Domes, Zomes, and Drop City

Paul Hildebrandt & Clark Richert
Zometool Inc.
Longmont, CO 80501 USA
paulh@zometool.com

Abstract

Two 20th century visionaries crossed paths at Drop City (near Trinidad, CO) USA. Buckminster Fuller awarded Drop City his Dymaxion award in 1969. Steve Baer went to Drop City to explore ideas that led to the discovery of his 31-zone system. Fuller is credited with the invention of geodesic domes, while Baer invented zomes. Both started with the icosahedron.

"The geodesic dome... is complicated in structure and simple in shape. Zomes are simple in structure and complicated in shape." - Steve Baer [1]

Introduction

Drop City was founded by artists Clark Richert, and JoAnn and Gene Bernofsky in 1965. Although it became known as the "first hippie commune in the United States," that wasn't their original intention. It grew out of a new art form that they called "drop art," for example, dropping a mattress from the roof of an apartment building into a street to see how people reacted. Drop artists realized it wasn't enough to drop art; they had to live in their art. So they bought seven acres of pasture for $450 and started building "live-in" sculptures -- that leaked. Which led them to geodesic domes, if only to keep the snow off of their heads.

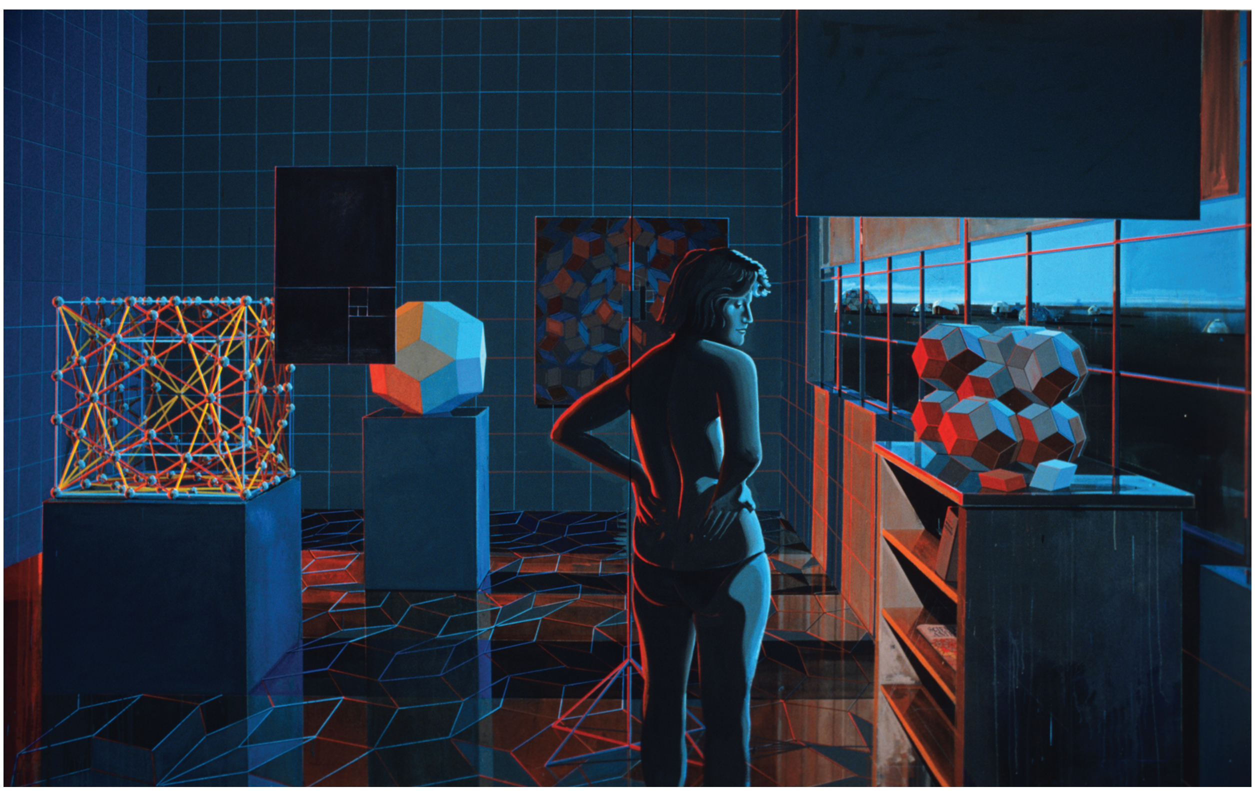
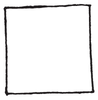
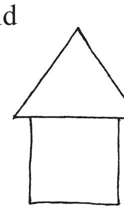


