TITAN: DEAD OR ALIVE?

Titan is like a much younger version of Earth. Due to its much greater distance from the Sun, this mysterious world is in a state of deep freeze, which allows scientists to study a scenario similar to what our planet looked like before life started here — the so-called "prebiotic" state. Titan, a world "uncontaminated" by life, has emerged as the best place in the solar system to study organic evolution on a lifeless world.

Life on Earth seems to have started about 4 billion years ago when simpler organic molecules combined into more complex organics capable of metabolism and reproduction. What were the conditions on the early Earth before living things evolved? Life has erased the record of the prebiotic mix of organic molecules that led to life on Earth. But we can look to Titan for clues of what Earth may have been like before life began.

But can we be sure Titan is lifeless?

When astrobiologists summarize the requirements for life, they mention not only organic molecules, but also liquid water and energy sources. Titan seems far too cold on the surface for liquid water. Given Titan's extremely low temperatures, Earth-type life seems highly unlikely — leaving scientists to wonder if there is some niche for strange life below Titan's surface.

Titan's icy crust hides a liquid water ocean, which sloshes around the mantle of the moon. And there is evidence that slushy water from ice volcanoes has flowed onto the surface, driven by energy from Titan's interior.

Since its arrival in Saturn's orbit in July 2004, NASA's Cassini spacecraft has confirmed that this moon contains a rich array of interesting organic chemicals. In its many close passes of Titan, Cassini has seen evidence of past ice volcanoes, "sand dunes" probably made of drifting grains of organic material, and several erosional features where liquids have flowed. Methane on Titan evaporates, forms clouds and rain, much like the water cycle on Earth. Titan's numerous lakes of liquid methane and ethane appear to fill and evaporate with seasonal changes.

On January 14, 2005, the Huygens probe descended through Titan's cloudy atmosphere and landed on the surface, revealing mountains, flood plains, and river channels carved by occasional torrents of liquid methane rainfall, and finding a rich mixture of organic molecules mixed into the surface material.

Titan forces us to address our assumptions about life. Are we sure that the liquid needed for life must be water? Titan's methane cycle, with its rivers, lakes, clouds, and rain, tell us that other substances can play water's familiar physical role on worlds with very different conditions. Could it possibly also play water's biochemical role? We don't know.

For astrobiologists trying to avoid "Earth-centric" thinking as they scour the universe for other life, it is valuable to consider the possibility of unfamiliar kinds of life, something drastically different from "life as we know it" — on a world with organics and liquids but conditions not at all like those on Earth.

INTRODUCTION

Children begin rudimentary scientific thinking from the time they are born as they explore their natural environment and seek to make sense of it. When they acquire language, they begin asking questions about what they experience, observe, and think. Once they are in school, children's natural curiosity links closely with science learning, which offers an ideal opportunity to help young students expand their budding knowledge about the world. Science learning is also an ideal opportunity to involve students in rich reading and writing activities that not only help improve the quality of their learning in science, but also help make them better readers and writers — a key goal in the elementary years.

The sets of lessons you are about to encounter purposefully bring together reading, writing, and science in ways that underscore the belief that scientific thinking and the intelligent use of language go hand-in-hand. These lessons build good language use into the science curriculum, helping students use reading and writing to learn. In doing so, the lessons also help spur students' growth in vocabulary as they acquire new words through their engagement in authentic learning experiences.

While the lessons are grouped for grades 1–4 and 5–8, they can readily be used interchangeably as needed. Older students with little space science background might benefit from the grades 1–4 lessons. English learners might benefit from the early grades' reading and writing activities, finding them more accessible. The upper-grade lessons can also be used for enrichment for younger students who are ready for further study. Teachers are encouraged to look at the lessons as a whole and use them as best suits their teaching context.

Most important, the lessons open up the world of Saturn and emerging data about this planet to young children, and invite them to be part of this latest space exploration. All of the scientific concepts, language and content have been reviewed for scientific accuracy by the NASA/Jet Propulsion Laboratory staff.

