# Zome-inspired Sculpture

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*"There's something irritating about doing something right by accident" -- S. Rogers*

## Abstract

An invitation to build 1) permanent, Zome-inspired sculptures 2) designed and built as a collaborative effort under the name of fictitious artist(s), 3) as much about art as mathematics, 4) which could serve as the basis for large-scale architectural projects for the 21st century 5) to be installed at Bridges venues, as possible, on an ongoing basis.

I'll give a little background about Zome, survey some sculptures and artists, and discuss the guidelines above in more detail. There are no designs yet. This is an invitation to get started!

## 1. Introduction

Zome seems best described by analogy. I call it a language for understanding the structure of space; Zometool Inc. cofounder Marc Pelletier has called it "frozen music."

If Zome is music, it's currently "played" on two instruments: kits of plastic balls and struts (distributed as an educational toy, mathematical manipulative and research tool), and vZome software. But just as music isn't limited to two instruments, Zome cannot be restricted to its current software and hardware incarnations. There are many ways to express Zome's elegant mathematics, and sculpture is a good medium to begin exploring possibilities.

If Zome is a language, most of us are illiterate. A few mathematicians and scientists have jotted down "shopping lists," [1] while artists like Jean Baudoin and Steven Rogers have composed "Haiku" in this new language. No one has ever written a short story, let alone a book. This is an invitation to do so; to form a team of artists to explore the richness of Zome's geometry as an artistic medium, to build sculpture(s) that inspire a deeper appreciation of both mathematics and art, and plant a seed for bolder projects. We may not "write a book," but even a few coherent paragraphs would be a good start.

## 2. Background

**2.1. What it is** -- Without the crutch of analogy, describing Zome concisely is a challenge for me. In Zome Primer, his classic introduction to this discovery, Steve Baer describes Zome as a [structural] "system based on the 31 lines that pass through the center of an icosahedron and either a vertex, edge midpoint or face midpoint, [which] is new and unusual." [2] David Richter claims that Zome geometry can be derived from the $E_8$ lattice [3]. Marc Pelletier's assertion that Zome is a projection of a 61-dimensional hypercubic lattice into 3-space works best for me, but leaves a lot of other lay people scratching their heads.

In its current physical form, the 61-zone system, Zome balls and struts represent points and lines which define regular 2, 3 and 5-fold symmetries in space. Each point in the 61-zone system generates an array of 122 vectors determined by the edge midpoints (blue lines), vertices (yellow lines), face midpoints (red lines) of the regular dodecahedron and the edge midpoints (green lines) of the 5 cubes associated with same. Lines follow the 122 vectors with respective lengths in Divine Proportion ($\tau$) powers of unity, cosine $30^o$, cosine $18^o$, and cosine $45^o$:

$A\tau^n$, where A = unity, cosine $30^o$, cosine $18^o$, or cosine $45^o$
$\tau = (5^{1/2}+1)/2$, and
n = 0,1,2...

The integers 2, 3, and 5 are the first three primes as well as Fibonacci numbers, and their incestuous spatial relationships have been explored by artists and mathematicians for centuries. Ratios of consecutive Fibonacci numbers are rational approximations of the Divine Proportion – which resonates throughout Zome geometry. Various claims and counterclaims have been made concerning Fibonacci numbers, the Divine Proportion and our inherent sense of beauty. Whether these relationships play into your sense of beauty is a subjective question, but they do for me.

