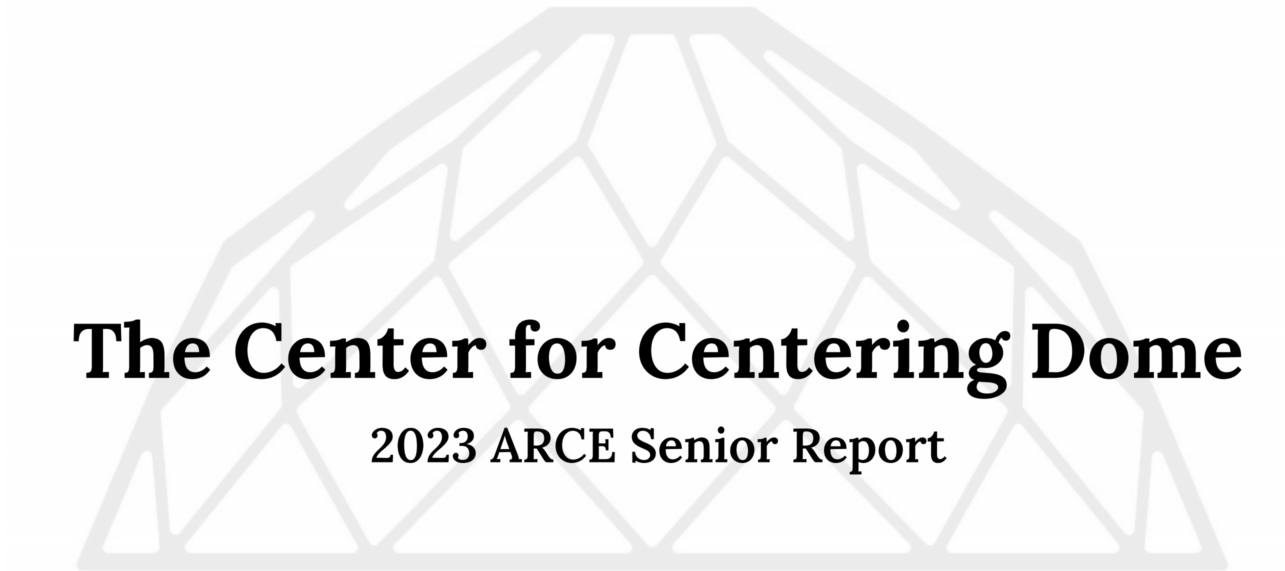

The Center for Centering Dome

2023 ARCE Senior Report

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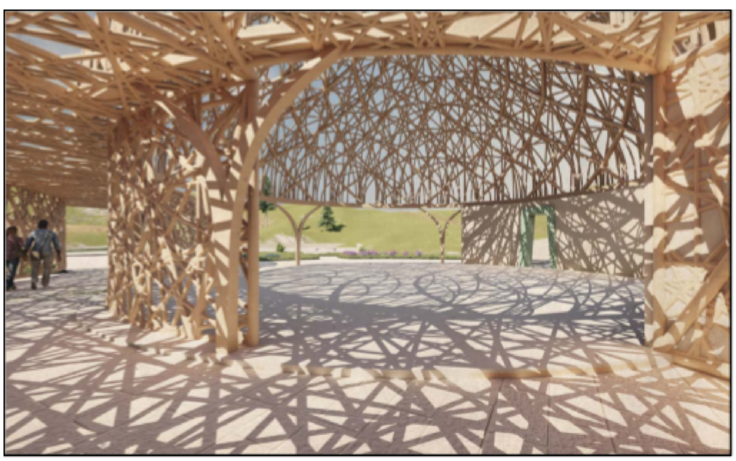
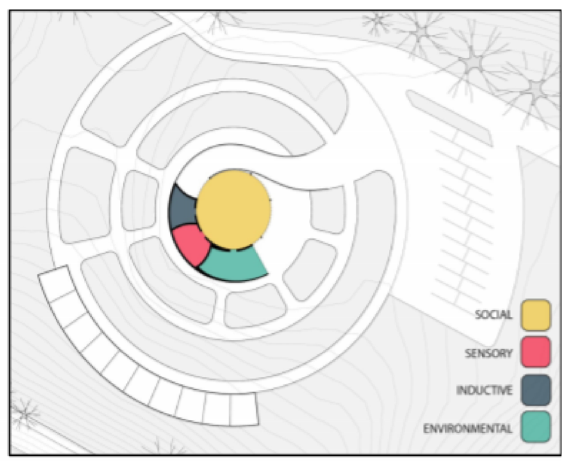
Introduction to the Project

"I'm not quite sure what this is supposed to be. It's a dome right?" It was what onlookers said as they saw a strange geometric *thing* come together. The smell of freshly cut wood, the brutal sun shining overhead, and the sound of hammers all painted an unfamiliar picture. This gazebo-like structure fascinated onlookers yet confused them about its purpose. The Center for Centering seeks to create a large-scale healing center, conducive to individual centering of the mind and body. This mobile installation provides a relaxing, enclosed space while still maintaining a connection to the outdoors. What started as the philanthropic vision from creatives Marcos Lutyens and Cynthia Campoy Brophy turned into a multidisciplinary student installation.

This collaboration began when the clients, Lutyens and Brophy, approached Cal Poly faculty, Thomas Fowler (ARCH) and Kevin Dong (ARCE). They hoped to utilize student creativity to produce their initial plans for a Center for Centering. During spring 2021, a team of ARCH and ARCE students distilled centering into four aspects: social, environmental, sensory, and meditative. To create a space intended for meditation, the students looked to nature for inspiration and settled on the Dudleya plant. Known for its resilience, the Dudleya is a California succulent which has a soothing appearance and concentric spiral leaf pattern, fitting with the idea of centering. A woven pattern was selected to enclose the structure for its symbolism of human interconnectedness and proximity. The resulting digital model showcased a spiraling path through four programs ending in the center with a cathedral-like space (Fig. 1). This central space (Fig. 2) relied upon the finely-woven pattern to cast organic shadows and evoke centering in the visitors.

While the clients loved this digital model, they wanted something portable which could start to promote their ideas of centering. A new team of students interested in construction and design were brought on to accomplish this high order. Between the faculty and clients, there was a consensus that the initial, theoretical design would need to be simplified. The three exterior spaces surrounding the spiral were removed to focus on the visually-striking central area. The clients liked the idea of having a pop-up installation that could be easily set up as a touring display. With a deadline for installation looming in June 2022, the students had five months to design and manufacture the structure. The faculty advisors and the students met regularly with the clients to facilitate a collaborative design process. These weekly meetings provided fruitful discussion between the students and clients, allowing the ideas to blossom into more satisfying designs. In winter 2022, the students developed custom geometry to minimize the number of individual parts and built a ¼ scale model of the design. In spring 2022, the students digitally modeled each part and manufactured the designs in the woodshop, culminating in the construction of the pavilion. What made this project remarkable was the students' opportunity to work with real clients, meet real deadlines, and learn how their design impacted construction while manufacturing the structure all by themselves. From creating countless digital models to troubleshooting tolerances and manufacturing mishaps, this project was the epitome of Cal Poly's "Learn by Doing" motto.

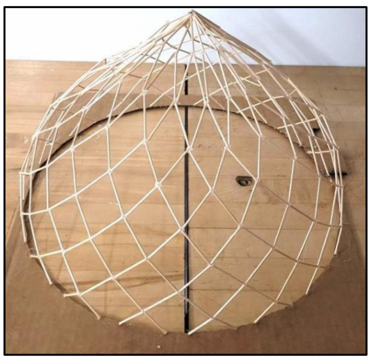




(1) Top: Overview of original graduate concept with dome and adjacent rooms
(2) Bottom Left: Close-up of dome's woven pattern
(3) Bottom Right: Plan of spiral layout and program

Winter 2022: The Simplicity is in the Details

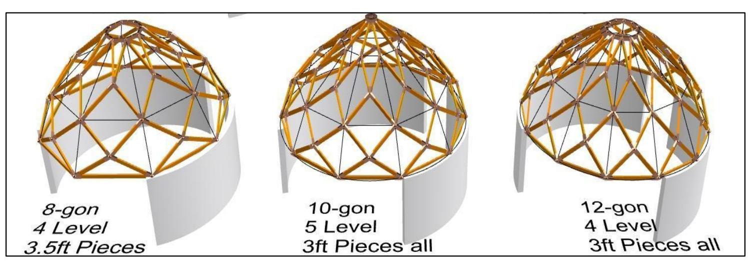
The beginning of this new chapter for the Center for Centering sprang from three developments: grant funding, new client deliverables, and an exuberance of new student minds. The recently-approved grant allowed these deliverables to become a physical reality instead of another digital model. The clients were interested in having some form of the dome that would allow visitors to experience their version of centering. This form would need to be transportable by trailer, so the original graduate concept would need to be scaled down, yet still large enough to promote centering. The original concept was a dome, 50-feet in diameter, with limited considerations for construction or structural integrity. While the dome looked to be aesthetically pleasing it was unfeasible to be constructed on a small scale by inexperienced students. There was a crucial balancing act between simplifying the geometry and maintaining the initial concept of that graduate dome.