Connecting Theory and Practice

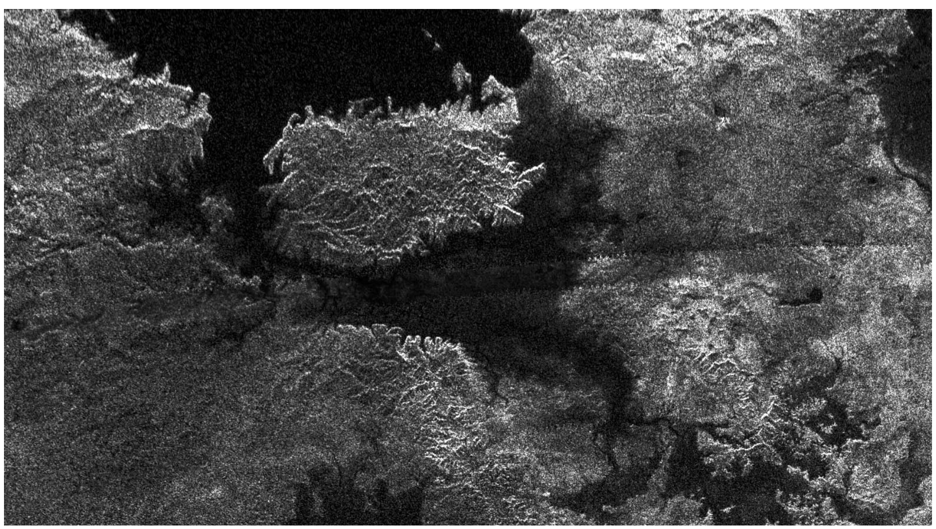
Common to the reading and writing activities found in the lessons is an underlying belief that metacognitive skills practiced in socially interactive situations can contribute to young children's capacity to think scientifically.

The lessons aim to improve science learning by enhancing metacognitive skills. For example, in science notebooks and logs, students are asked to think about what they have learned and think about how they have learned, both key components of metacognition, which concerns the ability to reflect on our own cognitive processes (the process of knowing) and knowledge about when, how and why to engage in various cognitive activities (Flavell, 1981). A number of key science process skills are metacognitive in nature and have close correspondence with the skills of reading and writing. The skills of observing, classifying, comparing, predicting, describing, inferring, communicating, interpreting data, organizing information, and drawing conclusions are among the skills young children engage in as they explore a scientific concept, read a text, draw a picture, or compose a piece of writing. The lessons seamlessly integrate and reinforce these important skills.

The instructional activities enable students to be active learners and take responsibility for their own learning. Children first learn how to engage in various problem-solving tasks such as those listed above through social interaction with others (Vygotsky, 1978). The lessons highlight social interaction through exploratory talk (Barnes, 1976) with teachers, partners, and in small groups and the use of expressive language (Britton, 1990) in talk and writing. This kind of language use among adults and peers helps students clarify ideas and work through new concepts. Little by little, students begin to internalize these new skills and processes.

