The Science Detectives

SETI Academy Planet Project

2009

SETI Institute

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Scope and Sequence
Life in the Universe Curriculum

This scope and sequence is designed to describe the topics presented and the skills practiced in the Life in the Universe series curriculum as they relate to factors in the Drake Equation:

$$(N) = R_{*} \bullet f_p \bullet n_e \bullet f_l \bullet f_i \bullet f_c \bullet L \bullet$$

In this equation, N is an estimate of the number of detectable civilizations in the Milky Way Galaxy that have developed the ability to communicate over interstellar distances. If a civilization has such ability, it most probably arose from the *desire* to communicate. It follows that such a civilization is probably trying to communicate, just as we are trying. This was the rationale for formulating the Drake Equation, and this is the rationale for the search for extraterrestrial life.

Factors in the Drake Equation	**Related Topics**
R_{*} = the number of new stars suitable for the origin and evolution of intelligent life that are formed in the Milky way Galaxy each year	*Astronomy, Chemistry, Mathematics*
f_p = the fraction of these stars that are formed with planetary systems	*Astronomy, Mathematics, Physics*
n_e = the average number of planets in each system that can sustain life	*Astronomy, Biology, Chemistry, Ecology, Physics*
f_l = the fraction of life-sustaining planets on which life actually begins	*Astronomy, Biology, Chemistry, Ecology, Geology, Meteorology*
f_i = the fraction of life-sustaining planets on which intelligent life evolves	*Anthropology, Biology, Geology, Meteorology, Paleontology*
f_c = the fraction of systems of intelligent creatures that develop the technological means and the will to communicate over interstellar distances	*Language Arts, Mathematics, Physics, Social Sciences*
L = the average lifetime of such civilizations in a detectable state	*Astronomy, History, Mathematics, Paleontology, Social Sciences*

Life in the Universe Series	**Topics**	**Skills**
Grades 3-4 *The Science Detectives*	• Art • Astronomy • Chemistry • Language Arts • Mathematics • Physics	• Attribute Recognition • Cooperative Learning • Mapping • Measurement • Problem Solving • Scientific Process
Grades 5-6 *The Evolution of a Planetary System*	• Art • Astronomy • Biology • Ecology • Geography • Geology • Language Arts • Mathematics • Meteorology • Social Sciences	• • Problem Solving • Cooperative Learning • Scientific Processes • Mapping • Measurement • Inductive Reasoning • Graphing
Grades 5-6 *How Might Life Evolve on Other Worlds?*	• Art • Biology • Chemistry • Ecology • Language Arts • Mathematics • Paleontology • Social Sciences	• Classification • Inductive Reasoning • Laboratory Techniques • Mapping • Microscope Use • Scientific Process • Cooperative Learning
Grades 5-6 *The Rise of Intelligence and Culture*	• Anthropology • Art • Biology • Ecology • Geography • Geology • Language Arts • Mathematics • Social Sciences • Zoology	• Cooperative Learning • Design • Graphing • Inductive Reasoning • Laboratory Technique • Microscope Use • Problem Solving • Scientific Process
Grades 7-8 *Life: Here? There? Elsewhere? The Search for Life on Venus and Mars*	• Art • Astronomy • Biology • Chemistry • Comparative Planetology • Ecology • Engineering • Language Arts • Mathematics • Physics • Zoology	• Cooperative Learning • Design • Graphing • Inductive Reasoning • Laboratory Techniques • Microscope Use • Problem Solving • Scientific Process
Grades 8-9 *Project Haystack: The Search for Life in the Galaxy*	• Anthropology • Art • Astronomy • Biology • Chemistry • Ecology • Geometry • Language Arts • Mathematics • Physics • Trigonometry • Zoology	• Cooperative Learning • Design • Graphing • Inductive Reasoning • Laboratory Technique • Microscope Use • Problem Solving • Scientific Process

Foreword

Carl Sagan, Cornell University
1934-1996

The possibility of life on other worlds is one of enormous fascination-and properly so. The fact that it's such a persistent and popular theme in books, television, motion pictures, and computer programs must tell us something. But extraterrestrial life has not yet been found–not in the real world, anyway. Through spacecraft to other planets and large radio telescopes to see if anyone is sending us a message, the human species is just beginning a serious search.

To understand the prospects, you need to understand something about the evolution of stars, the number and distribution of stars, whether other stars have planets, what planetary environments are like and which ones are congenial for life. Also required are an understanding of the chemistry of organic matter–the stuff of life, at least on this world; laboratory simulations of how organic molecules were made in the early history of Earth and on other worlds; and the chemistry of life on Earth and what it can tell us about the origins of life. Include as well the fossil record and the evolutionary process; how humans first evolved; and the events that led to our present technological civilization without which we'd have no chance at all of understanding and little chance of detecting extraterrestrial life. Every time I make such a list, I'm impressed about how many different sciences are relevant to the search for extraterrestrial life.

All of this implies that teaching about the search for extraterrestrial life is an excellent way of teaching science. There's a built-in interest, encouraged by the vast engine of the media, and there's a way to use the subject to approach virtually any scientific topic, especially many of the most fundamental ones. In 1966, the Soviet astrophysicist I.S.Shklovskii and I published a book called *Intelligent Life in the Universe,* which we thought of as an introduction to the subject for a general audience. What surprised me was how many college science courses found the book useful. Since then, there have been many books on the subject, but none really designed for school curricula below the college level.

The Life in the Universe series fills that need. I wish my children were being taught this curriculum in school. I enthusiastically recommend these course guides.

-----------------------------*Carl Sagan*

Preface

Are we alone in the Milky Way Galaxy? Many people think of science fiction stories or tabloid reports about UFO abductions when they hear about the search for intelligent life on other planets. The reality is that many scientists take seriously the possibility of life on other worlds, and some have undertaken the difficult task of finding out if we are the only intelligent beings in our galaxy. Astronomer Frank Drake proposed an equation to estimate the number of civilizations in our galaxy that produce radio waves. We might be able to detect such civilizations with our radio and optical telescopes. The Drake Equation estimates this number using the answers to the following sequence of questions:

1 How many stars are formed in the Milky Way Galaxy each year?
2. What fraction of stars are similar to our Sun?
3. What fraction of stars are formed with a planetary system?
4. What is the average number of planets in such a system?
5. What fraction of planets are like Earth, capable of sustaining life?
6. On what fraction of these planets does life actually begin?
7. On what fraction of life-sustaining planets does life evolve into intelligent civilizations?
8. What fraction of intelligent civilizations develops radio technology?
9. What is the average lifetime of a radio-transmitting civilization?

Scientists pursuing these questions work in many fields, including astronomy, geology, physics, chemistry, biology, anthropology, and the history of science. Several projects that "listen" for radio signals produced by civilizations on distant planets have been conducted. The most ambitious of these has been undertaken by the research staff at the SETI Institute (Search for Extraterrestrial Intelligence); at first in cooperation with NASA and later using privately donated funds. The SETI team is listening for intelligent signals. The interdisciplinary makeup and highly motivational nature of the search for intelligent life prompted the NSF (National Science Foundation) and NASA to support the development of the Life in the Universe Curriculum Project. Designed by curriculum developers working with teachers and NASA and SETI scientists, this program reflects the real-life methods of science: making observations, performing experiments, building models, conducting simulations, changing previous ideas on the basis of new data, and using imagination. It brings into the classroom the excitement of searching for life beyond Earth. This search is a unifying theme that can unleash the imagination of students through integrated lessons in the physical, life, space, and social sciences.

From the students' viewpoint, *The Science Detectives* is about solving a mystery. They are challenged to use clues to track an enterprising astronaut (Amelia Spacehart) through our solar system. She has borrowed a prototype spacecraft (the *Interplanetary Express)* to search for the source of an extraterrestrial radio signal. In the course of tracing Amelia's voyage, students learn about the solar system. Eventually, when Amelia transmits the alien signal to students, they have the first opportunity to decipher what it means.

Through a downloadable video created by the SETI education team especially for this unit, students receive clues from the maverick astronaut Amelia Spacehart, as well as vital information they will need to solve the mystery. The video is divided into segments that correspond with the missions in this guide. Together, the text and video segments direct students to solve the mystery through a series of hands-on activities in which they construct models of the planets in our solar system, experiment with states of matter, learn about lenses and magnification, and study the mechanisms of large scale measurements.

Classroom trials suggest that this unit requires about five weeks of activities, if you teach science every day. *The Science Detectives* activities can be counted not only as science activities, but as activities in writing and mathematics, because skills in these areas are emphasized alongside science skills.

The Science Detectives makes an ideal introduction to the *SETI Academy Planet Project,* a three-volume set of teacher's guides for fifth- and sixth-grade students. In the *SETI Academy Planet Project* students are invited to participate in a "SETI Academy" education and research program in which they act as scientists who are exploring Earth history for clues to the possible existence of life beyond our solar system.

The Evolution of a Planetary System addresses the evolution of stars and planets, *How Might Life Evolve on Other Worlds?* addresses the evolution of plant and animal life, and *The Rise of Intelligence and Culture* addresses intelligence, culture, technology, and communication.

With these guides, students learn what scientists have discovered about Earth and the evolution of life and humans. Then they apply what they have learned about the Earth to construct fictitious planets with life and culture that might have evolved elsewhere (Planets X, Y, and Z). The three *SETI Academy Planet Project* guides are best used in sequence but they can also be used as stand alone units.

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Introduction

Learning Objectives

Concepts

Through the activities in this guide, students will learn about and be able to apply concepts in the following areas:

- The order, relative sizes, and distances of the planets in our solar system.
- The composition and characteristics of the planets in our solar system.
- The orbits of the planets in our solar system.
- The natural satellites of the planets in our solar system.
- The existence of matter in at least three states: solid, liquid, and gas.
- Changing the state of matter by heating or cooling a substance.
- Characteristics of lenses and telescopes.
- Phases of the Moon.
- Differences between the inner rocky planets and outer gas giants.

Skills

The activities are also designed to help students develop the following abilities:

- Making metric measurements.
- Ordering and classifying.
- Surveying and charting.
- Finding the circumference of a sphere.
- Making and interpreting Venn attribute diagrams.
- Using deductive reasoning.
- Developing a hypothesis and modifying it when new information is available.
- Making scale models.
- Making measurements of scale models, and then converting scale sizes to actual sizes.
- Using charts.
- Using maps.
- Making scale drawings.
- Using simulations to explain phenomena.
- Projecting an image with a lens.
- Using a telescope.

Timeline and Planning Guide

The following time estimates are based on feedback from teachers during trial tests. They do not include time required to read this guide or shop for materials. Actual times will depend on the particular group of students and the time spent extending these activities. Some missions will need to be taught over several class periods, and some may take longer the first time they are presented. Each mission subdivision is designed to take one class period. Teachers may want to take two or even three class periods with some mission subdivisions.

Mission 1: The Space Chase Begins

Mission 1.1: Students watch a video segment that introduces them to the "space chase" involving the imaginary *Interplanetary Express* spacecraft. Students draw their concept of what our solar system looks like.
Mission 1.2: Students use a scale map of the solar system to plan flight paths for the *Interplanetary Express* spacecraft. Next, they calculate travel times using a scale measurement.

Mission 2: What a State We're In!

Mission 2.1: Students watch a video segment and then classify familiar substances as solid, liquid, or gas.
Mission 2.2: Students apply the concept of state of matter to large-scale planetary features in an experiment that simulates temperature conditions of other planets. Students observe and record changes in the states of matter of familiar substances.

Mission 3: What's My Planet?

Mission 3.1: Students watch a video segment. Student teams then use Amelia's clues and information from their Science Detectives Notebooks to identify which planet they will build.
Mission 3.2: Student teams create models of the solid center of their assigned planets.

Mission 4: How Big Is My Planet?

Mission 4.1: Students create scaled and unsealed drawings.
Mission 4.2: Students convert a scale measurement of their planet model to actual size.

Mission 5: "Seeing" Planet Attributes

Mission 5.1: Students watch a video segment and then learn to use Venn attribute diagrams. Students use these diagrams to group planets by attributes.
Mission 5.2: Student teams add liquid layers to their planet models. Students measure the new circumference of their planet models, using the scale factor to find the circumferences of the actual planets.

Mission 6: Making the Most and Least of Things

Mission 6.1: Students watch a video segment and then group planets in a series based on particular attributes.
Mission 6.2: Student teams add gas layers to their planet models. Students measure the new circumferences of their planet models, using the scale factor to find the circumferences of the actual planets.

Mission 7: Adventures with Telescopes

Mission 7.1: Students watch a video segment and then explore the properties of lenses.
Mission 7.2: Students construct a telescope.

Mission 8: Observing the Planets!

Mission 8.1: Students observe their model planets with their telescopes. They determine that the distance and the size of a planet affect how visible it is from Earth. Students then watch a video segment and discuss Amelia's next clue. Students are encouraged to use their telescopes to find planets in the real sky.

Mission 9: Cosmic Wheels

Mission 9.1: Students use a scale model to compare orbit times of the planets with a Cosmic Wheel (trundle wheel). Students then watch a video segment and discuss Amelia's next clue.

Mission 10: Moon Phases

Mission 10.1: Students use a model of the phases of our Moon, finding that they are caused by the relative positions of the Moon, the Sun, and Earth. Students also watch a video segment and discuss Amelia's next clue.

Mission 11: Planets and Moons

Mission 11.1: Students create scale models of moons for their planet models.
Mission 11.2: Students watch a video segment and then decode a message of extraterrestrial origin. Students each receive a Science Detective Certificate.

Preparation

The Science Detectives Video

A video is provided with this teacher's guide. It provides a fictional story line that ties together all the missions. The first video segment introduces the challenge to track Amelia Spacehart's borrowed spacecraft–and reveals the first clue. Dr. Orbit (a fictional NASA scientist) and Buzz Sawyer (a fictional NASA assistant administrator), provide helpful information and humor. Each subsequent video segment begins with a confirmation of what students discovered about Amelia's previous clue, adds new information, and (in most cases) a new clue.

Most of the video segments are intended to be shown just before one of the hands-on missions, though some video segments are intended for use just after a mission. Mission 4 does not have a video segment. Information on when to show each segment is given in this guide. A script for each video segment is included at the end of the appropriate mission.
The following are some tips for using the video:

- Introduce the video as a lighthearted, humorous drama, rather than a strict, professional, totally serious documentary.
- The video segments are short enough that each can be shown twice before beginning any activities, the first time for overall content and the second time for close attention to details and clues. (The second time through, you will want to pause the video so you're your students can pick through the information on the tape for clues.)
- Student teams may find it helpful to have a "recorder of the day" take notes during the video segment.

Assessment

The projects in this guide are designed to help teachers assess students' learning and understanding. The planets that students create, along with the worksheets they complete independently, will reflect their grasp of the concepts and skills presented in the lessons, experiments, and projects. Teachers can use the Science Detectives Notebooks and the students' projects as a portfolio-based assessment.

Planning

Classroom trials suggest that this guide requires about four to five weeks of activities (about 22 days), if science is taught every day.

Expanding or Compressing the Unit

There are a variety of activities that can add richness and interest to this unit, such as trips to museums, observatories, or planetariums. Concepts and topics presented in the missions can be expanded upon by providing related activities; there are ideas in the "Going Further" section at the end of each mission.

It is difficult to delete any of the missions in this unit because it is an integrated package, united by the video, and by the coverage of the solar system. However, some of the lab activities may be cut if the background or previous experience of students is insufficient.

Student Logbooks and Lesson Handouts

To help reduce the preparation time for each mission, arrange to have a parent or volunteer photocopy, collate, and file the masters for the Science Detectives Notebook and other activity worksheets. These are found at the end of each mission. Please note that Science Detectives Notebook pages are a part of the entire logbook that is assembled.

Nine teams (one for each planet plus Pluto, a dwarf planet) of two to four students each should share a Science Detectives Notebook. Assemble one notebook for each of the nine teams before the first video segment is shown. Additionally, most lessons include a variety of student data sheets that you will need to copy for each student. Students will complete these sheets individually rather than as a team. You may wish to copy these all at once at the beginning of the unit. It is also possible to give each team a Notebook and have them copy the assignments from projected images of the Notebook sheets. Many of the student pages can be made this way.

Helpful Procedures

Parent or Aide Support

This guide is primarily hands-on, using experiments and art projects to help students learn the material. Parent helpers or aides would be very helpful. You may also wish to enlist the support of a class of older students!

Prerequisite Concepts and Skills

During this unit, students will use the following concepts and skills.

1. Make measurements using meter sticks.
2. Construct and interpret Venn diagrams.
3. Analyze bar graphs.

Cooperative Learning

This guide is designed to be used by nine teams (one for each planet plus Pluto, a dwarf planet) of two to four students each. The most successful way of teaming is to use cooperative learning groups, where each member is assigned a specific task (*e.g.*, facilitator, record keeper, supply person, *etc*.). These tasks should be rotated among team members each time they meet. It has been found that the most successful team groupings are those that are balanced both academically and socially. Teams should be given the opportunity to share regularly their observations, problems, or questions. Throughout, as students acquire new knowledge, oral team reports to the rest of the class are strongly encouraged.

Preparation of Special Materials

Building Model Planets

The majority of the necessary supplies (newspaper, paints, brushes, and clay) should be readily available in any elementary school classroom. The remainder of the supplies (wheat paste, bubble wrap, cotton batting, and paper towels) are available from local fabric, grocery, hardware, or art stores. See the appendixes for a materials list. Building model planets is fun, but messy.

Arrange for parents or classroom aides to help out, especially for the Jupiter and Saturn teams. These two planets take the longest to build and can be worked on by the teams during their spare time. Set aside a specific area for planet building and keep it stocked with appropriate supplies.

Centers Versus Kits

The planet-building and lens activities are designed to be set up as individual "centers" of activity. However, if you have space limitations in your classroom, put the materials for these activities into boxes to form kits, and circulate the boxes from team to team.

Special Supplies: Dry Ice and Telescopes

Dry ice is necessary for mission 2. See the appendixes for details. To complete mission 6, you will need to purchase telescope kits or create your own from paper-towel tubes and lenses. If you choose the second option, ask your students to start collecting and bringing in paper-towel tubes at the beginning of this unit. See the appendixes for information about ordering telescope kits.

Class Charts

Class charts are an excellent way to record video clues and student responses. The teacher can record information on sheets of butcher paper or poster board, which can be displayed around the classroom for student reference. Suggestions for specific charts are included in this guide.

Display of Student Work

The class will create a set of model planets that need to be suspended. Jupiter and Saturn will present special problems, as they are quite large. Arrange for space in a multipurpose room or hallway to accommodate these planets, or suspend them like piñatas so that they can be lowered down to student height during planet-building sessions.

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Mission 1
The Space Chase Begins

On Your Mark ... Get Set ... Go!

Overview

In mission 1.1, students watch the video introduction, meeting Amelia Spacehart and the supporting characters in the "space chase," Dr. Orbit and Buzz Sawyer. Amelia believes that she has received a radio signal from intelligent beings, originating from somewhere in our solar system. She borrows the *Interplanetary Express,* a high-tech spacecraft, to find the source of the transmission. Students draw their concept of what our solar system looks like. In mission 1.2, students calculate possible flight plans and guess what route Amelia might take as she searches for the ETI (extraterrestrial intelligence) signal's point of origin.

Concepts

- Students learn the positions of the planets in relation to one another and the relative distances between them.

Skills

- Using a scale map of the solar system to plan flight paths through space.
- Calculating travel times based on a map scale.

Mission 1.1

Materials

For the Class

- *The Science Detectives* video, "Lesson 1"
- Computer, and projector or monitor
- 2 sheets of chart paper
- Masking tape

For Each Team

- Science Detectives Notebook

For Each Student

- "What's Out There?" worksheet
- Pencil

Getting Ready

One or More Days Before Class

1. Divide the class into Planet Investigation Teams (teams of two to four students each). Keep a record of the teams on the "Planet Investigation Teams Roster" sheet (page 33). Many of the activities in this unit require reading, so each team should have at least one strong reader. Also, every mission requires writing, both in the Science Detectives Notebook and on activity worksheets, so each team should have at least one student with good writing skills. For more information on organizing cooperative teams, see the "Preparation" section.

   Later in the unit, the teams will build planet models. The larger and more complex models (Team 3—Neptune, Team 5—Jupiter, Team 6—Uranus, and Team 8—Saturn) may require teams with more students or students who work more effectively in teams. Do not tell students which planet has been assigned to them! Teams should be designated only by numbers 1-9 at this time. The "Planet Investigation Team Roster" sheet may be posted in an area visible to students after mission 3. The remaining teams are: Team 1—Pluto, Team 2—Mars, Team 4—Venus, Team 7—Earth, and Team 9—Mercury.

2. Copy and collate a Science Detectives Notebook for each team. For more information on organizing the notebooks see the "Preparation" section. Copy the "What's Out There?" worksheet for each student.

3. Cut one very large piece of butcher paper for a class chart. Hang the chart at the front of the room. This chart will be used throughout the unit to record clues from the video segments. Write "Clues from video" at the top of the paper. Write the subtitle "First Transmission" below that. If you have room, leave about three feet of space below the titles and then draw the chart from table 1.1, or put it on a separate piece of chart paper.

Table 1.1—Class Survey Chart.

Class Survey Chart: Where Will Amelia Go Next?										
Teams	Sun	Mercury	Venus	Earth	Mars	Jupiter	Saturn	Uranus	Neptune	Pluto
1										
2										
3										
4										
5										
6										
7										
8										
9										

This chart will be used to record team guesses about Amelia's route in her search for the source of the ETI signal.

Just Before the Lesson

1. Set up the computer, and monitor or projector. Screen the video to "Lesson 1."

Classroom Action

1. **Lecture.** Introduce the unit. Explain to the students that they will be doing an investigation that involves an exploration of our solar system. This exploration will begin on Earth and will take them out into space (in their imaginations)!

2. **Activity.** Distribute the pre-assessment student worksheet "What's Out There?" (page 34) to each student. Ask students to draw on the first side of the page what they think they might see if they were out in space. They should draw Earth and anything else they might see. If they can, they should draw themselves, their place in the "big picture." This exercise is an opportunity to see what ideas students already have about the solar system. Allow students 10 minutes to make their drawings. Collect the worksheets.

3. **Video.** Tell students that they will be watching the first part of a story about a space mystery. Show the video segment "Lesson 1." As students watch the video segment, they should look and listen for information that might help them solve the mystery. Show the video segment twice, if desired.

4. **Discussion.** Discuss the information presented in the video segment. Instruct students to define the problem scenario:

   > Amelia Spacehart has borrowed the *Interplanetary Express* to look for the source of an ETI transmission. She believes that the signal came from intelligent beings somewhere in our solar system.

   Be sure students understand the challenge for the unit:

   > NASA wants them to help track Amelia and the *Interplanetary Express.* Students will be using clues that Amelia gives them to guess which planet she is searching for as the source of the ETI transmission.

   Record information that students suggest as clues on the "Clues from video" class chart under the heading "First Transmission." Give student teams time to record their groups' ideas in their Notebooks (on the page that looks like it is from a spiral-bound notebook). Conduct a discussion with students about how fast familiar objects (cars, planets, space shuttles, *etc*.) can go, and how long it would take to reach Jupiter at these speeds. Compare them with the speeds claimed by the *Interplanetary Express.* Could anything that exists today really go that fast? Ask students if they think this story takes place in the past, present, or future. It is important that students realize that, with today's technology, it is not possible to race around the solar system as fast or in the way that Amelia Spacehart does in the video. Table 1.2 may be useful for this discussion.

Table 1.2—Comparative Speeds.

Vehicle	Speed	Time to Reach Jupiter (from the Sun)
Person Walking	5 km/hr	18,000 years
Car	85 km/hr	1,044 years
High-Speed Train	160 km/hr	555 years
Airplane	800 km/hr	111 years
Space Shuttle	27,000 km/hr	3.3 years

Video Clues: Lesson 1, January 1
(Travel time = 1 day)

- It's January 1.
- Amelia has 140 days worth of fuel.
- Amelia has 14 months worth of food and water.
- Dr. Orbit's hunch: Amelia probably has just enough fuel to get to Jupiter and back.
- Amelia wants to explore the planets in our solar system.

Remind students of Dr. Orbit's hunch about Amelia's travels: She only has enough fuel to make it to Jupiter and back.

Explain, or have students explain, the importance of hunches in scientific study and detective work. Scientists and detectives are alike in that they both make hunches *(hypotheses,* not theories) to explain the way things might work or why certain events happened. Once scientists have some hunches, they work to prove or disprove them scientifically. (Once a scientific hypothesis has been established, it becomes a scientific *theory.)* The goal is to find the best hunch that explains why something works or why an event happened. If nothing yields a good explanation, scientists must formulate and test new hypotheses.

5. **Activity.** Tell students their job is to figure out where Amelia is going. They will need the ability to make hunches. They will keep track of their hunches in a Science Detectives Notebook. Have students team up, and hand out the Science Detectives Notebooks.

   Allow time to record their names on the cover. Have a recorder from each team write down information from the class discussion in the team's Science Detectives Notebook.

Mission 1.2

Materials

For the Class

- Transparent tape
- Scissors
- Metric measuring tapes, one per team
- Felt tip markers

For Each Team

- Science Detectives Notebook
- "Where Can Amelia Go?" Logbook sheet
- "Dear Dr. Orbit" Logbook sheet
- Solar system map (page 37) assembly:
- 9 straight pins with round heads (or push pins)
- 150 cm of heavy thread
- 30-by-87-cm piece of corrugated cardboard
- Solar system map pages (4)
- One metric measuring tape

For Each Student

- Pencil

Getting Ready

One or More Days Before Class

1. Copy the Logbook sheets "Where Can Amelia Go?" and "Dear Dr. Orbit" for each team's Science Detectives Notebook.

2. Solar System Maps: Method 1: Make nine copies of each solar system map using the masters provided. Each set of pages should be taped together, lined up along their curves, in numerical order, using transparent tape, as shown in figure 1.1. Laminate the maps if possible. Cut the cardboard sheets to size (30 cm x 87 cm) and tape the maps to the cardboard. Place the straight pins on the map X's that mark the planet positions, as shown in figure 1.1.

3. Solar System Maps: Method 2. The map is made on a piece of paper 11 inches by (at least) 32 inches. This can be cut from tag board or butcher paper, or made by taping together smaller sheets of paper. If using paper, you may wish to laminate the maps, which can be reused. Make a compass from a tack, string and fine-tipped marker. First, locate the Sun at 9.5 cm from the left end of the paper, and 14.9 cm from the top of the paper. (This matches figure 1.3.) The Sun is the center point for your "compass." Draw the solar system to match the measurements in "Solar System Map Measurements." Using a meter stick or tape, measure from the Sun to the "radius of orbit" and mark for each planet. Then, using your

tack and string compass, draw the solar system. Mark the planet locations like they are shown in Figures 1.3 through Figure 1.6.

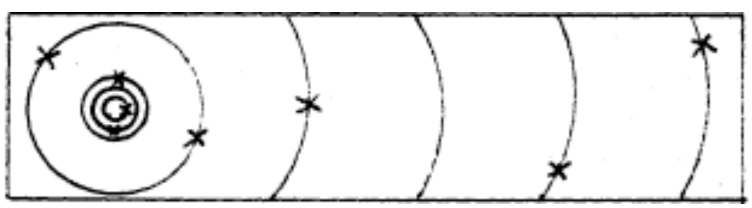
Solar System Map Measurements:

Planet	Radius of orbit	Drawing	Mark location at
Mercury	.6 cm	complete circle	As in figure 1.3
Venus	1.1 cm	complete circle	As in figure 1.3
Earth	1.6 cm	complete circle	As in figure 1.3
Mars	2.5 cm	complete circle	As in figure 1.3
Jupiter	8.8 cm	complete circle	As in figure 1.3
Saturn	15.8 cm	arc — partial circle	As in figure 1.4
Uranus	31.7 cm	arc — partial circle	As in figure 1.5
Neptune	50.3 cm	arc — partial circle	As in figure 1.6
Pluto, the dwarf planet	67.3 cm	arc — partial circle	As in figure 1.6

Teacher's Note: Do not reduce or enlarge the solar system map as a change in scale will make all measurements in cm incorrect. Before photocopying the map sheets remove the page numbers and headers

The finished Solar System Maps look like this:

Figure 1.1—So1ar System Map.



4. On the whiteboard, draw the flight record shown in table 1.3. Students have this same flight record on their activity sheets.

Table 1.3—Flight Record.

Flight	Planet 1	Planet 2	Planet 3	Planet 4	Planet 5	Planet 6	Planet 7	Planet 8	Earth?
1	Earth								Yes
Days	0								No

Any fuel left? _____ cm = days　　　　　How many planets did you reach? _____

Classroom Action

1. **Lecture.** Remind students that Buzz Sawyer thinks that Amelia can travel for a total of 140 days on the fuel that she has. Students will use a scale map of the solar system to determine the most effective flight plan that Amelia can take in her search for the source of the ETI transmission. At the conclusion of this activity, student teams will vote on which planet they think is most likely to be Amelia's first destination.

2. **Demonstration.** Demonstrate how students should use the solar system maps. The thread represents the total number of days that Amelia can travel (scale: 1 cm = 1 day's travel). If necessary, explain the concept of a scale model.

   The thread is attached to the Earth pin because that's where Amelia started her journey. From Earth, the thread can be stretched from one planet to another. A flight must end up back on Earth to be considered a good plan, but all attempted flights should be recorded. The student can anchor the thread to a planet by looping it around the pin once (this is similar to an orbit around the planet). Students should use the model to discover which planets are within Amelia's reach.

   Allow students 20-30 minutes to calculate possible flight plans. Show students how to record a flight plan. An example flight might be to visit some of the inner planets (Venus, Mercury, Mars, and then back to Earth). This flight plan would be recorded as in table 1.4.

   The number of days to travel from one planet to another can be determined by measuring the centimeters of thread stretched between them.

Teacher's Note: With a good flight plan, Amelia should be able to visit all the planets except Pluto. If she chooses to go to Pluto, she has enough fuel to go directly there and then directly back to Earth.

Table 1.4—Flight Plans.

Flight	Planet 1	Planet 2	Planet 3	Planet 4	Planet 5	Planet 6	Planet 7	Planet 8	Earth?
1	Earth	Venus	Mercury	Mars	Earth				Yes
Days	0	2.5	1	3	3				No

Any fuel left? 132.5 cm = days How many planets did you reach? 4

   Students should see that there is a lot of fuel (thread) left over after this example flight. They should record the leftover fuel by measuring the remaining thread with the meter stick and recording the number of centimeters. They can record the number of days of travel between the planets by measuring the distance between the pin heads that represent them on the map. Have teams do at least three flight plans.

3. **Activity.** Have Planet Investigation Teams do this activity with the solar system maps, and then complete their activity worksheet "Where Can Amelia Go?"

   Students may have difficulty fitting the planet names in the space provided on the activity sheet. Write an abbreviation key on the chalkboard: Me = Mercury, V = Venus, E = Earth, Ma = Mars, J = Jupiter, S = Saturn, U = Uranus, N = Neptune, and P = Pluto. Use these abbreviations in place of the full names of the planets.

4. Teams should try to agree on a single "route hunch" for their team. This hunch should be included in a letter to Dr. Orbit. Have them draft a letter on scratch paper and then write it on

their "Dear Dr. Orbit" activity sheet. Collect the team letters. Also collect the measuring tapes.

Closure

1. **Discussion.** Take a class survey of flight plan predictions. The teams should say where they think Amelia will go first, second, third, and so on. Record the survey information on the class chart "Where Will Amelia Go Next?" What planet do most students think Amelia will visit first? Have any teams predicted the same flight plan? Results from this survey could also be used to make a graph of which planets the class thinks will be visited and in what order, as in table 1.5.

   Ask students if they can really know where Amelia is going with the information they were given. *(Not really, they are only guessing at this point.)* What does the class need to get a better idea of what Amelia is up to? *(More information.)* Let's hope Amelia sends another video transmission with more clues!

   Was Dr. Orbit's hunch correct? *(No!)* Discuss the process of forming hypotheses, testing them, then revising your original hypotheses.

Table 1.5—Class Survey Chart.

Class Survey Chart: Where Will Amelia Go Next?										
Teams	Sun	Mercury	Venus	Earth	Mars	Jupiter	Saturn	Uranus	Neptune	Pluto
1										
2										
3				6th	5th	4th	3rd	1st	2nd	
4										
5										
6										
7										
8										
9										

Going Further

Activity: How Much Fuel?

Ask students what would be different if Amelia had taken off in a hurry, with only one-half tank of fuel. Have students cut their solar system map threads in half and try to chart a new flight plan.

Discussion: Reality and Fantasy

Could the scenario in the video really happen? Students raised on science fiction movies and programs may not understand the limitations of real space travel. Have students discuss whether spaceships can really go as fast as Amelia's.

SETI INSTITUTE

Mission 1
The Space Chase Begins

Script for First Transmission

Synopsis: Lesson 1, January 1
(Travel time =1 day)

- Amelia is responding to a message from an ETI signal that seems to have originated from within our solar system.
- Amelia has 140 days of fuel.
- Amelia has 14 months of food and water.
- Dr. Orbit's hunch: Amelia probably has just enough fuel to get to Jupiter and back.
- Buzz asks students to help track Amelia.

BUZZ SAWYER
[worried, on the phone] "Yes, Mr. Administrator. Yes. Of course it'll be at the Air Show. Yes, Sir. Well, we always get it washed first. Waxed? No I don't think we ever got it waxed."

[Hangs up.] "I'll be blasted." *[Turns to camera.]* "The *Interstellar Express,* it's a special prototype spaceship, has been stolen from its hangar here in California." *[Shot of exterior of hangar, with missing Interplanetary Express. Shot of Sawyer walking into scene. Sawyer looks around.]* "Where's the Express? I know I left it here. Hey, a note."
[He picks up an envelope where the Express used to be.] "Well, I'll be blasted!"

"We know from this note that the perpetrator is Amelia Spacehart. Everyone knows Spacehart. She's America's favorite astronaut, and a radio astronomer to boot."

"Amelia says she's on a mission to track down a message from an ETI. That's an extraterrestrial intelligence."

[snap, crackle EFX] "Sounds like something's on the interphone. I'll be blasted. I don't think we paid last month's bill."

AMELIA SPACEHART
Date on screen: January 1
"Sorry, Sawyer, but you wouldn't take me seriously, so I had to take the *Express* for myself. You see, I've been receiving this extraterrestrial radio signal, and it's originating from within our solar system. I'd like to take a look around, visit a few planets. Now if I can find out where it's

coming from, I can communicate with them. Don't worry about your spaceship. I'll bring it back when I'm done."

BUZZ SAWYER
"I'll be blasted! Amelia took off this morning with a full tank of fuel. A full tank. Now that means she can travel … up to 12 billion kilometers. Now her average speed is 1,000 kilometers per second. So, averaging the fuel and the speed that ... she can be up there for 140 days! Lt. Onzin, give me that inflatable, spheroidal, terrestrial, cartographic representation, will yah?— The globe!"

Uses globe to show how long it would take to get from San Francisco to New York, China, and the Moon at a rate of 1,000 km per second.

"Now, let's see, 1,000 kilometers per second, that means she can go from California to New York in four and a half seconds, California to China in six seconds, the Earth to the Moon in six minutes. "We can't track her because she's turned off the auto-beacon and the computer link! We can't monitor her life support systems, and we can't send refresh signals to her onboard computer! Now this could be serious if any of the *Interplanetary Express'* computer modules should fail. Amelia has enough grub and water for 14 months, more than enough for most travel needs–but we don't know what she has in mind!"

[worried] "And the Fleaburg Air Show's coming up pretty soon."

"Look, Space Detectives, we need your help. Can you help us keep track of Amelia?"

[Points to map of the solar system.] "She's out there. The solar system. A lot of space, a central star, a few planets: Jupiter, Saturn. A sprinkling of asteroids. Trace Amelia's travels and try to figure out where she's going before she gets there."

"We need some more information. Fortunately, Dr. Orbit–a former child genius who's now an adult genius–is with us. Dr. Orbit, you excellent role model, you!"

DR. ORBIT *[also in lab]*
[excited] "Wooh! She's really done it! Amelia has taken off with the *Interplanetary Express.* Unlike that bureaucrat over there, I'm not so worried about this. I think it's very fascinating and I hope we can learn a thing or two about the solar system from it."

"Now Amelia is checking out a signal that she thinks is coming from an extraterrestrial civilization. Let's have a look at this chart to see where she may be searching."

Picture of solar system, viewed from above. Dr. Orbit gives a brief lecture to familiarize students with the planets. Groups and names rocky planets, groups and names gas giants, labels Pluto / Charon as a double planet system.

"Here in the center of our solar system is the Sun. Close to it are four small, rocky planets, all going around it in the same direction: Mercury, Venus, the Earth, and Mars. Farther away from the Sun are four giant planets called the gas giants: Jupiter, Saturn, Uranus, and Neptune. Finally, the last planet is the dwarf planet Pluto, a little oddball double planet with a very large moon named Charon.

"She's out there somewhere. My hunch is she only has enough fuel to make it to Jupiter and back. Good luck, Science Detectives!" *[to himself]* "Fascinating!"

BUZZ SAWYER
"A few billion dollars' worth of hi-tech hardware ... and she takes it on a joy ride. I'll be blasted."

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The Space Chase Begins

Planet Investigation Team Roster

Use this page to record student teams. Include one strong reader and one student with good writing skills on each team. Keep the planet names a secret until after mission 3.

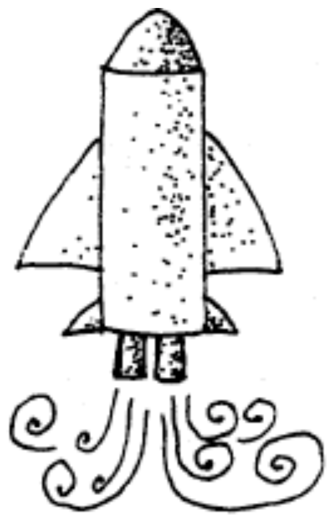
Table 1.6-Team Roster.

Team 1 – Dwarf Planet Pluto	**Team 6 – Uranus**
Team 2 – Mars	**Team 7 – Earth**
Team 3 – Neptune	**Team 8 – Saturn**
Team 4 – Venus	**Team 9 – Mercury**
Team 5 – Jupiter	

What's Out There?

Name: ____________________________________ Date: ______________________

Figure 1.2-NASA Spacecraft.



You have been invited to join a special NASA mission to explore our solar system. You have a window seat. As the spaceship takes off, you can see the people and buildings getting smaller and smaller. Soon, the spaceship has traveled so far that Earth looks like a tiny blue ball. As you travel farther, you can see the other objects in our solar system. Take a good look! In the space below, draw what you see.

Mission 1
The Space Chase Begins

Where Can Amelia Go?

Amelia has 140 days worth of fuel in the *Interplanetary Express,* the spaceship she has borrowed from NASA to search for the ETI signal. Use your scale solar system map to measure the days of travel between planets. How can Amelia Spacehart search our solar system so that she visits as many planets as possible without running out of fuel before she returns home to Earth? The thread represents 140 days of travel (1 cm = distance traveled in 1 day). Try at least three flight plans. Record them below.

Table 1.7-Student Flight Record.

Flight No.	Planet 1	Planet 2	Planet 3	Planet 4	Planet 5	Planet 6	Planet 7	Planet 8	Return To Earth?
									Yes
Days									No

Flight No.	Planet 1	Planet 2	Planet 3	Planet 4	Planet 5	Planet 6	Planet 7	Planet 8	Return To Earth?
									Yes
Days									No

Flight No.	Planet 1	Planet 2	Planet 3	Planet 4	Planet 5	Planet 6	Planet 7	Planet 8	Return To Earth?
									Yes
Days									No

Flight No.	Planet 1	Planet 2	Planet 3	Planet 4	Planet 5	Planet 6	Planet 7	Planet 8	Return To Earth?
									Yes
Days									No

Mission 1

Logbook

The Space Chase Begins

Dear Dr. Orbit,

Here is *our* hunch:

Table 1.8-Our Hunch.