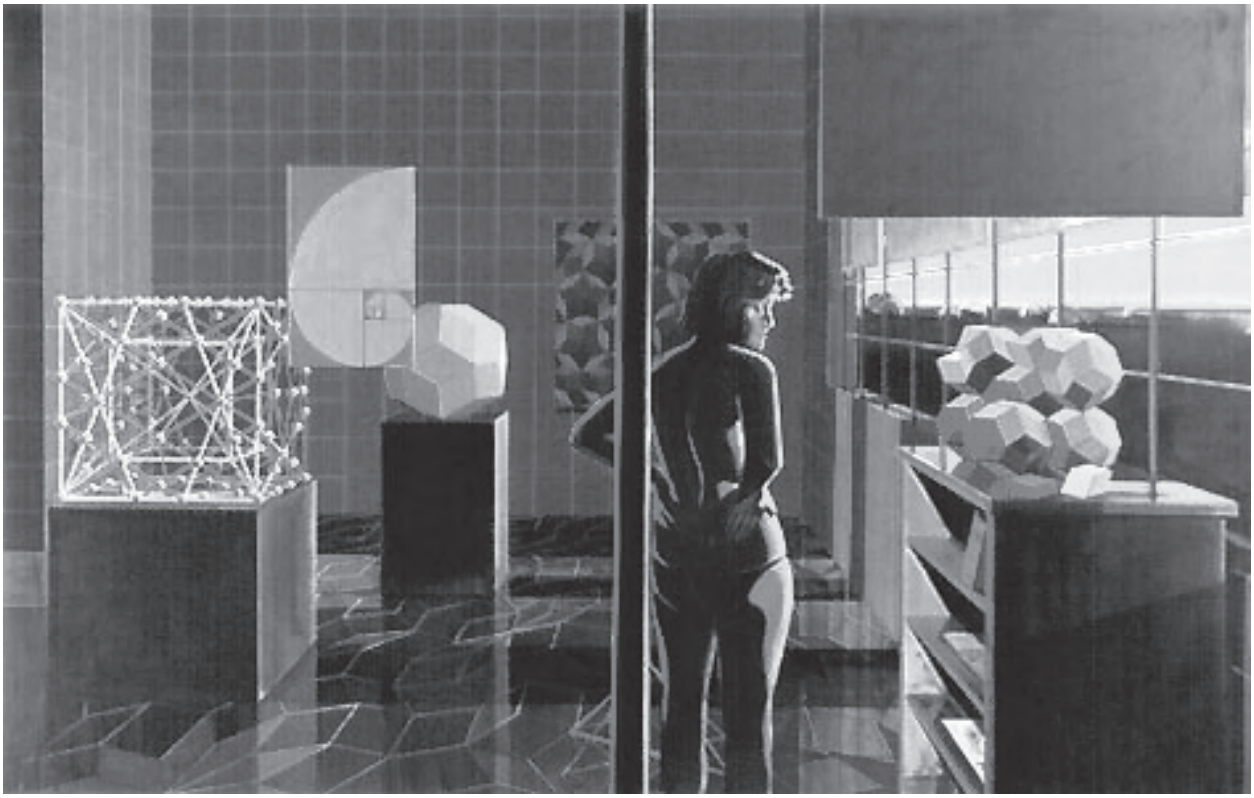


**Figure 1:** *Clark Richert's "True Story of the Quasicrystal" (with Drop City in the background)*

**2.2. History** -- Zome was born of a confluence of art, architecture and mathematics. Steve Baer and associates discovered the 31-zone system while searching for a structural system based on the geometry of the icosahedron, and artists at Drop City adopted the geometry as an alternative to geodesic domes. The mathematics of Zome was derived from explorations in art and architecture, and its appeal seems to be related to the natural beauty and structural versatility of icosahedral symmetry and the Divine Proportion.

Artists Clark Richert and Gene & JoAnn Bernofsky conceived of Drop City in Spring of 1964. Their antecedent art events, "Droppings," were highly informed by the "Happenings" at Black Mountain College and the work of R. Buckminster Fuller. "We envisioned a whole city as a live-in work of Drop Art." [4] So they bought 7 acres of pasture near Trinidad, Colorado, and founded Drop City. Living in sculptures turned out to be somewhat impractical, so they built geodesic domes from car tops purchased at a nearby junkyard.

In his artistic explorations, Richert discovered quasiperiodic tilings in 2 and 3 dimensions at about the same time Sir Roger Penrose sought them in his mathematical research [5]. These mathematical and artistic explorations preceded by roughly two decades the physical reality of quasicrystals, which were discovered by Dan Shectman in 1984 and previously thought to be impossible.

While Drop City was growing, Steve Baer started Zomeworks Corporation to seek commercial applications of the 31-zone system, which he and his associates discovered in 1968. Most of the applications were architectural, although Zomeworks also built playground climbers, a monkey cage at the Albuquerque zoo, and they manufactured Zometoy, the predecessor to the Zome modeling system in its current form. Years later, when asked how he derived the Zome's exquisite mathematics from his structural research, Baer remarked, "that's where the pipes ran into each other [so we had to cut them in Divine Proportion ratios.][5]"

In a curious parallel to Richert's and Penrose's explorations, French artist and master carpenter Jean Baudoin independently discovered the 15-zone system (Zome's blue lines) about the same time Baer and associates discovered the 31-zone system (Zome's blue, yellow and red lines.) Baer introduced Richert et al to the concept of zomes [6] when he visited the Drop City in 1969, spawning a rich cross-pollination of ideas that ultimately led to Zome in its present forms [7].