T I T A N   A T   A   G L A N C E

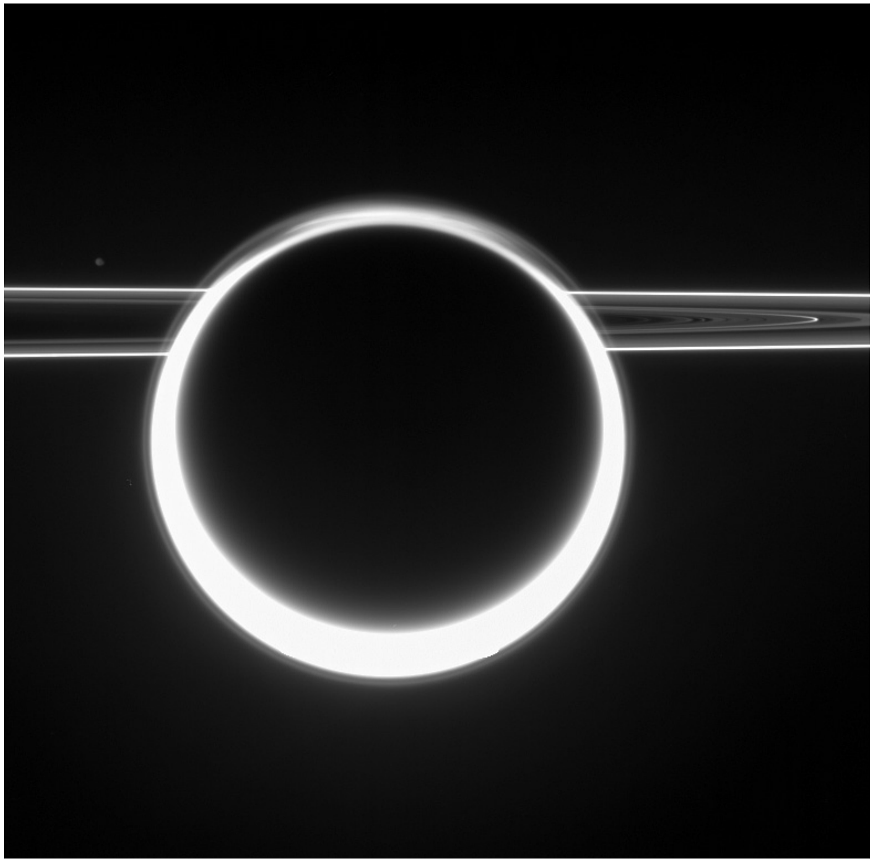
Discovered by Christiaan Huygens in 1655
Distance from Saturn — 1,221,850 km (759,222 miles)
Period of orbit around Saturn — about 16 days (15.945 days)
Diameter — 5,150 kilometers (3,200 miles)
Mass — 1.34×10^{23} kilograms (2.95×10^{23} pounds)
Density — 1.88 grams/cubic centimeter
Temperature at surface — 95 kelvins (–178 °C, –288 °F)
Atmosphere — 98 percent nitrogen; 2 percent methane
Atmosphere pressure — 1.5 bars

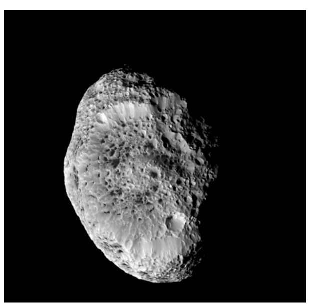


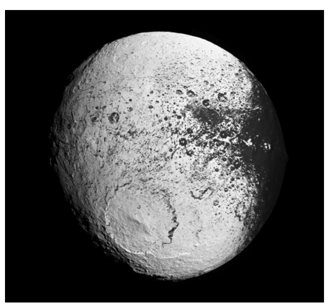
This Cassini radar image shows a big island smack in the middle of one of the larger lakes imaged on Saturn's moon Titan. The island is about 90 kilometers (62 miles) by 150 kilometers (93 miles) across — about the size of the Big Island of Hawaii.

On its journey to Saturn, Cassini carried the European-built Huygens probe. On January 14, 2005, Huygens achieved humankind's first landing on a body in the outer solar system when it parachuted through Titan's murky skies. Huygens took measurements of atmospheric composition and wind speeds during its descent, along with an incredible series of images showing telltale patterns of erosion by flowing liquid. The probe came to rest on what appeared to be a floodplain, surrounded by rounded cobbles of water ice.

ACTIVITY
GRADES 1–4







Above: Titan appears to be suspended in front of Saturn's ringplane; Janus can be seen at left just above the ringplane. Left: The impact-blasted surface of Hyperion; the "two-toned" moon Iapetus.

Moons of Saturn — Worlds Unto Themselves

LESSON TIME

May be carried out over two days; total time 90 minutes.

PREPARATION TIME

Allow time to make copies and collect materials.

MATERIALS CHECKLIST

For the teacher:

- **"Saturn's Moons" chart (transparency or copy)*

For each student:

- **Moon illustrations, one copy*
- *Scissors; glue; writing paper; pencil*
- *One piece of 12 × 18 inch construction paper*
- *Science Notebooks*

*The Moon Chart and the moon illustrations can be downloaded from *http://saturn.jpl.nasa.gov/education/titanposter/*.

STUDENT PREREQUISITES

Students should have some basic background information about Saturn's moons.

Language Arts Focus — Descriptive Scientific Language
Science Focus — Sorting by Scientific Characteristics

OVERVIEW

In this lesson, students learn that Saturn has many moons and that the Cassini mission discovered even more moons. Students will examine and sort through images of Saturn's varied moons to see characteristics they share and those which set them apart. Students will write a paragraph about Saturn's moons and explain how they sorted them.

