The magic of the Atwood Sphere

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Exactly a century ago, on June 5, 1913, a "celestial sphere demonstration" by Professor Wallace W. Atwood thrilled the populace of Chicago. This machine, built to accommodate a dozen spectators, took up a concept popular in the eighteenth century: that of turning stellariums. The impact was considerable. It sparked the genesis of modern planetariums, leading 10 years later to an invention by Bauersfeld, engineer of the Zeiss Company, the Deutsche Museum in Munich.

Since ancient times, mankind has sought to represent the sky and the stars. Two trends emerged. First, stars and constellations were easy, especially drawn on maps or globes. This was the case, for example, in Egypt with the Zodiac of Dendera or in the Greco-Roman world with the statue of Atlas supporting the sky, like that of the Farnese Atlas at the National Archaeological Museum of Naples.

But things were more complicated when it came to include the sun, moon, planets, and their apparent motions. Ingenious mechanisms were developed early as the Antikythera mechanism, found at the bottom of the Aegean Sea in 1900 and currently an exhibition until July at the Conservatoire National des Arts et Métiers in Paris.

During two millennia, the human mind and ingenuity worked constantly developing and combining these two approaches using a variety of media: astrolabes, quadrants, armillary spheres, astronomical clocks, copernican orreries and celestial globes, culminating with the famous Coronelli globes offered to Louis XIV. In 2006 they were exhibited at the National Library of France.

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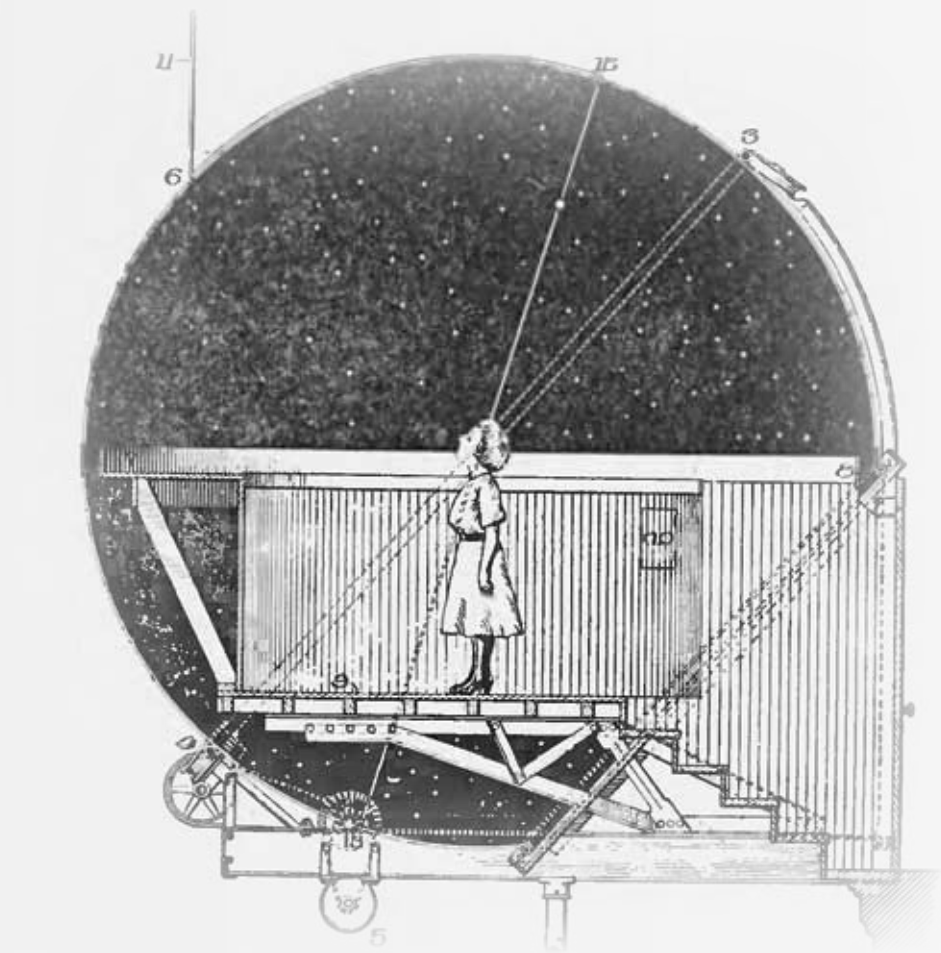

