The Woods Hole Geodesic Dome - A Synergetic Landmark

By James W. Mavor, Jr.

Editors' note: The Woods Hole Historical Collection has long worked for preservation in Woods Hole, thereby protecting the unique historic character of our village. Now we want to call attention to the possible loss of the Woods Hole Dome. For this reason, James Mavor has written the article about the geodesic dome and the designer Buckminster Fuller. The Historical Collection feels it is important to preserve the dome as a work of engineering art, perhaps an open air sculpture, and as a significant historic part of Woods Hole history. This may be one of the first Buckminster Fuller geodesic domes built.

Introduction

I have undertaken to describe and interpret the Woods Hole geodesic dome because it is my neighbor and because I have been informed that it may be in danger of removal or destruction. I saw my task as learning enough about the dome to form an opinion as to whether it is worth preserving or not, and why. In the past, I saw the dome as an architectural novelty with a chronic water leakage problem. I knew it was designed by R. Buckminster Fuller, built by his students and commissioned in 1953 by the Petersen family. I had heard that Fuller held controversial views about architecture. My research in 2004 commenced with Amy C. Edmondson, who had been an associate of Fuller. She wrote "A Fuller Explanation – The Synergetic Geometry of R. Buckminster Fuller," published by Birkhauser, Stuttgart in 1986. I read this fascinating volume and soon found the reason for the pun in the title.

The Dome Restaurant in Woods Hole was designed and built in 1953 and '54 as a wooden framework of struts whose envelope is nearly in the shape of a sphere. It is 54 feet in diameter (Figure 1). While open to the sky between the struts during its first year, it has since had a weatherproof covering. (Figure 2) R. Buckminster Fuller (1895-1983) was the designer and construction supervisor. This year, on its 50th anniversary, the building stands as a fine example of an early, large, wooden, geodesic dome in a spectacular setting. Also, the structure was assembled using diamond-shaped panels, a feature which is unusual and architecturally interesting. Fuller called the dome geodesic, which refers to a segment of a great circle of a sphere, because all the struts are very close to great circle segments. The geodesic dome has become the outstanding example of Fuller's lifelong and world-renowned adventure in searching for generalized principles of both the physical and metaphysical world.

The basic idea behind the dome as structure is that the spherical shell under distributed loading is the strongest for its weight. Under a uniform external load, nearly all the stresses are compressive, while structural failure almost always is due to tension or shearing. Because of this, the spherical framed structure is efficient in its use of material and easy to build. It also provides the greatest internal volume of any shape of structure. Wood is a suitable material for this because while weak in tension, it is strong in compression and it is light. The spherical dome shape with its practical advantages as well as its beauty have

