MOONS OF THE SOLAR SYSTEM

A PROGRAM FROM THE HOLT PLANETARIUM

by Cary I. Sneider and Alan D. Gould

revised by Debra Sutter

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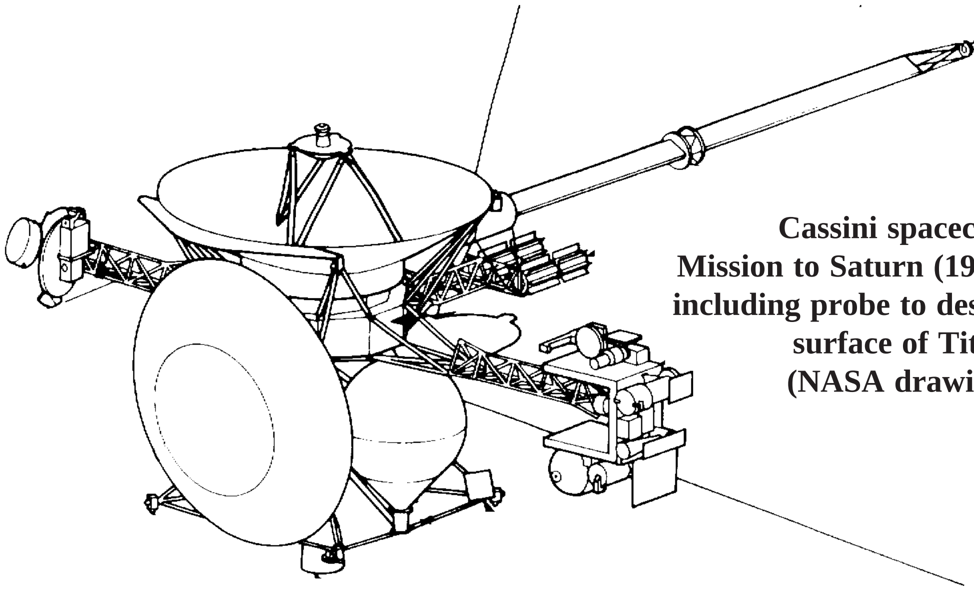

Cassini spacecraft
Mission to Saturn (1995 to 2000)
including probe to descend to the
surface of Titan
(NASA drawing)

Cover photograph collage of Jupiter with four moons courtesy of NASA.

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PASS Volume 7 Photos & Illustrations

p.ii, Cassini spacecraft drawing; p. 2, Alan Gould, Sun Simulator diagram; Alan Gould, Tracking Jupiter's Moons Chart; p.8, Lick Observatories, Gibbous Moon Photo (Age 20.05 days); p.10a, Lick Observatories, Mars photo; p.10b, LHS, Jupiter and 4 moons; p.10c, Galileo's Notes; pp.10–12, LHS, Tracking Jupiter's Moons; p.12, Lick Observatories, The Moon; p.13, Clementine Mission, Crater Tycho; pp.13-18, NASA, Mars & Phobos, Phobos, Deimos, Jupiter Montage, Callisto, Ganymede, Europa, Io, Saturn Montage, Mimas, Titan, Iapetus, Saturn's Rings, Uranus & Miranda, Miranda Cliffs, Neptune, Pluto; p.29, Alan Gould, Throwing Meteoroids; p.36, Alan Gould, Lunar Settlement; p. 42, Alan Gould, Moon Map.

Planetarium Activities for Student Success (PASS)

Series Editors: Cary Sneider, Alan Friedman, and Alan Gould

If you have access to a planetarium for teaching about astronomy, space science, and other subjects, this series of books is for you. Designed for both experienced planetarium professionals and teachers who will be using a planetarium for the first time, these volumes provide a wealth of field-tested strategies and practical suggestions for presenting enter-taining and educationally effective programs for students.

The first four books provide a general orientation to astronomy and space science education with applications for both the planetarium and classroom settings. Each of the remaining volumes presents a complete planetarium program and related classroom activities. We hope you will find the materials useful in your work with students and teachers, as well as springboards for your imagination and creativity.

Volume 1: Planetarium Educator's Workshop Guide

Participatory planetarium programs involve students actively in the planetarium environment. The most effective programs are both entertaining **and** educational. This guide introduces the theory and practice of developing effective planetarium programs through a series of thought-provoking activities and discussions.

Volume 2: Planetarium Activities for Schools

This volume provides a wealth of effective planetarium activities for elementary and middle school students, as well as ideas for developing new activities for students of any age.

Volume 3: Resources for Teaching Astronomy & Space Science

There is a wide spectrum of resources for teaching astronomy and space science in elementary and middle schools. This annotated resource guide has the best resources that we have found, including school curricula, books, periodicals, films, videos, slides, professional organizations, planetariums, and telescopes.

Volume 4: A Manual for Using Portable Planetariums

Primarily a "how-to" manual for setting up and using a portable planetarium, this guide has many suggestions useful for teaching school programs in **any** planetarium.

Volume 5: Constellations Tonight

In this participatory version of a classic night sky planetarium program, students receive star maps and have an opportunity to use them to find constellations in the planetarium sky. Classroom activities include creating constellations and using star maps.

Volume 6: Red Planet Mars

Students discover Mars three different ways during this planetarium program. They find the red planet by observing it over a period of several nights as it moves against the background stars. Then they view it through a telescope and try to map its surface. Finally they see Mars via space probes. Classroom activities involve students in modeling the solar system, and creating creatures that could survive under different planetary conditions.

Volume 7: Moons of the Solar System

This program begins with observations of the Earth's Moon and a modeling activity that shows why the Moon goes through phases and eclipses. Then the students look at Jupiter's four major moons on a series of nights and figure out how long it takes each one to circle Jupiter. Finally, the students journey through the Solar System to see many moons through the "eyes" of modern spacecraft. Classroom activities involve students in performing experiments in crater formation, using moon maps, and designing lunar settlements.

Volume 8: Colors From Space

What can we learn about the stars and planets from their colors? Answering this question requires a fundamental understanding of why we see color. During this program, students deepen their understanding through a series of activities in which they "travel" to an imaginary planet circling a red sun, and experiment with color filters and diffraction gratings. Related classroom activities include making secret messages that can only be decoded with color filters, and then using the same filters to view nebulae and planets.

Volume 9: How Big Is the Universe?

Based partly on ideas from the short film *Powers of Ten*, this program surveys distances and sizes of things in the universe. Starting with ordinary things on Earth that students are familiar with, they move to progressively more distant astronomical objects: the Moon, the Sun, the Solar System, nearby stars, the Milky Way galaxy, and clusters of galaxies. Students use various methods to determine distance: parallax, "radar," and comparing brightness of objects. Classroom activities include students writing their complete galactic address, making a parallax distance finder, finding the distance to the "Moon," and activities about the expanding universe.

Volume 10: Who "Discovered" America?

Students ponder the meaning of the word *discover* in this program. Can one "discover" a land where people are already living? Students learn the reasons and methods by which Columbus navigated to the "New World," and some of the impacts of his voyages on Native Americans. They also find that certain myths about Columbus are untrue. He was not, for example, alone in believing that the Earth is round. Students also learn about other explorers who "discovered" America long before Columbus's time. Classroom activities include determining the shape and size of the Earth, using quadrants to determine latitude, and modeling lunar eclipses.

Volume 11: Astronomy of the Americas

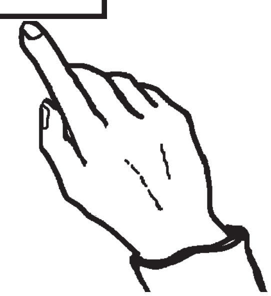
There are hundreds of Native American cultures, each with distinctive views of the heavens. There are also common threads in many of those cultures. In this program students visit five cultures: the Hupa people of Northern California, plains and mountain tribes that have used Medicine Wheel in Northern Wyoming, the Anasazi of Chaco Canyon in New Mexico, the Mayan people in Mexico and Central America, and the Incan people in Peru. Students observe moon cycles and changes in the sunrise and sunset positions on the horizon and learn how solar observations help Native Americans stay in tune with the harmonies of nature. Classroom activities include the Mayan and Aztec number systems, observing changes in real sunset positions, and learning how Venus can appear as either the "Morning Star" or "Evening Star."

Volume 12: Stonehenge

In this program, students learn what Stonehenge is and how it could have been used by its builders as a gigantic astronomical calendar. They also learn how astronomer Gerald Hawkins discovered Stonehenge's probable function, by actively formulating and testing their own hypotheses in the planetarium. Along the way, they learn a lot about apparent solar motion, and the creation of the research field of "archaeoastronomy." Classroom activities include constructing a special Solar Motion Demonstrator to represent the entire yearly cycle of solar motion.

Moons of the Solar System

Contents



Moons
of the
Solar System

Planetarium
Program

Preface

Moons of the Solar System was designed for public audiences and for school children in grades one and above. Presentations for younger age children (grades 1-3) require simplification as noted in the script.

The program begins by students observing how the Moon changes position and apparent shape during a two week time period. To better understand their observations, each student models the Earth-Moon-Sun sytem with a light in the center of the planetarium representing the Sun, a hand held ball as the Moon, and the student's own head as the Earth. This is the best way we have found for anyone (including adults) to understand why the Moon goes through phases. The model is also used to explain lunar and solar eclipses.

In the next activity, students observe the moons of Jupiter. Classes of children in grades 4 and up will be able to plot the Galilean moons' positions on a data chart. Younger groups will watch the moons' positions change from night to night and draw conclusions from those observations without attempting to record them.

The last part of the program is a tour of the solar system to see the moons of each planet through the eyes of spacecraft that have visited those planets. Viking and Voyager images are featured.

We would be very grateful to hear from you about how you used this program, what modifications you made, what worked well and what didn't work well.

Objectives

After attending this planetarium program, the students will be able to:

1. Explain the phases of the Moon—why the Moon appears to change shape in a monthly cycle.
2. Explain why we have solar and lunar eclipses.
3. Explain how Galileo was able to measure the periods of Jupiter's four largest moons.
4. Explain the role of meteoroids in crater formation.
5. Name and describe some of the moons found in the solar system.
6. Differentiate between a "planet" and a "moon" or "satellite."

Primary grade students will be able to:

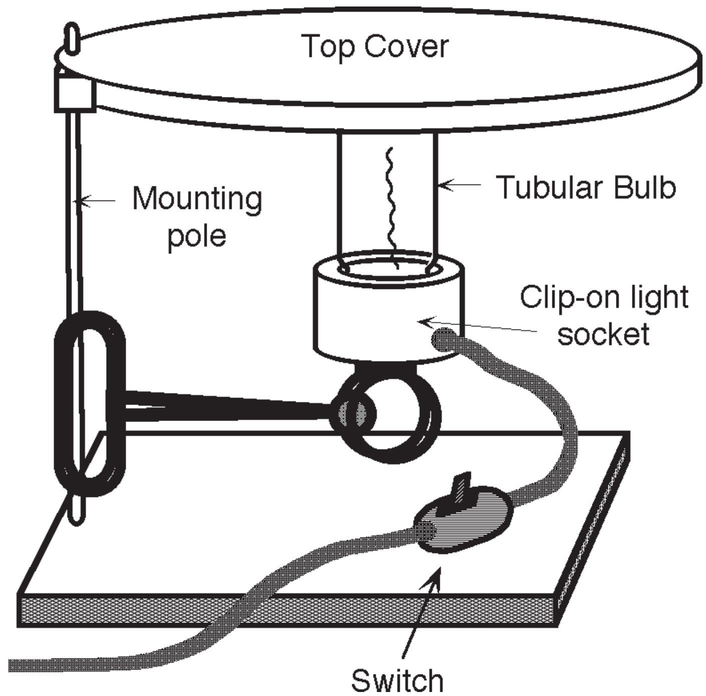
1. Describe the phases of the Moon.
2. Describe the appearance of the Moon close-up.
3. Explain that other planets have more than one moon, and that these moons look different from Earth's moon.

Materials

1. Your **planetarium** must have the capabilities of diurnal motion and Moon phases with proper position relative to an image of the Sun.

2. Sun simulator: Mount in the center of the planetarium a short unfrosted tubular light bulb (about 25 to 40 watts) for simulating the Sun. Such a clear, single filament bulb is necessary to create crisp shadows on the model Moons. Ideally, supply electrical power to the bulb through a dimmer switch. Place a top shade over the bulb to prevent reflection of white light from the dome. (See diagram for one version of Sun simulation light.) In a STARLAB portable planetarium you can simply use the star lamp with the cylinder removed. To protect the main star bulb, put a clear plastic or glass cover (e.g., a jar) over the bulb. A round top cover as shown in Figure 1 can then be supported above the main star bulb.

Sun Simulator



3. Light Pointers: You will need at least two light pointers (one bright and one dim) or a single light pointer with variable brightness. See *Constellations Tonight*, PASS Volume 5, page 2, for more information on light pointers.

4. Reading lights for the students. In our permanent planetarium, we have 7-watt night-light orange bulbs under the cove, with shades so they shine down on the audience. This is very convenient, because visitors can see their “Tracking Jupiter’s Moons” charts and look back at the sky freely. The program can also be done by turning up the daylight for people to mark their charts, and then turning down for the next observation. In our STARLAB portable planetarium, we use the reading light system described in PASS Volume 4, pp. 19-21.

