



# The Courage to Soar Higher

## The Story of NASA and the U.S. Space Program



**Educational Product**

**Educators**

**Grades 4-6**

EG-2009-05-03-MSFC



Cover:

Original art by Robert S. Sallee

Pictured:

Ares I crew launch vehicle on launch pad

Ares V cargo launch vehicle launching

Philip, Susan, Annie, and Leapold in the Firing Room  
of the Launch Control Center at Kennedy Space Center  
in the year 2020, the year NASA has scheduled the first launch to  
return humans to the Moon



# **The Courage to Soar Higher**

## **The Story of NASA and the U.S. Space Program**

**National Aeronautics and Space Administration**

**Marshall Space Flight Center**

**Exploration Systems Mission Directorate: Ares Projects Office**

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# Acknowledgements

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## How to Use This Guide

The Courage to Soar Higher was written for two main purposes. The first was to tell the story of the National Aeronautics and Space Administration (NASA) and the United States (U.S.) space program with the hope that students may one day join the workforce that will send humans to the Moon, Mars, and beyond, or perhaps aspire to be one of the astronauts who will make those journeys. The second was to give students the opportunity to conduct not only simple research where the information is shared, but to also conduct research that enables them to design and create some of the engineering challenges faced by NASA scientists and engineers today.

### Lesson Format

This educator guide is made up of 20 lessons. Within each lesson, teachers will find the objectives, the national standards, a materials list, the pre-lesson instructions, and the procedure for teaching the lesson, in that order. Seven of the lessons include a student text (reading selection) with vocabulary words and definitions. When student text and vocabulary are a part of the lesson, they are located after the procedure. Homework assignments, pictures for the lessons, patterns, diagrams, charts, etc., are found at the end of the lesson.

The activities in this guide have been divided into lessons that generally represent one class period of 1 to 1½ hours long. However, teachers should feel free to modify these lessons to meet the needs of their students, and to vary the length of time needed to complete each one. The preparation times to gather the materials and follow the pre-lesson instructions are listed at the beginning of the lesson. The approximate teaching times for the lesson and the subjects that are emphasized in that lesson are listed there, as well.

### Unit Overview

The Courage to Soar Higher was originally intended to be one or two lessons at the end of the educator guide The Courage to Soar. However, the story of NASA could not be contained in such a small space. So another guide was created to focus on the achievements of NASA with an emphasis on its contributions to the field of astronautics, that is, the science and technology of space flight. It is recommended that The Courage to Soar be taught before this guide, but it is not necessary.

The Courage to Soar Higher covers just a small part of the whole NASA story. The accomplishments of this Agency are vast; however, this guide addresses only the work thought to be most interesting to young students. The combined knowledge, intellect, and creativity of the scientists, engineers, and other workers who make up the NASA family is a significant treasure. These workers are dedicated to NASA's mission and they are determined to make it successful. Teachers should try to instill a great respect for these workers and inspire their students to join the next generation of scientists, engineers, and explorers as they teach the unit.

Students in fourth through sixth grades will enjoy this unit on NASA, and it may interest and challenge seventh graders, as well. Even though the content is primarily science, many of the lessons are rich in the language arts skills of reading, writing, speaking, and listening. These skills are included so that teachers can meet their language arts objectives as they present their students with enriching science activities.

In the first two lessons, students discuss why they believe the U.S. should or should not pursue the exploration of space. They will also learn about the layers of the Earth's atmosphere and some NASA vehicles that fly in each layer. Between Lessons 2 and 3, the optional Solar System Pop-up Book Activity is provided for classes with no prior teaching on the solar system.

This overview will help them to envision the space travel that is discussed in following lessons. Lesson 3 gives the students an introduction to space travel and asks them to share their ideas about future trips into space. Lesson 4 includes student text giving a brief overview of the National Advisory Committee for Aeronautics (NACA), the predecessor to NASA, and enough history to give students an understanding of how the space race started. Other than one reading selection on rockets, the remaining student texts in the guide discuss NASA's achievements in space and do not include NASA's aeronautics programs. These texts will discuss Projects Mercury, Gemini, and Apollo; the Space Shuttle; early space stations and the International Space Station; and the U.S. Space Exploration Policy, the plan for human exploration of the Moon, Mars, and beyond.

Several research projects are provided throughout the guide. The first requires students to research the vehicles that are being developed to carry humans back to the Moon and later to Mars. The second asks students to research a NASA technology transfer and report how that technology is used in our homes and communities. A third research activity is conducted by teams as they create a project about astronauts at work in the Space Shuttle (or the Orion Crew Exploration Vehicle) and on the International Space Station (ISS). The last research project will require each member of the Mars Expedition Team I to research the planet Mars and find and study available research about how to survive on Mars in order to build a colony there. Math problem solving in Lesson 13 is another team activity. As students work together to solve these problems, they experience how engineers work together to solve problems.

The unit concludes with the U.S. Space Exploration Policy, the plans for human exploration of the Moon, Mars, and beyond. Other activities in the unit require the students to design and present their own ideas for Orion and the Altair lunar lander that will be used to return a human to the Moon and eventually to Mars and beyond; design planes to be flown in a wind tunnel; research and present designs for an advanced model of a Personal Satellite Assistant (PSA), a robot to be used by the first astronauts

on Mars; and, finally, to plan and build a model of a Mars colony and write and present a team journal describing that experience.

Opportunities for assessment are built into the lessons throughout the unit. Teachers are encouraged to provide additional enrichment activities through field trips and guest speakers. Field trips may include a visit to a NASA visitor center located near most of the NASA Centers (Search <http://www.nasa.gov/about/visiting/>), a Challenger Learning Center (Search <http://www.challenger.org/>), an air and space museum such as the National Air and Space Museum in Washington, DC, or a rocket museum. Guest speakers might include current or retired NASA workers or aerospace engineers from a local company. Try to arrange for an aerospace engineer or a school administrator to come and listen to the Orion/Altair presentations. Contact the nearest chapter of the National Association of Rocketry (Search <http://www.nar.org/index.html>). Many clubs have speakers who will come to the classroom to acquaint students with their hobby. Some speakers may even bring a rocket to demonstrate a launch for the students.

