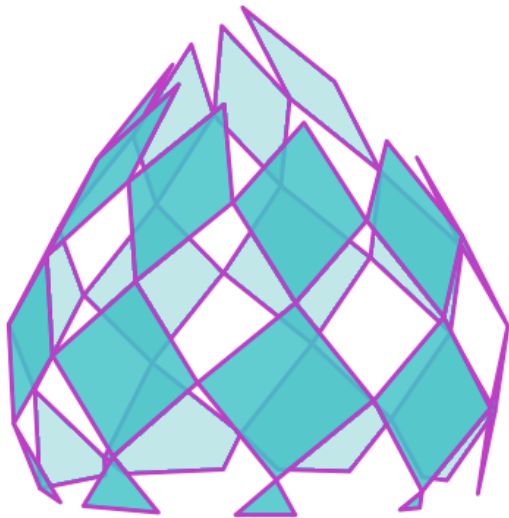


BOTTLE GENII

build manual

Matt Brand 2022.08.04 revised 2022.08.16

Welcome to the Bottle Genii build/strike team(s)!



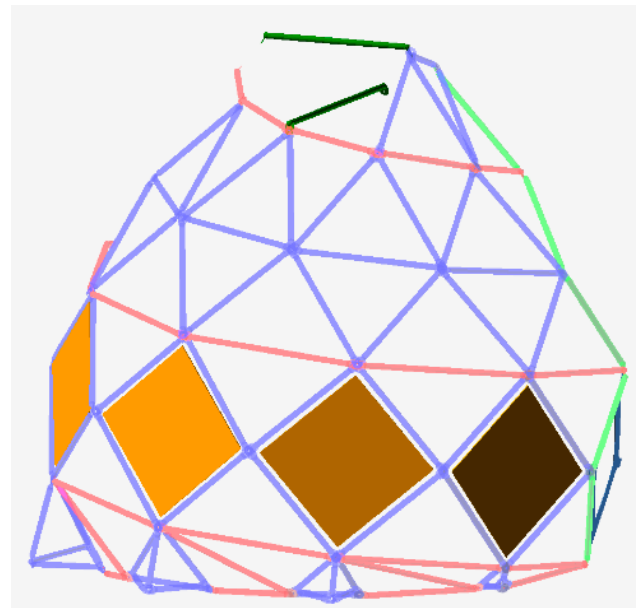
Understanding the structure: Think of the framework as a spiraling checkerboard of diamond-shaped panels. There are 3 levels:

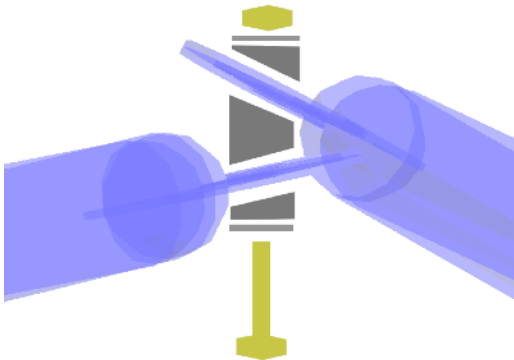
- The bottom triangles form the base spiral.
- The middle layer consists of 8 square perforated steel panels and 2 portal panels.
- The top layer diamonds are open strut-work panels (each 4 struts plus a horizontal “belt” strut).

Bottle Genii is actually just two copies of the front half of this checkerboard; one rotated 180° and attached to the other along a zig-zag seam

The basic build plan is: Add panels in spiral order, attaching each to the panel below and to the previous panel (to the right), then adding a stabilizing crossbar that connects the top of the new panel to the top of the previous panel.

Here is a corresponding view of the strut work for the each half of Bottle Genii. Purple struts are simple and straight; pink crossbars may have a twist and bent end-tabs. The light green struts along the right edge are “seam” struts that connect the two halves. The dark green struts at top are roofline crossbars that support a central chandelier (not shown) and the fire cannons (not shown). Note that the the 3 largest base triangles at the base been expanded to tetrahedra, to simplify assembly. Looking just at the purple areas, each half of Bottle Genii has 4 base triangles/tetrahedra, topped by 4 imaging diamonds, topped by 4 open (strut work) diamonds. Then there are some additional triangles at the roofline and along the seam. The stacked diamonds determine our build plan.