Diagram of the Atwood Sphere from 1913. One place this diagram appeared was in *Popular Science Monthly*, the precursor to *Popular Science*, Volume 84, 1914. Creative Commons. archive.org/details/popularsciencemo84newyuoft

As the venerable device celebrates its 100th birthday, two authors take a look at where it fits in the evolutionary history of planetariums

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When considering cutting-edge technology from a century ago, one might reasonably expect it either to be obsolete (say, Formica) or to be still used with little change (such as the zipper or windshield wipers). Rare indeed is the object that is both obsolete and yet still used with little change, but the Atwood Sphere is one. Its allure makes it unusual and unique among the inventions of 1913.

What is the Atwood Sphere?

The Atwood Sphere is a 17-ft-diameter stainless steel sphere punctured by 692 holes of different sizes that map the night sky. It opened to great acclaim at Chicago's Academy of Sciences on June 5, 1913.

Built for the impressive sum of $10,000, designer Wallace Atwood wowed his audiences that evening, and for several years to come, by demonstrating the visible motions of the night sky.

The 500 lb. metal globe, being only 1/64th in. thick, bowed and flexed as it rotated, so that visitors could also hear it and imagine the music of the heavenly spheres. Hearing stories illustrated with constellations drawn on the interior surface, accompanied by glowing disks to represent planets and a moveable light providing solar illumination, children and adults alike were enthralled by the wonders of the heavens.

When the Adler Planetarium opened just a few miles away from the Atwood in 1930, the Atwood was considered obsolete, and never regained its popularity at the Academy. Indeed, it was not used at all for some years in the 1930s, although in 1941 it was used to teach navigation principles to the US Na-

The Atwood Sphere today, Courtesy Adler Planetarium.

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Early 17th and 18th centuries

Now became the problem of representing a globe's sky. In the Arab world and India, some arches in luxurious palace were decorated with diamonds. Lit with candles, they allowed the viewer to enjoy a sparkling "starry" sky, but the image was fixed.

This changed in the seventeenth century with the invention of the Gottorp Globe. With a diameter of 3.1 meters, it was designed by Adam Olearius at the behest of the Duke of Holstein-Gottorp and built by Andreas Busch of Limberg between 1654 and 1664. Painted on the outside with continents and oceans known at the time, it is tilted 54 degrees.

An entry in the Indian Ocean allowed spectators inside, where they could see constellations painted on the interior and lit by holes for the stars appear. An operator was to manually rotate the sphere.

Tsar Peter the Great received the globe as a present in 1715 and it was installed at the Academy of Sciences in St. Petersburg. Destroyed by fire in 1747, it is completely rebuilt between 1748 and 1752 and is now preserved at Lomonosov Museum.

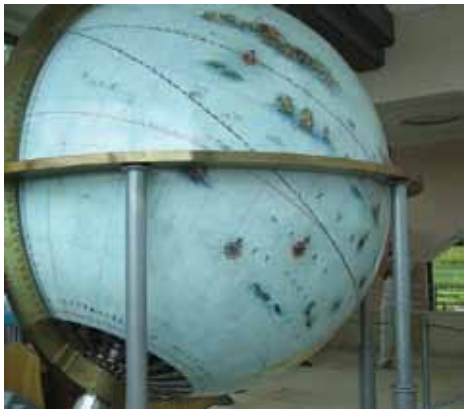
Alongside this first stellarium, was another world designed by Erhard Weigel, professor of mathematics at Jena between 1654 and 1699. This globe, at a diameter of 11 feet, is a little more involved with an earthly sphere installed in the center.

