

Comet!

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Abstract

Swooshing across the science center atrium at Albion College, my sculpture *Comet!* is over 100 feet long from one end to the other. It consists of nine different orbs of powder coated aluminum suspended by chain from the ceiling, each between 42 and 48 inches in diameter. They can be seen as 3D slices of a four-dimensional sculpture which is visibly polyhedral at the start and gradually morphs into an intricate flower-like final form. Each stage has a darker core structure intertwined with a lighter tangle. The initial orb is colored with two shades of light yellow, successively deeper shades of orange are used in the middle of the room, and rich reds appear at the far end. Viewing each component in turn, the final orb can be understood in logical steps, like a mathematical derivation. On the construction day, after three years of planning, over one hundred members of the Albion college community—students, faculty, and others—worked with me to assemble it at a large public “sculpture barn-raising.”

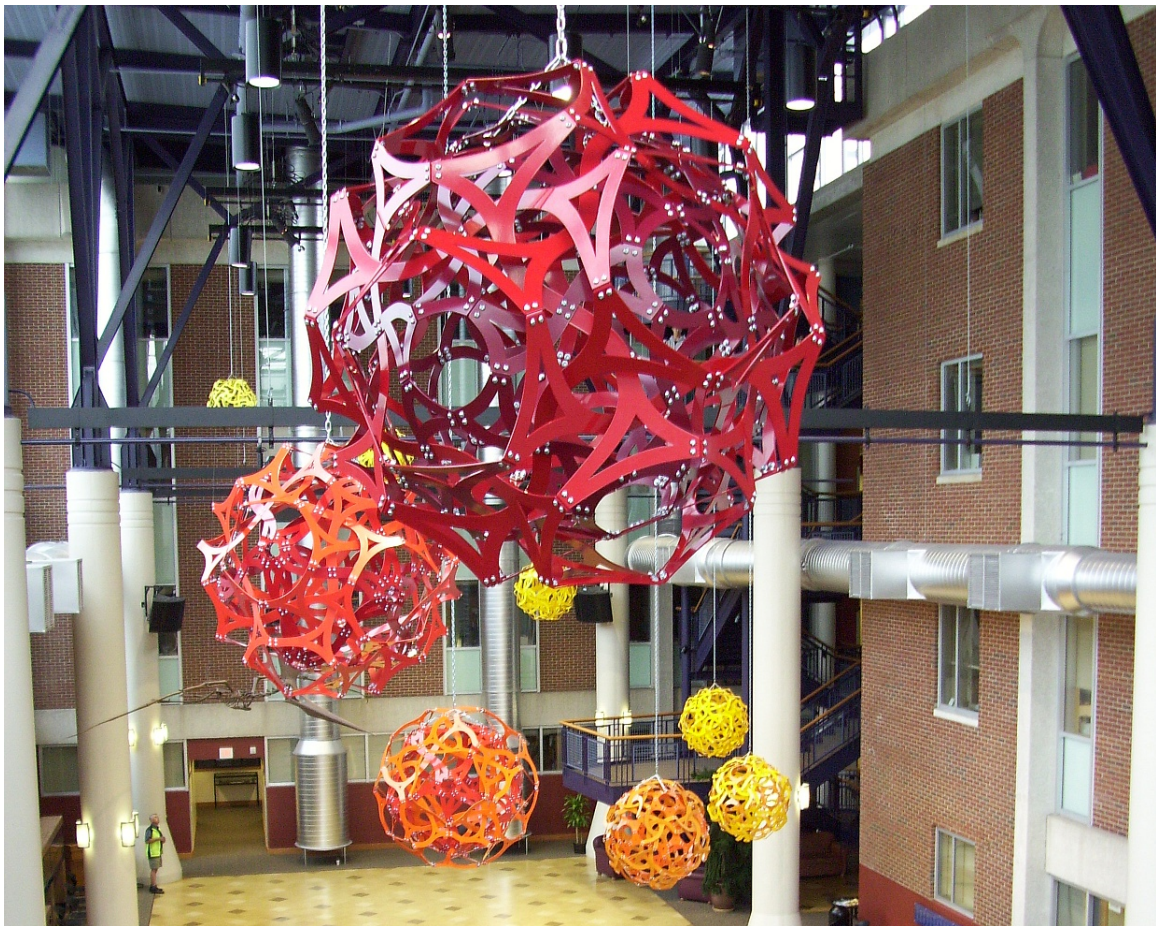


Figure 1: *Comet!* aluminum, with steel connectors, 100'