BACKGROUND

Titan, Saturn's largest moon, was discovered in 1655 by the Dutch astronomer Christiaan Huygens — after whom the Huygens probe was named. When Cassini launched in 1997, Saturn had 18 named moons and we knew of a total of 31 moons. The majority of Saturn's smaller moons were discovered during flybys of Saturn by the two Voyager spacecraft in 1980 and 1981. As of 2010, we know that Saturn has at least 62 moons, 53 of which have been named. The icy moons of Saturn are indeed an interesting and very diverse set of orbiting satellites. See the "Saturn's Moons" chart for an overview of their various characteristics (the chart can be adapted for students).

For more information on Titan and Saturn's other moons, see: *http://saturn.jpl.nasa.gov/science/titan.*

Objectives

Students will:

1. Learn that the moons of Saturn are diverse.
2. Learn that the moons have identifiable characteristics.
3. Learn that Saturn's moons, like our Moon, reflect light.
4. Sort and classify Saturn's moons by their characteristics.
5. Write a paragraph describing the moons' characteristics and explaining the basis for how the moons were sorted.

Teacher Preparation

Make a copy, for each student, of the moon illustrations (18 moons, two pages). Gather other materials needed for each student — construction paper can be any color. Make a photocopy, or a transparency, of the "Saturn's Moons" chart (two pages) for discussion. Optional: you may wish to make copies of this chart for the students; there is a column for new information that Cassini has discovered about the moons.

Procedure

Day One

Building Background Information — 45 minutes

1. Students will need some background information about the moons of Saturn.
2. Use the "Saturn's Moons" chart to guide your discussion. Recommended for enriching background information is the book *Saturn* by Elaine Landau.
3. During your discussions, highlight the following:
   - Saturn is so far away from Earth that seeing and studying its moons is very difficult.
   - Scientists learn many new things about the moons during the Cassini mission.
   - The moons of Saturn have various sizes, shapes, colors, surfaces, and orbital patterns.
   - Titan is the largest of Saturn's moons and has a very complex atmosphere.
   - The Huygens probe was dropped into the atmosphere of Titan to get information about this large moon and sent exciting science results back to Earth.
4. Show the moon illustrations to your students as you introduce the moons' diverse attributes — their varied shapes, sizes, surfaces, and colors. Write on the board any descriptive words that you and your students generate in your class discussions. If you have created a Saturn Word Wall, be sure to add these new words.
5. Distribute a set of moon illustrations to each student. Discuss each moon, asking students to describe what they see. Allow students time to color the moons as you discuss them. Use the "Saturn's Moons" chart as your guide for discussion.
6. Have students write their names on their illustrations; collect for the follow-up sorting activity.

Day Two

Sorting Moons by Attribution and Writing — 45 minutes

1. Return the moon illustrations to the students.
2. Have students cut the illustrations apart into individual "moon cards." They should have 18 separate cards, each one illustrating a moon.
3. Ask students to sort their moon cards according to the moons' different attributes. Give students the opportunity to sort the moons several times, using different criteria. For example, the moons might be sorted by shape (spherical and irregular), color (white, orange, etc.), or type (shepherding, co-orbital, etc.). Encourage students to come up with their own ideas for sorting.
4. When students are finished, ask them to pick their favorite "sort." Give each student a piece of 12 × 18 inch construction paper and have them glue the sorted moons onto their construction paper. They should glue the moons just as they were sorted.

Day Two (continued)

5. After they have completed gluing down their moon cards, have students write a descriptive paragraph explaining how they sorted their moons. Be sure to have them include the categories they generated for sorting as well as a brief explanation about the reasons for sorting the moons as they did. Encourage the use of the descriptive language generated during earlier classroom discussions.

6. Take some time to have students share their ideas about their sorting. Students should be able to explain to their peers how they sorted their moons, and recount why they chose that particular way to sort them.