The struts around a diamond all have co-planar tabs, so when two diamonds are attached to each other, their tabs lie in two distinct planes. Bottle Genii uses a system of inclined washers to make strong joints with two planes. Here you are looking down from inside the structure at a side-to-side connection between two strut work diamonds. There are 3 coplanar struts on each side, for a total of 6 struts. The joint, from inside the structure to outside, is: 4.5" bolt, flat washer, singly-inclined washer, 3 strut tabs from the previous diamond, doubly-inclined washer, 3 strut tabs from the new diamond, singly-inclined washer, flat washer, nut. Most of these washer assemblies will ship already attached to one or two of the participating struts. There is a table at the end of this document that lists what inclined washer angles (if any) belongs at each node.

A similar arrangement is used when attaching diamonds vertically, with two modifications:

- The top crossbars are added to the first (inner) plane, under the doubly-inclined washer.
- Exception: the base ring, where the crossbars and then the vertical strut of each tetrahedron are added to the second (outer) plane, under the singly-inclined washer.

We have shipped the solid panels and the base tetrahedra pre-assembled. The upper diamonds will need to be assembled on-site. When assembling, keep in mind that the edge struts of *all* panels (triangles & diamonds) are assembled with the clockwise over/under rule: Each strut tab goes under the next, in clockwise order. If assembling the upper-level diamonds, the end tabs of middle "belt strut" go in between the end tabs of the edge struts.

Some other useful invariants:

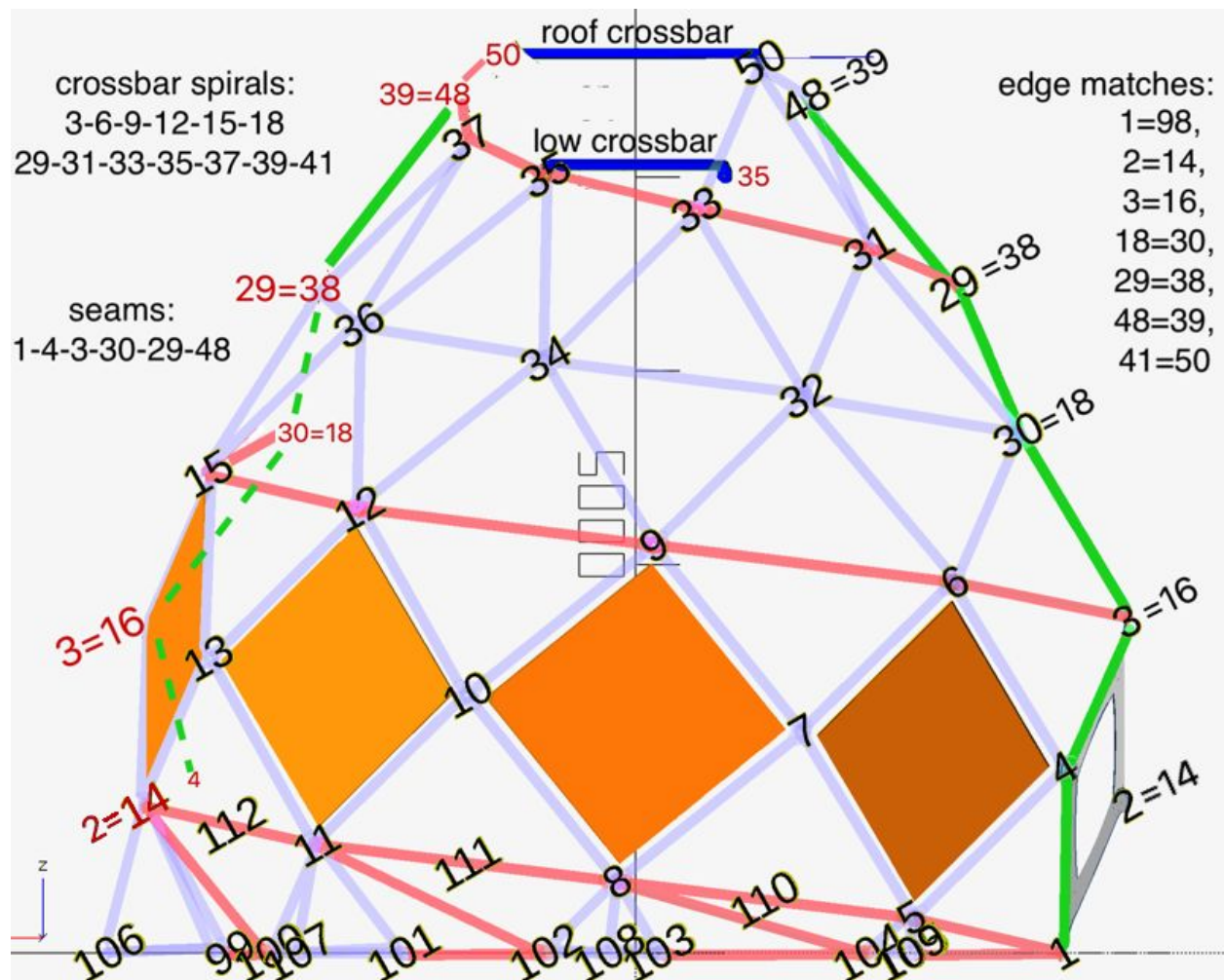
- All bolts point outward; bolt heads are inside the structure.
- Diamonds are added to the structure by sliding their lower and right-hand corners onto bolts that are already on the structure.
- Aside from the struts at the base of the tetrahedra, all bent tabs point inward.
- All diamond edge struts are the same length and have no twist and no bent tabs (seam struts excluded).
- All diamond-to-diamond connections have an inclined washer assembly and use 4.5" bolts (seam nodes excluded).
- Seam nodes are uni-planar and use a 3" bolt.
- Bolt assemblies with inclined washers should be rotated in the hole so that the bolt end tilts out toward the panel corner.