## 3. Some Sculptures and Artists

There is a tendency to see Zome as a medium for modeling purely mathematical ideas. It is a uniquely elegant means of mathematical expression, but not to the exclusion of more fanciful artistic explorations. Following is a discursive survey of sculptures and artists related in some way to Zome, ranging from purely mathematical models to more artistic expressions. If you see your name in this section, you're invited to participate. If you don't, but think it should have been included, you're also invited. If you'd just like to join in, please do. I'd especially like to hear from Johannes Kepler, Paul Donchian and Jean Baudoin.

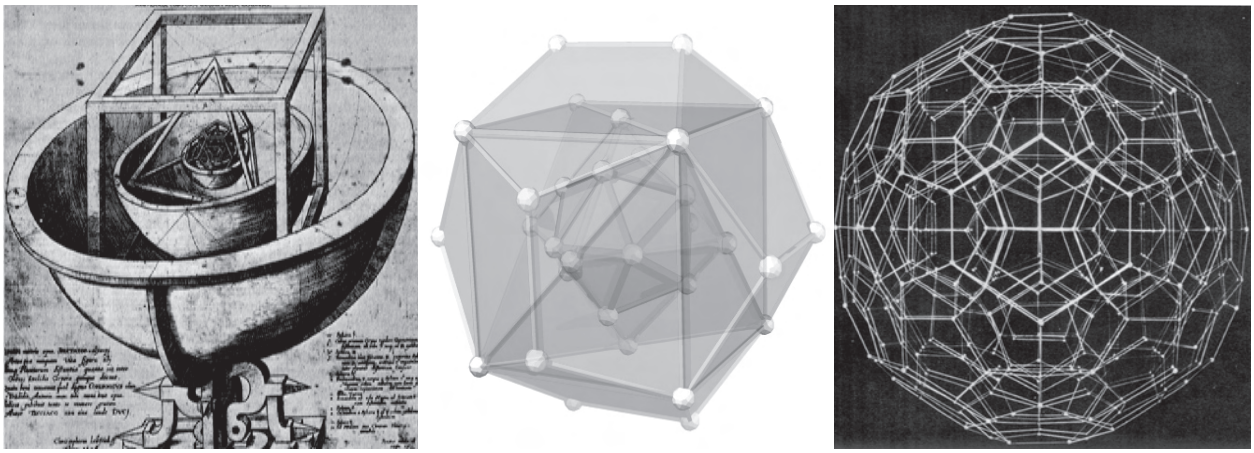


**Figure 2:** *Classic mathematical models: Kepler's "Weltgeheimnis" (left), Conway's "Cosmogram" (center) and Donchian's 120-cell (right)*

**3.1 History** -- Johannes Kepler's "Weltgeheimnis [8]," which nested the five Platonic solids in five concentric spheres, was a kind of 17th century theory of everything, providing a complete explanation for the number of known planets and the distances between them [9]. There must be scores of ways to model the relationships among the 5 Platonics in Zome. My favorite is John Conway's "cosmogram," a simple, 3-dimensional way to see how the Divine Proportion "falls out" the natural inter-dependence among 2-, 3- and 5-fold symmetries, which could be called the "Rosetta Stone" of Zome.

Paul S. Donchian [1895-1967] built dazzling models of projections of 4- and higher-dimensional figures. According to Donald Coxeter, after a "series of startling and challenging dreams of the previsionary type… he determined to make a thorough analysis of the geometry of hyperspace. His aim was to reduce the subject to the simplest terms, so that anyone like himself with only elementary mathematical training could follow every step. For this purpose he devoted many years to the task of making… exquisite models [10]." Some of these would qualify as sculptures, such as the projections of the 120-cell {5, 3, 3} and 600-cell {3, 3, 5} featured in Regular Polytopes [11] . He painstakingly soldered these models together from wire segments, taking up to 2 years to complete one. Many of Donchian's surviving models are suffering from benign neglect at the Franklin Institute in Philadelphia [12].