Flight No.	Planet 1	Planet 2	Planet 3	Planet 4	Planet 5	Planet 6	Planet 7	Planet 8	Return To Earth?
									Yes
Days									No

Figure 1.3-Solar System Map

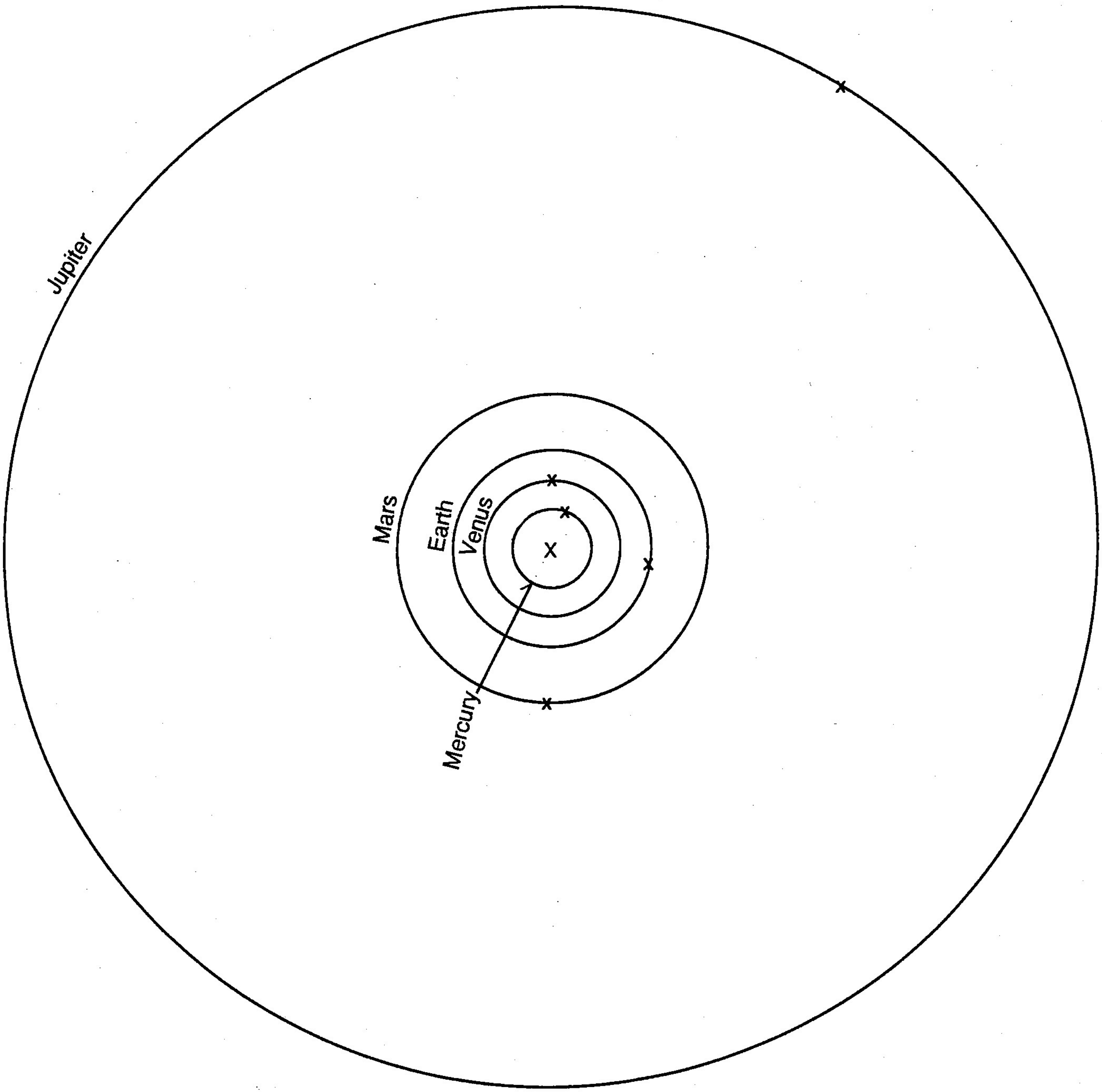


Figure 1.4-Solar System Map

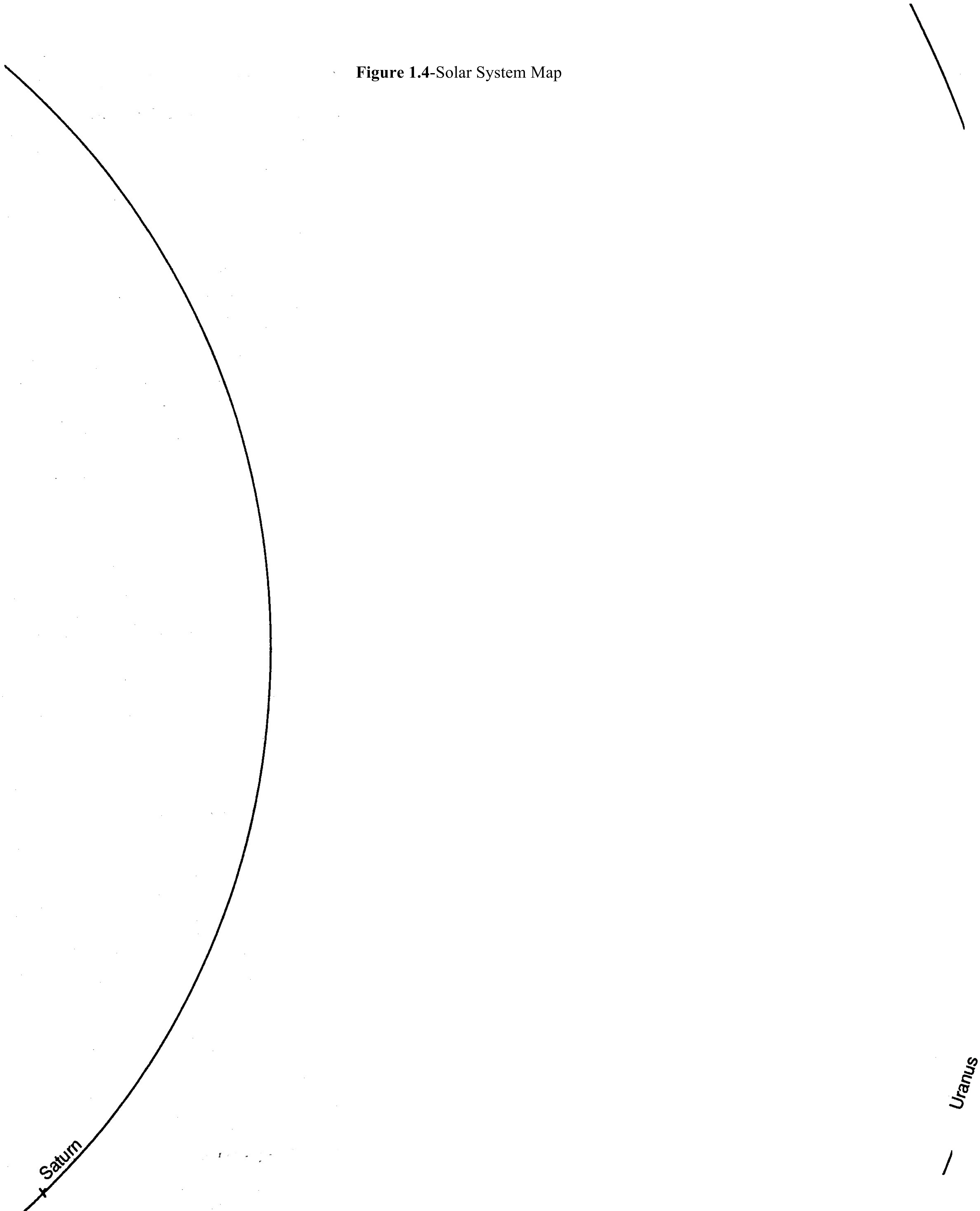
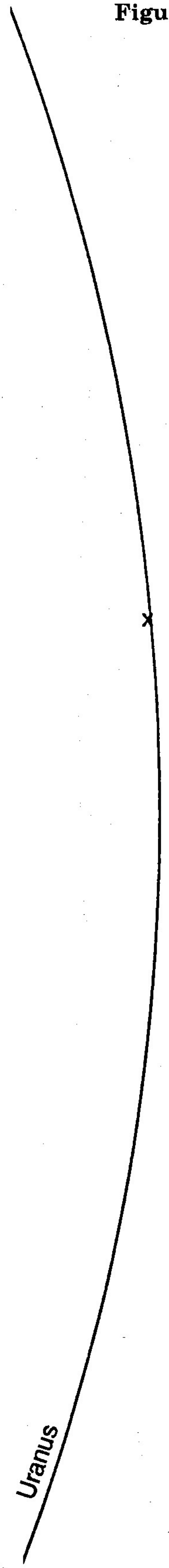


Figure 1

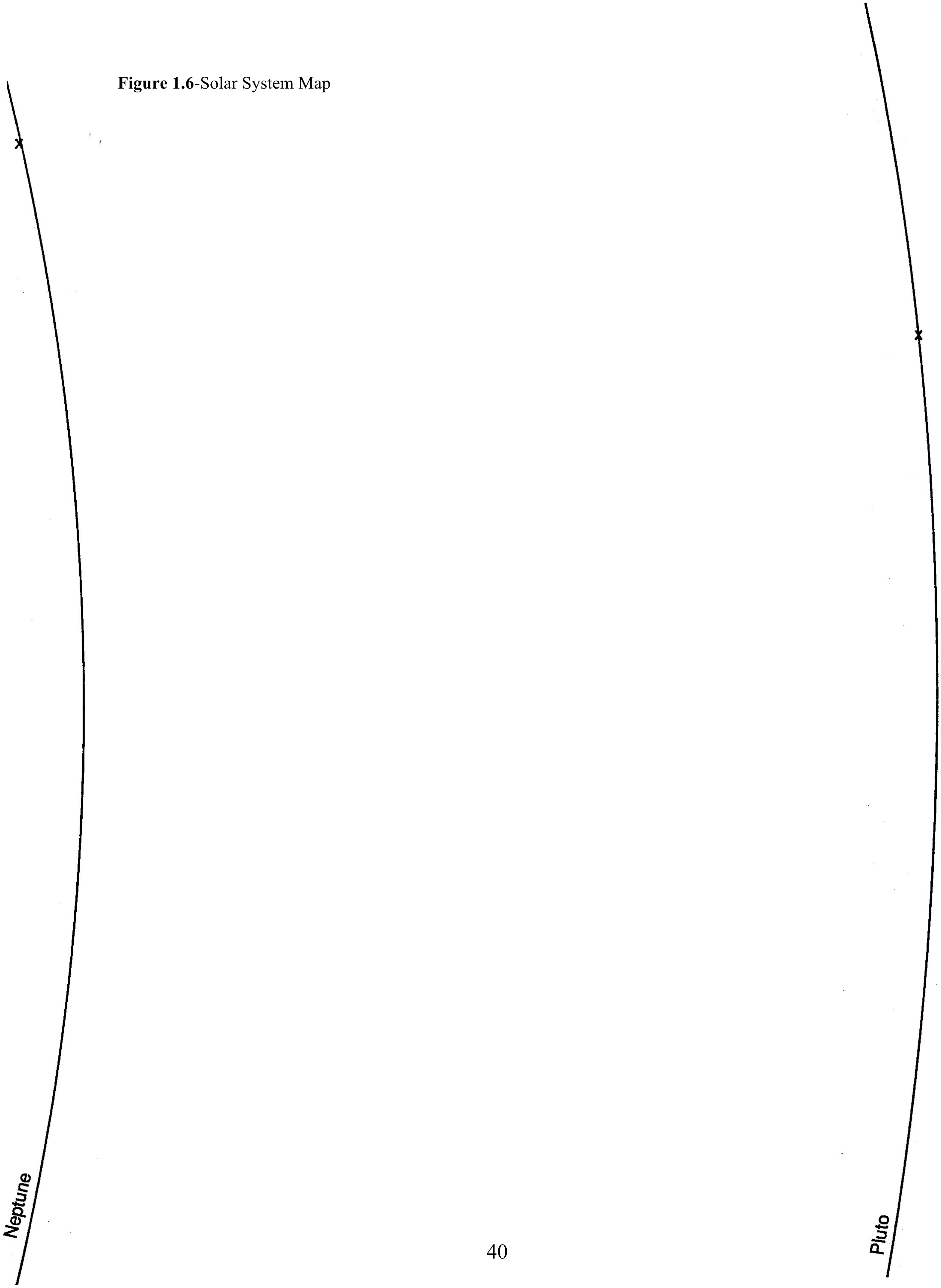
Figure 1.5-Solar System Map



Solar System Map

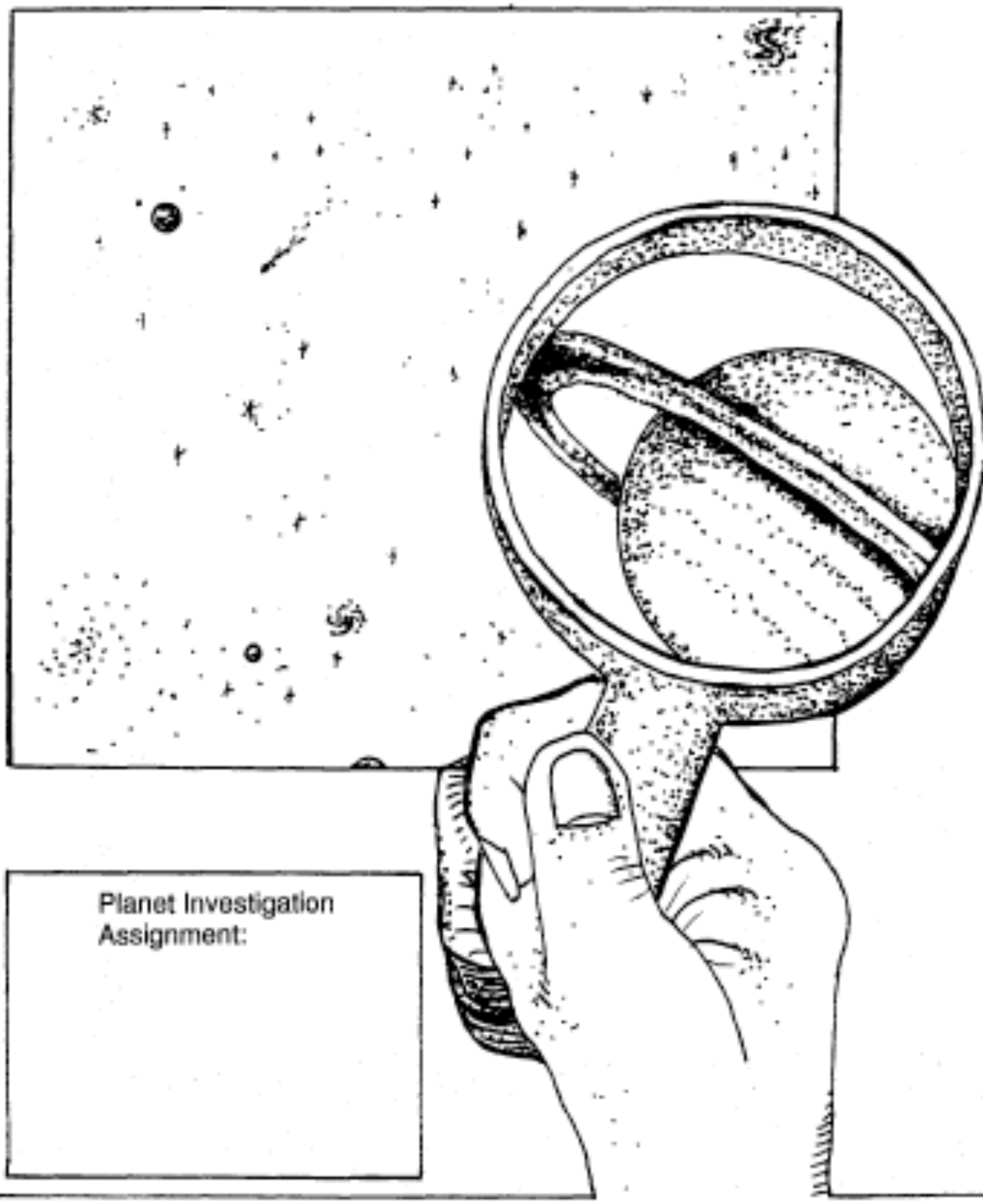
- ☞ Distances are to scale: 1 cm = 86,400,000 km (the distance the *Interplanetary Express* can travel in one 24-hour day).
- ☞ X shows where the planet is located in its orbit. (At this scale, the planets would be invisible!)

Figure 1.6-Solar System Map



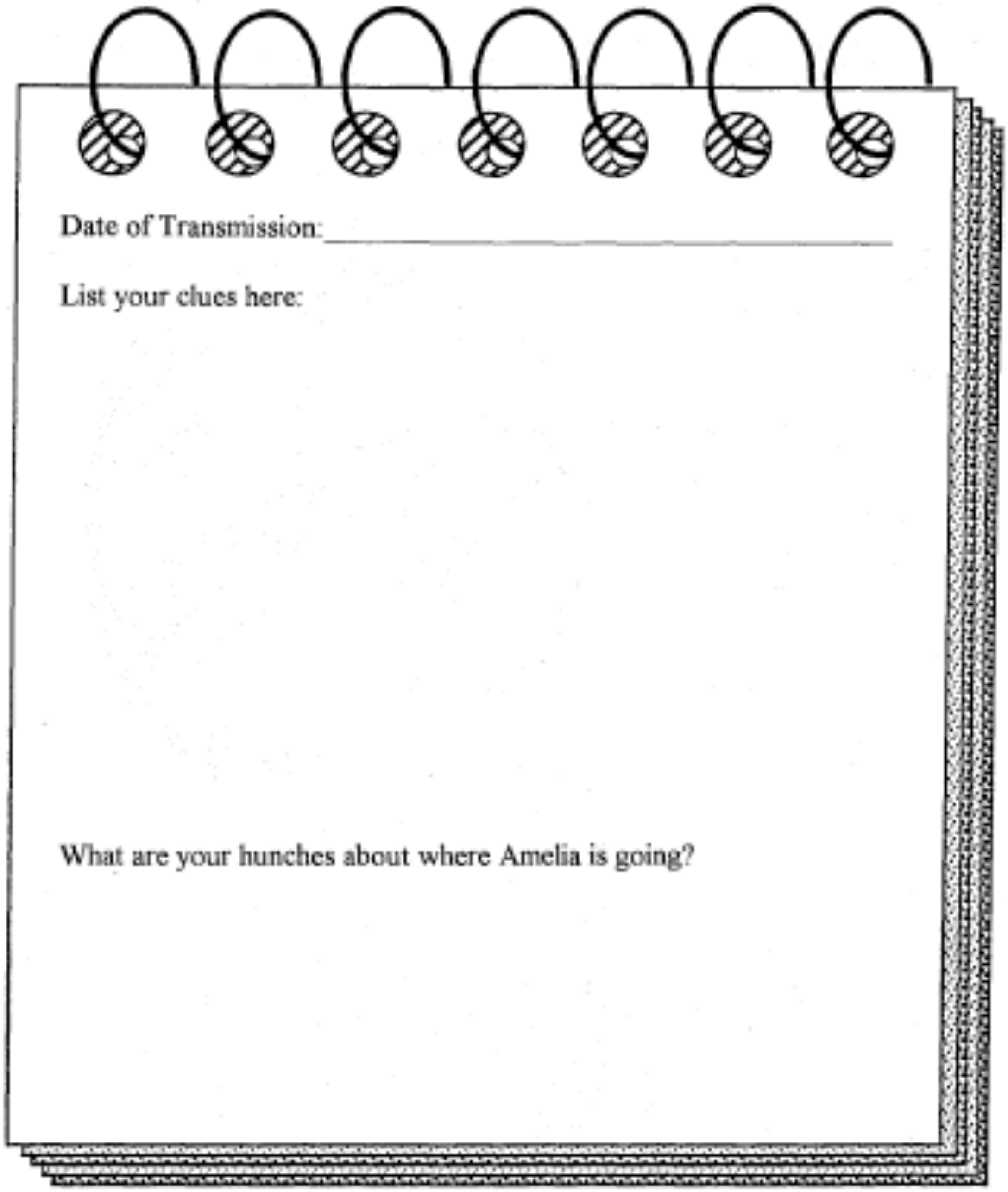
Science Detectives

Team Name



Planet Investigation
Assignment:

Figure 1.9-Science Detectives Notebook.



Now that you have had a chance to collect more information about Amelia's trip, which hunch was correct? Why? (Use the back of this sheet for your answers.)

Mission 2
What a State We're In!

The Anatomy of a Planet

Overview

In this mission, students explore three states of matter and the changes brought about by heating and cooling substances. The concepts of solid, liquid and gas are related to the "anatomy" of a planet. In missions 3, 4, 5, and 6, students use these concepts as they build planet models.

In mission 2.1, students watch a video segment, which continues the challenge to find Amelia Spacehart's first destination with another clue: Amelia says that she is headed for a planet with a rocky center (core) and a circumference of 37,400 kilometers. Students discover that Amelia's next destination is Venus.

In mission 2.2, students apply the concept of state of matter to large-scale planetary features in an experiment that simulates temperature conditions on other planets. Students observe and record changes m the states of matter of familiar substances.

Concepts

- Matter exists on Earth most commonly in three states: solid, liquid, and gas. (Several other less common states of matter are not discussed here.)
- The state of matter can be changed by heating or cooling a substance.
- The circumference of a circle is the distance around the outside edge.

Skills

- Classifying familiar substances as solid, liquid, or gas.
- Applying states of matter to large-scale planetary features.
- Observing and recording changes in the states of matter of familiar substances.

Teacher's Note: This mission deals with solid, liquid, and gas because these states can be manipulated in the classroom. Dr. Orbit makes a technically incorrect statement indicating that the* only *states of matter are solid, liquid, and gas. Actually, there are several more, but not included in this lesson. One, plasma, is superheated gas, so hot that electrons are stripped from the atoms. Among other places, plasma can be found in lightning, neon lights, and stars. Plasma is something not commonly understood by students, and is difficult to demonstrate.

Mission 2.1

Materials

For the Class

- *The Science Detectives* video, “Lesson 2”
- Video and projector or monitor
- Soccer ball (or ball of equivalent size)
- Meter tape
- Guess My Classification Rule game supplies
- 3 solid objects (e.g., rock, pencil, magnet)
- 3 liquids in various transparent containers (*e.g*., water with blue food coloring, honey, milk)
- 3 empty containers (*e.g*., bottle with cap, balloon, zip lock bag)
- Masking tape
- 2 balloons, 9-inch or larger
- Felt tip markers
- Chart paper

For Each Team

- Science Detectives Notebook
- “Familiar Solids, Liquids, & Gases” worksheet (page 58)

For Each Student

- Pencil

Getting Ready

One or More Days Before Class

This mission requires certain supplies that may be difficult to obtain. It may help to have a volunteer locate and collect the necessary supplies, and to help with the setup and cleanup of this mission.

1. Collect the supplies for the teacher demonstration. The mission begins with a Guess My Classification Rule game using examples of solids, liquids, and gases. The solids can be any objects normally found in the classroom. The liquids should be in a variety of containers. Try to choose liquids that vary in thickness (viscosity) and color. The empty containers are for “catching” gases–CO_2 (blow into a balloon); air (mostly N_2, nitrogen).
2. Prepare a space at the front of the classroom where you can place example objects in three separate piles.
3. Copy a “Familiar Solids, Liquids, & Gases” worksheet for each team.

Just Before the Lesson

1. Set up the video and projector. Screen the video to "Lesson 2."
2. Label the sheet of butcher paper "Second Transmission."

Classroom Action

1. **Video.** Tell students that they will be watching another transmission from Amelia Spacehart. They should watch and listen very carefully for clues. Remind them that they are challenged to figure out where Amelia is going in her search for the source of the ETI signal. As students get more information, their ideas may change. Tell them that changing ideas based on new information is a very important skill for a Science Detective!

   Show the video segment "Lesson 2." Play part one of the tape for students.

2. **Discussion.** Pause after the first part of "Lesson 2" and discuss the clues given as in "Lesson 1." All suggestions by students should be recorded on the clues chart. Each team should record in their Science Detectives Notebook the clues discussed. Continue the video after the class has completed this activity.

Teacher's Note: The video segment for this mission is in two parts. In Part One, students are given Amelia's clue: she is headed for a planet that has a rocky center with a circumference of 37,400 kilometers. The states of matter are introduced. Dr. Orbit dissects a planet and discusses the solid, liquid, and gas components of planets.

Video Clues: Lesson 2, January 2
(Travel time = 2 days)

- Amelia has enough fuel to get to the dwarf planet Pluto and back.
- Amelia might operate the hydrogen fuel siphon to get more fuel.
- Amelia is going to a rocky planet, a little smaller than Earth, which has a solid surface of 37,400 kilometers in circumference.
- Matter exists in three different forms.
- Gas giant planet–huge gaseous atmosphere; ocean under the atmosphere; solid, rocky center inside.
- Rocky planet–thin gaseous atmosphere; thin ocean under the atmosphere; solid, rocky center.

Amelia gave a clue about where she will look for ETI first. Her clue mentioned the word *circumference.*

To use the clue, the Science Detectives must understand what circumference means. Circumference is the distance around a circle or spherical object. Demonstrate the measurement of the circumference of the soccer ball using the meter stick. Ask students what they think the circumference measurement will be if it is measured in a direction perpendicular to the first measurement. What if it is measured diagonally to the first measurement? *(Students should understand that the "equatorial", or "great circle", circumference of a sphere is always the same, regardless of the direction of the measurement. It may be useful to demonstrate an incorrect measurement around a part of the sphere that is not the equator.)*

Dr. Orbit also mentioned the term *matter.* Matter is the stuff of which everything is made. There are many different kinds of matter, but all matter has two characteristics: it takes up space and it has mass.

3. **Demonstration.** Explain that you have some objects that exist in different states of matter. You are going to sort these objects into three different groups. Each group of objects is the same in some way. Students should watch as you place objects into each group. Ask students to think about how the objects in each particular group are the same. There may be many ways. Ask students to think of as many as possible.

Teacher's Note: You may wish to introduce the concepts of* diameter *and* radius. *These terms are not used in this unit, but they are frequently used to describe spheres and circles in the real world. If your students are ready, you may also wish to introduce the term pi--the fixed ratio between circumference and diameter.

Start the game "Guess My Classification Rule" by placing two objects into each group—solid, liquid, and gas. The objects should be placed in random order (*i.e*., don't place both solids, then both liquids, *etc*.). Hold up each object before placing it into a group so that the class can see it clearly. You should manipulate the object in some way before putting it down (*i.e.*, try to bend the pencil, shake the bottle of water). Gas samples should be "collected" as you place them. Blow up the empty balloon and tie it off. Open a container, show the students that it is empty, then swing the container through the air and cap it.

In the second part of the game, students share their ideas about the objects in the groups, but they do it silently. Explain that you will hold up a new object, and then you will hold the object above each group. Ask students to show whether or not they think the object belongs in a particular group with a "thumbs up" or "thumbs down" gesture. Show each object letting them vote for a group for each. After each vote, place the object in its correct group.

4. **Discussion.** After all the objects are placed, invite students to discuss all the ways that the objects in a particular group are alike. They will not necessarily come up with solid, liquid, and gas classifications. All the properties that they describe, however, can be related to the properties of the different states of matter (*e.g.*, solids are hard, liquids are wet, and gases look "empty" or invisible). Try to relate everything that students say to the rule that you were using to classify the objects. Explain to students that scientists classify or put matter into groups based on many properties. Solids, liquids, and gases are just one way to classify matter, and this classification may be very useful for Science Detectives.

5. **Activity.** Instruct teams to make lists of things from their daily life that could be classified as solids, liquids, and gases. The lists should be recorded on the Logbook sheet "Familiar

Solids, Liquids, & Gases." Ask each team to share three objects–a solid, a liquid, and a gas–and have teams write their examples on the whiteboard.

Mission 2.2

Materials

For the Class

- Chart paper from mission 2.1
- Picture of Earth from space
- Clip-on heat lamp
- Medium-sized Styrofoam cooler with top
- Aluminum foil
- 3 pounds of dry ice
- Thermometer (optional)
- Pair of canvas gardening gloves
- Hammer
- Towel
- Short tube or funnel with a 2-cm diameter opening (for filling a balloon with dry ice)
- 4 plastic cups
- 9 small rocks
- 9 small pieces of crayon
- 500 ml of water
- 100 ml of peppermint extract (one large bottle)

For Each Team

- Science Detectives Notebook
- "More Solids, Liquids, & Gases" worksheet
- "Changing the State of Things" Logbook sheet
- 4 plastic cups
- Felt tip marker
- 4 eyedroppers

For Each Student

- "What Do You Think an Intelligent Extraterrestrial Looks Like?" worksheet
- Pencil

Getting Ready

One or More Days Before Class

1. Obtain the dry ice. See the appendix for details.
2. Copy of the worksheet "What Do You Think an Intelligent Extraterrestrial Looks Like?" (page 56) for each student. Make nine copies each of the Logbook sheet "Changing the State of Things" and "More Solids, Liquids, & Gases Worksheet."

Just Before the Lesson

1. On a table, set up the heat lamp and dry ice. Put a large sheet of aluminum foil on one end. The lamp should be clipped on the back of a chair, with the chair turned so that the bulb is about five centimeters above the plastic cups and the foil is under the lamp. If you have a thermometer, put it under the lamp.

2. Use canvas gardening gloves when handling dry ice. Break the dry ice into smaller pieces (that will fit through the 2-cm funnel opening) by wrapping it in a towel and hitting it with a hammer. The dry ice should be placed in an insulated cooler and put at the other end of the table. Do not seal the cooler. As the dry ice evaporates it will build up pressure in the cooler. Put the lid on loosely.

3. Put rocks and crayon pieces in plastic cups labeled "S 1" and "S 2." Put water and peppermint extract put in plastic cups labeled "L 1" and "L 2." Place two eyedroppers in each cup of liquid. Place these materials on a separate table with space on all four sides for teams to prepare their solid and liquid samples.

Classroom Action

1. **Lecture.** Explain to students that we can classify the stuff that Earth is made of by its states of matter. Ask teams to find the solids, liquids, and gases in the picture found on their Logbook sheet "More Solids, Liquids, & Gases."

2. **Discussion.** Encourage teams to discuss the picture. Ask each team to name a solid, liquid, or gas found in the picture *(Solids: trees, fish, hills, roads. Liquids: water. Gases: air, clouds, Sun (though technically plasma).* Allow students to repeat objects shared by other teams.

   Show the class a picture of Earth from space. Ask them to find the solids, liquids, and gases in this picture. In the view of Earth from space, what colors are the solids? *(green and brown, or possibly white ice)* The liquids? *(blue).* The gases? *(white).*

   Ask students what might happen to a solid, liquid, or gas if we took it from Earth to another planet. Any answer is acceptable. Explain that class can't go to another planet to find out, but that they will simulate the conditions found on other planets. They will make a "laboratory" in the classroom with conditions like those found on other planets. In the classroom, the conditions cannot be simulated exactly, but they will be making the laboratory warmer and colder, similar to other planets.

Explain that the heat lamp will be used to simulate very hot conditions because some planets in our solar system are much hotter than Earth. Dry ice will be used to simulate planets where temperatures are much colder than on Earth. Explain that dry ice is a solid carbon dioxide (CO_2) is very cold (about -109° F) and that it can cause instant frostbite, which feels just like a third-degree burn. Warn students not to put their hands into the cooler, and explain that you will be using protective gloves.

3. **Activity.** Directions for students are on the Logbook sheet "Changing the State of Things." Instruct teams to prepare samples of solids and liquids. Have teams label their 8-ounce plastic cups with team numbers on the sides with felt markers. Have each team get their samples.

Teacher's Note: Alternatively, you may choose to give the four materials to each group yourself to minimize lines around the materials. Students could begin working on the worksheet "What Do You Think an Intelligent Extraterrestrial Looks Like?" while others prepare their solid and liquid samples.

Put the sample cups under the heat lamp or in the cooler with the dry ice for approximately 10 minutes. After heating and cooling, have the teams look at the cups and record their observations. Then return the samples to their simulated planet environments.

Next, cool previously heated samples and heat previously cooled samples and record observations after 10 minutes. Ask students to add to their lists of solids, liquids, and gases, or to work on their drawings of extraterrestrials.

4. **Demonstration.** Students may notice that they did not prepare a gas sample to test under simulated planet conditions. Ask students if they have any ideas about how to get a gas sample to test by heating and cooling. Show the class a piece of dry ice. Ask the class if dry ice is a solid, a liquid, or a gas. *(Dry ice is a solid that changes directly to a gas—sublimates–under normal Earth conditions.)*

Tell students that you will put two small pieces of dry ice into a balloon. Stretch the balloon over the tube or funnel and wear gloves while you place several small pieces of dry ice inside. Adding several more pieces of dry ice will result in the balloon inflating faster. Tie off the end of the balloon. Students will observe the balloon for approximately five minutes. Take the balloon to each team and let students feel it. Ask students what has happened to the balloon. *(The balloon is cold at first, and then gets warmer over time. As the balloon heats up, the dry ice becomes a gas, which inflates the balloon.)* Ask students what might happen if the gas inside the balloon is heated. Record student predictions on the whiteboard. Place the balloon under the heat lamp.

After approximately 10 minutes, remove the balloon from under the heat lamp and show it to the class. Pass the balloon to each team and let students feel it. Ask the class what has happened to the balloon. *(It is bigger. It is warmer. There is no solid inside anymore.)* Blow up another balloon and put it into the Styrofoam cooler with the dry ice. Ask students what will happen and let them make predictions. Leave the balloon in the container until the end of the day. Ask students what happened to the balloon as it cooled. Pop the balloon and let students observe what is inside. They should be able to feel moisture from condensed water on the pieces of the balloon.

5. **Video.** Show students the second part of "Lesson 2." Discuss the information presented in this video segment and record any remaining clues on the chart as well as in team notebooks.

Closure

1. **Discussion.** Ask students how solids, liquids, and gases might look on other planets. Why are some things that are liquid on Earth, such as water, found as a solid on other planets? Why is water a gas on some planets?

Going Further

Art Activity: Alien Life-Forms

Instruct students to construct alien life-forms that might live on a solid world (like people on the ground) or a liquid world (like a fish in the water) or a gas world (like a bird in the air) using materials such as bubble packing material, Styrofoam peanuts, bottle caps, corks, pieces of household junk. Let students be creative!

Research: Other States of Matter?

Challenge students to discover other states of matter and give examples of them.

SETI INSTITUTE

Mission 2
What a State We're In!

Script for Second Transmission

Synopsis: Lesson 2, January 2
(Travel time =2 days)

- Amelia has enough fuel to get to the dwarf planet Pluto and back.
- Amelia might operate the hydrogen fuel siphon to get more fuel.
- Amelia is going to a rocky planet, a little smaller than Earth, which has a solid surface of 37,400 kilometers in circumference.
- Matter exists in three different forms.
- Gas giant planet–huge gaseous atmosphere; ocean under the atmosphere; solid, rocky center inside.
- Rocky planet–thin gaseous atmosphere; thin ocean under the atmosphere; solid, rocky center.

NARRATED MONTAGE
Background segment on Amelia Spacehart. Childhood, interest in space. Astronaut training.

NARRATOR
"Amelia grew up in a modest community, Sheet Metal Estates, on the west side of town. Her interest in astronomy developed early. As a kid, Amelia showed star quality, and she was soon scoping out a scientific career. Studying hard was the name of the game at Millard Fillmore High. And during college, Amelia used radio telescopes to do landmark research on pulsars, spinars, quasars, and masers. Always a space buff, Amelia decided to join NASA's young-astronaut program. Rigorous training was sometimes a stretch, but soon Amelia was rocketing into space as a research scientist, and had earned her fins as a shuttle pilot. Now one of NASA's leading astronauts, Amelia is proud to be part of America's greatest adventure."

DR. ORBIT
[In lab, pounding on keyboard. Turns to camera.] "Oh, hi there, Science Detectives. MEL, our base computer, has been working on Amelia's options. The data indicate that she has enough fuel to go 12 billion kilometers. That will take her all the way from Earth out to the dwarf planet Pluto and back again, as long as she doesn't take any side trips. It's also enough to get her back and forth between the rocky planets several times, or she can go out to one or two of the gas giant planets and come back from there. I guess my original hunch was wrong. I thought she only had enough fuel to get out to Jupiter and come back, so I'll have to change my hunch. This is really fascinating."

BUZZ SAWYER
"Criminy, Dr. Orbit! Amelia can go anywhere in our solar system she wants. We just don't know what she has in mind. This stuff's terrible. What is it, space pizza? Anyhow, she won't be

gone very long unless she can figure out how to operate the hydrogen fuel siphon. She wouldn't do that, would she? You know, headquarters is counting on showcasing the *Express* at the Fleaburg Air Show..."

[snap, crackle EFX] "Well I'll be blasted!"

AMELIA SPACEHART

Date on screen: January 2

"I'm not going to tell you where I'm going, Sawyer, because you might try to stop me. That would be just like you. Anyway, at this point the message seems to be originating from a nearby rocky planet. The center of this rocky planet, the solid center, is probably just a little smaller than Earth's solid center. I'd say the total circumference is 37,400 kilometers. You got that, Sawyer? 37,400 kilometers in circumference. Anyhow, I'm going to visit the planet, check it out thoroughly, and I'll get back to you later."

DR. ORBIT

"Dr. Orbit here. I've been reviewing your "hunch" forms, and they're all very imaginative. Congratulations on good work. A good hunch is often the best way to start on solving a scientific problem. Because your hunches are so excellent, you are all hired to help NASA track Amelia. We're very discriminating here."

"Before I reveal your next mission, I'd like to review a few facts about the solar system. Everything in the solar system, from the Sun to the dwarf planet Pluto, is made of matter. Matter exists in three different forms. Matter is stuff. It takes up space and it has weight. Some matter *[weighs balloon]* doesn't weigh as much as other matter, but all of it has weight. Heck, even Clyde here *[weighs rubber chicken]* is made of matter." *[Technically, Dr. Orbit should have used the term* mass *instead* of {weight.]

"Amelia's last transmission indicates that she is heading for a rocky planet with a solid center. She has revealed one of the three states of matter. Your teacher has a lesson which will help you discover what the other two are.

"Your mission now is to explore all three states of matter as they occur throughout the entire solar system."

Pause video. Teacher pauses to do a guided exploration of matter activity with student teams.

DR. ORBIT

"I wonder if Amelia realizes how much useful information she gave us in that last message. We have a team of scientists standing by to analyze every word that she says. You'll notice she said something about the solid centers of planets. If you're wondering what that means, let's take a look at a couple of models of planets to find out."

Dr. Orbit dissects two planets, to show the inside view. He cuts open clay models, focusing on layers of solid liquid and gas. He compares a rocky planet to a gas giant planet.

“This is a model of a gas giant planet. If I could reach into the atmosphere to see what’s inside there, and actually open it up, I would find there’s an ocean under all that atmosphere. If I could now open up the ocean to find out what’s inside it, I would find that, inside the planet, is a solid, rocky center. The gas giant planet, then, consists of a solid rocky center, a lot of liquid around that, and a huge amount of gaseous atmosphere around that.”

“Now if we move over to a small, rocky planet, we can see that it has a little bit of atmosphere, a little gas on it, a little bit of liquid on the surface, and we might ask, “What’s inside it. If we could cut it open and have a look, we would find that the center is also rocky and solid. You can easily see from comparing these two why one is called a gas giant and why the other is called a rocky planet. “I hope this information helps! Good luck tracking down Amelia, Science Detectives!”

BUZZ SAWYER
“Dr. Orbit is counting on you. NASA’s counting on you. And I, Buzz Sawyer–Under Assistant Honcho here at Space Command–am counting on you. If we don’t get that *Space Express* back, the Administrator’s going to have my head.” *[whimpers]* “I like my head.”

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Mission 2
What a State We're In!

Logbook

Changing the State of Things

1. Label your sample cups like the cups in the drawing below. (The letter *S* stands for "solid" and *L* stands for "liquid.") Put your team number on the label.

Figure 2.1-Four Cups.

2. Your teacher help you choose examples of solids and liquids to put into the cups.

3. Give your samples to your teacher. They will be placed in hot or cold simulated planet conditions for about 10 minutes.

4. When your teacher gives back your samples, study them. Record any changes below:

Solid 1 was put ____

How did it change?

Solid 2 was put ____

How did it change?

Liquid 1 was put ____

How did it change?

Liquid 2 was put ____

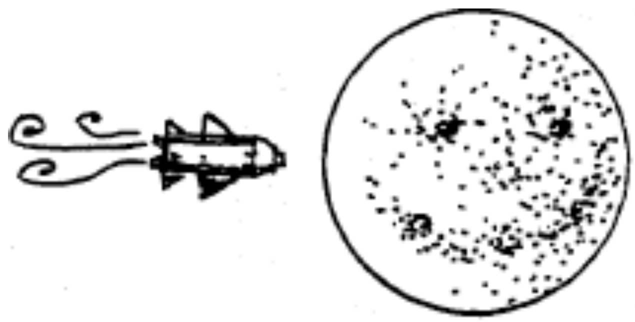
How did it change?

Mission 2
What a State We're In!

What Do You Think an Intelligent Extraterrestrial Looks Like?

Name: ______________________________________ Date: ____________________

Figure 2.2-Rocket.

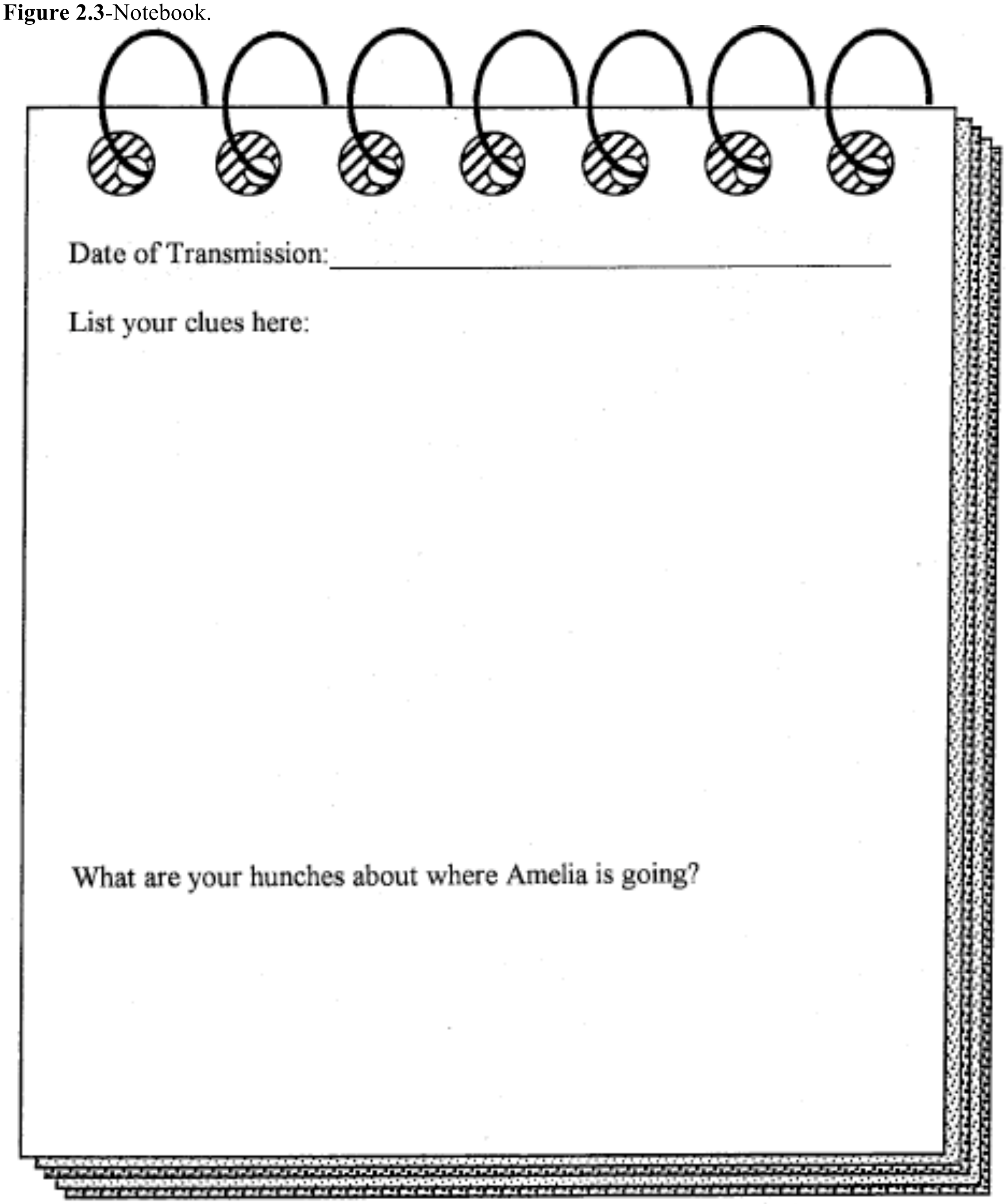


You have found a planet far, far from Earth. You are landing on this planet to search for a life-form. If you find an ETI life-form, what do you think it will look like? Draw what you imagine below.