5. Audio cassette tape player with a tape of a countdown and rocket launch noise is a very exciting touch for beginning the tour of moons. The bigger and deeper the sound, the better the effect. Students can fasten their "safety belts" and imagine they are taking off in a rocket ship. Such an audio segment can be found on sound effects tapes and record albums such as "Authentic Sound Effects, Vol. 3" of Elektra Records. Optional: You can have a tape of "sunset music" to play when you make the sun set near the beginning of the program.

6. For each student, have a pencil and a copy of the **"Tracking Jupiter's Moons" data sheet** (master on p. 5).

7. Moon Models. Make a class set of moon models that can be reused for each program. These can be made with white polystyrene balls, about 2"-3" in diameter, mounted on sticks or pencils. Such balls are made by Plasteel Corp. in Inkster, Michigan and distributed by Molecular Model Enterprises, 116 Swift St., P.O. Box 250, Edgerton, WI 53534, (608) 884-9877. Polystyrene balls are also available at craft and hobby stores. Styrofoam does not work as well, since it is translucent.

8. Images for this program are listed on the following page. They have been assembled from several different sources. A complete slide set is available from Learning Technologies, Inc., 59 Walden St., Cambridge, MA 02140, (800) 537-8703. If you have a video system with a laser disc player and the Optical Data Corporation's "Astronomy Disc" (a.k.a. "Earth Science Sides 3 & 4"), many of the needed images can be programmed from that disc. As an alternative for images in the "Tracking Jupiter's Moons" activity, you can make posters or hand drawn overhead projector transparencies using Jovian satellite data from *Astronomy* or *Sky & Telescope* magazines.

Image 40 in the script is given as "Home," but since this slide must be produced by each planetarium that presents the show, image 40 in the slide set available from Learning Technologies, Inc. is a full Moon image that can be used for the Moon Map activity on page 38.

Image	Optical Data* Laser Videodisc #	Slide Source*
1. Moon through a telescope	F11626-53, 7336-70	ASP, Hansen, ...
2. Mars through a telescope	F11800, 11801, 11802	ASP, Hansen, ...
3. Jupiter + 4 moons	F12944	Lawrence Hall of Science
4. Galileo's notes	n/a	Lawrence Hall of Science
5. Jupiter + moons color code	n/a	Lawrence Hall of Science
6-14. Tracking nights 1-9	n/a	Lawrence Hall of Science
15. Moon close-up	F11626-11653	ASP, Hansen, ...
16. Clementine Image		
17. Mars + Phobos	F11811	ASP, Hansen, Finley Holiday, ... NASA
18. Phobos	F11812-11813	ASP, Hansen, Finley Holiday,... NASA
19. Deimos	F11814-11815	ASP, Hansen, Finley Holiday, ... NASA
20. Jupiter + moons	12917	ASP, Hansen, Finley Holiday,... NASA
21. Calisto Crater Chain		
22. Ganymede w/ close-up inset		
23. Europa		
24. Io Crescent w/ close-up inset		
25. Saturn	13170	ASP, Hansen, Finley Holiday,... NASA
26. Mimas	13172	ASP, Hansen, Finley Holiday,... NASA
27. Iapetus	13186 or 13187	ASP, Hansen, Finley Holiday,... NASA
28. Titan	13182 or 13183	ASP, Hansen, Finley Holiday,... NASA
29. Cassini Huygens Mission		
30. Saturn's rings w/ "spokes"		
30a. Rotating rings†	48708-49058	Finley Holiday, NASA
30b. Anim. of ring particles†	32364-32741	Finley Holiday, NASA
30c. Shepherd moons†	33705-34130	Finley Holiday, NASA
31. Uranus collage	n/a	ASP, Hansen, Finley Holiday,... NASA
31a. Uranus encounter†	34684-35170	Finley Holiday, NASA
32. Miranda cliffs	n/a	ASP, Hansen, Finley Holiday,... NASA
33. Titania		
34. Triton	n/a	ASP, Hansen, Finley Holiday,... NASA
35. Voyager leaves Neptune	n/a	Finley Holiday,... NASA
36. Pluto and Charon	n/a	ASP, Hubble Space Telescope Center... NASA
37. Home	n/a	you

Other laser videodisc movies that can be used for this show are:
Discovery Photos of Charon F13331-13335
Animations of volcanic eruption on Io and Jupiter's rings 45526-45865

† Optional motion picture sequences.

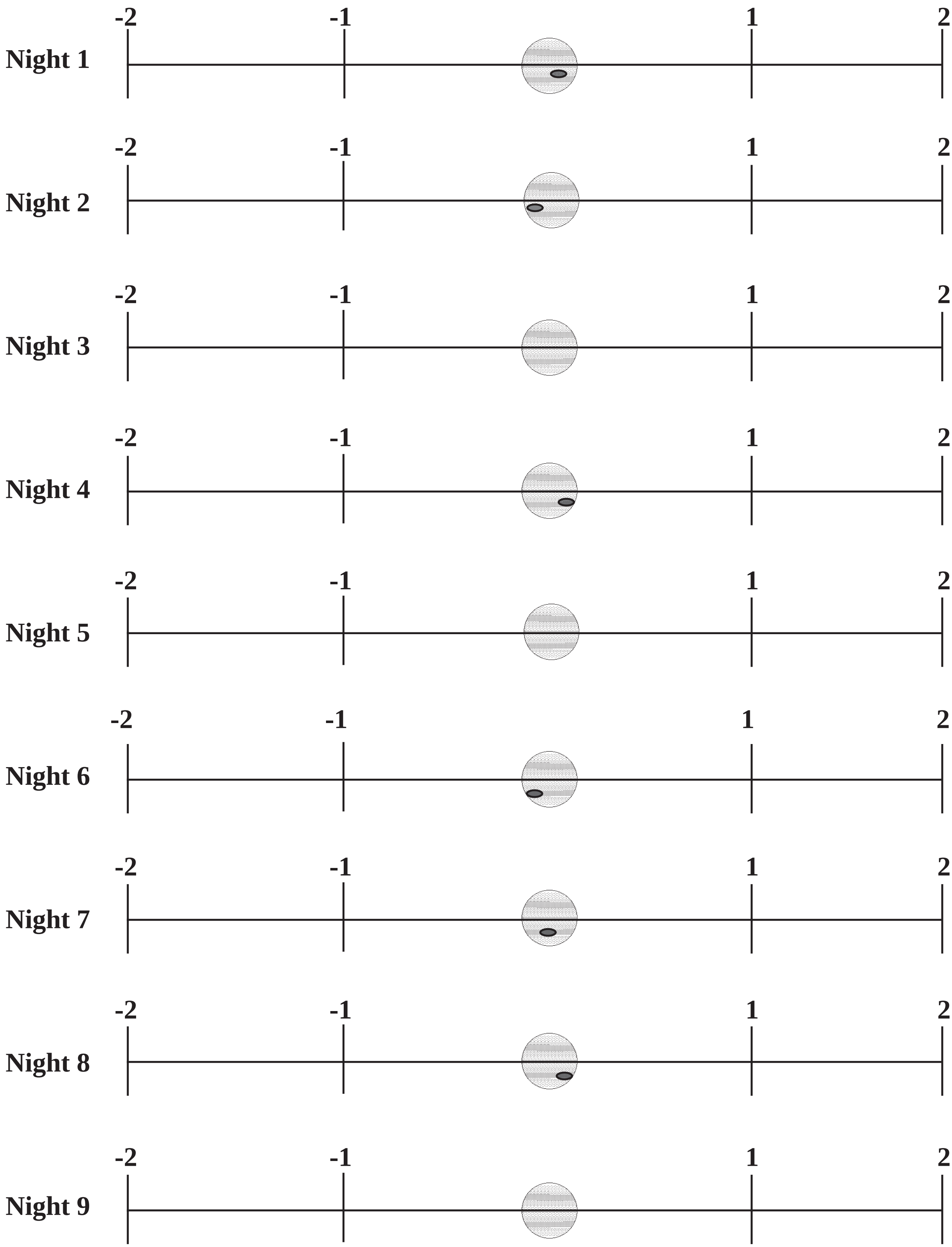
***** Sources: list at the top of page 6.

Sources for Images:

ASP: Astronomical Society of the Pacific, 390 Ashton Ave., San Francisco, CA 94112
Hansen: Hansen Planetarium, 15 South State St., Salt Lake City, UT 84111
Finley Holiday: Finley-Holiday Film Corp., P.O. Box 619, Whittier, CA 90601
LHS: Lawrence Hall of Science, University of California, Berkeley, CA 94720

Tracking Jupiter's Moons

Color code of your moon: ____________



Set-Up

1. Move diurnal motion until the Sun is above the western horizon, about an hour before sunset.
2. Set the Moon phase so that the Moon is about 3 or 4 days old (narrow crescent to the east of the Sun).
3. Test unfrosted tubular light bulb for Sun simulation in the center of the planetarium. Be sure the top cover is over the bulb to prevent dome reflections.
4. Test light pointer(s) (bright and dim).
5. Cue image sets (slides and/or video).
6. Cue audio tape for rocket launch.

Recommendations for Using the Script

We don't expect the script which follows to be memorized (as an actor might memorize a part) but to be used as a guide in learning, rehearsing, and improving presentations. We recommend that you read the script once or twice, then work with it in the planetarium, practicing the projector controls, slides, special effects, and music. You should be able to imagine yourself presenting information, asking questions, and responding to participants. For your first few presentations, you can have the script on hand, using major headings as reminders of what to do next.

The script is organized in blocks or sections. The purpose of these separations is only to help you learn and remember what comes next. Once you have begun a section, the slides or special effects and your own train of thought will keep you on track. When beginning a new section, make the transition logically and smoothly.

Directions for the instructor are printed in *italics*, the instructor's narrative is printed in regular type, and directions and questions to which the students are expected to respond are printed in ***bold italics***. There is no point in memorizing narration word-for-word since what you need to say will depend upon the students. The language you use and the number and kinds of questions you ask will depend on how old the students are, how willing they are to respond, and how easily they seem to understand what is going on.

We believe the most important elements of the program are the questions and the activities since these involve the students in active learning. If you must shorten your presentation, we recommend that you borrow time from the narration.

Script

Introduction

Good afternoon! It is getting close to sunset in our planetarium, but before it gets dark, let's find both the Sun and Moon in the sky right now. It is a common misconception that the Sun and Moon are never up at the same time, but in fact, they often are. ***Can you see the Sun and Moon?***

Let students use the light pointer to point them out.

Please take careful note of where the Moon and Sun are located while I switch on our planetarium "time machine" to accelerate the sunset.

Turn on music and start diurnal on slow for a leisurely sunset. Slowly turn down daylight and cove lights and turn up stars.

Observing Phases of the Moon

Even though the Sun is now below the horizon, we know about where it is because we saw where it just set.

Point out place on horizon where the Sun set.

We can still see the Moon. ***How would you describe the shape of the Moon right now?*** (*Crescent, banana, finger nail clipping.*) ***If we were to watch the sunset from this same spot three days from now, do you think the Moon would look the same?*** (*No.*) ***How might it be different?*** (*Different shape; different location.*) The Moon could change its shape in one of two ways, getting fatter or getting thinner. If you think that in three days the Moon will appear narrower, please indicate so by raising your hand. Raise your hand if you think the Moon will appear fuller three days from now. Let's see if our predictions are correct by moving ahead in time using our time machine.

Turn up daylight. Turn off Sun/Moon. Set Moon ahead about 3 days. For young audiences, have them count the days going by with you. Then turn up the Sun/Moon and turn off the daylight.

Those who thought the Moon would grow fatter are indeed correct. ***What shape would you say this Moon is now?*** (*Half Moon.*) Oddly enough, and for reasons that you will learn in a few minutes, astronomers refer to this shape of Moon as a quarter Moon. ***Is the Moon in the same place as it was when it was crescent, three days ago?*** (*No.*) ***Does it seem closer to or farther from the Sun?*** (*Farther.*) Guess where you think the Moon will be and what shape it will be three days from now.

Turn up daylight. Turn off Sun/Moon. Set Moon ahead 3 more days.

Was your guess correct? When the Moon is this shape, bigger than quarter but not yet full, it is called a gibbous Moon. It seems even farther from the Sun than when it was quarter. Let's step just three more days into the future. Again, try guessing where the Moon will be.

Turn up daylight; turn off Sun/Moon; set Moon ahead 3 more days; advance daily motion forward some to guarantee that the Sun is still below the horizon.

The Moon is very nearly full. Remember where the sunset occurred. Note that the Moon is all the way on the other side of the sky from where the Sun is setting. Whenever a full Moon occurs, you can expect it to rise in the eastern part of the sky right around the time of sunset. The different shapes of the Moon that we observe are known as phases of the Moon. ***Why does the Moon seem to change shape as we have just observed?*** (*Accept any answers.)*

Explaining the Phases of the Moon

Practically every culture throughout human history has come up with a different explanation in answer to that question. One rather interesting theory was invented by the Egyptians who believed that a new Moon was born each month (literally) and it grew and grew until it was full. At the moment the Moon reached the fullness of maturity, a giant pig attacked it and kept feasting on it for the rest of the month until there was no Moon left, at which time a new Moon was born. ***Do you think that's really how the Moon changes its shape?*** Even though we don't believe this explanation now, in its time this was a perfectly good explanation and accounted for the phases of the Moon quite well.

The theory most accepted in modern times has to do with relationships between the Earth, Sun and Moon. To see how this works let's make a working model. ***Will everyone please stand up?***

Turn on the white light (tubular bulb) to about 1/2 brightness; or in STARLAB, set latitude to 90° and remove star cylinder from projector and put protecting cover over the main star bulb, as described in "Materials" section on page 2.

Let's pretend that this light is the Sun. Pretend that your head is the Earth. All you need to complete the model is the Moon.