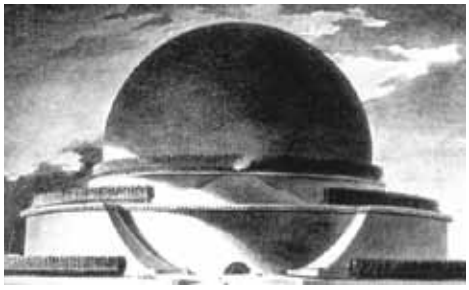
In the early eighteenth century, Roger Long, professor of astronomy at Cambridge, made another mobile globe that was kept at Cambridge's Pembroke College in 1758. Named Uranium, it had a diameter of 18 feet and could accommodate 30 people. Its complicated rotation was accomplished with ropes. Despite the enthusiasm of Long, his Uranium did not receive the expected popular welcome.

Architecture takes over

Mobility being an obstacle, the stellarium concept was kept alive by the architects of the eighteenth century. A current against the Baroque and classical style that reigned, the architects proposed bold figures where the geometry was at the service of creativity. The spherical shape was directly interested in astronomy. This was particularly the case in the Cenotaph for Newton, designed in 1784 by Étienne-Louis Boullée as a perspective on the centenary of universal gravitation. Although it was never built, Boullée was the first architect to design such a permanent building with bright stars and the effect of day and night.

Boullée devised his cenotaph, or an "empty tomb" to honor remains interred elsewhere, during the period of time when science was flowering. The theory of universal gravitation, spread throughout France by Voltaire





From top: The Gottorp Globe from 1664, Eise Elsinga's planetarium from 1781, and the concept for Boullée's Newton Memorial. All images on these two pages Wikimedia Commons.

and Maupertuis, was used to calculate the return of Halley's comet in 1759 and paved the way for celestial mechanics.

Boullée was born in 1728, the year following Newton's death. His concept was great. It obeys the geometry of a pyramid face, insertable into a triangle, and incorporates the fascination with spheres, a trendy artistic theme following the launch of the first balloon flight in 1783 by the Montgolfier brothers.

Boullée's vision was a huge sphere with a cylindrical drum base with an opening that allows the entire sphere to be seen. Beyond the imposing appearance, the most spectacular concept was inside with a representation of the sky.

Long considered an impossible dream, the hollow sphere designed by Boullée experienced renewed interest after the Second World War, with the progress of the construction of metal structures. Buckminster Fuller went on to develop the principles of the architecture of geodesic domes, and this form was consecrated by the Géode at La Villette, designed by the French architect Adrien Fainsilber in 1983 at the time of the project for the bicentennial of Boullée. The Géode is located at Cité des Sciences et de l'Industrie in Paris.

Temple to Earth, Lequeu (1790)

A few years after Boullée's design, to celebrate the Revolution, Jean-Jacques Lequeu, a cartographer by profession, an unknown artist and an astronomy enthusiast, imagined the Temple to the Earth with the same starry sphere, adding an educational aspect with a globe Earth at the center, as the Stellarium Weigel in Jena.

Again, the project remains only in the state of diagram, but it marks a theoretical result showing the architectural progress of the time.

The nineteenth century saw the development of panoramas, the ancestors of cinema, as illustrated by Daguerre's Diorama and other theater devices. They bloomed in large cities and included shows dedicated to starry sky.

At the threshold of the twentieth century, in 1902, George Méliès' production A Trip to the Moon (Le Voyage dans la lune) reflects the public's enthusiasm for astronomical events

Professor Atwood's Sphere, 1913

Tonight is June 5, 1913. People flock to Museum of the Academy of Sciences of Chicago for the opening of a large rotating celestial sphere. Professor Wallace Atwood, director of the museum, its designer, is in charge. The door closes, and viewers see a beautiful starry night. Slowly, familiar constellations rise in the east, while others plunge to the west. With suitable projectors, it is the moon and planets' turn to be on stage. And then the sun, represented by a small flashlight, eclipses the stars to simulate the arrival of the day. The enthusiastic shouts echo in the museum.