Mission 2
What a State We're In!

Logbook

Figure 2.3-Notebook.



Now that you have had a chance to collect more information about Amelia's trip,
Which hunch was correct? Why? (Use back of this sheet for your answers.)

Mission 2
What a State We're In!

Logbook

Familiar Solids, Liquids, &Gases

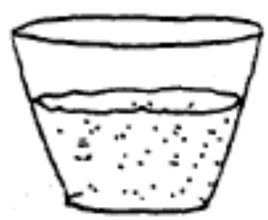
List some things around us that are solid, liquid, and gas.

Things that are solid are:

Figure 2.4-Rocks.

Things that are liquid are:

Figure 2.5-Water.



Things that are gas are:

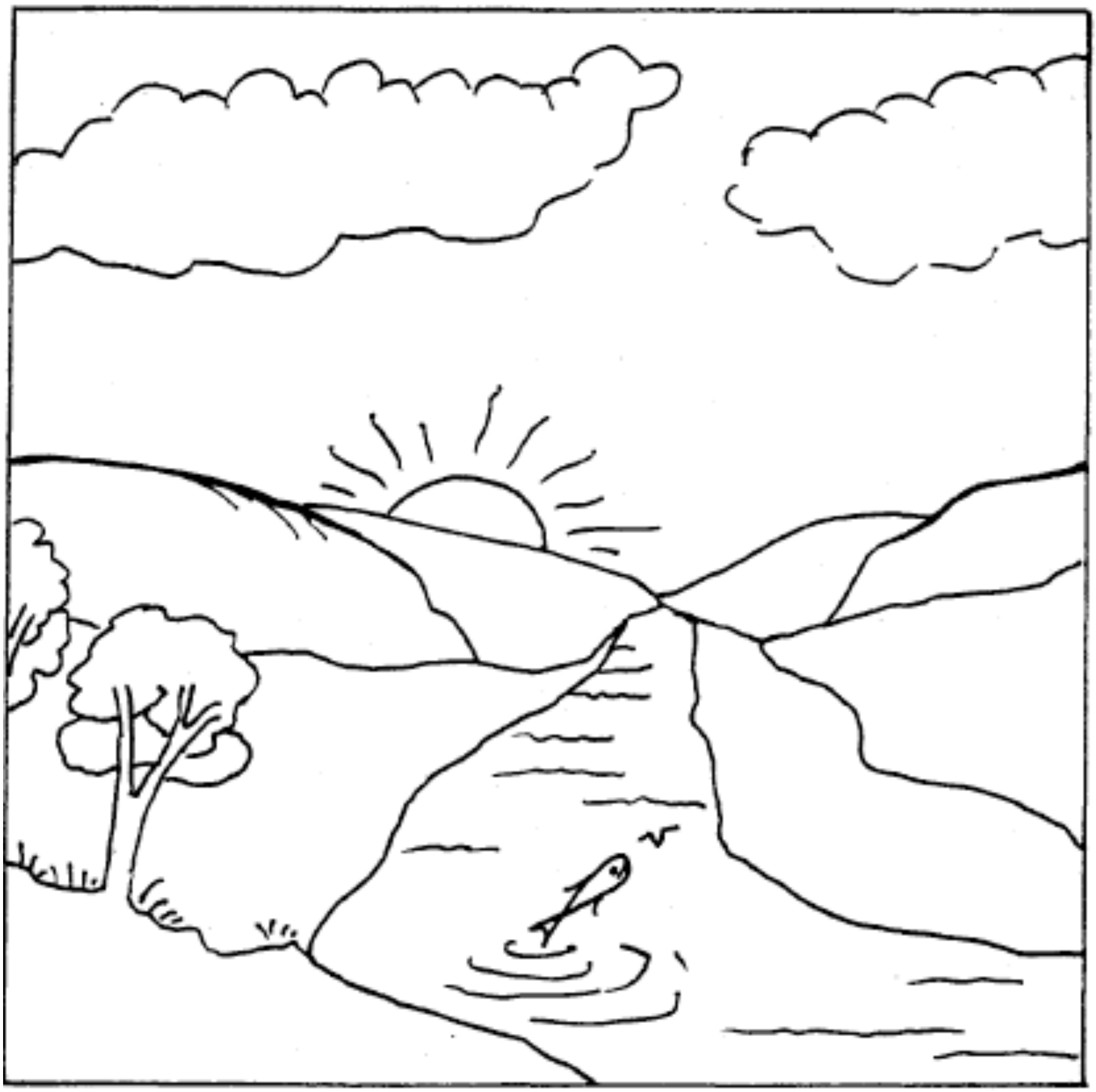
Figure 2.6-Air.

Mission 2
What a State We're In!

More Solids, Liquids, &Gases

Find as many solids, liquids, and gases as you can in this picture. Write the letter *S* for "solid," *L* for "liquid," or *G* for "gas" on each object.

Figure 2.7-Picture.



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Mission 3
What's My Planet?

Building a Planet Layer by Layer

Overview

In this mission, each student team begins building a model of one of the planets in our solar system. Teams discover their planet assignments by successfully completing a guessing game, and by using clues found in the "NASA Planetary Directory" (pages 73-99) at the end of their Science Detectives Notebooks. In mission 3.1, students watch a video segment that reinforces the concept of circumference and encourages students to use data collection, organization, and model building as scientific tools. In mission 3.2, teams build models of the rocky center of their assigned planets.

Teacher's Note: Due to of the nature of this mission's activities, and the space constraints of a classroom, the model solar system is not scaled with regard to distances between the planets. Given the sizes of the model planets, they should be spaced much farther apart. In mission 9, students create a model solar system that is correctly scaled for distances between planets.

Concepts

- Students learn the composition of each planet.

Skills

- Using clues and information from student notebooks to identify an assigned planet.
- Creating a model of the solid center of a planet.

Mission 3.1

Materials

For the Class

- *The Science Detectives* video, "Lesson 3"
- Computer, and projector or monitor
- Sheet of chart paper

For Each Team

- Science Detectives Notebook

- "Clues for Our Planet" Logbook sheet (page 100)
- "NASA Planetary Directory" (pages 73-99)
- Envelope containing the "Planet Clues" for the team's assigned planet

For Each Student

- Pencil

Getting Ready

One or More Days Before Class

1. Make one copy of each of the eight "Planet Clues" sheets, and one copy of the Logbook sheet "Clues for Our Planet" for each team. Cut the clues on each page into separate pieces and put them into envelopes marked with the appropriate team number.

Just Before the Lesson

1. Set up the computer, projector or monitor. Screen the video to "Lesson 3."

2. Label the "Clues from Video" chart with the heading "Third Transmission."

Classroom Action

1. **Lecture.** Tell students that they will be working together in teams to build one of the planets in our solar system. Their first job is to evaluate a series of clues to figure out which planet they are supposed to build. Tell them they should use all of their skills as Science Detectives.

2. **Activity.** Give each team the appropriate envelope, containing that team's eight clues.

Teacher's Note:

- ***Have teams sort their clues and record or paste them onto the back of Notebook or on a sheet of blank paper.***
- ***Teams should then check the "NASA Planetary Directory" at the end of their Notebook for the planets that fit the clues.***
- ***Many of the clues are meant to point to more than one planet.***
- ***Check to be sure that teams have guessed correctly. Help students, if necessary.***

3. **Discussion.** Ask each team to share their conclusion and to share how they came to that conclusion. Ask which clues were most useful in their decisions? Which clues were least helpful? Was there one clue that really helped them decide on one particular planet?

4. **Video.** Announce that you have another transmission from Amelia Spacehart. Show the video segment "Lesson 3."

5. **Discussion.** Stop the video and ask students if they remember Amelia's hand motion from the previous transmission as she was hinting her destination: "Anyway, at this point the message seems to be originating from a nearby rocky planet. The center of this rocky planet, the solid center, is probably just a little smaller than Earth's solid center. I'd say the total circumference is 37,400 kilometers." If students don't remember, you may want to play it again. *(Amelia made a ball shape between her hands, then revolved her finger all the way around it.)*

Teacher's Note: This video is intended to be paused after the first few moments. When this segment begins, Buzz is discussing circumference with Mr. Administrator. He asks the students, "Remember when Amelia said she was searching for a planet which had a solid center measuring 37,400 kilometers in circumference? Huh?" At this time, pause the video when "Pause Tape" appears. Ask students what this clue might mean.

Was this clue about the meaning of *circumference?* Help students recall the previous lesson's discussion and define circumference as "the distance around the largest part of a ball or sphere." When you are satisfied that students comprehend the term, continue the video.

Ask if there are any new clues to record on the "Clues from Video" chart. *(Scale model building is important.)* A recorder from each team should write down the information from the class discussion in their team's Science Detectives Notebook.

Video Clues: Lesson 3, January 3
(Travel time =3 days)

- Reminder: The rocky center of the planet that Amelia is going to is 37,400 kilometers in circumference; the circumference of this rocky center is a little smaller than Earth's rocky center. Also, the planet is nearby and rocky.

- Build models, keep charts, do research. Remind the class that Dr. Orbit concluded his science briefing with a suggestion to students that they test their hunches by keeping charts, building models, doing research, and organizing their data scientifically. Congratulate the class for having done much of this already. Tell them that it is now time to build scale models, like the NASA scientific team is doing.

Teacher's Note: Scale is the topic of mission 4; you do not need to explain it now.

Mission 3.2

Materials

For the Class

- Newspaper
- Papier-mâché paste, water and wallpaper paste *or* white flour *or* liquid starch

- Gallon zip lock bags *(optional)*
- Transparent tape
- Felt tip markers
- Scissors
- About 20 rocks, various sizes

For Each Team

- Science Detectives Notebook
- “Planet-Building Instructions” for the team’s assigned planet
- Newspaper, whole pieces and strips
- Papier-mâché paste
- Aluminum pie tin (or shallow container the size of a dishpan)
- 1 meter of string
- Circumference strings (mentioned below)
- Meter tape
- Masking tape

For Each Student

- Pencil

Getting Ready

One or More Days Before Class

1. The papier-mâché paste can be made in advance if it is put into gallon zip lock bags and refrigerated. If you choose to make your own starch paste, mix starch and water in equal parts. Wallpaper paste will work best for the models. The directions on the package will describe how to mix up the paste. Make the paste a little thicker, using one-quarter less water than the amount listed in the directions.

2. Newspaper strips can be prepared by ripping the paper into 1/2” to 2” strips. You may want to have student helpers prepare the newspaper strips. Whole sheets of newspaper are also necessary.

3. Collect assorted rocks to serve as anchors for each planet. They should range from pebbles with a diameter of 1 centimeter (for Pluto) to rocks with diameters of 5 to 10 centimeters. Teams sort and measure materials to find the best size for their planet.

4. Pre-cut the meter-long strings and circumference strings if your students do not have strong measuring skills.

5. Copy the “Planet-Building Instructions” for the rocky centers of planets (each team gets one set of instructions for one planet).

Just Before the Lesson

1. When you are ready to begin building the models, put the paste into the aluminum pie tins or other shallow containers.

Classroom Action

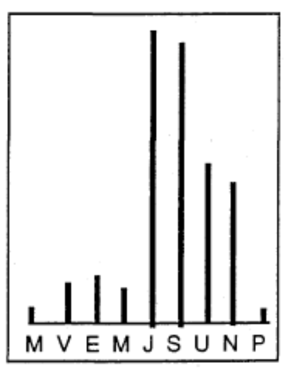
1. **Activity.** Hand out the "Planet Building Instructions" to each team. Teams have already identified their planet and can begin to build their rocky centers. Teams assigned to make smaller planets could make one planet for each student or pair, so that everyone has enough to do. The "Planet-Building Instructions" give the final scale circumference for each model. Each team needs papier-mâché paste, newspaper, rock, string, and a meter tape. The models will take at least one day to dry.

Teacher's Note: Store the papier-mâché planets in a dry place to prevent the development of mold. You can add a few drops of Lysol to the paste to help prevent mold.

Closure

1. **Discussion.** When students have finished measuring their planets, collect their circumference strings. Label the strings by planet name and store them for mission 4. The strings could be stored on a wall graph that compares the relative circumferences of the planets, as shown in figure 3.1.

Figure 3.l-Circumference of the Planets.



Attach strings with small pieces of masking tape for easy removal when needed. Ask students what the strings represent and how will the strings help them track Amelia?

2. **Optional Discussion.** Ask students of other ways to arrive at the circumference of a circle or sphere (besides physically measuring the actual circumference). If they do not suggest them, explain *radius* and *diameter.* Amelia had told students the radius or diameter of her destination planet so how could they have used that information to tell where she was going?

Going Further

Demonstration: The Inner Earth

Though scientists cannot directly observe the center of the Earth, they have theorized from the speed of earthquake waves that it is not a solid. In fact, the core of the Earth appears to be molten rock, a liquid. Simulate the molten inner Earth with a mixture of cornstarch and water. Add cornstarch to water until the mixture looks and feels solid, but flows when picked up.

Activity: Spheres and Circles

Students can make clay balls of various sizes and measure the circumference of each ball. Cut open the balls and measure the radius and diameter of each. Ask students if there is a relationship between these measurements? Students should use calculators so that their arithmetic will be accurate enough to identify a relationship.

SETI INSTITUTE

Mission 3
What's My Planet?

Script for Third Transmission

Synopsis: Lesson 3, January 3
(Travel time = 3 days)

- Reminder: The rocky center of the planet that Amelia is going to is 37,400 kilometers in circumference; the circumference of this rocky center is a little smaller than Earth's rocky center. Also, the planet is nearby and rocky.

- Build models, keep charts, do research.

BUZZ SAWYER
[on phone] "Uh-huh. Uh-huh. Circumference, Mr. Administrator. Circum-fer-ence." *[aside]* "Must be 50 years since the Administrator has had geometry." *[on phone]* "That's right. That's right." *[Puts phone down. Turns to camera.]* "Remember when Amelia said she was searching for a planet which had a solid center measuring 37,400 kilometers in circumference? Huh?"

Pause video. Ask students to verbally give their hunches about what circumference means.

"The NASA scientific team believes this will be a clue to Amelia's next step. See, the scientists are busy making scale models of the solid centers of the planets because this will tell us where she is. You see, once the models are built, all we have to do is measure their circumferences, multiply by the scale factors, and that'll give us Amelia's destination! I have to deal with the Administrator here, but you stand by for a science briefing." *[on phone]* "Yes ..." *[aside]* "You can also sit by." *[on phone]* "Yes sir. Circumference. Yes sir, I know it has four syllables."

DR. ORBIT
"Hey Sawyer, did you notice that Amelia gave us several other clues in that last transmission? First, she mentioned the circumference of the rocky center of the planet that she's going to. Second, she said that that rocky center is just a little bit smaller than that of the Earth. Third, she said it's a rocky nearby planet. We're starting to form some hunches as to where she's going."

Dr. Orbit gets a chart.

"This shows the Earth." *[Refers to chart.]* "Here's the solid rocky center, here's a little bit of liquid on the outside, and a gas atmosphere on the outside of that. Here's the rocky center of the planet she's going to. And she didn't tell us anything about whether it has any liquid or gas. This is really getting fascinating. We're checking each hunch by making charts, maps, models, and doing research. My advice to you, Science Detectives, is to organize your data scientifically!"

"She's really something, isn't she?"

BUZZ SAWYER
"Something? What something? Off on some crazy search for extraterrestrials ... with my–with *our* rocket?" *[on phone]* "Yes sir, it's C-I-R-C-U-M- ..."

Mission 3
What's My Planet?

Planet Clues-Teacher's Key

Table 3.1-Planet Clues.

Clues for Team 1	Clues for Team 2	Clues for Team 3	Clues for Team 4	Clues for Team 5	Clues for Team 6	Clues for Team 7	Clues for Team 8	Clues for Team 9
	Has craters	Has one moon that orbits backwards	Has clouds	Has a magnetic field	Rotates on its side	Has ice	You can't see its solid surface	Smaller than Earth
Is very, very cold		Is very, very cold	Has a rocky surface	Has rings	Is very, very cold	Has liquid water	Has moons	Has a rocky surface
Has a strange orbit	Is very cold		You can't see its solid surface	Is very cold	Has clouds	You can see its surface	Larger than Earth	You can see its surface
Smaller than Earth	Has clouds	Has rings		Has clouds	You can't see it without a telescope	Has a magnetic field	You can see it without a telescope	It is very, very hot
Has one moon	Has moons	Larger than Earth	Almost the same size as Earth		Has a blue-green color	Has a rocky surface	Has an atmosphere	Has craters
You can't see it without a telescope	Has a rocky surface	Has moons	Is very, very hot	Has a red spot		Has clouds	Has bright rings	Has a magnetic field
Has a rocky surface	Has volcanoes	Has clouds	Has volcanoes	Larger than earth	Has dark rings		Has clouds	Has almost no atmosphere
Has ice	Smaller than Earth	You can't see it without a telescope	Doesn't have moons	Has a thick atmosphere	Larger than earth	Has volcanoes		Has a volcano
Has a blue-gray color	Has ice	Has a bluish color	Has craters	Has moons	Has moons	Has one moon	Has a yellowish color	
Pluto	**Mars**	**Neptune**	**Venus**	**Jupiter**	**Uranus**	**Earth**	**Saturn**	**Mercury**

SETI INSTITUTE

Mission 3

What's My Planet?

Team #1
Clue Sheet

Is very, very cold	Has a strange orbit	Smaller than earth	Has one moon
You can't see it without a telescope	Has ice	Has a rocky surface	Has a blue-gray color

Team #2
Clue Sheet

Has craters	Is very cold	Has clouds	Has moons
Has volcanoes	Smaller than Earth	Has ice	Has a rocky surface

Team #3
Clue Sheet

Has one moon that orbits backwards	Is very, very cold	Has rings	Has moons
Has clouds	You can't see it without a telescope	Larger than earth	Has a bluish color

Team #4
Clue Sheet

Is very, very hot	Has clouds	Has a rocky surface	You can't see its solid surface
Almost the same size as earth	Has volcanoes	Doesn't have moons	Has craters

Team #5
Clue Sheet

Has a magnetic field	Has moons	Is very cold	Has clouds
Has a red spot	Larger than Earth	Has a thick atmosphere	Has rings

Team #6
Clue Sheet

Rotates on its side	Is very, very cold	Has clouds	You can't see it without a telescope
Has a blue-green color	Larger than Earth	Has dark rings	Has moons

Team #7
Clue Sheet

Has ice	Has liquid water	You can see its surface	Has a magnetic field
Has a rocky surface	Has clouds	Has volcanoes	Has one moon

Team #8
Clue Sheet

You can't see its surface	Has moons	You can't see it without a telescope	Has bright rings
Has an atmosphere	Has clouds	Larger than Earth	Has a yellowish color

Team #9
Clue Sheet

Smaller than Earth	Has a rocky surface	You can see its surface	Is very, very hot
Has craters	Has a magnetic field	Has almost no atmosphere	Has a volcano

NASA Planetary Directory

Table 3.11—NASA Planetary Directory #1.

NASA Planetary Directory	
Symbol ☿ **Mercury**	
	Distance from Sun: 57,900,000 km Number of Moons: 0 Rings: None Circumference: 15,300 km
Description: Mercury is the closest planet to the Sun. Because it is so close, its surface is very, very hot (up to 342 ^{o} C). However, on the side facing away from the Sun, it gets very cold (-139^{o}C) because Mercury has little atmosphere to hold in the heat. This planet is only a little bigger than our Moon. And like the Moon, it is covered with craters. Mercury is visible to the naked eye, but it is hard to see because it is so close to the Sun. There is a magnetic field caused by a very large iron core. The core is so large, in fact, that Mercury's rocky crust is only 643 km thick. At some time in the past, a large rock cruising through the solar system smashed into Mercury and broke through its crust. A sea of lava welled up forming a volcano.	

NASA Planetary Directory

Table 3.12--NASA Planetary Directory #2.

NASA Planetary Directory	
Symbol ♀ **Venus**	
	Distance from Sun: 108,200,000 km Number of Moons: 0 Rings: None Circumference: 38,000 km
Description: Venus is the second planet from the Sun. It is about the same size as Earth. It is even hotter on Venus than it is on Mercury, which is closer to the Sun. This is because the atmosphere of Venus is made almost entirely of carbon dioxide, which acts a thick blanket to lock in the heat. This trapping of heat is commonly known as the greenhouse effect. Although you cannot see the surface because of the thick cloud layer, scientists have discovered it has a rocky surface with several craters and lava volcanoes. Venus is one of the few planets with no moons.	

Mission 3
What's My Planet?

NASA Planetary Directory

Table 3.13--NASA Planetary Directory #3.

NASA Planetary Directory	
Symbol ⊕ **Earth**	
	Distance from Sun: 149,600,000 km Number of Moons: 1 Rings: None Circumference: 40,000 km
Description: Earth is the third closest planet to the Sun. It is far enough away from the Sun that liquid water on it's surface does not boil, yet close enough so that most of the water does not freeze. It has a thin atmosphere. Its temperature ranges from -88°C to 58°C. It is the only planet known to support life. Seen from space, Earth looks like a giant blue marble with swirls and patches of white made by the clouds and polar ice caps. Oceans cover nearly three-quarters of Earth's surface. The rest is composed of rocky land masses called continents. The Earth's core is made up of molten rock. Lava spews out of many volcanoes on the surface. The Earth also has a magnetic field with definite north and south poles. Its single moon is covered with craters formed by meteorites and comets smashing into it.	

NASA Planetary Directory

Table 3.14--NASA Planetary Directory #4.

NASA Planetary Directory	
Symbol ♂ **Mars**	
	Distance from Sun: 227,900,000 km Number of Moons: 2 Rings: None Circumference: 21,300 km
Description: Mars is the fourth planet from the Sun and is about half the size of Earth. It has two moons that orbit around it. The planet is very cold. The temperature ranges anywhere from -124°C to +20°C. This means that Mars can have polar caps made of ice at all times. Mars also has the largest volcano in the solar system. It is 25 km high and is 2.5 times as tall as Earth's Mt. Everest! Not only does this rocky planet have volcanoes, but it has giant craters as well. Red dust from the surface can form thick clouds. This red dust comes from the soil on Mars, which contains iron. When iron rusts it turns red, giving Mars its red color.	

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Mission 3
What's My Planet?

NASA Planetary Directory

Table 3.15--NASA Planetary Directory #5.

NASA Planetary Directory	
Symbol ♃ **Jupiter**	
	Distance from Sun: 778,400,000 km Number of Moons: 63* Rings: Yes Circumference: 449,200 km
Description: Jupiter is the fifth planet from the Sun and it is the largest of all the planets—more than 11 times larger than Earth. It has 63* moons that orbit around it. It also has thin rings that are difficult to detect with Earth based telescopes, but which have been photographed by space probes that have visited Jupiter. It has a very deep atmosphere. Within the atmosphere are dense clouds and a large red spot. Scientists think that the red spot is a storm, like a hurricane, that has been raging for hundreds of years! Jupiter is so large that two Earths could fit side by side into the red spot. Even though Jupiter is far from the Sun, the pressure of Jupiter's huge atmosphere makes it warm inside the planet, where there is an ocean of liquid hydrogen. Next to the Sun, Jupiter has the largest magnetic field in the solar system. *More moons can be found at any time. This is the count as of October, 2009.	

NASA Planetary Directory

Table 3.16--NASA Planetary Directory #6.

NASA Planetary Directory	
Symbol ♄	**Saturn**
	Distance from Sun: 1, 421,100,000 km Number of Moons: 61* Rings: Yes—Thousands! Circumference: 377,450 km
Description: Saturn is the sixth most distance planet from the Sun. Seen through a telescope it is one of the most beautiful sights in the sky. It looks like a yellow ball surrounded by several bright rings. This planet is about 9 times as big across as Earth. It has a thick atmosphere, and you cannot see its surface because of the continual cloud covering. Saturn is similar to Jupiter. As for Saturn's rings, they are made of millions of pieces of ice and ice-covered particles that can be as small as a speck of dust or as large as a house! * More moons can be found at any time. This is the count as of October, 2009.	

NASA Planetary Directory

Table 3.17--NASA Planetary Directory #7.

NASA Planetary Directory	
Symbol ♅ **Uranus**	
	Distance from Sun: 2,854,000,000 km Number of Moons: 27 Rings: Yes Circumference: 160,600 km
Description: Uranus is the seventh planet from the Sun. Because it is so far away, it is very, very cold. Like other of the large planets, it has several moons. This planet, which is about four times as big across as Earth, can be seen through a telescope. It is blue-green in color and has a thick gas atmosphere and dark rings. One interesting fact about Uranus is that it is tipped over and rotates on its side. Its rings circle the planet "top-to-bottom" instead of "side-to-side", like Saturn's, because they are tipped over, too.	

NASA Planetary Directory

Table 3.18--NASA Planetary Directory #8.

NASA Planetary Directory	
Symbol ♆ **Neptune**	
	Distance from Sun: 4,478,000,000 km Number of Moons: 13 Rings: yes Circumference: 155,900 km
Description: Neptune, a blue-colored planet, is usually eighth from the Sun. Sometimes, the dwarf planet Pluto is closer to the Sun than Neptune. It is only slightly smaller than Uranus. Because the planet is so far from the Sun, you need a telescope to see it and its moons. One of the moons is very strange—it orbits Neptune backwards. Scientists have hypothesized that it was captured by the planet's gravitation some time ago as it wandered through the solar system. The planet itself is also strange. Neptune has clouds and does not have a solid surface. The core of the planet is surrounded by water, ice, and liquid methane.	

NASA Planetary Directory

Table 3.19-NASA Planetary Directory #9.

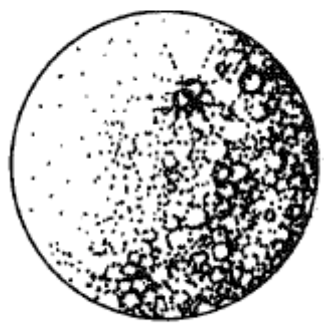
NASA Planetary Directory	
Symbol ♇ **Pluto**	
	Distance from Sun: 5,879,000,000 km Number of Moons: 3 Rings: None Pluto's Circumference: 7,414 km Charon's Circumference: 3,726 km
Description: Pluto is a blue-gray colored dwarf planet. This dwarf planet also has a very unusual orbit. Although Pluto is usually the farthest planet from the Sun, approximately every 240 years it is actually closer to the Sun than its neighbor, Neptune. It is closer to the Sun than Neptune for about 20 years out of each 240 year orbit around the Sun. Recently it was closer than Neptune from 1979 to 1999. Pluto is very, very cold, and it is covered with methane ice. You can see Pluto, which is about five times smaller across than Earth, and its moons only through a large telescope. The largest moon, Charon, is so big that some scientists think of it as a double dwarf planet system.	

Mission 3
What's My Planet?

Planet-Building Instructions– The Rocky Center of Mercury

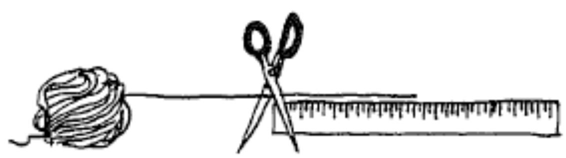
Mercury is a rocky planet smaller than Earth. The solid part of Mercury is made up of an iron core covered by a thin, rocky crust.

Figure 3.2-Mercury.



1. At this scale (1 to 210 million), the rocky center of your model of Mercury should have a circumference of 7.3 centimeters. Cut a piece of string that is 7.3 centimeters long. Wrap a piece of tape around each end of the string.

Figure 3.3-Measuring String.



2. Select a small rock. Measure the rock to make sure that the circumference of the rock is smaller than the circumference of the rocky center of your planet. Tie a long string to the rock so that you can hang up Mercury later. Secure it with tape.

Figure 3.4-Rock on String.

3. Crumple a piece of newspaper around the rock, forming a ball. Keep the long string outside of the newspaper. Check the circumference of the newspaper covered rock with your 7.3 cm-long string. Add or take paper away until it has the correct circumference.

Figure 3.5-Crumpling a Ball of Newspaper.

4. Tape the ball to hold its size and shape.

Figure 3.6-Taped Ball.

5. Cover the ball with a thin layer of papier-mâché. Be careful not to increase the circumference of your planet by using too much papier-mâché.

Figure 3.7-Papier-mache.

6. Hang up your model of Mercury to dry while you clean up.

Mission 3
What's My Planet?

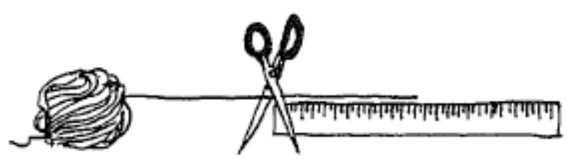
Planet-Building Instructions–
The Rocky Center of Venus

Venus is only a tiny bit smaller than Earth. The solid part of Venus is made up of an iron core covered by a rocky mantle and crust, similar to Earth's core.

Figure 3.8-Venus.

1. At this scale (1 to 210 million), the rocky center of your model of Venus should have a circumference of 18.0 centimeters. Cut a piece of string that is 18.0 centimeters long. Wrap a piece of tape around each end of the string.

Figure 3.9-Measuring String.



2. Select a small rock. Measure the rock to make sure that the circumference of the rock is smaller than the 18.0 cm circumference of the rocky center of your planet. Tie a long string to the rock so that you can hang up Venus later. Secure it with tape.

Figure 3.10-Rock on String.

3. Crumple a piece of newspaper around the rock, forming a ball. Keep the long string outside of the newspaper. Check the circumference of the newspaper-covered rock with your 18.0 cm-long string. Add or take paper away until it has the correct circumference.

Figure 3.11-Crumpling a Ball of Newspaper.

4. Tape the ball to hold its size and shape.

Figure 3.12-Taped Ball.

5. Cover the ball with a thin layer of papier-mâché. Be careful not to increase the circumference of your planet by using too much papier-mâché.

Figure 3.13-Papier-mache.

6. Hang up your model of Venus to dry while you clean up.

Mission 3
What's My Planet?

Planet-Building Instructions–
The Rocky Center of Earth

Earth is made up of an iron core and a rocky mantle and crust. There are large continents on the surface. Each pole is covered by an ice cap.

Figure 3.14-Earth.

1. At this scale (1 to 210 million), the rocky center of your model of Earth should have a circumference of 19 centimeters. Cut a piece of string that is 19 centimeters long. Wrap a piece of tape around each end of the string.

Figure 3.15-Measuring String.

2. Select a small rock. Measure the rock to make sure that the circumference of the rock is smaller than the 19 cm circumference of the rocky center of your planet. Tie a long string to the rock so that you may hang up Earth later. Secure it with tape.

Figure 3.16-Rock on String.

3. Crumple a piece of newspaper around the rock, forming a ball. Keep the long string outside of the newspaper. Check the circumference of the newspaper-covered rock with your 19 cm-long string. Add or take paper away until it has the correct circumference.

Figure 3.17-Crumpling a Ball of Newspaper

4. Tape the ball to hold its size and shape.

Figure 3.18-Taped Ball.

5. Cover the ball with a thin layer of papier-mâché. Be careful not to increase the circumference of your planet too much by using too much papier-mâché.

Figure 3.19-Papier-mache.

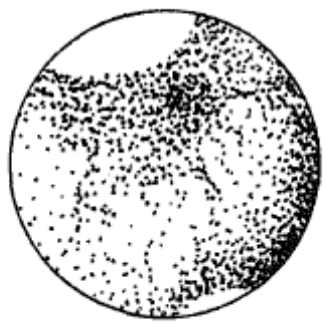
6. Hang up your model of Earth to dry while you clean up.

Mission 3
What's My Planet?

Planet-Building Instructions–
The Rocky Center of Mars

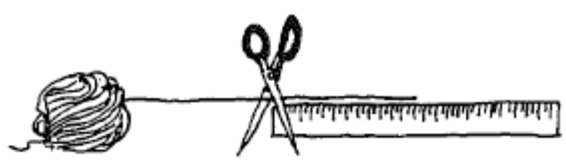
Mars is a small rocky planet about half the size of Earth. The solid part of Mars is made up of an iron core and a rocky mantle and crust, like Earth.

Figure 3.20-Mars.



1. At this scale (1 to 210 million), the rocky center of your model of Mars should have a circumference of 10 centimeters. Cut a piece of string that is 10 centimeters long. Wrap a piece of tape around each end of the string.

Figure 3.21-Measuring String.



2. Select a small rock. Measure the rock to make sure that the circumference of the rock is smaller than the 10 cm circumference of the rocky center of your planet. Tie a long string to the rock so that you may hang up Mars later. Secure it with tape.

Figure 3.22-Rock on String.

3. Crumple a piece of newspaper around the rock, forming a ball. Keep the long string outside of the newspaper. Check the circumference of the newspaper covered rock with your 10 cm-long string. Add or take paper away until it has the correct circumference.

Figure 3.23-Crumpling a Ball of Newspaper.

4. Tape the ball to hold its size and shape.

Figure 3.24-Taped Ball.

5. Cover the ball with a thin layer of papier-mâché. Be careful not to increase the circumference of your planet too much by using too much papier-mâché.

Figure 3.25-Papier-mache

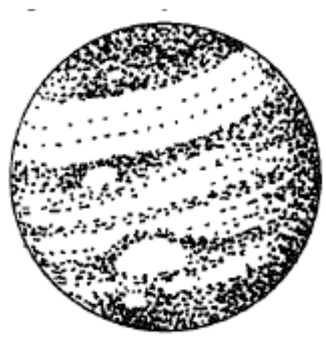
6. Hang up your model of Mars to dry while you clean up.

Mission 3
What's My Planet?

Planet-Building Instructions–
The Rocky Center of Jupiter

Jupiter is the largest of the planets in our solar system. Scientific evidence suggests that its solid center is probably made up of a rocky iron core.

Figure 3.26-Jupiter.



1. At this scale (1 to 210 million), the rocky center of your model of Jupiter should have a circumference of 79 centimeters. Cut a piece of string that is 79 centimeters long. Wrap a piece of tape around each end of the string.

Figure 3.27-Measuring String.

2. Select a large rock. Measure the rock to make sure that the circumference of the rock is smaller than the 79 cm circumference of the rocky center of your planet. Tie a long string to the rock so that you may hang up Jupiter later. Secure it with tape.

Figure 3.28-Rock on String.

3. Crumple a piece of newspaper around the rock, forming a ball. Keep the long string outside of the newspaper. Check the circumference of the newspaper covered rock with your 79 cm-long string. Add or take paper away until it has the correct circumference.

Figure 3.29-Crumpling a Ball of Newspaper.

4. Tape the ball to hold its size and shape.

Figure 3.30-Taped Ball.

5. Cover the ball with a thin layer of papier-mâché. Be careful not to increase the circumference of your planet too much by using too much papier-mâché.

Figure 3.31-Papier-mache.

6. Hang up your model of Jupiter to dry while you clean up.

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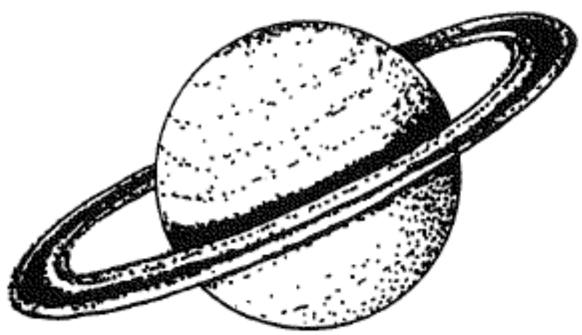
Mission 3
What's My Planet?

Planet-Building Instructions–
The Rocky Center of Saturn

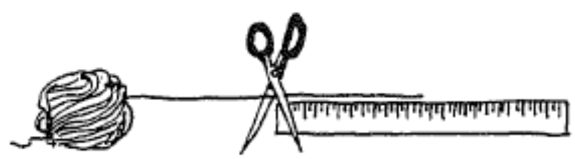
Saturn is the second largest planet in our solar system. Scientific evidence suggests that its solid center is probably made up of rock.

Figure 3.32-Saturn.



1. At this scale (1 to 210 million), the rocky center of your model of Saturn should have a circumference of 84 centimeters. Cut a piece of string that is 84 centimeters long. Wrap a piece of tape around each end of the string.

Figure 3.33-Measuring String.



2 Select a large rock. Measure the rock to make sure that the circumference of the rock is smaller than the 84 cm circumference of the rocky center of your planet. Tie a long string to the rock so that you may hang up Saturn later. Secure it with tape.

Figure 3.34-Rock on String.

3. Crumple a piece of newspaper around the rock, forming a ball. Keep the long string outside of the newspaper. Check the circumference of the newspaper covered rock with your 84 cm-long string. Add or take paper away until it has the correct circumference.

Figure 3.35-Crumpling a Ball of Newspaper.

4. Tape the ball to hold its size and shape.

Figure 3.36-Taped Ball.

5. Cover the ball with a thin layer of papier-mâché. Be careful not to increase the circumference of your planet too much by using too much papier-mâché.

Figure 3.37-Papier-mache.

6. Hang up your model of Saturn to dry while you clean up.

Mission 3
What's My Planet?

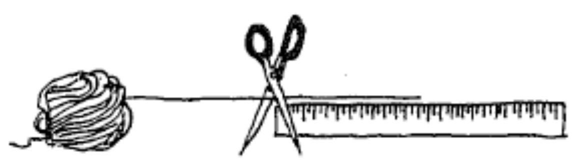
Planet-Building Instructions–
The Rocky Center of Uranus

Scientific evidence suggests that the solid center of Uranus is probably made up of rock and ice.

Figure 3.38-Uranus.

1. At this scale (1 to 210 million), the rocky center of your model of Uranus should have a circumference of 22 centimeters. Cut a piece of string that is 22 centimeters long. Wrap a piece of tape around each end of the string.

Figure 3.39-Measuring String.



2 Select a large rock. Measure the rock to make sure that the circumference of the rock is smaller than the 22 cm circumference of the rocky center of your planet. Tie a long string to the rock so that you may hang up Uranus later. Secure it with tape.

Figure 3.40-Measuring String.

3. Crumple a piece of newspaper around the rock, forming a ball. Keep the long string outside of the newspaper. Check the circumference of the newspaper covered rock with your 22 cm-long string. Add or take paper away until it has the correct circumference.

Figure 3.41-Crumpling a Ball of Newspaper.

4. Tape the ball to hold its size and shape.

Figure 3.42-Taped Ball.

5. Cover the ball with a thin layer of papier-mâché. Be careful not to increase the circumference of your planet too much by using too much papier-mâché.

Figure 3.43-Papier-mache.

6 Hang up your model of Uranus to dry while you clean up.

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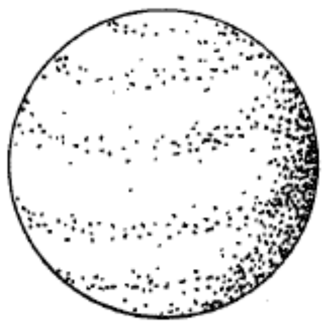
Mission 3
What's My Planet?

Planet-Building Instructions–
The Rocky Center of Neptune

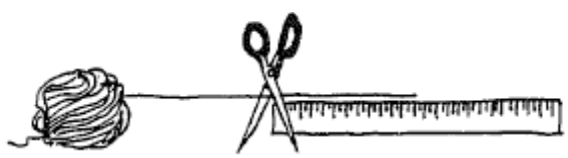
Scientific evidence suggests that the solid center of Neptune is probably made up of rock and ice.

Figure 3.44-Neptune.



1. At this scale (1 to 210 million), the rocky center of your model of Neptune should have a circumference of 46 centimeters. Cut a piece of string that is 46 centimeters long. Wrap a piece of tape around each end of the string.

Figure 3.45-Measuring String.



2. Select a small rock. Measure the rock to make sure that the circumference of the rock is smaller than the 46 cm circumference of the rocky center of your planet. Tie a long string to the rock. Secure it with tape.

Figure 3.46-Rock on String.

3. Crumple a piece of newspaper around the rock, forming a ball. Keep the long string outside of the newspaper. Check the circumference of the newspaper covered rock with your 46 cm-long string. Add or take paper away until it has the correct circumference.

Figure 3.47-Crumpling a Ball of Newspaper.

4. Tape the ball to hold its size and shape.

Figure 3.48-Taped Ball.

5. Cover the ball with a thin layer of papier-mâché. Be careful not to increase the circumference of your planet too much by using too much papier-mâché.

Figure 3.49-Papier-mache.

6. Hang up your model of Uranus to dry while you clean up.

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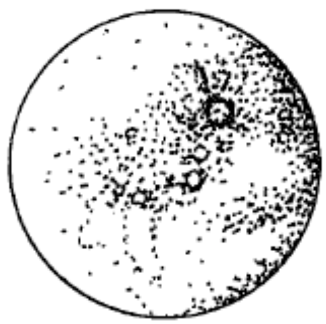
Mission 3
What's My Planet?

Planet-Building Instructions–
The Rocky Center of Dwarf Planet Pluto

The dwarf planet Pluto is probably made up of ice-covered rock. Pluto's moon, Charon, is about one-half the size of Pluto. Some scientists consider it a double planet system.

Figure 3.50-Pluto.



1. At this scale (1 to 210 million), the rocky center of your model of Pluto should have a circumference of 1.5 centimeters. Cut a piece of string that is 1.5 centimeters long. Wrap a piece of tape around each end of the string.

Figure 3.51-Measuring String.

