Where Would CINDI Be?
A 3-D Scale Model of the Earth-Moon System

With guidance from the teacher and working in small groups, students will build a scale model of the Earth-Moon system, predict the Earth-Moon distance on their model, the distance of Earth-orbiting spacecraft, and the upper limit of Earth's atmosphere.

Purpose: to aid students in understanding the scale of the Earth-Moon system and the Earth's atmosphere within that system.

Texas Essential Knowledge and Skills (TEKS) for Science (http://www.tea.state.tx.us/rules/tac/chapter112/index.html):

3.2.B, 3.2.F, 3.3.C, 3.4.A, 3.8.C
5.2.B, 5.2.F, 5.3.C, 5.4.A, 5.8.D
6.2.C, 6.2.E, 6.3.B, 6.3.C, 6.4.A, 6.11.A, 6.11.C
7.2.C, 7.2.E, 7.3.B, 7.3.C, 7.4.A, 7.9.B
8.2.C, 8.2.E, 8.3.B, 8.3.C, 8.4.A, 8.7.C
Astronomy: 6.A

Materials Required

- 1/2 standard container of child's play dough for each group of 2 to 4 students.
- 2 metric rulers per group of students
- 1 calculator per group of students (optional)
- 1 meter stick or tape measure per group of students (optional)

Time required: One class period for a teacher-directed interaction with students working in small groups.

Part 1

1. Divide the class into small groups of 2 to 4 students. Give each group of students a half a standard-sized container of Play Doh TM or other similar product.

2. Ask each group to divide it into 50 roughly equal parts (for younger students, this can be a worth-while math problem by itself). Encourage them to think about possible ways to divide the dough, and to work as a group.

3. Ask each group to choose one piece of "average" in size, roll it into a ball, and then set it aside.

Note: the next step can be frustrating, but is important to the learning goal.

4. Next ask each group to combine the other 49 pieces back into a large ball. (Explain that you have a good reason for asking them to do this, but don't expect your students to like it.)

5. When cries of protest have died down, explain that the students have just created a scale model in size of the Earth – Moon system. The Earth has 49 times the volume of the Moon.

Note: Students will recognize that it takes 49 Moons to fill 1 Earth; they just did it. Likewise, if Earth and Moon were made of the same stuff, their mass would follow this ratio. (Actually, the Moon has at best a very small iron core, and the bulk of it is composed of a material similar to Earth's lower-density mantle, so the Earth is about 80 times the Moons mass).

6. Have each group measure and record the diameters of their two balls.

7. Now ask each group to create a ratio of the diameters of their "Earth" and "Moon" balls. The "Earth" should be a bit less that 4 times the diameter of the Moon (about 3.7 times would be closer to the real Earth-Moon system.)

8. Ask the students how far apart their model Earth and Moon should be if we use the use the same scale for distance as we do for size. (Imagine we could shrink the entire Earth-Moon system down to the size of our play dough balls.)

Most students will predict the Earth and the Moon to be close together, with only a few Earth diameters between them.

Part 2

1) How does the ratio of the real Earth and Moon compare with your model "Earth" and "Moon"?

2) Give students the data that the Moon is 30 Earth diameters away from the Earth.

3) Next, have students measure out the appropriate distance between their "Earth" and "Moon", and either hold them out at that distance, or place them on their desks/table at the appropriate spacing. The distance should be about the distance between two hands outstretched on either side of the body, or a little bit greater.

4) Now ask students to predict where an orbiting spacecraft such as C/NOFS (CINDI), the space shuttle, or the space station would be if added to the model. Where would the “top” of the atmosphere be?

Part 3 – Real Distances and the Earth’s Atmosphere

Table 1: Real Distances and Sizes

Property	
Real Earth Diameter	12,734 km
Real Moon Diameter	3,476 km
Ratio of Earth to Moon Diameter	~4/1
Real Earth-Moon Distance	384,000 km
Orbit of the International Space Station (ISS)	~390 km
Lowest height of the C/NOFS satellite with CINDI	~400 km

1) Give students the distances to spacecraft in the Table 1.

2) Ask students to predict far away should a model of a spacecraft in the table above, be from the model Earth? Find that place on your Earth-Moon model.

2) Give the Earth-Moon distance, and ask students to revise their predictions with the data. (The distance to the spacecraft in the model is roughly $1/1000^{th}$ of the Earth–Moon distance.) This height is low Earth orbit.

3) Tell students geosynchronous satellites orbit at the same rate as the Earth turns. The distance for those satellites, such as satellite TV and other communication satellites, is 36,000. Ask students to that distance on their Earth-Moon model. (This is a bit less than $1/10^{th}$ of the Earth–Moon distance.)

Note for the Teacher: Many people, adults and children alike, do not understand how much farther away the Moon is than the International Space Station or the altitude where the Space Shuttle flew. This distance directly impacts the challenges for a return to the Moon.

(When done with the dough, make sure the students place it back into the containers and close the lids tightly!)

Extension: Combine with the *How High is Space?* atmosphere scale model:

1) How many sheets of paper are in your model of the Earth's atmosphere?

2) The Moon is about 384,000 km from the Earth. How many sheets of paper would you need to add the Moon to your atmospheric model?

3) The Earth has a diameter of 12,756 km. How many sheets of paper would you need to add the size of the Earth to your scale model?

4) The Moon has a diameter of 3476 km. How many sheets of paper would you need to include the size of the Moon to scale on your model?

Note: You can use this Earth-Moon model for other purposes, too, including the teaching of eclipses. Have a bright light bulb or even your overhead projector on in a dark room. Have students try to cast shadows on their model Earth with the model Moon and vise versa. (You can use toothpicks as handles for your dough balls.) It's not a easy thing to do at all. Your students will probably want to bring their model Earth and Moon close together, which means they are no longer in scale in distance. This exercise can help reinforce an understanding of why lunar eclipses are relatively rare, and why solar eclipses (Moon's shadow on the Earth) are even more rare. The Earth, Moon, and Sun must be aligned just right for either type of eclipse to occur, and the larger Earth produces a much bigger shadow than does the Moon.