(4) Scale model of graduate dome

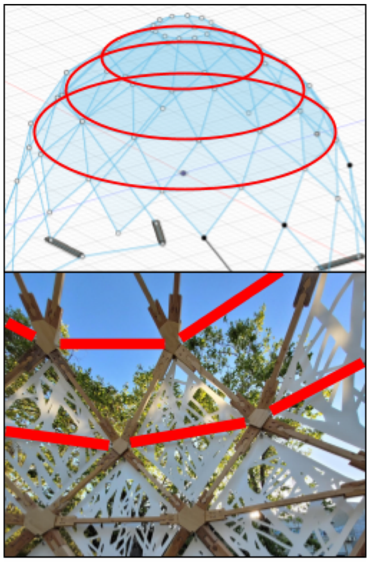
To begin these updates, a scale model of the graduate design was made out of hot glue and sticks (Fig. 4). Despite its small scale, this model acutely demonstrated the limitations of the prior, fantastical design: over 300 short-span pieces solely for the dome's construction and an overly-flexible dome with inadequate structural supports. These became chief concerns for the redesign. How do you simultaneously simplify, strengthen, and continue developing a design while still preserving what the clients liked originally? The answer came from examining the overall size and purpose of the Center for Centering. Providing guests the full experience of centering could only happen with a complete, enclosed pavilion. This would also provide guests insight of the potential for a 50-foot dome. The 50-foot diameter was reduced to a more feasible 16-foot dome. This dome would still need to be easily transportable, which also meant it needed to be easily deconstructed. Given its semi-permanent nature, this structure would also benefit from a simple assembly process. While reducing the overall size of the dome somewhat limited the complexity of the structure, the dome still consisted of over 300 pieces with a variety of lengths.

The first attempt to lower the piece count was to make all the members the same length. The pieces were stretched from 2 feet to 3, 3.5, and 5 foot lengths to determine their effects on the look of the dome. As the pieces were made longer, the dome would become more geometric and would start to lose its naturalistic qualities. However, even slightly increasing the length from 2 to 3 feet lowered the total number of pieces to around 200. Despite a reduction in 100 pieces, the design could further be refined by looking to the base of the dome.



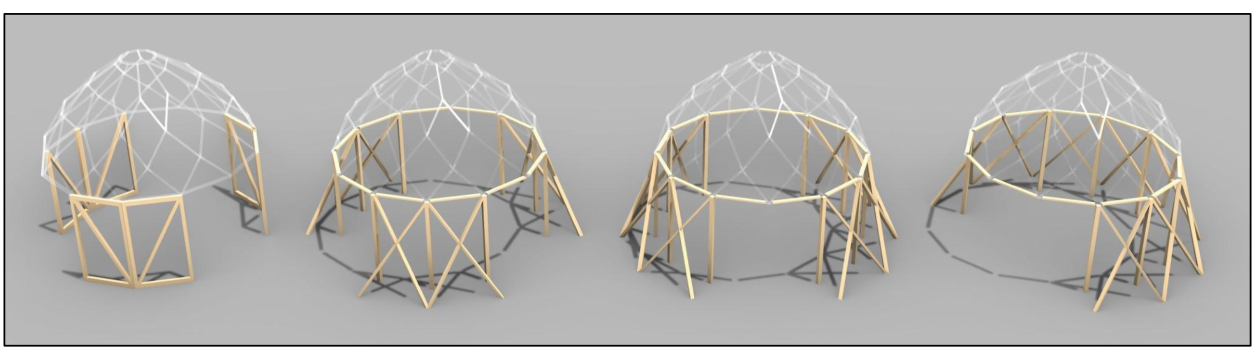
(5) Left to Right: Effects of changing base polygon and member length

The original dome concept had a base of an octadecagon, an 18-sided polygon, which helped approximate a circular, flowery shape. The number of sides of the base polygon dictated how many facets the dome would have. By adjusting the number of sides, the piece count could also be reduced. A range of 8 to 12-sided shapes were tested, demonstrating where the effects were slight or pushed too far into angular geometry (Fig. 5). Anything less than 10 sides began to exhibit a very crystalline structure which the clients did not want. To reach a happy medium, the dome would be derived from a dodecagon, a 12-sided polygon, featuring 4 levels of identical, 3-foot-long members. This meant the dome would be less than 100 total pieces and the variety of pieces would also be minimized.



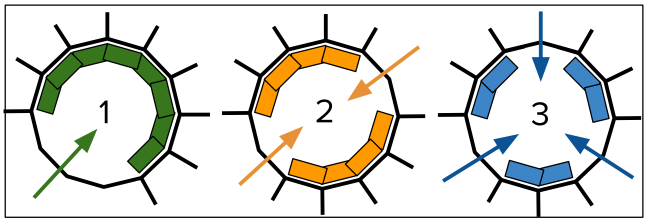
(6) Tension Rings (in red)

There were concerns if the dome could bear its own weight and how to support that weight off the ground. The idea was to use wood construction to preserve the dome's natural relationship with the environment, promote sustainability, and utilize a relatively light building material. To reduce weight further, 2x2 dimensional lumber was chosen for the dome's construction. These light members, though, were so small that they could easily start to bend just under the total weight of the dome. Therefore, rings were added at every elevation level to restrain the member nodes from moving towards or away from the center (Fig. 6). The rings minimized any outward bow which could negatively impact the member's strength. With the dome's stability partially solved, the team began considering how best to support the dome eight (8) feet from the ground. Columns were the obvious choice to evenly distribute the weight of the dome. These columns would extend from each of the 12 nodes at the base of the dome. However, columns by themselves can be unstable against lateral forces; another element was necessary to brace the pavilion against these forces. The solution was to place a diagonal brace between the columns. Borrowing from ordinary timber construction, the braces guaranteed the dome had no chance of twisting. The combination of columns and braces could act as walls around the dome's base. Although the engineering was solved, it was at the cost of aesthetics.



(7) Left to Right: initial wall concept with one brace, dual brace variations

At the same time the stability concerns were being addressed, ideas for the dome's program began to spring up. With the dome now at least 8 feet off the ground, what would go inside this dome? How best can the dome live up to its name and cater to centering? Formerly, the pavilion featured four separate spaces all connected by the dome. Now, aspects of these spaces had to be merged into this compact dome. The clients wanted seating inside the pavilion and expressed the importance of relaxation in the world of centering. As the lateral supports were being developed, the columns still had no additional support. They sat directly on the ground without a base. The dome needed seating and the columns needed a base. Eureka! Why not design the seating so that it partly acts as a base to all the columns and anchor the bracing? Obviously, there could not be continuous seating around the dome otherwise there would be no entrance or exit. The placement of the columns and braces also depended upon the number of openings. Three seating iterations were made, each focusing on a different number of openings: 1, 2, or 3 (Fig. 8). The team decided one large opening would be difficult to construct because much of the dome would be unsupported; the 3-opening option, on the other hand, created a hectic program where pedestrians could not easily exit the space. The 2-opening option was chosen as it best emphasized centering, allowing guests to enter and exit on opposite sides. Seating could now be placed between these openings, along the two "C" shaped arcs.