## Pre-unit Instructions

### Teaching the vocabulary and student text

When student text is included in the lesson, the vocabulary words and their definitions are listed just before the student text. Teachers should teach the vocabulary as they would for any guided reading. It is recommended that teachers duplicate all of the vocabulary lists (seven lists in all) for each student. Then, the students can insert these in their logs so that they are readily available when the class begins to read the student text. Teachers may also want to duplicate the student text (seven lessons of student text) ahead of time.

Teachers who plan to teach the unit again may want to ask their school to purchase a class set of 1-inch binders. Then, insert the seven vocabulary lists and student texts in each binder, and use these as “readers” for the unit. The students will still need their own binders for notes, research, homework assignments, etc.

## Materials

A list of materials is given at the beginning of each lesson. It is recommended that teachers begin to gather the materials in advance of teaching the unit. It may be helpful to duplicate the materials lists and pre-lesson instructions and give them to a team of parent volunteers. As materials are collected, have a predetermined way to organize and store them. One or two labeled tubs or boxes would help to plan and prepare the lessons. Keeping and storing the materials will be helpful for teaching the unit again to future classes and will greatly reduce the prep time for each lesson. Use a color printer for printing the provided pictures and laminate each one if possible. Teachers with computer technology in their classroom will only need to display these images, not print them. Some important materials to collect beforehand include the following.

1. **Weeks in advance**, start collecting 16 half-gallon-size heavy paper milk or orange juice cartons for building a wind tunnel. The cartons must be the same size. (Directions for the wind tunnel follow this section. The wind tunnel will be used in Lesson 5.)
2. **Weeks in advance**, start collecting film canisters with an **internal-sealing lid**. This is a lid that fits inside and does not overlap the canister. One canister for every two or three students will be needed in Lesson 9 and may be found in camera supply stores or portrait studios. Visit or call and ask them to start saving these for you.
3. Purchase the IMAX movies [The Dream Is Alive](#) for Lesson 12, [Destiny in Space](#) for Lesson 13, and [Space Station](#) for Lesson 17 in DVD form. (Try Amazon.com to find these.) Ask your administrator or librarian for help with payment.
4. Purchase a toy space shuttle with parts that can be disassembled for Lesson 11. Amazon.com has one for about \$4.00.
5. Several research projects will require the use of picture books. Teachers should try to fill their classrooms with a variety of picture books on the Earth's

atmosphere, the solar system, the exploration of space, the U.S. space program (including Projects Mercury, Gemini, and Apollo, the Space Shuttle, the International Space Station, and the current U.S. Space Exploration Policy), astronaut biographies, current and future spacecraft, and a few books on making paper airplanes.

6. Using a colored printer, print and laminate the images provided at the end of some of the lessons. Teachers with computer technology in their classroom will only need to display these images, not print them.
7. Send for a free NASA CORE Catalog. This catalog lists all NASA materials available for purchase but it takes about 4 weeks for the catalog to be delivered. You can call the office at (440) 775-1400 or go online at <http://core.nasa.gov> to order the catalog. However, it is quicker to search the catalog and place your order online. Ask your building administrator or librarian for help with payment. (The unit does not require any materials from this catalog, but it offers many videos, posters, etc., that could be used for enrichment.)

NASA Education Resource Centers (ERCs) allow educators to preview, copy, and receive without charge NASA materials at their sites. ERC locations can be found at [http://education.nasa.gov/about/contacts/Educator\\_Resource\\_Center\\_Network.html](http://education.nasa.gov/about/contacts/Educator_Resource_Center_Network.html).

## Wind Tunnel

Before beginning the unit, construct a wind tunnel using the directions provided at the end of this section. Even though this guide is primarily about space, several lessons on the atmosphere and the National Advisory Committee for Aeronautics (NACA) wind tunnels provide a bridge between the guide [The Courage to Soar](#) and this guide. The wind tunnel requires the 16 milk or orange juice cartons mentioned previously. The construction of the wind tunnel should be done by the students under the guidance of an adult. However, teachers should feel free to use the same wind tunnel for several years. Be sure to give successive classes a brief explanation of how it was built.

## Bulletin Boards

A few days before beginning the unit, teachers should prepare a “Layers of the Atmosphere” bulletin board. Use the “Layers of the Atmosphere” chart as a guide. This chart, with information about the depth of each layer, follows the wind tunnel instructions found at the end of this section. Show the surface of the Earth and each of the five layers: troposphere, stratosphere, mesosphere, thermosphere, and exosphere. Label the corresponding altitudes in miles and kilometers. It may be impossible to display the layers in scale, so try to represent the layers as closely as possible using small and large spaces. Teachers should insert pictures of the Space Shuttle, ISS, and the Hubble Space Telescope (provided at the end of this section) in their correct layers on the bulletin board. This will prevent duplication when the students are asked to bring in pictures of aircraft and spacecraft. Teachers should consider preparing a bulletin board to post current events concerning NASA, private space travel, world events dealing with space exploration, and science articles about space. Newspaper and magazine articles could be added throughout the study of the unit.