Some useful technique:

- When modifying a connection at a node, always put vise-grips on all the tabs involved to keep the holes aligned while the bolt is being moved or removed.
- If holes get out of alignment, use the dug wrench (spike-ended black wrench) or a pry spike to get the holes back into alignment, then put on vise grips to preserve alignment.
- Tighten bolt assemblies by turning the nut, not the head.
- If inclined washers rotate out of alignment or bind, turning the bolt head a little can fix the problem. Or they can be directly manipulated with the small red pipe wrench.

- Nuts and bolts do not need to be fully tightened until the end. Leaving them a little loose gives the structure a little play which can be useful for pulling nodes together at higher positions.
- If you attach any *dangling* struts whose other end will be hooked up later, either position them in the lowest potential energy position, or tighten up the bolt until the strut cannot rotate. MAKE SURE THE DANGLING STRUT CANNOT ROTATE AND HIT SOMEONE.

The nodes are numbered and all struts tabs are labelled with their node #s. These labels are either red or black, indicating which half of the structure the strut belongs to. For historical reasons, numbers are not in sequence and the nodes along the seams have two numbers, so you will see some strut tabs with labels such as “2=14”. Here is the numbering scheme for one half of the structure; it is the same for the other half, but black and red are reversed:



NB: Node 109 has been removed from the structure; in the above map, it obscures node 105.
 NB: Kudos to Jane Wu for making this diagram.