This 4.57-m sphere consists of sheets of galvanized sheet iron of 0.4 mm thickness, suitably curved. Weighing 227 kg, it is inclined at 42 °, corresponding to the latitude of Chicago, and rests on three wheels that permit its rotational movement. An electric motor actuates the two lower wheels.

Small perforations in the outer skin form 692 pinhole stars visible to the naked eye. The moon is made by a series of small disks coated with a light coating, corresponding to the different phases, while the planets Venus, Mars, Jupiter and Saturn are also figured with their changing positions.

Initiated by the president of the Academy of Sciences, La Verne W. Noyes, the sphere is

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val Reserve unit at Northwestern University. Approximately 900 men passed through the school every three months.

Over time, the instrument itself suffered some decay. Being labeled a "white elephant" by the media in 1956 did not help matters. With little attendance and dwindling respect for it, the Atwood eventually suffered the indignity of being completely brought down to Earth; its exterior was plastered and painted to simulate a terrestrial globe in 1959. It was given a new name as well: "The Globe-Planetarium."

The name changed again in 1983 to the "Atwood Celestial Sphere," but even so, it was not used from the early 1960s until 1986.

The sphere's big move

In 1995, the Atwood left the Academy when it was donated to the Adler Planetarium. The entire globe was dismantled—its wood interior taken apart and the sphere itself cut into 6 pieces—and put into storage. In the fall of 1996, the Adler began planning its restoration, and completed that task in 1999 in the significantly expanded Adler facility that added 50% to its exhibit space as well as a new state-of-the-art digital theater.

Today, ironically, the Atwood is located just a few steps away from the world's most technologically-advanced planetarium system; just as ironically, it again enjoys a level of attendance and popularity it did a century ago. Understanding why takes us on a historical tour of how we have built devices that demonstrate the wonders of the cosmos.

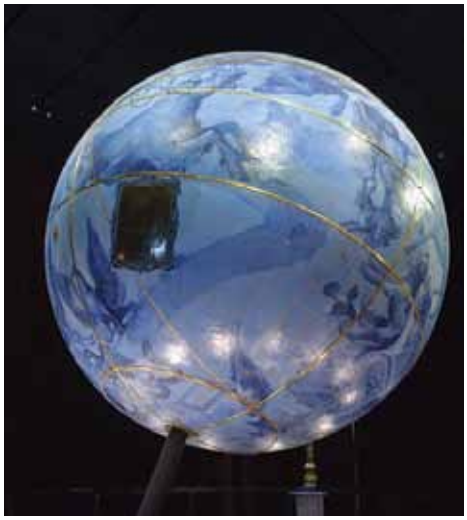
Mechanical planetariums before Atwood

Throughout history, astronomy has enjoyed a high reputation, due to its cosmic scope and the universal belief in the powerful, yet mysterious connections between heaven and earth. Every known culture has its own astronomically-informed myths of origins, associated rituals of meaning, and some material manifestations that express them.

Around the world, we know of altars, temples, homes, cities, and other spaces designed to mirror on earth the structure and motions of the heavens.

The most specialized imitations find expression in mechanical systems that closely mimic the movements and timings of specific heavenly bodies. Indeed, the oldest known mechanical device of any kind is the Antikythera Mechanism, an extraordinary instrument made 2000 years ago and found just a century ago in a shipwreck. While scholars still debate its complex details, all agree on its fundamental astronomical purpose.

We know of very few physical or mechanical models of the heavens during the next millennium. Reports of various devices in Asia merit more investigation, as the most well-researched sources address the European setting. There, the invention of the clock soon led to devices that displayed the changing positions of key, selected heavenly bodies.