Figure 1: *"The True Story of the Quasicrystal," 84"x136," Clark Richert, 1989. (Drop City seen through window.)*

We all learned how to build a house in kindergarten:



You start with a square,



stick a triangle on top for the roof,

then add windows, a door, a chimney, the sun, maybe some trees (or maybe not, if you are living in the Great American Desert).

This is the way most houses are built in the USA. The contractor nails together (some variation of) a 3-dimensional square out of 2x4s, adds triangles (cross-braces) when he finds it's not too stable, then cuts in windows, doors, etc. (sun and trees are an afterthought). Or he stacks cinder blocks like kinder-blocks.

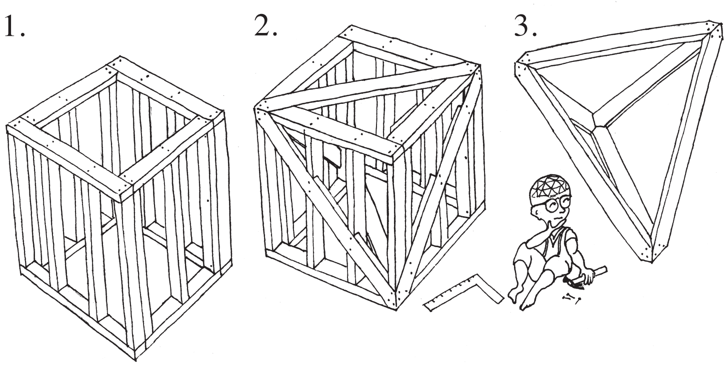


Figure 2: *A cube(1), stabilized with cross-braces (2). If you remove the cube, you get a tetrahedron (3).*

When Buckminster Fuller built a house in kindergarten, he *started* with triangles. Fuller was introduced to the 19th Fröbel [2] gift, toothpicks and peas, in an early 20th century kindergarten in Milton, MA. Other students built strutctures out of squares, but Fuller, with his bad eyesight, chose triangles: "pushing and then pulling, I found the triangle held its shape when nothing else did." [3] Triangles are inherently stable; squares... not so much. Fuller's natural attraction to the triangle eventually led him to the oct-tet truss and the geodesic dome. [4]

Artists at Drop City were also attracted to the triangle, perhaps because they didn't want to be "square." Their standard construction unit was the car top, hacked off an auto using an ax, sold at the local junkyard for 25 cents. They folded the edges with a bending brake and bolted them together with sheet metal screws. An argument about the cost of construction: *Clark* - "We built this house for $7." *Richard (emphatically)* - "No, it was *$14!* You forgot the cost of the screws!" [5]

Building with Triangles

The (equilateral) triangle offered a more versatile library of shapes than the square. Bolt together 3 car-top triangles, you get a pyramid/tepee shape, with a 4th triangle for the dirt floor: a tetrahedron. This would make a fine chicken coop. Four triangles around a point generate a pyramid with a square floor: half an octahedron; a dog house. Five triangles around a point generate a pentagonal pyramid: the top of an icosahedron. Keep adding triangles, 5 around every point, you get a dome with a pentagonal floor that a person could (barely) stand up inside: an outhouse.

