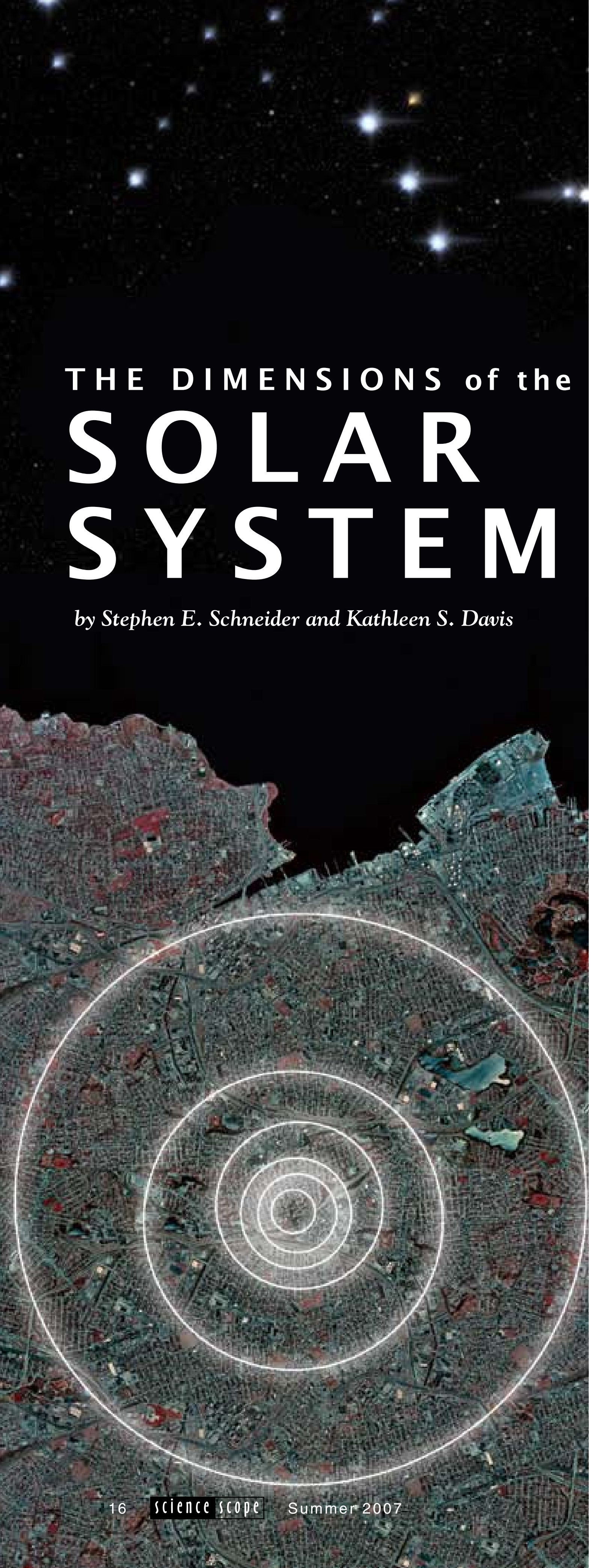

# THE DIMENSIONS of the SOLAR SYSTEM

*by Stephen E. Schneider and Kathleen S. Davis*

We have added a few new wrinkles to the popular activity of building a scale model of the solar system. The new activity takes advantage of some of the special features of Google Earth. Our goal was to create an activity that would give a much more powerful sense of the enormity and emptiness of the solar system and, at the same time, provide an opportunity to make connections with the community.

## *Traditional models*

Historically, solar-system models are built by choosing objects of the appropriate relative sizes as the Sun and planets, and then laying them out along a line from the Sun outward. Unfortunately, the sizes of the Sun and planets often need to be exaggerated relative to their distances to make them visible. This may seem inevitable given the huge difference in the distances versus the sizes, but we see this as an obstacle to students gaining a deeper insight into the scale of the solar system. The problem can be solved if we expand our model sufficiently, so that we can have realistic separations between the solar-system bodies and still have an Earth that is not microscopic.

The second problem with traditional models is the practice of laying out the planets along a straight line. Again, this is understandable as a convenience, but what if we could make a scale model that reflected the essentially two-dimensional character of the solar system? When everything is placed along a line, it is not hard to find even small objects. However, imagine trying to find a grain of rice somewhere in the outskirts of your community. That gives a clearer idea of the challenge facing astronomers who are hunting for dwarf planets in the Kuiper belt.