From top: The Antikythera Mechanism, the Coronelli Globe at the National Library of France, and *A Philosopher Lecturing on the Orrery* by Joseph Wright of Derby at the Derby Museum and Art Gallery, England.

These astronomical clocks were found in public spaces, such as town squares or in churches, or in private collections. While their key informational feature was a dial face with a pointer indicating the current location of the specified object, the demonstration of regularity and predictability manifested divine order, which was the underlying message to be disseminated and to be absorbed by medieval and later audiences.

The use of the word planetarium itself most likely derives from the device made in the mid-1300s by Giovanni de' Dondi, or rather from his text describing his machine. Like many instruments of this kind from the late middle ages and later, it displayed the locations of the seven classical "planets"—Mercury, Venus, sun, moon, Mars, Jupiter, and Saturn—on dials or faces of a clock. In this instance, the device had seven different "clock" faces, one for each planet then known.

This kind of object—with faces or dials using a pointer of some kind to indicate positions—fits the broader category of mechanical devices leading to the modern planetarium.

These planetary machines took on a different form after the Copernican revolution in the sixteenth and seventeenth centuries, with various geared devices teaching the new astronomy of planets orbiting the sun.

After Newton provided an intellectually compelling explanation of the Copernican system, the public appetite for it led to a new material culture. Around 1705, George Graham built the first mechanical model of the sun-Earth-moon system; this device is now part of the collection at the Adler Planetarium.

Artisans produced many more such tabletop models in the following centuries, thereby disseminating astronomical knowledge to a wider public audience eager to own this universal knowledge. These are frequently known as orreries, named after the Fourth Earl of Orrery, who commissioned a device similar to Graham's.

Globes before Atwood

Alongside the mechanical planetarium history, we find another tradition that eventually produced the Atwood. This genealogy chronicles spherical models of the heavens, usually portraying the distribution of the stars, but not the motions of the planets.

The earliest reference to a celestial globe dates from about 370 BC, when Eudoxus either made one or brought one from Egypt, while the oldest surviving celestial globe is the Farnese Atlas, circa AD 150, now in Naples. Other records indicate the existence of Islamic celestial globes from the 9th century, with the oldest surviving example from the late 11th century.

European globes are known circa 1300, although the oldest survivor dates more than a century later. Since 1500, celestial globes, almost always in tandem with terrestrial globes, summarized what was known of the heavens and the Earth.

Along with these globes, armillary spheres provided an effective way to teach the motions of the heavens. Since 1400, armillary

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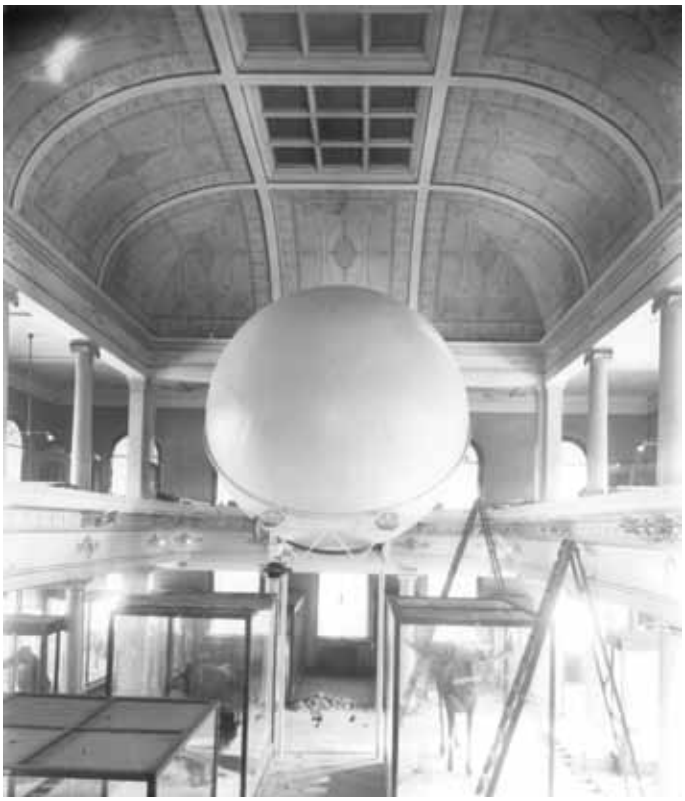

