

The Colorado Scale-Model Solar System

"How vast those Orbs must be, and how inconsiderable this Earth, the Theatre upon which all our mighty Designs, all our Navigations, and all our Wars are transacted, is when compared to them. A very fit consideration, and matter of Reflection, for those Kings and Princes who sacrifice the Lives of so many People, only to flatter their Ambition in being Masters of some pitiful corner of this small Spot."

—Christiaan Huygens, in *New Conjectures Concerning the Planetary Worlds, Their Inhabitants and Productions*, c. 1690.

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Scaled representations of the Solar System can provide a unique educational tool to illustrate the inconceivably vast distances that characterize our universe. Such models rarely are attempted, however, because of the practical difficulty of depicting the planets and their distances on a convenient, human scale.

On the Boulder campus of the University of Colorado we constructed the Colorado Scale-Model Solar System. The display illustrates, on a scale of 1 to 10 billion, the sizes and distances of the Sun and the nine planets. The extensive educational information presented in the display, and its elegant, artistic design make it unique among such exhibits. We describe the details here in hopes that similar scale exhibits can be mounted at other schools, museums, and campuses.

The Colorado Scale-Model Solar System is dedicated to the memory of University of Colorado alumnus Ellison S. Onizuka (B.S., M.S. Aerospace Engineering, 1969) and his six crewmates

of the space shuttle *Challenger*. The theme of the 1986 *Challenger* shuttle mission was "teacher in space," and the cargo included experiments built by University of Colorado scientists to study Halley's comet. The educational display is a fitting memorial to the astronauts and their mission.

Educational Value

We designed and built the scale model of the Solar System to stimulate further public interest in astronomy and the exploration of the planets. We chose the theme of the exhibit to illustrate one of the most important concepts in astronomy: astronomical size and distance scales.

We believe that the scale-model Solar System provides the best available means of conveying the concept of astronomical distances to students and the public. As examples, we list just a few of the interesting facts illustrated in the Colorado Scale-Model Solar System:

- The model Earth is located 15 m from the model Sun and is about a mm in diameter. Indeed, the Earth and the orbit of the Moon together can fit in the palm of a hand. (The moon, of course, is the farthest humans have traveled.)
- A visitor can walk the length of the model in about ten minutes; each step represents approximately 10 million km. *Voyager 2*—which visited Jupiter in 1979, Saturn in 1981, Uranus in 1986, and Neptune in 1989—required well over a decade to travel the same distance.
- On the 1 to 10 billion scale, the speed of light is 3 cm/s—about the speed at which insects crawl.
- To gain an appreciation for the size of the Universe, consider the following: In the Colorado Model, the Sun is about the size of a grapefruit, and the rest of the Solar System is clustered within a half-kilometer of the model Sun. The nearest stars (the triple system of Alpha Centauri) would be located some 4,000 km



Fig. 1. The Colorado Scale-Model Solar System stretches along a heavily traveled pedestrian pathway. The gold-anodized model Sun (in the pyramid-shaped monument) can be seen in this view; the monuments for the four inner planets are located to the left of the Sun. The street (notice the truck) marks the asteroid belt, and the outer planets extend along the walkway beyond. The domed structure on the right is the Fiske Planetarium.

away, approximately the distance from Boulder to Panama. Our Milky Way galaxy is some 30,000 times wider than the separation between the Sun and the nearest stars; yet our galaxy is only one of ten billion to one hundred billion galaxies in the observable Universe.

Physical Description

On a scale of 10^{-10} ($1 \text{ \AA} = 1 \text{ m}$, $1000 \text{ km} = 1 \text{ light-year}$), the inner four planets (Mercury, Venus, Earth, and Mars) lie within 25 m of the Sun, and the realm of the planets extends to the aphelion for Pluto at about 740 m. The Sun is 14 cm in diameter, and the planets range in diameter from 0.3 mm for Pluto (about the size of the period at the end of this sentence) to 1.4 cm for Jupiter (about the size of a marble).