## Student Needs

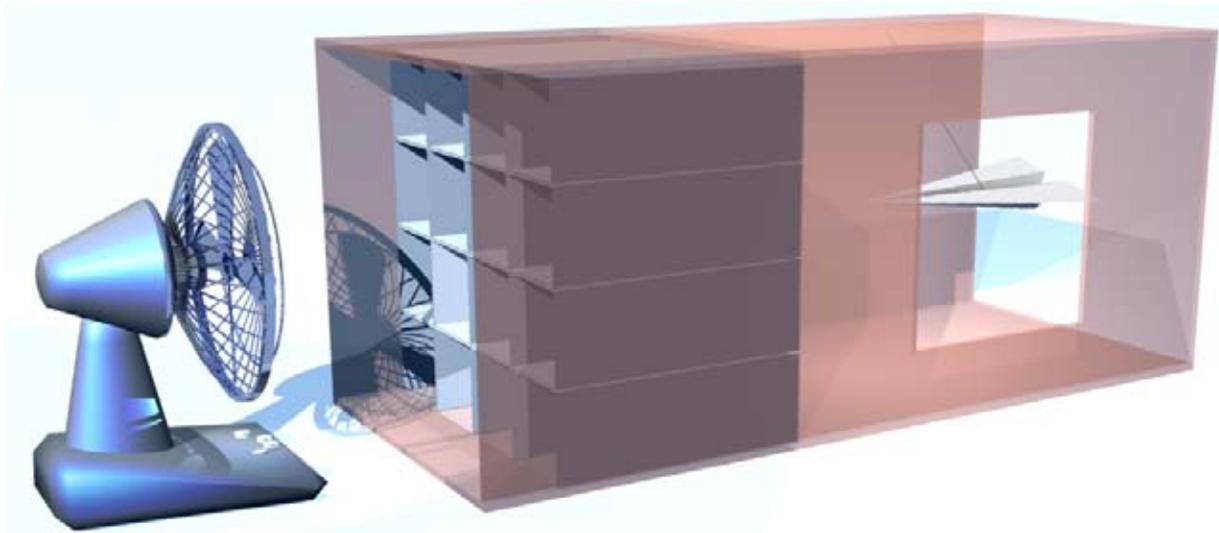
Each student will need a binder with three 1-inch diameter rings. This will be used as a student log as well as a place to store vocabulary lists, student texts, homework assignments, and worksheets. The students should insert about five sheets of notebook paper in the binder.

Humankind’s exploration of space is an exciting unit of study for any age. Most of all, teachers should try to have fun as they and their students learn about the courage to soar higher!



*An example of a bulletin board to post current events in space*

## Building a Wind Tunnel



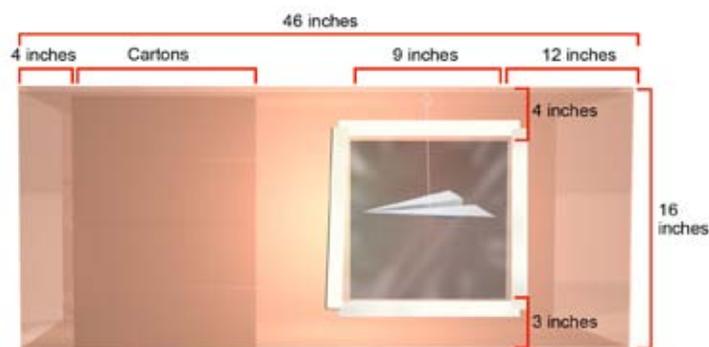
**Prep time for gathering materials and assembly —  
1-1½ hours**

### Materials

- 16 half-gallon-size milk or orange juice cartons (heavy paper)
- Heavy cardboard box, about 16- by 16-inch opening and 40-46 inches long
- Electric fan with several speed settings (especially low, medium, and high)
- Strong-fastening glue
- Strong scissors or shears
- Plastic or transparent material (to cover the 9- by 9-inch window)
- Heavy-duty tape
- 1 small cup hook
- Notebook reinforcement rings (two for each paper plane)
- Lightweight string – not thread (about 12–15 inches for each plane)
- Straight pins – one for each plane

### Instructions for Assembly

1. Cut out the top and bottom of the milk (or juice) cartons. Glue the cartons together to make a 4- by 4-carton square (honeycomb).
2. Slide the cartons completely into the cardboard box until they are about 4 inches from the end. They should fit snugly. If necessary, cut off the sides of the cartons until they slide in snugly.
3. Cut a 9- by 9-inch window in the side of the box about 12 inches from the other end of the box and about 4 inches from the ceiling. Securely tape the transparent material over the window.
4. Attach the cup hook in the center of the ceiling so that a plane hung from the hook will also be in the center of the window.
5. Set the fan facing the cartons outside the box.



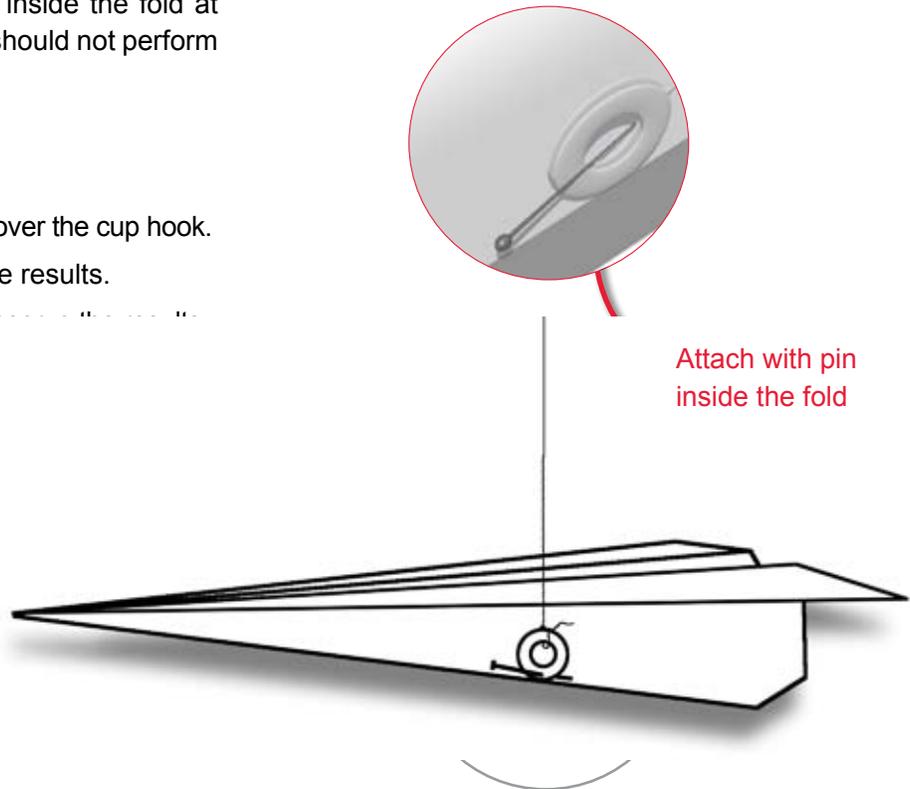
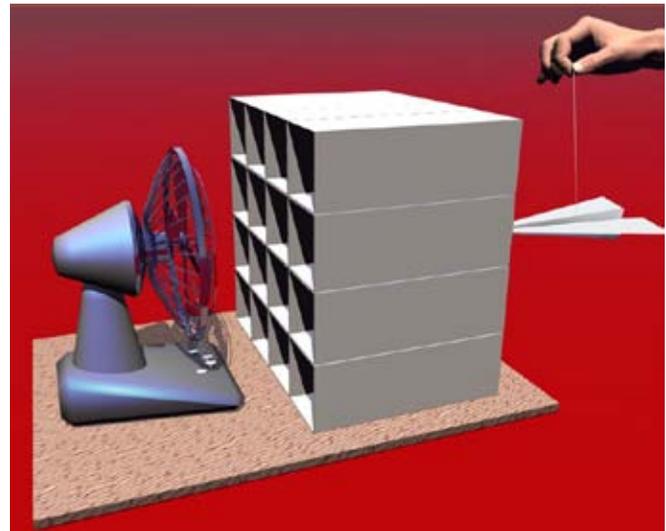
**Note:** An easier, though less effective, version of a wind tunnel would be to glue the cartons together, but not put them in a box. Secure the cartons to a board so that they are stationary. Place the fan behind the cartons so that it is exactly in line with them. With this version, students would have to hold the string of their planes in line with the air flow.

