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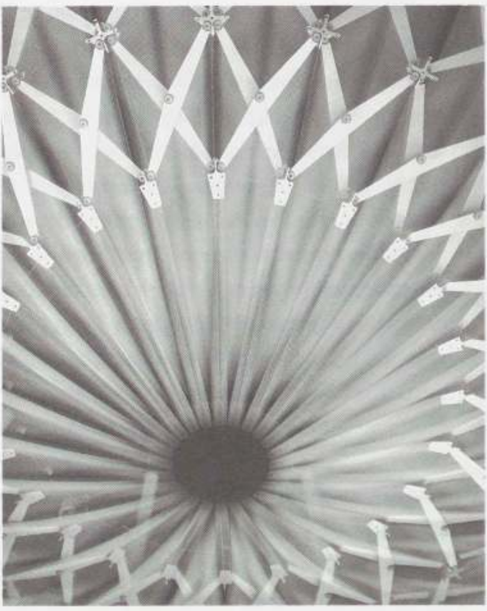


The Museum of Modern Art

New York

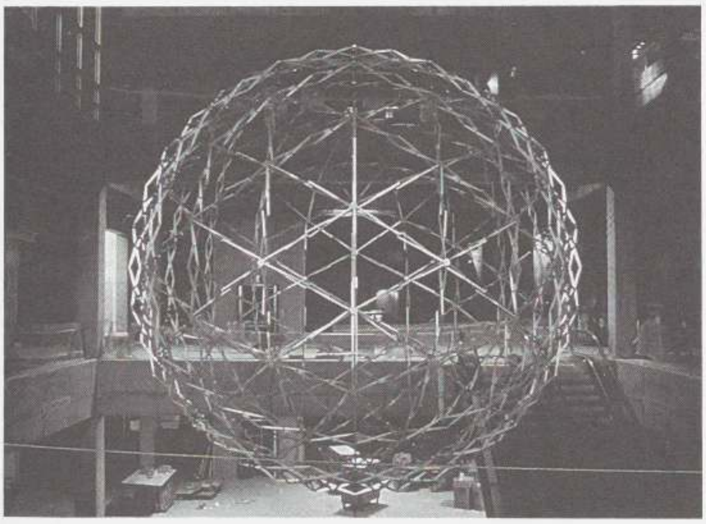
February 24–April 12, 1994

Transformation, the changing of one form into another, is a fundamental process in the natural world. Rarely do we have the opportunity to encounter its technical and aesthetic applications in nature's counterpart: the mechanical domain. Although we marvel at the raising of a drawbridge or the complex choreography of a printing press, in the end their forms remain unaltered. Chuck Hoberman's *Iris Dome* , on the other hand, seems autonomous, changing its shape and size; expanding and contracting like a living being. Its animation captures cycles of change while the hypnotic and uninterrupted flow of its metamorphosis challenges and stimulates our visual senses.

Hoberman is an inventor who over the past ten years has concentrated on the study of deployable or unfolding structures. Essential to his research are the ideas of expansion and contraction, of folding and unfolding, and their effect on form and design. Hoberman's first studies utilized a range of materials such as metal, paper, plastic, wood, and fabric. He inscribed pleats in certain patterns or made hinges at specific junctures to obtain intricate folds that convert palm-size packages into fully extended units. Their metamorphosis is as magical and supple as any mutation in nature. His most recent work applies these principles to mechanisms.

Movement and mechanical processes have been important themes in twentieth-century art as a reflection of the emerging technological world. One of Marcel Duchamp's first mechanical objects, *Rotary Glass Plate* (1920), reinforced physical movement as an indispensable part of the work. Without motion, the series of concentric circles would appear as static parts of the whole. In that same year, Naum Gabo created *Kinetic Sculpture: Standing Wave*, a thin metal rod attached to the vibrator of an electronic doorbell, which caused the rod to quiver. Between 1921 and 1931 Lazlo Moholy-Nagy worked on his *Light-Space Modulator*, a kinetic construction involving machine design, light, and complex movement. In the last twenty years, artists have continued to be fascinated with moving apparatuses. Jean Tinguely explored machines and their functions (or non-functions) and created contraptions that served no clear purpose, but instead insisted on their own uselessness through repetitive pulling, lifting, and turning of the parts. The kinetic artists were "occupied with the exploration and demonstration of physical and psychological phenomena, not with creation and invention." [1]