Using Science Notebooks

Writing prompts for this lesson:

1. Focus question: What are some of the differences among Saturn's moons?

2. Process question: How many ways did you sort the moons of Saturn? What were those ways?

Extension Activity

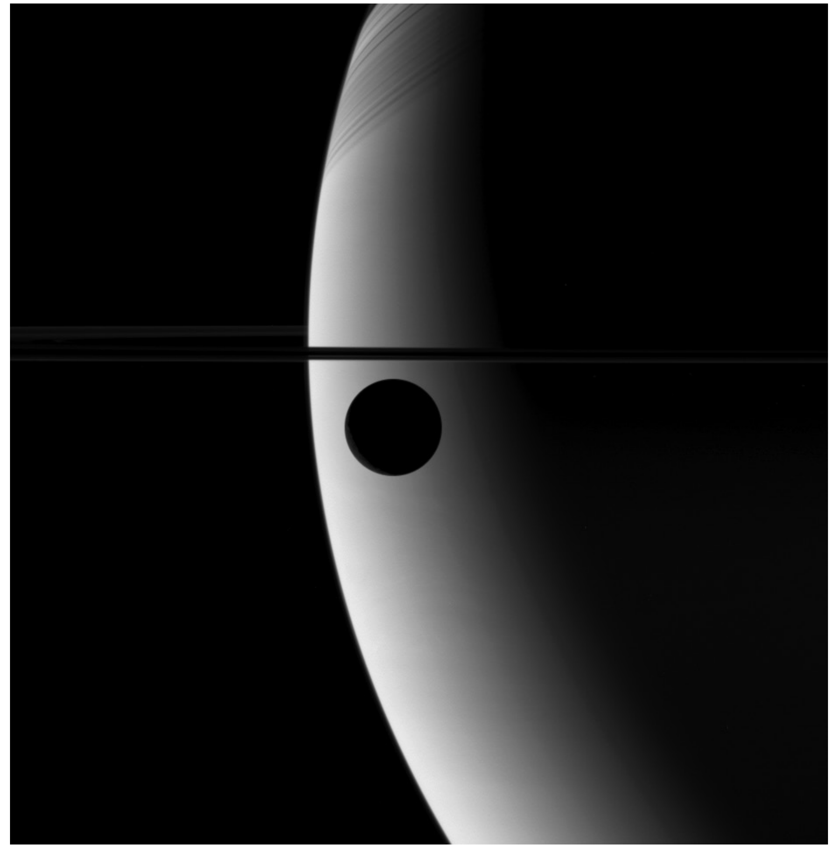
This lesson focuses on 18 of the moons of Saturn. Students can create a blank grid, based on the grid for the "Saturn's Moons" chart. The chart contains a "new information" column that can be filled in with the latest discoveries. Happy moon hunting!

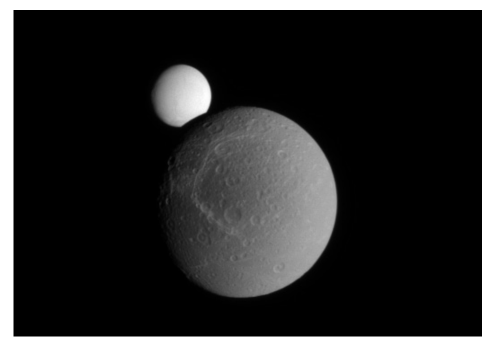
Why This Works

One way to enhance student learning of new information is to provide them with an opportunity to "manipulate" that new information. Here manipulation takes the form of careful examination and sorting of images of Saturn's varied moons. Sorting activities of this kind require that students pay close attention to a variety of characteristics. They also help students develop the higher-level thinking skill of differentiating between common and unique characteristics.

Sorting and classifying are important scientific skills. As students select discrete data from a larger set, and then describe that selection process in their paragraphs, they are thinking and writing much like scientists do. Seeing how students classified the moons will allow you to evaluate student learning.

Adapted from Reading, Writing & Rings, a language arts/science elementary school program. For more information, see *http://saturn.jpl.nasa.gov/education/educationK4Program/.*