Design and Preparation

Mathematical sculpture celebrates the aspect of what it means to be human that centers on our innate attraction to form, pattern, and structure. I enjoy creating such artwork and involving others in the assembly process. Spread out over a period of more than three years, I led a project to create a large mathematical sculpture for the newly constructed Science Center atrium at Albion College, in Albion, Michigan. The project culminated in a public assembly event on Saturday, September 13, 2008, where thousands of pre-cut metal parts were assembled into a series of colorful orbs and lifted into the air. The sculpture, called *Comet!*, is permanently suspended along a curved path in the atrium for all to enjoy. Figure 1 is a view from the end of the room closest to the ninth orb.

Comet! consists of nine orbs, each made of 90 laser-cut aluminum parts joined with 120 laser-cut steel brackets and held together by 600 nuts, 600 washers, and 600 bolts. That makes a grand total of 18090 parts not including the suspension chain and connection hardware. The laser-cut steel and aluminum parts were first powder coated in ten different shades, being careful to keep track of different shades for connector brackets with two different dihedral angles. Although I designed the sculpture and supervised its construction, this was certainly not a one-man job!

I was first contacted early in 2005 by Albion faculty with the idea that their new Science Center would be enhanced by the inclusion of a mathematical sculpture. After some discussions and planning, I visited the campus in October 2006 to present a talk on mathematical sculpture and view the site. On seeing the atrium space, I was attracted to the architectural design, which includes a floating bridge with a floating staircase down to the ground level, plus a well thought-out four-story staircase with varied projections into the space. Large glass walls to the outside and windows from surrounding offices allow viewing objects in the space from additional points of view. My main concern was the large size. I didn't think I could make something sizable enough to fit properly in such a vast volume. In discussion with the core group of Albion faculty on the project—David Reimann, Darren Mason, and Gary Wahl—we came up with the idea to have a multipart sculpture which would span across the space. They wrote a proposal for funding the project, emphasizing interdisciplinary connections between mathematics, computer science, and the arts, and pointing out the value of a public sculpture barn raising to the academic and broader community.



Figure 2: Helium balloons, for positioning

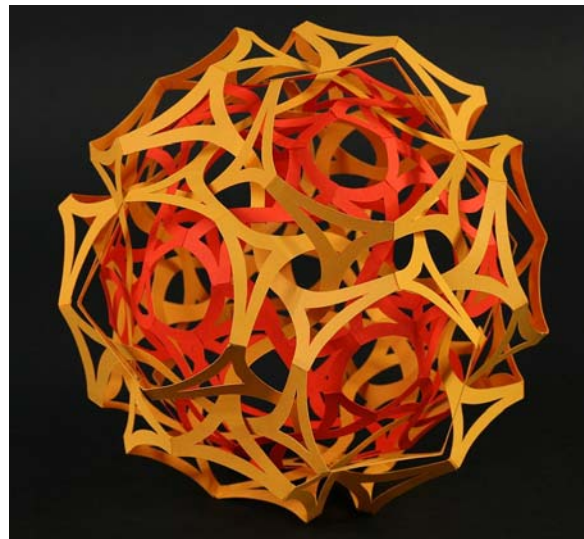


Figure 3: Six-inch paper model of orb nine

The proposal was approved, additional funding was also found, and I began detailed work on the design. The atrium roof is divided into nine bays by support beams and there were lights, dinosaurs, and projection equipment already suspended from those beams that had to be worked around. From the architectural plans, I selected approximate locations for the nine orbs to hang at the midlines of the nine bays. They would each hang from a “V” of chains tied to two dividing beams, so as to be clear of the existing obstacles. On my second trip to the campus, we placed nine helium balloons in the space to get a sense of the nine positions. We tied these to chairs so we could move them around and adjust the height of the strings. We viewed them from all vantage points and measured their positions. Figure 2 shows the balloons in place. From the balloon measurements, we made plans for chain to be suspended down from the beams to the appropriate height for each.