Layout on Campus

The Sun and the four inner planets are located near the entrance to the Fiske Planetarium (Fig. 1). The outer

planets extend along a heavily traveled, straight walkway. Each of the planets is located at its scaled mean distance from the Sun, with the exception of Pluto. To avoid a major street, the scale model Pluto is located 500 m from the Sun, somewhat less than its scaled mean distance of 590 m, but beyond its perihe-

lion distance (and beyond the location of Neptune). By a happy coincidence, a street running through campus coincides with the location of the asteroid belt (Fig. 2).

Model Sun

The model Sun is a gold-anodized, aluminum sphere 14 cm in diameter. It

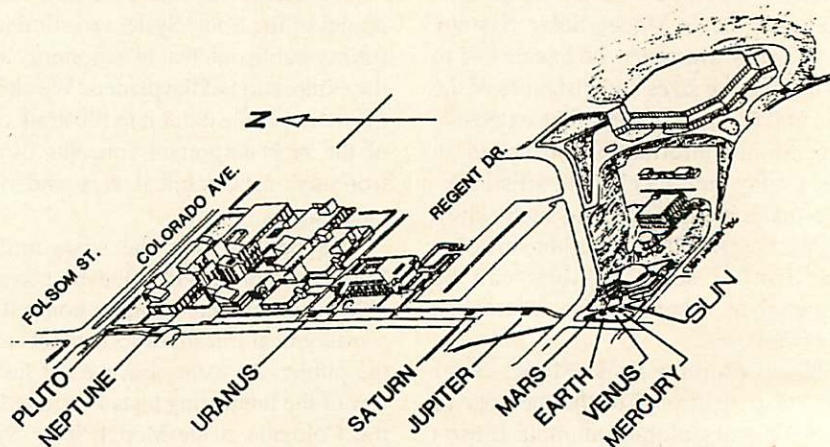


Fig. 2. A map showing the layout of the Colorado Scale-Model Solar System on the Boulder campus of the University of Colorado. The distance between the Sun and Pluto on the campus is 500 m.



Fig. 3. Lorna Onizuka (widow of the *Challenger* astronaut) and University of Colorado Chancellor James Corbridge unveil the plaque dedicating the exhibit. University President E. Gordon Gee stands to the right. The model Sun is located under glass in the apex of the black granite pyramid. (Photo by M. Natvig)

is located in the glass-capped top of a 2-m-tall, pyramid-shaped monument (Fig. 3). The monument is constructed out of polished black granite, the same material used in the Vietnam Veterans Memorial in Washington, DC.

Information plaques are embedded on three of the four sides of the pyramid-shaped monument: one is a bronze plaque dedicating the exhibit; one has general information about the model Solar System; and one has color pictures and a description of the Sun. The plaques are trapezoidal in shape to con-

form to the geometry of the central monument.

Model Planets

The nine planets are housed individually in meter-high pedestals, also constructed of black granite (Fig. 4). The top face of each structure is sloped at a 30° angle and holds a 25- × 40-cm information plaque covered with a 1.2-cm glass plate. The model planets are hemispheres cut into the underside of the glass cover plates, and are painted to enhance the three-dimensional appearance. Located over a black background

in the upper left corner of the plaque, the hemispheres create the illusion of a planet floating in space. In addition to the planets themselves, the orbits of moons are illustrated to scale whenever they fit within the 7-cm square available space (see Fig. 5).

Information Plaques

The information plaque for each planet includes two color pictures, a table of vital statistics, and a set of "fun facts." Each plaque is produced as a single photographic print with a gold-colored background. One such plaque is shown in Fig. 5.

Because the model solar system is an outdoor display, it experiences an enormous range of harsh conditions. Boulder temperatures vary from a minimum near -25°C to a maximum near 40°C, and the summer sun is quite intense. Finding a suitable process with which to display color photographs under these conditions has proved the most difficult task in the building of the project. We settled on a photographic material developed primarily for archival use. Unfortunately, substantial fading has occurred on most of the original plaques. It has been determined, however, that this fading occurred as a result of water intrusion, rather than from temperature extremes or sunlight exposure, so we are now developing new methods of sealing the photographs against moisture.