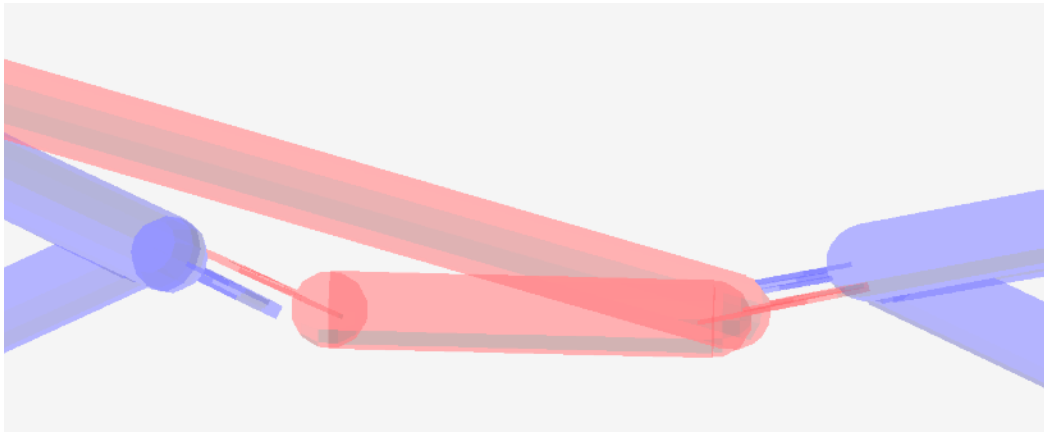
Packing inventory as of 8/4

- 8 imaging panels each framed with 4 struts.
- 6 base tetrahedra and 2 base triangles.
- 8 upper diamonds packed as 8 4-strut bundles plus 2 bundles of the diamond belts.
- 22 base struts (to connect the tetrahedra) packed as 4 bundles.
- 10 crossbars connecting the tops of the imaging panels, packed as 2 bundles.
- 12 crossbars connecting the tops of the upper diamonds, packed as 2 bundles.
- 16 struts forming the seam and some extra triangles at the top of the spirals, packed in 2 bundles.
- 2 long roofline crossbars and the 10' chandelier stem that they support, bundled together with 4 7' poles for the build-week shade structure.

This totals 8 panels and 21 strut bundles.

Assembly sequence

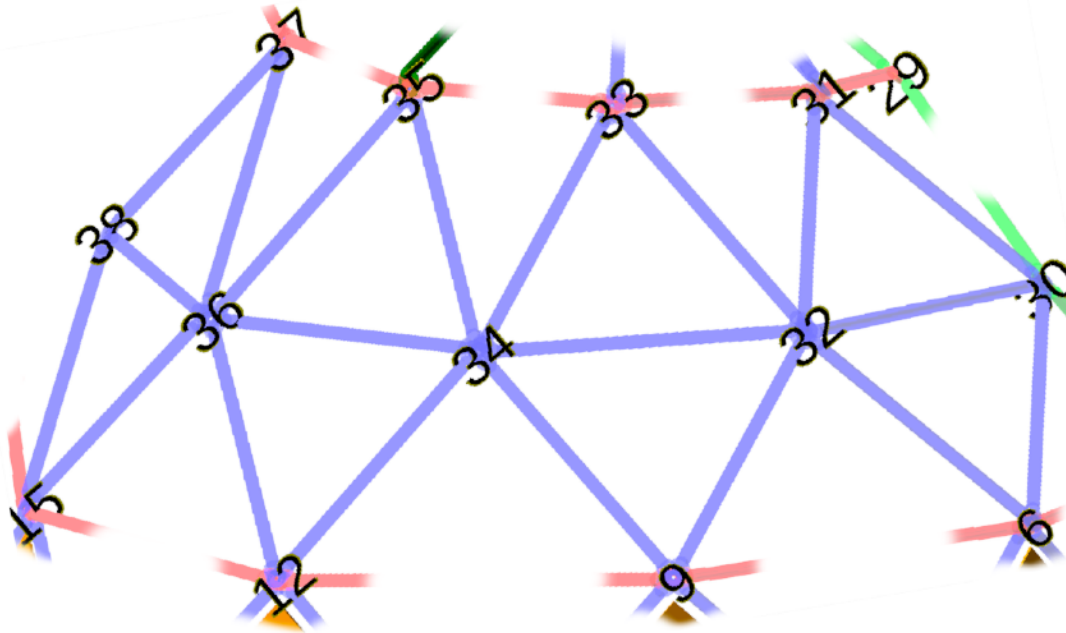
1. Lay out the site (fuel tanks, generator, fences, &c.) and call for a trencher. Then start the **base** by laying out the “toes” (tetrahedra) around a roughly 14' diameter circle, going largest to smallest (twice) in the counter-clockwise direction, with the largest two positioned at the north and south ends of the circle. Note: the smallest toe is just a triangle.
2. Using the end tab labels as a guide, attach base ring struts and diagonal struts to the tetrahedra to. The tabs go inside the bigger tetrahedron and outside the smaller tetrahedron. Here we are looking down at one such assembly from the outside: a tetrahedron (purple, left) gets bolted to a small base ring strut (pink, center); and that plus a diagonal (pink) get bolted to a smaller tetrahedron (purple, right). This linking continues until we get to node 1, where the base ring strut and the diagonal are temporarily pinned together with a short 1.5” bolt.



3. Attach the crossbars at the top of each base spiral. These go outside the doubly-inclined washer. (There may be an exception at one of the node 8s).
4. Pull the two half-spirals together and attach the node 98 of big tetrahedron to node 1, the beginning of the base spiral. The in-to-out order is: bolt, flat washer, singly-inclined washer, tetrahedron, doubly-inclined washer, spiral start (struts 1:105 and 1:4), bottom (flat) portal section, seam strut 1:4, singly-inclined washer, flat washer, nut.
5. Run ratchet straps between opposite nodes and tighten until the nodes form a circle roughly 172” inches across.