Middle school students are expected to have some understanding of the solar system, the Sun, and planets and may even be able to name them in their order from the Sun (NRC 1996). However, as one middle-school teacher stated, "I have learned over the years that middle schoolers have zero concept of distance." In addition, at the middle level, students' attention needs to shift from the properties of particular celestial objects toward an understanding of the place of the Earth in the solar system (Massachusetts Department of Education 2006). Thus, building an accurate model helps students grasp the size of the solar system.

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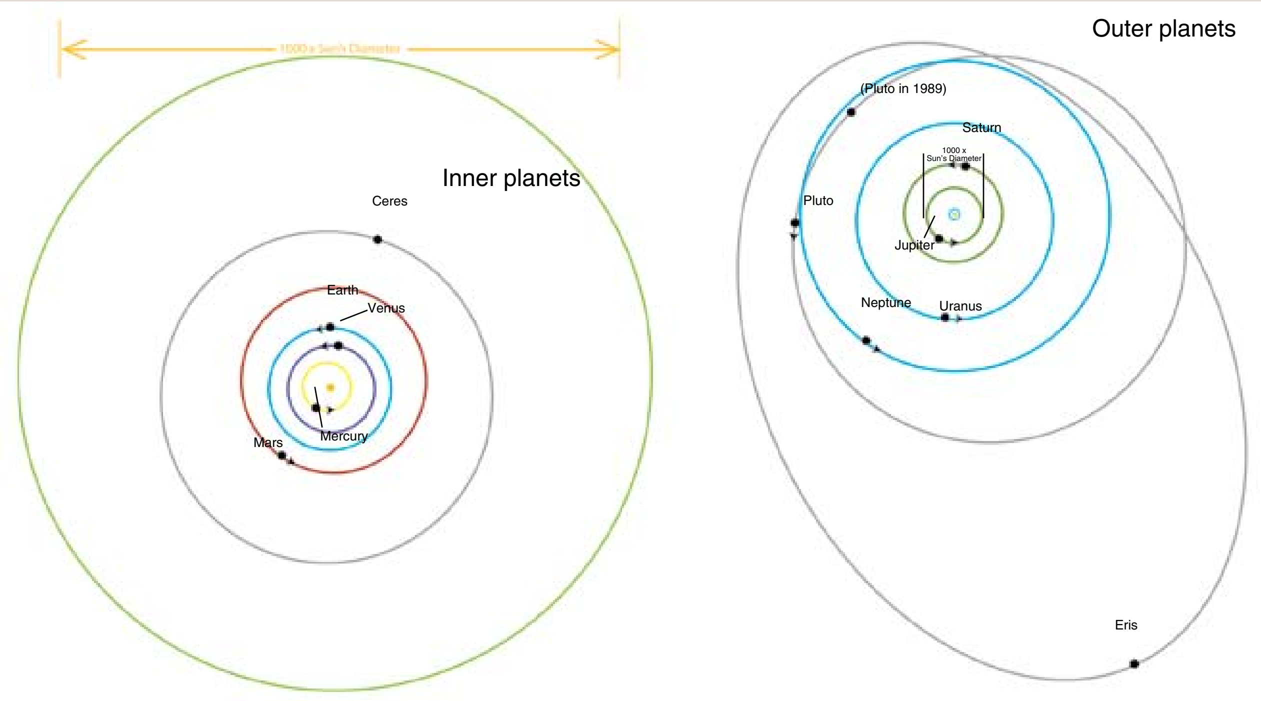
**FIGURE 1** **GIF overlays showing the orbital paths of planets in the inner solar system (A) and outer solar system (B).**
The digital files are available at *www.umass.edu/seo.*




We have found a fun way to design a more-realistic "2-D" model of the solar system where students can learn about maps and scaling using easily accessible online resources that include satellite images. This activity also invites reaching out to a school's community in a way that will engage and educate.

## Using Google Earth

Google Earth is a wonderful, free resource for looking at our planet (see Resources). Once installed, play with the program to learn how to zoom in and out, select layers to show different information on top of the images, and tilt the landscape to see it in 3-D. Under "Tools/ Options" you can change to metric units.

For this project, we suggest using Google Earth to focus on the landscape around your school. Type in your school address and Google Earth will take you there. Now "back out" using the zoom controls until the image encompasses the community surrounding your school. This article is based on a scale in which the Sun is 1 meter in diameter, but you might decide to rescale the numbers we provide so you can make the solar system reach to local landmarks and stores that students are familiar with.

