Gyring Gyroid

For G4GX
Dedicated to Tom Rodgers

Chaim Goodman-Strauss
Eugene Sargent
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Gyring Gyroid

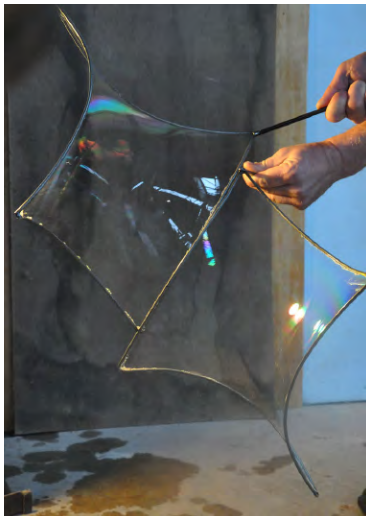
The proposed sculpture is a spherical portion of the famous gyroid, a minimal surface found by Alan Schoen in 1970.

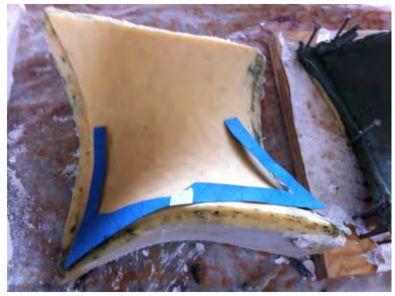
The piece is to consist of 42 steel units; it is scaled to the geometry of its companion piece, *Double Triamond, w/ Hexastix!* As usual, it will be completely hand-crafted and assembled on site.

The remarkable gyroid is a periodic minimal surface, discovered by Alan Schoen.

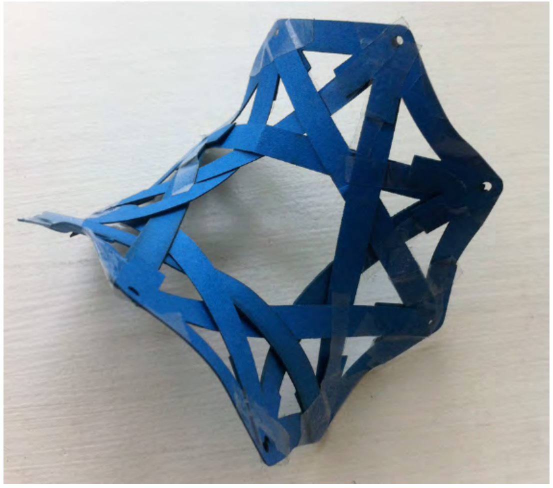
Minimal surfaces are precisely those that are perfectly balanced under tension—soap films, for example, necessarily form minimal surfaces. Another way to state this is that minimal surfaces are locally area minimizing; for this reason they often appear, for example, at the boundary of two non-mixing fluids, in living systems and in certain crystallographic structures. The gyroid, for example, appears in nature in certain zeolites and in the chitinous structures creating iridescence in some butterfly wings.

These soap films are the precise shape of the unit we will use in the sculpture, showing how they fit together to form the gyroid.





Through various precisely tuned processes, we build up this gyroid surface, in units that were then assembled at G4GX.



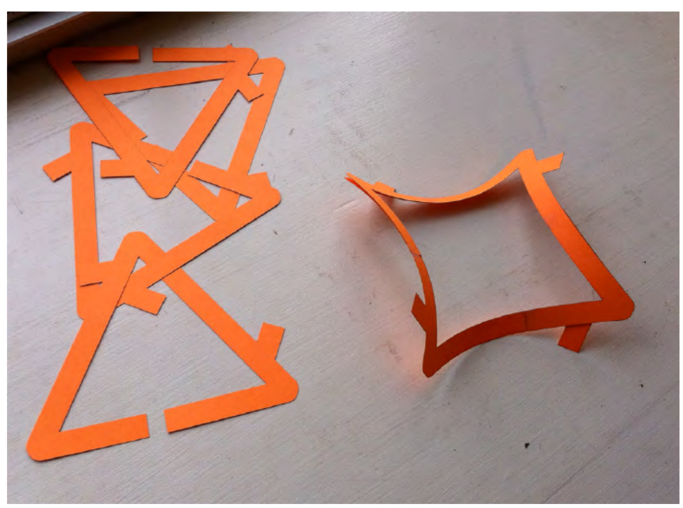
We use a technique of building surfaces of negative curvature, from strips of flat material:

The celebrated Gauss-Bonet Theorem demonstrates that the total curvature of a disk-like region of a surface (for example, one of our units) is precisely captured by measuring the turning excess or deficit around its boundary. For example, consider this decagon with ten 120° angles; as we go around its boundary, we turn 60° ten times, for a total of 600° — an excess of 240° over the customary 360° for flat surfaces. This excess is a precise measurement of the total negative curvature across the decagon.

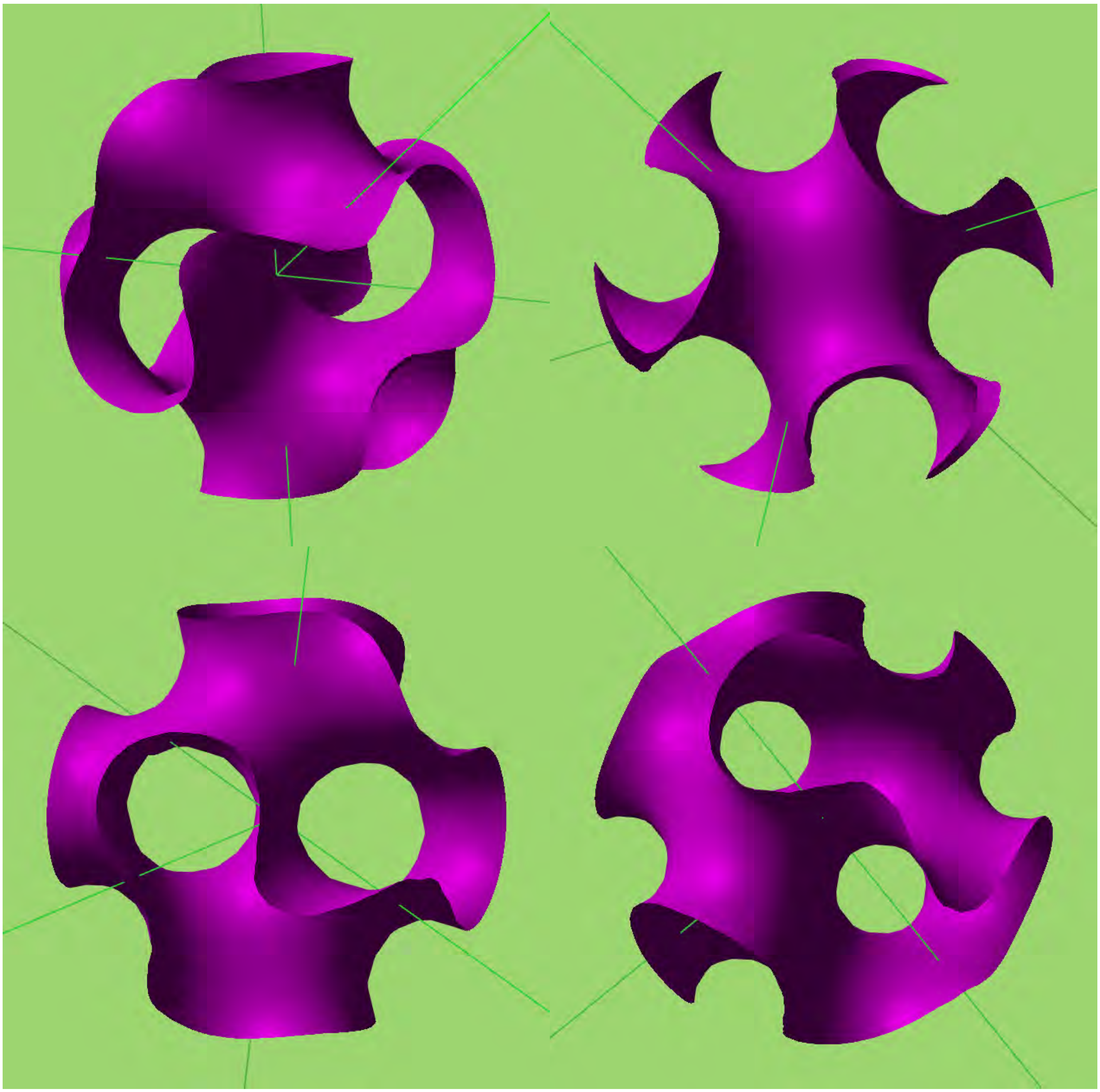
We can control this with exquisite precision. Here is a recent sculpture of a constant negative curvature surface made from pentagons and squares; the angles at the corners are worked out precisely so that the total curvature per unit of area (i.e. the Gaussian curvature) is the same across the entire surface.