Top: Dr. Wallace W. Atwood inside the Atwood Celestial Sphere at the Academy of Sciences of Chicago. Below: the sphere, exterior front with lower exhibits, Laflin Building, circa 1920s. From the collection of the Chicago Academy of Sciences, used with permission.

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completely renovated in 1959. The exterior is painted to present a geophysical globe and colored filters are installed for the brightest stars. Ultraviolet lamps simulate dawn and dusk. And a horizon is added: a skyline of the skyscrapers of Chicago.

Stellarium reborn

The impact of this remarkable stellarium rapidly raises identical projects, particularly in Germany. In 1914, another stellarium is built in Heilbronn by Robert Mayer, while the Deutsches Museum in Munich began studying a comparable installation. This seemingly small initiative will lead to a quantum leap that will revolutionize the history of representations of the sky.

The planetary mechanisms

As with the representation of stars with stellariums, modeling the solar system also has experienced several centuries of development. Museum collections are full of these orreries, which set the planets in motion around the sun with clockwork mechanisms, both through horizontal devices and vertical, integrated astronomical clocks. Astronomical clocks multiply after the lead of the astrarium by Giovanni Dondi, developed between 1348 and 1364.

The particular case of the moon leads to telluriums and lunariums, allowing the representation of eclipses, while from the eighteenth century on, spurred by the return of Halley's comet, another device modeled the elliptical planetary movements of comets, a cométarium.

The 1766 painting *A Philosopher Lecturing on the Orrery* by Joseph Wright, housed in the Derby Museum (United Kingdom), illustrates the success of these miniature planets.

Larger projects began emerging, such as the well-known global built by Eise Eisinga at his home in Franecker (Holland, 1774-1781; see *Planetarian*, 40-4, December 2011). Updated with electricity in 1925, the Copernican planetary at the Deutsche Museum, Munich, marked a climax in this representation of the solar system's precision, but with the disadvantage of a single viewer placed in a rotating cage. The instrument was partially destroyed by bombing during the war.

1913-23: Genesis of planetariums

But the most important consequence resulting from the impact of the Atwood stellarium in 1913 was the fusion between these two previously separate representations of stars and planets.

Larger projects were born from a meeting between several actors. In the months following the entry into service of the Atwood Sphere in Chicago, the founder and first director of the Deutsche Museum, Oskar von Miller, entered into a relationship with Max Wolf, director of the Observatory of Heidelberg, and Walter Bauersfeld, engineer from the Zeiss Company. Starting in July 1913, the idea emerged to take the rotating sphere to higher dimensions and incorporate the planetary movements.

Delayed by the war, Bauersfeld's concept still faces technical difficulties to achieve a rotating sphere of 6 meters. Starting in March 1919, he reworked the initial idea and came up with a large fixed sphere with a central projector to show both moving images of the night sky as well as the sun, moon and planets.

A first design of this new projector mounted at the center of the sphere appears in his notebooks in May, 1920. Developed over the next three years, it is first demonstrated in August, 1923 in Jena, under a 16-m dome specially fitted on the roofs of the Zeiss Company. It was demonstrated in October that year in Munchen under a 9.8-m dome, before coming back to Jena.

There, the design was improved with the help of Walter Villiger, who developed its educational functions, and finally, in May 1925, the new planetarium was installed at the Deutsche Museum in Munich and open to the public.