### Preparing the Plane for Testing

1. Tie a small loop in one end of a 12- to 15-inch piece of string. This will be used to slip over the cup hook.
2. Glue two notebook reinforcement rings together. Thread the other end of the string through the ring and tie a knot to secure it.
3. Teachers should locate the center of gravity and anchor the ring with a straight pin inside the fold at the center of gravity. The students should not perform this step.

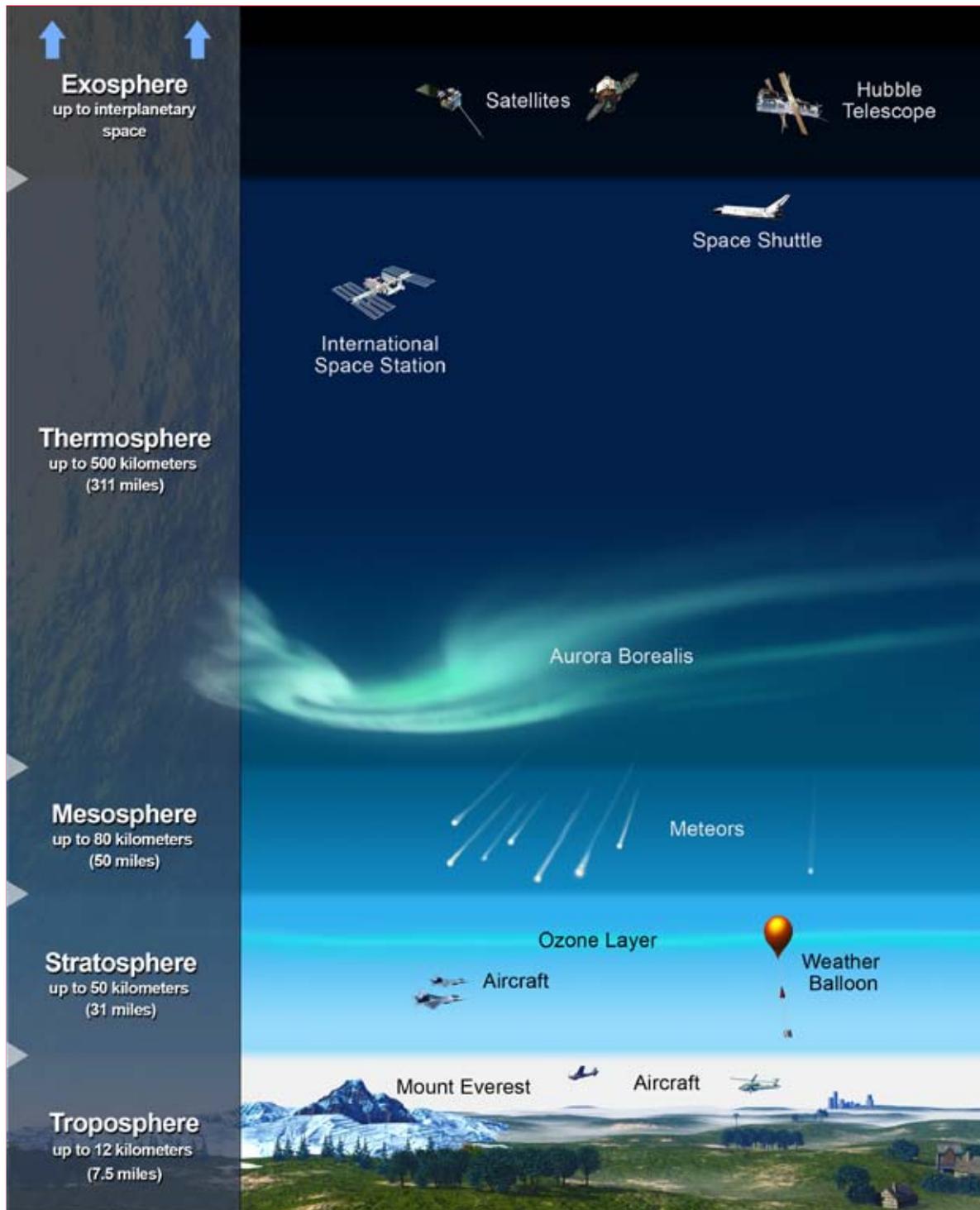
### Testing the Planes

1. Slip the loop at the end of the string over the cup hook.
2. Turn the fan on low and observe the results.
3. Then, turn the fan on medium and observe the results.
4. Finally, turn the fan on high and observe the results.
5. Record how the plane performed.