Give each student a ball on a stick.

Hold your Moon so that it is directly in front of the Sun. ***Does your Moon look dark?*** *(Yes.)* At this time of month, in reality, the Moon is so dark you could not see it at all. The Moon doesn't stay in one place; it orbits (goes around) the Earth. Slowly move your Moon to your left, just beginning the orbit of the Moon around the Earth (your head). Move the Moon until you see a small part of it lit by the sunlight.

Go around and check to see each student understands and is observing the crescent Moon.

What shape would you call that lit part of the Moon? (*Crescent.*) ***Does it look like the shape of the Moon when we first saw it in the planetarium sky today?*** (*Yes.*) Now continue the Moon in its orbit, moving it slowly to the left, until you see a half disc lit up, which you may recall is the "quarter Moon." Notice that when the Sun is setting, from your point of view, the first quarter Moon is directly overhead.

Continue moving your Moon in its orbit until you see the gibbous phase (nearly full). Now try to hold your Moon in a place where it is fully lit and could be called a full Moon.

Let the students discover the shadows of their heads. If necessary, hint that they hold their Moons above those shadows.

We have now modeled the Sun-Moon-Earth system so that we have seen everything that we observed in the planetarium sky. The lit part of the Moon grew from nothing to full and in reality it takes about two weeks for it to do that. However, the Moon does not stop there in its orbit. ***What do you think happens as the Moon continues in its orbit?*** *(Appears to get smaller.)* Try slowly moving your Moon the rest of the way in its orbit around its Earth. Try going slowly through a couple more orbits so you can observe the complete cycle of the phases of the Moon. In reality, it takes about one month for the Moon to complete such a cycle (*29.5 days, to be exact; for young students it is fun to refer to this as a "Moonth."*)

While we have this model working, let's see if we can explain a couple of other kinds of events that have startled and terrified people through the ages. Hold your Moon right in front of the Sun so that it blocks the Sun. ***What is the name for the event in which the Moon blocks the Sun?*** *(Solar eclipse.)* While you hold your Moon so that it blocks the Sun, look around the room at the other "Earths" which are other peoples' heads. ***Do you see the shadows of their Moons on them? What phase must the Moon be in for there to be a solar eclipse?*** *(New.)* In the real Sun-Earth-Moon system, that shadow of the Moon on the Earth during a solar eclipse is only about fifty miles (80 km) wide. In comparison, the whole Earth is about 8000 miles (13,000 km) wide.* During a total eclipse of the Sun, only people located in that narrow shadow region can see the eclipse.

Now move your Moon around until it moves into the shadow of the Earth (your head). ***What is this type of eclipse called?*** *(Lunar eclipse.)* ***What phase must the Moon be in for there to be a lunar eclipse?*** *(Full.)* People on the whole night time half of the Earth, the half that points away from the Sun, can observe a total lunar eclipse. ***Could people who live on the back of your head see the Moon move into the Earth's shadow?*** *(No, it's daytime for them.)*

Many more people have seen lunar eclipses than have seen solar eclipses. This is because whenever a lunar eclipse occurs, people on half of the Earth have the opportunity to see it, but to see a solar eclipse, you must be where the comparatively tiny shadow of the Moon sweeps across the Earth.

Collect Moon balls.

*Optional: If your head represents the earth, the shadow of your moon ball should be only about 1/20 inch (1 mm) wide. (In that scale, the light bulb (sun) should be about a mile and a half away and your arm would have to be 20 feet long to hold your moon ball at the proper distance from your head!)

The Moon Through a Telescope

So far, we have observed the moon just as our ancestors did, thousands of years ago. About 400 years ago, telescopes were invented and exciting new views of the moon were possible. Let's see how our moon looks through a telescope.

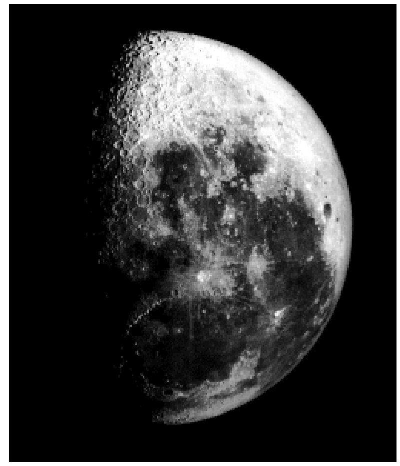


Image 1: Moon through a telescope

Pretend we are looking through the eyepiece of a telescope. Let's aim it at the moon.

What features can you see? (*Dark areas; light areas, little circles*) The light areas are mountainous regions. ***What type of terrain do you think we would find in the darker areas?*** *(Flat.)* The first person to carefully examine objects in the sky through a telescope was a man named Galileo Galilei, an Italian scientist who lived about 400 years ago. He also thought those dark areas were flat, but he called them "maria," the Italian word for ocean. ***Do you think they are really oceans?*** *(There really is no water on the moon.)*

Galileo also looked at the planet Mars and saw how it looked different from stars. Stars are much farther away and look like pinpoints of light, while nearby planets such as Mars can be seen as balls through a telescope.

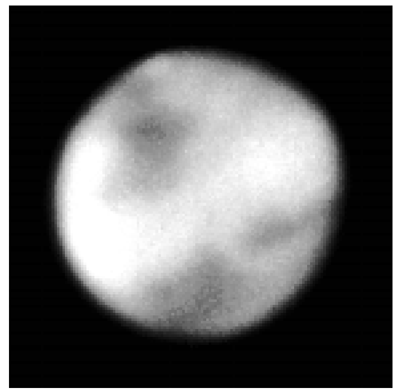


Image 2: Mars through a telescope

The Galilean Moons of Jupiter

Galileo also looked at Jupiter.

Image 3: Jupiter + 4 moons

He saw the planet Jupiter with four small objects in a line near it. Galileo thought the objects were stars, but when he observed Jupiter on subsequent nights, those "stars" appeared in different places. This was quite upsetting (and intriguing) since patterns of other stars never change in relation to one another. Galileo kept careful records of the positions of Jupiter's companion "stars."

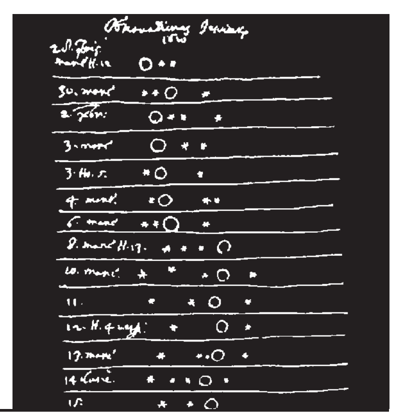


Image 4: Galileo's Notes*

* Optional: place image 4 *after* image 14 (Night 9); see option box on page 12.

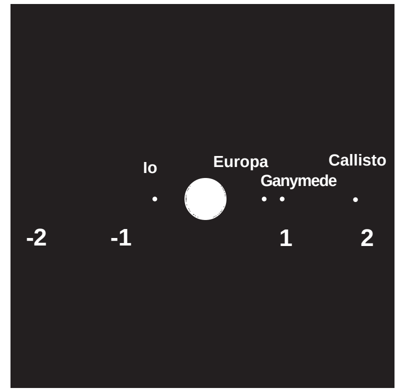
Don't worry if you can't read the words. It's written in Italian. Each night Galileo recorded the positions of Jupiter *(Use arrow to indicate.)* and its 4 companion "stars." ***Do you think they are really stars?*** *(No.)* ***What else could they be?*** *(Moons!)* Galileo determined that they wre moons. Let's see why. Let's watch Jupiter and its moons for a few nights just as Galileo did. Here is some astronomical note paper for you to note the changing positions.

Hand out a "Tracking Jupiter's

Moons" sheet to each person.

One sticky problem Galileo had was trying to tell which "star" was which. Let's make our job easier by doing something Galileo could not: color each moon a different color.

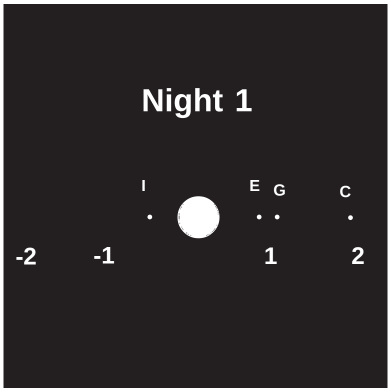
Image 5: Jupiter + moons color coded



Let's further simply our task by specializing: look at only one moon at a time.

Divide the class into four groups and assign each group one "star" to keep track of. Point out color, letter, and name of each moon. Point out numbers that indicate distance from Jupiter in millions of miles. For younger classes (grades 1-2), do not hand out paper. Do not divide the class into groups. Have the entire class observe one moon at a time.

Image 6: Tracking Night 1



Here is our view for our first night's observation. Please put a mark on your "Night 1" line indicating the position of your moon as you see it in relation to Jupiter.

Go around and check to see that each student understands. Help as needed.

Now we will let one day go by to arrive at "Night 2." Then we will let a second day go by to arrive at "Night 3." After eight days have gone by, we will have arrived at "Night 9." Each night, mark where your moon is with respect to Jupiter on the appropriate line.

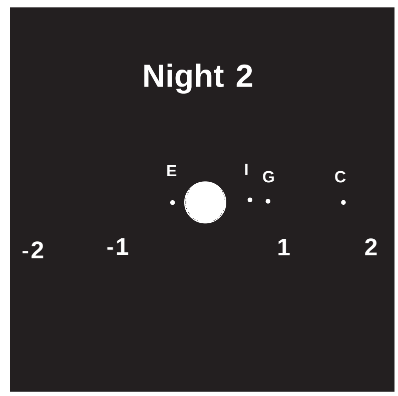


Image 7: Night 2

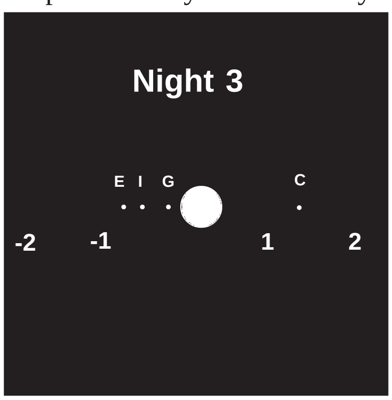


Image 8: Night 3

Images 7–14:
Tracking Nights 2–9

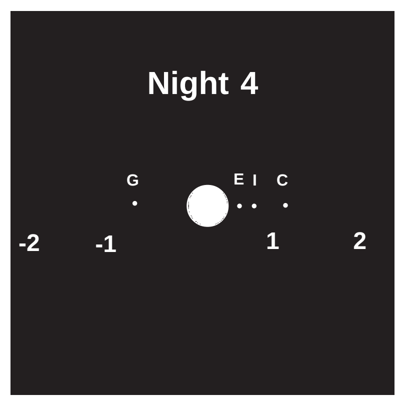


Image 9: Night 4

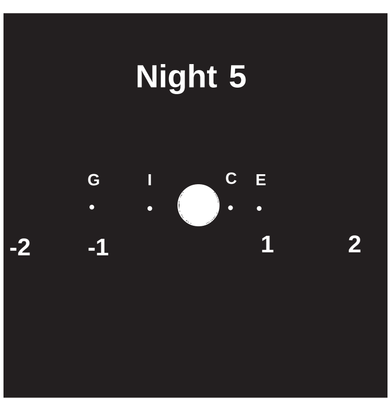


Image 10: Night 5

By now, you can see why Galileo concluded that his odd "stars" must really be moons. ***How can you tell they are moons, not stars?*** (*They move back and forth, "around" Jupiter.*) A moon orbits a planet. These moons seem to move back and forth in a straight line because we see their orbits from the side. If we could see Jupiter from above its North Pole, we would see these moons go around Jupiter. ***How could you tell how many days it***

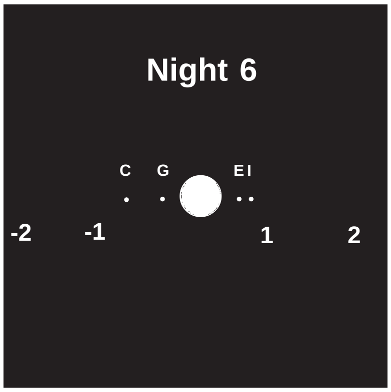


Image 11: Night 6

Image 12: Night 7

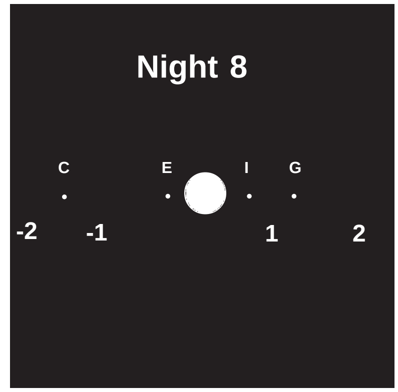


Image 13: Night 8

takes for your moon to orbit Jupiter? *(Count how many days it takes to return to its starting position. Be sure to count just the spaces in between the nights to get a correct answer for the number of days gone by.)*

Ask a member of each group to report the orbital period of the moon that s/he tracked.

Can you see any relationship between the farthest distance each moon gets from Jupiter and the time it takes to orbit Jupiter? *(The more distant moons go around more slowly.)*

Not all four moons are visible all the time. Sometimes one or more moons are in front of or behind Jupiter and cannot be seen.