During the interwar period, planetariums multiply rapidly in the world, particularly in large cities in Germany and mostly in the domes of large diameters. There were 25 erected by 1939, including 11 in Germany and five in the United States.

America's first planetarium was built in Chicago in 1930 at the Adler Museum, evoking in its architecture Boullée Cenotaph for Newton.

Paris was no exception, with the first planetarium built for the six months of Expo 1937 and coordinated by Reysa Bernson. But it was after the Second World War, and especially during the exploration of the moon, that planetariums saw their highest development, built by the hundreds in the United States, Europe and Asia, mainly Japan.

In conclusion.

The year 1913 is, therefore, a major turning point in the history of representations of the sky. The entry into service of the first modern planetarium that merged the approach of stellariums with Copernican orreries had a resounding impact. The advent of planetariums

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spheres became a standard tool for teaching astronomy to students.

For present purposes, what distinguishes the mechanical tradition from the globe tradition is that the former point out locations in the sky, whereas the latter address the appearances in the sky. That is, the mechanical devices indicate, for example, that the sun is currently located in the constellation Aries. This knowledge could be put to use for various computational, astrological, or even medical purposes.

While one could, and many did, put globes to a similar use, the globe and armillary also provided explanations of what appeared in the sky, for example, providing a way to understand how the sun's location in Aries made the other constellations appear (or disappear) in the night sky, why the moon appeared in different phases in various constellations over the month, and more.

The Copernican shift

The adoption of the Copernican system marked a significant moment in these two traditions. A model of how the sky appears did not need to show the reality of the solar system; just as significantly, indeed even more significant from an economic standpoint, the model of reality became distinct from how the sky appeared.

The 17th and 18th centuries saw the continued production of mechanical devices with dials that showed the Copernican reality with no attention to what appeared in the sky. The Graham orrery was followed by a variety of gadgets: pocket orreries, without which no gentleman would be caught, and grand orreries, whose enchantment was captured best by Joseph Wright of Derby.

Other devices, sometimes called Copernican moving spheres, retained the look and feel of armillary spheres but instead of teaching about what appeared in the sky, they illustrated a God's eye view of planetary orbits.

A new kind of globe

It is one thing to explain the heavens; it's quite another to offer a simulated experience of them. A large celestial globe, made in 1654-66 in Gottorp (Gettorf), near what is now the German-Danish border, did just that. Made of 7000 lb. of copper and measuring 11 ft. in diameter, it included a small door near the South Pole to provide access to the interior.

About a dozen people equipped with oil lamps could see gilded stars and constellations portrayed on the globe's interior, and watch them rise and set against the artificial horizon as the sphere turned about them.

After liberating it from its original home, Peter the Great moved it to the St. Petersburg Academy of Sciences, where it burned in a fire in 1747. How much survived is unclear, but seven years later, a new globe, now known as the Great Academic Globe, engaged audiences again.

After several moves and restorations, it is once again open to the public, now at the Lomonosov Museum in St. Petersburg.

A related experience was provided by a much smaller, 20-in. sphere built at the University of Jena in 1654. This globe displayed stars as tiny holes punched in the globe. The recently reopened Mathematisch Physicalischer Salon in Dresden, Germany features one of these globes made by Erhard Weigel.

Roger Long, a Cambridge Professor of Astronomy, combined these two techniques in his 17 ft. globe at Pembroke College in 1758. Originally, a lamp illuminated the constellations, although after 1764, newly-bored holes allowed up to 30 visitors to see stars illuminated from the outside. A photograph from 1874 provides evidence of this sphere, which was demolished and sold for scrap, but the key inspiration for the Atwood had arrived.

Right: Dr. William J. Beecher, director of the Chicago Academy of Sciences, in the foreground and Thurston Wright, preparator, in the background, circa 1959, with the sphere transformed into the Globe-Planetarium. From the collection of the Chicago Academy of Sciences, used with permission. Below: The Atwood Sphere in use today at the Adler Planetarium. Photo courtesy the Adler.