# Layers of the Atmosphere

Teachers, use the chart below to construct a “Layers of the Atmosphere” bulletin board in your classroom.



## NASA Vehicles

Teachers should print and cut out the NASA vehicles and insert them in the correct layer on the “Layers of the Atmosphere” bulletin board. The Space Shuttle flies mostly in the thermosphere, the ISS flies in the thermosphere, and the Hubble Space Telescope flies in the exosphere.



**Space Shuttle Atlantis**



**Hubble Space Telescope**



**International Space Station**

# National Education Standards

Science																				
Lessons	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Abilities necessary to do scientific inquiry																				
Understandings about scientific inquiry																				
Properties of objects and materials/Properties and changes in matter																				
Position and motion of objects/Motion and forces																				
Properties of Earth materials/Structure of Earth and sky																				
Objects in the sky																				
Changes in Earth and sky/Earth in the solar system																				
Abilities of technological design																				
Understanding about science and technology																				
Risks and benefits																				
Science and technology in local challenges/in society																				
Science as a human endeavor																				
History of science																				

Mathematics																					
Lessons	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
Compute fluently and make reasonable estimates																					
Understand patterns, relations, and functions																					
Use mathematical models to represent and understand quantitative relationships																					
Analyze change in various contexts																					
Investigate, describe, and reason about the results of subdividing, combining, and transforming shapes																					
Specify locations and describe spatial relationships using coordinate geometry and other representational systems																					
Use visualization, spatial reasoning, and geometric modeling to solve problems																					
Understand measurable attributes of objects and the units, systems, and processes of measurement																					
Apply appropriate techniques, tools, and formulas to determine measurements																					
Formulate questions that can be addressed with data and collect, organize, and display relevant data to answer them																					
Select and use appropriate statistical methods to analyze data																					
Develop and evaluate inferences and predictions that are based on data																					
Understand and apply basic concepts of probability																					
Problem solving																					
Reasoning and proof																					
Communication																					

Geography																				
Lessons	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
How to use maps and other geographic representations, tools, and technologies to acquire, process, and report information from a spatial perspective																				
How to use mental maps to organize information about people, places, and environments in a spatial context																				
The physical and human characteristics of places																				
How culture and experience influence people's perceptions of places and regions																				
The physical processes that shape the patterns of Earth's surface																				
The patterns and networks of economic interdependence on Earth's surface																				
The processes, patterns, and functions of human settlement																				
How the forces of cooperation and conflict influence the division and control of Earth's surface																				
How human actions modify the physical environment																				
How physical systems affect human systems																				
How to apply geography to interpret the past																				
How to apply geography to interpret the present and plan for the future																				

Language Arts																				
Lessons	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Students read a wide range of print and non-print texts, fiction and non-fiction, classic and contemporary works.																				
Students apply a wide range of strategies to comprehend, interpret, evaluate, and appreciate texts.																				
Students adjust their use of spoken, written, and visual language to communicate with a variety of audiences and for different purposes.																				
Students employ a wide range of strategies as they write and use different writing process elements appropriately to communicate with different audiences for a variety of purposes.																				
Students apply knowledge of language structure, language conventions, media techniques, figurative language, and genre to create, critique, and discuss print and non-print texts.																				
Students conduct research on issues and interests by generating ideas and questions, and by posing problems. They gather and evaluate data from a variety of sources to communicate their discoveries.																				
Students use a variety of technological and information resources to gather and synthesize information and to create and communicate knowledge.																				
Students participate as knowledgeable, reflective, creative, and critical members of a variety of literacy communities.																				
Students use spoken, written, and visual language to accomplish their own purposes.																				

Technology-ISTE																				
Lessons	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Students are proficient in the use of technology.																				
Students develop positive attitudes toward technology uses that support lifelong learning, collaboration, personal pursuits, and productivity.																				
Students use productivity tools to collaborate in constructing technology-enhanced models, prepare publications, and produce other creative works.																				
Students use telecommunications to collaborate, publish, and interact with peers, experts, and other audiences.																				
Students use a variety of media and formats to communicate information and ideas effectively to multiple audiences.																				
Students use technology to locate, evaluate, and collect information from a variety of sources.																				
Students employ technology in the development of strategies for solving problems in the real world.																				

Technology-ITEA																				
Lessons	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Relationships among technology and other fields																				
Cultural, social, economical, and political effects																				
Effects of technology on the environment																				
Role of society in the development and use of technology																				
Influence of technology on history																				
Attributes of design																				
Engineering design																				
Role of troubleshooting, research and development, inventions and innovation, and experimentation in problem solving																				
Apply the design process																				
Use and maintain technological products and systems																				
Assess impact of products and systems																				
Communication technologies																				
Transportation technologies																				



## Lesson 1 – Why Reach for the Stars?

**Pre-unit prep time:** 2–2¼ hours (See the Pre-unit Instructions in “How to Use This Guide” for instructions about duplicating vocabulary lists and student texts, gathering books, preparing bulletin boards, and collecting materials. Wind tunnel assembly time is separate.)

**Lesson prep time:** 1½ hours (for gathering materials, following pre-lesson instructions, reading the article “The Earth’s Atmosphere,” and preparing an optional bulletin board)

**Teaching time:** 1¼–1½ hours (Science, Language Arts, Technology)

### Objectives

1. The students will distinguish between fiction and non-fiction as they listen to a fictional space story and practice identifying other works as fiction or non-fiction.
2. The students will use their prior knowledge of human exploration of space to answer the question, “Why reach for the stars?”
3. The students will share their knowledge about the human exploration of space and develop questions about space exploration as they construct a What We

Know, What We Want to Know, What We Learned (KWL) chart.

4. The students will name the five layers of the Earth’s atmosphere, identify certain characteristics of each layer, and answer questions about the atmosphere and its five layers.
5. The students will distinguish the difference between aircraft that need air to fly and spacecraft that need rockets to fly in the absence of enough air.
6. The students will identify human-made objects found above Earth’s surface and observe images taken by Earth observation satellites and space observation satellites.
7. The students will locate pictures of aircraft and spacecraft, describe their function, and find either the altitude at which they fly or orbit or their primary destination in space.