The path of orbs starts high at one end of the room, where it can be seen through windows from the outside street, swoops dramatically down towards the floor to engage the viewer, bends back and up to follow the curve of the internal stairway, then makes a reverse hook over the floating bridge for a close-up finish. Along the way, the path stays clear of the suspended fossil dinosaurs and tries not to block the light beam between a digital projector and its screen. By walking around and through the space, the viewer has opportunity observe the sculpture from above, below, and all sides.

I had considered many ideas and made many sketches for the design of the nine individual orbs. In the end I narrowed them down to two design proposals which I brought to the faculty at Albion for feedback. In Plan A, the nine orbs were identical in structure except that small curving appendages varied from one to the next to give a sense of a swimming motion. This underlying uniformity of design would have simplified the logistics significantly. Plan B involved nine different structures, entailing a much more complex design, fabrication, and assembly process, but would result in a much richer final result. I made a paper model of the ninth orb from the Plan B design, shown in Figure 3, to help communicate the richness of its ideas. In the end, the Albion faculty opted for the more complex Plan B, in part because math faculty liked the analogy between a formal mathematical proof and a series of sculptural forms which start at a familiar place and evolve stepwise to an ultimate result.

To deal with the assembly-day logistics of making nine distinct orbs simultaneously, we expanded the faculty committee by a dozen members. Each orb involves a highly



Figure 4: *Nine orbs' component parts*

intricate and slightly different interweaving of component parts, so there would be too much going on for me to supervise alone. We planned instead to build one orb the evening before the main event, with a committee of sixteen faculty members helping me. I would train them in the procedure and coach them about foreseeable problems to be alert for. Then on the assembly day, the remaining eight orbs could be assembled by the public in eight groups, with two trained faculty serving as leaders at each table. Additional faculty enlisted and this plan turned out to work well.

Figure 4 gives a summary of the nine shapes in glyph form. Each pattern shown is repeated 30 times, rotated once into each of the 30 face planes of a rhombic triacontahedron. [1] Thus the overall form can be understood as a subset of a stellation of the rhombic triacontahedron. This is not a familiar structure for people unfamiliar with polyhedral geometry, but if we draw the two diagonals in each rhombic face of a rhombic triacontahedron, one sees that the short diagonals form the edges of a dodecahedron and long diagonals form the edges of its dual icosahedron. As these Platonic solids are well known, I chose a design very close to this structure for orb one. To enrich it and provide landmarks, the vertices of the dodecahedron are shown as open circles and the vertices of the icosahedron are made in a pentagrammatic star form. From that starting point, a series of gradual morphings, crossings, and piercings lead ultimately to the final orb nine.

The next step was to make detailed engineering designs and prepare files to send to the laser cutter. This involves keeping track of thousands of little details involving spline curves, bolt sizes, hole diameters and clearances, material thickness, bending radii, dihedral angles, weight, tensile strength, etc., while not losing sight of the overall artistic vision. For visualization of the nine overall forms and verifying that the components can be physically positioned without intersecting each other, I used my own sculpture design software, described in [1]. Final drawings were prepared with general purpose drawing tools and sent to the laser cutter. As a check, to make sure that all the parts actually mate together as planned, we asked the laser cutter to prepare an initial ten parts of each shape to use in a fit-test.

I flew out to Albion for a third visit in August 2008. We put together the test parts and verified that no corrections were needed in the parts design. Figure 5 shows one of the test assemblies of the uncolored aluminum components. At that visit, we also finalized the color choices to tell the powder coating company. I wanted the orbs to gradually change in color from one end of the room to the other. I also wanted each to be two colors: one color for the 60 outer components and a slightly darker color for the 30 inner components. In addition there are 60 brackets connecting inner parts and another 60 connecting outer parts, and each bracket must match its part in color. To minimize the number of colors required and introduce another level of continuity, we chose to have the darker color of each orb be the same as the lighter color of the next orb. With this design, a total of only ten colors were needed: yellows, oranges, and reds. The remaining parts were cut, all were powder coated, chains were suspended from the ceiling beams, the sculpture barn raising was advertised, food was ordered, etc.