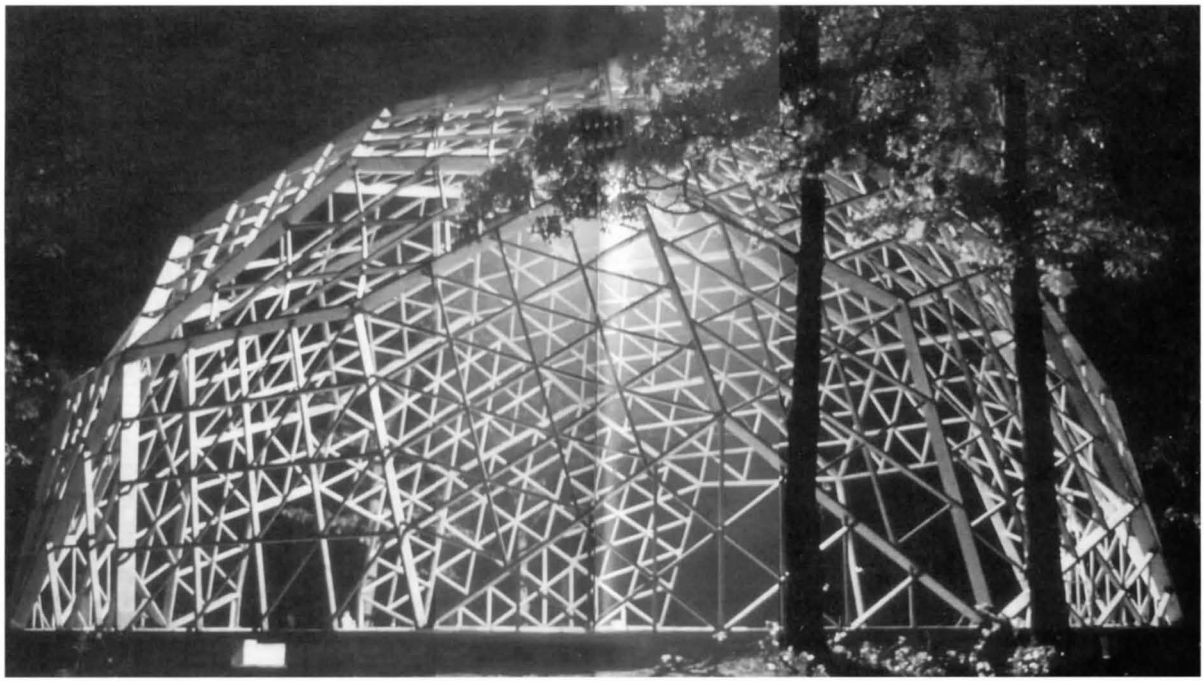

Fig. 1 Photo of Woods Hole Dome at night in 1954. From Krausse and Lichtenstein.

been known the world over ever since people first made pottery and reed baskets thousands of years ago.

The many two inch by three inch and two inch by eight inch wooden struts of which the dome is built are fastened at their ends to one another, in one of a number of geometrical arrays. The result is an open structure that has been proven to be exceptionally light, strong and cost-effective. It is considered a break-through concept in building architecture. For historical perspective, a sample comparison can be made with the weight per square foot of enclosed floor area of famous historical domes. The Dome of St. Peter's cathedral and the Pantheon in Rome each weigh 3200 pounds per square foot of floor under the dome. The Woods Hole geodesic dome weighs 3 pounds per square foot, less by a factor of 1,000. That is why Fuller did not choose a dome design having a shell of uniform thickness of a homogenous material. He would have said the application that he had in mind, an open air restaurant, was not suited to that approach.

R. Buckminster Fuller

R. Buckminster Fuller (1895-1983) was an inventor, architect, engineer, mathematician, poet, cosmologist, and inspired teacher. He was praised as the most innovative thinker of our time, received 43 honorary doctorates, and at the same time was dismissed as an "incomprehensible maverick." His theories are explained in 28 books under the heading of "Synergetics," a word he invented in a language he created because he felt that the classical language of geometry was unacceptably misleading. For example,

in describing the domes, he invented a new meaning for the word, geodesic, which he saw as closer to nature than the conventional one. It is "the most economical relationship between two events." Fuller wrote, "The prime barrier to humanity's discovery and comprehension of nature is the obscurity of the mathematical language of science. Fortunately, nature is not using the strictly imaginary, awkward and unrealistic coordinate system adopted by and taught by present-day academic science."

Edmondson

Edmondson set out to interpret Fuller in ordinary language, but later felt that Fuller's complex passages expressed his meaning more precisely than any substitute. Her explanation is a useful prelude to struggling with Fuller's writings. In spite of the obstacles to easy interpretation, I found that Fuller's work interested me because I share some of his complaints about the methods of academic science. For example, Fuller claims to have discovered the mathematical coordinates of both physical and metaphysical phenomena alike. I remain curious about how he did it and am not yet convinced that he did. I see rather that academic science ignores the metaphysical. I read other books about Fuller and by Fuller. He kept a meticulous diary for 56 years, parts of which have been published. Joachim Krausse and Claude Lichtenstein, in "Your Private Sky, R. Buckminster Fuller," published by Lars Muller, Zurich, 1999, page 354, wrote, "Geodesic domes have become Fuller's trademark. Patenting them was the only financial success of his life. Since they were introduced, the domes have been significant in two different ways. As technical artifacts, they aimed at maximum efficiency in the relationships of volume to weight, use of materials to useful surface, and assembly time to mobility. As sociocultural alternatives to typical rectangular architecture, the domes crystallized society's dreams of a life liberated from constraints and tutelage."

I concluded that to understand Fuller's domes, and in particular the Woods Hole Dome, one must consider his approaches and methods as part of his search for understanding how the cosmos works. To do this I have started with the geodesic dome described in Fuller's patents, then moved to the Woods Hole dome.