## National Standards

### Science

- Abilities necessary to do scientific inquiry – S2Ea, S2Ma
- Understandings about scientific inquiry – S2Eb, S2Mb
- Properties of objects and materials/Properties and changes in matter – S3Ea, S3Ma
- Position and motion of objects/Motion and forces – S3Eb, S3Mb
- Properties of Earth materials/Structure of the Earth system – S5Ea, S5Ma
- Objects in the sky – S5Eb
- Changes in Earth and sky/Earth in the solar system – S5Ec, S5Mc
- Abilities of technological design – S6Ea, S6Ma
- Understanding about science and technology – S6Eb, S6Mb
- Risks and benefits – S7Md
- Science and technology in local challenges/in society – S7Ee, S7Me
- Science as a human endeavor – S8Ea, S8Ma
- History of science – S8Mc

### Mathematics

- Understand patterns, relations, and functions – M4
- Use mathematical models to represent and understand quantitative relationships – M6
- Specify locations and describe spatial relationships using coordinate geometry and other representational systems – M9
- Use visualization, spatial reasoning, and geometric modeling to solve problems – M11
- Understand measurable attributes of objects and the units, systems, and processes of measurements – M12
- Formulate questions that can be addressed with data, and collect, organize, and display relevant data to answer them – M14
- Problem solving – M18
- Communication – M20

### Geography

- How to use maps and other geographic representations, tools, and technologies to acquire, process, and report information from a spatial perspective – G1
- How to use mental maps to organize information about people, places, and environments in a spatial context – G2
- The physical and human characteristics of places – G4
- The physical processes that shape the patterns of Earth's surface – G7
- How human actions modify the physical environment – G14

### Language Arts

- Standards 1, 3, 4, 5, 7, 8, 11, and 12 (See the Language Arts Matrix on page 22.)

### Technology – ISTE

- Students are proficient in the use of technology – I2
- Students develop positive attitudes toward technology uses that support lifelong learning, collaboration, personal pursuits, and productivity – I5
- Students use productivity tools to collaborate in constructing technology-enhanced models, prepare publications, and produce other creative works – I7
- Students use technology to locate, evaluate, and collect information from a variety of sources – I10
- Students employ technology in the development of strategies for solving problems in the real world – I14

### Technology – ITEA

- Relationships among technology and other fields – T3
- Cultural, social, economical, and political effects – T4
- Effects of technology on the environment – T5
- Role of society in the development and use of technology – T6
- Influence of technology on history – T7
- Engineering design – T9
- Use and maintain technological products and systems – T12
- Assess impact of products and systems – T13
- Information and communication technologies – T17
- Transportation technologies – T18

## Materials

- A fictional story about living in space or space travel
- Student logs
- Optional “Why Reach for the Stars?” bulletin board
- For the optional bulletin board, a small spacecraft cutout (provided) for each student to record his/her answer to the question “Why reach for the stars?” or 6- by 9-inch sheets of multi-colored construction paper for the students to design their own spacecraft
- A KWL chart on the human exploration of space
- “The Layers of the Atmosphere” bulletin board (See the “Layers of the Atmosphere” chart on page 17.)
- Copies of the article “The Earth’s Atmosphere” for each student (optional) or pictures, charts, and diagrams of the Earth’s atmosphere
- A copy of the homework assignment “How High Can They Go?” and the article “Flying Above the Earth” for each student
- Images taken by Earth observation satellites and space observation satellites (provided)

## Pre-lesson Instructions

1. Choose a fictional story about living in space or space travel to introduce the unit. Younger students may enjoy *Stanley in Space* by Jeff Brown. All students will enjoy *Baloney (Henry P.)* by Jon Scieszka as they listen and try to decode the alien words. The students may also enjoy Janet and Isaac Asimov’s series of stories about Norby the robot. (See the Resources section for information on these books.)
2. Make a decision as to whether or not you will create the “Why Reach for the Stars?” bulletin board to display the students’ answers to that question. If you decide to use this technique for displaying their answers, you will need to duplicate and cut out the small spacecraft (provided) to be used by the students for writing their answers. A more creative idea would be to provide multi-colored construction paper for the students to draw and cut out their own simple designs of a spacecraft.
3. Be sure that the “Layers of the Atmosphere” bulletin board (as shown in the Pre-unit Instructions) is in place.
4. Prepare a KWL chart. Use a large sheet of bulletin board paper about 4½ feet wide. Write the title “Space Exploration” and then divide it into three equal columns, each being 1½ feet wide. This should be displayed before Lesson 1 is taught.

Space Exploration		
What We Know	What We Want to Know	What We Learned

5. Read the article “The Earth’s Atmosphere” and decide if you would like the students to read and discuss this article in class. This article was not written to be used as student text (a reading selection), but the informative illustrations will help the students to learn and understand this information. It can also be used by the students as a reference. If you decide to use the article as a reading selection, duplicate enough copies for each student and punch holes so that students can insert these in their logs. If you decide not to use the article as a reading selection, be prepared to review or teach this information. Use the “Layers of the Atmosphere” bulletin board and books on the atmosphere, or find and print pictures, charts, and diagrams to help students learn, or recall, the information in the article.
6. Duplicate a copy of the homework assignment “How High Can They Go?” and the accompanying article “Flying Above the Earth” for each student. Punch holes so that students can insert these in their logs.