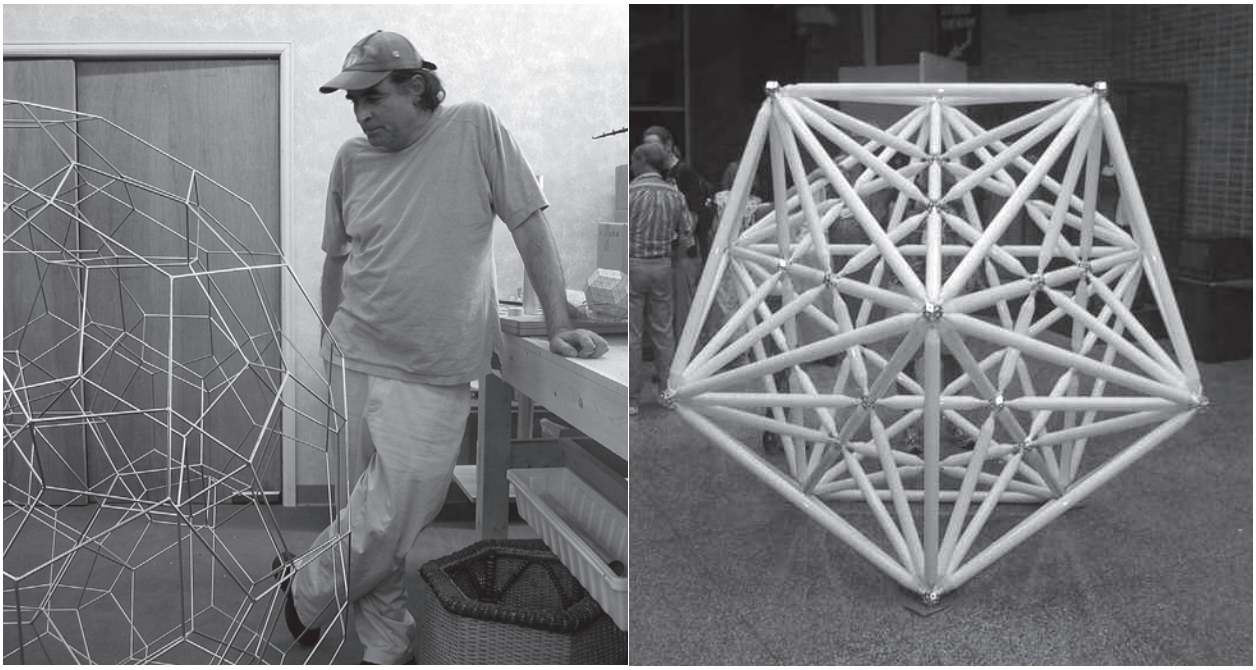


**Figure 3:** *Marc Pelletier with his 120-cell before installation at the Fields Institute for Coxeter's 95th birthday (left) and a stellated dodecahedron in an icosahedron by Pelletier and Chris Kling (right).*

**3.2 Recent events** -- Zome cofounder Marc Pelletier built several sculptures of the120-cell from welded stainless steel rods. One was anonymously donated to the Fields Institute in Toronto, to honor Coxeter on his 95th birthday on February 15th 2002. Pelletier also developed, with Chris Kling, an architectural-scale version of Zome's versatile blue lines, introduced at the Bridges Conference in Towson University, Towson, Maryland in July 2002. They built a model of a stellated dodecahedron inside an icosahedron, using 32 aluminum nodes of some 500 manufactured. A spectacular array of far more beautiful and complex sculptures would be possible using this giant Tinkertoy kit. Kling's company, Aurodyn Inc., is advancing architectural applications of Zome geometry. Pelletier has also collaborated with Chris Palmer, exploring decorations of zonohedral structures based on traditional Islamic patterns. Their work demonstrates Baer's assertion that all aspects of a piece, from gross structure to fine detail, can be derived from one simple, elegant system.