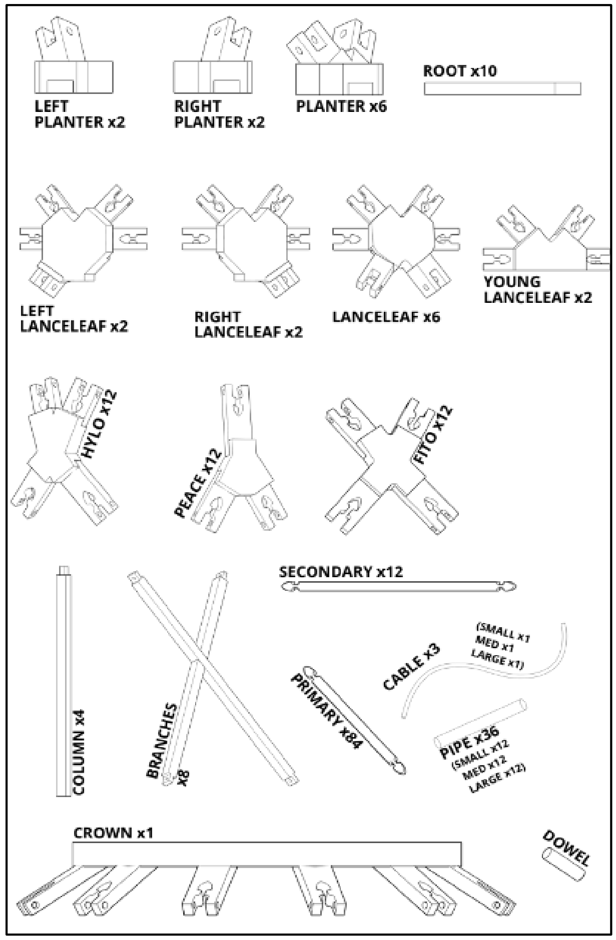


(8) Number of Entrances with Seating Block Arrangement

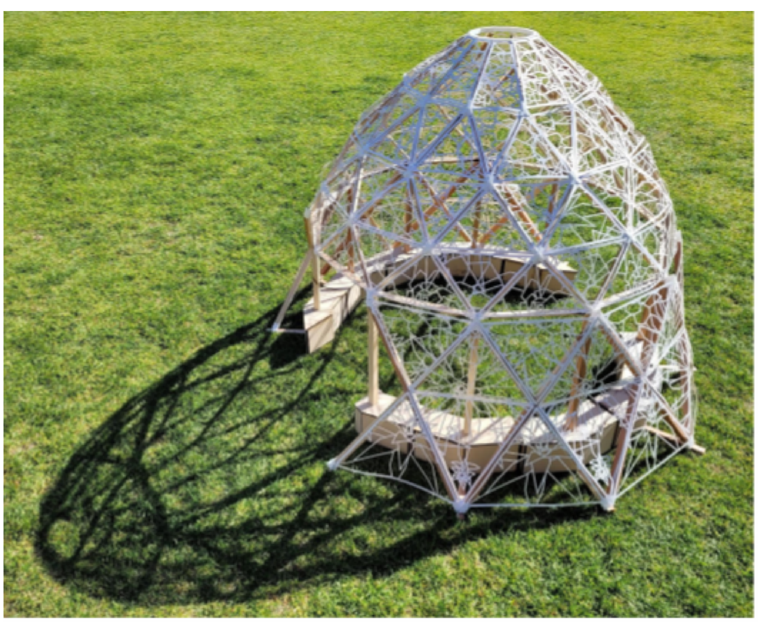
The pavilion looked like a cylinder with an ornate dome on top. The flat walls clashed with the naturalism of the initial concept. To preserve the flowery appearance of the dome, the braces were brought outside the columns. Referring back to the Dudleya for inspiration, the braces could be used to emulate flower petals. The braces still connected to the top of columns but were now able to extend out from all sides of the dome like buttresses (Fig. 7). Along with fanning out the bracing, all of the bracing was doubled to allow for a more redundant, structural system. Additionally, the petal-like braces were able to support a majority of the total weight of the structure, allowing all but four (4) columns to be removed. These remaining columns framed around the two openings. The dome now had fewer pieces, a column and bracing layout, and even seating to act as a foundation.

There was still one element left to address about the original dome: the woven pattern. Without a pattern, the dome would lose those organic shadows that catered to a centering space. The original woven pattern appeared natural yet was uninspired, tacked on to look nice but lacking in its purpose. The clients and students agreed that the pattern should imitate the feeling of sitting under a dense forest canopy. This natural inspiration would help to ground the outlandish dome geometry and provide the necessary shadows inside the pavilion. The initial concepts for the panels seemed to be too open, but further development would take place in spring. While the dome's geometry had been greatly simplified, the intersection nodes of the dome's members repeatedly proved to be a challenge just to conceptualize. With a variety of angles and different placements, these connection nodes would require their own specialized design framework. The team was well aware this issue would have to be addressed, but that would be a future effort.

With all of these updates to the dome's design, it was decided to merge them together into a new physical model. It would be a culmination of all the alterations made to the graduate concept over winter quarter. This model demonstrated how the Center for Centering would be constructed as a temporary installation (Fig. 10). Elements that had only been visualized digitally were now physical models. The model was constructed at a 1:4 scale to be large enough to show a concept of these connective nodes and identify fabrication issues (Fig. 11). It was 4 feet in diameter with wooden members and 3D printed nodes made to scale. These nodes also had a hole through the center to allow a tension ring, made of fishing line, to pull the nodes together. The remaining parts, the panels and blocks, were laser cut from cardstock and medium density fiberboard (MDF). As construction ensued, it became apparent that the dome needed a naming convention for every component part.