## Procedure

1. Read aloud a fictional story about space travel. After reading the story aloud, ask the students to identify which parts of the story were non-fiction and which were fiction.
2. Ask the students to recall some of the books and articles they have read and some of the movies and TV shows they have seen about space exploration. Encourage them to share both fiction and non-fiction media and ask them to differentiate between the two. These may be listed on the board.
3. Write the following question on the board: “Why reach for the stars?” Instruct the students to take out their logs and copy the question. Tell the class that humans have been looking at the stars and wondering about them for thousands of years. Ask the students, “Why should humans try to explore the solar system planets, moons, asteroids, and comets, as well as other solar systems in space?” Give them 3–5 minutes to write an answer to the question in their logs.
4. Ask students to share their answers, and allow time for a brief discussion. After all of the responses have been shared, read the following quote from a script spoken by Neil Armstrong: “From the time of our birth, our instinct is to explore. To map new lands, we must explore. To chart the seas, we must explore. To make new discoveries, we must explore.” Make the point that before any thing or any place was discovered, someone felt the need to explore. Before any new place or thing can be discovered in the future, someone must feel the need to explore.
5. Teachers may want to consider posting the answers on a bulletin board titled “Why Reach for the Stars?” Have the students copy their answers onto the provided spacecraft, or distribute multi-colored construction paper and have them draw and design a spacecraft of their own. When these are finished, display all of their spacecraft on the bulletin board. (You may want to help them edit the answers they wrote in their logs before having them displayed.)
6. Next, direct the students’ attention to the KWL chart. Ask them what they know about space exploration. Record their answers in the “What We Know” column. Most students will know quite a bit about space exploration. If incorrect responses are given, try to guide the student into a correct response. You may have to make a note to look up the correct answer or record it as a question in the “What We Want to Know” column. Use teacher discretion for displaying incorrect information in the classroom.
7. Ask the students what they would like to know about space exploration. Record their questions in the “What We Want to Know” column. Teachers may need to guide the class or even suggest some questions that may spark their curiosity. This may be a good time to encourage an interest in some of the people who have traveled into space, such as Alan Shepard (the first American in space), Neil Armstrong (the first man to step on the Moon), or Sally Ride (the first American woman in space).
8. Explain that the “What We Learned” column will be filled in after they have completed the unit on space exploration. The KWL chart should be on display throughout the unit.
9. Direct the students’ attention to the “Layers of the Atmosphere” bulletin board and point out the five layers. If the article “The Earth’s Atmosphere” was duplicated for the students, distribute this now. Read aloud and discuss the information in the article. If the students have previously studied the atmosphere, use this as a review. If the article is not distributed to the students, use books, pictures, charts, and diagrams to help students learn, or recall, this information.
10. Check for understanding by asking the students the following questions:
  - 1) Why is the atmosphere essential to life?
    - **It contains the gases we need to breathe.**
    - **It protects the Earth by absorbing the harmful ultraviolet radiation from the Sun.**
    - **It blankets the Earth to help keep heat from**

the Sun from escaping back into space.

- It is a major part of the water cycle.
- It maintains a moderate climate on Earth compared to that of other planets.

2) Why doesn't our atmosphere drift out into space?  
• **The Earth has enough gravitational pull to keep the atmosphere from drifting into space.**

3) What are the main gases found in the atmosphere?  
• **Nitrogen (78%), oxygen (21%), and argon (1%)**

4) In which layer do we find the greatest mass of our atmosphere?  
• **The troposphere, which contains about 85% of the mass of the atmosphere**

5) In which layer does weather occur?  
• **The troposphere**

6) Why is ozone an important gas and in which layer is it found?  
• **Ozone, which is found in the stratosphere, acts as a shield for the Earth's surface by absorbing harmful ultraviolet radiation from the Sun.**

7) Why do meteors burn up in the mesosphere? What do people call these fiery trails?  
• **They burn up because of atmospheric friction.**  
• **These are called shooting stars.**

8) Why can't aircraft fly above the stratosphere?  
• **There is not enough air for airplanes to operate.**

9) What form of propulsion is used beyond the stratosphere?  
• **Rocket propulsion**

10) Where does space begin? Where does interplanetary space begin?  
• **Space begins somewhere beyond 60 miles (96.6 kilometers) above Earth.**

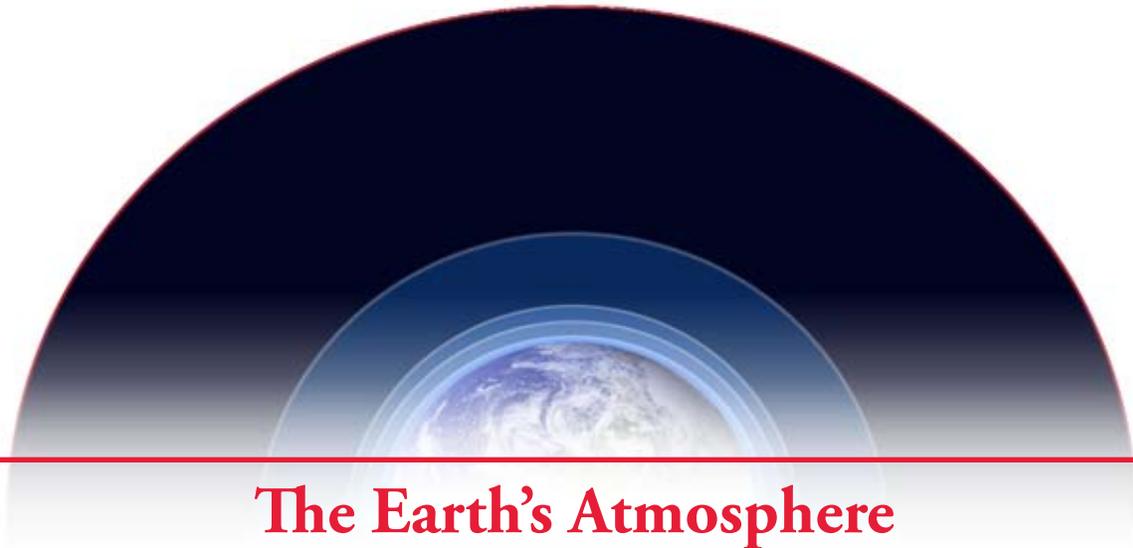
• **Interplanetary space begins beyond Earth's atmosphere.**

11. Be sure to point out that vehicles requiring air for lift and thrust (propulsion) are found in the first two layers of Earth's atmosphere, which contain almost the total mass of the atmosphere.

12. Distribute the homework assignment "How High Can They Go?" and the article "Flying Above the Earth." Read aloud the homework assignment and emphasize the necessity of determining the altitude of the vehicle.