The gyroid, like all minimal surfaces (other than the plane) is not a constant curvature; nonetheless, this technique gives precise control, and we use this technique to control the surface of the piece very finely.

Throughout, we relied on physical models for gaining intuition. Below are paper models of the mu-snub cube which has the same topology as the gyroid surface, a smooth version of the mu-snub cube and paper versions of our unit, assembled into a version of the sculpture.



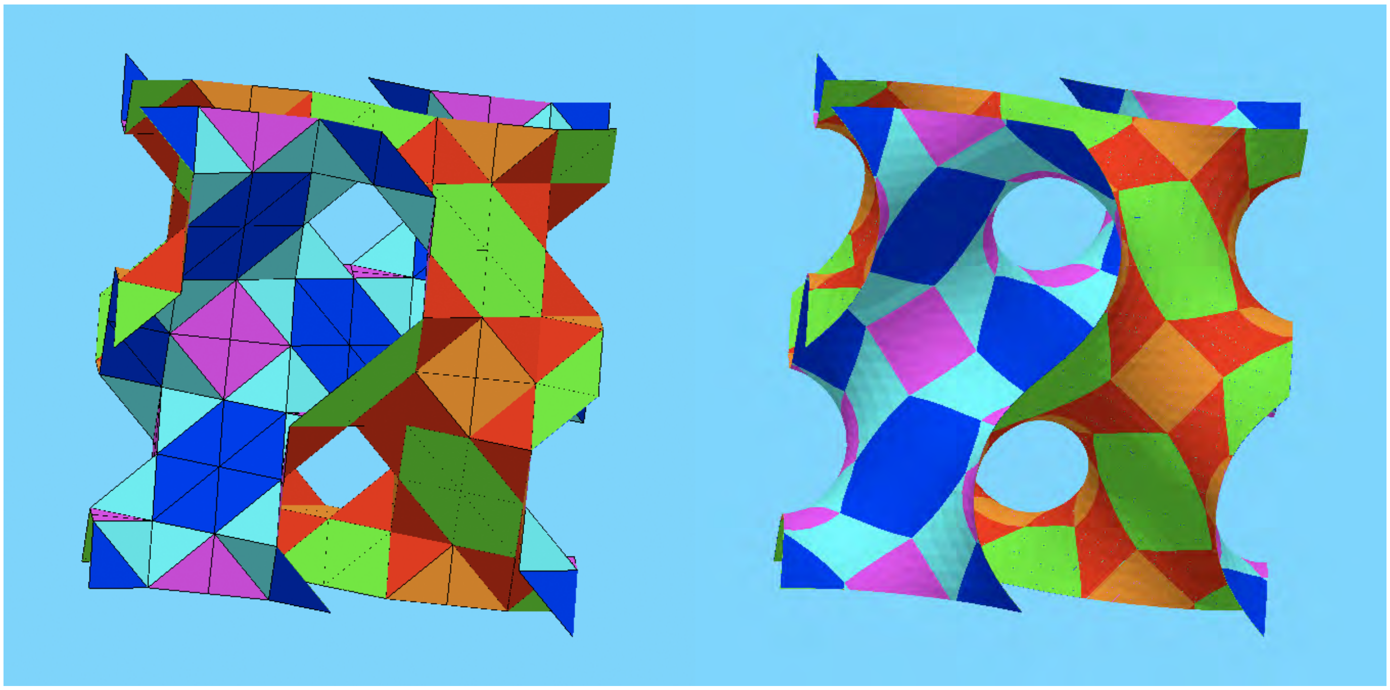
The symmetry of the gyroid is the top quarter space group, $8^0/4$ in the Conway notation. As such, like the *Double Triamond w/ Hexastix!* it is remarkably hard to "see", even when looking directly at a model of it! Amusingly, the gyroid is closely approximated by the solution to $\cos x \sin y + \cos y \sin z + \cos z \sin x = 0$, which gives a quick way to make images such as these. Our clipping sphere is of radius $5/4\ \pi$.