The Ideal Geodesic Dome

R. Buckminster Fuller held 28 patents, published in "Inventions, The Patented Works of R. Buckminster Fuller," St. Martins Press, New York, 1983. They avoid Fuller's obscure turn of phrase and are the clearest and most specific descriptions of his domes. He patented the geodesic dome in June, 1954, where it is described as a framework that approaches a sphere in shape, composed of triangular segments built of struts fastened at their ends. The smaller the triangles, the more nearly the structure approaches spherical and the stronger it is. Its design is based on the light weight of structure compared with strength and the inherent stability of triangles, which are nature's only self-stabilizing pattern.

Buckminster Fuller claims that a geodesic dome is more than triangles and that it demonstrates the most economical relationship between any two events. This he saw as equivalent to the great circle on a sphere, which is the shortest line between points. He pointed out that three differently oriented great circles is the minimum for a stable structure, and that the more great circles, and thus the more great circle struts in the dome, the stronger the sphere. The amount of increase in rigidity between the structure with 3 circles and one with 31 circles, the strongest, was considered by Fuller to be unexplainable

by physical considerations of its parts, and therefore metaphysical.

In designing a geodesic dome, Fuller started by searching for a polyhedron that was the best fit to a sphere. Three polyhedrons were considered for the basic shape of the structure. They were the tetrahedron with 6 edges, the octahedron with 12 edges and the icosahedron with 30 edges. Of these stable symmetrical polyhedrons, the icosahedron, named for its 20 faces in Greek, was considered the most efficient (Figure 3). It has the maximum enclosed space with minimum structural material.

Each polyhedron has both advantages and disadvantages. The icosahedron is more sensitive to collapse from a push on one of the vertices than the other polyhedrons. It is also sensitive to a dynamic effect which Fuller called jitterbugging, brought on by resonance of the structural members with the exciting forces and seen by Fuller as partly metaphysical. However, this can be minimized by transforming the icosahedron by replacing each of the twenty flat faces (Figure 4a) by a near spherical face as shown in Figure 4b. Each vertex in Figure 4a is projected outward to the surface of an imaginary sphere (Figure 4b).

The net result is a near-spherical structure having 320 triangular openings bounded by wood struts (Figure 5). There are 12 major vertices each forming the intersection of 5 small triangles. There are 30 longer struts, each four small triangles long, which nearly approach segments of great circles and which give the structure additional stiffness. To assure convexity of the structure, each of the small triangles in