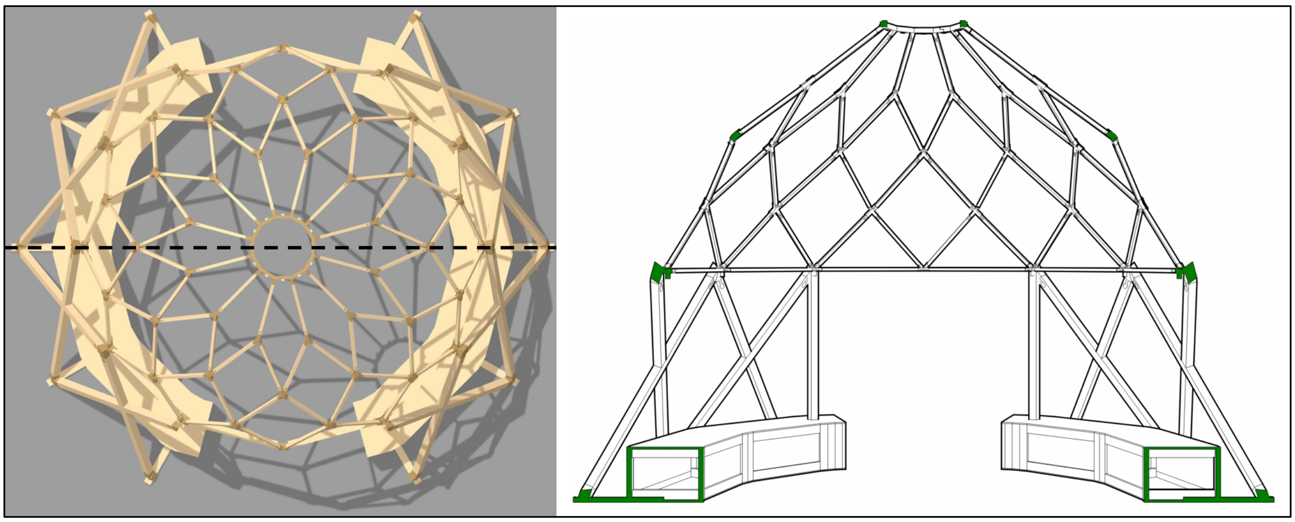


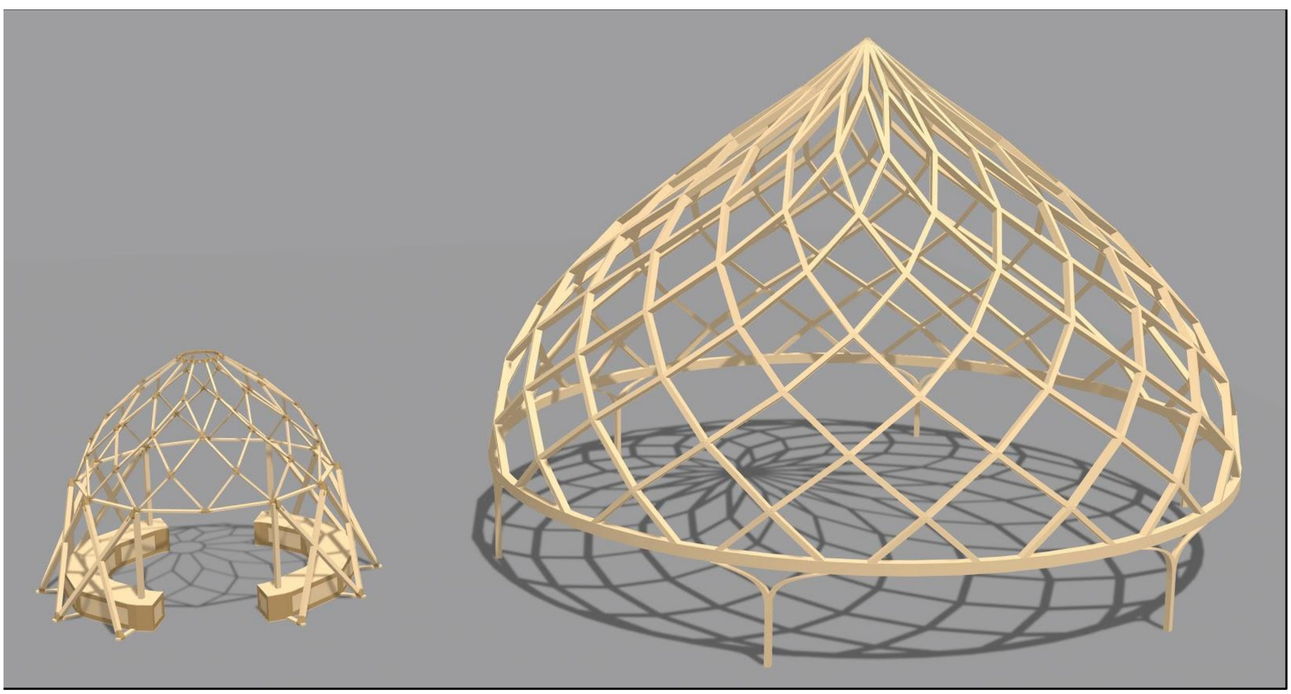
(9) Connector Naming Convention



(10) Left to Right: ¼" scale model, close-up of early dome connections

The names were derived from aspects of centering, succulent anatomy, and nature (Fig. 9). Two of the names, “Hylo” and “Fito”, were directly inspired by the Greek words for forest and flower respectively. With the model complete, there was general excitement from the students, faculty, and clients. This dome both evoked the original and showcased everything novel about this design. The team had simplified the geometry and added structural stability, while maintaining the intrinsic feeling of centering. All the work up to this point was only half of the battle. Next came manufacturing a *full scale* dome.

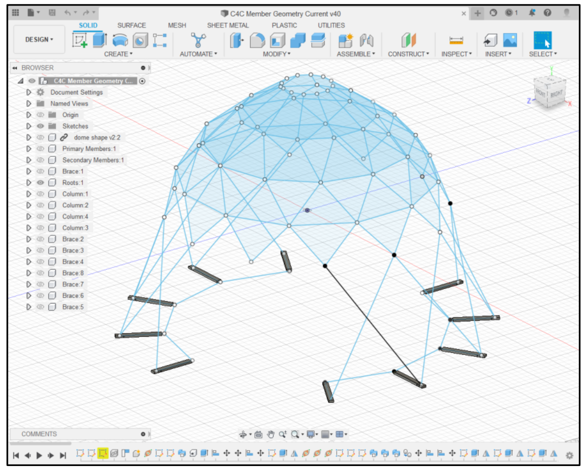


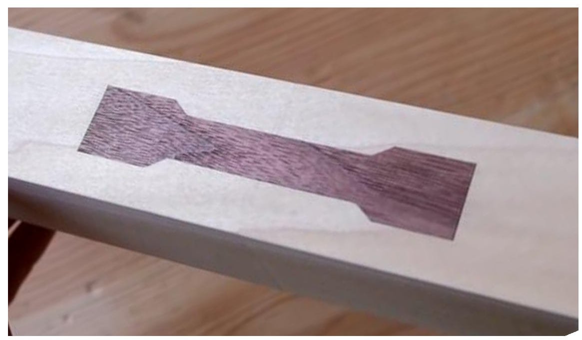


(11) Top (Left to Right): Plan view, Section elevation
(12) Bottom (Left to Right): Simplified 16-foot dome, Original 50-foot dome

Spring 2022: Manufacturing Challenges

Before any manufacturing could take place, a new Computer Aided Design (CAD) modeling software was needed. The team needed this new software to import the previous digital work, ensure precise dimensioning, and be able to export Computer Aided Manufacturing (CAM) files. CAM files would be used along with Computerized Numerical Control (CNC) manufacturing to make this project feasible for student construction. All the prior digital work was made in Rhinoceros, a program suited for generating designs quickly and allowing for basic schematic design. However, it lacked the precision and reliability of a dedicated manufacturing software. One program with both the precision and CAM compatibility was Fusion 360, an Autodesk product with cloud computing for virtual team sharing capabilities. Using Fusion 360, the team could create individual models of each part and compile them into one model displaying the entire structure. These features were perfect for a team of students to collaborate and create precise, individual components. The basic dome geometry from Rhino was recreated in Fusion 360, now with total dimensional accuracy and precision.





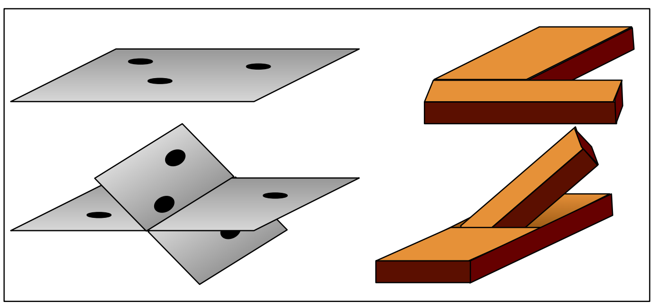
(13) Top: Node Geometry from Fusion 360
(14) Bottom: Example of Japanese Wood Joinery
[Source: "The Art of Traditional Japanese Wood Joinery". https://www.youtube.com/watch?v=3KqIIOyuo1Q]

The next big challenge came after the modeling issues were solved: how will the members fit together? The goal of a mobile and rebuildable design had been accounted for with disconnecting joints, but what the joints looked like was still unclear. Thus far, there was only agreement that the structure should be held together by wood, not metal. Since the structure was to be exposed, the clients and students also agreed having an aesthetically pleasing connection would emphasize the centering effect of the space. The initial inspiration came from

(15) Dowel Through Slot and Peg

Japanese wood joinery for its simple shapes and strong connections (Fig. 15). While most wood joinery is permanent, there is a sliding joint that can be locked together with a pin. This joint between a peg and slot was chosen for the dome's connections. These joints needed to be manufactured hundreds of times, strong enough to support the structure, and easily disassembled.

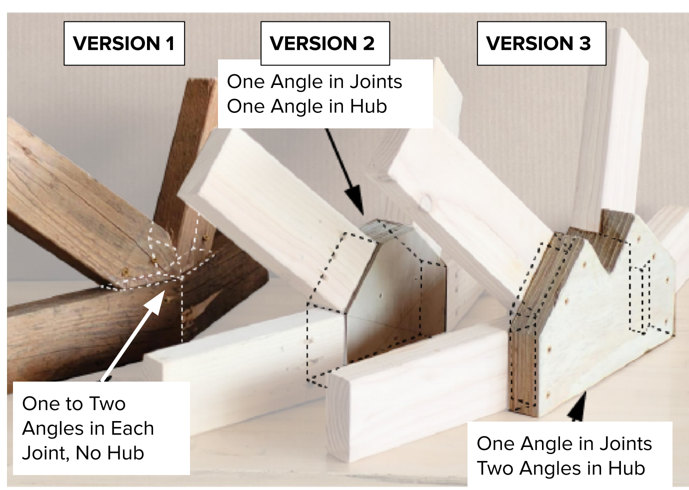
The slots and pegs were cut using the CNC mill to allow for repeatability and to save on manual student woodwork. Machining tests revealed that the joint design could not have 90 degree corners since the milling bit left a ¼" radius. Additionally, the peg was not allowed to be thinner than ½". If it was thinner, the peg could be broken by light handling. The resulting geometry consisted of a double sided shoulder in the shape of an arrowhead. In order to manufacture this joint, there needed to be some tolerance between the peg and slot. Otherwise, it would be impossible to fit both pieces together. The team applied an offset to the peg's edge to create the necessary tolerance. The tolerances applied were 0.001", 0.01", and 0.1" offsets. Through prototyping, an offset of 0.014" resulted in the desired fit; however, the joint naturally wanted to slide apart. To fix this, a dowel was used through the side of the sliding joint, locking the peg and slot together (Fig. 15).