## An overlay of the solar system

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Explore the solar system at *www.scilinks.org*
Enter code: SS070701

The next thing we want to do is to lay a map of the solar system on top of the bird's-eye view of your community. To do this, we created two transparent GIF images (Figure 1) that you can download to your computer. These diagrams show the orbits of the planets (and dwarf planets) in the inner and the outer solar systems—it is almost impossible to show both on the same map because of the huge difference in distances.

To incorporate these images in Google Earth, adjust the zoom until you are at an "Eye alt[itude]" of about 1.5 kilometers (this is displayed in the lower-right corner). This gives you a field of view of a little under 2 km across in your viewing window. In the "Add" menu, select "Image Overlay" then click "Browse" and select the copy of "sol-sys-inner.gif" that you downloaded to your computer.

You will now see the orbit diagram on top of your map, something like Figure 2. You might name this new overlay "Inner Solar System." The green "handles" let you adjust the size, position, and rotation of the overlay. To adjust the position, grab the central green cross so the Sun is on top of your school. To change the size, first press shift then grab a corner marker to maintain the proportions of the figure.

**FIGURE 2** **The inner solar system overlay has been imported into Google Earth and displayed over a school in Sunderland, Massachusetts**

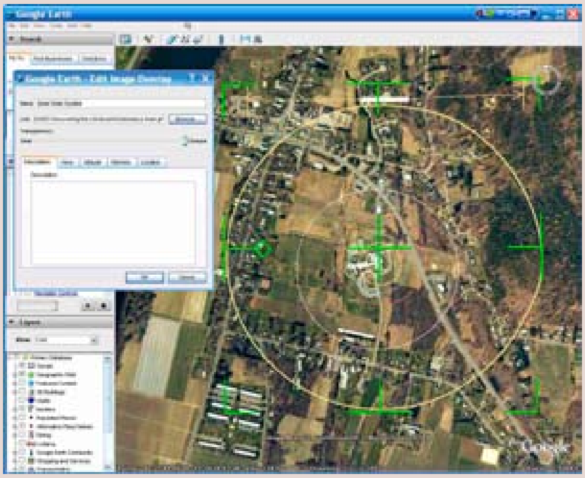
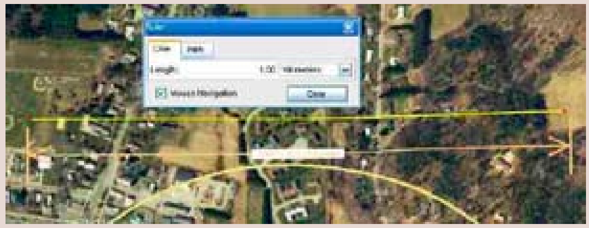


**FIGURE 3** **Making a scaling mark in Google Earth.**
Click on one spot with the ruler tool, then pull out a horizontal line 1 km long (yellow line). Rescale the overlay until the "1,000 x Sun's Diameter" bar is the same length.



## Setting the scale

Next use the ruler (under the "Tool" menu in Google Earth) to help set the overlay to the scale you want. For our example, we want the Sun to be 1 meter in diameter, so we used the ruler tool to draw a horizontal bar on the figure that is 1 kilometer across (yellow bar in Figure 3). You can choose other sizes, but our scale is about the smallest you might want to use because the Earth is about the size of a pea.

Along the top of the inner-solar-system overlay is a bar that shows the diameter of the Sun multiplied by 1,000. (Incidentally, this is approximately the size of Jupiter's orbit.) Because we decided to make the Sun 1-meter across for our example, we adjusted the size of our overlay so that the bar was 1,000-meters (1 km) long. (Note: If your green overlay adjustment handles are gone, you can get them back by right-clicking on your inner-solar-system overlay under "Places" on the left side of the window, then selecting "Properties.")

Once you've resized the overlay so that the "1,000 × Sun's Diameter" bar is the length you want, realign the overlay so the Sun is over your school in a location you'd like. The images in Google Earth are often clear enough to position the Sun right over your own classroom! You can save a copy of your image by going to the "File" menu, clicking "Save," and then "Save Image."