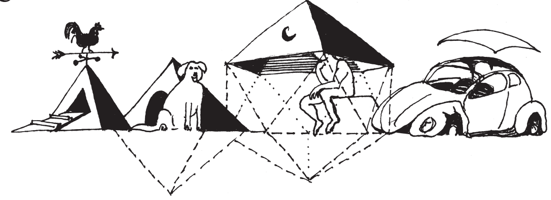
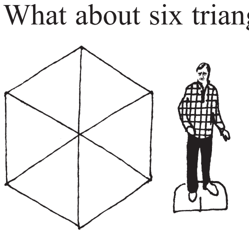


Figure 3: *Fun with triangular car tops.*

What about six triangles around every corner? You get a flat hexagon. It's not really suitable for a house,



unless you live in two dimensions. Then you could pretend it's a cube. Of course, the hexagon is only flat when you use equilateral triangles. If you shorten any of the lines, even slightly, it would pop out of the plane, into three dimensions (a point not lost on Fuller, who used tiny variations in edge-length to force curvature in his domes). So how could the Droppers build larger, without resorting to stacking up cubes like kindergarten blocks?

Birth of the Geodesic Dome

Fuller said the idea for the geodesic dome came to him when he was contemplating suicide. He was 29, a jobless Harvard drop-out with a head full of ideas and a wife and a baby to support. As he stared into the bubbles coming up from the floor of Boston Harbor, he started to wonder how nature approximates a sphere out of points and lines at the interface between air and water molecules.

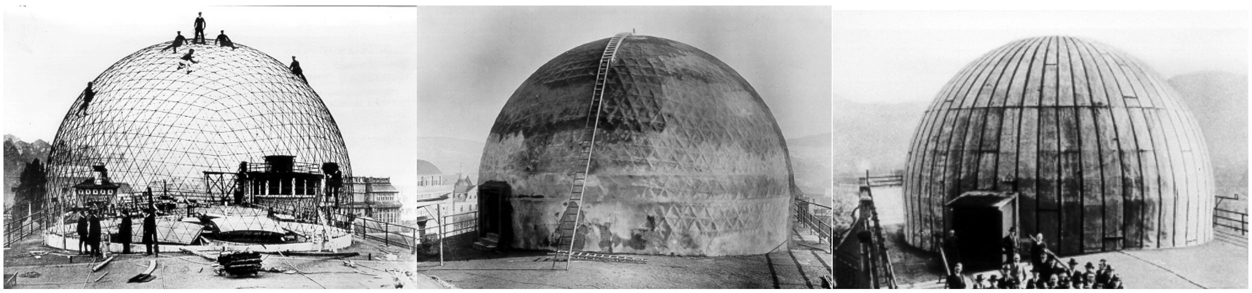


Figure 4: *Carl Zeiss Planetarium, Jena, Germany, 1922. The steel framework was sprayed with concrete.*

Like other great inventions, somebody else had the same idea at about the same time. Dr. Walter Bauersfeld, Chief Designer for Carl Zeiss AG, realized a geodesic dome as a metal framework for a sprayed concrete planetarium at the company's headquarters in Jena, Germany, a few years earlier (1922 vs. 1924). Both men had the same goal of rationalizing an irrational number, π, by breaking up a sphere into a discrete number of straight lines and points. This gets complicated, because the lines are almost (but not quite) the same length, and they meet at angles that are also almost (but not quite) the same angle. The result is a lot of tedious calculations and special care when putting the thing together. In Baer's words, a "complicated way to make a simple shape."

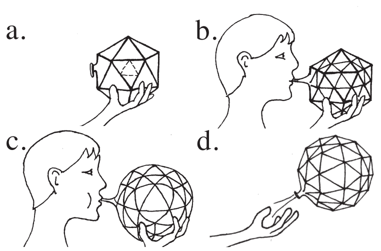


Figure 5: *Geodesic inflation*

"Droppers" (as they called themselves) started their approach to geodesic domes with the dodecahedron and shortly thereafter the icosahedron. Imagine a balloon stretched around an icosahedral framework (a). Subdivide each triangle (bisect each edge to get 4 triangles per face, etc.(b)) and inflate the balloon to project the triangulated icosahedron onto the surface of a sphere(c). If you keep the vertices (where the lines intersect) on the surface of the sphere and allow the lines to relax into straight segments, you get a geodesic sphere (d).

