This lesson was created as a supplement to the Fuller’s Fantastic Geodesic Dome program at the National Building Museum. It is designed to be used in your classroom independently, or as an activity before or after a school program at the Museum. For more information about and to register for the National Building Museum’s school programs, visit http://go.nbm.org/schoolvisit.

The Fuller’s Fantastic Geodesic Dome school program is intended to help students, grades five through nine, recognize geodesic domes and discover their importance in the world around them. The lessons and activities encourage young people to explore the complexity of structural design in buildings and help them understand the basic engineering principles of the geodesic dome.

About the National Building Museum

The National Building Museum is America’s leading cultural institution dedicated to advancing the quality of the built environment by educating people about its impact on their lives. Through its exhibitions and educational programs, including innovative curricula for students, as well as online content and publications, the Museum tells the stories of the world people design and build.

The Museum is an independent, non-profit institution and is located in a historic landmark structure at 401 F Street NW, Washington, D.C. 20001. Connect with the Museum online at www.nbm.org, on Twitter at @BuildingMuseum, and on Facebook at www.facebook.com/NationalBuildingMuseum.
Introduction to Domes

Basic Engineering Principles

A dome is defined as a large hemispherical roof or ceiling. Although many different types of domes exist, all domes share certain advantages, whether or not they are geodesic. Their compound-curved shape is inherently strong, giving a self-supporting clear span with no columns as supports. Domes are resource and energy-efficient because they are hemispheres. A sphere is the 3-dimensional form that contains the most volume with the least amount of surface area. Thus, as a hemisphere, for a given amount of material, a dome encloses more floor area and interior volume than any other form.

A dome’s design is dependent upon many factors, including:

- Needed area and span, or distance between supports.
- Budget and building schedule.
- Forces, such as compression and tension, acting on the structure.
- Building materials.

Area and Span

The architect must consider the area to be covered by the dome and the needs of the structure in terms of space and uses. Span is the length of a structural element between supports. The shape of the structure, materials, and budget all impact the total length of the span.

Forces of Compression and Tension

A force is a push or a pull on an object that is the result of its interaction with another object. In every structure, there are invisible forces at work. In this program we will focus on two: compression and tension. Compression is a force that pushes or squeezes an object; objects in compression tend to get shorter. Tension is a force that stretches or pulls an object; objects in tension tend to get longer.

Materials

Engineers must consider the properties of building materials when making choices for any structure. When considering building materials, engineers take into account the cost, proposed use of the structure, location, aesthetics, and durability.

Space-Framing

Space-framing (a network of triangular supports) is often used in dome construction. The most important element of a space frame is the triangle, which is also the strongest form used in architecture. Different types of geometric forms (or polyhedra) are used in space framing. One common form is the tetrahedron—a four faced triangular polyhedron, or a kind of pyramid with four faces and six edges. The connecting of triangles in this way provides a structural system that is strong and uses minimal amount of materials, all of which are interchangeable.
Geodesic Domes

R. Buckminster Fuller spent much of the 20th Century investigating ways to improve housing. In 1944, the United States suffered a serious housing shortage with the many millions of veterans returning after the war. At this time Fuller began focusing on the problem of how to build a shelter that would be more comfortable, more efficient, and more affordable for a larger proportion of the population.

Fuller would exploit the strengths of triangles to create a stronger and more cost efficient housing structure. Fuller investigated the properties of triangles, and platonic solids including the icosahedron (a 20 sided polyhedron made of equilateral triangles). He discovered that by subdividing the triangular faces of the icosahedron into smaller triangles he could approach a form that was essentially a spherical structure created from triangles. This new type of dome consisting of triangles, would be both very strong and very economical.

Positive Features of Geodesic Domes

Geodesic domes are:

- The strongest structures per pound of material employed.
- Inherently strong and light; their curved form creates a span with no need for additional support (such as columns) and equally distributes stress throughout the structure.
- Resource- and energy-efficient because of all possible shapes, a sphere contains the most volume with the least surface area.
- Streamlined spherical forms let wind slide smoothly over their surface, thus helping to maintain a constant interior temperature with less need for heating and cooling systems.
- Structures that allow air to easily circulate, reducing heating and cooling costs.
- Easy to manufacture and construct due to interchangeable parts.

Negative Features of Geodesic Domes

Geodesic domes:

- Do not fit certain lot shapes, particularly traditional rectangular city blocks.
- Do not gracefully accept additions.
- Difficult to enlarge by adding a second story.
- Often look identical to each other.
- Quickly distribute sound, smells, heat, cold, smoke, and fire because of their efficient circulation.
- Difficult to divide into separate spaces (such as rooms of a house or office).
- As its exterior becomes warm or cold with changes in weather, a dome’s materials expand and shrink causing gaps where water can leak into the structure.
geodesic dome

geodesic dome outline drawing

geodesic dome photograph and outline drawing combined
Who Was Buckminster Fuller?

Architect, mathematician, engineer, inventor, visionary humanist, educator, and best-selling author, R. Buckminster Fuller, also known as Bucky, has been called “the 20th century Leonardo da Vinci.” Born in 1895, he grew up in the northeast United States without automobiles, aircraft, radio, television, or computers.

Bucky attended Harvard University—the fifth generation of his family to do so—only to be expelled twice and never earn a college degree. His jobs included work in a cotton mill and meat packing plant. During World War I, he served as a naval officer, all the while learning about complex mechanical systems.

Bucky dedicated himself to a “lifelong experiment” to discover what he could do to help make humanity a success on Earth. He documented nearly everything he did and amassed an archive weighing 45 tons! It includes sketches, statistics, trends, models, even traffic tickets and dry cleaning bills.

Bucky’s first inventions and discoveries were numerous. During the 1930s and 40s he created an aluminum car and house. They were radically different from structures known then or now. At the time, aluminum processing was expensive, so mass production of these inventions was impossible.

Following the mixed success of a home constructed as a dome, Bucky began researching how to strengthen and enlarge such a shelter. He soon discovered that a sphere constructed of geometric shapes was the most efficient way to enclose a space. The first such structure to become known as a geodesic dome was built in 1922 by Walter Bauersfeld for a planetarium in Germany. However, Bauersfeld never patented his structure or developed the principles of building this way. Bucky likely knew of this earlier dome. His first large-scale outdoor model was attempted in 1949.

Geodesic structures can now be found everywhere. They are present in the structure of viruses and the eyeballs of some vertebrae. The soccer ball is the same geodesic form as the 60-atom carbon molecule C60, named buckminsterfullerene in 1985 by scientists who had seen Bucky’s 250-foot diameter geodesic dome at the 1967 Montreal Expo. This dome was the largest of its time and still stands today.

Though he secured many patents for his designs, Bucky put his profits towards his research and never became wealthy. He was often disappointed that he did not receive more credit for his work. The geodesic dome at Disney’s EPCOT center is familiar to much of the world, but its inventor is not.

Of all his contributions and creations, Bucky considered his World Game Institute, founded in 1972, to be one of his most important. This organization collects and shares comprehensive, world resource data. Bucky hoped that it would show that international cooperation was such an obvious advantage that war would become unthinkable. Thousands participate in World Game workshops, and the Institute is one of the largest of its kind.

Fuller was seen by his peers as both a genius and a failure because his ideas were so new and little understood by the time of his death. Over the course of his life, Fuller received 47 honorary degrees for his contributions in design science. Since his death in 1983, appreciation for Fuller has continued to grow. The Fuller Institute in Santa Barbara, California, which opened in 1995, now educates the world about his life and work.