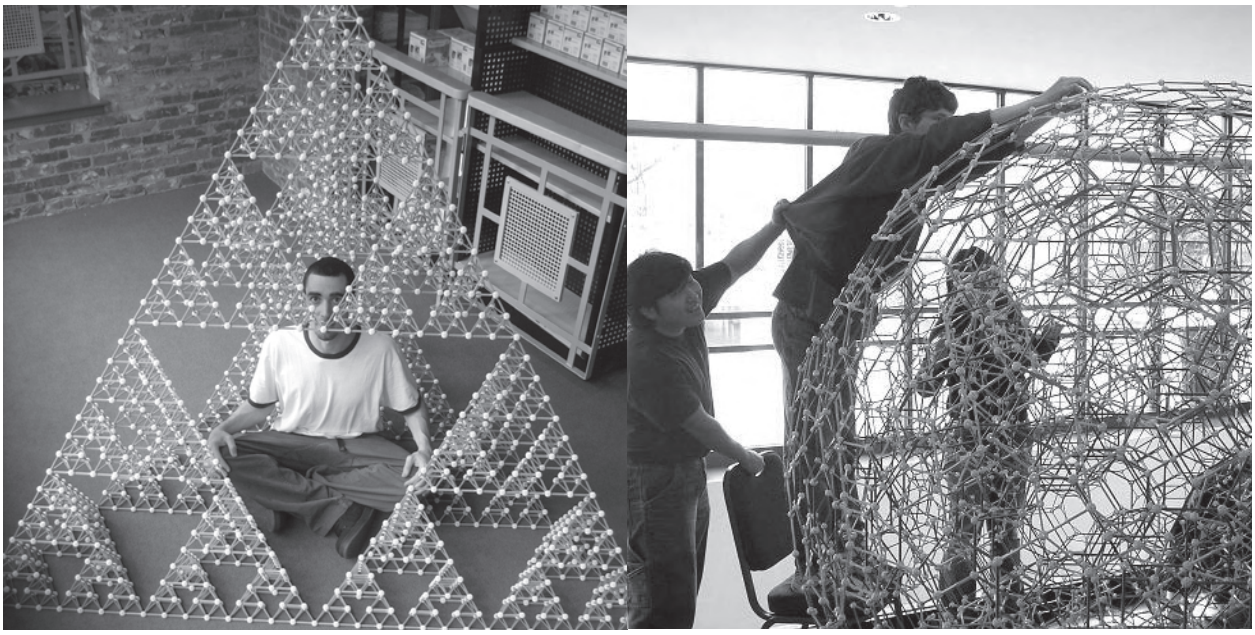


**Figure 4:** *Dan Duddy's Sierpinski tetrahedron (left) and George Hart's "Truncated Ambo 600-Cell," under construction (right).*

Professors David Richter and George Hart, and mathematics student Dan Duddy build large-scale "rZome"[13] mathematical models. Among his larger projects, Duddy built a 6' Sierpinski tetrahedron from 6,000 Zome components in about 30 hours. Hart and Richter have spent much time exploring the 15 rZome constructible "shadows" of 4-dimensional figures in the H4 group [14]. Richter and Duddy organized a team to build the cantellated 120- and 600-cells at Bridges 2005 in Banff; Hart has led numerous workshops to build these and other interesting mathematical models, sometimes involving scores of human-hours with part counts exceeding 10,000. An artist in his own right, Hart's permanent sculptures wax whimsical.

Jean Baudoin, Fabien Vienne, Sam Verbiese and Steve Rogers have mined Zome's richness as an artistic medium. Rogers has built dragons with a Chinese "flavor" based on projections of 6- and 10-dimensional cubes, and explored a world of nanotechnology during his "carbon phase." In 2004, Rogers also discovered that models such as the hyperbolic parabaloid could be generated as ruled surfaces in Zome, opening another world for artistic and mathematical explorations [15].