2. Select a very small rock. Measure the rock to make sure that the circumference of the rock is smaller than the 1.5 cm circumference of the rocky center of your planet. Tie a long string to the rock so that you can hang up Pluto later. Secure it with tape.

Figure 3.52-Rock on String.

3. Crumple a piece of newspaper around the rock, forming a ball. Keep the long string outside of the newspaper. Check the circumference of the newspaper covered rock with your 1.5 cm-long string. Add or take paper away until it has the correct circumference.

Figure 3.53-Crumpling a Ball of Newspaper.

4. Tape the ball to hold its size and shape.

Figure 3.54-Taped Ball.

5. Cover the ball with a thin layer of papier-mâché. Be careful not to increase the circumference of your planet too much by using too much papier-mâché.

Figure 3.55-Papier-mache.

6. Hang up your model of the dwarf planet Pluto to dry while you clean up.

Mission 3
What's My Planet?

Clues for Our Planet

We think our planet is: ____

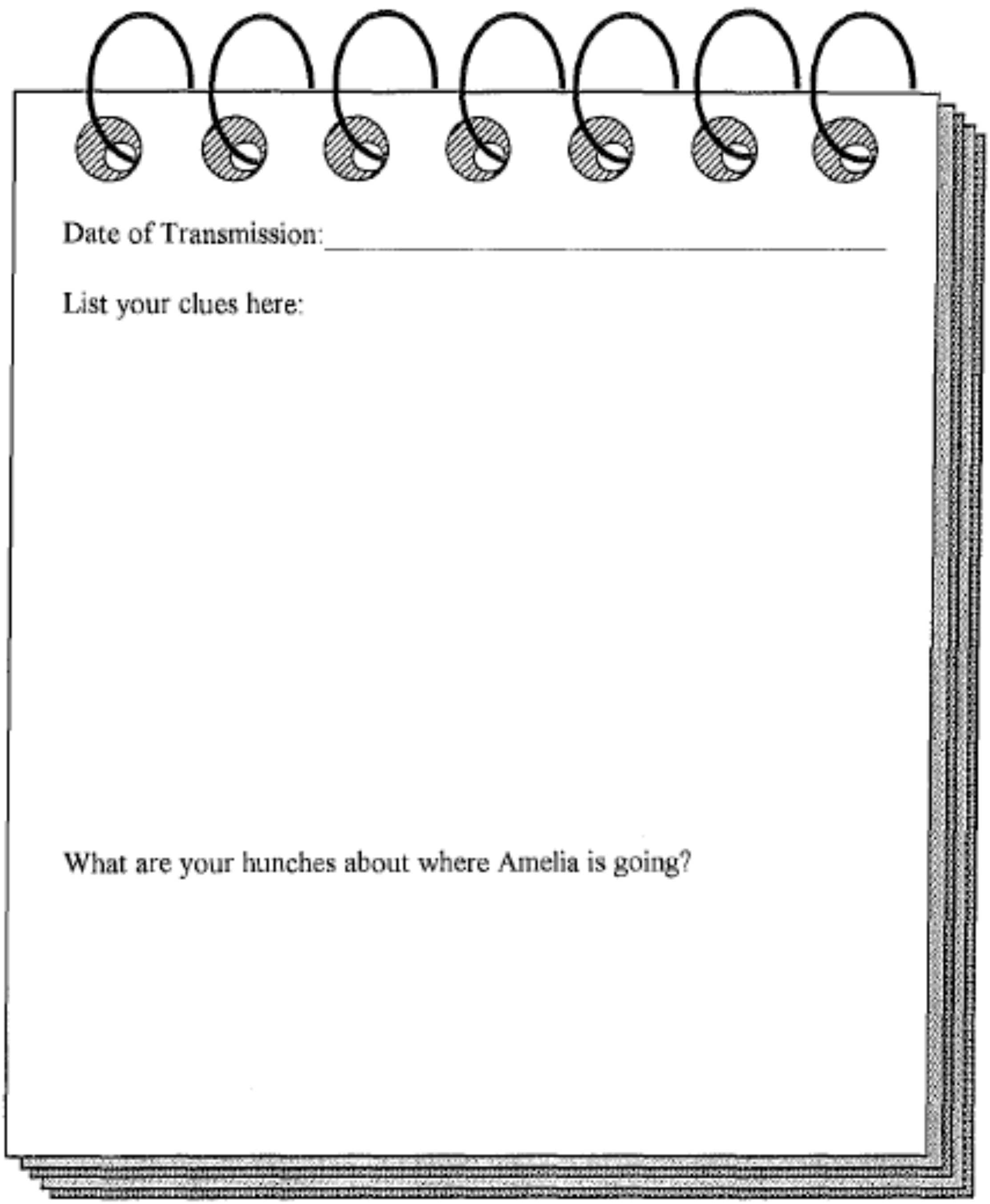
Notes:

Mission 3

What's My Planet?

Now that you have had a chance to collect more information about Amelia's trip, which hunch was correct? Why? (Use the back of this sheet for your answers.)

Figure 3.56-Science Detectives Notebook.



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Mission 4
How Big Is My Planet?

Learning About the Concept of Scale

Overview

In mission 4.1, students learn about the concept of scale by creating scaled and unscaled drawings. In mission 4.2, students find out that the circumference of each planet model is 210 million times smaller than the circumference of the actual planet. Each student team converts the scaled circumference measurement of their model planet to actual size to see if it matches the clue that Amelia gave in mission 3's video transmission.

Teacher's Note: There is no video segment for this mission.

Concepts

- The apparent size of an object changes as the distance between the observer and the object changes.

Skills

- Creating scaled and unscaled drawings.
- Converting a scale number to an actual measurement.

Mission 4.1

Materials

For the Class

- Assortment of Earth globes and maps
- Transparency of "View of Saturn" (Fig. 4.4a, page 110)
- Transparency of "View of Saturn with Grid Lines" (Fig. 4.4b, page 111)
- Overhead projector
- Masking tape (for projector)

For Each Team

- Science Detectives Notebook

For Each Student

- 2 sheets of drawing paper (8-by-8-inches)
- Pencil

Getting Ready

One or More Days Before Class

1. Make 8-by-8-inch drawing sheets for each student.

2. Make a transparency of each of the two pages "View of Saturn" and "View of Saturn with Grid Lines."

3. Set up and adjust the computer or projector so that it will project a 32-by-32-inch image of the "View of Saturn" onto a screen. Check the size by holding up one of the 8-by-8-inch squares. It should fit inside one of the square segments of the planet view with grid lines. Mark the position of the projector on the floor with masking tape so you can align it quickly. Now, move the projector toward the screen until it projects a 16-by-16-inch image. Check the size by holding up one of the 8-by-8-inch squares. It should fit just inside four of the square segments of the planet view with grid lines. Mark the position of the projector on the floor with masking tape so you can replace it quickly.

Classroom Action

1. **Lecture.** Remind students about the scientists' suggestion from the previous video segment: build planet models to learn more about Amelia's whereabouts. Ask if anybody remembers what Buzz Sawyer said they should do with the planet models.

   Buzz says, "See, the scientists are busy making scale models of the solid centers of the planets because this will tell us where she is. You see, once the models are built, all we have to do is measure their circumferences, multiply by the scale factors, and that'll give us Amelia's destination!"

   Point out the maps and globes in the classroom. Explain the concept of a scale model by asking why people don't make full size maps and globes. *(They are much too large and unmanageable. For instance, if it were possible for the class to make a full-size model of Jupiter and rest it on the roof of the school, it would reach one-third of the way to the Moon! And it would be much larger than Earth itself!)*

2. **Demonstration.** Project the image of Saturn without gridlines (page 110) onto the screen. Tell students that this is a view of the planet Saturn and one of its moons as it might be seen from a different moon of Saturn. The very bright star in the picture is the Sun!

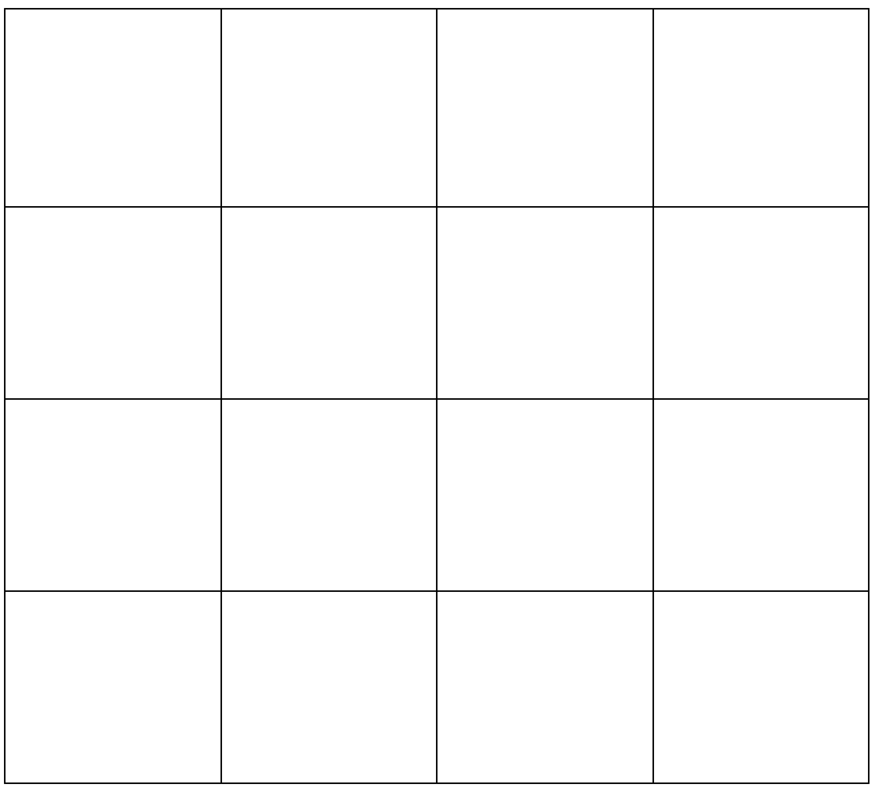
3. **Activity.** Hand out the square sheets of paper and ask students to take three minutes to draw a picture of the planet view onto their sheets of paper. Prompt them to sketch their drawings quickly, and so they look just like what they see on the screen, only smaller.

4. **Discussion.** Ask students to compare their sketches to the projected image. Discuss how accurate their pictures are. Point out how difficult it is to draw something accurately if you don't use a scale.

5. **Demonstration.** Project the image of the planet view with grid lines (page 111) onto the screen. Explain that dividing the picture into squares might make it easier to draw accurately.

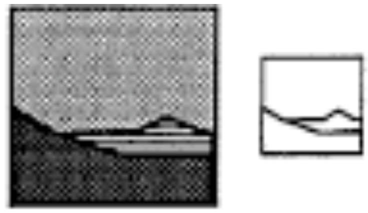
   Give each student a new 8-by-8-inch sheet of drawing paper. Demonstrate how to fold the paper twice, unfold it, and fold it twice in the opposite direction to make a grid four squares by four squares as shown in figure 4.1. Ask students to follow your example with their sheets. They should then unfold their sheets. Point out that their sheets should have a blank side with a grid just like the grid on the planet view that is projected.

Figure 4.1-Sixteen Squares.



6. **Activity.** Challenge students to try drawing the scene again, this time using the grid lines to help them make it more accurate. Encourage them to focus on one grid square at a time, as shown in figure 4.2.

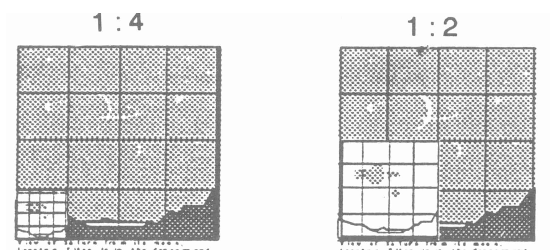
Figure 4.2-Drawing One Square.



7. **Discussion.** Ask students to discuss their results and how it was easier to draw an accurate picture with the grid.

8. **Demonstration.** Position the overhead projector so it will project a 16-by-16-inch image. Hold one student's completed 8-by-8-inch drawing against the projected image with a grid, as shown in figure 4.3. Show that the projected planet view is exactly two times bigger than the drawing. Explain that the scale of the drawing is 1:2 (1 to 2). That means that one square on the vertical axis of the drawing represents something in the real world that is two times bigger. Back up the projector and repeat for the 32-by-32-inch image. The scale of the student's drawing is now 1:4 (l to 4).

Figure 4.23-Two scales.



Invite students to look at the maps and globes you brought. Ask them if they can find the map scale. Allow students time to find some of the scales and see how large they are. If a scale factor is 1:50,000–for example–emphasize that this means that one centimeter on the globe represents 50,000 centimeters in real life! Scale is usually also shown graphically on maps, in the key.

Demonstrate how to use the map scale to find the distance between two places on a map or globe by using a piece of string as a measuring tool. Use the graphical representation of the scale to find the actual distance.

Mission 4.2

Materials

For the Class

- Dry models of the rocky centers of the planets, from mission 3

For Each Team

- Science Detectives Notebook
- “Scale Size in Kilometers Measuring Tape” (pages 112 and 113)
- Measuring tapes used in mission 1
- Circumference strings from mission 3
- Scissors
- Transparent tape

For Each Student

- Pencil

Getting Ready

One or More Days Before Class

1. Copy the first “Scale Size Measuring Tape” page for each team. Jupiter and Saturn teams will eventually make measurements that are greater than 1 meter in mission 5.2.

2. (210,000 actual kilometers).

2. *(optional)* To save class time, construct the “Scale Size Measuring Tapes” for students by cutting each strip out and taping them together, end to end.

3. On the “Clues from Video” chart, prepare a table for recording circumference measurements, like the one shown in table 4.1.

Table 4.1-Rocky Center Circumference Table.

Planet	Model Circumference	Approximate Actual Circumference of Planet
Mercury		
Venus		
Earth		
Mars		
Jupiter		
Saturn		
Uranus		
Neptune		
Pluto		

Classroom Action

1. **Lecture.** Remind students why they constructed the planet models: They are supposed to measure them to find out which planet has a rocky center circumference of 37,400 kilometers. Tell students that the scale of the planet models is 1:210,000,000 (1 to 210 million)! This means each centimeter on the model is equal to 210 million centimeters in "real life."

2. **Activity.** Announce that you have a special measuring tape that will measure a model planet as if it were actually 210 million times bigger than it is. Hand out the "Scale Size Measuring Tape" pages (or the pre-constructed measuring tapes, if you made them yourself) to each team (only the Jupiter and Saturn teams need the second page) and give teams time to assemble their tapes (see step 2 under "Getting Ready" for mission 4.2). Have each team measure the circumference of their model with the actual size measuring tape. Let students know that you don't expect their measurements to be exact. The tape measurement will be an approximation, and they will need to estimate. Hand out the circumference strings from mission 3 and have teams measure those for comparison. Have students measure the model size with the regular measuring tapes used in mission 1. Show them how to record their scale size and actual size circumferences on the "Rocky Center Circumference Table" on the "Clues from Video" chart. When teams have finished, collect and save the "Actual Size Measuring Tapes" and regular measuring tapes. Teams will use them again in mission 5.

Closure

1. **Discussion.** Students' numbers on the "Rocky Center Circumference Table" will not be exactly the same as those in table 4.2. Have students look for the number that most closely matches Amelia's clue: 37,400 kilometers. Remind students of Amelia's second clue: Just a

little smaller than Earth's solid center. Students should be able to confirm that Amelia is headed for Venus!

Table 4.2-Rocky Center Circumference Table-Teacher's Key.

Planet	Model Circumference (Solid/Rocky Center)	Approximate Circumference of Planet Rocky Core (Used in Guide)	Actual Circumference of Planet's Solid/Rocky Core (According to Recent NASA Data)
Mercury	7.0 cm	15,300 km	15,300 km
Venus	18.0 cm	38,000 km	38,000 km
Earth	19.0 cm	39,900 km	40,000 km
Mars	10.0 cm	21,000 km	21,300 km
Jupiter	79.0 cm	165,900 km	Not accurately measured
Saturn	84.0 cm	176,400 km	Not accurately measured
Uranus	22.0 cm	46,300 km	Not accurately measured
Neptune	46.0 cm	96,600 km	Not accurately measured
Pluto	1.5 cm	7,400 km	7,400 km

Going Further

Activity: Scientific Illustration

Have students use photographs of astronomical objects, animals, or other scientific subjects from magazines as models for scientific illustration of an accurate, scaled drawing. They may fold the magazine photograph or use a ruler to draw a grid over it. They should make two pictures: one twice as big as the original and one only half the size of the original. Have them label the scales.

Activity: Take Planetary Hikes

Take a Solar System Walk. Complete instructions are at:

http://www.noao.edu/education/peppercorn/pcmain.html

Mission 4
How Big Is My Planet?

View of Saturn

Figure 4.4a-View of Saturn from Its Moon, Iapetus. Titan is in the foreground; the bright star is Sol (the Sun).

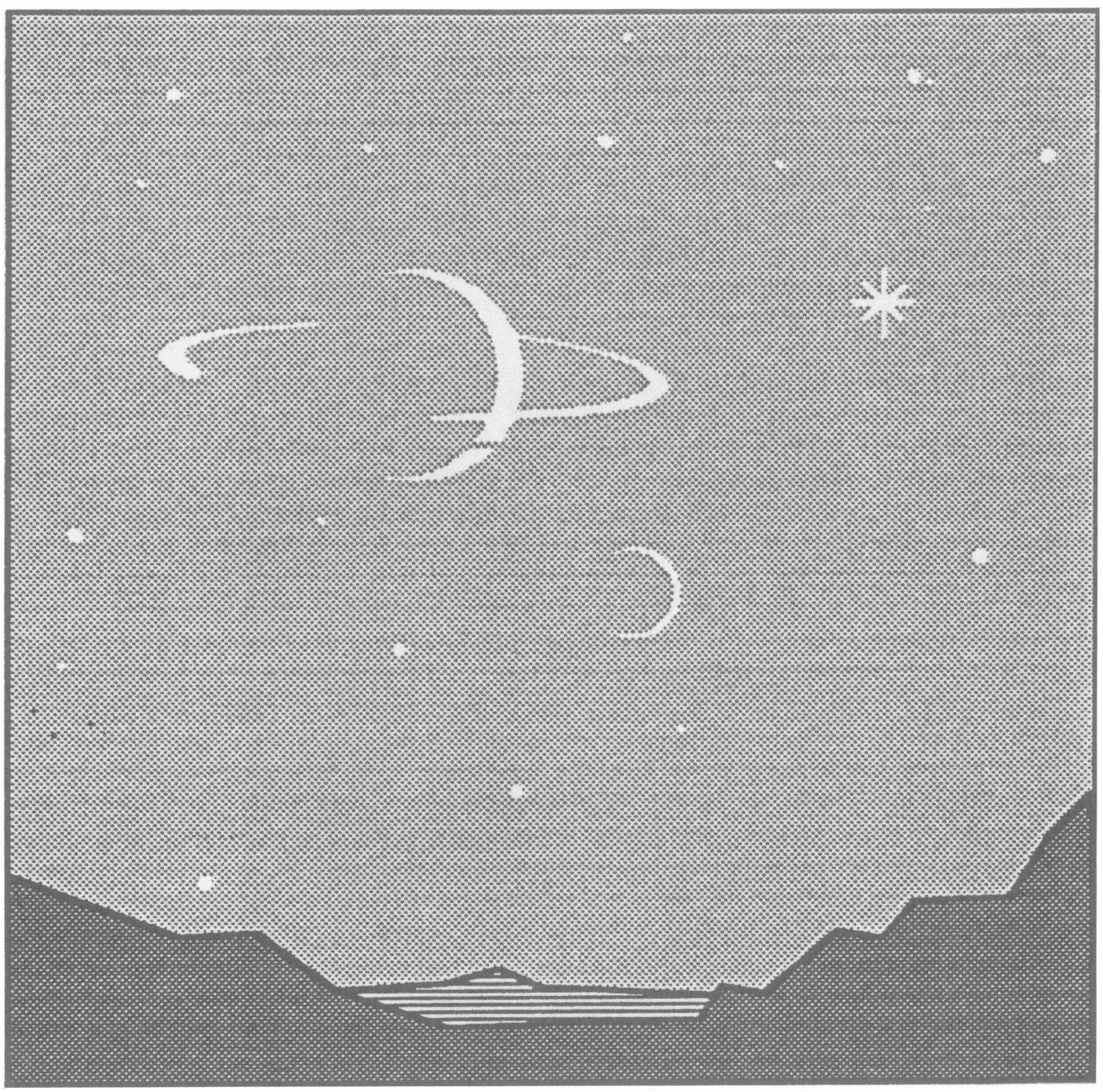


Figure 4.4b-View of Saturn from Its Moon, Iapetus. Titan is in the foreground; the bright star is Sol (the Sun).

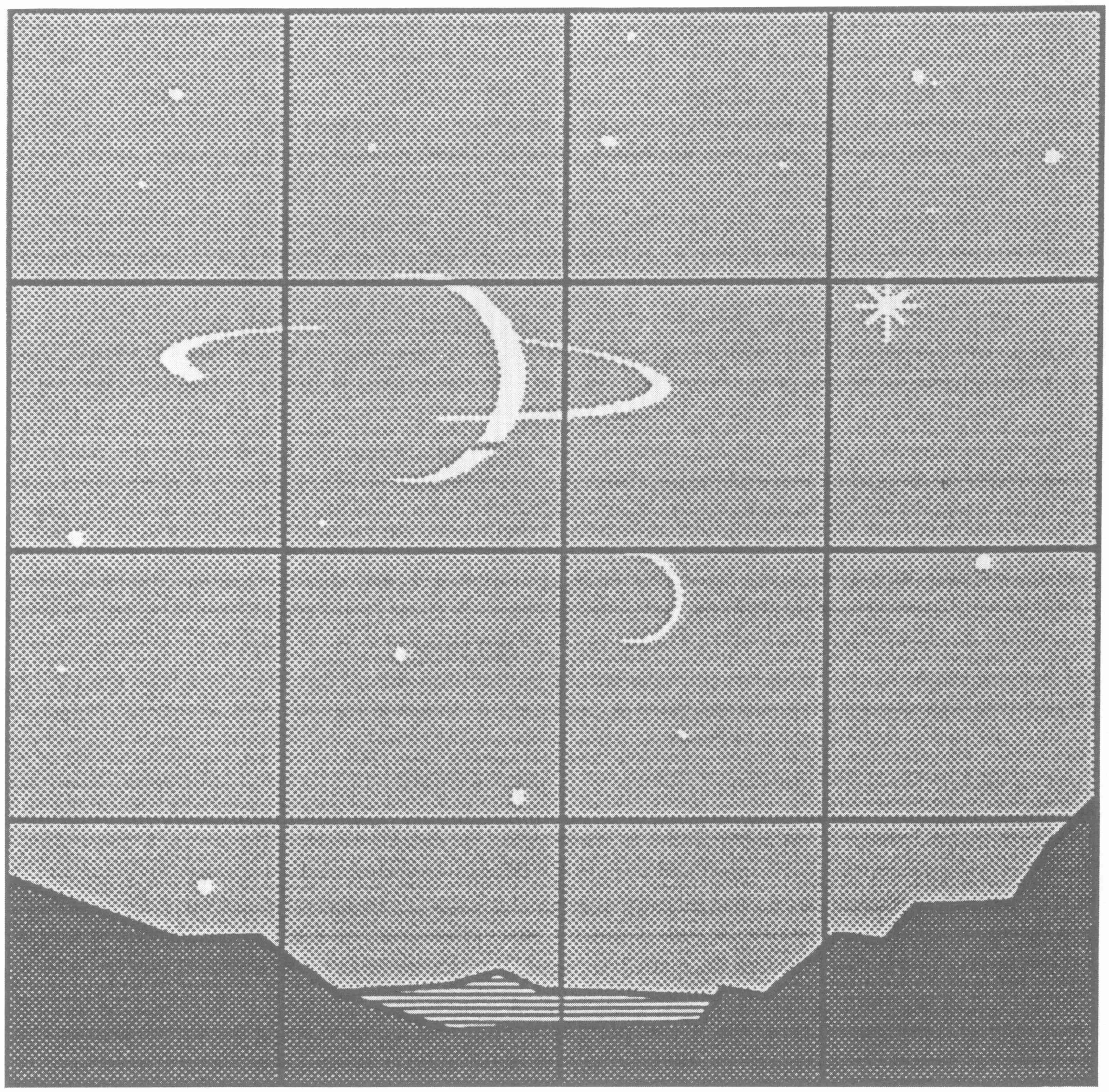


Figure 4.5—Scale Size in Kilometers Measuring Tape.

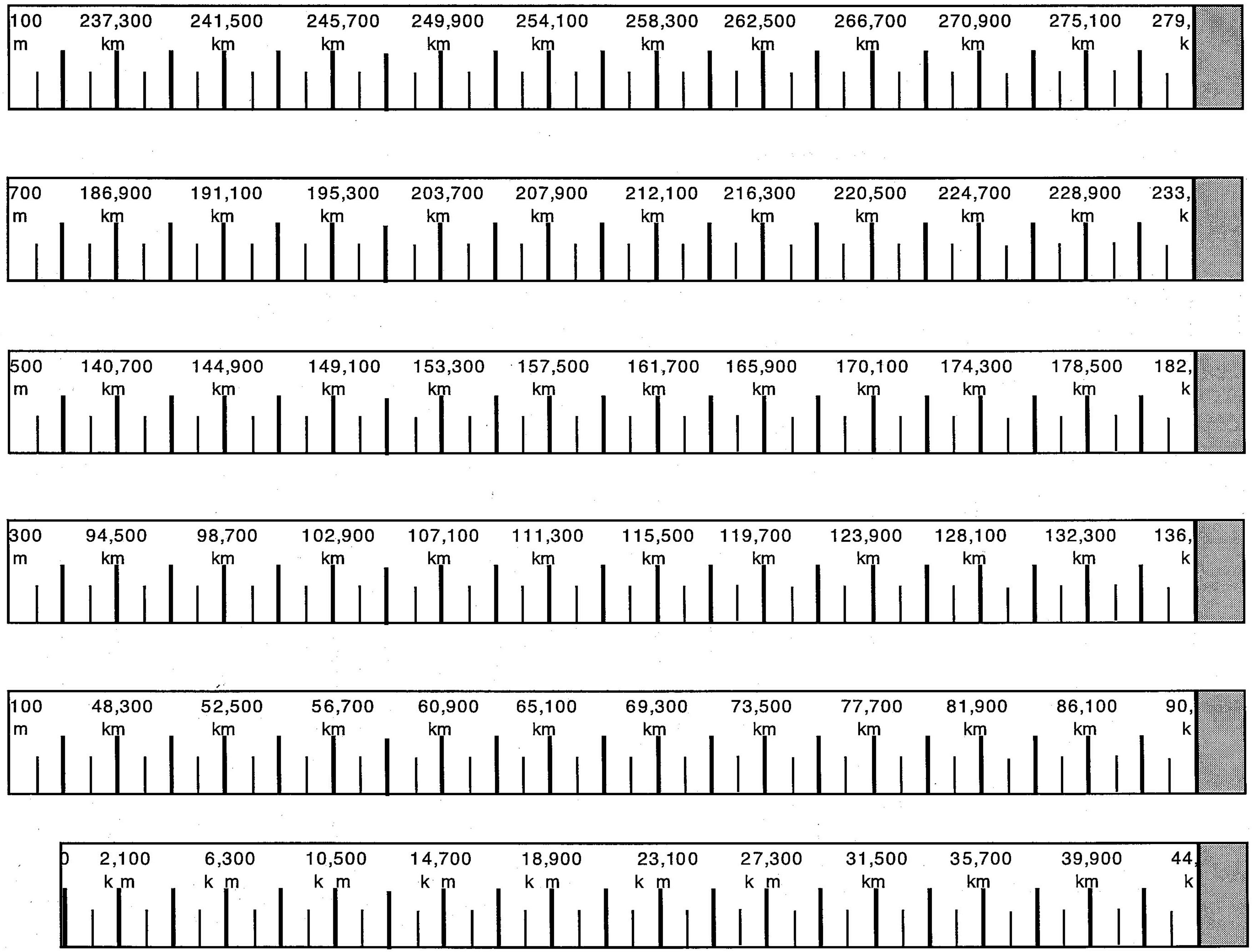
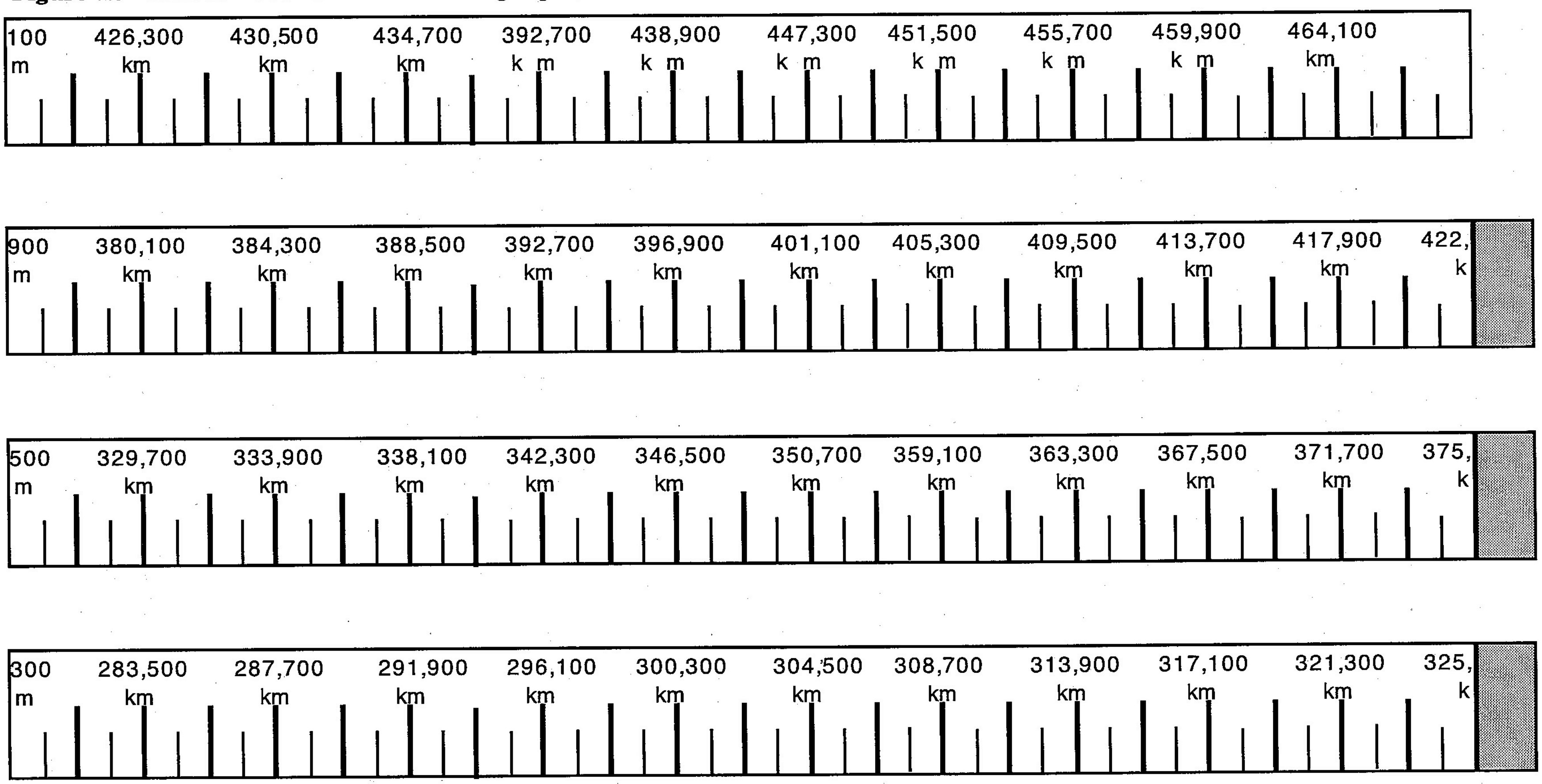


Figure 4.5—Scale Size in Kilometers Measuring Tape *(continued)*



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Mission 5
Seeing Planet Attributes

Many Things Are the Same and Many Things Are Different

Overview

In mission 5.1, students watch a video segment that confirms Amelia's first destination: Venus. The clue for this mission: Amelia is now headed for a planet that has a liquid layer (hydrogen envelope) that is 445,000 kilometers in circumference. Her next destination is Jupiter. Students learn about attribute diagrams, also called Venn diagrams, as a way to visualize the similarities and differences of the planets in our solar system. In mission 5.2, student teams add liquid layers to their planet models and measure the new circumferences, using the scale factor to find the circumferences of the actual planets. Teams create attribute diagrams for their planets.

Concepts

- The planets in our solar system have many similarities and differences.

Skills

- Making and interpreting Venn attribute diagrams.
- Using diagrams to group planets by attributes.
- Measuring the circumference of a planet model using a scale factor to measure the actual circumference of a planet.
- Adding a liquid layer to a planet model.

Mission 5.1

Materials

For the Class

- *The Science Detectives* video, "Lesson 5"
- Computer, and projector or monitor
- "Planet Bar Graph"

For Each Team

- Science Detectives Notebook
- "Organizing Attributes" Logbook sheets (pages 140-141)

For Each Student

- Pencil

Getting Ready

Just Before the Lesson

1. Add a heading "Fourth Transmission" to the "Clues from video" chart.

2. Set up the projector. Forward video to "Lesson 5" (This is the fourth transmission from Amelia because there was no video segment for mission 4.)

3. Make one copy of the "Planet Bar Graph" (page 125)

Classroom Action

1. **Video.** Tell students that they have received another message from Amelia Spacehart. Let's find out if NASA has caught up with the Science Detectives! They should watch and listen very carefully to find out if Amelia gives a clue about her next destination.

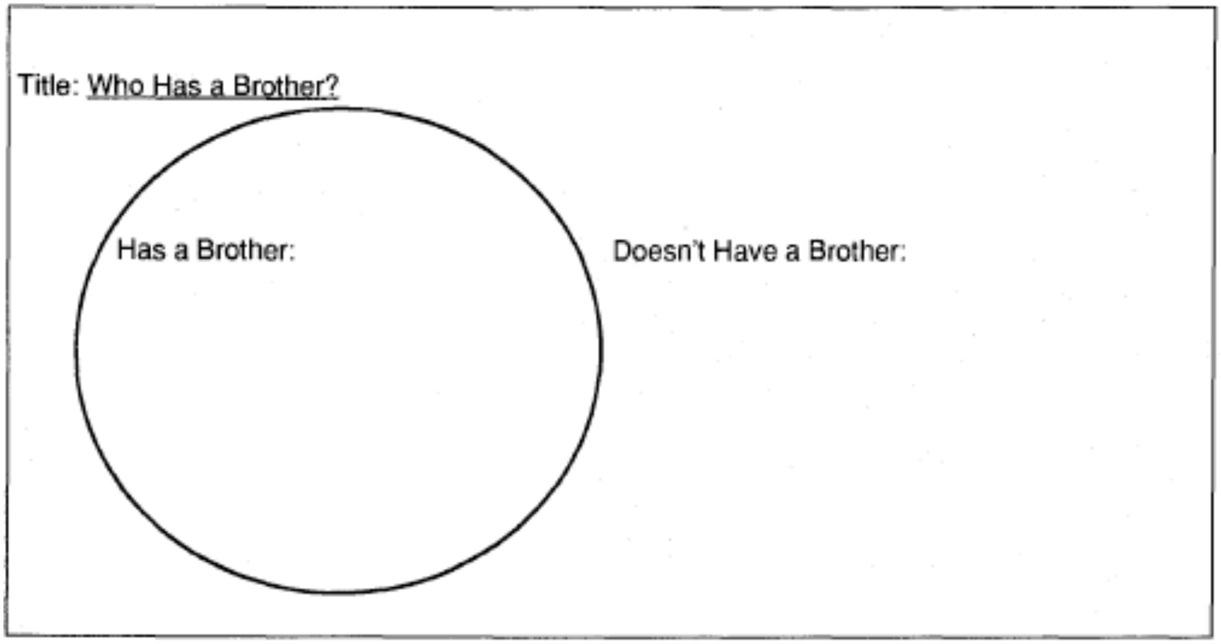
   Show the video segment "Lesson 5" that confirms that the planet with a solid surface circumference of 37,400 kilometers is Venus.

2. **Discussion.** Discuss the new information presented in the video segment. Record any clues suggested under a heading "Fourth Transmission" on the "Clues from video" chart. Amelia is looking for a planet with a liquid hydrogen envelope (or ocean); the planet has a circumference of 445,000 kilometers. Show the students the "Planet Bar Graph"; it is the message downloaded from MEL. Explain that each team will get their own copy for use during the next mission. Record her first destination and ask students to predict, based on their knowledge of the positions and distances between the planets, where Amelia will go next. Record their votes on the chart. Teams should record all clues in their Science Detectives Notebooks.

3. **Lecture.** Introduce attribute diagrams by telling students that organizing information is very important to Science Detectives and we often get information in written form, as in books, but often written information doesn't help us see the relationships between facts. Encourage understanding that Science Detectives need to know the relationships between facts as much as they need to know the facts themselves.

4. **Demonstration.** Tell students that pictures can show information in a way that helps us see the relationship of facts. Draw a one-attribute diagram on the whiteboard, as shown in figure 5.1. Title the diagram "Who Has a Brother?" Title the circle "Has a brother:" and the area outside the circle "Doesn't have a brother:"

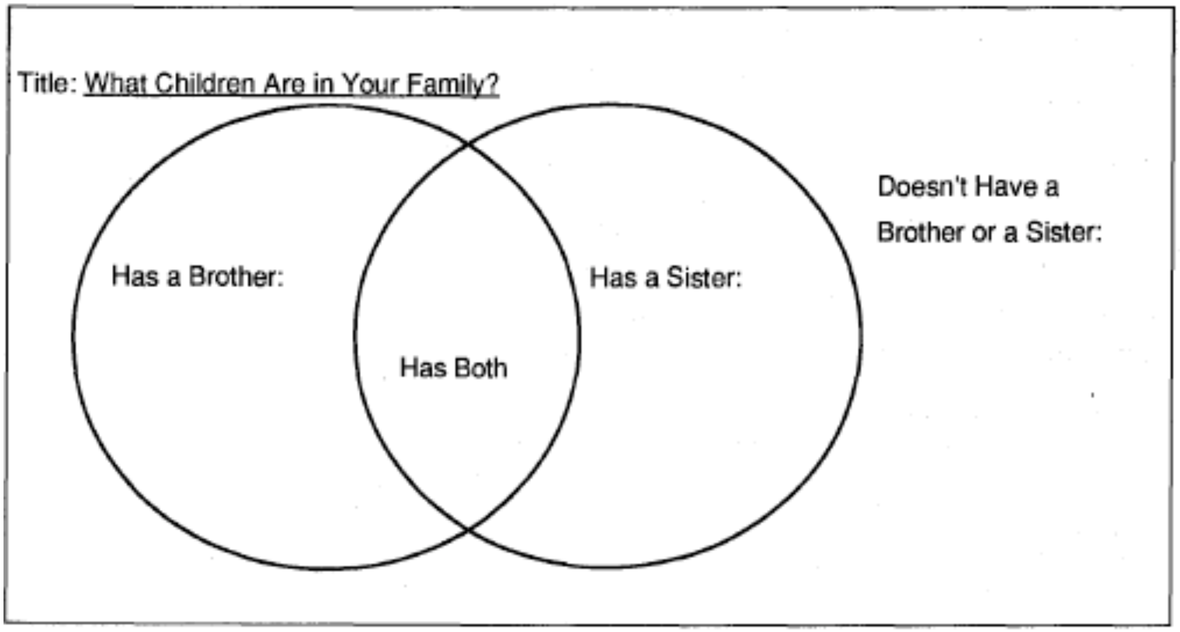
Figure 5.1-Who Has a Brother?



Ask students "Who has a brother? Who does not?" Make sure that students understand the organization of the diagram: Names inside the circle are names of people who have brothers. Names outside the circle are of people who do not. Draw a second copy of the one-attribute diagram to illustrate "Has a sister:" "Doesn't have a sister:" List students' names again.

Explain to students that a one-attribute diagram can give us a lot of interesting information, but things get much more interesting when a two-attribute diagram is used. Draw a two-attribute diagram on the chalkboard, combining the two attributes used in the first demonstration: brothers and sisters, as shown in figure 5.2.

Figure 5.2-What Children Are in Your Family?

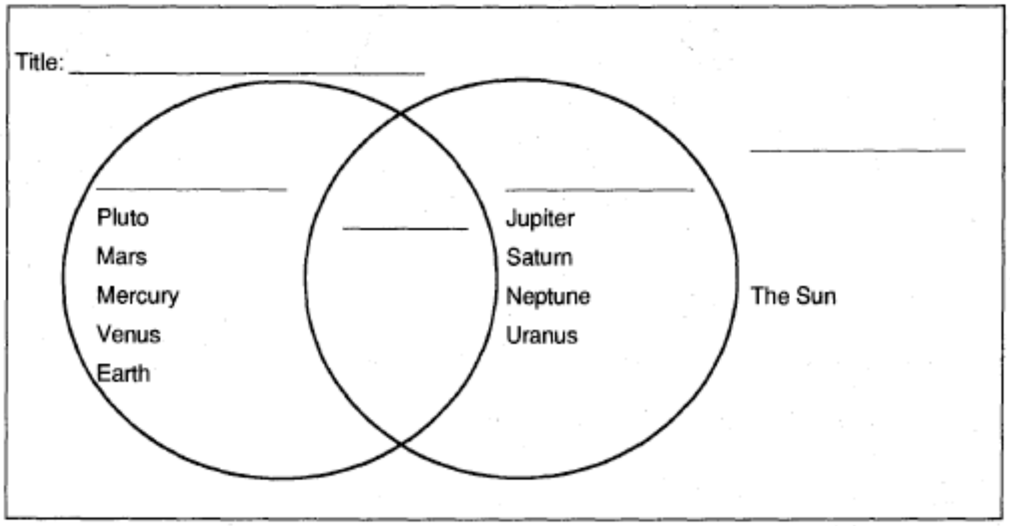


Encourage students to try to interpret the information as you write it on the whiteboard. Who has both a brother and a sister? These people should be listed inside the lines where the two circles overlap. Who has a brother but no sister and where should they be listed? Who has a sister but no brother and where should they be listed? Is there anyone who was outside the circle on both of the one-attribute diagrams? Where should they be placed on the two-attribute diagram?