6. Build the **portal** on top of node "1=98":
 1. Using vise-grip pliers to hold together the two planes of node "2=14" (top of the largest tetrahedron), back out the bolts and put the right portal plate (has biggest tab bend) in the middle of the doubly-inclined washer (which has been split for this purpose). Reassemble the joint and remove the vise-grips.
 2. Using a 1.4" bolt and nut, attach the two portal sections.
 3. Attach the left portal section to the left (looking in) hole of the bottom portal section with a 1.5" bolt and nut,
 4. Using strut 1:4, start node 4: 3" bolt, flat washer, left portal section (has shallow bend), strut 1:4, strut 4:3.
 5. Attach the top portal section to the left with a 1.5" bolt and nut.
 6. Using strut 4:3, start node 3: 3" bolt, flat washer, top portal section (has angled bend), strut 4:3, crossbar 3:6, flat washer, nut.
 7. Attach the right and top portal sections with a 1.5" bolt and nut.
 8. Note that the portal is only framed on 3 sides; the missing upper-right-hand strut 2:3 is in one of the holo panel assemblies.
7. To prepare for **mounting the imaging** panels, put vise grips on node 4 and on the two planes of node 5.
8. Get the ladder, extend to full height, and place it so that it straddles node 5. Using an orange 2-loop strap, hang the winch from the top rungs and position it so that the hoisting hook is almost directly above node 5.
9. Go get the first holo panel and run the hoisting hook around strut 6:7 near node 6. With the blackened perforated side facing out, hoist it up so that the bottom joint lines up with node 5 (top of base triangle) and the right joint lines up with node 4 (left corner of portal).
10. Put vise grips on the bottom and right corners of the panel.
11. Hook up node 5: Remove the small bolt from the bottom corner of the panel, and from node 5 of the triangle below, temporarily remove the nut, flat washer, and singly-inclined washer. Maneuver the panel corner onto the bolt end, and replace the singly-inclined washer, flat washer, and nut. Remove vise-grips.
12. Hook up node 4: Remove the small bolt from the right corner of the panel, and from node 4 of the adjacent portal square, temporarily remove the nut and flat washer. Maneuver the panel corner onto the bolt end, and replace the flat washer and nut. Remove vise-grips.
13. Add crossbar 3:6 to the tops of the two diamonds. Crossbars go under the doubly-inclined washers. Remember to use vise-grips to hold each node together while the nut is off.
14. Release and unhook the winch from the panel, and move it into position over the next base triangle.
15. Repeat the last 6 steps for each of the holo panels, always putting the panel corners under the singly-inclined washers of the bolts below and to the right, and always putting the top cross-bars under the doubly-inclined washers. It's a little faster to put the next crossbar on while the top bolt is open; if doing so, be careful that it cannot rotate and hit anyone.
16. The fourth and highest holo panel also needs to connect to the portal: In this case, you will amply vise-grip node 3 of the portal, pull out the bolt, vise-grip put node 3 of the holo panel, put the bolt into it, and then put the bolt back into the portal corner. If this is a tight maneuver, you can use the dug wrench for alignment or you can undo connections between portal plates to get more play.
17. When putting node 3 back together, add strut 3:30 to the outside of the node and also crossbar 15:30 from the top of the highest holo panel to node 30. Also add strut 30:29. Pin the three struts going into node 30 with a 1.5" bolt.
18. Repeat the entire holo panel mounting sequence for the other side.