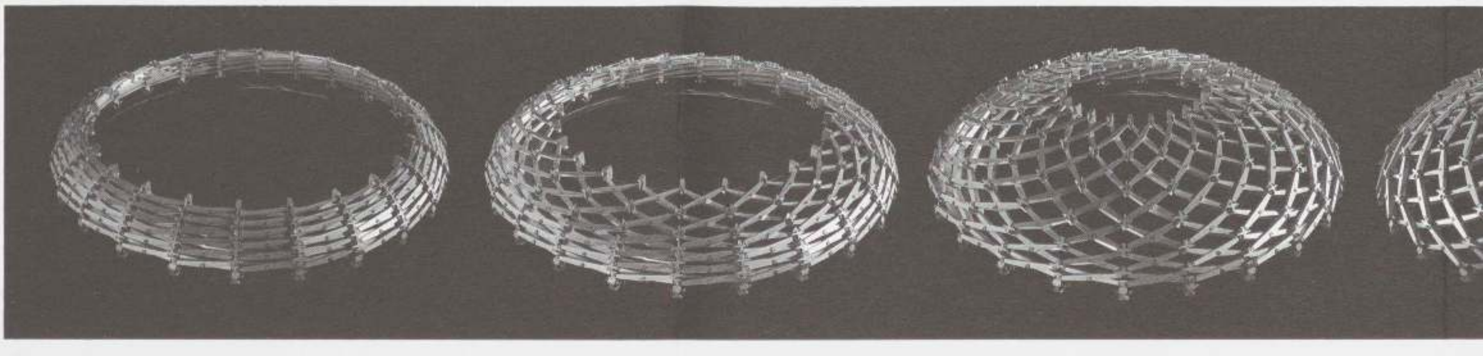
Hoberman first developed a curiosity for the design of mechanisms at Cooper Union where he studied sculpture. After graduating in 1979 he worked with the artist Vito Acconci, whom Hoberman considers an important mentor. At the time, Acconci was working on one of his early automechanical projects, *Decoy for Birds and People*, a piece which involved dangling ladders outside the window of a gallery, where they were moved up and down. This experience reinforced Hoberman's interest in learning more about the nature and behavior of mechanisms, and in 1984 he earned a degree in mechanical engineering from Columbia University. In that same year, he became a partner of Honeybee Robotics where he began a close and continuing collaboration with Bill Record of Zengineering in the fabrication of his projects. At Honeybee, he was responsible for the design and project management of automation systems. The technologies involved robotics, computer vision, and advanced motion control. He has also worked as a consultant for NASA on the conceptual planning, design, and analysis of deployable structures that could be used in future space stations.



Expanding Geodesic Sphere. 1993. Aluminum and stainless steel, 4½' expands to 18'. Liberty Science Center, Liberty State, New Jersey. Photo: Dennis L. Dollens

Hoberman prefers the title of inventor to that of artist or engineer, and indeed, many of his designs have received patents. They exhibit diverse shapes and uses, from pleated sheets to geodesic spheres in the spirit of R. Buckminster Fuller. His design for pleated sheet structures (Patents #4,780,344, #4,981,732, and # 5,234,727) considers both the lines inscribed on the surface and the thickness of the material itself, and its applications include toys, tents, and

Iris Dome, from retracted to closed position. 1990–93. Aluminum and stainless steel, 4' diameter. Photo: Alec Harrison