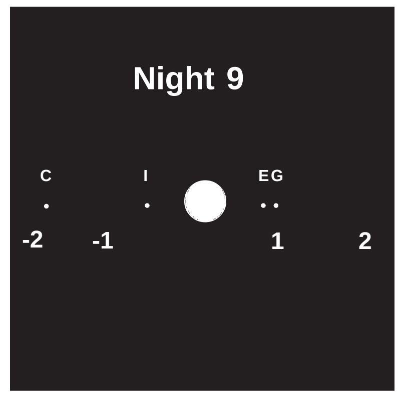


Image 14: Night 9

Tour of Moons

We are not completely satisfied to look at moons in our solar system through telescopes. Let's take a spaceship ride to some of the planets in our solar system to get close-up views of their moons. While this is an imaginary spaceship ride, we will view real images transmitted to Earth by Viking and Voyager spacecraft. Please fasten your (imaginary) seatbelts while we prepare to lift-off.

Start rocket launch tape at countdown. At ignition, start blue daylight and orange covelights alternating in intensity. Turn on stars. Start diurnal motion and gradually accelerate while rocket noise gets louder. As rocket noise subsides, gradually bring diurnal motion to zero and dim daylight and covelights to off.

Before we leave the neighborhood of Earth, let's get a super view of our own Moon.

Image 15: Moon close-up.
Point out mountains, craters, and maria.

Image 16: Crater (Clementine image of Tycho)

Discuss what craters are and how they are formed. See references for latest info on Clementine, Lunar Prospector, and later missions. There is evidence of water ice in polar regions of the Moon!

If it's moons we want to see, there is no point in traveling to the two planets, Mercury and Venus, that are closer to the Sun than Earth. They have no moons at all. Let's journey outward in the solar system towards Mars.

Turn on diurnal and music for journey to Mars. Stop diurnal and lower music on arrival at Mars.

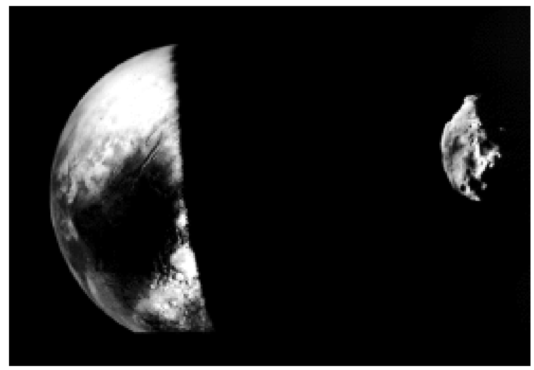
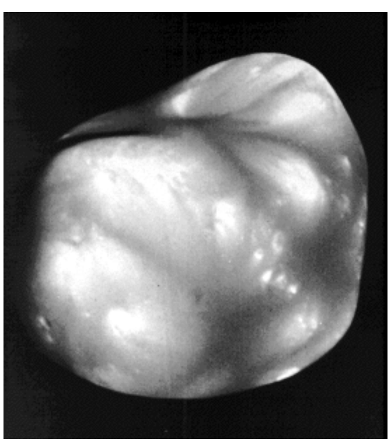


Image 17: Mars + Phobos

Note the shapes of the illuminated parts of Mars and its moon Phobos. ***Can you explain those shapes?*** *(Quarter phase.)* ***From which direction is the sun shining?*** *(Have an audience member indicate with battery light pointer.)* Phobos is only about 15 miles (10 km) long. It is very small compared to earth's moon which is 2000 miles (3200 km) across. If you want to play baseball, but can't find anyone to play, you could still have a good game on Phobos. The gravity on Phobos is so weak that if you stood on its surface, you could throw a baseball into orbit or beyond (just like superman on Earth). So, you could pitch the ball in one direction, then pick up your bat and wait for the ball to come at you from the other direction.



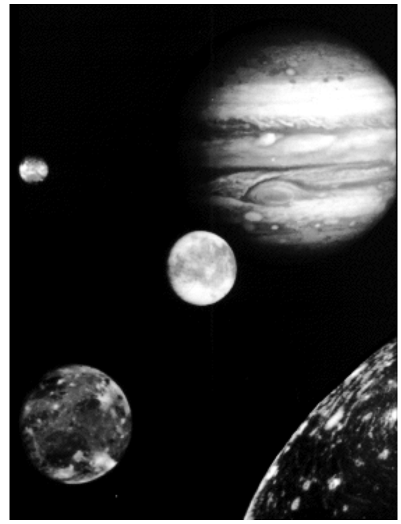
Here is a zoom close-up view of Phobos.

Image 18: Phobos

Mars may have a small moon compared to earth's moon, but it has an extra moon just for good measure. This moon Deimos is only a bit smaller than Phobos.

Image 19: Deimos

Let's head on to the next planet out in the solar system. ***Anyone know which planet that is?*** *(Jupiter.)*



Diurnal and music up for cruise to Jupiter.

Let's see those four moons we tracked before. They each have unique markings and geology.

Image 20: Jupiter and moons

The Galileo spacecraft arrived at Jupiter on December 7, 1995. Galileo's atmospheric probe plunged into Jupiter's atmosphere and relayed information on the structure and composition of the solar system's largest planet, while the Galileo orbiter studied Jupiter and its moons, encountering one moon during each orbit.

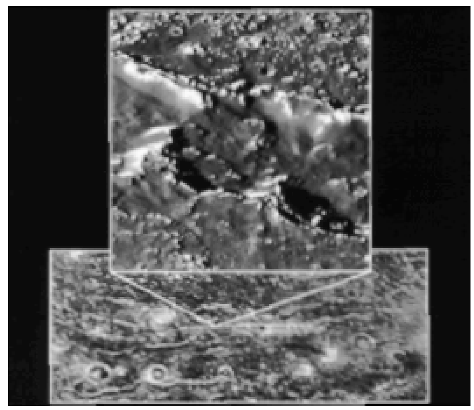


Image 21: Callisto crater chain blowout

What does this intriguing image of Callisto's surface look like to you? [It's a portion of a chain of craters believed to result from the impacts of an object such as a comet or asteroid which was ripped asunder by the powerful gravitation of Jupiter, similar to the fragments of Comet Shoemaker-Levy 9 which smashed into Jupiter's atmosphere in July of 1994.] Callisto has a very old, heavily cratered crust showing remnant rings of enormous impact craters. The largest craters have apparently been erased by the flow of the icy crust over geologic time.

Galileo spacecraft data received in October 1998 suggest that something is hidden below Callisto's surface, and that something may very well be a salty liquid ocean!

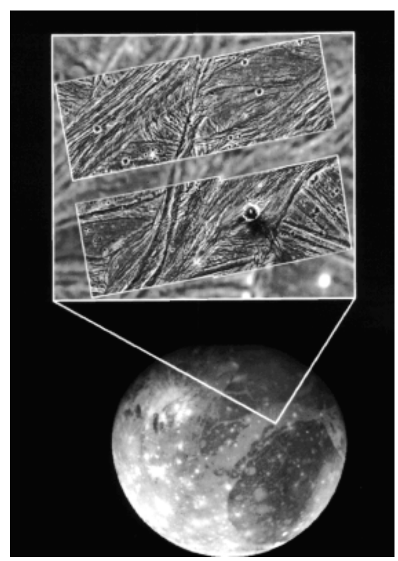


Image 22: Ganymede

Ganymede has frosty polar caps as well as two other types of terrains: bright, grooved terrain and older, dark furrowed areas. The two types of terrain suggest to us that Ganymede's entire icy crust has been under tension from global tectonic processes. Craters with diameters up to several dozen kilometers are visible. Ganymede is the largest moon in the solar system—5,276 kilometers (3,280 miles) in diameter.

Image 23: Europa

Europa (the "yellow moon" we tracked) is one of the smoothest moons in the solar system, and only slightly smaller than Earth's Moon. With Europa's surface temperature of -260° F, we expected to find quartzhard ice like on Ganymede, but the latest, most detailed pictures of the Jupiter moon Europa lend support to the theory that slush or even liquid water is beneath the moon's surface. The warmth from a tidal tug of war with Jupiter and neighboring moons could be keeping large parts of Europa a liquid ocean. Large plates of ice seem to be sliding over a warm interior on Europa, much like Earth's continental plates move around on our planet's partly molten interior. Some recent images show features that have many similarities to new crust formed at mid-ocean ridges on the Earth's sea floor.

Europa may be slushy just beneath the icy crust. There are chunky textured surfaces like icebergs, an area littered with fractured and rotated blocks of crust, and gaps where new icy crust seems to have formed between continent-sized plates of ice. Rough and swirly material between the fractured chunks may have been suspended in slush that froze at the very low surface temperatures. Studies of craters on Europa show that they are relatively young and that subsurface ice is warm enough to collapse and fill them in time periods that are short, geologically speaking.

The combination of interior heat, liquid water, and organic material falling onto Europa from comets and meteorites means that Europa has the key ingredients for life, making this moon a laboratory for the study of conditions that might have led to the formation of life in the solar system.

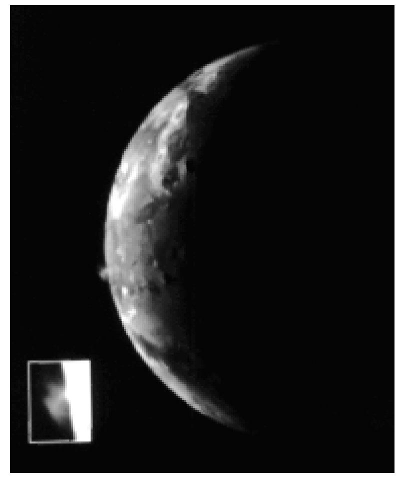


Image 24: Io crescent with close-up inset

Io (the "red moon" that we tracked) is the closest Galilean moon to Jupiter and is slightly larger than Earth's Moon. It is quite a startling contrast to other moons we have seen. It is the most volcanically active body in the solar system, sizzling with dozens of molten sulfur and silicate volcanoes. In this color enhanced image, deposits of sulfur dioxide frost appear in white and grey hues while yellowish and brownish hues are probably due to other sulfurous materials. Bright red materials, such as the prominent ring surrounding the volcano named Pele, and "black" spots with low brightness mark areas of recent volcanic activity and are associated with high temperatures and surface changes.

Io acts as an electrical generator as it moves through Jupiter's magnetic field, developing 400,000 volts across its diameter and generating an electric current of 3 million amperes that flows along the magnetic field to the planet's ionosphere.

Most bodies in the solar system do not have radical surface changes that are noticeable over short periods of time. But several such changes have been observed on Io between the times of the Voyager spacecraft visits to Jupiter in 1979, when no less than 9 simultaneously erupting volcanoes were seen, and the Galileo mission of 1995-2000, which captured an image of a 120 kilometer (75 mile) high plume. The extreme volcanic activity is caused by Jupiter's gravity generating 100 meter high tides in its otherwise solid surface. The last part of the Galileo mission is to glimpse fiery Io with breathtaking details (as small as 6 meters) in kamikaze style, crashing in to Io!

The Galileo mission was supposed to end December, 1997, but the spacecraft was in excellent shape so its duties were extended to include eight more encounters with Europa (Dec, 1997 - Feb 1, 1999) and two more encounters with Io on Oct 11, 1999 and Nov 26, 1999. The extra Europa encounters are aimed at possibly confirming that an ocean presently exists on Europa, and locating some areas where the ice is thinnest. This would lead the way to possible future Europa orbiting or ice drilling missions looking into a key question for the 21st century—is there life on Europa?

Image 24a: Jupiter rotating (movie)

Optional: This is a time lapse movie showing Jupiter rotating. It is constructed from hundreds of images that the Voyager spacecraft transmitted to Earth during the Voyager's encounter with Jupiter. Jupiter actually rotates about once every 10 hours. If you watch carefully, you can see three moons whiz by.

Let's move on to the next planet out in the solar system, the most beautiful one for many people: Saturn.

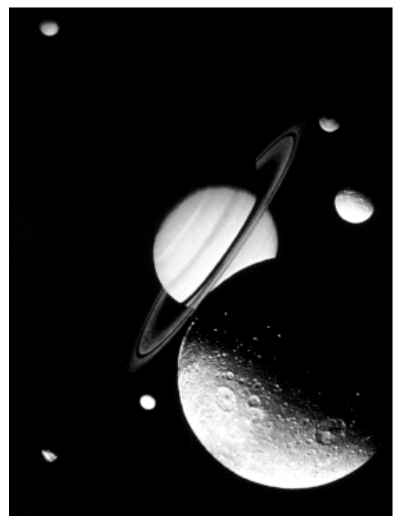


Image 25: Saturn

Saturn has at least 18 known moons orbiting at distances ranging from 84,000 to 8 million miles (134,000 to 13 million km) from Saturn. The planet itself is not as colorful as Jupiter. It does have a similar banded appearance, but the zones are not as obvious, perhaps because they are partly obscured by higher layers of atmosphere.

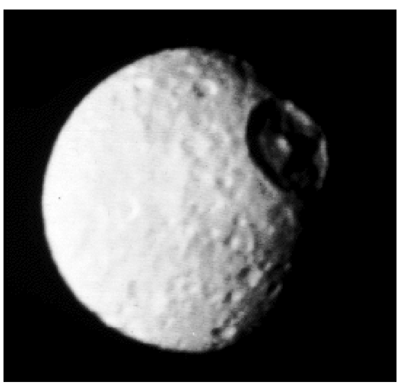


Image 26: Mimas

This little moon of Saturn is about 250 miles across and is made of almost solid ice at –300˚F. A prominent impact crater can be seen here almost 1/3 the diameter of Mimas. Images of the other side of Mimas show a large rift which could imply that the impact that caused this crater nearly cracked Mimas into two (or more) pieces.