Educational Use

Since its completion the Colorado Scale-Model Solar System has been used extensively for educational purposes. Instructors of undergraduate astronomy courses have designed homework sets around the project. Primary and secondary school teachers often bring their classes to the exhibit as part of a field trip to the Planetarium.

In addition, because the model is located along a heavily traveled pedestrian path, thousands of people pass by it each month. During the day it is common to find individuals at particular pedestals, reading the information plaques.



Fig. 4. The plaque for Saturn, with the model planet in the upper left corner, is shown in its black granite pedestal. The "flatirons" geologic formation is seen in the distance.

Future Plans

The design of the model makes replacement of the planetary plaques a relatively easy task. We expect replacement of the plaques to be necessary approximately every three to five years, in part because as we learn more about the planets the model will need to be updated.

We hope that other similar exhibits will be built at other locations. Any institutions wishing to pursue such a project are invited to contact the authors for further information.

Educational Poster

The descriptive plaques for each of the nine planets and the Sun, plus an eleventh plaque describing the real Solar System and the physical layout of the model, have significant educational value; therefore, we have produced a large (about 70- x 90-cm), full-

color poster on which all of the plaques are reproduced. The poster contains the text of the dedication to the *Challenger* astronauts (see Fig. 3) and a crew picture as well. Posters may be ordered for \$12 each (checks payable to the University of Colorado) by writing to the authors at CASA, Box 391, University of Colorado, Boulder, CO 80309. All proceeds from poster sales go to the maintenance and improvement of the Colorado Scale-Model Solar System.

Acknowledgments

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The Colorado Scale Model Solar System represents the Sun (on the pyramid at Fiske Planetarium) and nine planets (along the walkway from Fiske to Engineering) on a scale of 1 to 10 billion. Here, at its scaled mean distance from the Sun, we see the scale model Earth, and the orbit of the Moon.

PLANET CHARACTERISTICS	
Radius (equatorial)	6,378 km
Mass	6.0×10^{24} kg
Volume	1.1×10^{12} km ³
Rotation Period	23.93 hrs
Axis Tilt	23.5°
Surface Gravity	1.0 g
Min. Temperature	-90°C
Max. Temperature	60°C

ORBIT CHARACTERISTICS	
Period	365.26 days
Avg. Distance from Sun (= 1 AU)	149,600,000 km
Perihelion	147,100,000 km
Aphelion	152,100,000 km
Inclination to ecliptic	0°

EARTH

Earth, third planet from the Sun, is the innermost planet with a moon. The Moon has a diameter about one-fourth that of Earth: some scientists refer to the Earth and Moon as a "double planet".

The Earth and Moon are the only worlds on which humans have set foot. Twelve humans walked upon the Moon between July 1969 and December 1972.

The Earth has experienced great changes in its 4.6 billion year history. Its surface is continually reshaped by tectonic activity; its atmosphere, oceans, and life evolve through an intricate web of interrelationships. The planet has not always been hospitable for humans, and is not guaranteed to remain hospitable in the future.

The current atmosphere of Earth is about 77% nitrogen and 21% oxygen, with traces of other gases. A weak "greenhouse effect" warms the surface to an average of 15° C. More than two-thirds of the Earth's surface is covered by water, some of it frozen.

The Earth is a strong source of radio waves, primarily from television transmissions and military radar. Modern radio telescopes could detect Earth-like signals from across our galaxy, although our own signals, traveling at the speed of light, have reached only a few tens of light-years into space.

Earth is, to date, the only world known to harbor life. More than 10 million species of plants and animals currently inhabit the planet.

Speculation abounds concerning the possibility of intelligent life on Earth. One species on the planet demonstrates the ability to study and understand the Universe, yet that species devotes much of its efforts to perfecting methods of self-destruction.




Fig. 5. Sample plaque: the Earth. The scale-model Earth is located at the position of the dot in the upper left corner of the plaque; the orbit of the Moon is indicated on the same scale as well. The plaques are produced photographically in full color. Each of the plaques for the other planets follows a similar layout, with photographs to the right, "fun facts" in the center, vital statistics on the lower left, and the model planet on the upper left.