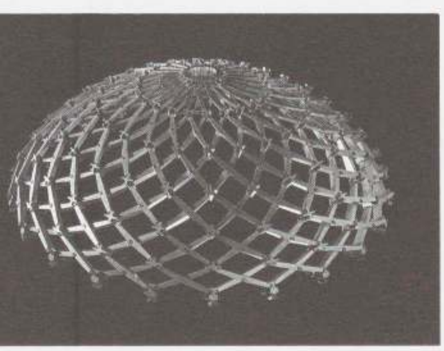


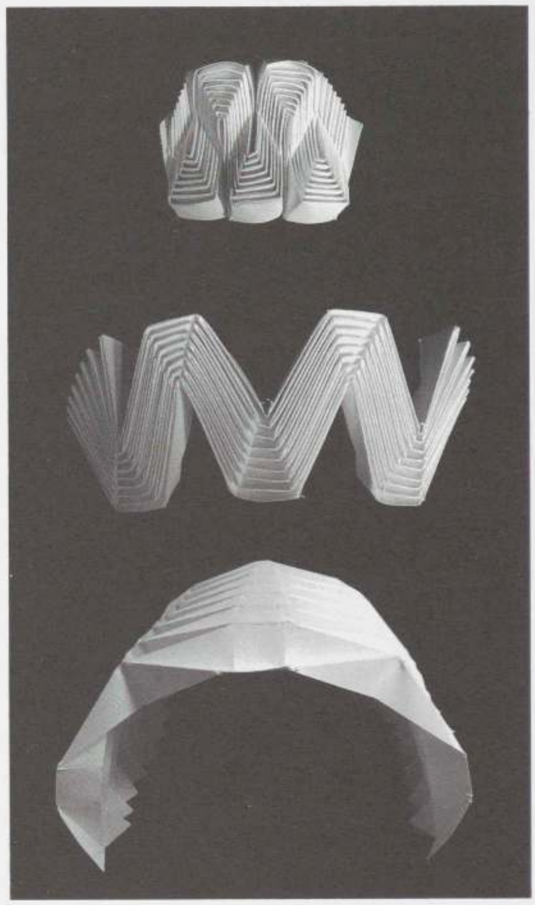
containers. His recent prototypes for small medical instruments also incorporate his unfolding technology. The instruments become complex extensions of the hand, vacillating between the form of an open palm and a tight fist. His anodized aluminum sphere at the Liberty Science Center (Patents #4,942,700 and #5,024,031) in Liberty State Park, New Jersey, is motorized; it expands and retracts from a four-and-one-half-foot object to a sphere eighteen feet in diameter. It is a dramatic study of a continuous transformation in size. Related to this sphere is his design of an expanding geodesic dome (Patents #4,942,700 and #5,024,031), which has potential practical applications in the development of new types of portable structures such as traveling exhibition pavilions or emergency shelters.

The *Iris Dome* (Patent #5,024,031), represented here by a large-scale, operational section of a sixty-foot diameter dome, as well as a smaller scale model of the entire structure, both opens and closes. This idea of metamorphosis has both a biological and mathematical basis in Hoberman's work, an alliance of the organic with the high-tech. The opening of the dome resembles time-lapse photography of a flower in bloom or the iris of an eye adjusting to changes in the light. These transformations are fluid and three-dimensional; explicable through a precise language of mathematics.

In the tradition of great twentieth-century engineering, Hoberman understands the beauty in geometrical and mathematical solutions. Similar to the geometry of Pier Luigi Nervi's Palazetto dello Sport in Rome, Hoberman's *Iris Dome* employs the spiraling lines that represent an elegant and efficient structural solution for a shell structure. In an essay on the creative process in mathematics, the mathematician Henri Poincaré discusses those entities in mathematics to which one attributes the character of beauty. His criteria are evident in Hoberman's designs for deployable structures. "They are those whose elements are harmoniously disposed so that the mind without effort can embrace their totality while realizing the details. This harmony is at once a satisfaction of our esthetic needs and an aid to the mind, sustaining and guiding." [2]

The *Iris Dome* is a precision machine. Motion, the essential function of the dome, gains aesthetic interest through rhythm and fluidity. There are no extraneous noises or movement as it operates smoothly and efficiently. The perfection of the individual components in the dome is made possible by advanced technology, most importantly the use of computers in the design and fabrication of its links and joints. Without the computer in the milling of the pieces, it would be nearly impossible to achieve the complex geometry present in the dome. The degree of accuracy represented in the scale model, for example, is one/one thousandth of an inch (the thickness of a sheet of paper is three/one thousandths of an inch). Aluminum, a lightweight yet strong metal, is the primary material in both the large-scale working section and the small-scale model, and its luminosity is accentuated by the process of sand-blasting and anodizing. The characteristics which define the dome's precision — its highly refined surface, the interlocking of finely crafted parts integral to the whole, and the repetition of simple elements to create a complex pattern — represent the essential qualities of machine art.