Almost all the moons of Saturn are frigid balls of solid ice like this one, but each has a differently engraved surface that contains unique puzzles for planetary geologists. Tethys is one such icy moon of Saturn.

Image 27: Iapteus

This is Iapetus, one of the outermost moons of Saturn. From your knowledge of phases, which direction is the sunlight coming from in this image?

Use pointer to indicate various directions as you poll the audience.

This is actually a trick question because the position of the Sun when this image was made would have been behind us. We would thus expect to see Iapetus in a full phase. This and other images made of Iapetus indicate that one side of it has really dark material on it. The dark side happens to be the leading side of Iapetus with respect to its orbital motion. That's another puzzle for the planetary geologists, as yet unexplained.

Image 28: Titan

Titan is almost as large as Jupiter's moons Ganymede and Callisto. But unlike those moons, Titan is able to retain an atmosphere. It can hold an atmosphere because it is in a colder part of the solar system. Any gases near Ganymede or Callisto would be warm enough and energetic enough to escape the gravity of those moons. Titan's cold atmosphere is mostly nitrogen, but is thickly laden with various hydrocarbons that some of the Voyager scientists have jokingly compared with LA smog. The atmosphere is so thick and opaque that we are for now denied images of the surface of Titan. Measured temperatures are just about cold enough that when we do send a probe to the surface of Titan, it could encounter pools of liquid ammonia, methane, or liquid nitrogen.

The Cassini mission to Saturn which was launched in October of 1997 and arrives at Saturn in July 2004 when it may help to answer some of the unsolved mysteries of Saturn: How did the system of Saturn satellites form? How are they continuing to evolve? What is the relationship between the icy satellites and the rings of Saturn? Why is Iapetus' surface half dark and half bright? Where does the dark matter originate?

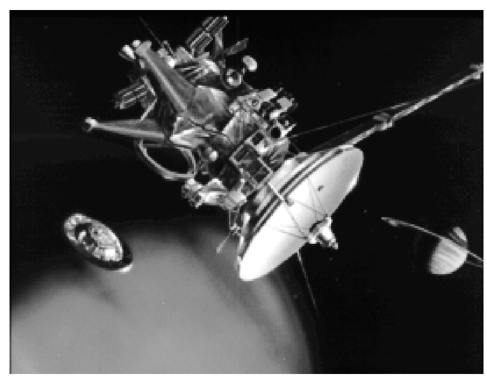


Image 29: Cassini Mission—release of Huygens probe

Cassini also carries the Huygens probe which, in November of 2004, will plunge through the dense atmosphere of Titan and scrutinize the clouds, atmosphere and surface of Titan. The nearly 3 meter (9 foot) diameter probe descends with parachutes, with its instruments measuring the temperature, pressure, density and energy balance in the atmosphere. As it breaks through the cloud deck, a camera will capture pictures of the Titan surface while other instruments directly measure the organic chemistry in Titan's atmosphere—hopefully revealing secrets that may relate to the origin of life.

After the Huygens probe lands on Titan, the Cassini spacecraft will make 30-40 flybys of Titan to study it with radio waves, observe its atmosphere, and map its surface. From the Voyager spacecraft data, some people think Titan may be covered by lakes of methane—liquefied form of the natural gas that we use in gas stoves. This remains a question that the Cassini/Huygens mission should be able to answer.

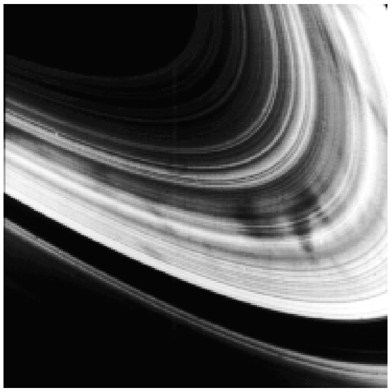


Image 30: Saturn's rings showing "spokes"

30a: Rotating rings (time lapse movie)

The Cassini mission may also help to answer the mystery of the "spokes" in Saturns rings.

Through the best Earth telescopes, Saturn appears to have only four rings. But as our spacecraft approaches, we see they are made of dozens, indeed hundreds of narrow "ringlets." The rings of Saturn are made of particles of ice, dust and rock. The particles range in size from a grain of sand to something larger than this planetarium. They are all orbiting Saturn as if they were each a tiny "moonlet."

OPTIONAL: The motion picture you see here is a time-lapse movie from Voyager made the same way as the one we saw from the Voyager-Jupiter encounter. The dark regions that you see moving around are referred to as "spokes" in the rings and present a great mystery because they seem to contradict laws of orbital mechanics. In the theory of orbital mechanics, particles closer to Saturn should take less time to go around in their orbits than the particles that are closer to the edge of the rings, just as we observed Io to take only 2 days to go around Jupiter while Callisto took 18 days to orbit. Since the spokes go around with the same orbital period for the inner rings as the outer ones, we have a serious dilemma. As yet, there is no theory to explain how the spokes can exist. Yet the spokes exist!

Images (Movies)

30b: Animations of ring particles

30c: Shepherd moons

OPTIONAL: Small moonlets have been observed orbiting just along the edges of certain rings. A theory has emerged that these moonlets, by means of their gravity, sweep ring particles inwards or outwards (depending on whether the moonlet is at the inner or outer edge of a ring) and keep the edge of the ring well defined. The moonlets have been dubbed "shepherd moons" and if it weren't for them (if the theory is correct), there would be no well defined boundaries between ringlets as we see in our Voyager images.

Now it is time to move on to Uranus. Voyager encountered Uranus on January 26, 1986. Here is an accelerated version of what you might have seen if you had been on board. This is a computer generated simulation of the encounter.

Image 31a: Uranus Encounter (animation)

Image 31: Uranus collage

This is a collage of Uranus and its ring system as if you were standing on Uranus' moon Miranda. Uranus has a paltry ring system compared with that of Saturn; only ten thin rings were seen. Notice the deep canyon and impact craters in the icy surface of Miranda. (Miranda and Uranus in this slide are Voyager 2 images, while the rings are artist's conception. The apparent blue color of Uranus is its true color and is a result of the absorption of red light by methane in Uranus' atmosphere, leaving primarily blue light to reflect back.)

Here is a great image of Miranda which is about 300 miles diameter (484 km.).

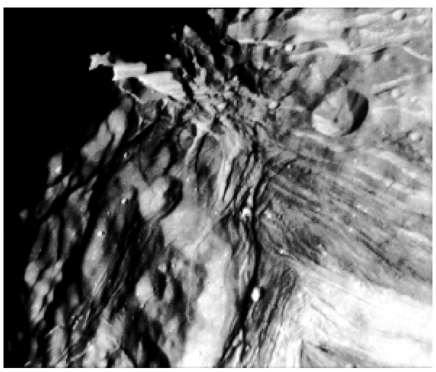
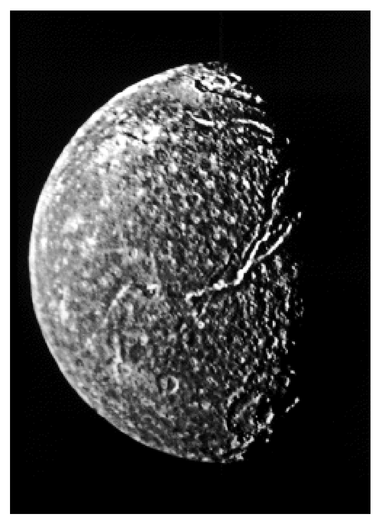


Image 32: MIRANDA, cliffs 6-9 mi. high (10-15 km.)

Note how strikingly clear and detailed these images are. Voyager also detected 10 new moons, bringing the total number of Uranian moons to 15. Remember that these images were transmitted across more than a billion miles of space by a spacecraft that had already endured encounters with Jupiter and Saturn in its 9 year odyssey through the solar system. (Voyager was launched in 1977.)

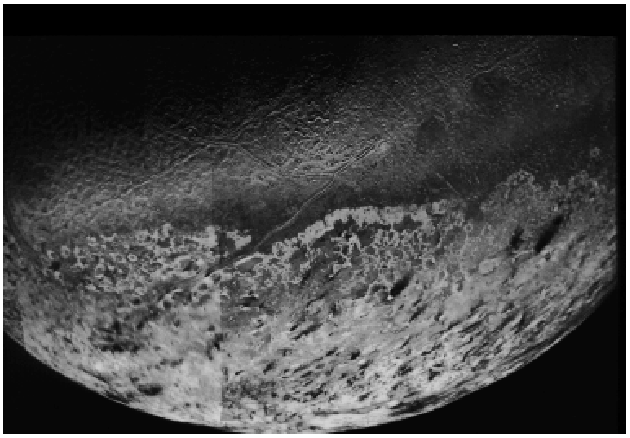
Image 33: Titania



Five large moons of Uranus were known before the Voyager 2 encounter. In order of increasing size they are Miranda across, Ariel, Umbriel, Titania and Oberon. Titania is one of the largest, about 1,600 kilometers (1,000 miles) in diameter, roughly half the size of Earth's Moon. Titania, for example, is marked by huge fault systems and canyons that indicate some degree of geologic activity in its history. These features may be the result of tectonic movement in its crust. The 10 new moons of Uranus discovered by Voyager brought the total number of known Uranian satellites to 15. As of June 1999, there were 18 known moons of Uranus.

Voyager has survived its Uranus encounter in which it performed beyond our wildest dreams. It went past Neptune in an encounter in August of 1989.

Image 33a: NEPTUNE ENCOUNTER (animation)



Voyager 2, a senior citizen spacecraft having spent 12 years of rigourous journey through space with 3 spectacularly successful encounters under its belt, performed superbly in its encounter with Neptune. It allowed us to discover 6 new Neptunian moons (bringing the total number for Neptune to 8),

Image 34: Triton

Voyager 2 sent us spectacular images of the huge moon Triton, revealing ice volcanoes. Voyager 2, its primary mission complete, is now on its way to exit the solar system, never to return.

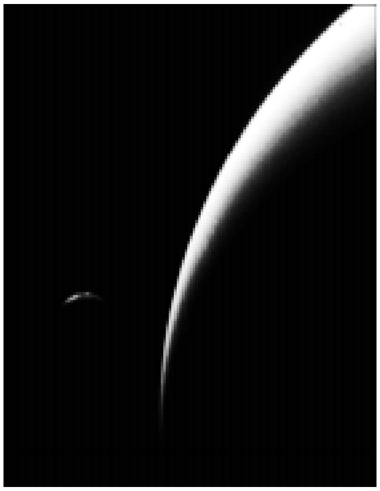


Image 35: Voyager leaves Neptune

As exciting as the Voyager images are, we must not forget about important discoveries are made by astronomers with earth-based telescopes.

Observations obtained by NASA’s Hubble Space Telescope and ground-based instruments reveal that Triton seems to have heated up significantly since the Voyager spacecraft visited it in—it has been undergoing a period of global warming. The warming trend is causing part of Triton’s frozen nitrogen surface to turn into gas, thus making its thin atmosphere denser. Even with the warming, no one is likely to plan a summer vacation on Triton, even though its temperature has risen about three degrees to a whopping -389 degrees Fahrenheit. If Earth experienced a similar change in global temperature over a comparable period, it could lead to significant climatic changes. By studying the changes on Triton, the scientists hope to gain new insight into Earth’s more complicated environment.

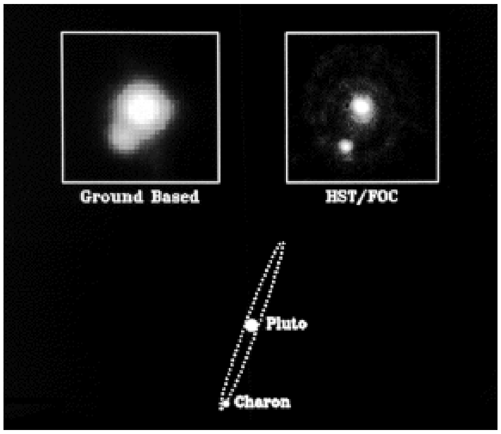


Image 36: Pluto and Charon

Pluto, which is usually the outermost planet in the solar system, was found to have a large moon. Pluto's moon, discovered in 1979 with the aid of an earth-based telescope, was given the name Charon (in Greek & Roman mythology, the boatman that carried souls across the river Styx to the underworld, in which the god Pluto reigned).

We land you now back at __________________Planetarium *[insert your home planetarium here]*. We hope you enjoyed your tour of the moons of the solar system. You are invited to come back to the our planetarium sometime to see our other planetarium shows.

Image 37: Your planetarium or school

Discover More About Moons of the Solar System

Worldwide Web Connections

and update information may be found at http://www.lhs.berkeley.edu/pass

Books

J. Kelly Beatty (Editor), Carolyn Collins Petersen (Editor), andr Chaikin (Editor), Andrew L. Chaikin (Editor), *The New Solar System*. Cambridge Univ Press, Sky Publishing, 1999. A superb series of review articles by noted scientists. Thorough, though somewhat technical. Excellent photos.