Synthesizing these efforts

Numerous other ingenious planetarium devices merit more attention that the current space allows, but the final one mentioned

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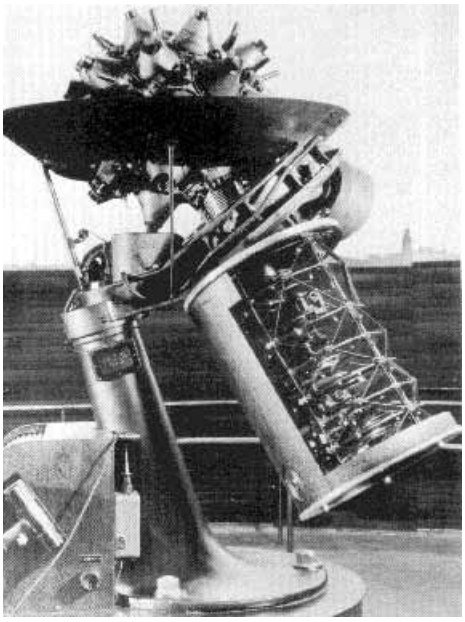

The Zeiss Mark 1. Wikimedia Commons

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is so tied to 1923 and Bauersfeld that the fact that the genesis of the idea actually started in 1913 is hidden.

This story of stellariums is an essential chapter opening the advent of planetariums. With digital technologies, their evolution continues today to immersive rooms to simulate space travel.

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here must be the hybrid system created at the Deutsches Museum in Munich, one that attempted to combine the mechanical model tradition with globe tradition that simulated the appearances.

In the early decades of the 1900s, Carl Zeiss tasked its engineers to develop innovative ways for public astronomy. Early approaches involved the same technique used by Long and Atwood; Max Wolf had sketched out such a plan in 1912 prior to his receiving a printed description of the Atwood and forwarding it to his German colleagues.

But Zeiss also built the largest mechanical orrery in the 1920s in Munich. In a 36-ft. cylindrical room, elliptical rails hanging from the 9-ft ceiling used electric motors to drive the planets, represented by poles with light bulbs. The central sun illuminated the planets and their movements, modeled on a scale of 12 minutes per terrestrial year.

The key feature was a small platform linked to the Earth; it carried visitors and a periscope through which one could watch planetary and stellar motions. The cumbersome nature of the room-sized orrery, the noise it produced, and the lack of a convincing experience of the sky soon led Zeiss to develop optical projectors that convey these appearances more effectively.

The current Atwood

I suppose that one of the reasons why I am especially fond of the Atwood Sphere is that it was my first project when I started working at the Adler in 1996. That fall, the Adler began a carefully-planned restoration for exhibiting the Atwood in the soon-to-be-expanded Adler facility. Preparatory work involved the removal of paint and putty (from its terrestrial incarnation) using scrapers, grinders, and even acid treatments before hammering the mountains back down again.

These efforts plugged many star holes, requiring their re-drilling. In its original installation visitors had to walk up a flight of stairs to enter the sphere, while we deemed it important to provide universal access. This required designing a carriage moved by a 21 ft. long screw built by a company that designed the mass production facilities at the Saturn car company. This provided a nice cosmic coincidence, not only because of the name but also because the assembly line mass production of cars was another one of those innovations from 1913.

Today's tour guides take up to 8 visitors at time into the Atwood, where they can watch the stars, illuminated from outside, rotating with diurnal motion. Fluorescent tubes light up otherwise invisible paint to illustrate the constellations. Young children, teens, and adults alike leave with a smile on their face, charmed by the simplicity of the experience, the solid basic content, and the charming antiquated technology that creates the Atwood's night sky.

The Atwood represents the culmination of many centuries of efforts to portray the wonders of the heavens in a controlled environment. It played an important role in motivating the development of modern planetarium projection systems, and was rendered obsolete by it. Yet, visitors today still love it! ☆