Pleated Surfaces. 1985. Paper, 10 x 14" when fully deployed. Folding stages of cylinder section. Photo: Dennis L. Dollens

The links of the mechanism in the *Iris Dome* are also integral parts of the structure. They consist of an assembly of paired struts with hinges at their midpoints. These hinges allow the members to move as a pair of scissors in an unrestrained rotation about an axis perpendicular to the surface of the dome. Each end of the scissors is attached to neighboring pairs of scissors at hubs, continuing the rotating motion. Although the scissors pairs act in a plane, the changes in slope necessary to generate curvature in the dome occur entirely at the hubs. To do this, the hubs are basically composed of four pins, one for each pair of scissors, which are not parallel. This allows each structural member to rotate about a slightly different axis where it connects to the hub. The design of the hubs and hinges is one of the more challenging aspects of the dome's design. They insure a smooth metamorphosis between the different stages of opening and closing. [3]

The *Iris Dome* represents an important collaboration between different engineering minds. The general concept was conceived in discussions among Hoberman and Peter Rice and Guy Nordenson of Ove Arup & Partners, one of the world's leading engineering firms. Hoberman wanted to ascertain the architectural possibilities of his principles. The question was raised whether the principles for expanding truss structures could be applied to a form which retracted outward to an edge instead of inward to a central bundle. Particularly emphasized in, and later crucial to, the design process of the large sectional model was an understanding of the effect on the dome's design when scale is increased. It is similar to the natural process of growth in nature, which, according to the naturalist D'Arcy Wentworth Thompson in his seminal book *On Growth and Form*, cannot "grow a tree nor construct an animal beyond a certain size, while retaining the proportions and employing the materials which suffice in the case of a smaller structure. The thing will fall to pieces of its own weight unless we either change its relative proportions, which will at length cause it to become clumsy, monstrous and inefficient, or else we must find new material, harder and stronger than was used before. Both processes are familiar to us in Nature and in art, and practical applications, undreamed of by Galileo, meet us at every turn in this modern age of cement and steel." [4]

The genius of the *Iris Dome* resides in its ability to be a mechanism and a structure simultaneously. The dome spans distances, encloses usable space, and is self-supporting. It maintains strength and rigidity in all positions of extension and retraction. At every stage, the dome retains a constant and stable perimeter.

Hoberman's dome is also an alternative way of thinking about the design of retractable roof systems. In the Toronto Skydome (Robbie/Young & Wright, architects; Adjeleian Allen Rubeli Limited, engineers), large portions of the dome are moved in rigid units, nesting on top of each other. Complete retraction never takes place. The cable structures by architect Frei Otto have been used for retractable roofs with the tension cable also serving as the mechanism; however, they are not stable at any intermediate position. In addition, there are several dome designs that have an underlying stationary structure with moving roof panels. The main support remains in place with the panels sliding over it so that the covering fully retracts retaining an open lattice-work of structural parts above. The *Iris Dome*, on the other hand, completely retracts yet is structurally stable at any position. It maintains a symmetry in both its mechanical and structural functions. The efficiency of the multiple linkages is expressed by the minimum movement of each individual part.

This efficiency recalls R. Buckminster Fuller's idea of maximum performance with minimum material. Basing his ideas in nature's economy of form and function, Fuller's designs are geometric systems developed from such fundamental building blocks of physics as tetrahedrons (pyramids with four sides including base), octahedrons (eight-sided figures), and icosahedrons (twenty-sided figures). In a discussion about nature's influence in architecture, Fuller commented that "structure in architecture comes from the structuring in nature. If patterning attempted by architects is not inherently associative with the local regenerating dynamics of chemical structure, his building will collapse." [5]

Fuller's geodesic dome can be compared with Hoberman's *Iris Dome*, although the individual thesis is different. When Fuller began making studies of the geodesic dome in 1947, he designed a structure that could span huge, unobstructed distances with minimum materials. It had economy of means but never was intended to retract and extend. The premise of the *Iris Dome*, however, is to span a large area, *and* be a transforming mechanism.

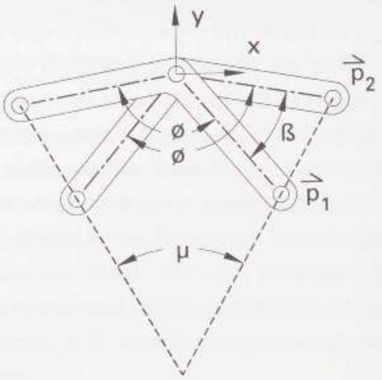
The *Iris Dome* is Hoberman's largest transforming structure to date. No doubt there will be others and all clearly based on his unique principles of folding/unfolding, expanding/contracting — a vision of a kinetic architecture. His work is rooted in science and theories of geometrical transformation and provides a "bridge between the hyperacive electronic media and the static built environment."[6] His inventions integrate fluidity and stability, alternately mirroring processes observed in nature and offering a symbol of the elegant promise of technology.