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Discover More About Moons of the Solar System

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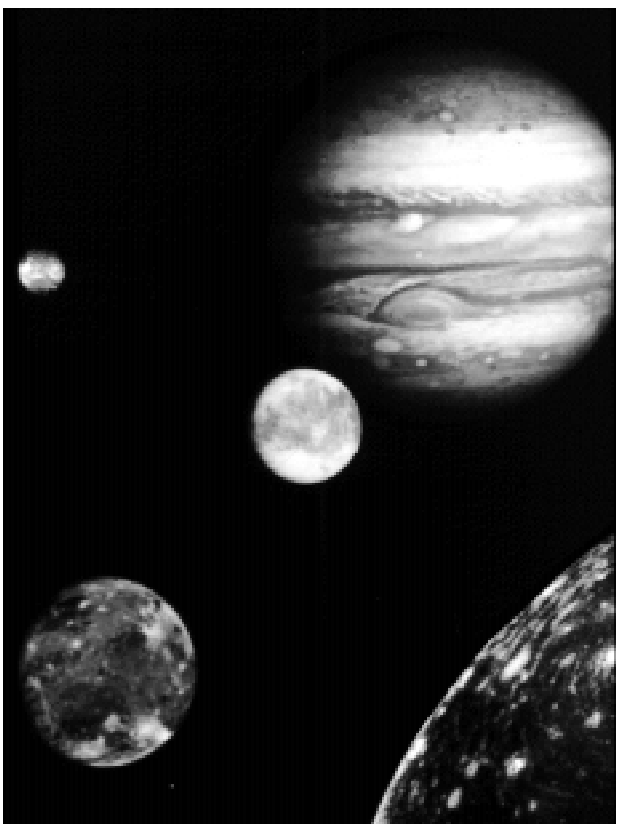
Moons of the Solar System

Classroom Activities

The Phases of Jupiter's Moons

If you happened to live on the planet Jupiter and looked up into the beautiful night sky, what might its moons look like? Imagine seeing the full moon of Io rising as the crescent-shaped Ganymede begins to set. To a "Jupiterian," the Galilean satellites would appear to go through the same phases as does our own Moon from Earth. For a classroom activity version of exploring moon phases, we recommend "Modeling Moon Phases and Eclipses" from the Great Explorations in Math and Science (GEMS) unit, *Earth, Moon, and Stars*. The simple moon phase model used in the planetarium show *Moons of the Solar System* to explain our Moon's monthly cycle of phases can also be applied to the more complex Jupiter system.



Adapt the procedures of that model as follows:

1. Have students work in teams of three. One student plays the role of "Jupiter" while the other two students each hold up two of Jupiter's four moons.

2. The room is darkened and one bright bulb is turned on, to be the "Sun." Jupiter slowly turns and the phases of two of its four "moons" can then be observed.

3. The students holding the moons can then move around a little further in their orbits and stop so "Jupiter" can again turn on its axis and students can see how the phases have changed.

4. To add a guessing game element, have have students take turns guessing what phases the other students are seeing. Competitively inclined students can have a point system to determine the "winner" of the guessing game.

5. For an even more complex challenge, divide the class into groups of 5 students: one student as Jupiter and the others being each of the four Galilean moons. Then do steps 2-4 again.

More on Tracking of Jupiter's Moons

1. **Comparing Charts.** If you made four overhead transparencies of the data sheets, and had four students traced the data from the four different moons onto them (using different colored pens if possible) you can combine them as follows: Stack the completed transparencies so they are carefully lined up. Punch two holes at the top or side, so paper fasteners can be used to line them up quickly. Stack the four transparencies together, one at a time, on the overhead projector as the students watch. Ask questions about the combined graph such as:

How will Jupiter's moons appear on night 3? 4? 5?

On what night does the white moon go from one side of Jupiter to the other?(6-7)

On what night will most of the moons be on the left side of Jupiter? (3, 7)

On what night will we see two moons on each side of Jupiter?(5, 6, 8, 9)

Occasionally, one of the outermost moons (Callisto or Ganymede) appears to be closer to Jupiter than the innermost moons (Io and Europa). On which night does this occur? (3, 5, 6)

2. **Magazines**. The magazines *Astronomy* and *Sky and Telescope* have a monthly graph of Jupiter's moons that looks very much like the combined graph above. Show this graph to your students, and ask them further questions, such as:

How many nights are represented on this graph? (one month, usually 30 or 31 nights)

What does the column down the middle stand for? *(Jupiter)*

How many moons are plotted on the graph? *(four)*

How will the moons appear on the 15th (or other interesting date) of the month?

How are the moons labeled on this graph? *(In Sky & Telescope they are labeled by Roman numerals.)* ***Which moon corresponds to which Roman numeral? When will moon III be behind Jupiter?***

Which moon orbits Jupiter the largest number of times? The smallest number of times?

Can you find a date when three of the moons will be found on the one side of Jupiter? On the other side?

3. **Galileo**. Have your students read more about Galileo's life, and the trouble he got into because of his defense of Copernicus's theory. Plays by Bertolt Brecht and others have been written about Galileo's life. Your students might want to put on such a play, or make up one of their own.

4. **Arrange an outing** on a night when Jupiter will be visible in the night sky. Using binoculars or telescopes, students will be able to see Jupiter and some of its four largest moons. Contact your local amateur astronomy club to see if they might help your students have a "star party" when Jupiter is visible.

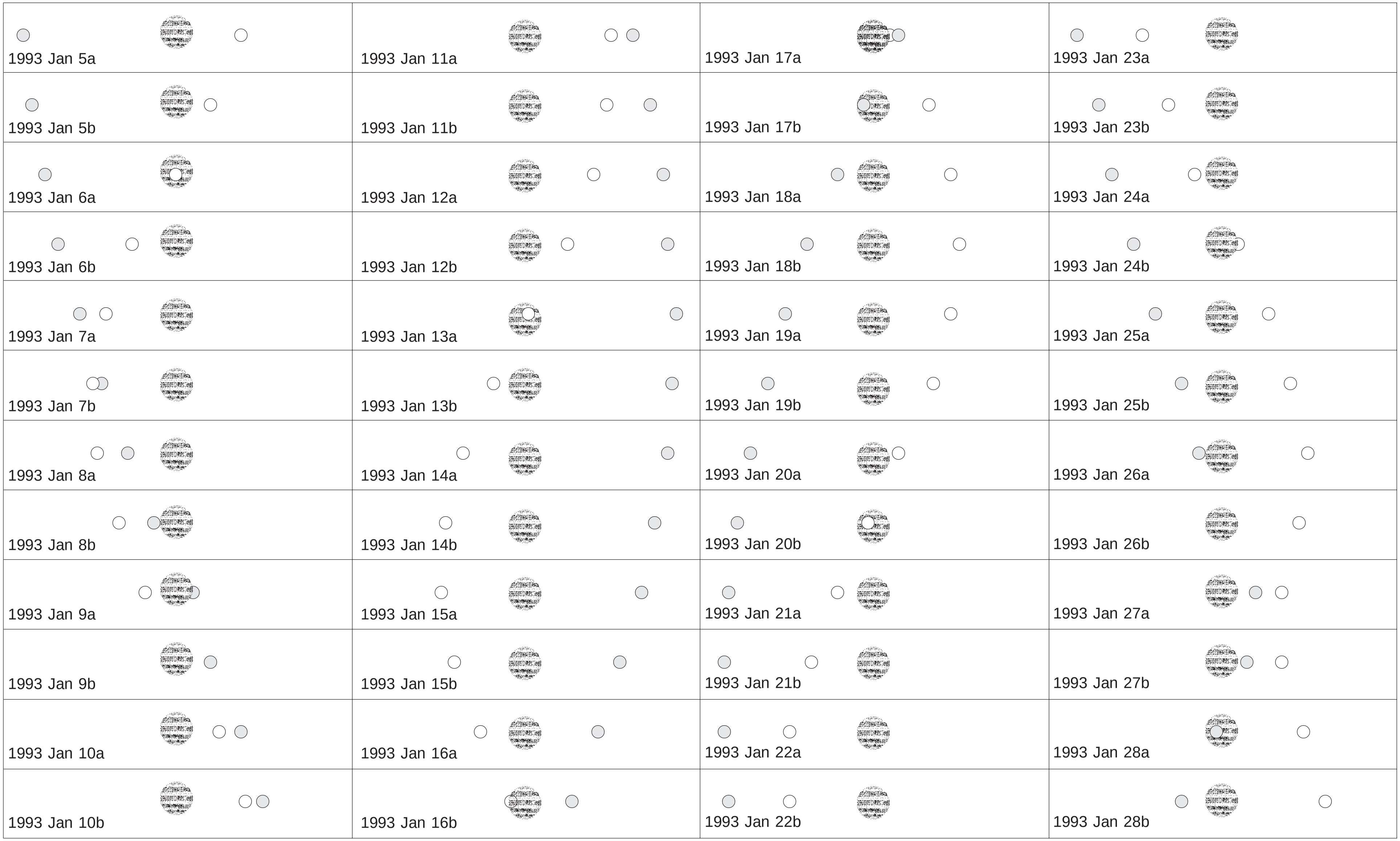
5. **Make a Scale model** of the Jovian system. A detailed description of how to do this as a classroom activity is laid out in Activity 3 of the *Moons of Jupiter* unit of Great Explorations in Math and Science (GEMS). Using the method described there, students can, as homework, make scale models of the moons systems of other planets: Saturn, Uranus, Neptune, Mars, and Pluto.

6. **Make a flip book** "movie" of Callisto revolving around Jupiter! Make a copy of page 24 for each student. Have them follow the directions on the page.

Ganymede and Calisto: The Movie

◯ = Callisto
◯ = Ganymede
Not to scale

1. Make up a color code and color the moons in each box according to your code. 2. Cut out the boxes. 3. Tape them onto successive pages of a notepad or book. Be sure each box is positioned in the same orientation and relative location on each page: upper right unbound corner is best. 4. Flip the pages to “run the movie.”



Meteoroids & Craters

This activity consists of a few simple experiments in which students will create a model of crater formation to determine the effect of (1) size of meteoroid, (2) speed of meteoroid, and (3) angle of approach. In the first two experiments, the outcome is fairly easy for students to predict. The third experiment is a bit more thought-provoking and surprising.

Objectives

For students who are already familiar with the idea of controlling variables in experiments, this activity will provide a good exercise in addition to providing insights into crater formation. For students in grades 4 and above, identifying variables and performing the controlled experiments should be a reasonable challenge. For younger ages, the activity can take on more of an exploratory approach in which ideas form as the model meteoroid impacts are observed.

After this activity, students will be able to:

1. Identify factors that might affect crater formation.
2. Predict the outcome of experiments.
3. Perform simple experiments concerning meteoroid impacts and crater formation.
4. Record their observations.

Materials

For the class:

- ❒ 1 slide projector and screen
- ❒ 1 or more brooms or whisk brooms to clean up spills
- ❒ 1 pair of scissors or a paper cutter (to cut the centimeter rulers off the student data sheets)
- ❒ one container instant chocolate milk powder. (Note: Real cocoa has also been used, but it tends to clump and to over-darken the flour too quickly.)
- ❒ three or four 5-pound packages of white flour
- ❒ Optional: slides of Earth's Moon and a close-up view of a large crater

For each student:

- ❒ 1 pencil
- ❒ 1 "Craters" activity sheet (master on page 32)

For each team of 4 students:

- ❒ 1 shallow basin (to be filled with about 3 to 5 inches of flour)

Examples: a dishpan, a heavy aluminum roasting pan, or cardboard box. To be sure to have enough, you may want to ask a student from each group to bring in a dishpan from home for the day of the activity. They don't all have to be the same size.

- ❒ 1 cup or small plastic container (to be filled about one-third full with powdered instant chocolate milk mix)
- ❒ an old newspaper
- ❒ three rocks: small, medium, and large with diameters **about:** .5 cm (1/4 inch), 2 cm (3/4 inch) and 4 cm (about 1 1/2 inches)
- ❒ 1 spoon (plastic or metal)

Before Class

1. Before the day of the activity, collect and sort the rocks needed for all the groups.

2. Make one copy of the "Craters" data sheet for each student (master on page 32). With scissors or a paper cutter, cut the centimeter rulers from the bottom of the data sheets.

3. Assemble sets of materials for the teams: newspaper, a dishpan filled with flour 3 to 5 inches deep, a cup about one-third full of instant chocolate milk mix, and three different-sized rocks. Have data sheets, paper rulers, and pencils handy, but separate from the other materials. Keep one set of all the materials handy near the place where you will demonstrate the activity.

4. Try the cratering activity yourself—decide whether your students will do the activity indoors or outdoors.

6. Optional: Set up the slide projector with Moon and crater slides

In Class

Part 1: Introducing Craters

1. The name of Earth's Moon is **Luna**.

What do you imagine the surface of our Moon is like? What would it feel like to be walking on Luna? What would you see around you?

Optional: Show slide of the Moon. This is how our Moon would look if viewed through a small telescope.

What do you see on the Moon's surface? *(Light areas, dark areas, craters etc.)*

If somebody mentions craters, have them point out an example of one for the class. If craters are not mentioned, point out a large one and identify it as a crater. Explain that craters are big "dents" or holes in the Moon's surface.

2. A **meteoroid** is a rock in space—it can be any size all the way from microscopic to many meters across; **a meteor** is the same rock falling through the Earth's atmosphere, creating a streak of light (sometimes also called a "shooting star"). Fragments of meteors that survive the fiery trip through the atmosphere and land on the Earth's surface are called **meteorites**.

3. ***What causes craters on the Moon?*** *(Meteors, asteroids, big rocks, comets, etc.)*

4. ***Are craters on the Earth?***

If anybody has visited a crater site, have them share their experience with the class.