Figure 5: *Test fit, with David Reimann*



Figure 6: *Sculpture barn raising activities.*

Construction

After careful planning and organized worry on my part about every possible thing which might go wrong, the assembly itself went off with no problems. Nothing got lost; not too many parts got scratched; nothing fell and was bent; no maniacs ran off with key components. One connection was a bit tight and it helped to have small hands to get its bolts in place. Some scratches occurred, but we had planned for this and had enough spares. Overall, everything went smoothly.

On the afternoon before the construction, I flew out to Albion for my fourth time. On the way from the airport, we picked up the parts from the powder coater, finished just-in-time. That evening, the sixteen group leaders and I assembled orb number nine and got it suspended above the atrium bridge. The parts went together exactly as planned and we worked out a good way to lift orbs into position and shackle them to the chains, which had already been installed. In preparation for the next day's construction, I explained to the group leaders how each of the remaining orbs was in some ways the same and in other ways different from the one we had built.

At the barn raising, over one hundred members of the Albion college community—students, faculty, and others—participated in the construction over a period of several hours. We worked around eight tables, each with two faculty build leaders and changing groups of volunteers who came and went according to the free time in their schedules during the day. I ran back and forth between all the tables checking on everything and debugging occasional problems. Figure 6 shows various views of the day.

Each orb has 30 inner parts, which each mate via angle connectors to four others. The participants must be careful not to reverse parts or mis-connect them. The bolts must be tightened securely, so we checked there is no vibrational buzz when tapping on everything. Then the 60 outer parts were connected. Each mates to the center of one inner part and to two other outer parts. At this stage there plenty of room for confusion and mis-connected parts. Occasionally, components had to be unbolted and replaced in the correct orientation. Getting every single bolt tight was something of a challenge because if we tapped and heard a rattle it was not always easy to locate the source of the sound. Eventually everything was ready to hang. Three of the bolts in each orb were replaced with eyebolts for the chain to connect to. These points were chosen symmetrically so each orb hangs with a three-fold axis vertical. We took a documentary photo of each (see Figure 7) and then the buildings staff were able to raise them up into position with no difficulties.

At the end of the day, it was deeply satisfying for this artist to see the fruits of so much labor hanging ripe for all to savor.

Conclusion

A collaborative artwork such as *Comet!* is an iconic way to illustrate the ties that connect art, math, computer science, and engineering. Academics sometimes need to be very narrow and compartmentalized when working deeply in their own specialties, so it is useful to also create a social event and a permanent sculptural reminder of the broader inter-relatedness of our fields. A sculpture barn raising event creates a community while creating a tangible focal point that manifests the common bonds between disciplines. In the process, many students are exposed to a new perspective on mathematics and computer science, which may have a subtle long-range impact on their career decisions. Informal feedback from students, faculty, and community members indicates that the *Comet!* project was a great experience for all participants. For more information, many additional images documenting details of the design, preparations, and the construction event are available online at [2]. In addition, there is an entertaining time-lapse video of the entire construction and hanging process.



Figure 7 (begins): *Comet!* nine individual orbs



Figure 7 (continued): *Comet! nine individual orbs*

Acknowledgments

This was a community art project and I am happy to thank many people who contributed in many ways, especially all the students and others who attended and participated in the assembly event. Prof David Reimann, chair of the Albion Mathematics and Computer Science department championed this project, found funding, and took care of many aspects of the organization. Professors Darren Mason (Math/CS) and Gary Wahl (Art & Art History) provided a great deal of additional support throughout all its stages. The additional group leaders who participated by attending the previous night's practice preparation and then leading the construction all day at one table are: David Anderson (Math/CS), Amy Bethune (Chemistry), Mark Bollman (Math/CS), Lynne Chytilo (Art & Art History), Michael Dixon (Art & Art History), Andrew French (Chemistry), Vanessa McCaffrey (Chemistry), Karla McCavit (Math/CS), Carrie Menold (Geology), Robert Messer (Math/CS), Aaron Miller (Physics), Daniel Mittag (Philosophy), and Martha O'Kennon (Math/CS). The local company Caster Concepts provided the laser cutting and Finishing Touch did the powder coating. Figure 7 photos courtesy of Gary Wahl; others by the author.

References

- [1] G.W. Hart, "Symmetric Sculpture", *Journal of Mathematics and the Arts*, 1:1, pp. 21-28, March, 2007.
- [2] G.W. Hart, <http://www.georgehart.com>