The gyroid and the triamond are closely related, as shown here; the sculptures Double Triamond and Gyring Gyroid are scaled to the same unit, and at least in principle could be intertwined. (The hexastix in the former precisely would go through the hexagonal holes in the latter.

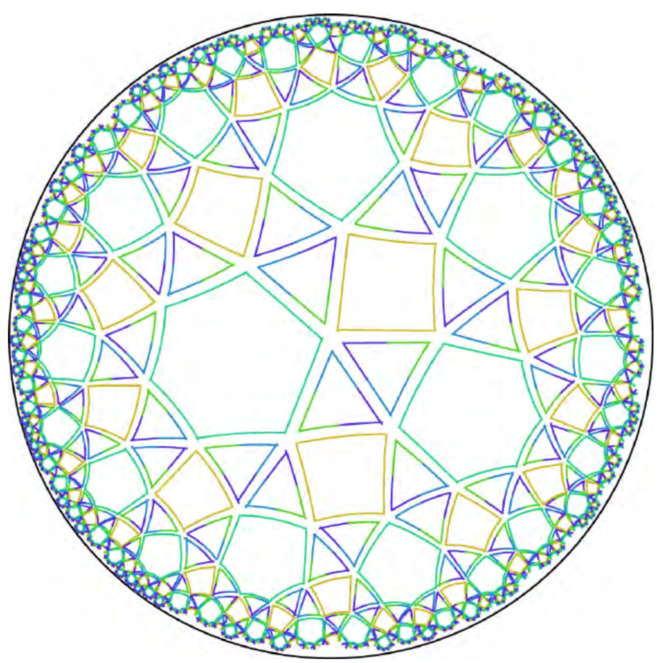
In this scale, the clipping sphere works out to be 42" in diameter.

The gyroid is approximated by Conway's mu-snub cube, a polyhedron consisting of a hexagon, a square and three triangles at each vertex. This gives, on the one hand, a map from the 642 symmetry of the hyperbolic plane, and on the other, a natural tiling of the surface of the gyroid. We exploit this in the sculpture: our basic unit is one of these squares, with its neighboring triangles attached; the hexagons are left as holes