The Earth has many craters. Some were caused by volcanoes. Others, called ***impact craters***, were made by meteorites. ***Why do we see***

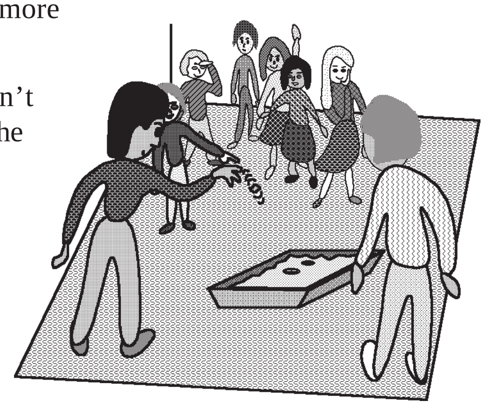
very few impact craters on the Earth? *(The Earth has rain and wind which erode away the evidence of most craters.)* Earth's atmosphere prevents small meteors from reaching the surface, because when a meteor falls towards a planet with an atmosphere, it "rubs" against the air. ***Rub your hands together quickly for several seconds to feel the heat of friction.*** If you could rub fast enough you would create enough friction to light a fire. In a similar way, the flash of light you see from a "shooting star" or meteor is a white-hot glow produced by the heat of friction between the meteor and the air. Because the Moon has no air to rub against, meteors do not burn up before hitting the Moon's surface. This is one reason why the Moon has lots of craters.

Part 2: Making Craters

1. Let's investigate what happens when a meteoroid hits a solid surface like that of the Moon. You will use a pan of flour and three different size rocks to investigate meteor craters. The flour will represent the surface of the Moon and the rocks will be the "meteoroids."

2. Here's what to do *(Demonstrate for the students)*:

- Place an old newspaper and a pan of flour on the floor near your feet.
- Sprinkle a light coating of instant chocolate milk mix on the surface of the flour to create a contrast that will help make changes more visible.
- Hold out a medium-sized rock at about shoulder level. Don't actually drop the rock. Drop, **DO NOT THROW,** the rock into the flour.
- After you drop the "meteoroid," observe what happens to the flour.



3. ***"What do you think will happen?"*** *(Have several students make predictions.)*

4. You will work in groups, and take turns dropping the rocks into the flour. It's not necessary to smooth the flour and apply chocolate milk mix after each try.

Distribute the materials to the teams and let them freely explore the materials and practice making craters for about five minutes.

5. ***What did you find out? What features did your craters have?***

You may want to have a few volunteers draw what they saw on the chalkboard. As students describe the various features, write some terms on the board. [The impression left on the surface is called a **crater basin.** *Students may have noticed a* **rim** *around the edge of the basin and streaks or* **rays** *that radiated outward from the crater.]*

Part 3: Meteor Experiments

1. There are craters of many different *sizes* on the Moon. ***What might affect how big craters will be?*** *(Meteoroid size or weight, speed at impact, direction, or type of surface material.)*

2. Our research teams will now conduct experiments to find out how two of those factors affect the size of the craters: the **size of the meteoroid** and the **speed of impact.**

Hold up a data sheet and explain the two experiments:

Experiment #1: Size of Rock

Make three craters with each of the three rocks (a total of nine craters for Experiment #1). Drop each rock from the same height. Measure the diameter of the crater, using a paper centimeter ruler. Record the crater diameters on the data sheet after each drop. Repeat three times for each rock.

Why it will be important to drop all the rocks from the same height? *(Then, if the crater size varies, they'll know it's because of the size of the rock.)* You can use one team member's shoulder height as a standard for every trial. Remove the rock from the flour very carefully, so you don't disturb the crater.

After each trial, jiggle the container back and forth a few times to level the flour and sprinkle more chocolate milk powder on top if the surface needs it.

If the flour becomes very dark from cocoa, or if a team has used up all its chocolate milk powder, sprinkle flour on the surface instead of the powder to create a contrast.

You may want to have the students calculate averages, although the results may be evident without it.

Experiment #2: Speed of Impact

This time, use only one rock to make all the craters, but drop the rock from different heights: knee-high, shoulder-high, and as high as they can reach when standing on the floor. A rock gains speed as it falls, so the farther it falls, the faster it will be going when it hits the flour. Make three craters from each of the three heights. (A total of nine craters for Experiment #2.) Record the crater diameters on the data sheet after each drop.

Why should we use the same rock when we are experimenting with different speeds of "meteors? *(If we used different rocks and different heights, we won't know which made the differences in crater sizes.)*

Knee-high, shoulder-high, and as high as you can reach may vary for different students. ***How an you keep the height standard on all three tries?*** *(Take turns dropping the rock, but use one student's shoulder height for all tries.)*

Hand out the data sheets and paper rulers and have them begin. Circulate during the experiment, checking to be sure students are working safely and cooperatively in their teams.

If a team finishes early, suggest that they extend their investigations in Experiment #2 by, for example, **carefully** *standing on a chair to drop the rock. (Older students may want to extend their investigation by observing or measuring crater depths created by various sizes or speeds of "meteoroids." The long "rays" that radiate from their "craters" could also be measured.)*

As teams finish, have them return their equipment to the materials area and clean up. Have them keep their data sheets for the discussion.

3. Analyze your experiment by looking at your data for Experiment #1, comparing meteor sizes. ***Describe what you observed and recorded. Does the size of the meteoroid have anything to do with the size of the crater?*** *(Your students' experimental data is likely to vary, but many students will find that crater size increases with the size of the meteoroid.)*

What can you conclude from Experiment #2, about meteors that have struck with different speeds? *(Again, student data will vary, but many students will conclude that the faster the meteor, the bigger the crater.)* Real craters caused by actual meteor impacts are about 20 times the diameter of the meteor itself.

Optional: Show the slide of Earth's Moon again. Ask volunteers to point out some of the features of craters on the Moon that they recognize from their experiments. Show the close-up of a Moon crater and ask

Going Further

1. Angle of Impact

Ask the students to predict the appearance of a crater if the meteroid strikes the ground at an angle. (Most will assume that the shape of the crater will be different—not round.) Have the students conduct experiments in which they throw identical sized pebble at about the same speed, but at different angles. Instead of recording the diameter of the crater, record the shape of the crater.

Is the shape of the crater different? How would you expect the shape of the crater to change as the angle of impact is increased?

The results of this test are often surprising. One normally would expect the crater to have an oblong shape on extremely wide angle impacts. In fact, all craters that we have seen on the Moon or on Earth are pretty much circular. The reason is that on impact, an explosion occurs and the forces associated with an explosion are always spherically symmetrical. If your students examine images of many craters, they may notice that they all appear round. No matter the initial shape of the meteor (or the angle of its impact) the resulting explosion will always form a round crater.

2. Craters in Liquids

In close-up views of some large craters students may notice the central peaks. Modern scientists have been able to simulate actual meteor impacts with rocks fired from powerful guns (at 30,000 mph). At such speeds the meteor does not stop moving at the moment of impact. Friction rapidly heats the meteor and a tremendous explosion occurs. (Imagine quickly trying to change all the energy of a room-sized meteor traveling at 30,000 mph into heat!) If the meteor is large and fast enough, the ground liquefies, forming a crater with a rim around it. In large impacts the rim collapses, and the liquefied material rushing back into the center of the crater forms a mountain in the middle. Debris thrown out by the explosion forms rays that may extend for hundreds of miles. On Earth, small pieces of a meteor are sometimes found at the impact crater, confirming that the crater was caused by a meteor impact.

Your class can observe craters forming in liquids as follows:

For each group of four to six students, you'll need a cup of water, a medicine dropper (optional), and 1 blank sheet of paper. Pour a cup of water into a pie pan. If you are using medicine droppers, hold the dropper about a foot over the pan and allow a drop of water to fall into the pan. Or, dip a finger into the water so that a drop hangs from it, and shake the drop loose so it falls into the water. (Although the drop of water is a little bigger with the dropper, the fingertip method works fine.)

Encourage all members of the team to observe what happens from the side and from just above the surface of the water. Have the students take turns releasing drops and observing what happens. Each team should discuss their results and draw what they see on their papers. Here are some possible observations:

— As soon as the drop hits, it goes below the surface of the water, making sort of a "crater."

— Ripples come from the center, hit the walls of the pan, and bounce back and forth.

— A mound of water forms in the center of the crater, right after the drop is dropped. It may seem *as if the drop "bounces" back after it hits the water.*

What crater features can you see that you have not seen in the experiment with solids? *(Concentric circles, ripples, and central peaks.)* Very large meteors that have struck the Moon move so fast that they melt the rocks. In these cases, even though the surface may have been solid before the impact of the meteor, we can sometimes see the central peak caused when the Moon's surface turned to molten rock for a few minutes, then solidified before the peak had a chance to become level again.

3. Making a Model of a Crater

As long as you have all that flour, why not use it to make sculptures of craters?

Show your students pictures of craters from various places in the solar system. Give each student a square of posterboard or cardboard. Mix flour, salt, and water into a thick paste and have your students use the paste to form craters on their boards. Set the finished craters aside to dry overnight.

Most craters in the solar system are various shades of grey in color, so painting of the craters may not be particularly exciting. However, Jupiter's moon Io has volcanic craters that have striking colors: orange, red, black, yellow. You can discuss with your class the difference between impact craters and volcanic craters and have your students form model volcanic craters such as those on Io which they can then paint in bright colors.

Crater Experiments

Experiment 1: Size of Meteoroid

What can you conclude?

Record the Crater Diameters for:

	Small	Medium	Large
1			
2			
3			
Average			

Experiment 2: Speed of Meteoroid

What can you conclude?

Record the Crater Diameters for:

	Small	Medium	Large
1			
2			
3			
Average			

Your Name:

Centimeters: 0 1 2 3 4 5 6 7 8 9

Building a Lunar Settlement

Here is a chance for you to use up some of those interesting scraps and snips of things that most people throw away, but could make perfect components for a model lunar settlement. In this activity, students first think of everything they would need to survive for years on a lunar settlement, and then design and build a model of such a settlement.

Objectives

This activity can take on different meanings to different age students. For older students (grades 4-8), the question of what is necessary to survive in space can have special significance, since they soon may be candidates for space missions themselves. For younger students (grades 1-3), this activity is more of an open-ended creative process of building a home on the moon.

In this activity students will be able to:

1. Recognize (brainstorm) needs for human survival in space.
2. Design and build a model lunar settlement.
3. Communicate their design concepts and ideas with other students.

Teacher leaders build a moon settlement in a summer institute of Participatory Oriented Planetariums for Schools (POPS) by Lawrence Hall of Science.

Materials

For the class

❒ 1 or 2 boxes of raw material or "doo-dads" for settlement building. "Doo-dad" suggestions include: plastic or paper cups, small containers (such as empty yogurt or orange juice containers), packaging material (such as plastic casings on small items, clear "bubble-wrap" and styrofoam "peanuts" and other packing materials), egg cartons, styrofoam meat trays, cardboard tubes, corks, straws, film canisters, scrap wood, colored paper or poster board, assorted stickers—YOU NAME IT!

Note: To reduce clean-up time, limit the amount of styrofoam peanuts to about four cups.

❒ 1 or 2 skeins of color yarn or string
❒ 1 or 2 rolls of foil
❒ 1 roll of plastic wrap
❒ 1 box of toothpicks
❒ 1 box of straws
❒ 1 package of blank stick-on labels (masking tape can also be used)
❒ chalk and chalkboard, or overhead projector, unused transparency, and pens
❒ Optional: tools for use by teacher or under direct supervision, such as pliers for bending wire, utility knife for cutting tubes or styrofoam, hand saws, hammers, paper clamps, etc.

For each group of 4–5 students:

❒ 1 poster board, about 30 cm x 60 cm (about 1 ft. x 2 ft.) These serve as the base for each team's settlement (size can be adjusted to your preference)
❒ 1 or 2 glue bottles or glue sticks
❒ 1 or 2 scissors
❒ assorted color marking pens
❒ 1 roll of masking or cellophane tape

Before Class

1. Gather a few examples of the "doo-dads" listed above. Before the day of the activity, give the students a list of "doo-dads" so that they can start collecting for their projects. To give them an idea of what may be useful, show them the materials you have collected. Encourage the students to save any small objects that might turn into "space material" with a little imagination. Have them bring in their supplies from home.

2. Cut the poster board into approximately 30 x 60 cm (1 x 2 feet) rectangles to serve as bases for each team's settlement.

On the Day of the Class:

1. For quick distribution, assemble each group's supplies (glue, scissors, pens, and tape) on a tray or in a container.

2. Place the building materials in an accessible location. Students need to be able to retrieve material easily. Keep the tools such as pliers in a place that you can monitor. You could also wear a "tool belt" or carry a toolbox so you can go from group to group with all the special tools needed to assist students.

3. Arrange desks or tables and chairs so groups of 4-5 students can work together building a settlement for one of Jupiter's moons.

In Class

Part 1: Planning a Moon Settlement

Imagine that you are to be among the first people to create a community on the Moon or on a moon of Jupiter or Saturn. It would take a spacecraft about **two or three YEARS** to transport people to or from the Jupiter system. You would need to establish settlements on the moons so you could live there for long periods of time. You will be working in teams to design and build a model of a settlement on a moon somewhere in our solar system.

In preparation for this mission, you first need to think about what conditions you will face. Imagine being on one of Jupiter's moons. ***How would things be different there?***

Take several answers and encourage the students to keep in mind such things as:

- Low gravity (1/3rd to 1/6th the gravity of Earth)
- Bitter cold temperatures: –100°C to –200°C (–148 F to –328 F) except on parts of Io
- Exposure to cosmic rays and radiation. (There is intense radiation on Io, Europa, and Ganymede, because of the interactions of Jupiter's gargantuan magnetic field with the solar wind. Only Callisto lies outside Jupiter's "magnetosphere" and so has less radiation.)
- No liquid water (except maybe on Europa)
- No air
- Little sunlight (1/25th as much as on Earth).