19. To prepare for **mounting the upper** diamonds, move the ladder inside the structure.



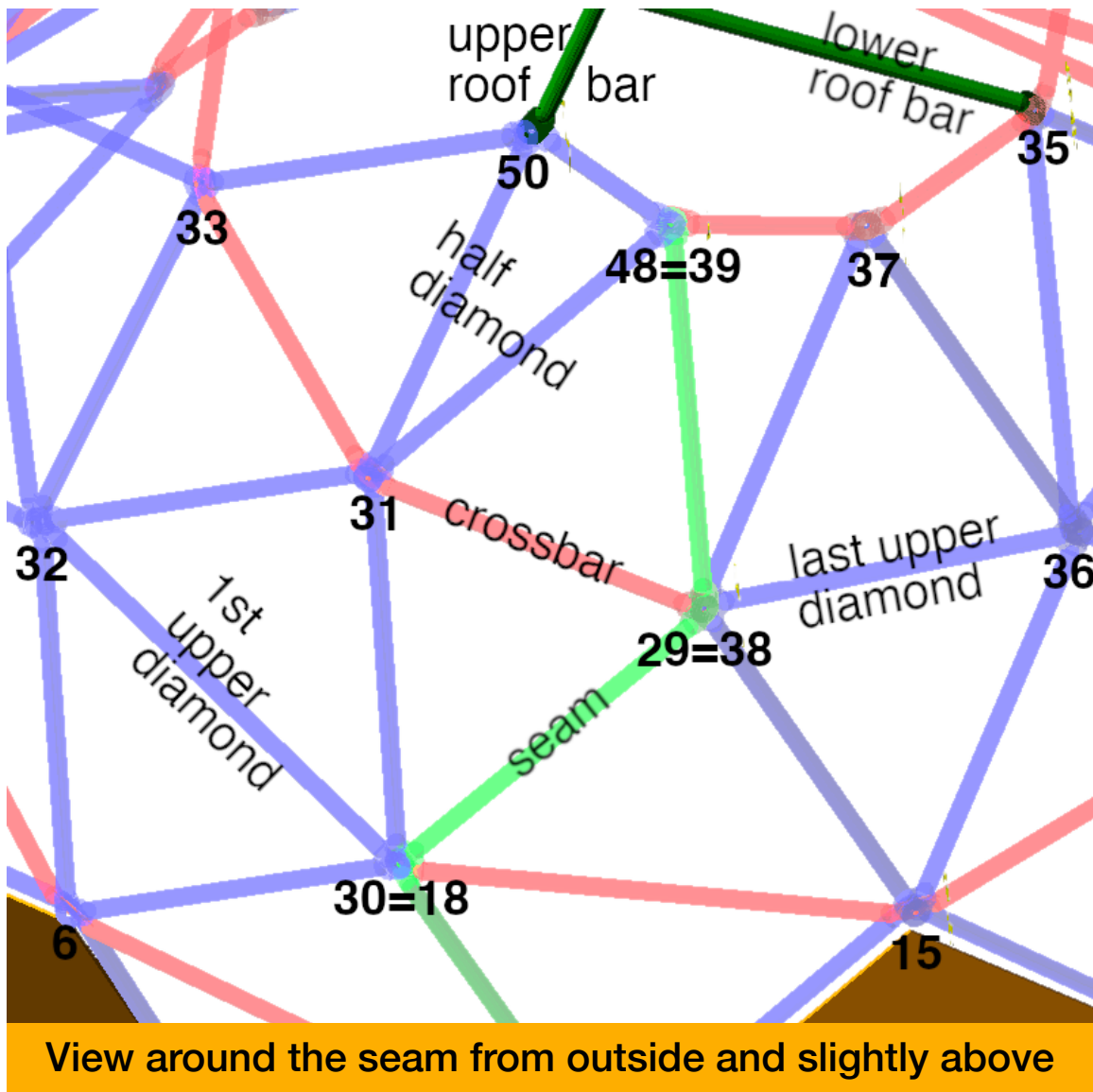
20. Assemble the upper diamonds if not done already. Each should be packed with a bolt assembly for their top and left corners (looking in from outside); keep the assembly at the top corner intact (but move any washers between the tabs to outside the tabs), and move the other assembly to the left corner. Check inclined washer angles against the table at the end of this document. The node sequences for the diamonds are, in clockwise order from the top: 31,30,6,32; 33,32,9,34; 35,34,12,36; 37,36,15,38. Remember that each end-tab goes under the next in clockwise order, and the belt strut's tabs go between the edge struts' tabs. Use temporary 1.5" bolts to hold together the bottom and left-hand corners.

21. For each upper level diamond:

1. Vise-grip the top node of the holo panel that it's going to rest on top of, and temporarily remove the nut, flat washer, and singly-inclined washer.
2. Turn the diamond *upside-down* (rotated in-plane, not out-of-plane), and seat its *bottom* corner on the open bolt. Replace the singly-inclined washer, flat washer, and nut (loosely).
3. Vise-grip the left corner on the previously-mounted diamond to the right and temporarily remove the nut, flat washer, and singly-inclined washer (if there is one).
4. Rotate the new diamond 180° around its bottom bolt until the diamond's right corner lines up with the open bolt. Then have someone climb the ladder and/or structure exterior, and bolt them together, putting the singly-inclined washer, flat washer, and nut back.
5. If doing the first upper diamond (with top node 31), add a crossbar 29=38:31 just under the singly-inclined washer at node 30, and pin its 29 end to strut 30:29.
6. At the top of the newly installed diamond, open up the bolt (take off nut, flat washer, singly-inclined washer) and connect the dangling top crossbar from the previous diamond (if any) then add a dangling top crossbar for the next diamond.