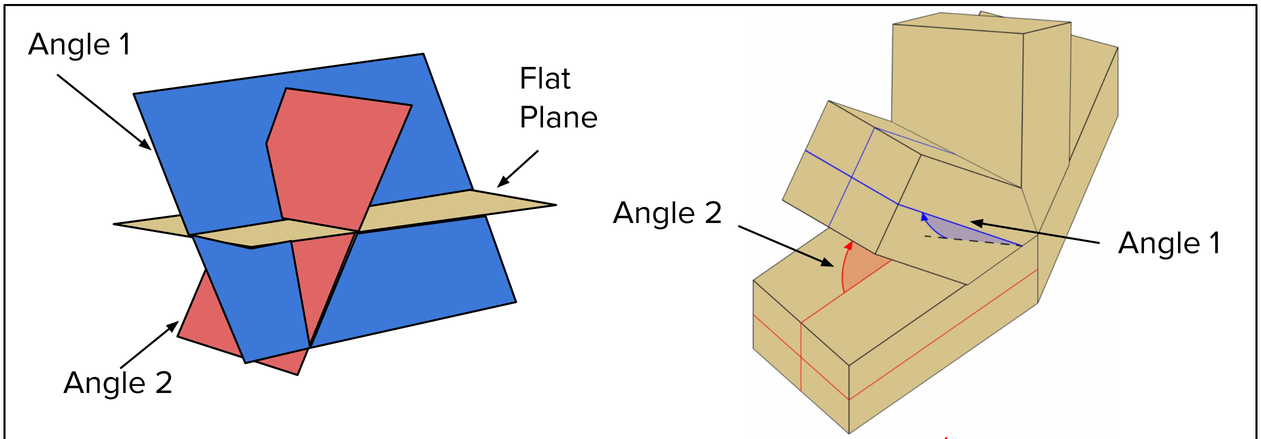
(16) Coplanar versus Out of Plane

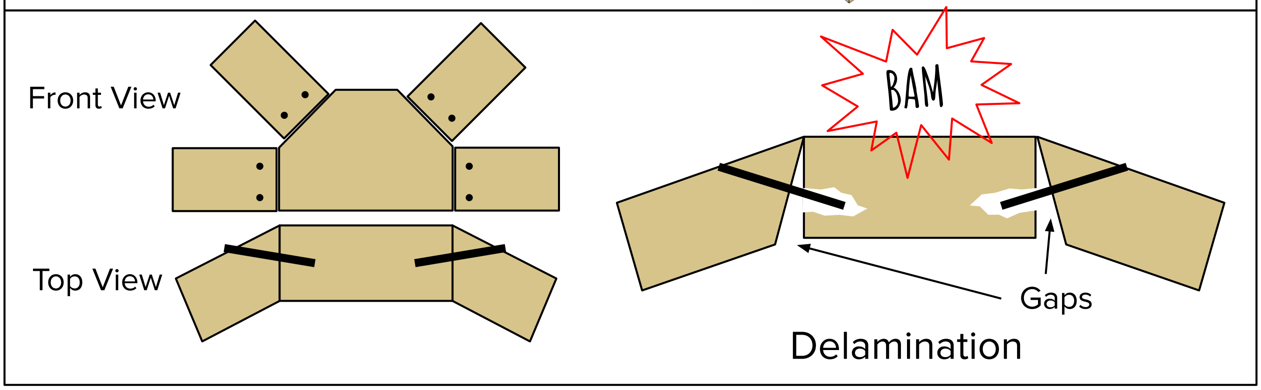
The sliding joints comprised just one part of the dome's connections. At each node, connectors had to be designed for all the pegs of the intersecting members. These connectors bridged the different angles at which the members intersected a single node. In total, there were 11 different types of nodes. Even though the dome could be taken apart, the nodes as an element needed to be permanently attached. So while the joints still relied on wooden joinery, the nodes were made of multiple elements attached together with wood glue and screws.

The first hurdle to overcome was the geometry at the node intersections. The dome shape created nodes with elements intersecting at different planes, none of which were coplanar (Fig. 16). The first test piece chosen was a node at the base level of the dome, called Little Lanceleaf. The connector joined two members out of plane in two axes, requiring four total angles. The angles were extracted from Fusion 360 using the relative geometry of each of the intersecting joints.

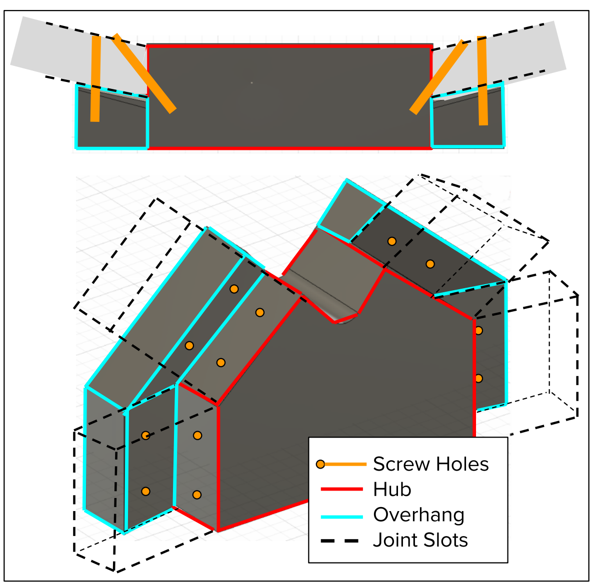


(17) Evolution of "Little Lanceleaf" Connector





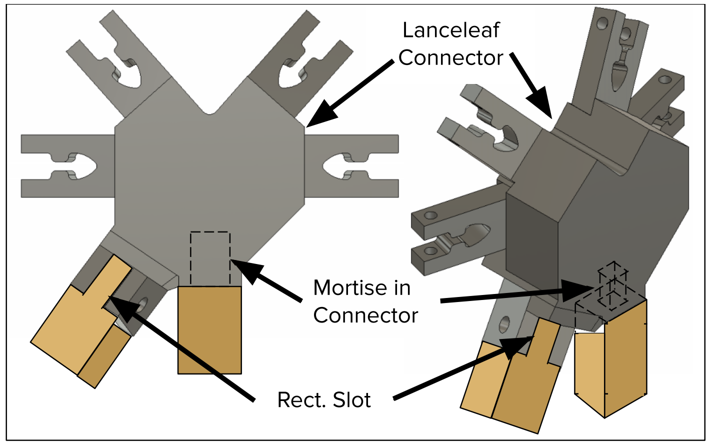
(18) Top: Version 1 of Little Lanceleaf Connector - Compound Angle Issue
(19) Bottom: Version 2 Little Lanceleaf Connector - Delamination Issue



(20) Connector Hub Anatomy for "Little Lanceleaf"

The first version of the connector had four pieces meeting together at a point, each with an arrowhead slot to carry the peg members (Fig. 17). The compound angles on these pieces were difficult to cut accurately with the available tools. Furthermore, there was no easy way to hold all four pieces as the parts were screwed together (Fig. 18). The second version utilized a central hub for all the joint pieces to mount to, allowing one angle to be cut into the hub and the other angle cut into the joint piece. The hub was made from multiple layers of plywood glued together. This second method was effective because it allowed the two angles to be cut separately which simplified the alignment between intersecting pieces. However, there was no secure way to screw the joint pieces into the hub, resulting in a weak joint that delaminated the glue between the plywood layers (Fig. 19). To eliminate the delamination failure, the third version implemented an overhang which extended from the hub to the joint pieces. This overhang permitted the screws to be driven into the hub in two directions so that rotation and translation were resisted (Fig. 20). Testing this final node design resulted in a 500 pound bending rupture limit, which meant the node was strong enough for the dome's construction.

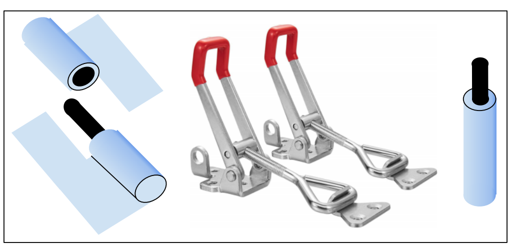
This third version became difficult to cut out of plywood using just a skill saw. The new method would need to be milled using the CNC. Multiple ¾" thick sheets of plywood were laminated in order to make the raw material for the connectors. Each connector was designed in CAD, run through Fusion 360 CAM, and then cut out of the laminated plywood block using the CNC wood mill. Then each connector was assembled with their respective joints using glue and screws. In total, 59 connectors were successfully made this way.