Think of essential items you would need to have with you on a moon settlement. Remember, you must be able to live for a few years there without returning to Earth.

Have the class brainstorm and list their ideas on the chalkboard or use an overhead projector. Among items that have been considered essential in actual planning of similar projects are such things as: living quarters, a greenhouse, solar panels/generators, storage facilities, a launch and landing pad, etc.

Divide the class into teams of 4–5 students who work well together. Arrange seating so they can share materials and work together on the model.

Part 2: Building the Settlement

Here are your raw materials.

Show the class a sample posterboard section and explain that they will be building their model, using a board like this as a base. Show the various raw materials they can use. If certain items are in short supply, you may want to set limits. (e.g. "Only one plastic tube per group, please!") Suggest ways for teams to be reasonable and cooperative in gathering and sharing materials.

After you have been working for a while, you will be given labels and asked to identify and label all the parts and structures you've developed. Your settlement should have all the essential requirements that we listed on the chalkboard.

Distribute group supplies and give a posterboard to each group. Let the teams get the "raw materials," and begin planning and building. Circulate and help as needed. Ask questions and encourage the students to use their imaginations.

When the settlements are well underway, bring around blank labels and have the students label each part of their settlement (launch pad, greenhouse, and so on).

Leave enough time at the end of class for clean up. If the students have not completed their models and you are planning more class time for them to work, encourage them to collect additional materials at home. Have them bring in these materials to incorporate into their settlements.

Part 3: Discussing Lunar Settlements

Now it's time to give the class a "tour" of your facility. Imagine that you are conducting tours for visiting dignitaries! I know you have put a lot of creative energy into your model settlements, and look forward to displaying and explaining your inventions and ingenuity.

Plan sufficient time for them to do this. They could present a "tour of the facilities." The presentations could all be made during one class period, or spread out over two or three days. Allow a few minutes for the other students to ask questions of each team. You may want to help guide and focus some discussion, with questions, such as:

- ***How does your settlement take into account the items on the requirement list?***
- ***What do you think it would it be like to live in this settlement?***
- ***What would you do for fun in your settlement?***
- ***What do you think the food would be like?***
- ***Would you really want to go on a mission like this?***

Going Further

1. Have the students write a story about daily life in their settlement. They may want to write a special report on an exploration to some of the unusual features of their world, or describe some of their experiments. Or, they may want to write a "letter home," describing, for example, what it is like to look up in the sky and see Jupiter instead of Earth's Moon.

2. An option is to have each student build their own moon settlement. For this, you can supply each student with a baseboard of posterboard, or simply them them do it completely from scratch on their own as an extended home project. A variation on this idea is for the students to build free-floating space communities designed not for a moon's surface but to travel through space or orbit a planet on its own. In such communities, there is a technical challenge of dealing with a weightless environment. Most designs have the whole structure spinning to create artificial gravity in a direction outwards from the center.

3. Ask students to respond to the concern, raised by some people, that perhaps people should not establish settlements on other worlds. Some might say, for example, that these worlds should be left alone, so as not to be polluted or changed by human exploitation of natural resources, or by competition by governments and businesses to control specific areas or establish settlements. Do your students agree or disagree? How would they feel if missions were limited to exploration? How about setting up mines and factories on other worlds?

4. Several videos about the Voyager missions are available from NASA. Videos can be ordered from your nearest local NASA Teacher Resource Center. The Jet Propulsion Laboratory Teacher Resource Center specializes in inquiries related to space and planetary exploration, and other JPL activities. That address is listed below. Other NASA Centers are listed in PASS Volume 3, under "Organizations."

Jet Propulsion Laboratory
Teacher Resource Center
JPL Educational Outreach
Mail Stop CS-530
Pasadena, CA 91109
Phone: (818) 354-6916

5. There are many great stories related to space settlement. Here are some:

2010: Odyssey Two by Arthur C. Clarke
Ballantine Books, New York. 1982
Grades: 10–Adult

This complex, mysterious, and thought-provoking sequel to Clarke's *2001: A Space Odyssey* had the benefit of being written subsequent to the Voyager mission. Chapter 13 specifically, "The Worlds of Galileo," focuses on the four main moons of Jupiter, although there are fascinating observations, accurate scientific information, and lots of interesting speculation about Jupiter and its moons throughout the book.

Against Infinity by Gregory Benford
Simon and Shuster, New York. 1983
Grades 10–Adult

This science fiction novel is an account of human settlement on Jupiter's largest moon, Ganymede. The story takes place several hundred years into the colonization process, and begins from the perspective of a 13-year-old boy whose father is one of the leaders of the settlement. Advanced students may want to read this novel to gather ideas about constructing biospheres, melting ice, obtaining minerals, and other ways humans might possibly survive on the moons of Jupiter.

Jupiter Project by Gregory Benford
Bantam Books, New York. 1990
Grades 7–10

A teenager lives with his family as part of a large scientific laboratory that orbits Jupiter, but he is ordered to return home. He has one chance to stay; if he can make an important discovery.. There is a nice mix of physics and astronomy with teen-age rebellion and growing maturity, some love interest, and an exciting plot. The descriptions in Chapters 6, 7, and 8, which are part of an account of an expedition to Ganymede, could be compared by students to the information they observe and learn about this mammoth moon.

The Planets edited by Byron Preiss
Bantam Books, New York. 1985
Grades: 8–Adult

This extremely rich, high-quality anthology pairs a non-fiction essay with a fictional work about the earth, moon, each of the planets, and asteroids and comets. Introductory essays are by Isaac Asimov, Arthur C. Clarke and others. The material is dazzlingly illustrated with color photographs from the archives of NASA and the Jet Propulsion Laboratory, and paintings by astronomical artists such as the movie production designers of *2001* and *Star Wars*. "The Future of the Jovian System" by Gregory Benford (about colonization and development of Jupiter's moon Ganymede) is a perfect match to the moon settlement activity. However, since the vocabulary is sophisticated it may be more suitable for high-level readers.

Moon Maps

In this activity, students learn to read maps of the moon and identify features on an image (slide) of the moon. The activity can be connected to "Building a Lunar Settlement," since location is an important consideration in the founding of a lunar community.

Objectives

This is a map reading activity, so students need to have the capability of reading maps. This activity is recommended for children in fourth grade or above. For more map reading activities, see PASS Volume 5: Constellations Tonight, Classroom Activities. In this activity, students will be able to:

1. Read a map of the moon.
2. Locate features on a telescopic image of the moon (slide) with the aid of their lunar maps.
3. Point out to their classmates the lunar features that they have found.
4. Decide what type of landscape might be best for a lunar community.

Materials

For each student:

1 Map of the Moon (Master on p. 40)

For the class:

❒ Slide projector

❒ Slide or poster of the full moon

❒ Battery light pointer or a stick that can be used as a pointer.

[If you have the Optical Data laser videodisc, you can find a suitable image in the series of frame numbers F7336-7344.]

Before Class

1. Make sure the light pointer works or stick is on hand.

2. Set up the slide projector with full moon slide or poster of full moon.

3. Duplicate moon maps (1 per student).

In Class

Show your students an image of the Moon (slide or poster).

What sorts of features are visible on the Moon? *(Craters, dark areas, light areas.)* ***What kind of terrain do you think the dark areas are?*** *(They are flat plains; long ago, they were thought to be oceans.)* ***What kind of terrain do you think the light areas are?*** *(They are mountainous areas or highlands.)* ***How are the craters formed?*** *(By impact of meteoroids.)*

Point out the "rays" which are straight lines radiating outward from a couple of the larger craters (notably, Copernicus).

The rays are lines of debris which formed right after the meteoroid impact when lunar surface material was splashed up and outward from the impact site.

In order to be able to locate appropriate sites for a lunar mission or building lunar settlements, we need to be able to use maps of the moon.

Hand out moon maps.

Note the directions north, east, south, and west on the moon maps. The map of the moon is drawn as seen through binoculars.

Each of you is going to find a particular "ocean," "sea," *or "bay."*

Assign a particular ocean, sea, or bay to groups of students. There are 12 oceans and seas, so you can divide your class into 12 groups. Help groups who need assistance. Those who finish quickly may practice finding other features that were not assigned to them. When each group has found its assigned feature, have the groups, one at a time, point out their feature to the rest of the class using the pointer.

For a more difficult challenge, assign each group a crater or mountain range. Again, have each group point out their feature to the whole class.

What type of terrain do you think would be best for a lunar settlement? Where on the moon would you build one?

Going Further: Rabbit in the Moon

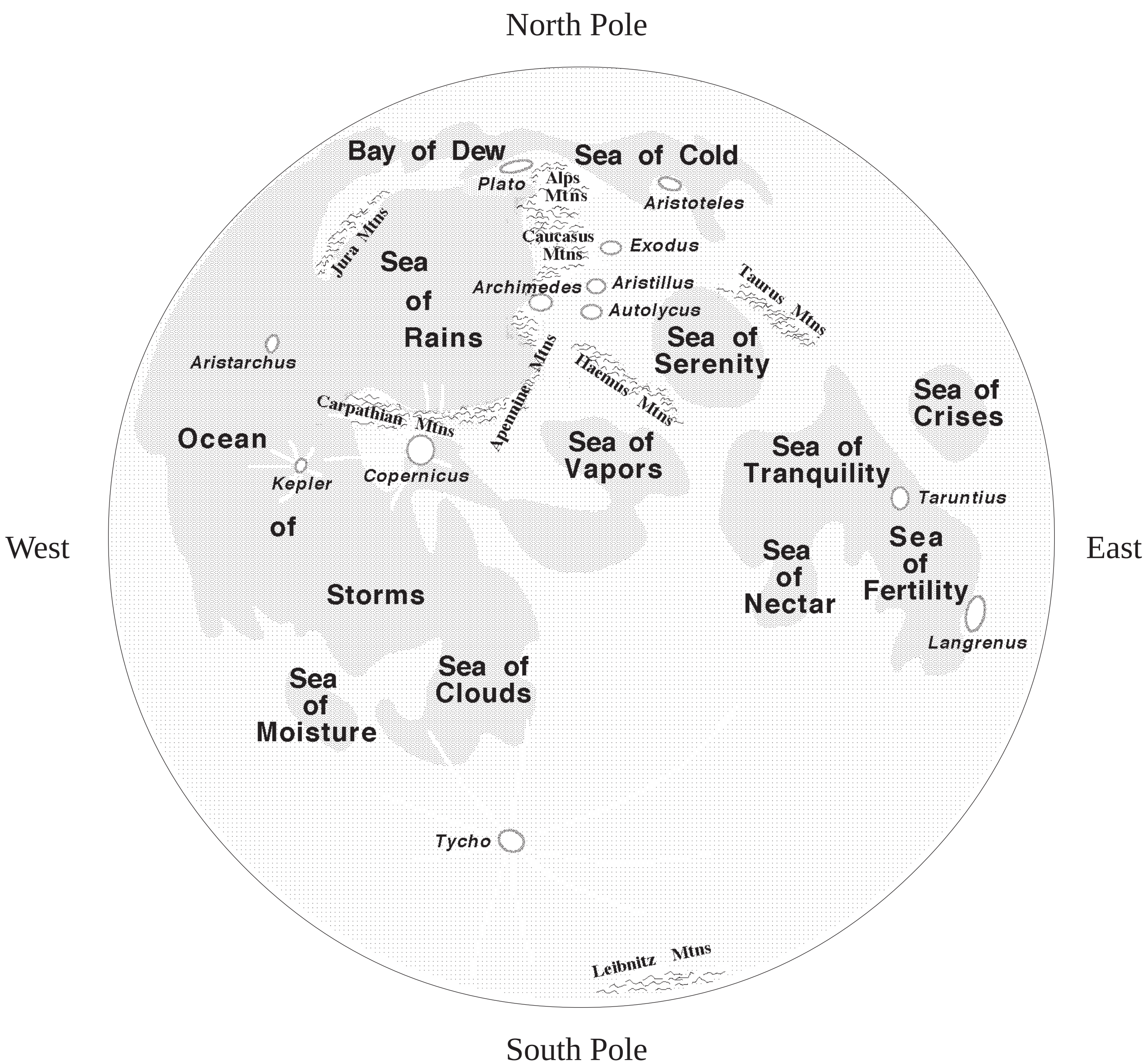
Show the moon slide again. Ask the students if they can see a rabbit. Ask where are the ears? Where is the tail? Tell the class that many Native American cultures associated the moon with a rabbit.

Many Native American cultures, the Japanese, and other cultures around the world visualize a "rabbit in the moon." Suggest that next time your students look at the real moon in the sky, they look for the rabbit—it's easy to see!

Optional: Duplicate the rabbit picture from PASS Volume 11, Astronomy of the Americas, page 23 or the cover, for each student. Tell them that the rabbit is a depiction of the rabbit in the moon found on pottery of the Mimbres tribe, who lived in what is now the Southwestern United States from the 9th to 12th centuries. (One piece of Mimbres pottery, which shows a burst of light below the leg of a rabbit, is believed to depict the supernova that created the Crab nebula in 1054!)

For younger students, a **"Faces in the Moon"** activity is very popular. Show a high contrast slide or poster of the Moon and ask the students if they can see a picture or face outlined by the light and dark areas. Have them draw the pictures or faces that they see. Explain that the light areas are actually mountains while the dark areas are low flat areas on the surface of the moon.

Moon Map



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