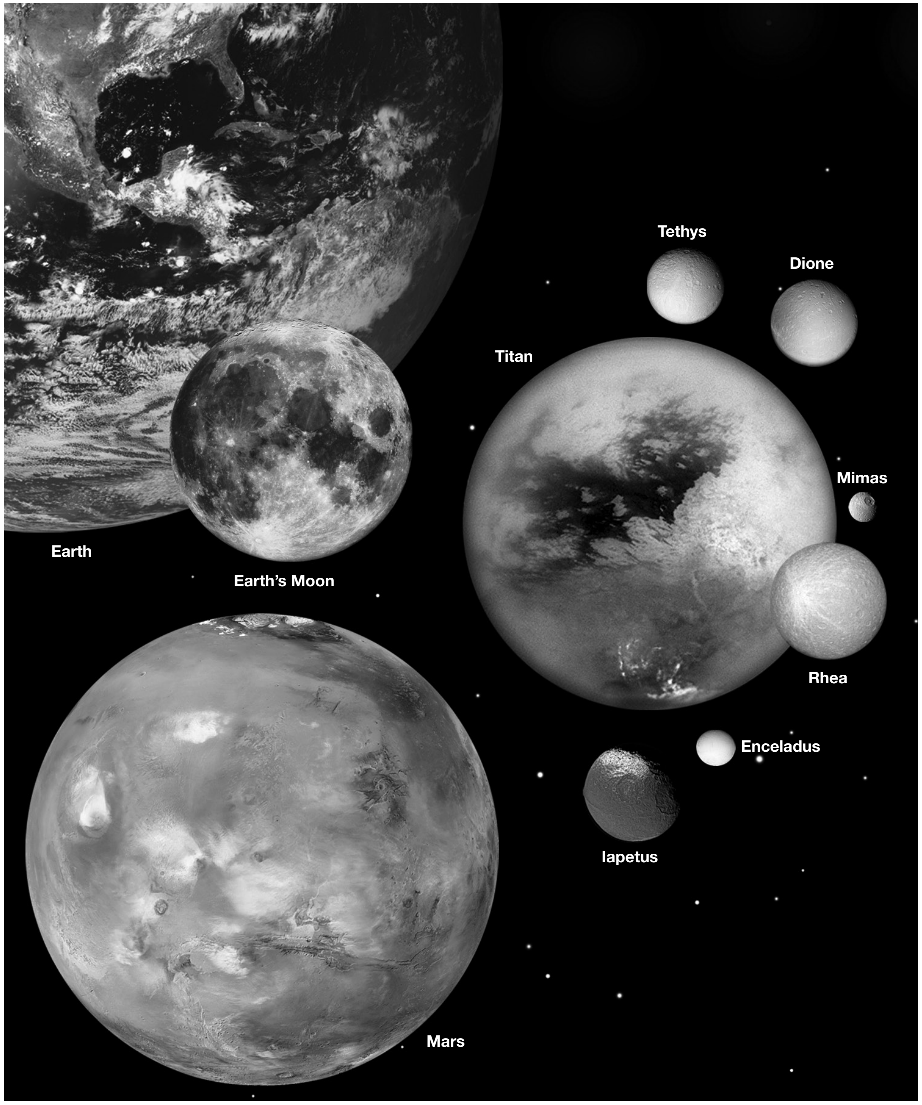




Above: The small moon Rhea transits across the face of Saturn, casting a circular shadow. Right: Brilliantly reflective Enceladus is seen behind the icy moon Dione. Enceladus reflects about 99 percent of the light that strikes it.

ACTIVITY
GRADES 5–8

Earth, Moon, Mars, and Titan Balloons



Size comparisons of Earth, the Moon, Mars, and Saturn's moons Titan, Rhea, Iapetus, Tethys, Dione, Enceladus, and Mimas. Titan's diameter is about 40 percent that of Earth. Mars is about 53 percent the size of Earth.

LESSON TIME

One to two class periods

PREPARATION TIME

Less than 10 minutes

MATERIALS CHECKLIST

For a class of 30:

- *One bag of blue balloons (all balloons 11–12-inch "helium" quality)*
- *One bag of black balloons*
- *One bag of red balloons*
- *One bag of yellow balloons*
- *Rulers or measuring tape*
- **Student pages (one per group)*

*The student page can be found at *http://saturn.jpl.nasa.gov/education/titanposter/*.

Language Arts Focus — Descriptive Scientific Language
Science Focus — Sorting by Scientific Characteristics

PRE-LESSON ACTIVITIES

Obtain balloons. If you cannot find red, white, and blue balloons, you can substitute a few other colors. Earth can be blue or green, Mars can be red or orange, and the Moon can be black or gray. Titan may be yellow or gold. Balloons should be available at your local grocery or party supply store.

Duplicate the student pages (one per group).