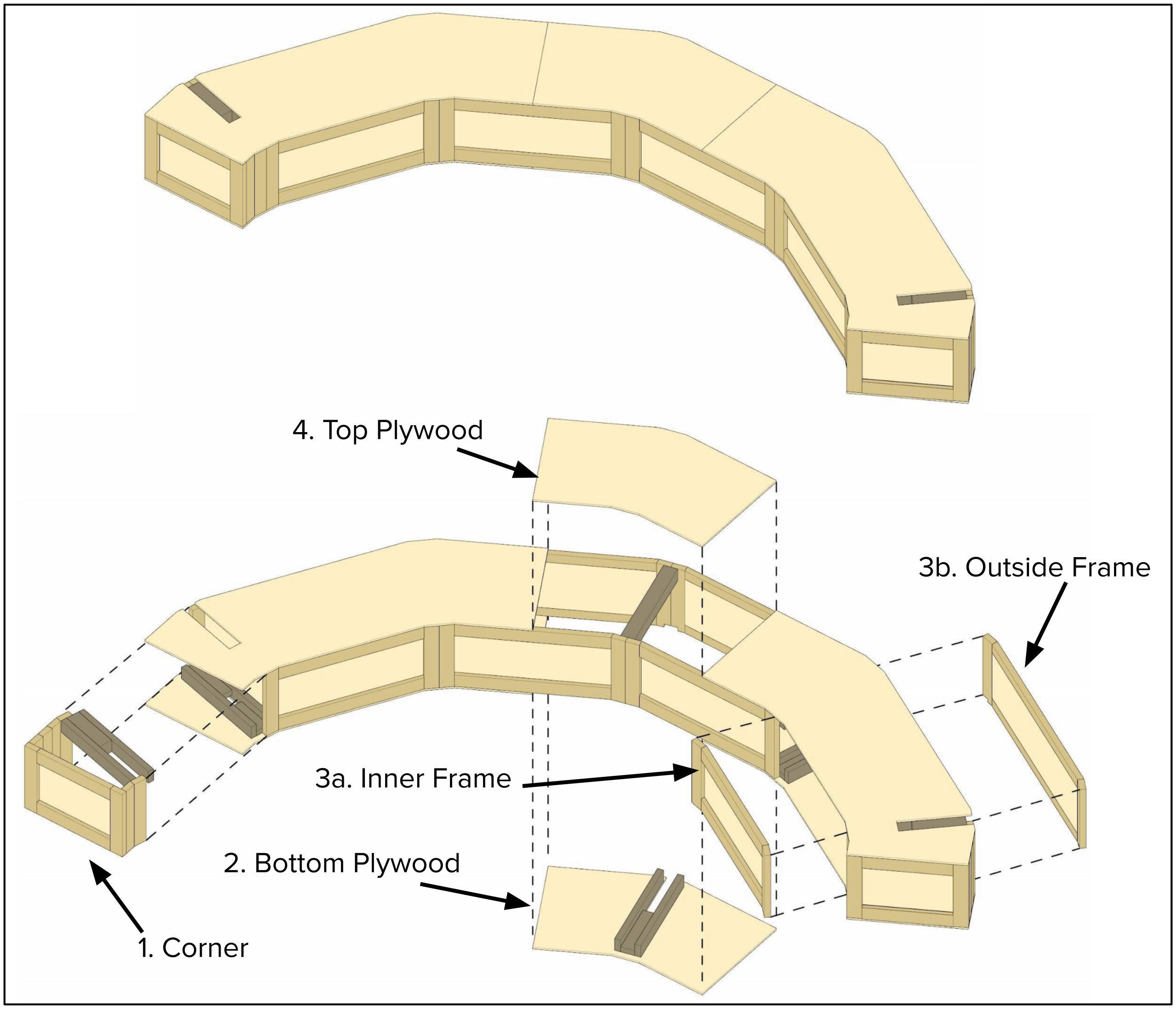


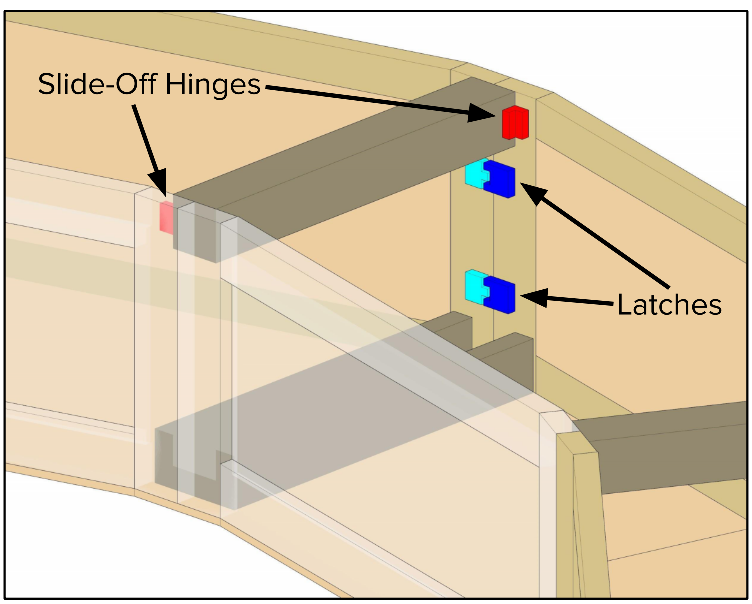
(21) Mortise/Tenon Connection, Rectangular Slot for Brace

At the same time the connectors were being designed, the team was designing the joinery of the lateral system. The columns would fit into the dome via a mortise and tenon joint. This joint would only occur at both openings, on the bottoms of four connectors (Fig. 21). Similarly, the braces used a square slot and peg instead of the arrowhead design as this would be easier to assemble on site. Large dowels were added to the brace joints to lock them together like the dome joints.

In addition to the lateral system, the block seating faced its own challenges: it had to feel strong enough as a bench while still able to come apart. To onlookers, there could be no doubts that the seating could come apart, even though it was designed to do just that. Clearly, a compromise needed to be made over which pieces were temporary. If every piece could come apart, it would be impossible to hold together under a person's weight. So how could the seating achieve this balance between permanent and temporary? The blocks were split into subassemblies, which were made to be permanent and light enough to be carried by hand. There were four types of permanently-attached pieces: the frames created the exterior walls of the seating, the corners held the columns, the bottom plywood helped align the braces, and the top plywood helped to anchor the frames (Fig. 23). These subassemblies would then come together with temporary connections through the use of pre-manufactured slide-off hinges, latches, and registrator pins (Fig. 22). Utilizing this hardware allowed for a consistent and reliable construction of the blocks (Fig. 24). This clever design, balancing permanent and temporary connections, now meant the seating could have the desired rigidity of a park bench and still be able to come apart.


(22) Slide-Off Hinges, Latches, Registrator Pins

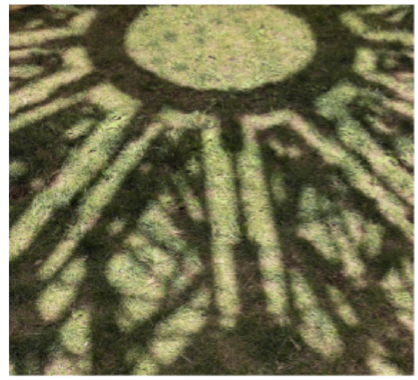




(23) Above complete block, exploded view with subassemblies

(24) Left: detail of temporary connections with latches (blue) and slide-off hinges (red)

Another challenge was finalizing the panel design. On top of reaching a satisfying look to the panels, there also needed to be a simple way to attach them to the dome. Some major concerns were identified; What material would it be made out of? How would the panels cover the structure? Would the connection to the dome structure be rigid or flexible? Would perforated panels make the structure an enclosed, partially enclosed, or open envelope for wind analysis?



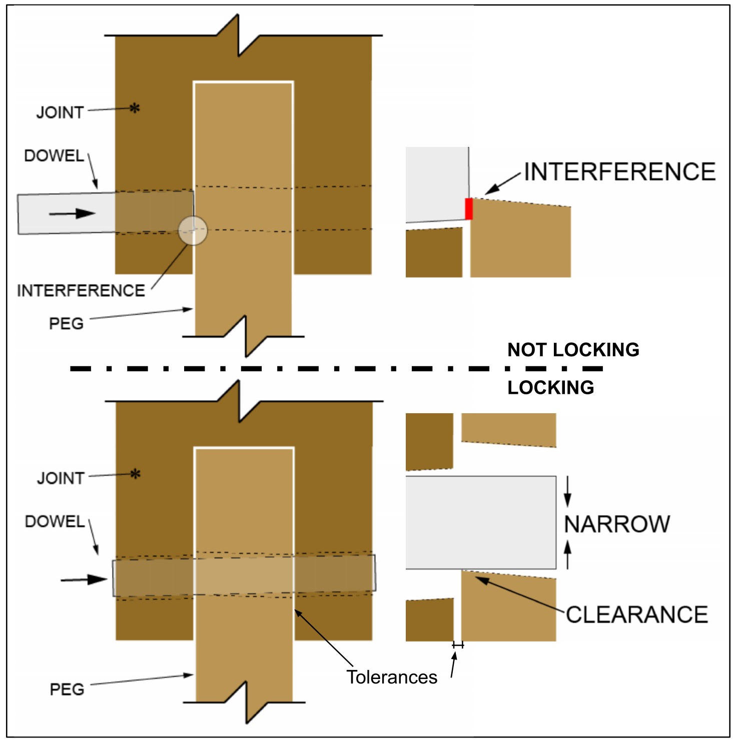
(25) Above: Panels Attached With Bungee Cords To Eye Hook In Braces
(26) Below: Panel Branching Shadow Pattern

To keep the panels easy to transport and to highlight the structural form, the pattern would only cover the spaces between the structural members. Choosing the panel material required considerations for three issues. First, the material needed to be light enough that the panels could be carried by hand. Second, these panels had to resist potentially windy and rainy outdoor environments. And third, the placement of the panels required the material to be strong enough for stretching tightly around the structure. After some debate, the team decided any type of wood or solid, acrylic panel would greatly increase the structure's weight. Even with perforations, the extra weight of the panels would negatively impact the lateral design as it would result in greater deflection of the dome, which opened the possibility for structural failure.