**Figure 5:** *Sculptures by Steven Rogers (left), Jean Baudoin (middle), and Sam Verbiese (right.)*

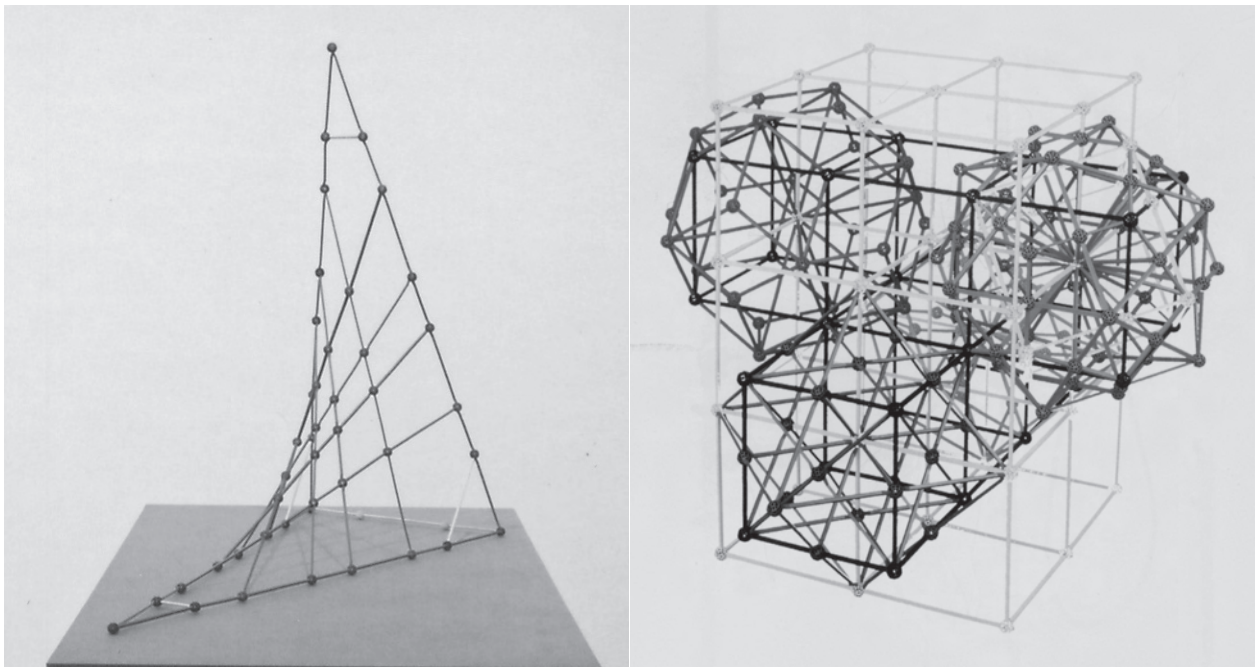


**Figure 6:** *Two Zome sculptures from the 2004 biennial "Formes Utiles" exhibit -- a ruled surface informed by Steve Rogers, and Fabien Vienne's CubeSpace.*

Samuel Verbiese is a versatile Belgian artist who has installed a number of Zome-inspired scultures, including a meta-zome [16] representation of the Atomium (a monument originally built in Brussels, Belgium, for the 1958 World Fair [17].) The artist generally calls his Zome models "expressions of art" but hesitates with the MetaZome Atomium, as it was an expansion of a known structure. However, it relates to the idea of using Zome-inspired sculpture to catalize a visionary architectural project in section 4.4.

As a co-discoverer of Zome geometry, Jean Baudoin outlined some of the most poetic manifestations of the system over the course of 30+ years. His design for la Géode in the Cité de la Science, Paris, was a powerful expression of Zome's architectural versatility. Unfortunately, the proposal placed 2nd in the design competition, after a more regressive utopian design [18]. It's a tragedy that Baudoin's work remains largely unknown [19]. The artist died in 2002.

Baudoin and Fabien Vienne co-designed the Zome's GreenLines. Vienne is also an accomplished artist and designer whose work with Scott Vorthmann, Marc Pelletier and others has helped to extend the understanding of Zome geometry from 61 to 181 zones. He was responsible for installing several Zome sculptures in the 2004 biennial "Formes Utiles" exhibit in the Musées Art Moderne in St. Etienne, France.

## 4. Guidelines for the Zome-inspired Sculpture Project

I hope many artists and mathematicians will participate in designs for Zome-inspired sculptures. Here's an explanation of guidelines outlined in the abstract:

**4.1 Permanent, Zome-inspired sculpture** – rZome components are an excellent medium for 3-dimensional sketches, but not ideal for permanent installations. The material is subject to UV degradation and the primary colors are corny (although a great shorthand for 2-, 3-, and 5-fold symmetries.) rZome components

also impose artificial limits on design: for example, the fractal nature of Zome can be shown in a MetaZome structure, but as an infinitely iterative process, it's not practical -- after two generations, the models falter under their own weight. But the sculpture should be "Zome-inspired," because (1) the anonymous donor who is funding the project has a keen interest in popularizing Zome, and (2) keeping the sculpture within Zome's mathematical framework can give the project visual and spatial coherence.