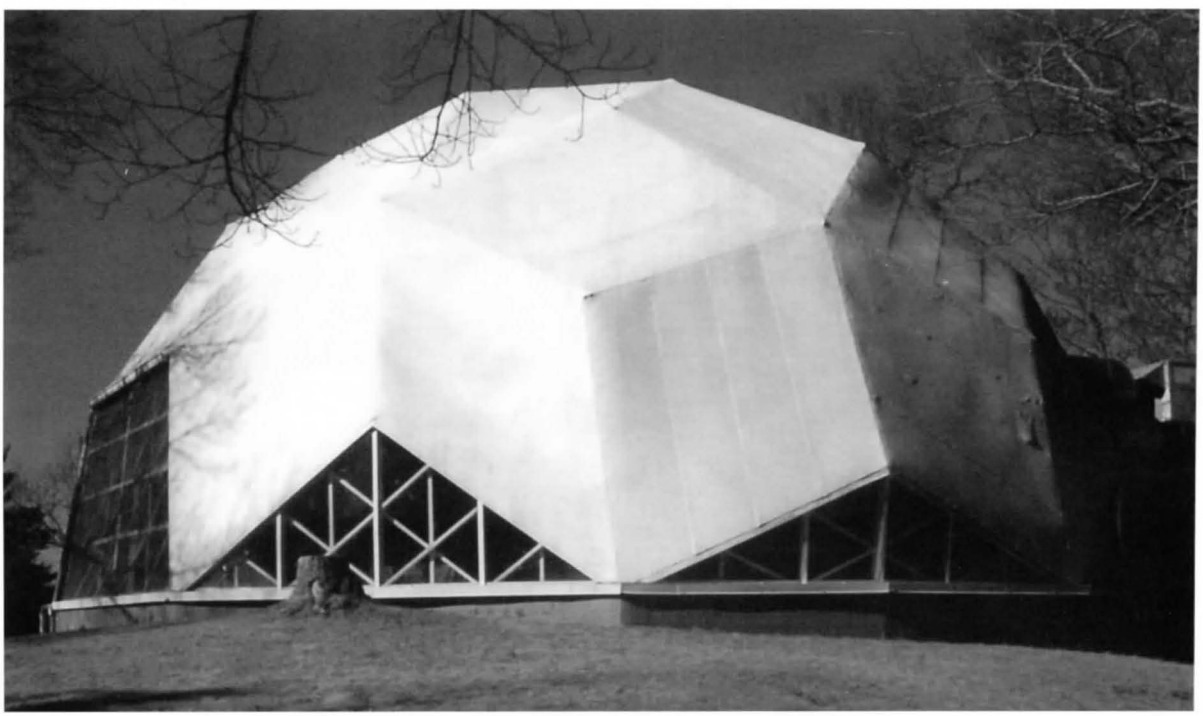

Fig 2. Woods Hole Dome in 2004. Photo by James W. Mavor, Jr.

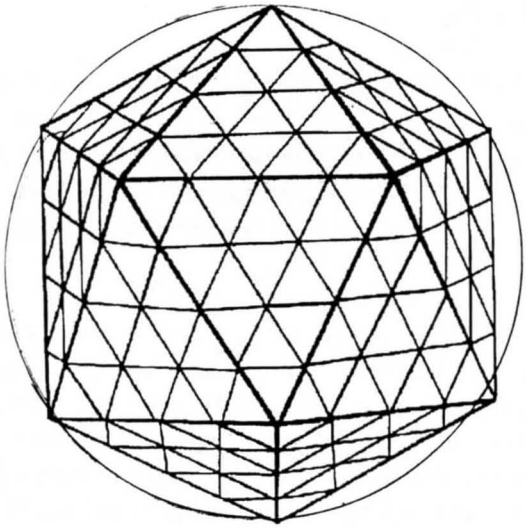

Fig 3. Drawing of Icosahedron with 16 triangles on each face. (Fig. 15-3 Edmondson).

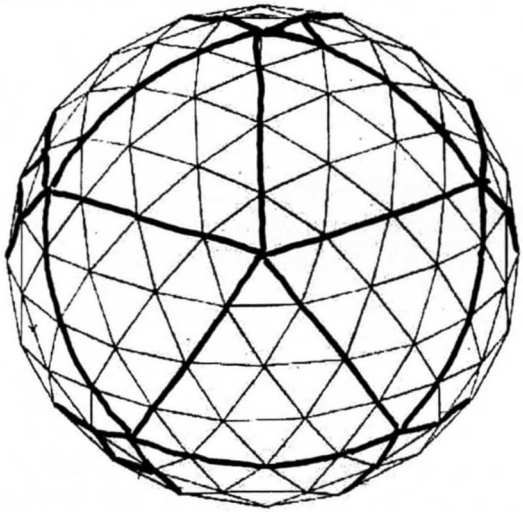

Fig 5. Drawing of transformed icosahedron (Fig. 15-5 Edmondson).

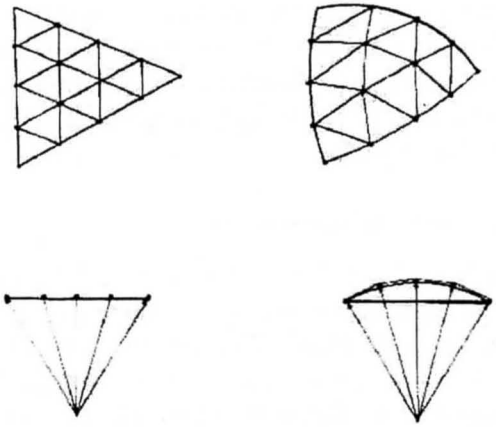

Fig 4. Each vertex in Figure 4a is projected outward to the surface of an imaginary sphere as shown in Figure 4b. (Figure is taken from Fig. 15-4 of Edmondson)

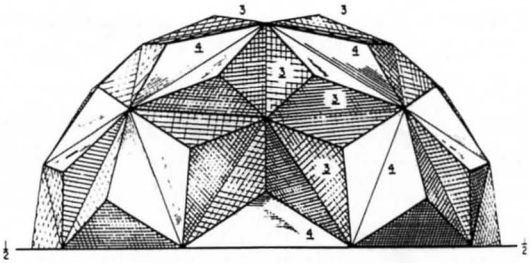

Fig 6. Rhombic segmentation of prototype of Woods Hole Dome, side view. (From Fuller, patent 3,203,144, Figure 13, Fuller, Inventions).