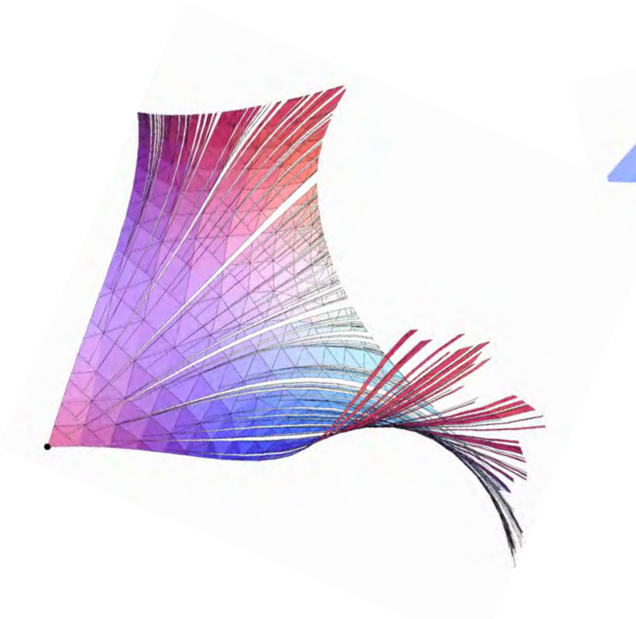


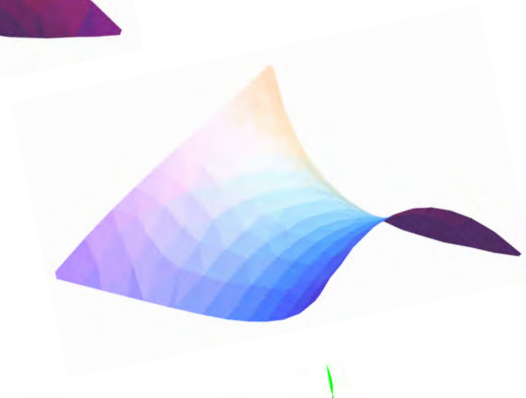
In the figures above, we see an early stage of our modeling process, as the mucube is "evolved" in Ken Brakke's *Surface Evolver*, steadily tightening its surface until it reaches a close approximation of the gyroid.

Here, for comparison, is the same tiling in the hyperbolic plane, which is wrapped up onto the gyroid at right above.

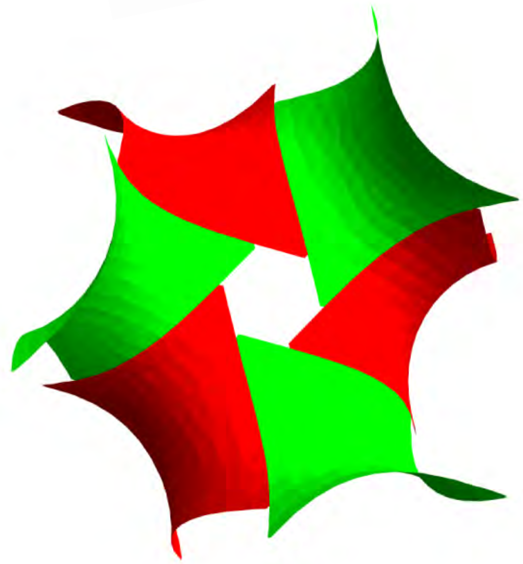


Our modeling process required finding appropriate modules for the sculpture. We modify our tiling of the surface to emphasize the squares and minimize the hexagons.