**4.2 A collaborative effort under the name of a fictitious artist** – Like Coxeter, the Zome sculpture team should be "guided almost completely by a profound sense of what is beautiful." [20] Collaborative work suggests that no one person is responsible for the design or execution of the sculpture any more than any one person was solely responsible for the discovery and development of Zome – it's an ongoing process, just as I hope the sculpture will pave the way for more and better art and architecture. No fictitious name for the team has yet been suggested. Any ideas?

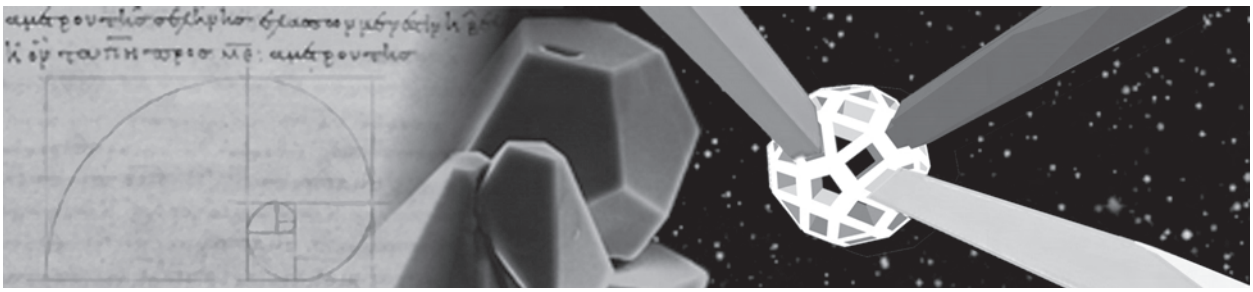
**4.3 As much about art as mathematics** – If Bridges Conferences are a call "to regain the lost mutual understanding" among artists and mathematicians, as well as "between mathematicians and the general public," this project hopes to tip the scales in favor of the artists and the general public. Bridges seems mathematics-heavy and art-light. Most artists and ordinary folks paging through the proceedings would find some images interesting, some obscure, and much of the text abstruse. I'd love to see more art for the sake of balance. After all, drawing a distinction between "mathematical" and "non-mathematical" art is silly, since everything that streams into our senses can be interpreted as mathematics.

**4.4 To serve as the inspiration for a visionary architectural project for the 21st century** – Where is the Eiffel Tower of the 21st century? Engineering feats like the Eiffel Tower, built for the 1889 Paris Universal Exposition, or the Ferris Wheel, constructed for the 1893 Chicago fair, inspired confidence in many fairgoers in the capacity of the world's fair organizers to engineer a better future. [21] While serving on Zometool Inc.'s board of directors in the 90s, Steve Baer suggested building a Zome-inspired architectural wonder at an apocryphal Y2K Expo to be located on the site of Drop City [22]. Fuller's geodesic sphere for the U.S. Pavillion at Expo '67 in Montreal was probably the last truly visionary structure paraded before the eyes of the world. It's time to change that.

**4.5 To be installed at Bridges venues, as possible, on an ongoing basis** -- Installations could be patterned after George Hart's "geometry barn raisings," as regularly scheduled conference events. [23]

## 5. Conclusion

Based on relationships among 2-, 3- and 5-fold symmetries and the Divine Proportion, Zome offers rich and scarcely explored possibilities as an artistic and architectural medium. Installing permanent, Zome-inspired sculptures at Bridges conference venues offers opportunities to more deeply mine those possibilities, and perhaps write a few coherent paragraphs in the "language" of Zome.