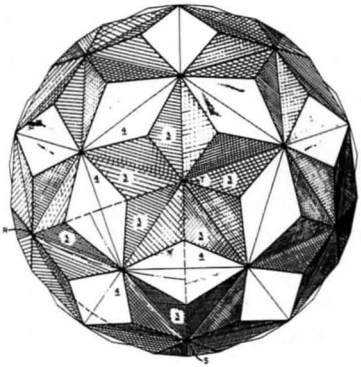

Fig 7. Rhombic segmentation of prototype of Woods Hole Dome, top view. (From Fuller, patent 3,203,144, Figure 14, Fuller, Inventions).

each group of 16 is slightly different in size and shape from an equilateral triangle and the others in the group. The geodesic dome is one half of a sphere. It is evident from Fig. 5 that it is a geodesic dome because every one of the lines along all the struts is very close to a great circle.

The Woods Hole Geodesic Dome

The 1954 patent for geodesic domes describes in detail only domes consisting of triangular shaped segments or panels. However, the patent mentions other panel shapes in a general way such as "diamonds and hexagons." The Woods Hole Dome is composed of equilateral diamonds, or rhombuses, in the language of geometry, and is covered specifically in a later patent, No. 3,203,144 of August 31, 1965. The arrangement of rhombuses in the prototype design of the Woods Hole Dome is illustrated in Figures 6 and 7. It departs substantially from the spherical surface shape and the basic segments are not triangles. They consist of 20 rhombic forms which add interest and perhaps beauty to its appearance but are not inherently stable and must be stiffened by struts within the rhombuses. A rhombus can be divided into two stable triangles by a strut connecting opposite corners or vertices. But this is not done in the Wood Hole Dome. This feature weakens the dome but it doesn't seem to have prevented the Woods Hole Dome from surviving for 50 years through hurricanes in a very exposed site.

Fuller was an avid believer in the notion that form follows function. He claimed that he never knew in advance the appearance of his designs but considered them beautiful solely because of their structural elegance. The Woods Hole Dome seems to contradict this belief of Fuller's.

The patent drawing in Figure 7 and a profile drawing of the Woods Hole Dome in Figure 8 reveal three levels of rhombic pattern. The lowest is a ring of ten rhombic accordion pleats that surround the dome. At the center level, there is a chain of rhombic segments surrounding the dome. At the top level, five rhombic segments are placed symmetrically about the top vertex where the segments join. Polyhedrons are described by the numbers of faces, vertices and edges. The Woods Hole Dome has 45 faces, 51 vertices and 96 edges built with 2 by 8 inch wood struts.

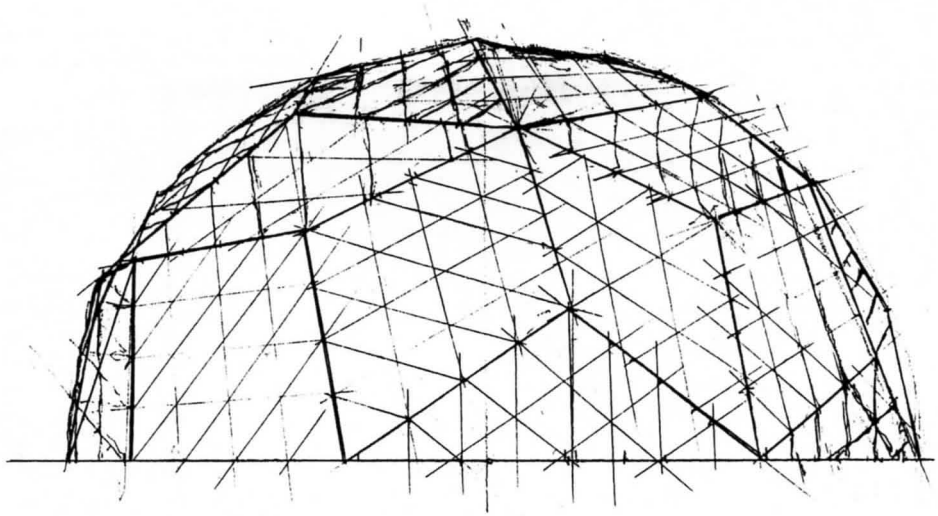

Fig 8. Sketch of Woods Hole Dome by James W. Mavor, Jr.

Within each rhombus, there are 32 triangles bounded by 2 by 3 inch struts.