Give students a series of statements about the relationships between the facts on the diagrams and let them decide if the statements are true or false. For example: More people in this class have brothers than sisters. True or False? As students interpret the diagram, point out that they are now determining relationships based on the facts listed on the diagram.

5. **Discussion.** On the whiteboard, draw an attribute diagram like the one in figure 5.3 to illustrate how students should design their own posters. Tell students that they will be creating their own attribute posters, like these, in mission 5.2.

Figure 5.3-Planets' Attribute Diagram #1.

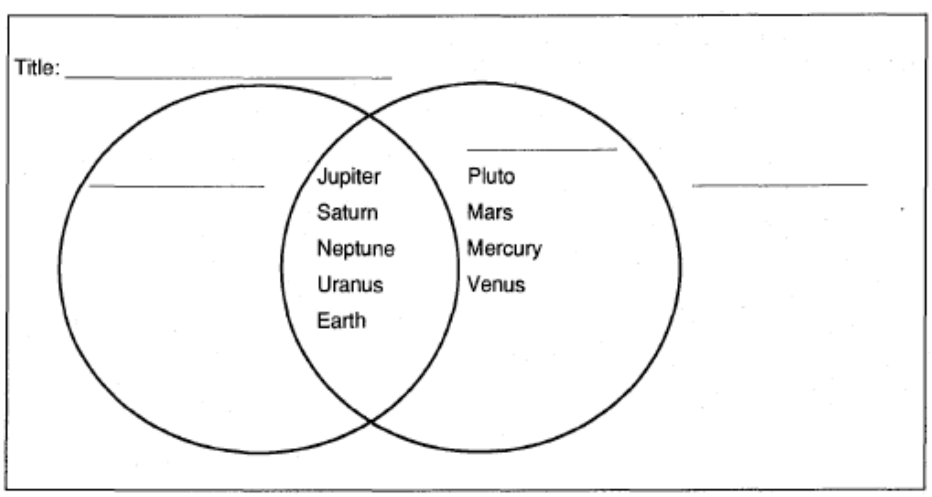


Ask students how the planets inside the circles are alike. Ask students to come up with attribute titles for the two circles, the intersection, and the space outside the circles. *("Rocky planets," "Gas giant planets," "Rocky* and *gas giant planets,*" *"Neither rocky nor gas giant planets.")* There are no planets listed where the circles intersect because no planets are considered to be both rocky and a gas giant.

Now have students come up with a title for the diagram. *("Large Objects in Our Solar System,"* or *What's in Our Solar System?'')* You could also write planet names on index cards and attach them to the Venn diagrams with masking tape. The cards could then be easily moved around to make different attribute diagrams.

Draw another illustration of an attribute diagram on the whiteboard like the one shown in figure 5.4.

Figure 5.4-Planets' Attribute Diagram #2.



Ask students how the planets inside the circles are alike and how the planets in the intersection are different from the others. Ask students to come up with attribute titles for the two circles, the intersection, and the space outside the circles. *("Planets that have a liquid layer," "Planets that have a gas layer," "Planets that have a liquid* and *gas layer," "Planets that have neither liquid nor gas layers.")* There are no planets listed outside the diagram because no planets lack both liquid and gas layers. Now have students come up with a title for the diagram. *("What Are the States of Matter of Our Planet?'')*

6. **Activity.** Once you are sure that the class understands the organization of the attribute diagrams, each team will complete the Logbook sheets "Organizing Attributes" using the "NASA Planetary Directory" and any information they have discovered as they worked on their planet models. Have student teams work together to complete the Notebook sheet.

Teacher's Note: If students need more examples, you could make other attribute diagrams, such as a two-attribute diagram with "Planets with Rings," "Planets with Moons," "Planets with Moons and Rings," and "Planets with Neither Moons nor Rings; or a one-attribute diagram titled "Which Planets Are Inside the Asteroid Belt?"

Mission 5.2

Materials

For Each Team

- Science Detectives Notebook
- Planet Building Instructions" for the team's assigned planet
- "Message from MEL to the Science Detectives" Logbook sheet
- "Scale Size in Kilometers Measuring Tape" from mission 4
- Felt tip markers
- String
- Several large sheets of white construction paper
- Meter tape
- Masking tape
- Newspaper
- Tempera paints
- Paintbrushes
- Pie tins for mixing paint

Teacher's Note: The information that is "downloaded from MEL" is a graph showing how much solid, liquid, and gas is present in each planet, and in two stars. This is extra material that you may give to students as reference when they begin new attribute posters. (See the Logbook sheet "Message from MEL to the Science Detectives" on page 125.)

Jupiter and Saturn teams will need the large tape made from pages 112 and 113.

For Each Student

- Pencil

Getting Ready

One or More Days Before Class

1. Mix various colors of tempera paint in pie tins. Have extra tins available for mixing new colors. You may want to tear the masking tape into small pieces at this time.

Table 5.l-Liquid Layer Circumference.

Planet	Circumference	Actual Size
Mercury		
Venus		
Earth		
Mars		
Jupiter		
Saturn		
Uranus		
Neptune		
Pluto		

2. Add a “Liquid Layer Circumference” table (like the one shown in table 5.1) to the “Clues from video” chart.

3. Copy the “Planet-Building Instructions” for the liquids and landforms of planets (each team gets one set of instructions for one planet). Also copy the “Message from MEL,” one per team.

Teacher’s Note: Adding the liquid layers to some of the larger planets can be quite messy and time consuming. See table A.5 (in Appendixes) for the actual finished sizes of the planet models.

Classroom Action

1. **Activity.** Hand out the appropriate “Planet Building Instructions” to each team. Teams add the liquid layers, or landforms, to their planets. Some of the layers are so thin that they are represented by a single, thin layer of color. Other planets do not have any liquid at all. The teams that have planets with no liquid should add painted landforms to their models.

   As teams finish, they should begin working on new attribute posters. Each team makes at least one poster, or more if they finish early. Teams use the Logbook sheets “Organizing Attributes” that they completed during mission 5.1 to decide which planet attributes they will use to create one or more attribute posters to share with the class. They use the large sheets of white construction paper and felt tip markers to make a two-attribute diagram. The planet names or drawings of the planets can be used on the posters. The attributes, titles, and headings should not be listed on the paper, though lines can be left to be filled in later. Suggest some attributes to use, such as colors, size (large and small), moons and no moons, warm and cold, and so on.

2. **Discussion.** After each team has created at least one attribute poster, hang the attribute posters on the whiteboard, one at a time, and encourage teams to guess the attributes that were used.

Closure

1. After the model planets have dried, ask teams measure the circumferences of their models using their "Scale Size Measuring Tapes." Record their measurements on the "Liquid Layer Circumference" table on the "Clues from video" chart. Review the last clue from Amelia: She was headed for a planet with a liquid layer circumference of 445,880 kilometers. Based on analysis of the information on the table, students should conclude that this planet is Jupiter!

Going Further

Homework Activity: Make More Venns

Challenge students to create new Venn attribute diagrams that relate to themselves as Science Detectives. For example, they could make diagrams using the clues that Amelia Spacehart has given in her last few transmissions. Challenge students to come up with a Venn diagram that uses more than three attributes.

Mission 5
Seeing Planet Attributes

Script for Fourth Transmission

Synopsis: Lesson 5, January 4
(Travel time =4 days)

- Confirmed: Amelia went to Venus, which has a rocky/solid circumference of 37,400 kilometers.
- Other data received by other Earth observing stations could be a possible ETI message.
- Amelia is looking for a planet with a liquid hydrogen envelope (or ocean) that has a circumference of 445,000 kilometers.
- Dr. Orbit demonstrates why planets near the Sun are rocky, and why planets far from the Sun are gaseous.

DR. ORBIT
"Good news Science Detectives! Based on her last transmission, we think that Amelia might have gone to Venus. [*Interstellar Express* cruising in the neighborhood of Venus.*]* This planet has a solid iron and rock center about 37,400 kilometers in circumference! It is also a nearby rocky planet slightly smaller than Earth."

[Administrator's voice, in background, off camera] "You incompetent, this is the Administrator. I'm going to have your head!"

BUZZ SAWYER
"Amelia, darn her astronaut hide, continues to chase the source of that possible ETI transmission. Well, we didn't believe her at first, well, I didn't believe her, but we've been hearing from other radio astronomers that they're also picking up possible ETI transmissions! The observatory in West Virginia sent us this tape of what some of their data look like."

Telescopes at Green Bank. View of computer screen with detected signal.

"Could there really be another intelligent civilization within our solar system? This signal doesn't come from a natural source, like a quasar or a supernova. However, we haven't yet been able to decode it. But it seems as if Amelia has. That's why she's borrowed the hi-speed, hi-tech, and hi-budget *Interplanetary Express:* to find out if the extraterrestrials are really broadcasting from within the solar system." *[snap, buzz EFX]* "Speak of the devil. .."

AMELIA SPACEHART
Date on screen: January 4
"Hi folks! Tell yah, I know a few places that are *not* the source of my extraterrestrial signal. However the clues are getting much clearer. Right now, I'm off to find a planet that has a liquid hydrogen envelope around the solid center. This envelope is 445,000 kilometers in circumference. It's incredible. 445,000 kilometers. Anyhow, I'm getting, well, a little low on gas here, and I'm hoping that I can use the hydrogen fuel siphon to fill up again!"

DR. ORBIT
"Hey Sawyer, looks like it will be a little while before you get your *Express* back! Boys and girls, remember when I dissected a planet so that we could see what it was made of? Today, I'd like to say a few things about why the planets are made of different amounts of the same stuff. Amelia's last message had a very important clue in it. She mentioned a hydrogen ocean. To understand which planets could have hydrogen oceans, we need to know more about how matter is spread around the solar system."

Visuals: Stellar nursery to the solar system. The Sun turns on and poof–matter spreads all around; gasses are blown out of the inner solar system, leaving only rocky material.

"A new star forms in the galaxy every few days. Stars are born with a disk of dust and gas around them. When the newborn star heats up, most of the gas is blown far away, and then when planets form close to the Sun, they form mostly of rocky material, and planets forming far from the Sun form of rocky and gaseous material. Our computer, MEL, is downloading more information on what planets are made of. Study this information very carefully, boys and girls. We believe that all of it is important to tracking Amelia. I will be working very carefully on this problem, and I hope that you will be also! Good luck, Science Detectives!"

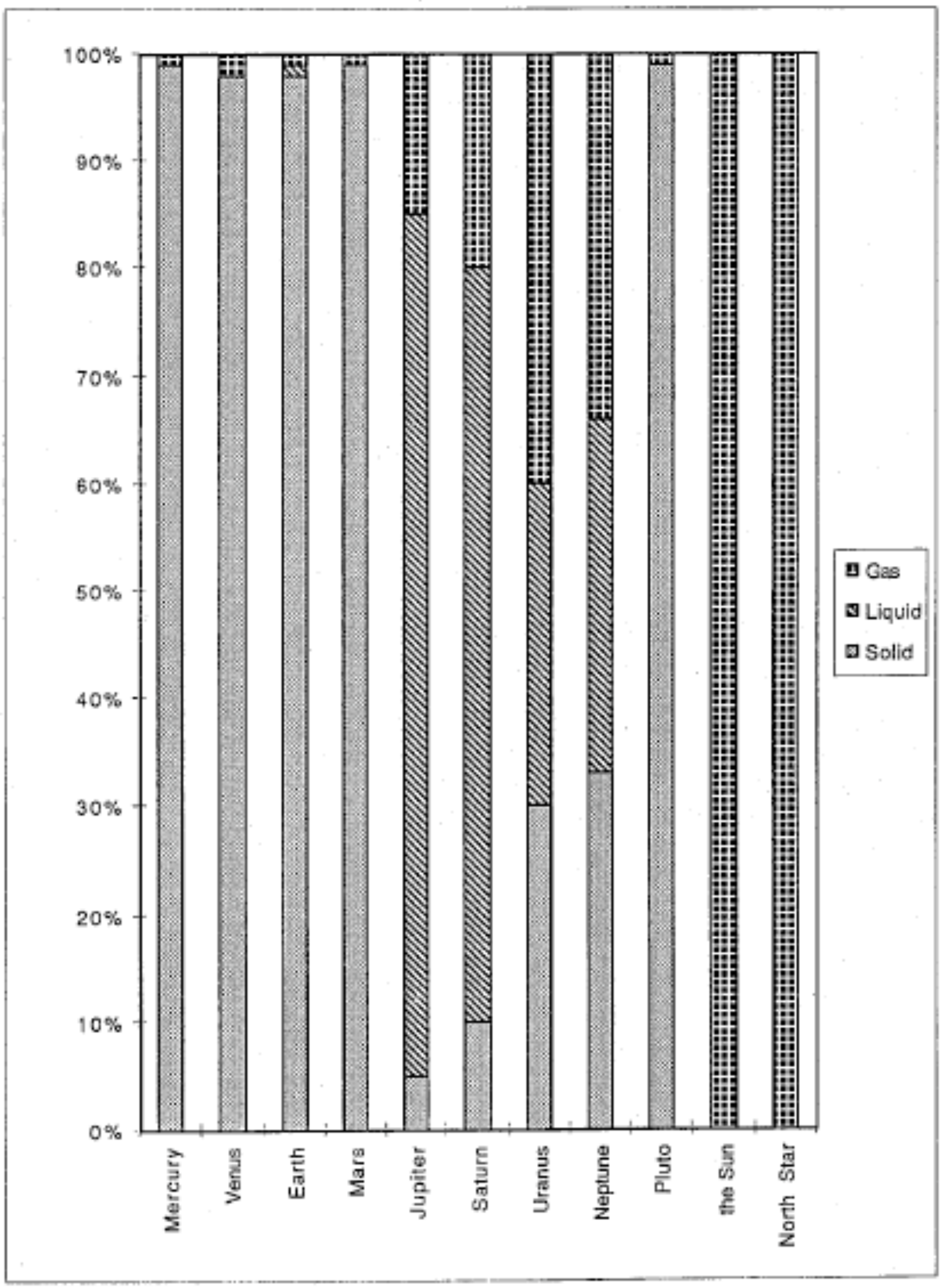
AMELIA SPACEHART
[zip, crackle EFXJ "Here I come!" *[Sound effect of diving plane.]*

Mission 5
Seeing Planet Attributes

Message from MEL to the Science Detectives

This message downloaded to you from the *Interplanetary Express* by Amelia Spacehart:

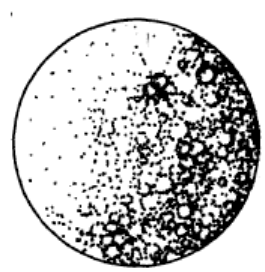
Table 5.2-MEL's Message.



Planet-Building Instructions– Liquids and Landforms of Mercury

Mercury is the closest planet to the Sun. Evidence suggests that it does not have any liquid on its surface because heat from the Sun would cause liquids to evaporate (turn to gas immediately).

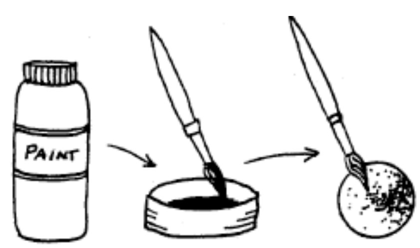
Figure 5.5-Mercury.



Because Mercury does not have a liquid layer, use this time to add surface features to your planet model.

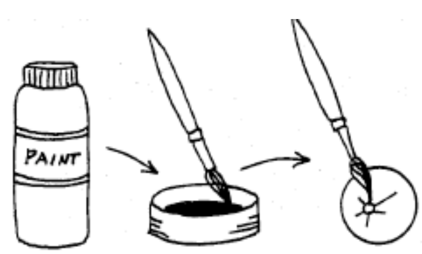
1. Look at the picture of Mercury. Find a picture of Mercury to get an idea of what the surface looks like. Choose a color you think would make the best background color and paint a base coat on your model of Mercury. Allow the model to dry before you go on to the next step.

Figure 5.6-Painting the Base Coat.



2. When the base paint has dried, paint on the features you found in the pictures.

Figure 5.7-Painting Features on the Planet.



3. Hang up your model of Mercury to dry while you clean up.

Mission 5
Seeing Planet Attributes

Logbook

Planet-Building Instructions– Liquids and Landforms of Venus

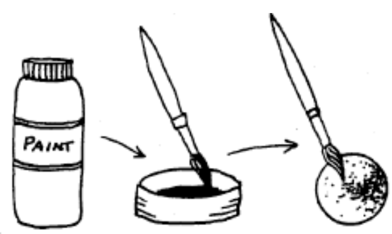
The surface temperature on Venus is 460 C (twice as hot as a household oven). This heat causes most liquids to evaporate (turn to gas) immediately. Venus has mountain ranges, old craters, and gigantic, active volcanoes.

Figure 5.8-Venus

Because Venus does not have a liquid layer, use this time to add surface features to your planet model. The surface of Venus is completely covered by its thick atmosphere (you will add the gas atmosphere to your model later). Paint your model to look like the *surface* of Venus.

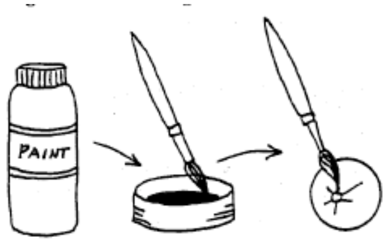
1. Look at the picture of Venus. Find a color radar image of Venus to get an idea of what the *surface* looks like. Choose a color you think would make the best background color and paint a base coat on your model of Venus. Allow the model to dry before you go on to the next step.

Figure 5.9-Painting the Base Coat.



2. When the base paint has dried, paint on the features you see in the pictures.

Figure 5.10-Painting Features on the Planet.



3. Hang up your model of Venus to dry while you clean up.

SETI INSTITUTE

Mission 5
Seeing Planet Attributes

Logbook

Planet-Building Instructions–
Liquids and Landforms of Earth

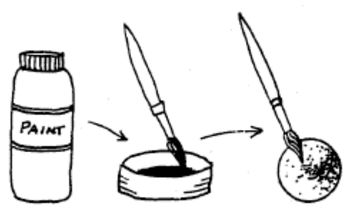
The surface of Earth is about two-thirds covered with water (hydrogen and oxygen). The one-third that is land is distributed in seven large continents (Africa, North America, South America, Asia, Australia, Europe, and Antarctica).

Figure 5.11-Earth.

The liquid layer of Earth is so thin that you will be able to paint it on. You will also add ice caps and land masses, even though they are solid features of the planet.

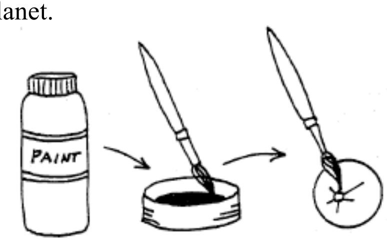
1. Look at the picture of Earth. Find a color picture of Earth taken from space. Look at maps and globes. Choose a color you think would make the best background color and paint a base color on your model of Earth. Allow the model to dry before you go on to the next step.

Figure 5.12-Painting the Base Coat



2. While you are waiting for your model to dry, do research on the features of Earth. Make some sketches that show the continents, ice caps, and oceans. When the base paint has dried, paint on Earth's liquid layer as well as its land formations and ice caps.

Figure 5.13-Painting Features on the Planet.



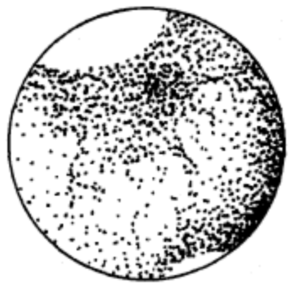
3. Hang up your model of Earth to dry while you clean up.

Mission 5
Seeing Planet Attributes

Planet-Building Instructions– Liquids and Landforms of Mars

There is no liquid on the surface of Mars because of the low gravity and thin atmosphere. The surface of Mars is a rocky desert covered with vast channels, volcanoes, craters, and carbon dioxide ice caps at the north and south poles.

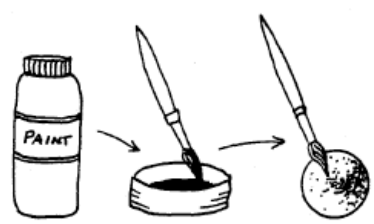
Figure 5.14-Mars.



Because Mars does not have a liquid layer, use this time to add surface features to your planet model.

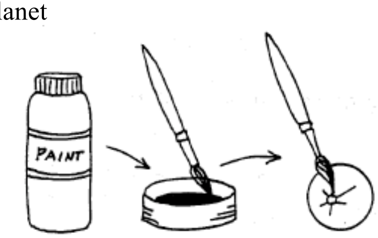
1. Look at the picture of Mars above. Find a color picture of Mars taken from space to get an idea of what the *surface* looks like. Choose a color you think would make the best background color and paint a base color on your model of Mars. Allow the model to dry before you go on to the next step.

Figure 5.15-Painting the Base Coat.



2. While you are waiting for your model to dry, do research on the features of Mars. Make some sketches that show the volcanoes, ice caps, craters, and channels. When the base paint has dried, paint on the features you see in the pictures.

Figure 5.16-Painting Features on the Planet



3. Hang up your model of Mars to dry while you clean up.

Mission 5
Seeing Planet Attributes

Logbook

SETI INSTITUTE

Planet-Building Instructions–
Liquids and Landforms of Jupiter

The solid center of Jupiter is completely covered by vast oceans of hydrogen. In fact, the hydrogen ocean on Jupiter is 65,000 kilometers deep, much deeper than Earth's water ocean.

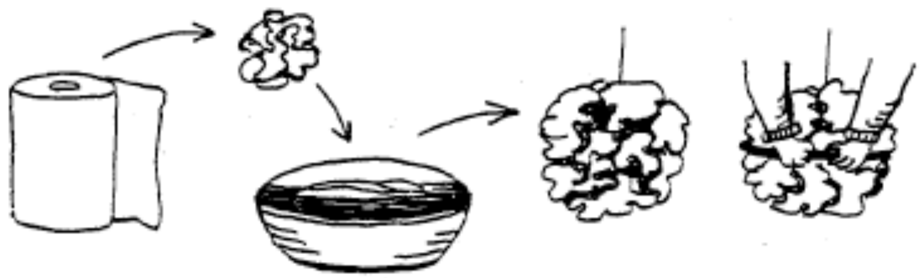
Figure 5.17-Jupiter.

1. At this scale (l to 210 million), the oceans on your model of Jupiter should be 19.5 centimeters deep, creating a total circumference of 202 centimeters (2 meters plus 2 centimeters). Cut a piece of string that is 202 centimeters long. Wrap a piece of tape around each end of the string.

Figure 5.18-Measuring String

2. Take several sheets of newsprint and ball them up loosely. Dip them in papier-mâché paste and stick to your planet. Do this until your planet is covered with balled up newspaper. Make sure the hanger string is still on the outside of the model. Measure the circumference with the 202-centimeter string. Add or take paper away until it has the correct circumference.

Figure 5.19-Using Paper Towels. ***Logbook***



3. Tape the ball to hold its size and shape.

Figure 5.20-Taped Ball.

4. Cover the ball with a thin layer of papier-mâché. Be careful not to increase the circumference of your planet too much by using too much papier-mâché.

Figure 5.21-Papier-mache.

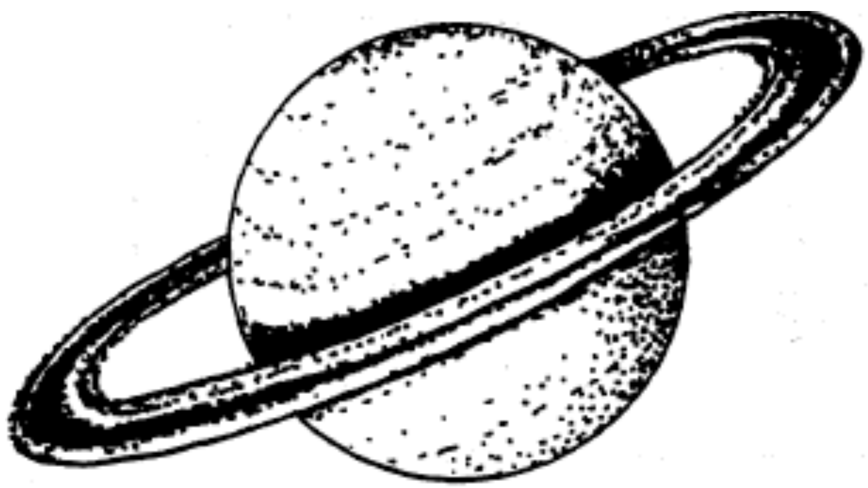
5. Hang up your model of Jupiter to dry while you clean up.

Mission 5
Seeing Planet Attributes

Planet-Building Instructions– Liquids and Landforms of Saturn

The solid center of Saturn is completely covered by vast oceans of hydrogen. In fact, the hydrogen ocean on Saturn is 44,000 kilometers deep, much deeper than Earth's water ocean.

Figure 5.22-Saturn.

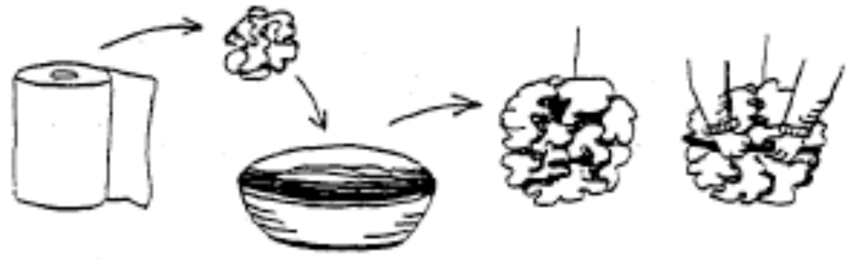


1. At this scale (1 to 210 million), the oceans on your model of Saturn should be 13 centimeters deep, creating a total circumference of 168 centimeters (1 meter plus 68 centimeters). Cut a piece of string that is 168 centimeters long. Wrap a piece of tape around each end of the string.

Figure 5.23-Measuring String.

2. Take several sheets of newsprint and ball them up loosely. Dip them in papier-mâché paste and stick to your planet. Do this until your planet is covered with balled up newspaper. Make sure the hanger string is still on the outside of the model. Measure the circumference with the 168-centimeter string. Add or take paper away until it has the correct circumference.

Figure 5.24-Using Paper Towels.



3. Tape the ball to hold its size and shape.

Figure 5.25-Taped Ball.

4. Cover the ball with a thin layer of papier-mâché. Be careful not to increase the circumference of your planet too much by using too much papier-mâché.

Figure 5.26-Papier-mache.

5. Hang up your model of Saturn to dry while you clean up.

Mission 5 Seeing Planet Attributes

Logbook

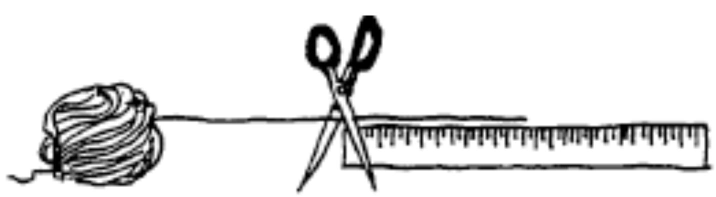
Planet-Building Instructions– Liquids and Landforms of Uranus

The solid center of Uranus is completely covered by vast oceans of water, ammonia, and methane. In fact, the ocean on Uranus is 7,900 kilometers deep, enormously deeper than Earth's water ocean.

Figure 5.27-Uranus.

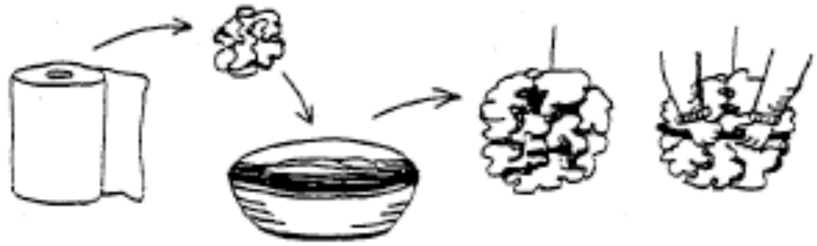
1. At this scale (1 to 210 million), the oceans on your model of Uranus should be 5 centimeters deep, creating a total circumference of 53 centimeters. Cut a piece of string that is 53 centimeters long. Wrap a piece of tape around each end of the string.

Figure 5.28-Measuring String.



2. Take several sheets of newsprint and ball them up loosely. Dip them in papier-mâché paste and stick to your planet. Do this until your planet is covered with balled up newspaper. Make sure the hanger string is still on the outside of the model. Measure the circumference with the 53-centimeter string. Add or take paper away until it has the correct circumference.

Figure 5.29-Using Paper Towels.



3. Tape the ball to hold its size and shape.

Figure 5.30-Taped Ball

4. Cover the ball with a thin layer of papier-mâché. Be careful not to increase the circumference of your planet too much by using too much papier-mâché.

Figure **5.31**-Papier-mache.

5. Hang up your model of Uranus to dry while you clean up.

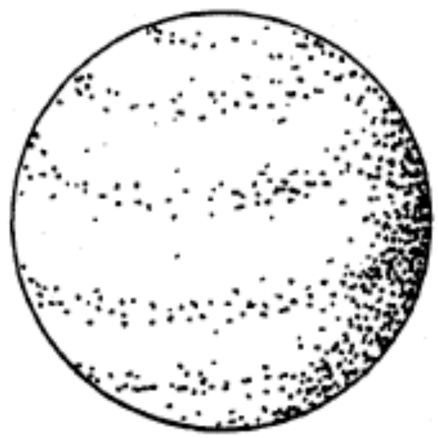
Mission 5 *Logbook*

Seeing Planet Attributes

Planet-Building Instructions– Liquids and Landforms of Neptune

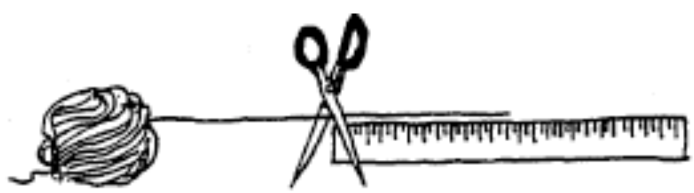
The solid center of Neptune is completely covered by vast oceans of water, ammonia, and methane. In fact, the hydrogen ocean on Neptune is 8,000 kilometers deep, enormously deeper than Earth's water ocean.

Figure 5.32-Neptune.



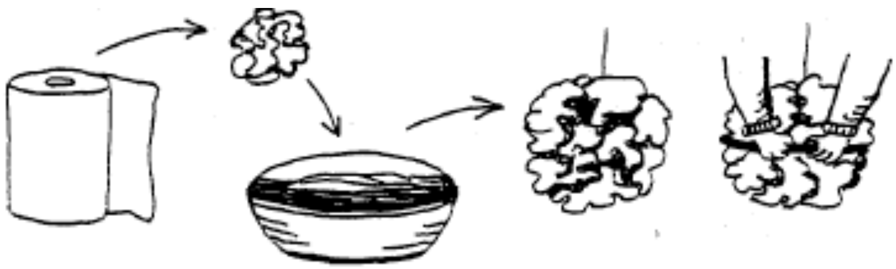
1. At this scale (1 to 210 million), the oceans on your model of Neptune's should be 2 centimeters deep, creating a total circumference of 58 centimeters. Cut a piece of string that is 58 centimeters long. Wrap a piece of tape around each end of the string.

Figure 5.33-Measuring String.



2. Take several sheets of newsprint and ball them up. Dip them in papier-mâché paste and stick to your planet. Do this until your planet is covered with balled-up newspaper. Make sure the hanger string is on the outside of the model. Measure the circumference with the 58-centimeter string. Add or take paper away until it has the correct circumference.

Figure 5.34-Using Paper Towels.



3. Tape the ball to hold its size and shape.

Figure 5.35-Taped Ball.

4. Cover the ball with a thin layer of papier-mâché. Be careful not to increase the circumference of your planet too much by using too much papier-mâché.

Figure 5.36-Papier-mache.

5. Hang up your model of Neptune to dry while you clean up.

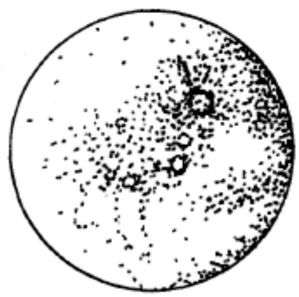
Mission 5 *Logbook*

Seeing Planet Attributes

Planet-Building Instructions– Liquids and Landforms of Pluto

Scientific evidence suggests that there is no liquid on the surface of Pluto. The surface of the planet is rock, covered with craters.

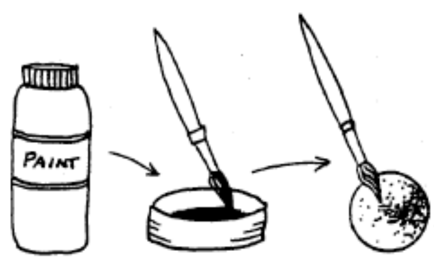
Figure 5.37-Pluto.



Because there is no liquid layer on Pluto, use this time to add surface features to your planet model.

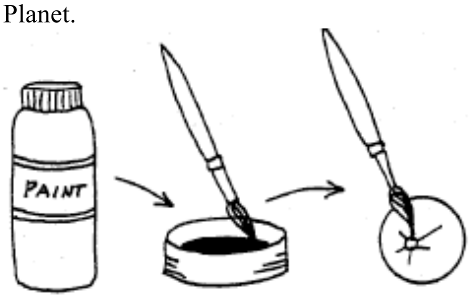
1. Look at the picture of Pluto above. Find an image of Pluto to get an idea of what the *surface* looks like. Choose a color you think would make the best background color and paint a base color on your model of Pluto. Allow the model to dry before you go on to the next step.

Figure 5.38-Painting the Base Coat.



2. While you are waiting for your model to dry, do research on the features of Pluto. When the base paint has dried, paint on the features you see in the pictures.

Figure 5.39-Painting Features on the Planet.



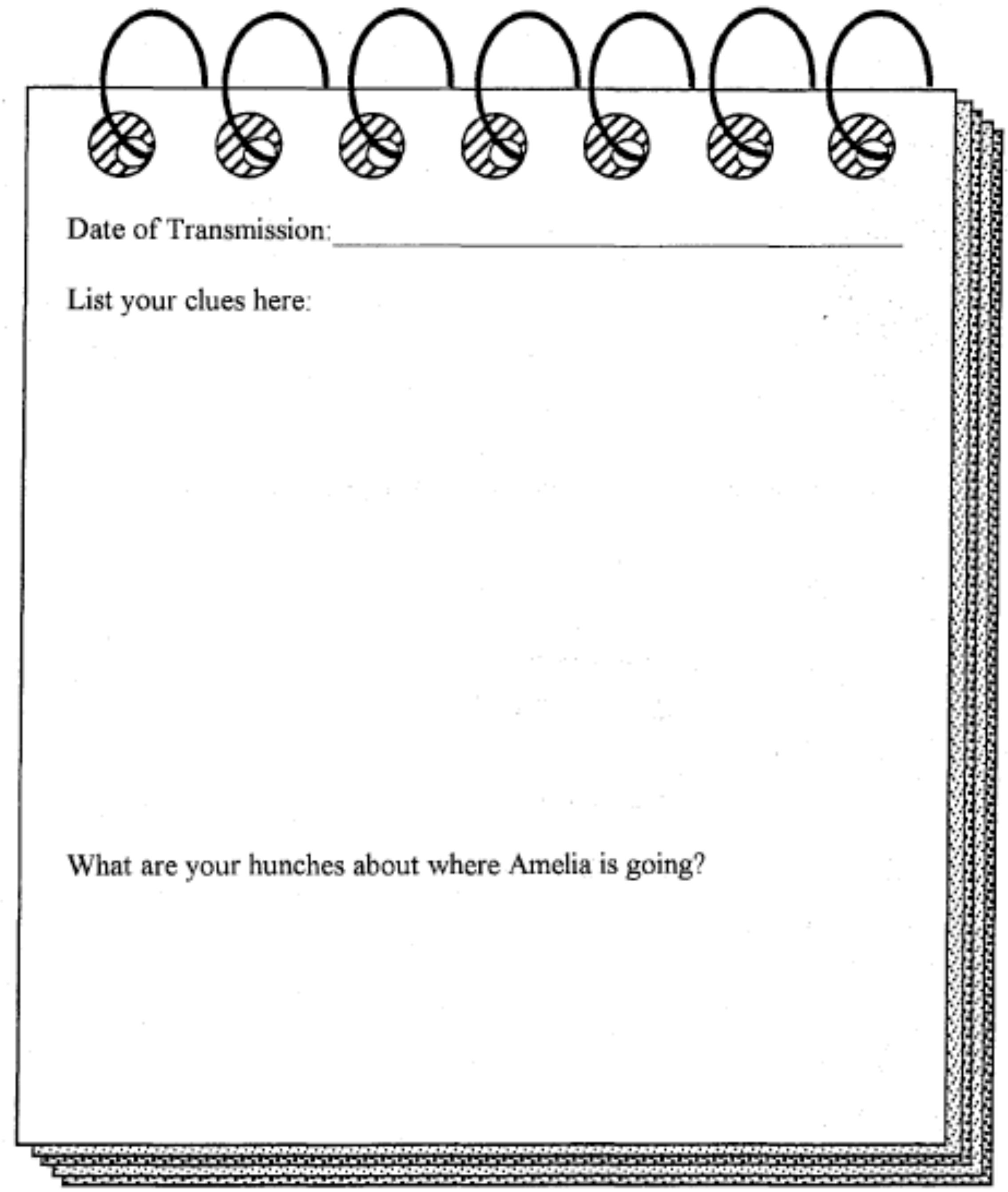
3. Hang up your model of Pluto to dry while you clean up.

Mission 5
Seeing Planet Attributes

Logbook

SETI INSTITUTE

Figure 5.40-Science Detectives Notebook.



Now that you have had a chance to collect more information about Amelia's trip, which hunch was correct? Why? (Use the back of this sheet for your answers,)

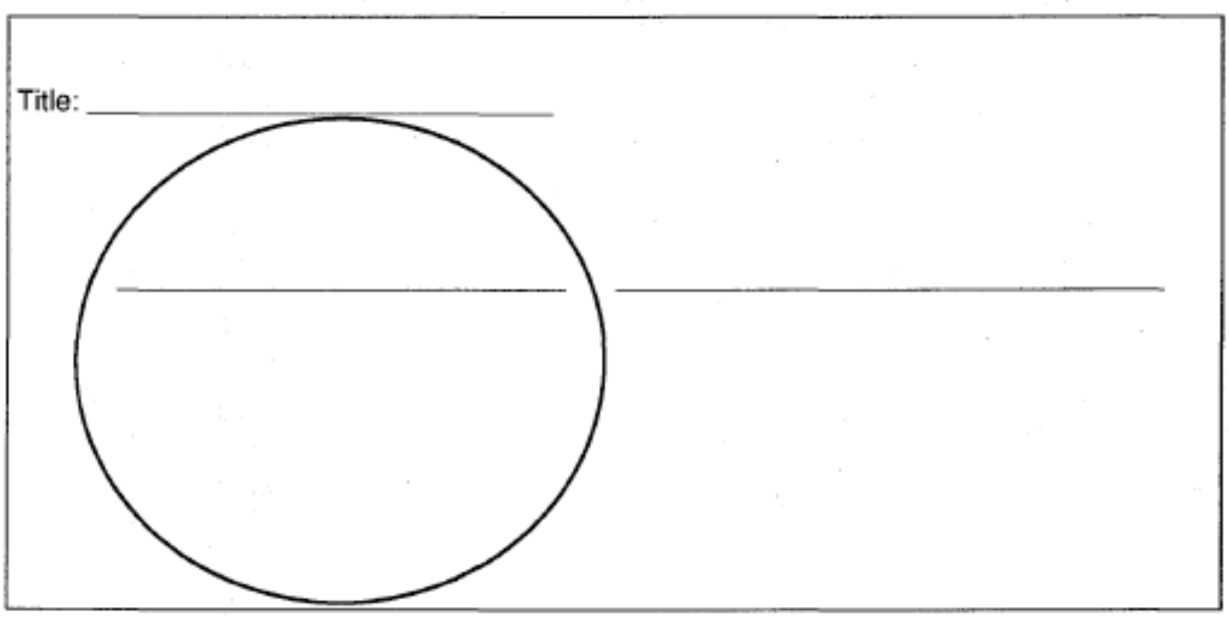
Mission 5
Seeing Planet Attributes

Organizing Attributes

1. Look through your "NASA Planetary Directory." Record as many planet attributes as possible in the space below:

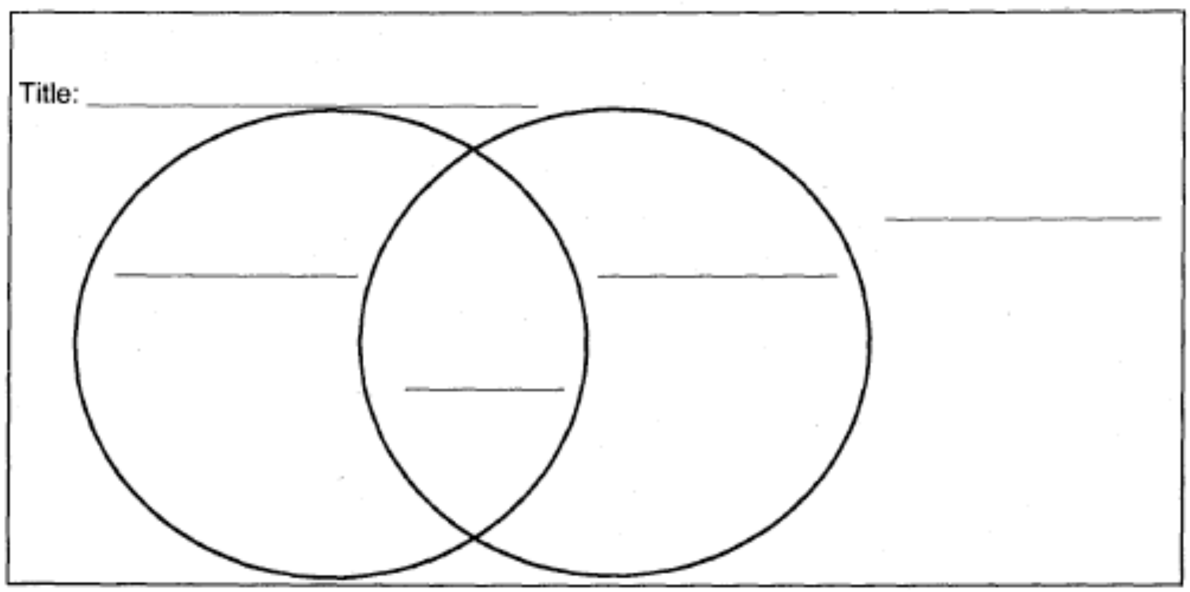
2. Choose an attribute and make a one-attribute chart:

Figure 5.41-0ne-Attribute Chart.