The team looked to possible fabric solutions that could easily accept perforations. Fabric was a great choice because it could be stretched to fit within the openings between the structural members. However, the team realized that the fabric would need stitching around the perforations to keep them from fraying. The experts at a local fabric company led us to a sail material. This vinyl was durable in exterior applications and would not require sewing around the openings given its woven plastic construction. The fabric company cut the team's design in the vinyl, saving valuable time for other manufacturing.

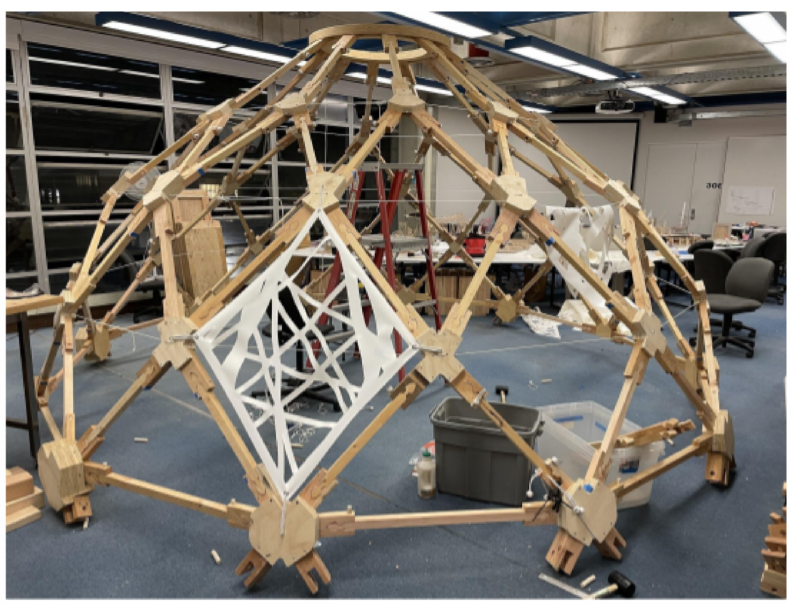
(27) Render Of Vinyl Panels With Thin vs. Thick Branching Pattern

However, the drawings initially sent to the fabric company could not be cut on their machine. The design had large openings and small branches which resulted in the fabric stretching on the cutting bed and making incomplete cuts at the corners. The extra labor to fix what the cutter did not complete would outweigh the benefits of using the machine to begin with. The team redesigned the cuts so there were less openings and the spacing between openings was increased. This made the branches thicker and easier to cut. Trying to find a balance between the number of openings, a design that could be cut easily, and maintaining client satisfaction proved to be immensely challenging. The white vinyl panels became a defining feature of the structure and were a successful method of creating unique shadow patterns inside the pavilion. These vinyl panels would be connected with flexible bungee cords, tied around anchor points on the structure.



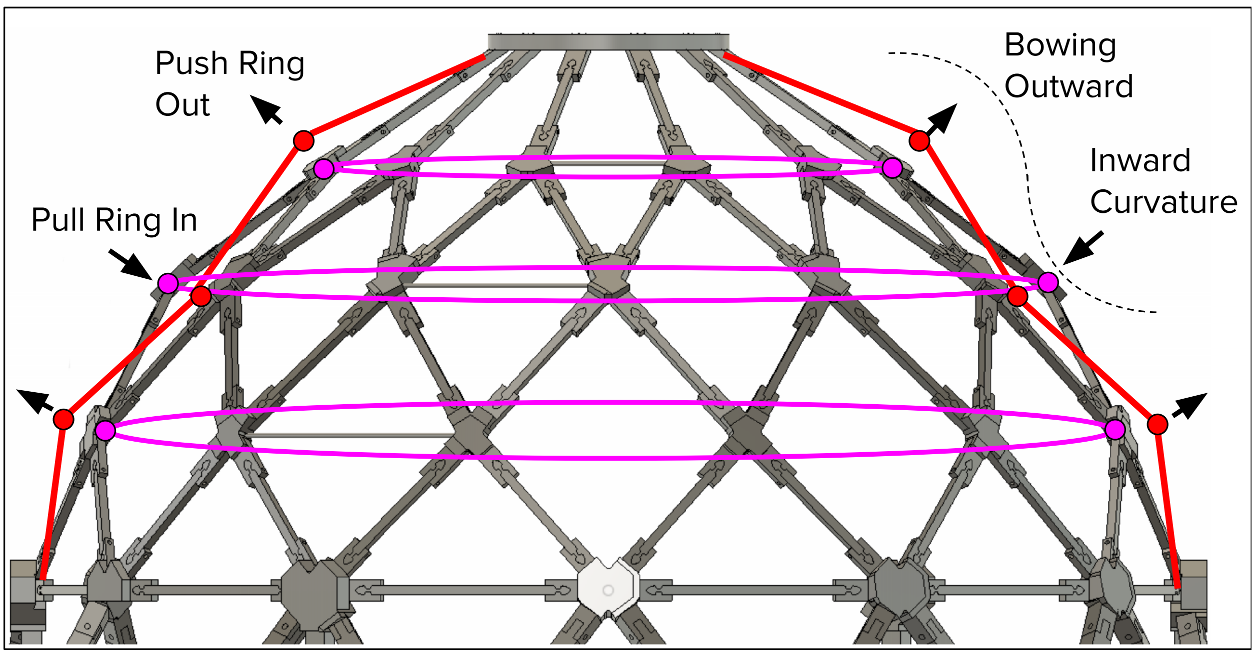
(28) Dowel Misalignment Issue and Solution

With the completion of the panels, the structure was ready to be assembled. However, given all of these components were designed separately, it was unknown how well all the parts would work cohesively. The team decided to build the whole base structure first, where many of these separately-designed components had to fit together to form a sturdy foundation (Fig. 29). The blocks went together with surprising speed and despite using latches and hinges, the seating felt robust. However, if the block frames were crooked, the latches came loose or were squeezed too



(29) Left: First Assembly of Blocks, Braces, Columns, and Connectors
(30) Right: First Assembly of just the Dome

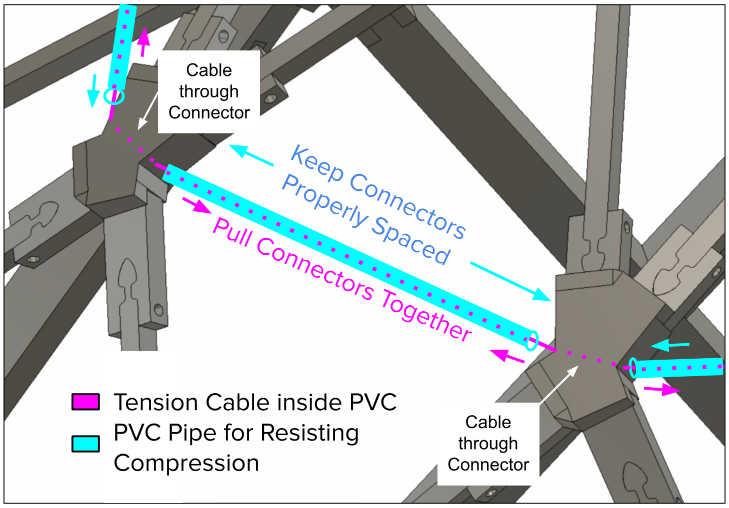
tight to be opened by hand. As soon as one latch became loose, an entire frame lost its structural integrity and the seating felt unsafe. The latches would work, they just required careful attachment and coordination between the entire team. The braces were trickier to align with the blocks given their large size. A few of the braces had misaligned dowel holes which meant the dowels would have to be sanded to fit properly (Fig. 28). Even with the smallest misalignment, the dowel was getting stuck where the brace peg met the square slot. Despite these assembly issues, the base structure worked as intended. Once all the pieces were carefully brought together, the seating and bracing felt secure.