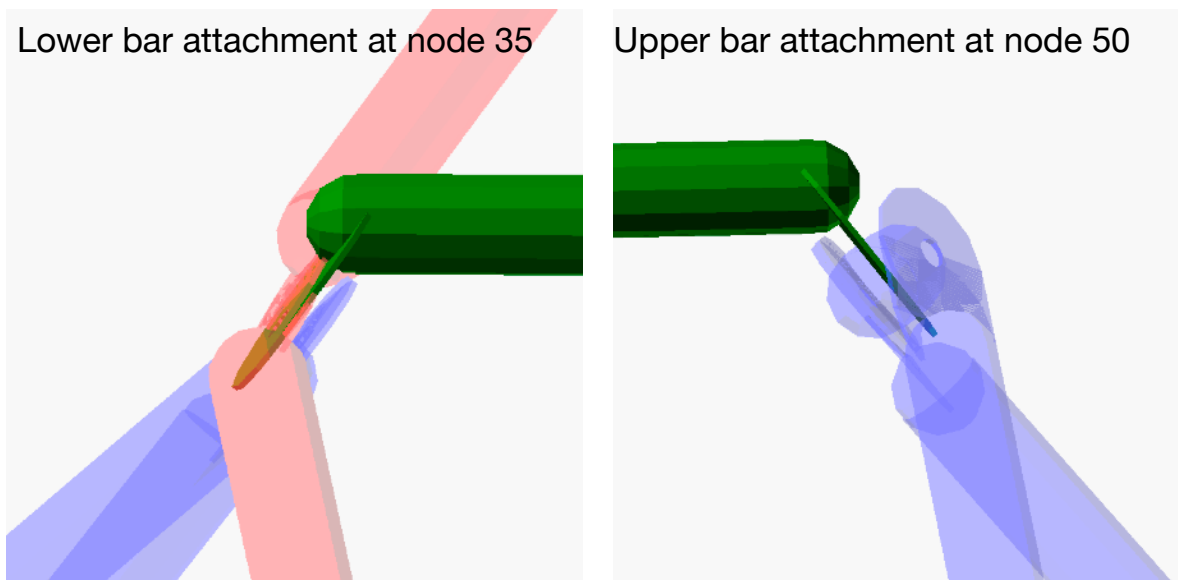
22. Once the last (4th) diamond is installed on each side, it needs to be attached to the seam on its left corner (looking in), at node 29=38. You should already have 2 struts pinned together at node 29=38: the seam strut 30=18:29=38 and the crossbar 29=38:31. Get strut 29=38:39=48, a 3" bolt, 2 flat washers, and a nut. Vise-grip together the two sets of tabs

that will meet node 39=38 at and pull out any pin bolts. Then bolt together the node in this order: bolt, flat washer, tabs of the last diamond, tabs from struts already attached to the first upper diamond, tab 29=38 of the new strut 29=38:39=48, flat washer, nut. You can also pin together the crossbar 37:39=48 and the seam strut 29=38:39=48 at node 48=39 with a 1.5" bolt for safety. Here is a picture, looking in and down, of the how the last upper diamond connects to the seam:



23. To prepare to **top off the roof**, assemble the half-diamond 31,48=39,50 on the ground.
24. Mount this half-diamond on node 31 under its singly-inclined washer as have for the other upper diamonds, rotate into place, and connect it's right corner to node 48=39. This node has two planes that are only 3° apart, so in principle no inclined washer is needed and a 3" bolt with flat washers should suffice. However, misalignments in the structure accrue as you build up from the bottom, and the angle may be greater. There are a variety of shallow inclined washers in the bolt box; use as needed to fill any angle between the tabs and then