Birth of Zome

Baer also started with the icosahedron, but he didn't try to turn it into a sphere. In Germany in the early 1960s, Baer was introduced to a toy version of MERO's cube-based space-frame system. He wondered if there was an underlying structural system based on the icosahedron, and with colleagues later discovered that a line from any vertex of an icosahedron to its center was about 95% (cosine 18º) of the length of any edge. Asked about how he figured this out, Baer replied, "That's where the pipes bumped into each other."

Likewise, they discovered that a line from any vertex of a cube to its center was about 86% (cosine 30º) of the length of any edge. These simple relationships formed the basis of Baer's 31-zone system: the edges of the cube and icosahedron (with a length of 1) became the Zometool's blue lines, while the cube-center diagonal became the yellow line and the icosahedron-center line became Zometool's red line. Clark Richert later added the face diagonal of the cube (cross-braces illustrated above), with a corner-to-center length of about 71% (cosine 45º) of its edge. This became Zometool's green line.

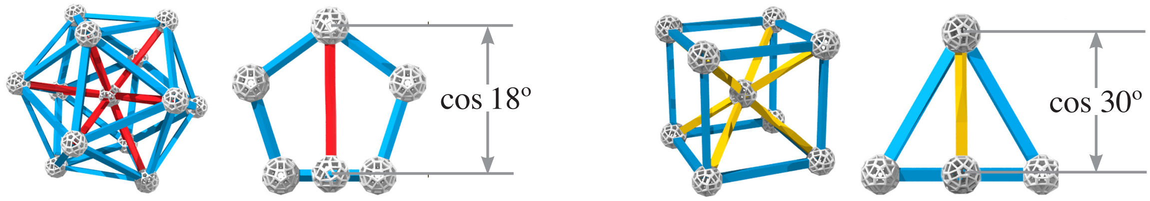


Figure 6: *Baer discovered Zometool's red lines by comparing the length of the edge of an icosahedron with the length of a line to its center. Yellow lines can be derived from a body-centered cube (or dodecahedron).*

Bear and colleagues also realized that relationships among these lines include the Golden (τ) and Silver (δ_S) Proportions. In contrast to Bauersfeld and Fuller, who attempted to rationalize π, Baer and colleagues observed the irrational numbers τ (($\sqrt{5}$+1)/2) and δ_S ($\sqrt{2}$) naturally emerging from simple, whole number spatial relationships. The fact that they realized these relationships were part of a single, coherent system that could be manufactured as discrete components is, on the whole, miraculous. Baer (who's not given to hyperbole) said he "was high for 2 weeks." [7]

Figure 7: *Baer zome (directly above the horse) stood in contrast to more geodesic Drop City structures*.

Conclusion

Not even Baer comprehended the depth of his discovery. In the years since, the 61-zone system has helped illuminate such concepts as quasicrystals, fullerenes, and hyper-dimensional theories of everything. But the folks at Drop City were content build and live in domes and zomes, perhaps giving us a brief glimpse of the architecture of the future. Of course, the domes leaked too.

References

[1] Steve Baer. *Zome Primer*. Zomeworks Corporation, 1970
[2] Norman Brosterman. *Inventing Kindergarten*. Abrams, 1997
[3] Karen Goodman and Kirk Simon. *Buckminster Fuller: Thinking Out Loud.* Zeitgeist Films, 1996
[4] R. Buckminster Fuller. *U.S. Patent # 2,682,235*. 1954
[5] Richard Kallweit and Clark Richert. *(previously) unpublished conversation*. Circa 1969
[6] Firma Carl Zeiss in Jena. *Reichspatentamt Patentschrift Nr. 415395*. 1925
[7] Steve Baer. *(previously) unpublished conversation with Hildebrandt*. Circa 1989