Matilda McQuaid
Assistant Curator
Department of Architecture and Design

Fabrication and engineering assistance by Bill Record, Zengineering, Pine Bush, New York.

Key mathematical construct underlying the geometry of the *Iris Dome*:

Given a link with three pivots that form an angle ø, where the distance between the central pivot and each pivot equals 1. When two such links are connected by their respective central pivots, to show that the angle μ formed by lines joining their endpoints is equal to $\frac{2}{\tan\frac{\phi}{2}}$ for any relative angle ß between the two links:



$$\vec{p}_1 = \left(\sin\frac{\phi-\beta}{2}, -\cos\frac{\phi-\beta}{2}\right)$$

$$\vec{p}_2 = \left(\sin\frac{\phi+\beta}{2}, -\cos\frac{\phi+\beta}{2}\right)$$

$$\frac{\tan\mu}{2} = \frac{\sin\frac{\phi+\beta}{2} - \sin\frac{\phi-\beta}{2}}{\cos\frac{\phi-\beta}{2} - \cos\frac{\phi+\beta}{2}}$$

$$= \frac{\left(\sin\frac{\phi}{2}\cos\frac{\beta}{2} + \cos\frac{\phi}{2}\sin\frac{\beta}{2}\right) - \left(\sin\frac{\phi}{2}\cos\frac{\beta}{2} - \cos\frac{\phi}{2}\sin\frac{\beta}{2}\right)}{\left(\cos\frac{\phi}{2}\cos\frac{\beta}{2} + \sin\frac{\phi}{2}\sin\frac{\beta}{2}\right) - \left(\cos\frac{\phi}{2}\cos\frac{\beta}{2} - \sin\frac{\phi}{2}\sin\frac{\beta}{2}\right)}$$

$$= \frac{2\cos\frac{\phi}{2}\sin\frac{\beta}{2}}{2\sin\frac{\phi}{2}\sin\frac{\beta}{2}} = \frac{1}{\tan\frac{\phi}{2}}$$

notes

[1] George Rickey, "The Morphology of Movement: A Study of Kinetic Art," in *The Nature and Art of Motion*, ed. Gyorgy Kepes (New York: George Braziller), 1965, p. 114.

[2] Henri Poincaré, "Mathematical Creation," in *The Creative Process*, ed. Brewster Ghiselin, p. 40.

[3] From "The Iris Dome: Research and Development Project," Progress Report, November 2, 1993, Ove Arup & Partners, Consulting Engineers PC, p. 1.

[4] D'Arcy Wentworth Thompson, *On Growth and Form*, complete revised ed. (New York: Dover), 1992, p. 27.

[5] R. Buckminster Fuller, "Conceptuality of Fundamental Structures," in *Structure in Art and in Science*, ed. Gyorgy Kepes (New York: George Braziller), 1965, p. 68.

[6] Chuck Hoberman, "The Art and Science of Folding Structures: New Geometries of Continuous Multidimensional Transformation," in *Sites Architecture*, no. 24, ed. Dennis L. Dollens, 1992, p. 35.

biography

Chuck Hoberman was born in 1956 and presently resides in New York City. Since 1988 he has been president of Hoberman Associates, Inc., his own company specializing in structures and mechanisms. His work has been featured in many publications such as *l'Arca, Architecture Design, Discover, Sites Architecture,* and *The New Yorker*.

His current patents are:

U.S. Patent 4,780,344
Reversibly Expandable Three-Dimensional Structure

U.S. Patent 4,942,700
Reversibly Expandable Doubly Curved Truss Structure

U.S. Patent 4,981,732
Reversible Expandable Pleated Sheet Structure
(International Patents Pending)

U.S. Patent 5,024,031
Radial Expansion/Retraction Truss Structure
(International Patents Pending)

U.S. Patent 5,234,727
Curved Pleated Sheet Folding Structure

U.S. Patent Pending
Deployable Starburst Reflector (co-invented with Dr. Martin Mikulas of NASA Langley Research Center)

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Cover: *Iris Dome* in motion. Photo: Wayne Sorce