I constructed a cardboard model of the Woods Hole Dome because I had seen no drawings nor read a description of it. I didn't know how to describe its shape. I used external photographs and a few measurements of the dome in this work. I observed that the panels appeared to be alike in shape and size and were rhombuses. But the shape as viewed from the ground is irregular, photos are distorted, and the adjacent restaurant buildings obscure parts of the dome. The project was a challenging puzzle. The model, however, enabled me to understand the geometry of the dome and to recognize it in the patent drawings of Figure 6 and 7. If you choose to make a model, I suggest one at least twelve inches in diameter because the parts must be cut accurately and be identical. Also, I suggest that in assembling the pieces, you start from the rhombuses that surround the peak and work downward, rather than upward from the base.

During its first use as a restaurant, the Woods Hole Dome was a structure open to the sky. Then it was glazed, then covered with various opaque coverings through the years. Since the Woods Hole Dome was built, there have been many thousand geodesic domes built all over the world. I do not know if there is one like the Woods Hole Dome, but in my search of the literature so far, I have yet to see one.

Fuller expanded the concept of the dome and other structures to the whole experience of man on earth. He is remembered by the Buckminster Fuller Institute in Santa Barbara, California which coordinates activities based on his example, mostly in the direction of conservation and better use of the world's resources. In Woods Hole, we are privileged to have a notable symbol of his work, the Woods Hole Dome. This dome is much more than an isolated or novel structure. It should be preserved.

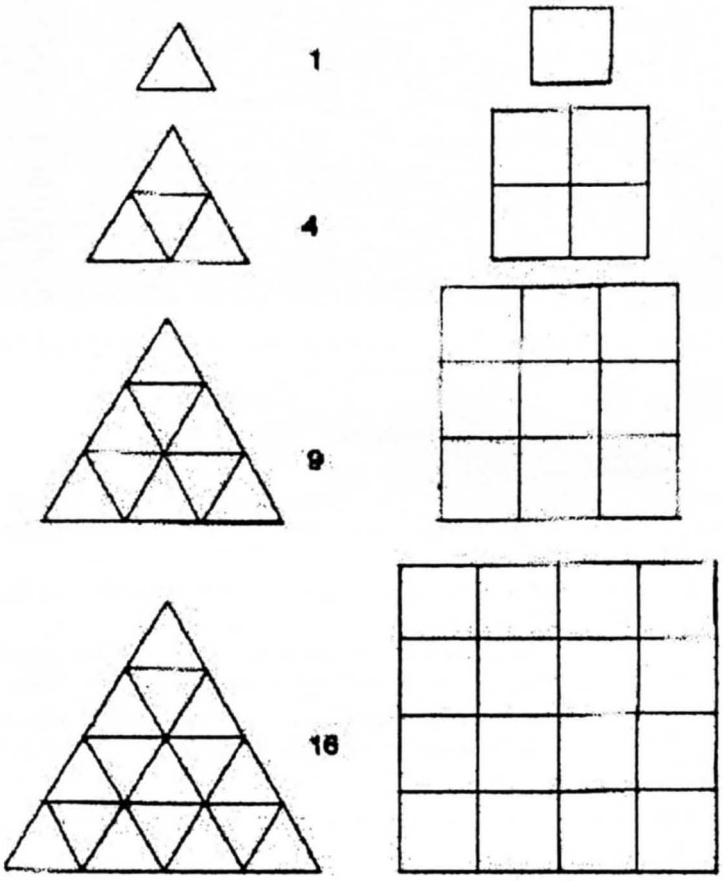

Fig. 9.

Students of MIT's Buckminster Fuller building the Woods Hole Dome in 1953. Full size components underway to left, model in background. Photo by Paul Ferris Smith.

Biography

James Watt Mavor, Jr. came to Woods Hole as an infant in 1923 when his father, an MBL investigator, and Stanley Eldridge were building the Mavors' summer cottage. After a career in college teaching Jim moved to Woods Hole year round with his wife, Mary, and their three small children. Jim joined WHOI full-time in 1961 to start a manned submersible program which produced *Alvin.* Since then his careers have included ship design, more college teaching and research, oceanographic engineering and, for the past 37 years, developing interest in interdisciplinary study of past cultures as an independent researcher and writer. He has published two books, *Voyage To Atlantis,* 1969, 1990, and *Manitou, The Sacred Landscape of New England's Native Civilization,* 1989. He has also contributed to *Woods Hole Reflections,* the *Book of Falmouth* and *Spritsail.*

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