BACKGROUND

How big is the Moon? How far from Earth is the Moon? Earth science and astronomy books depict a Moon that is much closer and much larger than in reality.

This balloon activity will allow students the opportunity to construct a scale model of the Earth–Moon system in terms of planetary sizes and distances. In addition, students make a scale model of Mars and Titan to discover how far one might have to travel to visit the other bodies in our solar system. This activity is also a good introduction at the beginning of a unit on the solar system to pre-assess student knowledge of planetary distances.

Objectives

To construct a scale model of a Earth-Moon-Mars-Titan system in terms of planetary size, and to discover how far one might have to travel to get to the Moon, Mars, or Titan.

Procedure

Guidelines

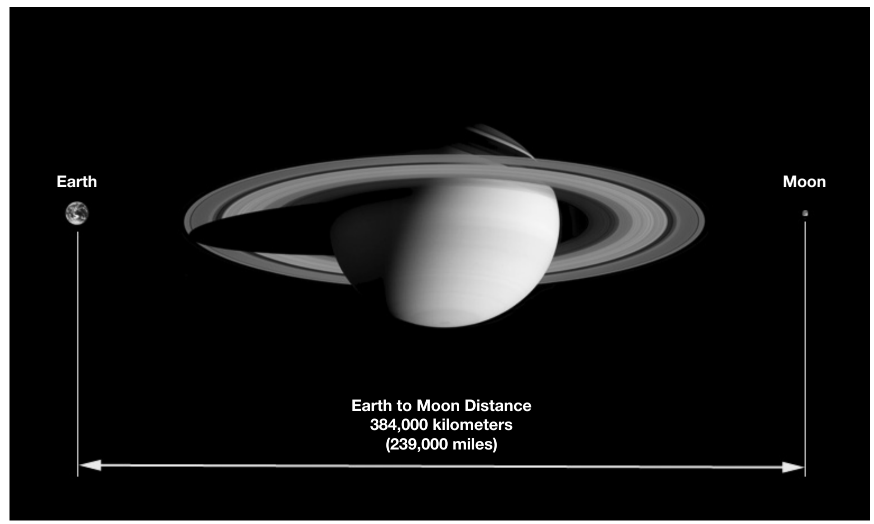
1. Discuss Earth's size relative to the Moon, to Mars and to Titan. Determine what misconceptions students may have.
2. The teacher should have "Earth" balloons (blue), "Moon" balloons (black or gray since the Moon reflects only 6 percent of sunlight and is the color of asphalt pavement), "Mars" balloons (red), and "Titan" balloons (yellow).

Classroom management plan, The "Guessing" Approach:

1. Teacher (with the help of a student with a ruler who is the official Measurer) inflates Earth balloon to 20 cm. Ask another student hold it in front of the class. Then teacher slowly inflates the Moon balloon, asking in advance for students to raise their hands when they think it is the right relative size and lowering their hands if the Moon balloon becomes too big. Teacher then says they can have a second chance as the Moon balloon is slowly deflated (making embarrassing noises! — always a hit with middle school children). Then teacher, with the help of the Measurer, inflates the Moon balloon to 5 cm. Repeat this process with Mars and Titan using the measurements Mars = 11 cm, Titan = 9 cm.
2. Ask students, "At this scale, how far apart are the Earth and the Moon? Earth and Mars? Earth and Titan?" The diagrams in common textbooks might lead many of them to suggest that the Moon balloon should be held less than a meter from the Earth balloon.

Guessing game again with distances:

1. This approach employs a Piaget-type conceptual bridge to address the "cognitive-conflict" posed by converting interplanetary distances into manageable knowledge. Using a familiar "measuring tool" — Earth — the teacher will involve the students in laying out the distance to the Moon using the balloons already adjusted to relative size. Place the Earth-holding and Moon-holding students side-by-side. Then ask the Moon-holding student to slowly walk away from the Earth-holding student. Ask students in the class to raise their hands when they think the relative Earth–Moon distance is correct. After the end of the classroom is reached or everyone has voted, say "We are going to use 'Earth' as our measuring tool. How many Earths, side-by-side, would be needed to measure the Earth–Moon distance? 4? 10? 20?" *The answer is 30 Earths*. The teacher can measure this out using the blue Earth balloon by roughly pacing the distance, measuring by holding out two hands an "Earth-diameter" apart and placing the Moon at the correct distance.
2. Repeat with Mars (6,000 Earth balloons away on average) and Titan (94,073 balloons away on average).