3. Now choose a second attribute. Make a two-attribute chart: ***Logbook***

Figure 5.42-Two-Attribute Chart.



4. (optional) Only for the team that needs a challenge! Choose a third attribute. Make a three-attribute chart in the space below.

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Mission 6
Making the Most and Least of Things

Getting Everything in Order

Overview

In mission 6.1, students watch a video segment. Amelia says that she is going to a planet that is very near a flaming ball of gas. Her next destination is Mercury. Buzz Sawyer and Dr. Orbit confirm that her previous destination was Jupiter. Students group planets in a series based on attributes and then use this information to make guesses about Amelia's plans. In mission 6.2, teams add gas layers to their planet models and then measure the new circumference, using the scale factor to find the circumference of the actual planets.

Concepts

- Grouping planets in a series based on particular attributes.

Skills

- Measuring the total circumference of a planet model.
- Using a scale factor to measure the actual size of a planet.
- Adding a gas layer to a planet model.

Mission 6.1

Materials

For the Class

- *The Science Detectives* video, "Lesson 6"
- Computer, and projector or monitor
- Four books, different thicknesses
- Masking tape
- Large sheet of butcher paper
- Felt tip markers
- MEL's Message from mission 5

For Each Team

- Science Detectives Notebook

- "Most and Least" Logbook sheet
- "Planet Bar Graph" from mission 5

For Each Student

- Pencil

Getting Ready

Just Before the Lesson

1. Add a heading "Fifth Transmission" to the "Clues from video" chart. Also add a "Gas Layer Circumference" table, similar to the "Liquid Layer Circumference" table from mission 5.

2. Set up the video projector. Show the video to "Lesson 6."

3. Make a copy of the "Planet Bar Graph" and "Most and Least" Logbook page for each team. Make a transparency of the "Planet Bar Graph."

Classroom Action

1. **Video.** Announce the video transmission for this mission. Have the NASA scientists figured out what the Science Detectives already know? Remind students to be on the lookout for clues about Amelia's future plans.

   Show the video segment "Lesson 6." The video confirms that Jupiter is the answer to the liquid layer circumference clue.

2. **Discussion.** Record clues suggested by the class in their discussion of the video segment on the class chart.

Video Clues: Lesson 6, January 12 (Travel time =12 days)

- Amelia siphoned fuel from Jupiter; she has enough fuel for another 140 days.

- Amelia is traveling to a planet that orbits the biggest "flaming ball" of gas in the solar system–the Sun!

Teacher's Note: Technically, all of the planets are orbiting the biggest flaming ball of gas in our solar system--the Sun! Amelia should have said she was going to the planet that is most

closely orbiting the biggest flaming ball of gas in our solar system. However, most students will assume that she meant most closely, and identify Mercury without trouble.

Teams should record the information from the class discussion into their Science Detectives Notebooks. Discuss ideas about Amelia's next destination. Remind students that Amelia's clue was: A planet orbiting the biggest flaming ball of gas in our solar system. Some students might know right away that Amelia is going to Mercury.

Ask students how learning facts about the solar system has helped them in their challenge to guess Amelia's destination based on the clues that she lets slip. Amelia now has another 140 days of fuel—ask how will this affect students' predictions?

Explain to students that learning and organizing information about the planets will help them figure out Amelia's clues faster. Show the "Planet Bar Graph". Do a quick lesson or review on analyzing a bar graph if necessary. Explain that this is one way to organize information– by putting all the data about one thing together. You will show them another way to organize facts about the solar system. It is often useful to group information in a *series* based on one attribute.

3. **Demonstration.** Demonstrate the series *tallest to shortest* using students. Don't reveal the attribute, just choose four students and line them up in front of the class according to height. Have the other students guess what attribute you are using for the series. Demonstrate the series *thickest to thinnest* using four books of varying thicknesses.

   Demonstrate how to place the planets in a series based on an attribute. Draw on the whiteboard the series diagram shown in figure 6.1. Have students complete the series. Which planet has the most moons? *(Jupiter)* Jupiter goes in the box labeled "Most." Which planet has the least number of moons? *(Both Mercury and Venus have no moons.)* It's a tie between Venus and Mercury, so they should be placed in the last two boxes of the series diagram and connected by an "=".

Figure 6.1-One Attribute of Planets.

Attribute:

Number of Moons

Jupiter							Mercury =Venus
Most							Least
63							0

   Fill in the other planets. You could also put planet names on index cards and attach them to the series diagram with masking tape. The cards could then be easily moved around to make different series diagrams.

4. **Activity.** Hand out a copy of Table 5.2 (page 125) to each team. Remind them that this is the information Dr. Orbit suggested they study carefully. Suggest they use it to create their own

most/least attribute chart. Student teams complete the Logbook sheet "Most and Least" (page 163) in their Science Detectives Notebooks, using the "NASA Planetary Directory."

Help small groups understand the activity by, first, helping them decide on an attribute, such as size, and then asking them questions: Which is the biggest planet? Which is the smallest? In what order should they be placed? Other attributes that students may come up with might include length of planet's name, distance between planet and the Sun, thickness of planet's atmosphere, and so on. Ask students to finish the table.

Teams should agree on an attribute series and create a poster using the white construction paper and felt tip markers. The posters should *not* show which attribute the team is using.

5. **Discussion.** After each team has created an attribute series poster, hang attribute posters on the whiteboard, one at a time, and encourage teams to guess which attributes were used.

Mission 6.2

Materials

For Each Team

- Science Detectives Notebook
- "Planet Building Instructions" for that team's assigned planet
- 4 meters cotton batting (amount varies according to planet)
- 4 meters bubble pack
- Bag of cotton balls
- Tempera paint
- Paintbrushes
- Pie tins for mixing paint
- Masking tape
- White glue
- Spray paint (yellow, blue, aqua, etc.)
- Needles
- Thread

Teacher's Note: Not every team may need all of the materials listed.

For Each Student

- Pencil

Getting Ready

One or More Days Before Class

1. The gas giant models will require about five yards of cotton batting or bubble pack. Most fabric stores carry batting used for quilting. Bubble pack can be collected from students or packaging and mailing stores.

2. Cut the cotton batting, or bubble pack, into 2-meter squares. You may want to tear the masking tape into 10 cm strips at this time.

3. Copy the "Planet-Building Instructions" for the gases on planets (each team gets one set of instructions for one planet).

Classroom Action

1. **Activity.** Hand out the appropriate "Planet Building Instructions" to each team. Have students add gas layers to their planet models according to the instructions. Some teams will not have a gas layer to add to their models. Students from those teams can assist the Jupiter, Saturn, Uranus, and Neptune teams. If there is not enough for everyone to do, some students could work on posters or charts that show the gas layers of all the planets.

2. **Discussion.** After the models have been completed, ask teams to share them with the class. Teams should name the major and minor components (solid, liquid, or gas) that their planet is composed of, by approximate volume or by depth; and discuss anything else of interest about their planet. (The "Message from MEL" distributed in mission 5 can help with this.)

Teacher's Note: Ask students why the outer planets have thick, massive atmospheres, compared to the inner planets. (Inner planets were hotter when they formed, so the lightweight gases like hydrogen and helium boiled off into space. The inner planets have weaker gravity. When the Sun "turned on" it blew much of the gas out to the range of the gas giants--away from the rocky planets.)

Closure

1. **Discussion.** Remind students that Amelia gave a clue about gases in her last transmission: Remind them that she said she was going to a planet orbiting a flaming ball of gas. Do they think this ball of gas could be any of their planets? Are any of the planets made entirely of gas? What other object is there in our solar system besides the planets? *(There are comets and asteroids, but the "flaming ball" must be the Sun.)* Which planet is nearest to the Sun? *(Mercury.)*

2. ***(Optional)*** **Activity.** Discuss which aspects of the video are realistic and which are make-believe. Ask students to help you make a list of the make-believe "facts" from the video. For

example: traveling 12 billion kilometers in 140 days, siphoning gas from Jupiter, and so on. Tell them that we do not currently have the technology to do any of these things.

Going Further

Creative Game: Attribute Journeys

Ask students to write and illustrate a creative story about an "Attribute Journey" through the solar system. Their main character(s) should visit the planets in an order based upon one attribute, such as size or number of moons. Encourage students to read or act out their story to the rest of the class. The object for the rest of the class is to guess the attribute used in each "Attribute Journey."

Mission 6
Making the Most and Least of Things

Script for Fifth Transmission

Synopsis: Lesson 6, January 12
(Travel time =12 days)

- Amelia siphoned fuel from Jupiter; she has enough fuel for another 140 days.
- Amelia is traveling to a planet that orbits the biggest flaming ball of gas in the solar system—the Sun!

Interstellar Express, *with hose leading down through Jovian cloud tops. Sounds of the Jovian wind. Slurping sounds.*

BUZZ SAWYER
"Hi, Buzz Sawyer–Under Assistant Honcho at NASA's Space Command–talking to you again. Well, we've been able to confirm that Amelia Spacehart has done it! She's managed to use a 100-kilometer hose to siphon liquid hydrogen fuel from Jupiter! This means she can stay up there another 140 days. She can go another 12 billion kilometers. She's driving me to drink–coffee." *[snap, buzz EFX] I* don't have to tell you what that means…"

AMELIA SPACEHART
Date on screen: January 12

"NASA Control, I'm happy to report that the hydrogen fuel siphon works beautifully! The *Express* seems to be designed around a most convenient fuel supply. Anyhow, I'm off to my next planet. This particular planet happens to be orbiting the biggest flaming ball of gas in the solar system, and I don't mean you, Sawyer! See you later!"

DR. ORBIT
"You're probably wondering what Amelia meant by 'flaming ball of gas.' *[Activity on the Sun.]* She's talking about a star. There's no hard surface on a star. Some stars die young, within 100 million years. And some stars live for a 100 billion years. Stars produce enormous amounts of light. Planets don't do that. Your teacher has information on what the objects in the solar system are made of."

BUZZ SAWYER
"Teachers? Who brought teachers into this? I'll be blasted! Yecch! Tastes like hot rocket fuel." *[pause; reaction]* "How do I know that?"

DR. ORBIT
“Just remember, any object that is a flaming ball of gas *[Solar flares erupt on screen; Dr. Orbit recoils.] Ahh*! is made up entirely of, of gases. Please analyze the information that your teacher gives you very carefully.”

BUZZ SAWYER
“That Dr. Orbit thinks he’s pretty hot stuff. I’ll be roasted! Uh, blasted.”

Mission 6
Making the Most and Least of Things

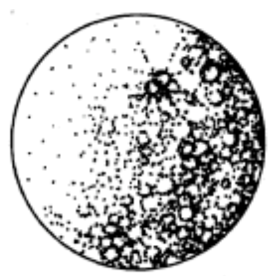
Logbook

SETI INSTITUTE

Planet-Building Instructions—Gases (Atmosphere) on Mercury

Most of Mercury's gases escaped into space because Mercury's gravity was too weak to hold them. A very, very thin atmosphere remains around the planet. It is composed mostly of hydrogen, with some helium.

Figure 6.2-Mercury.

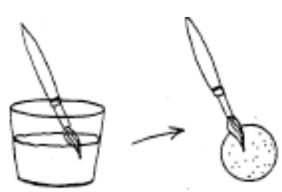


1. Mix 1 cup of warm water with 1 tablespoon of white glue. Stir until the glue is dissolved.

Figure 6.3-Mixing Glue and Water.

2. Paint this thin glue mixture over your model of Mercury.

Figure 6.4-Painting with Glue Mixture.



3. Hang up your model of Mercury to dry, and clean up.

Mission 6 *Logbook*
Making the Most and Least of Things

Planet-Building Instructions—
Gases (Atmosphere) on Venus

Venus has a dense atmosphere made up of droplets of sulfuric acid, lots of carbon dioxide, and some nitrogen and rare gases. You cannot see the surface of Venus through its atmosphere.

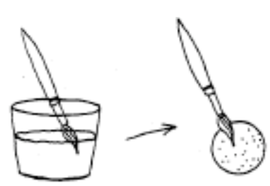
Figure 6.5-Venus.

1. Stretch some cotton balls until they are thin and flat. Cover your model of Venus until you cannot see the surface any longer. Use glue, as needed, to hold the cotton to the surface of the model.

Figure 6.6-Using Cotton.

2. Do research on Venus. Find out what its cloud cover looks like from space

Figure 6.7-Painting with Glue Mixture.



3. When the model is dry, paint the cotton to look like Venus.

Mission 6 *Logbook*
Making the Most and Least of Things

Planet-Building Instructions—Gases (Atmosphere) on Earth

Earth is covered by a layer of gas, mostly nitrogen and some oxygen. It is possible to see most of the planet from space, except where clouds of dense water vapor hide the surface.

Figure 6.8-Earth.

1. Pull a piece of cotton so thin that it almost falls apart. Wrap this around your model of Earth such that you can still see the surface of the planet.

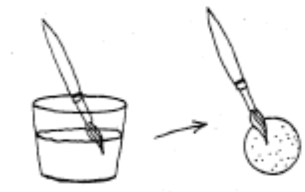
Figure 6.9-Using Cotton.

2. Mix 1 cup of warm water with 3 tablespoons of white glue. Stir until the glue is dissolved.

Figure 6.10-Mixing Glue and Water.

3. Paint the glue mixture over the planet model. Moisten the cotton with the glue mix, to help it stick.

Figure 6.11-Painting with Glue Mixture. ***Logbook***



4. Paint the glue mixture over the planet model. Moisten the cotton with the glue mix, to help it stick.

5. Hang up your model of Earth to dry while you clean up.

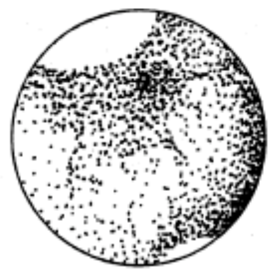
Mission 6
Making the Most and Least of Things

SETI INSTITUTE

Planet-Building Instructions– Gases (Atmosphere) on Mars

Mars has a very thin atmosphere of carbon dioxide, with small amounts of nitrogen, argon, and oxygen.

Figure 6.12-Mars.

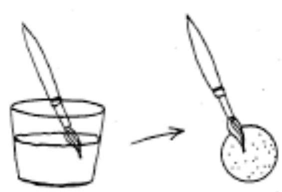


1. Mix 1/4 cup of warm water with 2 tablespoons of white glue. Stir until the glue is dissolved.

Figure 6.13-Mixing Glue and Water.

2. Paint a thin layer of the glue mixture over your model of Mars.

Figure 6.14-Painting with Glue Mixture.



3. Hang up your model of Mars to dry, and clean up.

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Mission 6 *Logbook*
Making the Most and Least of Things

Planet-Building Instructions– Gases (Atmosphere) on Jupiter

Above Jupiter's hydrogen ocean is a gaseous atmosphere of hydrogen, helium and ammonia, ice, and water vapor. This layer is 400 kilometers deep, much deeper than Earth's atmosphere.

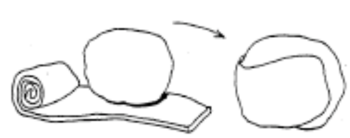
Figure 6.15-Jupiter.

1. At this scale (1 to 210 million), the gaseous part of your model of Jupiter should have a circumference of 213.5 centimeters. Cut a piece of string that is 213.5 cm long. Wrap a piece of tape around each end of the string.

Figure 6.16-Measuring String.

2. Wrap your planet model in a layer of cotton batting. Keep the hanger string on the outside of the ball. Cover the model in this way until you cannot see the surface any longer. Check the circumference with your 213.5 cm string and add more cotton if it is too small. Tape or sew the cotton to the planet model when the circumference is correct.

Figure 6.17-Wrapping with Cotton Batting.



3. Do research on Jupiter. Find out what its cloud cover looks like from space.
4. Paint the cotton atmosphere to look like Jupiter.
5. Hang up your model of Jupiter to dry, and clean up.

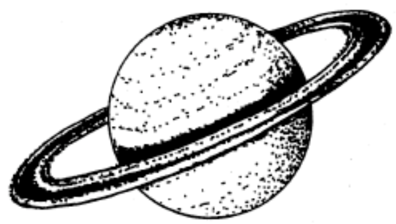
Mission 6 Making the Most and Least of Things

Logbook

Planet-Building Instructions– Gases (Atmosphere) on Saturn

Above Saturn's hydrogen ocean is a gaseous atmosphere of ammonia, hydrogen, helium, and water vapor. This layer is 1,000 kilometers deep, more than twice as deep as Earth's atmosphere.

Figure 6.18-Saturn.



1. At this scale (1 to 210 million), the gaseous part of your model of Saturn should have a circumference of 181 centimeters. Cut a piece of string that is 181 cm long. Wrap a piece of tape around each end of the string.

Figure 6.19-Measuring String.

2. Wrap your planet model in a layer of cotton batting. Keep the hanger string on the outside of the ball. Cover the model in this way until you cannot see the surface any longer. Check the circumference with your 181 cm string and add more cotton if it is too small. Tape or sew the cotton to the planet model when the circumference is correct.

Figure 6.20-Wrapping with Cotton Batting.

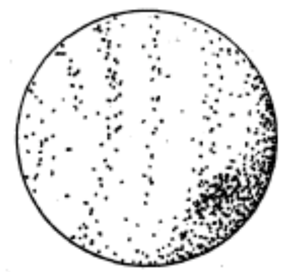
3. Do research on Saturn. Find out what its cloud cover looks like from space.
4. Spray paint the cotton atmosphere to look like Saturn.
5. Hang up your model of Saturn to dry, and clean up

Making the Most and Least of Things

Planet-Building Instructions–
Gases (Atmosphere) on Uranus

Above the ocean on Uranus is a thick, gaseous atmosphere of hydrogen and helium, with some small amounts of methane, ice crystals, and ammonia. This layer is 4,000 kilometers deep, four times as deep as Saturn's atmosphere. Above this layer is another layer. The high, thin layer is gaseous hydrogen.

Figure 6.21-Uranus.

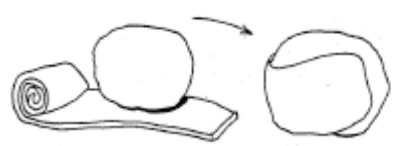


1. At this scale (1 to 210 million), the first thick layer of atmosphere on your model of Uranus should have a circumference of 65.5 centimeters. The second, thin layer should have a circumference of 70.5 centimeters. Cut two pieces of string, one that is 65.5 cm long, and one that is 70.5 cm long. Wrap a piece of tape around the ends of each piece of string.

Figure 6.22-Measuring String.

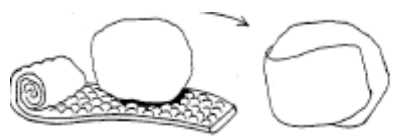
2. Wrap your planet model in a layer of cotton batting. Make sure to keep the hanger string on the outside of the ball. Cover the model in this way until you cannot see the surface any longer. Check the circumference with the shorter string (65.5 cm) and add more cotton if it is too small. Tape or sew the cotton to the planet model when the circumference is correct.

Figure 6.23-Wrapping with Cotton Batting.



3. Wrap your planet model in a layer of clear bubble pack. Make sure to keep the hanger string on the outside of the ball. Cover the model in this way until you cannot see the cotton any longer. Check the circumference with the 70.5 cm long string and add more bubble pack if it is too small. Tape or sew the bubble pack to the planet model when the circumference is correct.

Figure 6.24-Wrapping with Bubble Pack.



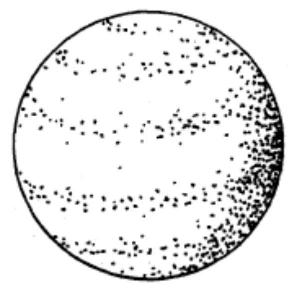
4. Do research on Uranus. Find out what its cloud cover looks like from space.
5. Have an adult help you spray paint your planet model.
6. Hang up your model of Uranus to dry, and clean up.

Mission 6
Making the Most and Least of Things

Planet-Building Instructions–
Gases (Atmosphere) on Neptune

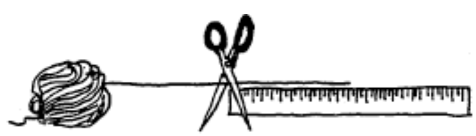
Neptune's ocean is covered by a dense atmosphere of hydrogen and helium with small amounts of methane, ice crystals, and ammonia. This gaseous layer is 8,750 km deep, twice as deep as Uranus' atmosphere.

Figure 6.25-Neptune.



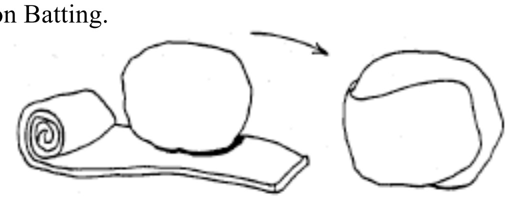
1. At this scale (1 to 210 million), the gaseous part of your model of Neptune should have a circumference of 67 centimeters. Cut a piece of string that is 67 cm long. Wrap a piece of tape around each end of the string.

Figure 6.26-Measuring String.



2. Wrap your planet model in a layer of cotton batting. Make sure to keep the hanger string on the outside of the ball. Cover the model in this way until you cannot see the surface any longer. Check the circumference with your 67-cm-long string and add more cotton if it is too small. Tape or sew the cotton to the planet model when the circumference is correct.

Figure 6.27-Wrapping with Cotton Batting.



3. Do research on Neptune. Find out what its cloud cover looks like from space.
4. Paint the cotton atmosphere to look like Neptune.
5. Hang up your model of Neptune to dry, and clean up.

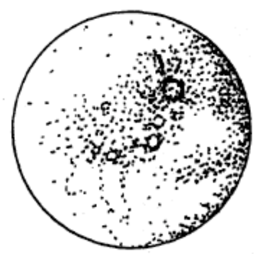
Mission 6
Making the Most and Least of Things

Logbook

Planet-Building Instructions–
Gases (Atmosphere) on Pluto

Pluto appears to have a very thin atmosphere of methane. As a dwarf planet, Pluto has the thinnest atmosphere of all the planets.

Figure 6.28-Pluto.

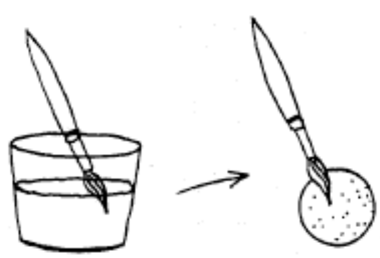


1. Mix 1/4 cup of warm water with 1/2 teaspoon of white glue. Stir until the glue is dissolved.

Figure 6.29-Mixing Glue and Water.

2. Paint a very thin layer of the glue mixture over your model.

Figure 6.30-Painting with Glue Mixture.



3. Hang up your model of Pluto to dry, and cleanup.

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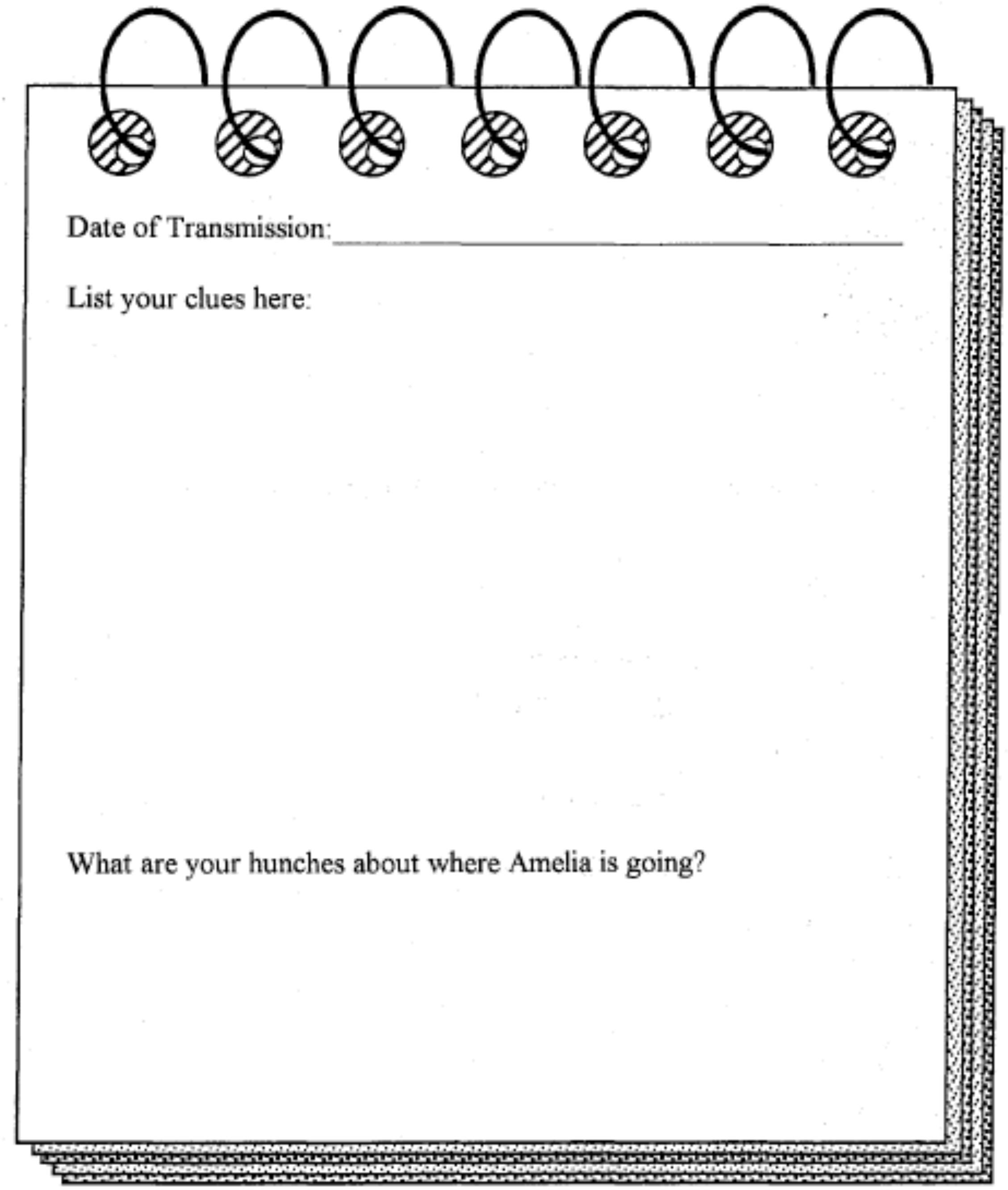
Mission 6

Logbook

Making the Most and Least of Things

Figure 6.31-Science Detectives Notebook,



Now that you have had a chance to collect more information about Amelia's trip, which hunch was correct? Why? (Use the back of this sheet for your answers.)

Mission 6 *Logbook*

Making the Most and Least of Things

Most and Least

Table 6.1—Most and Least.

Attribute: ____________

Most								Least

Attribute: ____________

Most								Least

Attribute: ____________

Most								Least

Attribute: ____________

Most								Least

Attribute: ____________

Most								Least

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Mission 7
Adventures with Telescopes

It's So Far Away, But It Looks So Near!

Overview

In mission 7.1, a video segment confirms that Amelia's third destination in her search for ETI was Mercury. Amelia gives the clue for her next destination: She will be able to see Earth from this planet, and a person on Earth can actually see this planet's surface. Her next destination is Mars. The clue that Amelia gives about her next destination leads students into an exploration of lenses. In mission 7.2, students construct a telescope.

Concepts

- Students learn how to project an image with a lens.
- Students learn how a telescope works.

Skills

- Exploring the properties of lenses.
- Constructing a telescope.

Mission 7.1

Materials

For the Class

- *The Science Detectives* video, "Lesson 7"
- Computer, and projector or monitor
- Black permanent marking pen
- Scissors
- Chart paper
- Sheet of butcher paper

For Each Team

- Science Detectives Notebook
- "Putting Lenses Together" Logbook sheet (page 174)

- “Magnifiers” Logbook sheet (page 173)
- 2 lenses, different focal lengths
- 1 to 3 magnifying glasses
- Scissors
- Transparent tape

For Each Student

- Pencil

Getting Ready

Just Before the Lesson

1. Add a heading “Sixth Transmission” to the “Clues from Video” chart paper. Create a new chart on a sheet of butcher paper titled “Lens Facts.”

2. Set up the computer and projector or monitor. Forward the video to “Lesson 7.” (This is the *sixth* transmission from Amelia because there was no video segment for mission 4.)

3. Copy the “Magnifiers” Logbook sheet, one for each telescope-building team.

4. If you purchased the telescope kits, remove the lenses from the kits to use for this activity.

Classroom Action

1. **Video.** Announce to students that it’s time to find out if the NASA scientists agree with the conclusions that the class came to in mission 6 about Amelia’s destination.

   Show the video segment “Lesson 7.” Mercury is confirmed as Amelia’s destination.

2. **Discussion.** Discuss the clues given in this segment and record them on the “Clues from Video” chart. Teams should record the information in their Science Detectives Notebooks.

Video Clues: Lesson 7, January 21
(Travel time = 21 days)

- Amelia was orbiting Mercury, the closest planet to the Sun.

- From her next destination, Amelia will be able to observe Earth and the surface of the planet she is orbiting with two special lenses.

- Combine the lenses to get the maximum magnification.

The new clue given is that we should be able to see the next planet's surface from Earth using a combination of two lenses. This clue is not as obvious as the ones given in previous missions. Ask students to use what they know about the planets and their distances from the Earth to make a reasonable guess as to the identity of the next planet. Ask that students share their ideas. Record all suggestions on the chart.

3. **Demonstration.** Students may not have heard the word *lens* before, but they probably have used a magnifying glass. Magnifying glasses are lenses. Ask the class what a magnifying glass does. Ask if all magnifying glasses work in the same way, and where else do we find lenses? Accept all reasonable answers.

Teacher's Note: If your students ask about the magnification (power) of their telescopes, it is simply calculated by the ratio of the focal lengths of the two lenses:

$$\text{magnification} = \frac{\text{focal length}_o}{\text{focal length}_e}$$

o: objective, the "weaker" lens
e: eyepiece, the "stronger" lens

Tell students that they will start by experimenting with lenses. Hand out two different lenses to each team. Ask students to feel the lenses and compare them. Students should note that they are different sizes and that one has surfaces that are more curved than the other.

4. **Activity.** Hand out the "Magnifiers" Logbook sheet and walk the students through the activities described. Tell students to look at various things such as printed words, a torn sheet of paper, the backs of their hands, or the tip of a pencil–using the lenses as magnifying glasses. To use a magnifying glass, they should place the lens above the object and slowly lift it away from the object toward their eyes. The object will appear larger and larger. If the object starts to look blurry, they should move the lens back toward the object until it becomes clearly focused. This is called the point of maximum magnification. Ask students to answer the questions on their "Magnifiers" sheet.

5. **Discussion.** Ask teams what they discovered about the lenses and if both lenses work the same way? *(One lens makes a larger image than the other. Both lenses make things appear bigger.)* Ask teams to find out which lens is a better magnifier. Have them feel the lenses to determine how the "better" magnifier is different from the other. Record information from the discussion on the "Lens Facts" chart.

   Ask students to hold up a magnifying glass to one eye while closing the other eye. They should move the magnifying glass away from their eye as they look at you at the front of the classroom (*you should be at least seven feet away from the closest student*). Ask students what happens to the image in the magnifying glass as they move the lens away from their eye. *(The image flips upside down.)*

(Optional). Teams take the "best magnifier" and hold it flat under a classroom light. Bare fluorescent tubes work best. They should hold a white index card under it and slowly move the card away from the lens. At the correct distance, the lens will project an image of the light fixture onto the card. *(The distance between the lens and the card is the approximate focal length of the lens.)* Teams may try this with the other lens, but the image will be difficult to see because the other lens has a longer focal length.

Mission 7.2

Materials

For Each Team

- Science Detectives Notebook
- "Putting Lenses Together" Logbook sheet
- "How to Build Your Own Telescope–From Scratch" (page 175) directions
- Telescope kit, containing:
  2 paper tubes, such as mailing tubes or paper-towel tubes that fit inside one another (this is handled by slicing one tube [see page 175]). Tubes should be at least as long as the focal length of the weaker-magnification lens.)
- 2 lenses, different focal lengths
- Scissors
- Tape
- "How to Build Your Own Telescope–From a Kit" (page 176)
- Pre-assembled telescope kits (see kit contents on page 176)

For Each Student

- Pencil

Getting Ready

Several Weeks Before Class

1. Each student should have his or her own telescope. If your budget is limited, each team can share one kit. This guide assumes that you are using one kit per team. The appendix has information about obtaining telescope kits, which should be ordered several weeks in advance of teaching this mission.

   The lenses in the kits have focal lengths of 43 mm (25 mm in diameter) and 400 mm (10 mm in diameter). If teams are building telescopes from scratch, the lenses you choose should have focal lengths of 40-90 mm (the stronger magnification lens described in the appendix) and 400-600 mm (the weaker magnification lens). You can check the focal length of a lens by holding it over your hand and under a light source. Raise and lower the lens until the light is focused in a crisp circle on your hand. The distance between the lens and your hand is the focal length. The focal length of the weaker magnification lens should be 8 to 10 times the focal length of the stronger magnification lens. You may find it useful to color code the two lenses using a marker or colored tape wrapped around the edges.

One or More Days Before Class

1. Copy the Logbook sheet "Putting Lenses Together" and the "How to Build Your Own Telescope–From Scratch" directions for each team (select the version of the directions you need: one works with the Edmond Scientifics kit, and the other is for building a telescope from scratch).

2. If you removed the lenses from the telescope kits for mission 7.1, be sure to replace them.

Classroom Action

1. **Demonstration.** Hand out the sheet "Putting Lenses Together" to each team. Demonstrate how to hold one lens in front of another and focus so the image of an object appears clear and sharp. Show how to reverse the order of the lenses, and how to compare which arrangement would make a better telescope. Ask students why *two* lenses are used in a telescope. *(The "weaker" lens in front gathers light to focus an image). The "stronger" lens, like a magnifying glass, allows the eye to examine the image close-up.)*

2. **Activity.** Give teams time to experiment with their lenses, then lead a short discussion about what they have learned. Give teams the rest of their telescope kits and "How to Build Your Own Telescope" directions. Make sure students put the lenses into the tubes in the correct order. Students should practice sliding the tubes back and forth to focus the telescope.

   As teams complete their telescopes, encourage them to use their telescopes to look around at objects in the room and notice how the lenses need to be moved closer together or farther apart to achieve a focused image, depending upon how far away the object is. Make sure each student has an opportunity to learn how to focus the telescope. Have students share strategies for steadying their telescopes–by supporting an arm on a chair or holding their elbows tight to their bodies.

Closure

1. **Discussion.** Ask students what they discovered about lenses and telescopes.

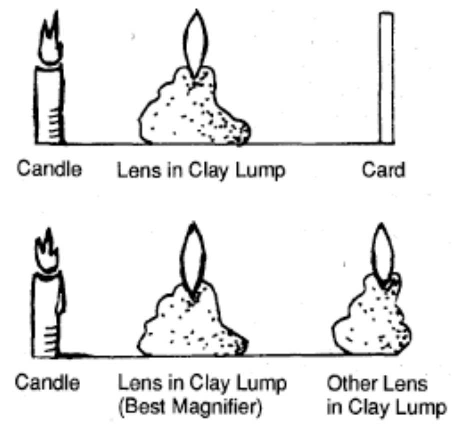
   Ask students if they remember the most recent clue: The planet is near Earth, and its surface can be seen by telescope. Ask students how they can use their telescopes to find out where Amelia is going next. *(Perhaps the model planets can be arranged to make a model solar system, so the telescopes could be used to look at the planets!)* Tell students that they will try this in mission 8.

Going Further

Demonstration: Table Telescope

Prop up one of the "best lenses" vertically using a fist-sized lump of clay, as shown in figure 7.1. Place a lit candle or bare light bulb on the left, near the lens, and hold a white index card vertically on the other side of the lens. The lens and the card should both be perpendicular to the line between them. The light source, lens, and card should form a straight line. Adjust the distance of the card until an image of the candle flame or light bulb can be seen on the card. Replace the card with one of the weaker-magnification lenses. Have students look through the weaker-magnification lens. They will see a telescopic effect, as if the candle flame or light bulb were very far away!

Figure 7.1-A Table Telescope.



Mission 7
Adventures with Telescopes

Script for Sixth Transmission

Synopsis: Lesson 7, January 21
(Travel time =21 days)

- Amelia was orbiting Mercury, the closest planet to the Sun.

- From her next destination, Amelia will be able to observe Earth and the surface of the planet she is orbiting with two special lenses.

- Combine lenses to get maximum magnification.

DR. ORBIT
"Oh! Howdy, Science Detectives. Dr. Orbit here." *[to himself]* "What a coincidence my name is." *[Refers to diagram.]* "Amelia was obviously talking about our central star, the Sun, when she mentioned the biggest flaming ball of gas in our solar system. Actually, it's the only flaming ball of gas in the solar system. Well, lots of you have figured it out already, and one of our satellites has spotted the *Interplanetary Express* orbiting Mercury!"

Visual of Interplanetary Express *near Mercury. Slide of Sun.*

[snap, crackle EFX] "Sounds like Amelia's phoning home ..."

AMELIA SPACEHART
Date on screen: January 21
"Well, I'm leaving Mercury. I figured it was a little too hot and a little too close to the Sun to be the source of my ETI transmission, but you never know what to expect from aliens."

Alien face on screen. Written caption: "Expect greatness, Earthperson!"

"Anyhow, from my next destination I will be able to observe Earth using a combination of two special lenses. I will also be able to make excellent surface observations of the planet that I will be orbiting. Boy, think of it. Over a billion miles on nothing but space pizza!"

BUZZ SAWYER
"Why does she always speak in riddles? The Fleaburg Air Show is coming up in a few months, and what am I supposed to give 'em? A rubber band airplane? A Fourth of July rocket? ... a big excuse?"

DR. ORBIT
"Science Detectives, if Amelia can see the Earth from the *Interplanetary Express,* then we should be able to see the planet that she is orbiting, from here. The trick is to take the lenses and combine them to get the most magnification. Good luck!"

BUZZ SAWYER
[Holding lenses in front of his face.] "Combine lenses ... ?"

Mission 7
Adventures with Telescopes

Logbook

Magnifiers

1. Put a lens above an object. Lift the lens slowly toward your eye. The object will look bigger and bigger. If the image looks blurry, move the lens down toward the object until the image is clear again. Test both lenses.

2. Which lens is the best magnifier?

3. Feel the lenses. How are they different?

Projecting an Image

1. Stand under a classroom light. Hold the “best magnifier” lens level and put a white card beneath it.

2. Slowly move the lens away from the card as you hold the card still.

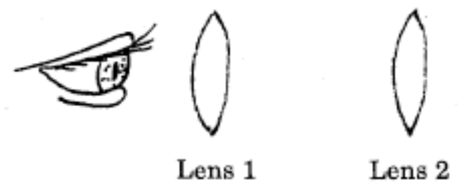
3. Stop when you see a clear picture of the classroom light on the card.

4. Repeat with the other lens. Was there a difference?

Putting Lenses Together

Using the two lenses provided by your teacher, discover what happens when you look though both lenses at the same time. Experiment with the lenses in the following ways:

Figure 7.2-Eye and Lenses.



1 Hold lens # 1 close to your eye with one hand and lens # 2 at arm's length with the other hand. Focus on a distant object somewhere in the classroom.

2. To bring the object into clearer focus, keep the lens close to your eye still. Move the other lens closer or farther away until the object can be seen clearly. Does the object look bigger or smaller? Is the image upside-down or right-side-up?

3. It's pretty tricky, isn't it? Practice makes perfect. Reverse the positions of the lenses and try again. How do things look when you hold the lenses this way? Does the object look bigger or smaller? Is the image upside-down or right-side-up?

Mission 7 Adventures with Telescopes

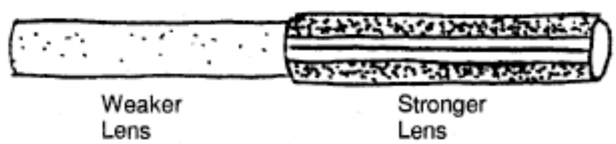
Logbook

How to Build Your Own Telescope–From Scratch

You will need:

- 2 paper-towel tubes
- Scissors
- Tape
- 2 lenses of different focal lengths

Figure 7.3-Telescope.



1. To make sliding tubes that fit snugly, carefully slit one tube lengthwise. Slide the tube with the slit over the other tube.

2. Put tape over the open slit to hold the tube tightly over the inner tube.

3. Tape the stronger-magnification lens to the end of the tube without the slit. (This is the end you'll hold close to your eye.)

4. Tape the weaker-magnification lens to the tube that has the slit.

5. Enjoy your telescope!

Mission 7
Adventures with Telescopes

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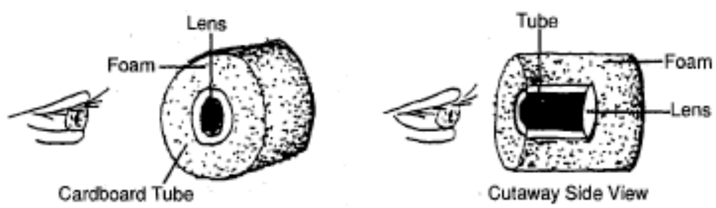
How to Build Your Own Telescope–From a Kit

Your telescope kit comes with:

- 2 large cardboard tubes
- 1 tiny cardboard tube
- Flat cardboard "donut"
- Foam
- Plastic cap
- 2 lenses of different focal lengths

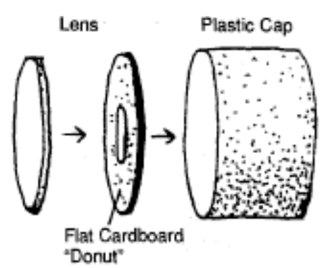
1. Make the eyepiece section using the stronger-magnification lens, as shown below:

Figure 7.4-Telescope Kit # 1.