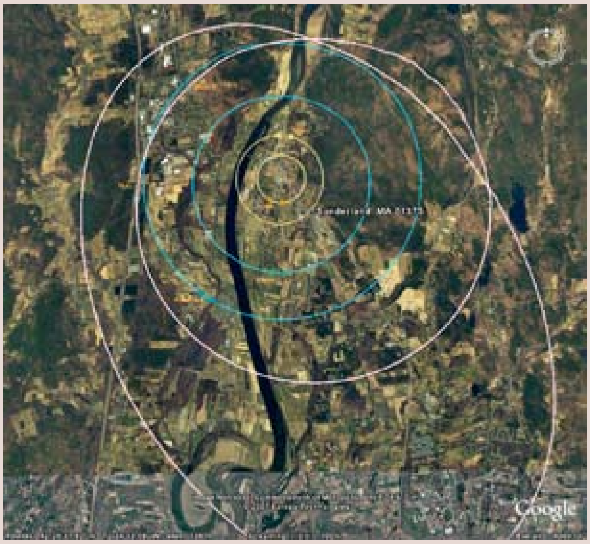
Next, you can add the outer solar system over your surrounding community. Zoom out until your "Eye Alt" is about 15 kilometers. Now load the "solsys-outer.gif" overlay onto this image. To get it so that it has the same scale as the first overlay, you can adjust the size until Jupiter's orbit and the 1,000 × Sun bar match those shown on the inner-solar-system overlay. You can save another image showing your outer-solar-system map over your community (Figure 4). Note that you can turn the layers you have created on and off by clicking the boxes next to them on the "Places" menu in Google Earth. These overlays will remain linked to the program even after you exit, so you can come back to them at a later time.

## Putting it all together

The next step requires a little math. What would be the diameter of the Earth, Jupiter, and other planets on a scale where the Sun is 1-meter across? This might be a good project for students to carry out using the first two columns of Figure 5. We have listed objects, mostly with a food theme, that could be used to match these sizes. You can find other objects or use clay to make any of these—although the Sun, at a meter across, is a challenge.

Now that you have the solar system mapped to scale in your community and have some objects that may serve as scale models of the planets, you can begin to set up your model in reality. You might build the Sun out of papier-mâché to the correct scale and place it in the school. In our example, we can only get the Sun and three inner planets to fit within the school, because the distances really *are* very large compared to the sizes! To add more planets, you might choose a spot where an orbit crosses a street or other accessible spot, and place the accurately scaled model of the planet there. Because the planets are so small, you might want to make larger signs to indicate each planet's location. You might also

**FIGURE 4** **Outer-solar-system orbits shown to same scale over Sunderland, Massachusetts**
The outer highly-elliptical orbit shows the path of the new dwarf planet Eris.




want to extend the activity by having students add the Moon and set it at its distance (about 28 cm) from the Earth, or have them figure out where the Earth will be in your model a month later.

Even if you do not put grains of rice several kilometers away to represent some of the outer dwarf planets, working with Google Earth will give your students a better grasp of the size and distances involved. Even finding a 9 mm Earth somewhere along its orbit around the entire school grounds would be quite a challenge. That might even make for a fun challenge—but you had better give students plenty of hints if they are to have much chance of finding it!

## Inside students' heads

You can get a sense of what students think about planetary size and the scope of the solar system both before and after this activity. Provide them with a model of the Sun made from clay. Ask them to form a model of the Earth made to the same scale. How far would they place the Earth from the Sun? Can they think of analogous objects from everyday life to represent these celestial bodies? Asking middle-school students to express what they think about these questions again after the activity should illuminate a new sense of distance. ■

## Acknowledgments

This activity was developed for an online course entitled "Discovering the Universe: Astronomy for Teachers," which was funded as part of National Science Foundation ESI #0243536—"Science Education Online" (*www.umass.edu/seo*).

## Resources

Google Earth—*http://earth.google.com*
Solar-system overlay maps—*www.umass.edu/seo*

## References

Massachusetts Department of Education. 2006. Massachusetts science and technology frameworks. Available at *www.doe.mass.edu/frameworks/current.html*.

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**FIGURE 5** **The sizes of the Sun and planets, and their scaled sizes in a model where the Sun is 1-meter across.**

| Celestial body | Diameter (km) | Rescaled size | Possible object |
|---|---|---|---|
| Sun | 1,392,000 | 1 m | Large beach ball |
| Mercury | 4,878 | 3.5 mm | Peppercorn |
| Venus | 12,102 | 8.7 mm | Pea |
| Earth | 12,756 | 9.2 mm | Pea |
| Mars | 6,794 | 4.9 mm | Caper |
| Ceres | 940 | 0.7 mm | Salt grain |
| Jupiter | 142,984 | 10.3 cm | Grapefruit |
| Saturn | 120,536 | 8.7 cm | Large orange |
| Uranus | 51,118 | 3.7 cm | Small lime |
| Neptune | 49,528 | 3.6 cm | Small lime |
| Pluto | 2,300 | 1.6 mm | Small grain of rice |
| Eris | 2,400 | 1.7 mm | Small grain of rice |