## Notes and References

[1] including Roger Penrose, Richard Smalley, Dan Shechtman and Linus Pauling
[2] Steve Baer, *Zome Primer*, Zomeworks Corporation, 1970, page 2
[3] David Richter, "Two Results Concerning the Zome Model of the 600-Cell," *Renaissance Banff Conference Proceedings*, 2005, pages 419-426
[4] "the real concept was to create an artists' community whose purpose was to provide food, clothing, studio space and housing for artists who would live their art" – Clark Richert, from personal interview in February, 2006
[5] Penrose points out that the critical difference between his tilings and others based on 5-fold symmetries (including Richert's and Kepler's) is his matching rules, which force periodicity, a point missed by many writers for popular media (and me, until I asked him about it in March 2006)
[6] from conversation with Baer after Zometool Inc. board meeting in 2002
[7] The word "Zome" was originally coined by Steve Durkee in 1968 as a conflation of the words "zonohedral" and "dome." See the Dome Cookbook, Lama Publications, 1970 (revised), page 24
[7] Richert suggested Zome's green lines in the early 70s; in 1997 Baudoin and Fabien Vienne designed a version to be compatible with the original shape-coded Zome node. Marc Pelletier suggested extending Zome's geometry from 61 to 121 zones in the 80s and Vienne, Scott Vorthmann, Brian Hall, David Richter and others are pushing Zome "to infinity and beyond"
[8] Literally, "universe-secret"
[9] In proving his theory wrong, Kepler discovered his three laws of planetary motion and launched the modern study of celestial mechanics
[10] H.S.M. Coxeter, *Regular Polytopes*, 1947, Dover, pg. 260
[11] Ibid, pages 161 and 177
[12] Marc Pelletier has been archiving photos of Donchian's work, a presentation of which is available at http://www.fields.utoronto.ca/audio/01-02/sculpture/pelletier/index.html?8;onesize#slideloc.
[13] "rZome" means "real Zome" vs. "vZome" for "virtual Zome"
[14] Scott Vorthmann integrated H4 mathematics into his vZome software package, available at http://www.vorthmann.org/zome/
[15] Rogers also contributed a number of key innovations leading to Zome's current form, among them, a method for modeling the first truncated triacontahedral Zome node and the design for Zome's "clicks"
[16] I.e., you can use the balls and struts to build bigger balls and struts. The term "MetaZome" was coined in 2002 by Andrew Mihal, at the time an Engineering PhD student at UC Berkeley.
[17] see http://www.atomium.be
[18] The winning entry was a mirrored sphere informed by the work of 18th century visionary architect, Claude Nicolas Ledoux (1736 - 1806)
[19] Pelletier rescued and archived a great deal of Baudoin's work, although even more has been lost
[20] Siobhan Roberts, "Donald Coxeter: The Man Who Saved Geometry," *Toronto Life*, January 2003 (quoting Robert Moody)
[21] Rydell, Robert W. et al, *Fair America*, Washington, Smithsonian Institution Press, 2000, p135 With their spectacular technological and ethnological narratives, fairs engaged in a mission of "manufacturing consent," the alternative to which, in the eyes of the ruling elites who organized the fairs between 1876 and 1916, was social and political revolution. If promoters of world fairs resisted social revolution, they boosted technological revolution, witnessed by the reaction of the Parisian "protectors of art" to the Eiffel tower: "We, the writers, painters, sculptors, architects and lovers of the beauty of Paris, do protest with all our vigour and all our indignation, in the name of French taste and endangered French art and history, against the useless and monstrous Eiffel Tower." --Maupassant, Emile Zola, Charles Garnier (architect of the Opéra Garnier), and Dumas the Younger (among many others.)
[22] Ironically, Drop City was portrayed by the media as the antithesis of naïve faith in salvation through technology (although the Droppers, informed by R. Buckminster, considered themselves pro-technology.) Clark Richert recalls a myth that on July 20, 1969, as Commander Neil Armstrong stepped onto the moon, network TV news planned to cut to Drop City for a counterpoint state of affairs on planet earth, a move that the editors nixed in the last moment. Media-wary Droppers once worked out a deal with CBS reporter Terry Drinkwater, agreeing to grant interviews if he didn't use the words "drugs" or "hippies" in his story. Of course, the segment opened with "hippies taking LSD" at Drop City.
[23] Thanks to Phillip Kent, photos of a proposed space at the London Knowledge Lab can be viewed at http://www.lkl.ac.uk/bridges/LKL%2Dphotos/. We are working on a "test" installation for Bridges 2006.

*"Civilization's greatest achievements all but wreck the societies in which they occur." -- A. N. Whitehead*