2. Make the end section using the weaker-magnification lens, as shown below:

Figure 7.5-Telescope Kit # 2.



3. Put your telescope together, as shown below:

Figure 7.6-Telescope Kit # 3.

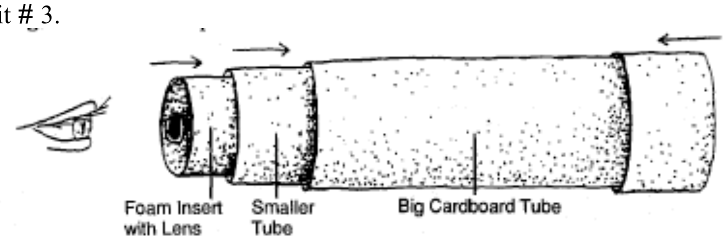
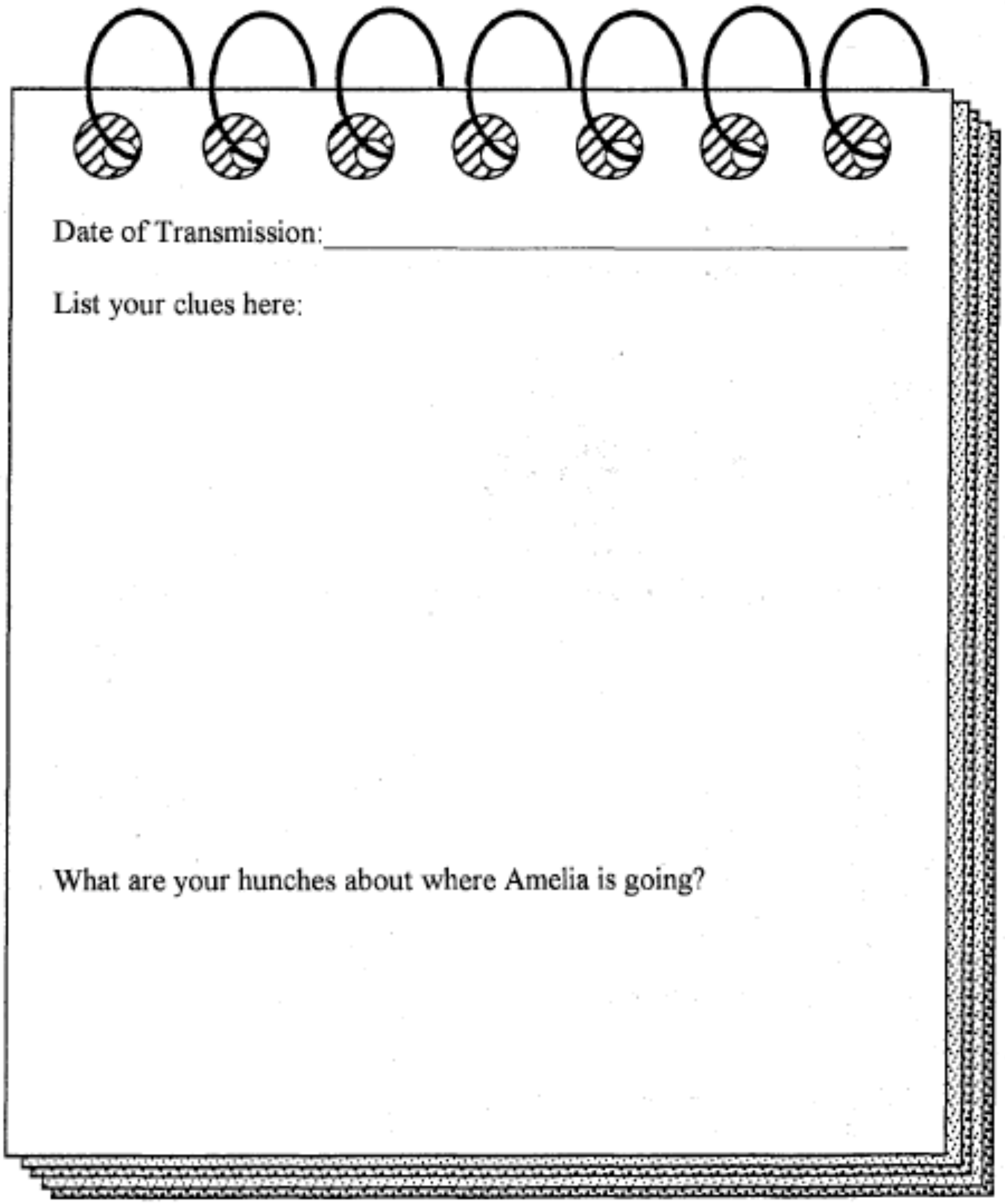


Figure 7.7-Science Detectives Notebook.



Now that you have had a chance to collect more information about Amelia's trip, which hunch was correct? Why? (Use the back of this sheet for your answers.)

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Mission 8
Observing the Planets!

Looking Into the Sky by Day and by Night

Overview

In mission 8.1, student teams use their telescopes to search for the planet that fits Amelia's clue from mission 7's video segment. A video segment confirms that Amelia's fourth destination was Mars. The clue for the next destination: Amelia will visit two planets, one with an orbit equal to 84 Earth years and another with an orbit equal to165 Earth years. Amelia is headed for Uranus and Neptune. Students get the first part of the ETI message Amelia has been tracking.

Teacher's Note: Because of the nature of this mission's activities, and the space constraints of a classroom, the model solar system is not scaled with regard to distances between the planets. Given the sizes of the model planets, they should be spaced much farther apart. In mission 9, students create a model solar system that is correctly scaled for distances between planets.

Concepts

- Telescopes permit observations of distant objects.
- Both the amount of light reaching a planet from the Sun *and* its distance from Earth affect the visibility of a planet.

Skills

- Observing model planets with telescopes.

Mission 8.1

Materials

For the Class

- Video
- Computer, projector or monitor
- Monitor
- Clip-on lamp with clear bulb (not frosted)
- Planet models from previous missions
- Chairs or tables on which to place the lamp and planets
- Felt tip markers

- Local map and compass (optional)

For Each Team

- Assembled telescope from mission 7
- The ETI message

Getting Ready

One or More Days Before Class

1. Find a large room that can be darkened with curtains or by putting black construction paper or black plastic bags over the windows.

2. Set out the lamp with a bare light bulb (the Sun) toward one side of the room, and place the rocky inner planets close to it; place the gas giant outer planets across the room, in much more distant orbits. Use the map of the solar system from mission 1 to approximate the locations of the planets. Place Mars fairly close to Earth.

3. Use a telescope from mission 7 to practice focusing on the model planets. Note that the image appears upside down. Find ways to steady the telescope by supporting it on furniture or by holding your elbows tight against your side. It can be frustrating for children to use a telescope, so be prepared to give them some helpful hints as in mission 7.2.

4. Add a heading “Seventh Transmission” to the “Clues from Videotape” chart.

5. Set up the video projector or monitor. Screen the video to “Lesson 8.” Show it towards the *end* of this lesson.

6. Copy “The ETI Message” from mission 11 (pages 218 and 219) for each team.

Classroom Action

1. **Lecture.** Introduce the mission by reviewing the video clue from mission 7: the planet is near Earth, and its surface can be seen by telescope. Ask students how the lenses can help them figure out where Amelia is going. Explain to the class that they will be using their telescopes to look at a simulation of our solar system (not to scale). Tell them again the distances between the model planets would be much greater if the simulation were a scale representation of our solar system.

2. **Activity.** Take students, with their telescopes, into the darkened room where the solar system model is set up. Students line up along one wall. Ask them if they know what the light bulb represents. *(The Sun.)* Ask students to look at the various planets through their telescopes.

(Team members should take turns looking through their telescope. Help individuals focus, as needed.)

Discuss the clue: The planet is near Earth, and its surface can be seen by telescope. Ask students which planets are near Earth (*Mercury, Venus, and Mars.)* Of these three planets of which can we see the surface? *(Mercury and Mars; Venus is hidden by a thick atmosphere.)* Instruct students to stand near the Sun, looking toward the rocky inner planets. Ask them to look at the surface of Mars with their telescopes. Ask if they can focus on it? *(Yes, if they pull their telescope tubes far enough apart.)* If students have difficulty, have them step farther back. Invite students to focus on the distant gas giant planets, too. Ask if they can see the surfaces of these planets? *(No, just the cloudy atmospheres.)*

Students can observe the various planets from different places in the room, as though they are moving across the solar system.

Ask students what they discovered.

Teacher's Note: Students may note that planets closer to the Sun and Earth should be brighter and easier to find. Distant planets (e.g., Neptune) are much harder to see because they are dimmer and/or smaller. Planets that are large may appear smaller to the eye because they are so far away.

Ask them which planet they think Amelia is headed for and why.

3. **Optional Demonstration.** Demonstrate where the orbits of the planets *should* be, based on the planet model scale of 1 to 210 million, as shown in table 8.1. Find a local map that shows the school. Mark the school as the center of the solar system–the Sun. Use a compass to make concentric circles to show the planets' orbits. At this scale, the Sun *should* be 6.62 meters in diameter! *(A compass of string, with a pen tied at one end and pencil tied at the other, can be used to mark the orbits of the more distant planets on the map.)*

Table 8.1-Planet Distances from the Sun at a Scale of 1 to 210 Million.

Planet	Meters from Sun	Miles from Sun
Mercury	300	0.20
Venus	540	0.33
Earth	750	0.5
Mars	1,150	0.75
Jupiter	3,900	2.50
Saturn	7,100	4.50
Uranus	14,350	9.00
Neptune	22,500	14.00
Pluto	29,500	18.00

4. **Video.** Announce to students that it's time to check in with NASA. Maybe they'll get some more information about Amelia's whereabouts. Show the video segment "Lesson 8." Amelia's last destination is confirmed as Mars. The two planets she will visit next are Uranus and Neptune.

5. **Discussion.** Discuss the information included in the video.

Video Clues: Lesson 8, January 25
(Travel time =25 days)

- Amelia could see Earth fairly well from the planet. She could make detailed surface observations of the planet. Therefore, the planet must be Mars, because the atmospheres of gas giant planets and Venus obscure their surfaces.

- Amelia left Mercury, and could not see the surface of Venus.

- New clue: Amelia is going to two planets, one with an orbital year equal to 84 Earth years, the second with an orbital year equal to 165 Earth years.

- Now we need models of the planets' orbits. Find the two planets that fit her description. Write down all clue suggestions on the "Clues from Video" chart. Teams should record clues in their Science Detectives Notebook.

- Distribute the ETI message. Have students place it into their notebooks for further analysis later.

Closure

1. **Activity.** Allow students to take a telescope home for an evening or weekend to search for real planets. A "Finding Planets" activity sheet is included at the end of this mission for your convenience.

2. ***(Optional)*** **Lecture.** Tell students what they should be able to see (conditions permitting) in the sky at this time of the year, and how to find these objects. Encourage them to use binoculars to look at the Moon and Jupiter *(Four of Jupiter's moons are visible with a good pair of binoculars.)*

Going Further

Research: Where Are the Planets?

Help students do research on the location of planets in the sky. Help them locate the general area of the sky where they should look, as well as the time of the evening different planets are visible. This information is available in *Sky and Telescope (http://www.skyandtelescope.com),* *Astronomy (http://www.astronomy.com),* and *Science and Children* magazines. It can also be located via internet searches, or by calling a local planetarium.

Field Trip: Looking at Stars

If there is an observatory within traveling distance, plan a field trip to give students an opportunity to view planets. Or contact a local astronomy club to arrange for a speaker or helper to come to an evening “Star Party” for students and parents.

Mission 8
Observing the Planets!

Script for Seventh Transmission

Synopsis: Lesson 8, January 25
(Travel time = 25 days)

- Amelia could see Earth fairly well from the planet. She could make detailed surface observations of the planet. Therefore, the planet must be Mars, because the atmospheres of gas giant planets and Venus obscure their surfaces.

- Amelia left Mercury, and could not see the surface of Venus.

- New clue: Amelia is going to two planets, one with an orbital year equal to 84 Earth years, the second with an orbital year equal to 165 Earth years.

- Now we need models of the planets' orbits. Find the two planets that fit her description.

BUZZ SAWYER
"Amelia, bless her little Spacehart, gave us two clues in that last message: one, she could see Earth fairly well with a telescope, and two, she could make detailed surface observations of the planet she was orbiting."

"Well, I'm as happy as a flea on a puppy, because that enabled our scientists and MEL to narrow down her possible destinations to one."

"Flea on a puppy? That reminds me of the Fleaburg Air Show ..."

DR. ORBIT
[Refers to a map of solar system.] "Amelia wouldn't be able to see the Earth very well if she were at any of the gas giant planets because they are so far away. Besides, she wouldn't be able to see the surfaces of the gas giants, because they're covered with dense atmospheres. So we figured she must be orbiting one of the inner, rocky planets."

SAWYER
"Yah!"

DR. ORBIT
"Now Amelia said that she was leaving Mercury." *[Points to Mercury on the map.]* "She said she was going to be observing Earth." *[Points to Earth on map.]* "We know that she can't see the surface of Venus, because that planet is covered with dense clouds." *[Points to Venus on map.]*

“That means that her destination must be Mars!” *[Points to Mars on map.]* “This fits because we know the atmosphere of Mars is thin enough for her to easily be able to see the surface.”

BUZZ SAWYER
“Nice work, Dr. Orbit. Maybe you’ll let me wash out some of your glassware, or maybe back up your hard disk?” *[snap, buzz EFX, Sawyer turns to camera.]* “Why does it have to make that strange sound?”

AMELIA SPACEHART
Date on screen: January 25

“Well, that last planet was not the source of my ETI transmission. But I picked up another chunk of the message, and I’m downloading it to the base computer, MEL, for her analysis, then Jupiter for a fill-up and off to two more planets. The first one has a year equal to 84 Earth years. The second one has a year equal to 165 Earth years. I’d be two months old on that planet!”

DR. ORBIT
“Science Detectives, if you’ve been making models and examples like we suggested ...”

BUZZ SAWYER
“... and you should. We want that craft back!”

DR. ORBIT
“... you’re now beginning to realize that *a year* is the amount of time that it takes for the Earth to go around the Sun once. Now, because the other planets are at different distances from the Sun, each one takes a different amount of time to complete one full orbit. Your task now is to try to identify the two planets that fit Amelia’s description. You know, it could be that we’re finally starting to close in on these extraterrestrials. Fascinating!”

BUZZ SAWYER
“Get you a cup of coffee, Dr. Orbit? By the way, do you have a first name?” *[reaction]* “What do you mean, ‘Doctor’ is your first name?”

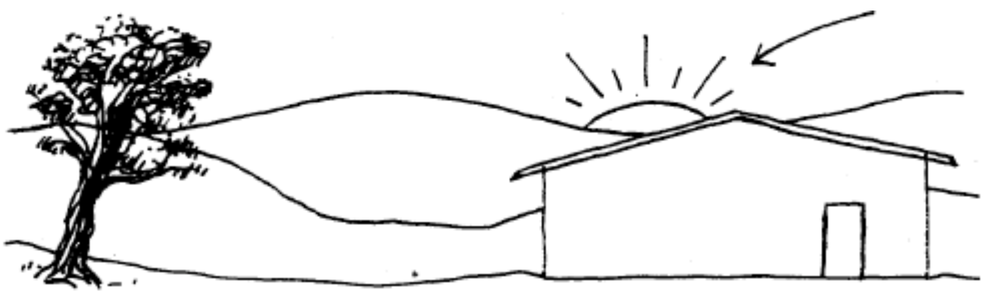
Mission 8
Observing the Planets!

Logbook

Finding Planets

Go outside after it gets dark. (Your parents may want to help you find the planets.) If you can, find a place that is far from the lights that are around houses and streets. If the Moon is visible, focus your telescope on the Moon. Choose a clear evening when the Moon is visible. Notice where the Sun goes down. Imagine an arc that spans to the east from where the Sun sets to where the Moon is in the sky. In the northern hemisphere, this will be in the southern part of the sky. This arc is called the *ecliptic.* It is on or near this line that you can see planets in the sky. The planets' orbits are of different lengths, and because planets move at different speeds, the planets that will be visible in the night sky changes over time.

Figure 8.1-Sunset.



Mars, Jupiter, Saturn, Venus, and sometimes Mercury are visible with small telescopes. They will appear as bright, untwinkling spots of light that are visible to the eye even without a telescope. Mars often appears red. Through a good small telescope Saturn often looks like an oval. Venus can usually be seen at dawn or dusk. With a high-powered telescope it is possible to see the red spot on Jupiter and even some of Jupiter's moons! You can use magazines such as *Sky and Telescope (http://www.skyandtelescope.com), Astronomy (http://www.astronomy.com),* and *Science and Children,* or else call your local library or planetarium to find out which visible planets are in the sky on a particular night. The internet also has this information.

If Venus is the "evening star" (sometimes it is the "morning star"), check the western sky after sunset for a bright object. Also scan the area between the Moon and the spot where the Sun set. Look for a bright, light-colored "star." Does it twinkle? If it does *not* twinkle, it could be a planet!

Can you find the North Star? You won't need your telescope for this. Just find the Big Dipper and draw a line in your imagination between two stars in the bowl of the dipper, as shown here. Follow the line to the North Star. Can you see the Little Dipper? If there are a lot of city lights, the fainter stars may not all be visible.

Figure 8.2-Big Dipper.

Now you can find all the compass directions–north, east, south, and west. West is approximately where the Sun went down. If you have an astronomical map of the sky, you can use it to find other constellations and special stars.

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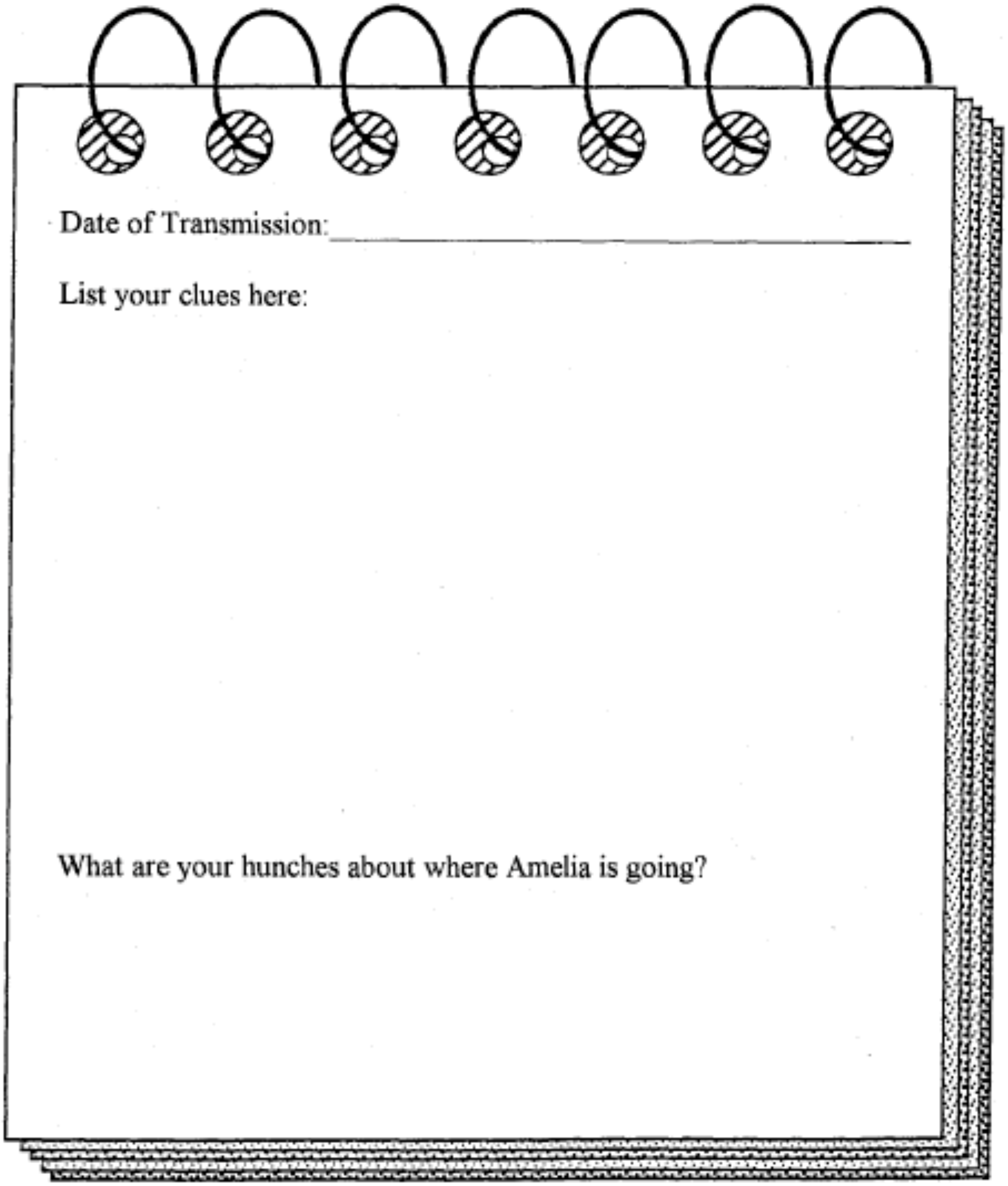
Mission 8
Observing the Planets!

Logbook

Figure 8.3-Science Detectives Notebook.



Now that you have had a chance to collect more information about Amelia's trip, which hunch was correct? Why? (Use the back of this sheet for your answers,)

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Mission 9
Cosmic Wheels

Measuring the Orbits of Planets

Overview

In mission 9.1, students build a model of planetary orbits that is a correctly scaled model of the solar system with regard to distances between planets. Students use the scale distance that the model Earth travels in one year as a basis for comparing the time other planets take to travel around the Sun *(a planet's orbital year)* with Cosmic Wheels *(trundle wheels).* Students observe that planets farther away from the Sun have orbits much larger than Earth's, and also that these outer planets move more slowly in their orbits than Earth does. Amelia's clue from mission 8 described two planets with orbital years equal to 84 and 165 Earth years. By measuring the orbits of their model planets, students find that Amelia's destinations were Uranus and Neptune. A video segment confirms those two destinations, and gives the science detectives their next clue: Amelia will visit the planet in our solar system that has the most rings and many moons. Amelia's next destination is Saturn.

Concepts

- An orbit is larger the farther a planet is from the Sun.
- Orbital speed is slower the farther a planet is from the Sun.

Skills

- Using a scale model to compare orbit sizes for the planets.
- Measuring planet orbital years using a Cosmic Wheel.
- Observing how the number of orbital years increases the farther a planet is from the Sun.

Mission 9.1

Materials

For the Class

- Computer, and projector and monitor
- *The Science Detectives* video, "Lesson 9"
- A large paved area or tiled room at least 15 meters (40 feet) across, with a smooth surface for making chalk circles
- 250 feet of heavy string
- Pencils

- Long pieces of chalk
- Masking tape
- Scissors
- Permanent marker

For Each Team

- Science Detectives Notebook
- "Earth Years for Planet Orbits" sheet (page 196)
- Styrofoam or heavy cardboard plates, 9-inch diameter
- Push pins
- Wooden meter stick
- Pencil

For Each Student

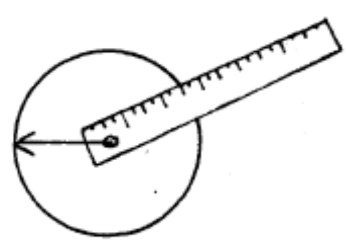
- Pencil

Getting Ready

One or More Days Before Class

1. Cut plates down to circles with radii as shown in figure 9.1. Use the permanent marker to draw a line from the center of each plate to its outer rim. Attach the plates to meter sticks at the 1-centimeter mark with the push pins. (For a more secure trundle wheel, drill a hole in the meter stick and use a small diameter bolt and nut as the axel for the plate/wheel.) For the outer planets, you will have to attach the plates closer to the end of the meter stick than the 1-centimeter mark. The plates should be secure but should still turn freely.

Figure 9.1-Cosmic Wheel # 1.



2. Make orbit-measuring strings as shown in figure 9.2. Tie a pencil to one end of a string to represent the Sun. Tie a piece of chalk to the other end to mark the distance of the planet's position from the Sun. Roll the extra string around the pencil. Mark it with tape showing the name of the planet. The distances between the planets and the Sun are given in table 9.1.

Figure 9.2-Cosmic Wheel # 2.

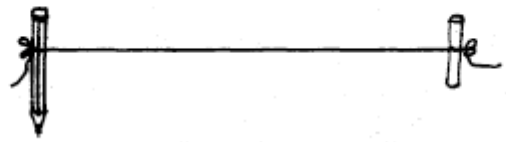


Table 9.1-Cosmic Wheels Data Table.

Planet	Orbit String	Radius of Cosmic Wheel (Plate Radius)	Orbital Period
Mercury	1.7 in / 4.3 cm	(No Wheel)	0.24 Earth Years
Venus	3.2 in / 8.1 cm	(No Wheel)	0.62 Earth Years
Earth	4.5 in /11.4 cm	4.5 in / 11.4 cm	1.00 Earth Years
Mars	6.8 in /17.3 cm	3.6 in / 9.1 cm	1.90 Earth Years
Jupiter	23.0 in / 58.4 cm	1.9 in / 4.8 cm	11.90 Earth Years
Saturn	43.0 in /109.2 cm	1.5 in / 3.8 cm	29.50 Earth Years
Uranus	86.0 in / 218.4 cm	1.0 in / 2.5 cm	84.00 Earth Years
Neptune	135.0 in / 342.9 cm	0.8 in / 2.0 cm	165.00 Earth Years
Pluto (dwarf planet)	178.0 in /452.1cm	0.7 in / 1.8 cm	248.00 Earth Years

3. Make sure you have a large enough room. Note that the orbit of the dwarf planet Pluto is almost 30 feet in diameter. If you do not have space for Pluto, end the model at the orbit of Neptune.

4. Copy the Notebook sheet "Earth Years for Planet Orbits" for each team.

5. Add a heading "Ninth Transmission" to the "Clues from video" chart.

6. Set up the video projector. Screen the video to "Lesson 9."

Classroom Action

1. **Discussion.** Review Amelia's last clue: She said that she was going to two planets this time, one whose orbital year was 84 Earth years and another whose orbital year was 165 Earth years. Explain to students that an orbital year is the amount of time it takes a planet to travel around the Sun. For the Earth, it is 365.25 days. Ask students if they have any hunches about which planets Amelia could be going to. Ask them to explain their hunches. Make a list of the planets that students suggest.

2. **Activity.** Clear the area to make space for the solar system model. Explain that they will make a realistic model of the solar system that is correctly scaled with regard to the distance between planets and the Sun.

   Use chalk to mark an X on the pavement or floor to represent the Sun. Choose one student to hold the "Sun" (pencil) end of the Earth orbit string at the center of the X on the floor.

Choose another student to play the part of Earth and orbit the Sun by holding the chalk and drawing a circle around the Sun, marking the orbit as he or she goes.

Ask other students to do the same thing with the orbit strings for the other planets. The orbits for the two inner planets (Mercury and Venus) may be omitted, if desired.

Teacher's Note: If you can't find a large area, try putting the Sun in the corner of your classroom and measuring one-quarter of each orbit, which should be multiplied by four to obtain the total length of the orbit.

3. **Discussion.** Ask students how the sizes of the orbits compare. Is there much difference between the size of the orbits for the first inner four planets and the outer four plus Pluto, the dwarf planet? Ask students to predict how long it will take for one of the outer planets to go around the Sun once. Then, ask students to predict what the effect will be of outer planets moving at different speeds than the Earth? Ask if any of their hunches about Amelia's destinations have changed, and why.

   Explain to students that they will use this scale model of the solar system to measure how long it takes each planet to go around the Sun once in "Earth years". This amount of time is its orbital year. The Cosmic Wheels will give the distance traveled by planets in one Earth year. Each team will measure the orbital year of their planet using a Cosmic Wheel.

4. **Demonstration.**

   - Use the Cosmic Wheel for the Earth to demonstrate the distance our planet travels in one year.

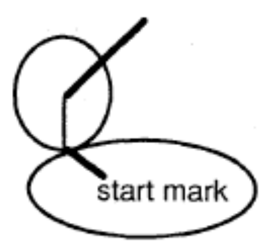
   - Roll the Wheel in a straight line on the ground, marking a start and end point of one rotation.

   - *Explain that this is the distance–in a straight line–that our planet travels in one year.*

   - Put a start mark on the Earth's orbit circle. The radial line on the Earth's Cosmic Wheel should be lined up with the bottom of the plate, on the start line. Explain that Earth isn't going in a straight line, but is in an orbit around the Sun.

   - Have a student from the Earth team roll the Cosmic Wheel once around Earth's orbit. The Cosmic Wheel will trace out one complete orbit, as shown in figure 9.3.

Figure 9.3-Using the Cosmic Wheel.



5. **Activity.** Teams for the remaining planets measure the length of their orbital year. Begin with Mars. (While one student rolls the Mars Cosmic Wheel around its orbit, another student counts the number of revolutions.) *The number should be approximately two, so Mars' orbital year is approximately two Earth years.* Continue with the other planets, and have teams record all results on their Logbook sheet "Earth Years for Planet Orbits."

   Roll the Cosmic Wheels in straight lines to show students that the distance the outer planets travel in one Earth year is less the farther they are from the Sun. In other words, planets move slower the farther they are from the Sun. Ask the students if they have any idea why this might be.

6. **Discussion.** Write down teams' orbital year measurements on the whiteboard. *Tell students that scientists always expect some error in their experiments, so students should not expect their results to be perfectly accurate.* Results will only approximate the lengths of orbital years. Ask students what their best guess is for Amelia's two destinations.

7. **Video.** Announce to students that it is time to check in with NASA again to see what their scientists have come up with, and to find out what Amelia is up to now. Show the video segment "Lesson 9." The video confirms Uranus and Neptune as the last destinations.

8. **Discussion.** Discuss the information included in the video.

Video Clues: Lesson 9, March 20
(Travel time =78 days)

- Amelia's last destinations were Uranus and Neptune.
- Amelia's next destination has the most rings and many moons.

The next clue points to Saturn, the planet with the most rings and many moons.

Discuss the information presented in the video. Record the ideas generated on the "Clues from Video" chart. Student teams should record the clues in their Science Detectives Notebook.

Closure

1. **Discussion.** Ask students how they define the word *year.* Why is it a different length of time on each planet? Review concepts as necessary. Ask students why Amelia said that she would only be two months old on a particular planet. How old would students be on Uranus? On Neptune?

Going Further

Tell students to imagine that there is an invisible planet hidden between Mars and Jupiter, and to determine how long its year would be. There are dwarf planets both in the asteroid belt, between Mars and Jupiter, and far beyond Neptune and Pluto. Ask students how they could estimate the orbital year of these dwarf planets. Check for information at the NASA Planet website:

http://solarsystem.nasa.gov/planets

Math Activity: How Old Am I on Mars?

Ask students to calculate their age on Mars, or on the other planets.

Mission 9
Cosmic Wheels

Script for Eighth Transmission

Synopsis: Lesson 9, March 20
(Travel time =78 days)

- Amelia's last destinations were Uranus and Neptune.
- Amelia's next destination has the most rings and the most moons.

BUZZ SAWYER
[Sawyer is fiddling with MEL.] "Well, MEL, what *is* the answer?"
[MEL replies in deep voice, "I'm sorry, Buzz."]

[Sawyer rips off paper.] "Oh, come off it, MEL. You're a supercomputer, aren't you?" *[MEL replies, "I can't do that."]* "Well, according to your analysis of the planetary orbits, it seems that Amelia has visited two outer planets, Uranus, with a year equal to 84 Earth years, and Neptune, with a year equal to 165 Earth years." *[snap, crackle EFX]*

AMELIA SPACEHART

Date on screen: March 20

[Interstellar Express, *with Neptune and the Sun.]* "Those last two planets were so far from the center of the solar system that the Sun blended in with all the other stars; it was just a little bit brighter—something you could be, Sawyer!"

BUZZ SAWYER
[annoyed] "Don't hassle me."

AMELIA SPACEHART
"At my next destination, I'm going to check out the planet that has the most rings. See, I figure if the message isn't coming from the planet, maybe it's coming from one of the moons!"

DR. ORBIT
"Seven of the nine planets in our solar system have moons. Four of the nine planets have rings. We're going to be researching moons and rings very carefully."

BUZZ SAWYER
[to computer] "Tell me, MEL, have you ever talked with an extraterrestrial?"
[MEL replies in a deep voice, "Other than you, Sawyer?"]
"No jokes, MEL, or I'll pull your plug ..."

Mission 9
Cosmic Wheels

Logbook

Earth Years for Planet Orbits

One Earth year is equal to one full turn of the Cosmic Wheel. On the chart below, record the number of times the Cosmic Wheel goes around for each planet.

Figure 9.4-Cosmic Wheel.

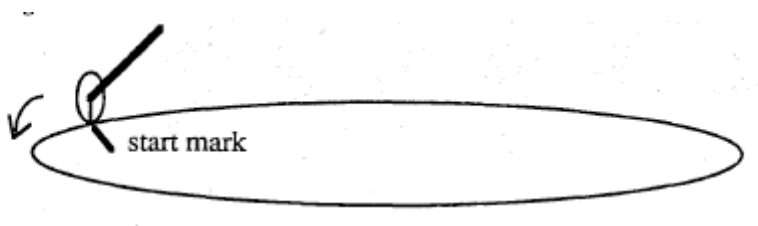


Table 9.2-Planet Data.

Planet	Number of Earth Years
Mercury	
Venus	
Earth	
Mars	
Jupiter	
Saturn	
Uranus	
Neptune	
Pluto	

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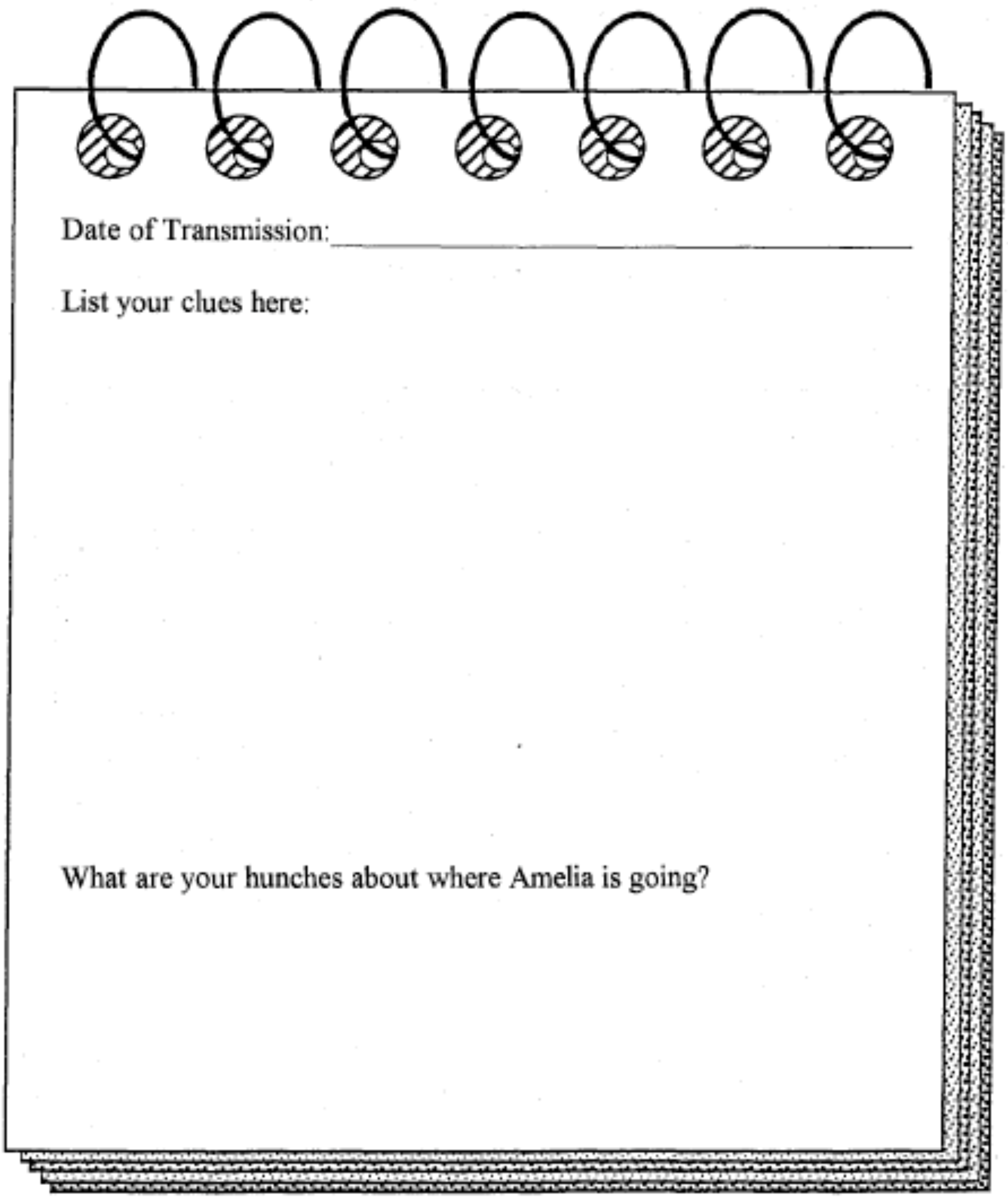
Figure 9.5-Science Detectives Notebook.



Now that you have had a chance to collect more information about Amelia's trip, which hunch was correct? Why? (Use the back of this sheet for your answers.)

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SETI INSTITUTE

Mission 10
Moon Phases

How the Sun Affects the Moon

Overview

In mission 10.1, students use a model of the Earth and our Moon to observe how the Sun contributes to the changing appearance of objects in our solar system. A video segment confirms that Amelia's last destination was Saturn. The clue for Amelia's next destination is a picture of the dwarf planet Pluto and its moon, Charon, taken from the window of the *Interplanetary Express.* The Sun appears in the background as a distant star.

Teacher's Note: This mission is adapted with permission from the Lawrence Hall of Science's activity "moonballs."

Concepts

- Apparent changes in the shape of the moon are brought about by changes in the moon's position relative to Earth and the Sun.

Skills

- Using a model to observe the phases of the moon.

Mission 10.1

Materials

For the Class

- Pictures of Saturn and its moons
- Floor lamp with no shade
- Extension cord
- Chair
- *The Science Detectives* video, "Lesson 10"
- Computer, and projector or monitor

For Each Team

- Science Detectives Notebook

For Each Student

- Small, light-colored ball (yogurt-covered candy, hard-boiled eggs, rubber balls, oranges, and Styrofoam balls have all been used successfully)
- Pencil

Getting Ready

1. Darken the classroom as much as possible. If your classroom cannot be darkened, see if some other room in the school is available.

2. Set up the lamp with a bare, clear light bulb in the middle of the classroom. A bright bulb usually works best.

3. Add a heading "Ninth Transmission" to the "Clues from Video" chart.

4. Set up the computer and projector or monitor. Screen the video to "Lesson 10."

Classroom Action

1. **Discussion.** Review the clue from mission 9's video segment: Amelia said she was headed for the planet with the most rings and moons. Because the Science Detectives already know so much about the planets in our solar system, they probably will know right away that Saturn is the planet that fits this clue.

   Tell the class that they have some time to learn a little more about moons to prepare for the next challenge. Tell students that their investigation of moons will begin with our Moon, which is named Luna. Ask them what they know about Luna and record all of their ideas and descriptions on the whiteboard. Guide them with the following questions:

   What have they noticed about our Moon?

   What are the different shapes that the Moon seems to have at different times? *(Crescent, first quarter, three-quarter or gibbous, full, etc.)*

   Why does the Moon seem to have different shapes at different times?

   Explain to students that they will be working with another model today to see if they can explain the changes in our Moon's shape.

2. **Demonstration.** Demonstrate the phases of the Moon. Take students to the area where you have set up the lamp and then darken the room. Students stand in a large circle around the lamp and face the lamp. *(If the room has light, reflective walls, it is best that they stand in a circle closer to the light rather than near the walls.)*

Ask students to imagine that the lamp is the Sun, and that their heads represent Earth. To review mission 9, ask them how long it would take them, if they really were Earth, to go around the Sun. *(One full Earth year–365 days.)*

Tell students that the Earth also turns on its axis once a day. Show students how to demonstrate this by turning around completely one time, stopping to face the Sun again. Recalling that their heads represent Earth, students should imagine people living all over their heads. Ask them:

For the people who live on your face, is it day or night? *(Day.)*

For the people who live on the back of your head, is it day or night? *(Night.)*

Hand out the balls and tell students that these represent the Moon. Have them hold their Moon at arm's length so that they cannot see the Sun. Ask students what it is called when the Moon gets in the way of the Sun. *(A solar eclipse.)*

Tell students to keep their arms outstretched. Ask them to "bring the Moon around." They should rotate their whole bodies on their axes. Demonstrate this movement to them.

Ask students to bring their Moon partway around, until part of their Moon is lighted and part of it is in the dark. Ask them to point to the light part and to the dark part. *(You may even want to go to each student and have them point this out to you–sometimes students look at the shadows on the wall, instead of right at the moon).*

After all students are focused on the light and dark parts of their Moon, have them adjust their Moon until they see a lighted crescent shape. They should be somewhere between facing the Sun and facing sideways from the Sun. Help students who turn the other way, or who watch the lamp instead of the ball.

When all students see the crescent, tell them to keep turning slowly to the left and to stop when their Moon becomes half light and half dark (first-quarter Moon). *(They should all be standing so that the Moon is at a right angle to the Sun.)*

Have students turn farther to the left so that their moons become more illuminated. Ask them what Moon phase comes next. *(Full Moon.)*

As they turn farther, ask students to pass the Moon just above the shadow of their heads to see the full Moon. *(If the Moon is held too high, the full phase will not be seen.)* After the Moon passes the shadow of their heads, students continue observing the change in phase as the Moon orbits the Earth (their heads).