Confident with the base's assembly, the upper dome structure could now be assembled (Fig. 30). While many of the parts fit together easily, again many of the dowels were not able to slide through the joint. The dowels were meant to all be the same diameter but some were larger and some were smaller. If the dowel was too large, it could not be hammered through the hole. If the dowel was too small, it would fall through the hole and then the joint might slide apart. Given some of the dowel holes were skewed, it was useful to have smaller diameter dowels. As the assembly continued, three dowel sizes were used to best fit the varying conditions: one smaller, one larger, and one that matched the hole exactly.



(31) Tendency Towards Deformed Geometry (red) vs Corrected Geometry by Tension Cables/Compression Rings (pink)

Although the team faced difficulties with the pins, another element of the dome worked as intended. The tension and compression rings effectively kept the levels of the dome from curving inward and bowing outward (Fig. 31). The assemblies were designed with a tension cable threaded through PVC pipes and through each of the nodes on that level (Fig. 32). The tension rings were easy to thread through each node and kept the levels of connectors from bowing outward. The PVC pipes were placed between the nodes to prevent the nodes from squeezing together and prevent any undesired compression. The combination of the tension cable and PVC piping allowed the dome to keep the nodes at their desired location without any extra tension or compression. This solution also was easy to hide behind the panels. Despite a handful of unforeseen issues, the rest of the structure fit together as planned during the second assembly. Seeing the dome finally come together after so much deliberation and careful manufacturing was a great feeling.



(32) Tension/Compression Ring Assembly

On the third assembly day the team focused on total construction of the full scale dome (Fig. 33). The first issue that arose was the alignment between the two sides of the blocks. Although a relatively flat location was chosen on the lawn, there were still some dips which affected alignment of the blocks, braces, and columns. The tilt caused by the unlevel foundation had to be fixed to connect the two sides of the blocks. A series of wood shims were used to prop up the lower side of the base elements including the blocks to level the structure as much as possible. Even with the shims, the latches holding the blocks did not want to close. Ultimately, without enough time to rectify the issue a small gap between panels was left in the center of the blocks which would not impact their rigidity.

Another takeaway from this assembly was that it took longer to build than expected. Details like choosing dowels that fit right, stringing the vinyl panel skins with mini bungee cords, and the difficulty of working on scaffolding drew out the process. Even with ample support from a team of eight students, it took about nine hours to fully construct the base and dome. These challenges were used to help consider the time needed for the final installation.


(33) Full Assembly on Dexter Lawn at Cal Poly

The final installation at Descanso Gardens in Pasadena, California was an exciting day for the clients but particularly for the students. The location in the gardens was an open lawn surrounded by oak trees, a distinct spot for visitors to experience the spectacle inside and out (Fig. 34). From the three previous construction days there were a few procedural improvements to streamline the assembly. The team began by preparing the connectors with members locked into the joints. This process meant the pegs could be hammered into place safely on the ground, reducing the work required while on top of the scaffolding. Another major improvement came from leaving the block seating for last. Instead of assembling them first, the team only placed the bottom plywood, roots, and planters on the ground. All of these components were made level to each other using wooden shims before any more building ensued. Leveling the base greatly reduced alignment errors as the dome started to take shape. The assembly of the structure at Descanso Gardens was faster with prepared assemblies, leveling of the base, and saving the block assembly for last.

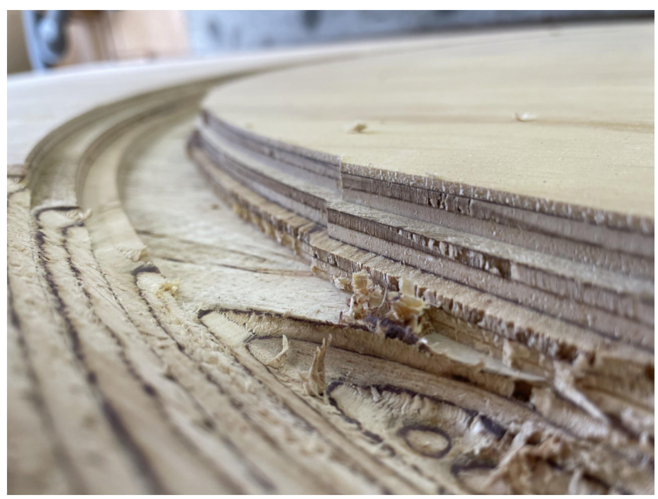
(34) Full Assembly at Descanso Gardens in Pasadena, California

Sharing the process of building with the clients showed the students the impact of managing the clients expectations. The clients were pleased to have a product to show their vision of a centering space, they were impressed by the simplicity of the assembly, but were confused when the blocks did not align together at the end of the construction. The students conceded that the major unsolved issues were leveling the base, getting the dowels to fit the connectors while not being loose, and the blocks latching together tightly. In the end the students were content to have delivered a large scale project on time with only minor unresolved issues. Despite an endless series of design, manufacturing, and assembly issues, the team managed to make an entirely wooden dome that only took a mallet to assemble. The clients and faculty advisors were impressed.

Conclusion and Reflections

As has been shown, this project presented an endless number of unique challenges. There have been similar dome structures built before, but none that required it to be easily taken apart. The Center for Centering combined so many specialized design inspirations to answer its problems and proved to be a rewarding experience every step of the way. Every student learned the importance of holistic design: design that considers aesthetics, practicality, and function equally. As more challenges were solved, it seemed two more took its place. Even with incredible amounts of planning, scheduling, and collaborating this project proved its mettle. But the students enjoyed just how interdisciplinary this project became; every perspective brought something valuable to the dome.

Hello, this is Olek Piechaczek and I *loved* every second of this project. It pushed me to think in ways I had not considered before and I never got tired of working with my other team members. Reflecting on this whole experience, a year later, has made me realize where our design exceeded expectations and where it fell short. I think everyone on the team should feel a massive victory for simplifying the original graduate concept without losing the essence of centering. That simplified geometry still proved to be visually striking and eased the construction process. Despite designing the block seating and appreciating the final product, there still were many issues with its construction. The blocks required a flat surface in order to attach together perfectly. There was not any room for error which became a problem with the uneven surfaces of the outdoor site. If I could change one thing about the blocks it would be that need for perfect alignment and a level surface. I think allowing more tolerance between the pieces would definitely aid the final assembly. Also, a leveling system for the base structure of the dome would be nice as well. We all knew leveling might be an issue but had no idea how to account for it, so we were unsurprised it was a problem during the assemblies. Even though this project had many challenges, the simple idea of making a structure like a LEGO set continually proved difficult. At the scale we were building at, it is a shock this project *was not* permanent. I truly believe we designed and constructed a novel structure, full of familiar aspects but combined in a wholly untraditional way.



CNC Through Plywood Laminations For “Crown”

My name is Ryan Scharf, I am proud to have contributed to the design and manufacturing of the majestic dome. Olek first pitched the project to me as an opportunity to create a design that we could make in the woodshop but it became so much more for me. It was a chance to refine interpersonal and technical skills, and foster a small community of colleagues bonded through hardship and fun times. I was able to help most with the connectors, their joints, and top compression ring, seeing the work from design through complete manufacturing. The success of the connectors came from the success of the top compression ring. I conceptualized the combination of laminated plywood blocks and subtractive manufacturing using the CNC mill to manufacture the oculus ring at the top of the structure. Attaching the joints to the ring with the correct angle and placement was made easy with the precisely machined ring, confirming the viability of the technique. This led to the adaptation of the technique for the rest of the connectors center blocks. The joints with the slot and peg design kept the structure connected and stable. The aspect which did not work well with the joints were the dowels. Fundamentally, the concept was sound but the customization for each hole alignment was not ideal. Given the opportunity to refine the joints, introducing more tolerance in the interface between the slots and pegs, and rethinking the mechanism that keeps the two sides from sliding apart would improve uniformity, fitment, and finish.

The Center for Centering represents how a project can have complete unity with its central concept in all parts of its design. While not every part obviously exudes the concept of centering and meditation, that was the driving force behind any decision. The team's adamant pursuit of the client's goals allowed for creative solutions to emerge for this unique project. Accomplishing all of these feats out of wooden construction is no easy task. Utilizing wooden lumber along with plywood demonstrates the variety of ways wood can be used. It is comfortable enough to sit on, strong enough to support an elevated dome, and light enough for all the pieces to be carried by hand. This project represents how passion, design, and collaboration can produce something both functional and beautiful. It is yet another triumph of Cal Poly's interdisciplinary collaboration across majors and colleges.