Saturn is the second-largest planet in the solar system. If Saturn and its rings were placed between Earth and the Moon, they would barely fit — and that excludes Saturn's diffuse outer E ring! The distance between Earth and the Moon is 384,400 kilometers (238,900 miles), while the diameter of the A ring outer edge measures 273,500 kilometers (169,980 miles).

Discussion/Wrap-up

- Discuss the relative distance between the Earth and Mars in the context of a human trip. How long did it take for Apollo astronauts to get to the Moon? Three days. How long would it take for astronauts using similar technology to get to Mars?

For the Teacher

Planet/moon	Diameter (km)	Relative Size using a balloon (cm)	Average distance from Earth (km)	Number of Earth balloons to measure relative distance
Earth	12,756 km	20 cm	—	—
Moon	3,475 km	5 cm	407,000 km	30 balloons
Mars	6,794 km	11 cm	76 million km	6,000 balloons
Titan	5,150 km	9 cm	1.2 billion km	94,073 balloons

For the Students

Activity: Grades 5–8: Earth, Moon, Mars, and Titan Balloons

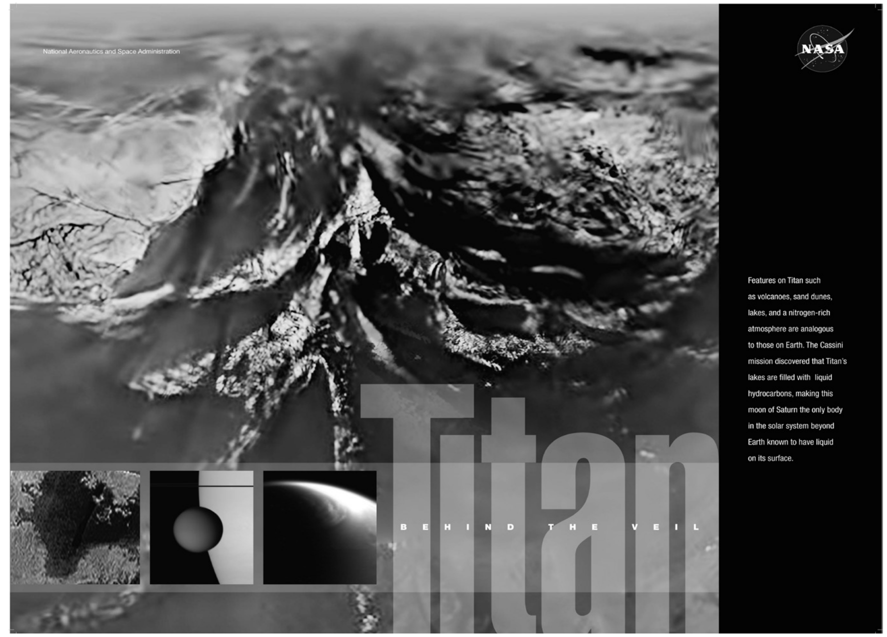
Student Page

Name ______________________________

Planet/moon	Diameter (km)	Relative Size using a balloon (cm)	Average distance from Earth (km)	Number of Earth balloons to measure relative distance
Earth	12,756 km	20 cm	—	—
Moon	3,475 km			
Mars	6,794 km			
Titan	5,150 km			

The student page can be found at full size for downloading and printing out at *http://saturn.jpl.nasa.gov/education/titanposter*.

O N T H E C O V E R



Though Titan's photochemical smog completely obscures the moon, the European Space Agency's Huygens probe captured images of the surface as it descended from the Cassini spacecraft on January 14, 2005. The main image shows a portion of the Huygens probe's view of the surface from 10 kilometers (6 miles) altitude. The small inset image at left shows an immense body of liquid (likely methane and ethane) at Titan's north pole. The middle image, showing Titan against Saturn, was taken just below the ringplane by the Cassini spacecraft in 2007. The image at right is a Cassini optical remote sensing image of color-coded clouds at Titan's north pole. While Earth's clouds contain mostly water vapor, Titan's clouds consist of ethane, methane, and other organics.

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