Ask students to put down their moon balls and explain why the real Moon has different phases at different times. *(The Sun's light shows only part of the Moon. It depends on how we see the Moon, or on our point of view.)*

Invite students to orbit or revolve (not rotate) the Moon all the way around them again, once or twice, to see the Moon go through all of its phases. *(You might wish to have students observe an eclipse of the Sun (have them pass the Moon directly between the lamp and their eyes) or an eclipse of the Moon (have them pass the Moon into the shadow created by their heads).*

3. **Video.** Tell the class that you have received another transmission from Amelia Spacehart. They can find out if the NASA scientists agree with their ideas about Amelia's last clue. Show the video segment "Lesson 10." The video confirms Saturn as the last destination.

4. **Discussion.** Discuss the information included in the video.

Video Clues: Lesson 10, July 25
(Travel time =205 days)

- Amelia's last destination was Saturn.

- We lost contact with Amelia, but found the view from the *Express* window–a planet and a large moon!

List all the clues that students suggest might be important on the "Clues from video" chart. The new clue in this video is a picture of the dwarf planet Pluto and its moon, Charon. Teams should record the clues in their Science Detectives Notebooks.

Closure

1. **Discussion.** Ask students to share what they learned about the phases of the Moon. Write all their responses on the whiteboard. Show the class a picture of Saturn and its moons. How are Saturn's moons like our Moon? How are they different?

Going Further

Activity: The Moon by Day

Check a calendar, your local newspaper, call your local planetarium or use the internet to find out when the Moon will be visible in the daytime sky. Take your class outside with telescopes to observe the Moon on a daily basis. In the classroom, ask students to draw the phases of the Moon that they see. Use their pictures to make a graph that shows the changing phases of the Moon.

Ask students why the Moon is sometimes visible during the day and sometimes during the night.

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Mission 10
Moon Phases

Script for Ninth Transmission

Teacher's Note: Explain that when the video was made the number of moons at Saturn and Uranus was correct. Many more have been discovered since. The "NASA Planetary Directory" (mission 3) has the correct numbers, as of October 2009.

Synopsis: Lesson 10, July 25
(Travel time =205 days)

- Amelia's last destination was Saturn.
- We lost contact with Amelia, but found the view from the *Express* window–a planet and a large moon!

BUZZ SAWYER
"Well, she's still out there. But our research indicates that Amelia must have been talking about either Uranus or Saturn, 'cause both have many moons and many rings. The latest astronomical data show that Uranus has 15 moons and 11 rings. For Saturn, 17 moons and at least 1,000 rings! So, this information allows us to narrow down her location to–that's right–Saturn! Amelia's been out there a very long time; I hope she'll be coming home soon." *[snap, crackle]*

AMELIA SPACEHART
Date on screen: July 25

[View from her window is of the dwarf planet Pluto and Charon from a low orbit perspective; includes the Sun as a bright star.] "NASA Control, I'm happy to say that I've totally perfected the use of the hydrogen siphon system, with all those refueling stops at Jupiter." *[very excited]* "But I have better news than that, I've figured it out! When you take the last part of the message and add it to the other messages, it forms an image, it makes a picture, ..." *[Transmission is cut off by static.]*

DR. ORBIT
"That transmission was terminated by interference from the solar wind. We don't know when we will be able to reestablish contact. However, as a clue, we were able to isolate the view from the *Express'* window. MEL is now downloading a copy for you. We hope that our planet models will give us enough information to figure out where Amelia is." *[Shows close-up of downloaded view from Amelia's window.]* "Could this be where the extraterrestrials are camped out?"

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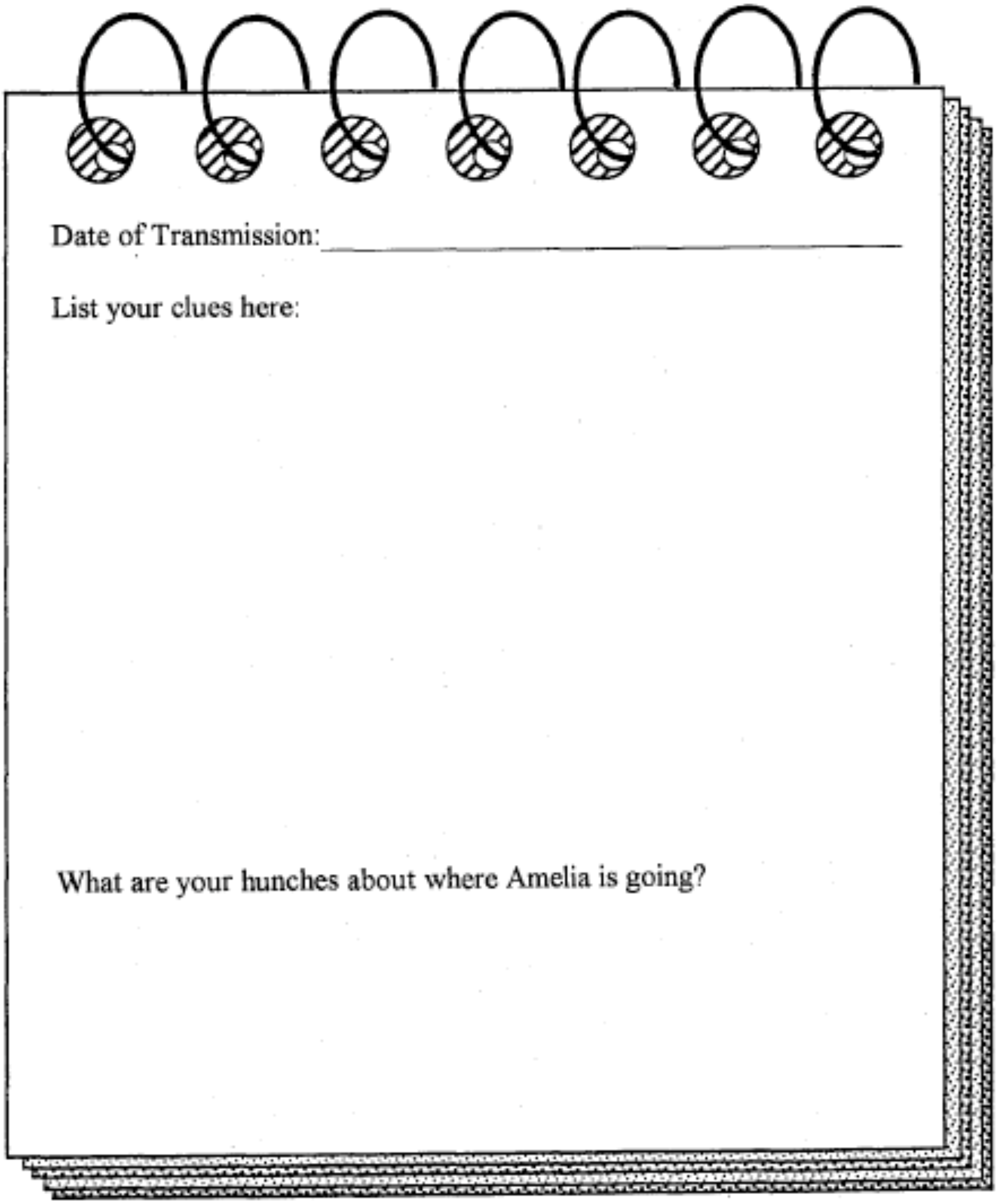
Mission 10
Moon Phases

Logbook

Figure 10.1-Science Detectives Notebook



Now that you have had a chance to collect more information about Amelia's trip, which hunch was correct? Why? (Use the back of this sheet for your answers.)

Mission 11

Planets and Moons
Am I Seeing Double?

Overview

The final clue for this unit was given in the video segment for mission 10. It was a picture of the dwarf planet Pluto and Charon taken from the *Interplanetary Express.* The only planet that Amelia has not yet investigated is Pluto, a dwarf planet. But how can Pluto appear so large when it was so small in the model solar system? The tiny dot in the corner of the picture is the Sun!

In mission 11.1, students create scale models of moons for their planet models.

In mission 11.2, students watch the final video segment, during which they receive a simulated message of extraterrestrial origin that must be decoded. Buzz Sawyer congratulates students for a job well done, and each student receives a Science Detective Certificate!

Concepts

- A message from an extraterrestrial civilization will be difficult to decode.
- A message from an extraterrestrial civilization may be based on universal concepts and images.

Skills

- Creating scale models of moons for the scale model planets.
- Decoding an extraterrestrial message.

Mission 11.1

Materials

For the Class

- "View from Amelia's Window" image
- 1 bar or container of modeling clay
- Computer, and projector or monitor

For Each Team

- Science Detectives Notebook
- "Moon Measurement" table
- Selection of round objects of various sizes (*e.g.*, sand grains, spherical cake sprinkles, marbles, ping pong balls, tennis balls, beach balls)

For Each Student

- Pencil

Getting Ready

One or More Days Before Class

1. Make one copy of the "Moon Measurement" pages (pages 213-216), and cut them apart into the tables for the various planets.

2. Collect a selection of round objects of various sizes.

Classroom Action

1. **Discussion.** Display figure 11.1 (computer projector or print)

Figure 11.1-View from Amelia's Window.

Encourage students to suggest possibilities for what the large round objects in the foreground might be. *(A planet and a moon; a double planet; two asteroids; two moons.)* Tell students that, because Amelia has followed a pattern of visiting planets, we can assume that the two objects are probably a planet and a moon. Ask students which planets are then ruled out as possibilities. *(Venus and Mercury, because they have no moons. Also, Saturn and Uranus, because we don't see any rings.)* Write the remaining planets on the board: Earth, Mars, Jupiter, Neptune, Pluto.

Many clues will point toward the dwarf planet Pluto. *(Accept students' guesses as hunches and remind them that Amelia has already been to Jupiter twice, and that she's perfectly capable of sneaking back to Earth to startle Buzz Sawyer. Tell students that one way to solve this puzzle is to build scale models of the planets' moons.)*

2. **Activity.** The Mercury and Venus teams combine with the remaining seven teams. *(The Saturn and Uranus teams should make their moons too. If seen from edge-on, the rings wouldn't be visible in that view.)* Hand out a selection of round objects and clay to each team. Instruct them to choose the round objects that best represent their planet's moons to scale (the same scale as the planet) or to make moon models from the clay.

   Congratulate students on their moon hunches and distribute the "Moon Measurement" tables. Students review their moon choices and make any changes necessary.

3. **Discussion.** Each team should display their planet's moon system on a table. Allow time for all teams to tour the room. Have a brief discussion. Ask if anyone changed their original hunch about the objects in the picture? *(It has to be Pluto!)* Only the Pluto/Charon system is so close in size. Remember from Dr. Orbit and the NASA Planetary Directory that some scientists consider Pluto and Charon to be a double planet system.

Mission 11.2

Materials

For the Class

- *The Science Detectives* video, "Lesson 11"
- Computer, and projector or monitor

For Each Team

- "The ETI Message" Logbook sheets (pages 218 and 219)

For Each Team

- Science Detectives Notebook

For Each Student

- Science Detective Certificate
- Pencil

Getting Ready

One or More Days Before Class

1. Make one copy of the Logbook sheet "The ETI Message" for each team. Make a copy of the Science Detective Certificate for each student. Write students' names on the certificates.

Just Before the Lesson

1. Add a heading "Tenth Transmission" to the "Clues from Video" chart.
2. Set up the video projector. Screen the video to "Lesson 11."

Classroom Action

1. **Video.** In the final video segment, Amelia and her friends bid the Science Detectives a fond farewell. Show the video segment "Lesson 11." The video confirms that the view was from the dwarf planet Pluto and Charon.

2. **Activity.** Give each team the sheet "The ETI Message." Tell students that this is Amelia's final transmission to students. Ask students what they think the message means. Give teams time to analyze the message, compare it to the other two, and discuss their hunches with each other. When they reach agreement, they record their ideas in their Science Detectives Notebook.

3. **Discussion.** Discuss as a class what the meanings of the ETI message might be. If there is any disagreement or confusion, post the message in the classroom and encourage ongoing debate. Tell them that messages are not always obvious and clear.

4. **Presentation.** Hand out the Science Detective Certificates. Applaud students for a job well done.

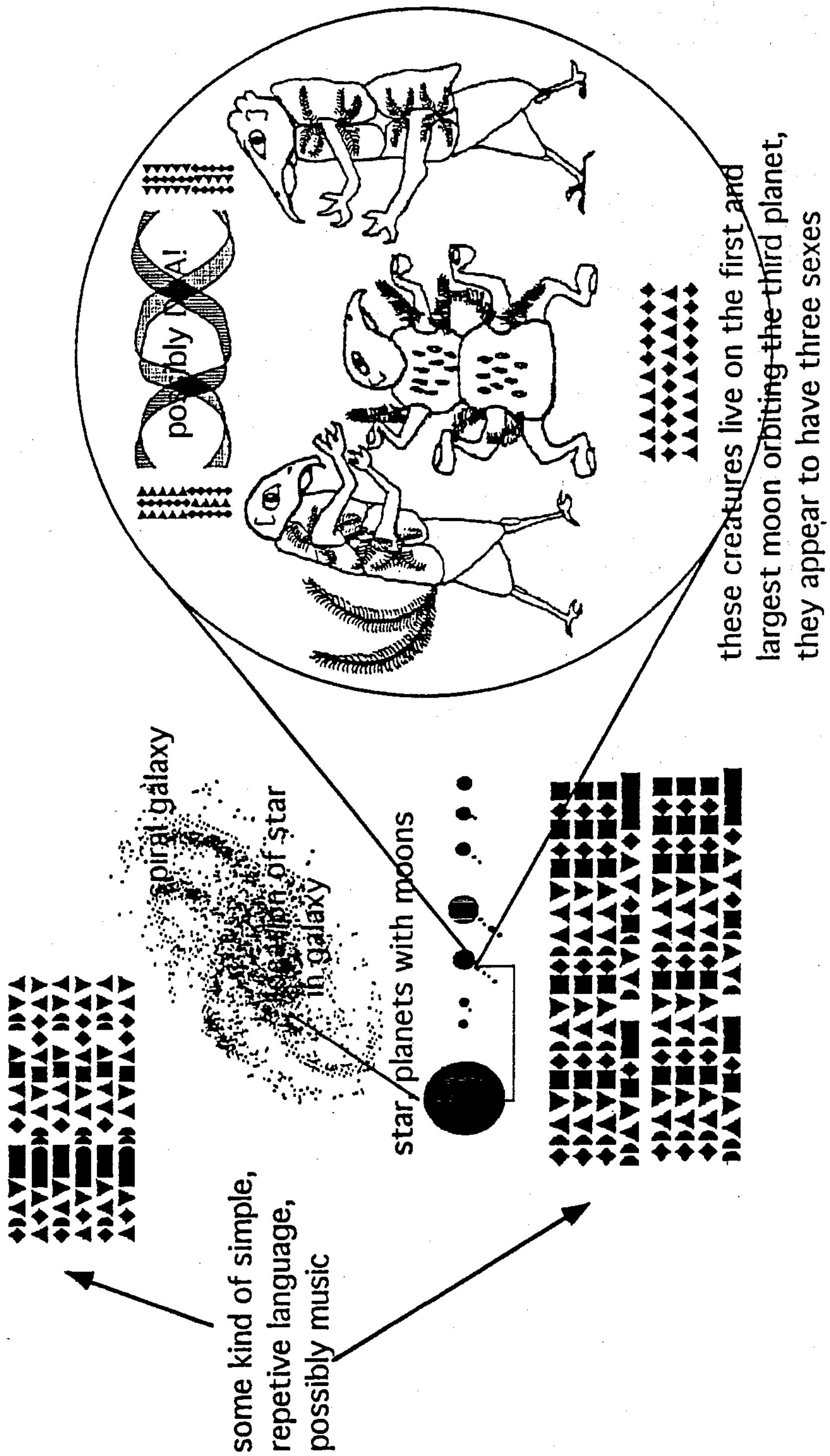
Closure

1. *(Optional)* **Assessment Project.** Challenge students to create a solar system mystery: "Treasure Hunt" and pretend to be "renegade" astronauts like Amelia, and to create a new series of clues that will lead another team through the solar system. This can be done for another class or for a group of parents.

2. **Discussion.** Ask students what they want to be when they grow up. Make the careers of astronaut, space explorer, scientist, astronomer, and so forth seem possible to all of your students. Tell them that they *can* be any of these if they want to be!

Mission 11
Planets and Moons
The ETI Message—Teacher's Key

Figure 11.2—The ETI Message.



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Mission 11
Planets and Moons

Script for Tenth Transmission

Synopsis: Lesson 11, September 26
(Travel time =237 days)

- The view from Amelia's window is a double moon, a moon and a planet, or a double planet.
- The view is of the dwarf planet Pluto, which is a planet with a moon that is large in comparison to Pluto.
- Amelia has realized that the message is from a probe that is moving along the plane of the solar system. The message looks like some sort of picture.
- Science Detectives must decipher the message!
- Amelia will arrive on Earth, November 11. Her total travel time is 283 days.

BUZZ SAWYER
"Well, we've analyzed the window view carefully. We guessed that it has to be one of three possibilities. Now either it's a double moon system, a moon and a planet, or a double planet. So, we considered all of those planets that have moons and that only leaves out Mercury and Venus. Then we created a scale model of the solar system, and we used that scale model to construct views from each of the planets. What did we find? Well, it looked like the Pluto/Charon system fit best. I kind of wonder what Spacehart has on her brain these days?" *[snap, crackle EFX. Turns to camera.]* "Can I call 'em?"

AMELIA SPACEHART
Date on screen: September 26

"I'm filling up at Jupiter and I'm heading back to Earth. Why? Well, it finally occurred to me. The message has to be originating from a traveling probe, which perfectly explains why I could never tell exactly where it was coming from. I thought of tracing the probe, realized it would take me ten, a hundred, a thousand lifetimes to finally track it down. Bad idea! So, definitely, time to head home. Good news for you, Sawyer. Anyway, once I'm home, I figure I can get a bunch of radio astronomers together. Between the lot of us, we can figure exactly where this message is coming from. Did you hear that, mom? I'm coming home!"

DR. ORBIT
"Amelia has sent the last of the ETI messages. They seem to form some sort of picture when put together! We don't know what it means yet, but it looks promising!"

BUZZ SAWYER

"You've been a great help, Science Detectives! You figured out all of Amelia Spacehart's destinations long before she got there. You used charts, models, graphs, all kinds of math, and general clear thinking to figure out all the puzzles we threw at you. Your last assignment: Decipher the message. And your teachers will be informing us of whatever conclusions you reach. So, good luck, farewell, Science Detectives, it's been great working with you!

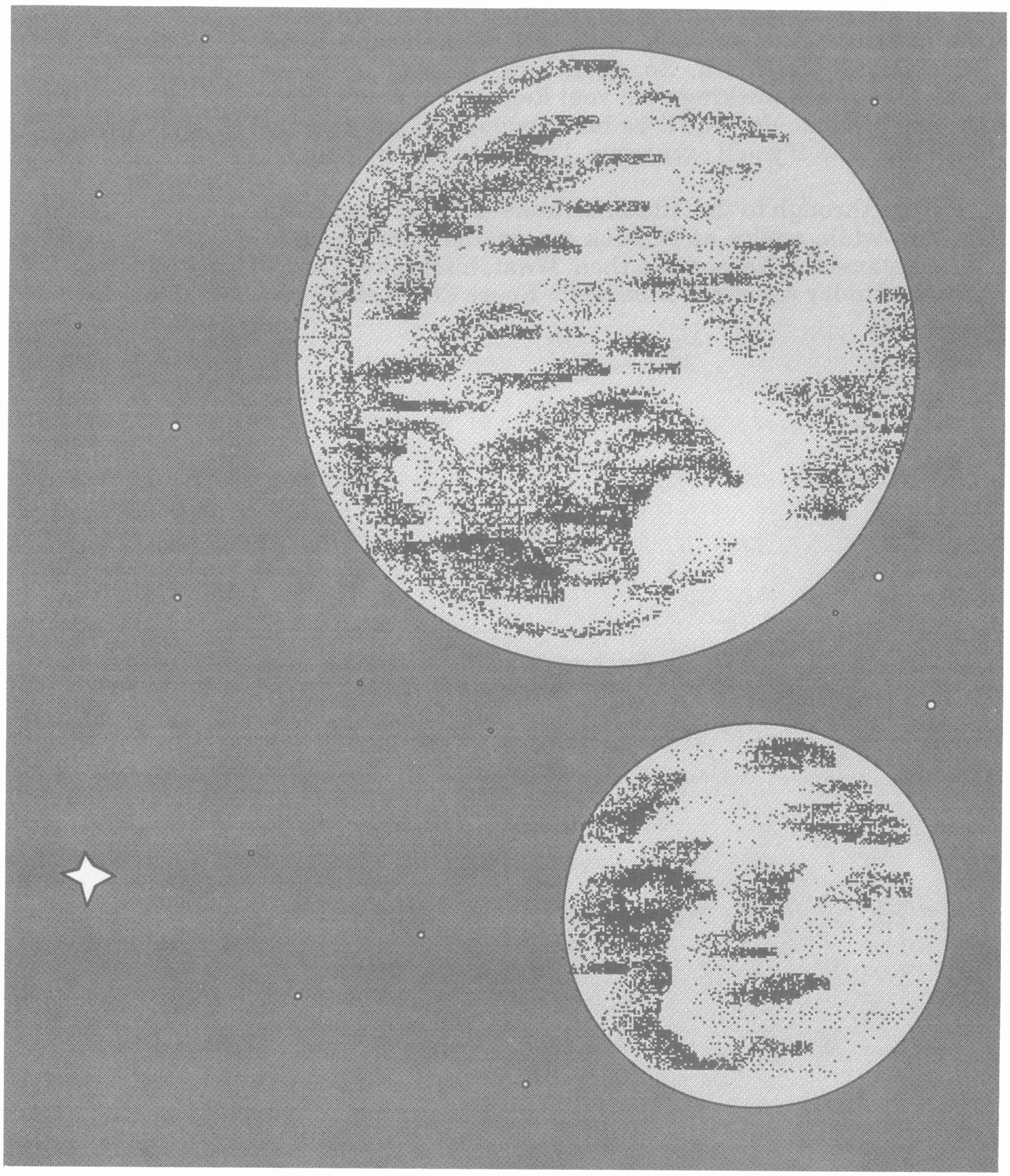
Remember, study hard, go to college, maybe some day you'll be lucky enough to get a really nifty job, like mine. Now if you'll excuse me, I've got to use the phone."

[on phone] "Put me through to the Administrator—I've got good news for him. Oh, and while you're at it, book me on the next flight to Fleaburg. Whaddyamean? Well–train then. What, hitchhike? I don't hitchhike. I'm the Under Assistant Honcho for Space Command here. I ... I don't do that."

Mission 11
Planets and Moons

View from Amelia's Window

Figure 1l.4-Enlarged View from Amelia's Window.



Mission 11
Planets and Moons

Moon Measurement

Teacher's Note: Cut planet moon sets apart to give to teams.

Table 11.1-Earth's Moon: Scale is 1 to 210 million.

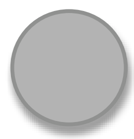
Luna Scale size = 1.5 cm in diameter	 Find an object about this big.

Table 11.2-Mars' Moons. : Scale is 1 to 210 million.

Phobos Scale size = 0.1 mm in diameter	Find an object the size of a grain of sand.
Demos Scale size = 0.05 mm in diameter	Find an object the size of a grain of salt.

Table 11.3-Jupiter's Moons. Scale is 1 to 210 million.

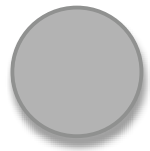
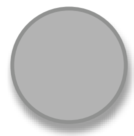
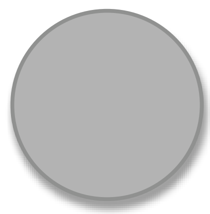
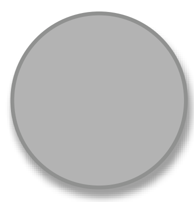
Io Scale size = 1.7 cm in diameter	 Find an object about this big.
Europa Scale size = 1.5 cm in diameter	 Find an object about this big.
Ganymede Scale size = 2.5 cm in diameter	 Find an object about this big.
Callisto Scale size = 2.3 cm in diameter	 Find an object about this big.
Jupiter has 59 other moons.	Find 59 other objects from the size of this dot to grains of sand and salt. ●

Table 11.4-Saturn's Moons. Scale is 1 to 210 million.

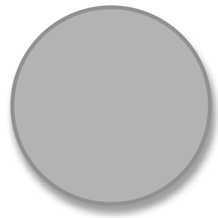
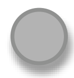
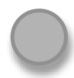
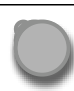
Titan Scale size = 2.6 cm in diameter	 Find an object about this big.
Rhea Scale size = 7 mm in diameter	 Find an object about this big.
Iapetus Scale size = 7mm in diameter	 Find an object about this big.
Dione Scale size = 5 mm in diameter	 Find an object about this big.
Tethys Scale size = 5 mm in diameter	 Find an object about this big.
Saturn has 55 other moons.	Find 55 other objects from the size of this dot to grains of sand and salt.

Table 11.5 -Uranus' Moons. Scale is 1 to 210 million.

Titania Scale size = 7 mm in diameter	 Find an object about this big.
Oberon Scale size = 7 mm in diameter	Find an object about this big.
Umbriel Scale size = 5 mm in diameter	Find an object about this big.
Ariel Scale size = 3 mm in diameter	Find an object about this big.
Miranda Scale size = 2 mm in diameter	Find an object about this big.
Uranus has 22 other moons.	Find 22 other objects from the size of this dot to grains of sand and salt.

	•

Table 11.6- Neptune's Moons. Scale is 1 to 210 million.

Triton Scale size = 1.3 cm in diameter	 Find an object about this big.
Proteus Scale size = 2 mm in diameter	Find an object about this big.
Neried Scale size = 1 mm in diameter	Find an object about this big.
Neptune has 10 other moons.	Find 10 other objects from the size of this dot to grains of sand and salt. ●

Table 11.7- Pluto, the Dwarf Planet's Moons. Scale is 1 to 210 million.

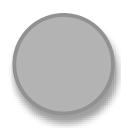
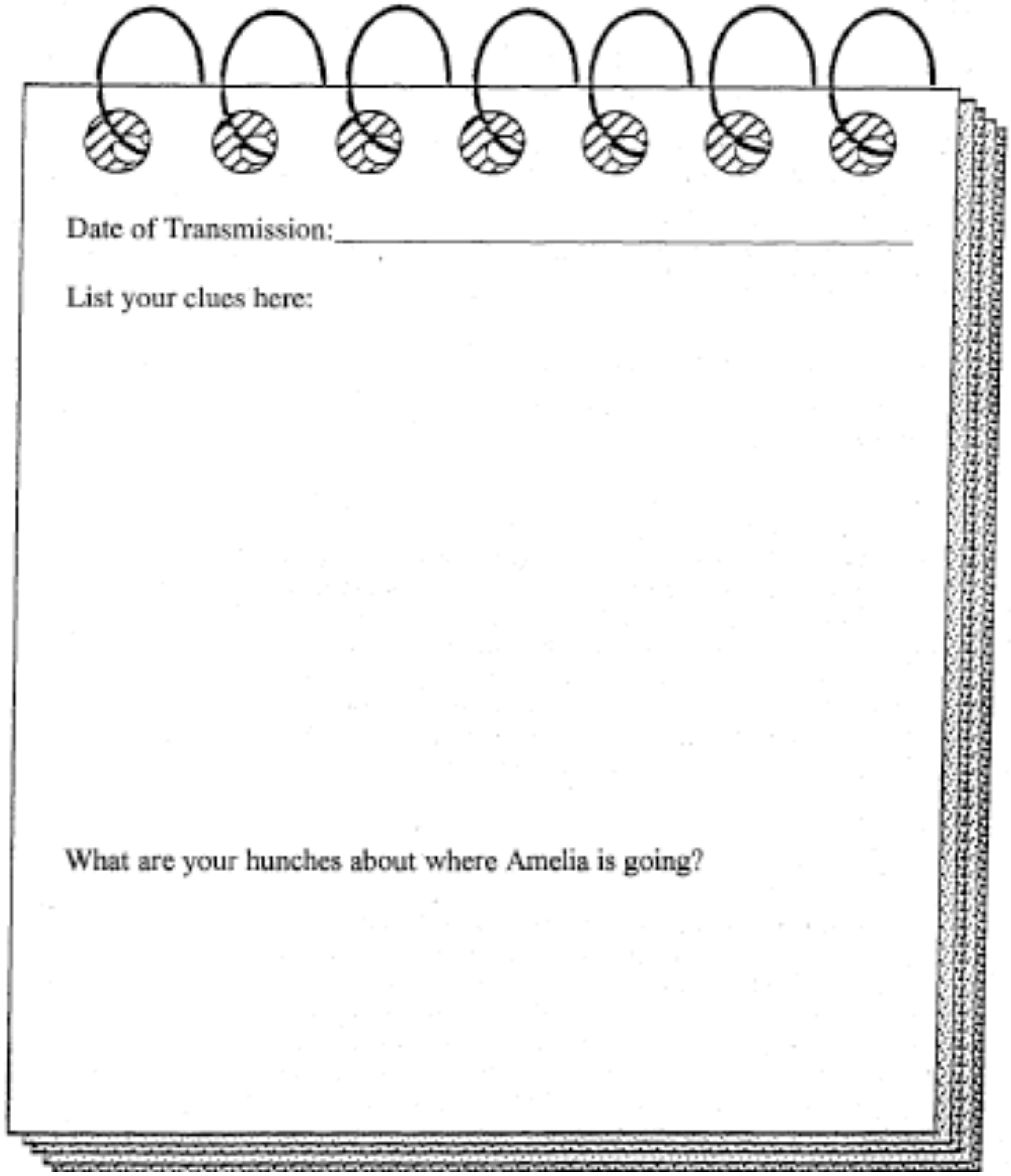
Charon Scale size = 1.3 cm in diameter	 Find an object about this big.
Pluto has 2 other moons.	Find 2 other objects the size of grains of sand or salt.

Figure 11.3-Science Detectives Notebook.



Now that you have had a chance to collect more information about Amelia's trip, which hunch was correct? Why? (Use the back of this sheet for your answers.)

Mission 11
Planets and Moons

The ETI Message-Part 1of 2

Figure 11.5-ETI Message Part 1.

Figure 11.5—ETI Message Part 1.

Mission 11
Planets and Moons

The ETI Message-Part 2 of 2

Figure 11.6-ETI Message Part 2.

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THIS CERTIFICATE IS TO INFORM THE SOLAR SYSTEM

____

IS A

SCIENCE DETECTIVE

Of the highest standing

This Student Has Proven Her/His Ability to Organize and Analyze Information,
Make Imaginative Hunches and Change Them to Hypotheses, and
Find Creative Solutions to Difficult Problems.

Amelia Spacehart — AMELIA SPACEHART
Eugene Orbit — DR. EUGENE "FLASH" ORBIT
Buzz Sawyer — BUZZ SAWYER
MEL — MEL, NASA COMPUTER

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Glossary

Amelia Spacehart. Fictional astronaut who borrowed the fictional *Interplanetary Express* spacecraft in *The Science Detectives* video.

Asteroid. Chunk of rock that orbits the Sun; too small to be a planet.

Astronaut. Person who travels beyond Earth to explore space.

Atmosphere. Gases that blanket some planets.

Buzz Sawyer. Fictional NASA official in *The Science Detectives* video.

Charon. Pluto's moon.

Circumference. The distance around a sphere or circle.

Cosmic Wheel. A device made in mission 9 to measure orbital years.

Dr. Orbit. Fictional genius and scientist in *The Science Detectives* video.

Dry ice. Frozen carbon dioxide; it turns from a solid directly into a gas.

Earth. The third planet from the Sun in our solar system.

ET. Extraterrestrial; not from our Earth.

ETI. Extraterrestrial intelligence.

Gas. A state of matter; for example, air in a balloon or the hydrogen atmosphere on Jupiter.

Gas giant. A large planet that orbits far from the Sun and is made mostly of gas; Jupiter, Saturn, Uranus, and Neptune are the gas giant planets in our solar system.

Hunch. A guess, or hypothesis; a good way to start solving a puzzle.

Interplanetary Express. Fictional spacecraft borrowed by the fictional astronaut Amelia Spacehart in *The Science Detectives* video.

Jupiter. The fifth and largest planet from the Sun in our solar system.

Lens. A curved surface, such as glass, that can make things look bigger or smaller.

Liquid. A fluid state of matter; for example, water or honey.

Mars. The fourth planet from the Sun in our solar system.

Matter. Stuff that has mass (weight) and takes up space.

MEL. Fictional computer in *The Science Detectives* video.

Mercury. The first planet from the Sun in our solar system.

Moon. A body that orbits a planet.

NASA. National Aeronautics and Space Administration; NASA is real!

Neptune. The eighth planet from the Sun in our solar system.

Orbit. The path a planet follows as it circles its star, or the path a moon follows as it circles its planet.

Orbital Year. The time it takes for a planet to complete one full orbit around the Sun. For the Earth, this is 365 days.

Planet. A body that orbits a star and does not produce light.

Pluto. A dwarf planet that orbits the Sun in our solar system.

Ring. Many tiny particles of dust and ice that orbit a planet in a group.

Rocky inner planet. A small planet that orbits close to the Sun and is made mostly of rock; Mercury, Venus, Earth, and Mars are the rocky inner planets in our solar system.

Saturn. The sixth planet from the Sun in our solar system, and the one with the most extensive set of rings.

Solar system. Our Sun, the eight planets that orbit our Sun, plus moons, rings, asteroids, comets and dwarf planets.

Solid. A state of matter; for example, rock or ice.

Star. A globe of hot gas that produces light.

Sun. Our own star; the center of the solar system.

Telescope. A combination of lenses used to make far-away things like stars and planets look bigger.

Uranus. The seventh planet from the Sun in our solar system.

Venus. The second planet from the Sun in our solar system.

Appendixes
Required Materials List
Office, Art, and General Supplies

Table A.1-Office, Art, and General Supplies.

Material	Substitutes or Alternatives	Quantity for Pair, Team or Center	Quantity for Each Class of 32	Reusable Each Class?	Used in Activity
Butcher paper			1	No	1, 2, 3, 6
Masking tape			1 roll	No	1, 2, 3, 5, 6, 9
Pencil and Notebook			32	No	All
Transparent tape			Several rolls	No	1, 3, 4, 7
Scissors			1	Yes	1, 3, 4, 7, 9
Glue or paste		1 or 2		Yes	
Meter stick, wooden		1		Yes	1, 9
Felt tip markers		1	Varies	Yes	1, 2, 3, 5, 6, 8
Straight pins		9		Yes	1
Heavy thread		150 cm			
Corrugated cardboard 30x70 cm piece					1
Soccer ball	Ball of the same size			Yes	2
Solid objects	Rock, pencil, magnet		3	Yes	2
Liquids	Food color, honey, milk		3	Yes	2
Containers	Liquid holders		3	Yes	2
Meter tape			1	Yes	2, 3, 5
Balloons, big (9” or larger)			2	No	2
Picture of Earth (taken from space)			1	Yes	2
Clip-on heat lamp	Small space heater		1	Yes	2
Cooler (ice chest)	Styrofoam box		1	Yes	2
Aluminum foil			1 box		2
Dry ice	See below		2-3 pounds	No	2
Thermometer			1	Yes	2
Canvas gloves	Gardening gloves		1 pair	Yes	2
Hammer			1	Yes	2
Towel			1	Yes	2
Funnel	Cardboard tube		1	Yes	2
Eye droppers		4			2
Small rocks		9			2
Crayon pieces	Broken crayons	9			2
Water			500 ml		
Peppermint extract			100 ml = 1	No	2
Envelopes		2		Yes	3
Newspaper			Lots	No	3

Papier-mâché	Wallpaper paste, white flour and water, or liquid starch and water		Lots	No	3
Zip lock bags, 1 gallon	Optional				3
Pie pan	Shallow container	1		Yes	3, 5
String		1 meter in 3	250 ft in 9		3, 9
Rock		1			3
Earth globe, maps	Textbook pictures				4
Drawing paper		3 per student		No	4
White construction paper		Several		No	5
Paper towels			Lots	No	5
Tempura paint	Acrylic paint		Varies	No	5
Paintbrushes			Varies	Yes	5
Books of four thicknesses	Blocks of four thicknesses		4	Yes	6
Light bulb, Clear single filament, 100-250 Watt	Frosted lamp, does not work as well		1	Yes	8, 10
Cotton batting	Packing material			No	6
Permanent black marking pen			1	Yes	7, 9
Chalk, long piece			Varies	Yes	9
Push pin		1		Depends	9
9-inch Styrofoam plate	9-inch round cardboard	1		Depends	9
Pictures of Saturn and its moons	Slide, drawing, etc. Saturn and its moons		Varies	Yes	10
Floor lamp			1	Yes	10
Chair			1	Yes	10
Light colored ball	Candy, rubber, eggs	1		Yes	10
Modeling clay			1 bar	Yes	11
Round objects	Sand grains, marbles, BB's, balls		Varies	Yes	11
Penny		1		Yes	11
Round headed pin		1		Yes	11
Basketball	Other large ball		1	Yes	11

* Review with students all necessary precautions when handling sharp knives

Audiovisual Materials

Table A.2-Audiovisual Materials.

Material	Substitutes or Alternatives. Optional Items are Indicated.	Quantity per Pair, team or Center	Quantity for Each Class of 32	Reusable in each Class	Used In Activity
Computer, projector or monitor			1	Yes	All except 4
Video The Science Detectives			1	Yes	All

Telescope and Related Materials

Table A.3-Telescope and Related Materials.

Material	Substitutes or Alternatives. Optional Items are Indicated.	Quantity per Pair, team or Center	Quantity for Each Class of 32	Reusable in each Class	Used In Activity
Lenses of two focal lengths	Telescope kits, see below	2		Depends	7
Magnifying glasses		1 – 3		Yes	7
Paper tubes that fit inside each other	Collect from students	2		Depends	7

Telescope Kits

Telescope kits are available from several sources, including:

Science First.
86475 Gene Lasserre Blvd
Yulee, Florida 32097
(800) 875-3214
http://www.sciencefirst.com
$69.95 plus for set of 10

Edmund Scientifics
101 E. Gloucester Pike
Barrington, NJ 08007-1380
(609) 573-6250
http://scientificsonline.com/
$12.95 each plus

Dry Ice

Dry ice is frozen carbon dioxide (CO_2). It can be found in most urban areas. Check *The Yellow Pages* under "Dry Ice." If there is no listing, try a butcher shop or a fishing store that carries live bait. Also, liquor stores often carry dry ice for parties. Some convenience stores carry dry ice. As dry ice is exposed to the air, it freezes the water in the air. Also, dry ice sublimates, or changes directly from a solid to a gas. This carbon dioxide gas is heavy, and it forms a visible cloud. Avoid breathing this cloud directly; it will sink to the floor and then dissipate into the air. Keep the dry ice in a tightly closed, insulated container at all times when not in use. If insulated properly, dry ice should last for approximately two days. Do not store in a frost-free freezer. It will all sublimate away as the freezer at 0° C is warmer than the dry ice. Use a cooler chest. Only the teacher should handle dry ice–with caution and never directly. It can cause severe burns. Handle dry ice with heavy canvas gloves. If the gloves become wet, they will no longer protect your hands.

Teacher Background Information
Planet-Building Tables

Table A.4-Planet Sizes.

Planet	Diameter, km (1)	Circumference, km (1)	Scale Circumference, cm (2)
Mercury	4,880	15,331	7.3
Venus	12,104	38,023	18.0
Earth	12,757	40,074	19.0
Mars	6,794	21,344	10.0
Jupiter	142,984	448,198	213.5
Saturn	120,536	378,675	181.0
Uranus	51,118	160,592	77.0
Neptune	49,528	155,597	67.0
Pluto (dwarf planet)	2,360	7,414	1.5

1—Measurements are rounded off
2—Scale = 1 to 210 million

Table A.5-Scale Model Sizes.

Planet	Scale solid	Ocean depth	Scale liquid circumference	Gas Depth	Scale gas (final measure) circumference
Mercury	7.0cm		None		7.0 cm
Venus	18.0 cm		None		18.0 cm
Earth	19.0 cm		Not measured		19 cm
Mars	10.0 cm		None		10 cm
Jupiter	79.0 cm	19.5 cm	202 cm	1.8 cm	213.5 cm
Saturn	84.0 cm	13 cm	168 cm	2.1 cm	181 cm
Uranus	22.0 cm	5 cm	53 cm	3.8 cm	77 cm
Neptune	46.0 cm	2 cm	58 cm	1.4 cm	67 cm
Pluto	2.0 cm		None		1.5 cm

Table A.6-Moons to Scale

Planet	Moon Name	Actual Diameter	Scale Diameter
Earth	Luna	3,467 km	1.5 cm
Mars	Phobos	28 x 20 km (oval)	About 0.01 cm
	Demos	16 x 12 km (oval)	About 0.007 cm
Jupiter	Europa	3,138 km	1.5 cm
	Io	3,630 km	1.7. cm
	Callisto	4,800 km	2.3 cm
	Ganymede	5,262 km	2.5 cm
	59 other moons	Smaller	
Saturn	Titan	5,150 km	2.4 cm
	Rhea	1,530 km	0.7 cm
	Iapetus	1,460 km	0.7 cm
	Dione	1,120 km	0.5 cm
	Tethys	1,060 km	0.5 cm
	26 other moons	Smaller	
Uranus	Titania	1,580 km	0,7 cm
	Oberon	1,524 km	0.7 km
	Umbriel	1,172 km	0.5 cm
	Ariel	720 km	0.3 cm
	Miranda	480 km	0.2 cm
	22 other moons	Smaller	
Neptune	Triton	2,720 km	1.3 cm
	Proteus	416 km	0.2 cm
	Neried	340 km	0.1 cm
	5 other moons	Smaller	
Pluto	Charon	1,160 km	0.5 cm
	2 other moons	Smaller	

New moons may be discovered, this count is from 2009.