- use the same after the tabs to cancel out the incline before putting on a flat washer and nut. Leave node 48=39 loose so that there is play available to do the last strut, 33:50.
25. Get the upper roof bar 41:50 and, using the ladder and some bungie cords and/or orange double-loop straps, dangle both ends of it from the highest struts on the both sides of the structure (48:50 atop the half-diamonds).
 26. Get strut 33:50, mount it under the singly-inclined washer at node 33, vise-grip the tabs at node 50 of the half-diamond, and then assemble node 50 in the following order: 4.5" bolt, flat washer, singly-inclined washer, tabs from the half-diamond, one end of the upper roof bar, doubly-inclined washer, tab from 33:50, singly-inclined washer, flat washer nut. Leave loose.
 27. Do the same on the other side. Be prepared to wrestle and/or insert extra inclined washers as necessary. One can also use the dug wrench and/or body weight and/or ratchet straps to pull things into alignment.
 28. Get the lower roof bar 35:35 (it's ~8' long) and using bungies & loop straps, dangle it safely so that its ends are near the two node 35s.
 29. Vise-grip node 35, take off the nut and flat washer, put the lower roof bar on, and put the washer and nut back on. To do the same on the other side, it may be necessary to back out the bolt and or pull the node inward/down with some force.



30. Tighten all nuts on the structure, add jam nuts where there is room on the bolt, and then slide rubber stoppers onto the bolt ends for safety. The structure is done.
31. For the **stem and chandelier**, loosen and slide the U-bolt brackets on the two roof bars until they are roughly aligned at the center. Turn them so that the unoccupied U's can receive the stem, and push the stem in from the ground, with the end that has two side holes down. Raise the stem to ~9' above ground, tighten the U-bolts that hold it up, slide the brackets on the roof bars to make the stem vertical, and tighten everything up.
32. Take the U bolt out of the chandelier, slide through the two holes of the stem, push the legs back through the chandelier plate, put the nuts back on, and tighten until the plate is snug with the end of the stem.
33. Joel will direct **mounting of the fire apparatus**.

34. For **wiring**, bring a heavy-gauge extension cord up from the trench along the inside of struts so that power gets up to the lower roof bar, and plug in a multi-outlet extension. Attach the 300W 120VAC-to-12VDC transformer here, and bring 12V lines down the stem to the chandelier and two whatever locations are deemed suitable for the controllers for the LED strips. Shrink-wrap connections or wrap in plastic bags and zip-tie to protect from (unlikely) rains.
35. Ask Joel what additional power routing he needs for the fire apparatus.
36. Mount **curtains** as directed by Jess.
37. Aim and tighten lights on chandelier. Flood lights should illuminate curtains; all other spotlights illuminate panels.
38. Determine LED strip locations, mount with zip ties, and wire in.
39. Position **propane tanks and generator** (20' from each other; >25' from structure).
40. Place generator(s) in dog cage and run extension cords to structure. Bag and zip-tie any connections that will be underground. Decorate the cage with solar LED string lights.
41. Place propane tanks and run pipe to structure. Decorate with solar LED string lights.
42. Hammer in 10 fence stakes to mark out an elongated hexagon enclosure around generators and tanks that keeps people 20' away from both.
43. Hang orange plastic fencing on the fence stakes and decorate with solar LED string lights.
- 45 Put "do not climb", "do not touch" stickers and retroreflective stickers on structure/tanks/generators as appropriate. Put remaining solar string lights, if any, on structure.

DECLARE VICTORY, clean up site, and go back to camp.

Strike is simply build in reverse: Remove fire apparatus, wiring, lights, curtains, then disassemble and bundle struts from top down. Leave panels & surrounding struts intact. Tentative plan for Saturday 4pm; this may get moved up depending on weather & personnel.

Useful info: **arrangement of inclined washers**

node#	angle_degrees	len slug mm	len mid mm	made	notes
001=098	19	47	30	x2	
002=014	19	48	30	x2	
003=016	15	38	23	x2	
004	20	48	30	x2	use 19
005	15	39	24	x2	
006	17	42	26	x2	
007	19	47	29	x2	
008	16	41	25	x2	
009	16	41	25	x2	
010	19	47	29	x2	
011	17	42	26	x2	
012	16	40	24	x2	
013	19	47	29	x2	
014,016	see above				
015	14	35	21	x2	
031	12	31	18	x2	
032	16	40	24	x2	
033	11	30	18	x2	use 12
034	16	41	25	x2	
036	15	38	23	x2	
039=048	3	12	6	x2	skip
041=050	17	43	26	x2	