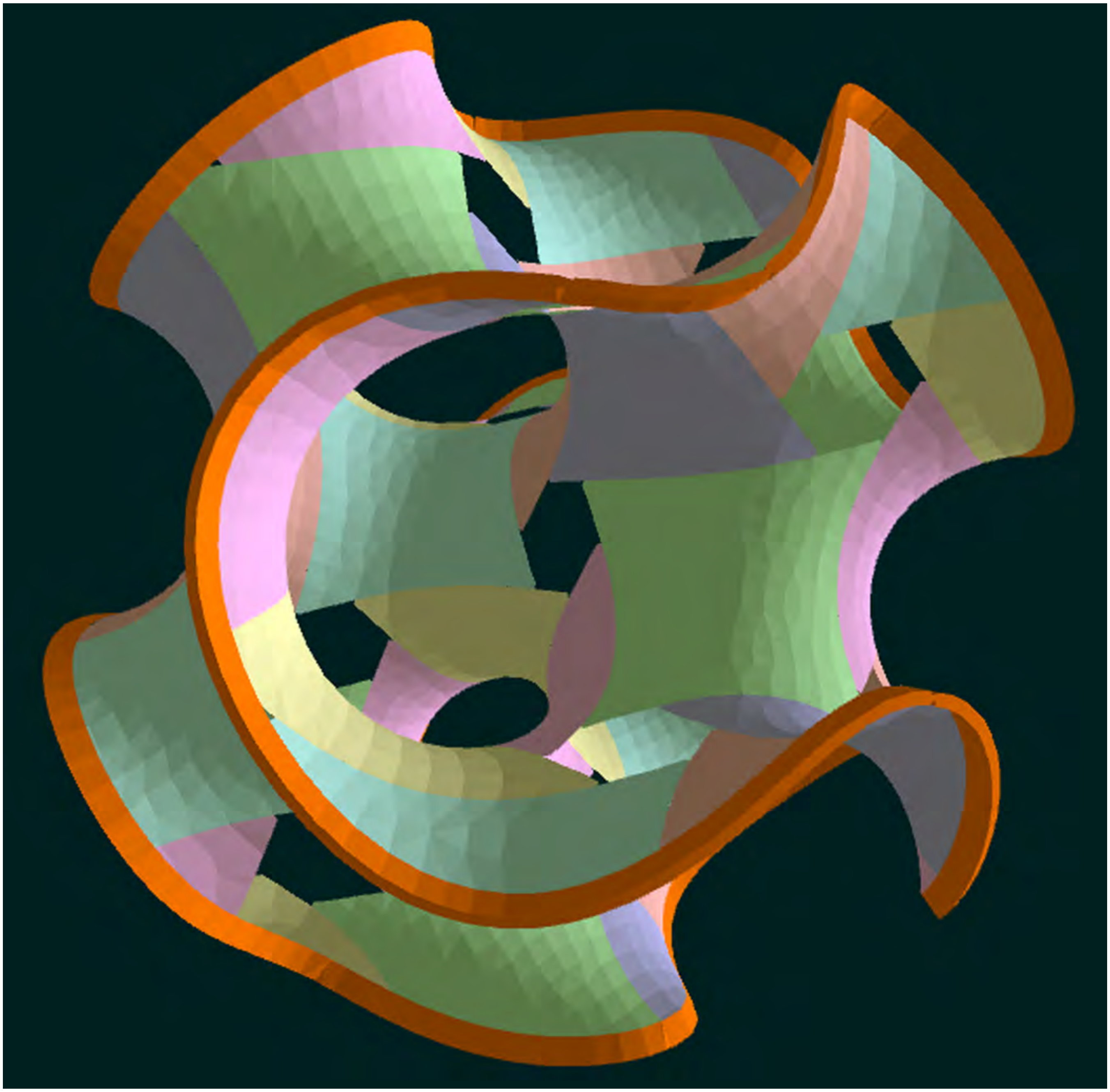




By eye we choose one of the geodesic paths radiating out of a two-fold center; this path becomes the edge of our unit.

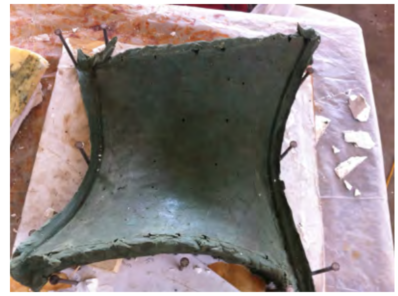


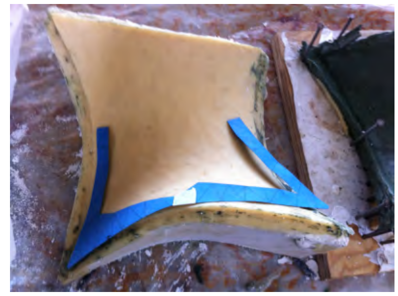
At last, after weeks of modeling, we were able to see the structure of the Gyring Gyroid sculpture for the first time!



To better understand the particular way the modules would be assembled, Sargent wrote a special purpose program for manipulating a model of the sculpture.

And we move out of the computer and into the shop!





From the computer data, we first built a jig, shown at left above, that positioned points on the surface. This was filled in with clay, then rubber and plaster molds were made.

From these, our first copies of the module were made, in fiberglass. On these, we drew the geometry of we would use for the strips, working by eye, seeking pleasing curves. Additional experimentation led to a method of shaping strips for the surface of the unit.

Early test assemblies.

The spherical clipping of the surface was sketched out directly on the untrimmed units, using a spherical compass—a wire anchored at the center of the sculpture

We invited friends over
to Chaim's house for a
Sunday afternoon test assembly.

Eugene wandered off for most of
it, to see how well it went together
in other people's hands.

We applied the final patina in front of our first piece, Double Triamond, w/ Hexastix! (2008)

The final assembly at the party on March 31, 2012, at Tom and Sarah Rodgers' house in Atlanta.







Our sincere thanks to Tom and Sarah Rodgers, and the Gathering For Gardner for this wonderful opportunity.