13. Read and discuss the article "Flying Above the Earth." Answer any questions the students may have about the article or their homework. Then, have them look closely at the images taken by Earth observation satellites and space observation satellites. Ask the students how the Earth-observing images might help scientists take care of our Earth. What value are the space-observing images?

14. Check to see which students do not have Internet access at home. These students may need computer time in school to complete their homework assignment.



# The Earth's Atmosphere

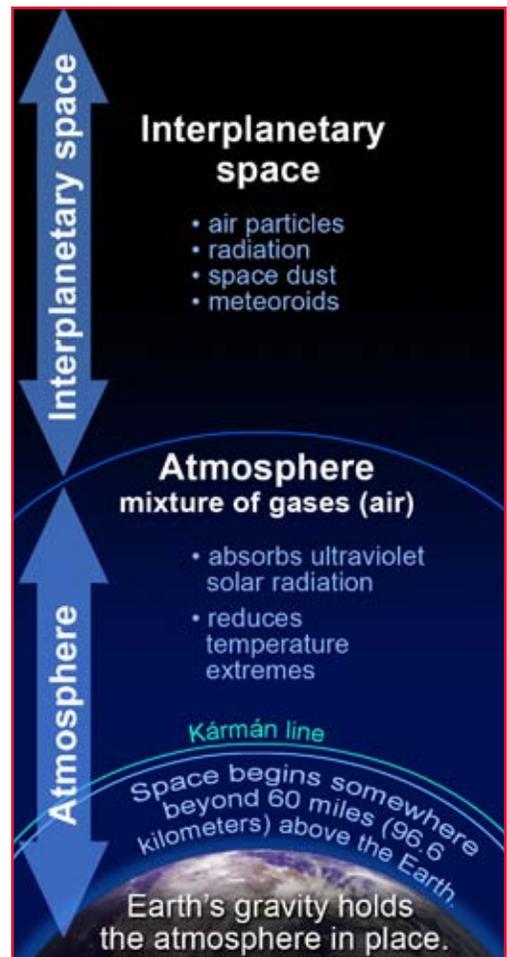
Some of the following information is taken from the NASA Educator Guide [How High Is It?](#).

The Earth's atmosphere is a layer of gases surrounding the planet Earth. The mixture of these gases is commonly known as air, and this air is held in place by the Earth's gravity. The atmosphere protects life on Earth by absorbing ultraviolet solar radiation and reducing temperature extremes between day and night. The region of space immediately beyond Earth's atmosphere is called interplanetary space, and even this area is not entirely empty. It contains some particles

of air and various kinds of radiation, as well as space dust and small sand to boulder-sized particles of debris called meteoroids.



Earth's atmosphere as seen from space





There is no clear boundary between the atmosphere and space. The air becomes thinner and fades into space. Most experts say that space begins somewhere beyond 60 miles (96.6 kilometers) above Earth. But this is still well within Earth's atmosphere. The Kármán line at 62 miles (100 km) above the Earth's surface is also frequently regarded as the boundary between atmosphere and space. This line is named for Theodore von Kármán, who calculated that, around this altitude, the Earth's atmosphere becomes too thin for aeronautic (aircraft flight) purposes. There is also a significant increase in temperature and solar radiation at this altitude.

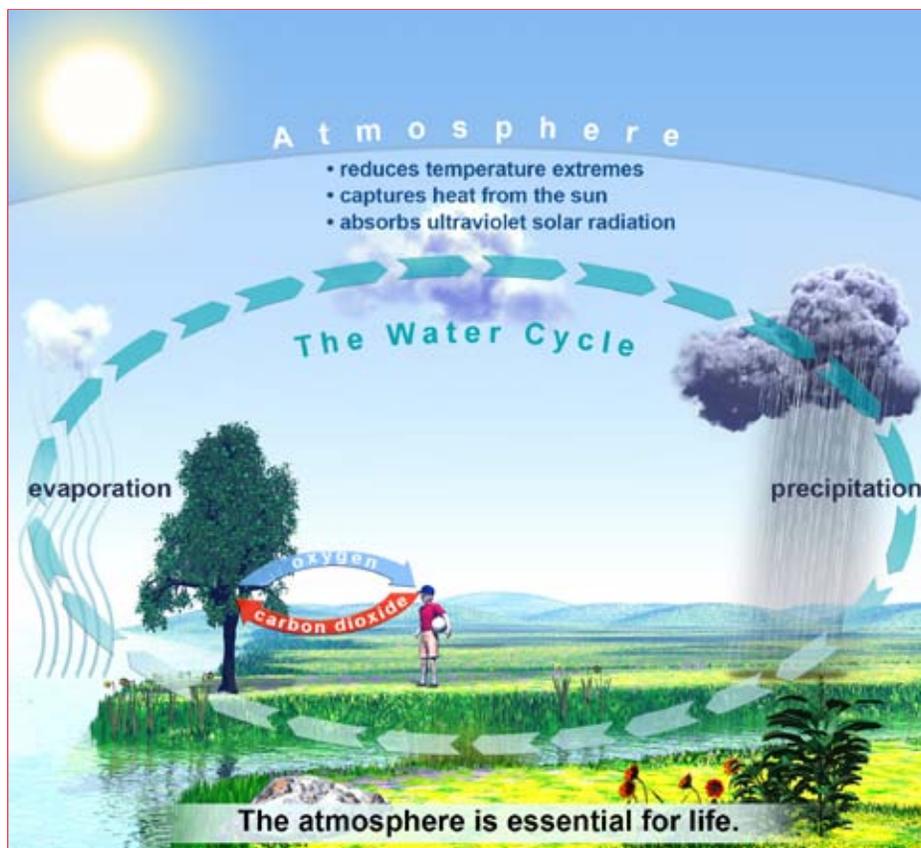


This satellite photo shows the Earth and its atmosphere. The clouds show the region of the troposphere and the stratosphere, the dark blue curve/edge is the mesosphere and thermosphere, and the dark blue to black region shows where our exosphere extends out to interplanetary space.

### The atmosphere is essential for life.

Without the atmosphere that surrounds our planet Earth, there could be no life on Earth. The atmosphere is essential to life for several reasons:

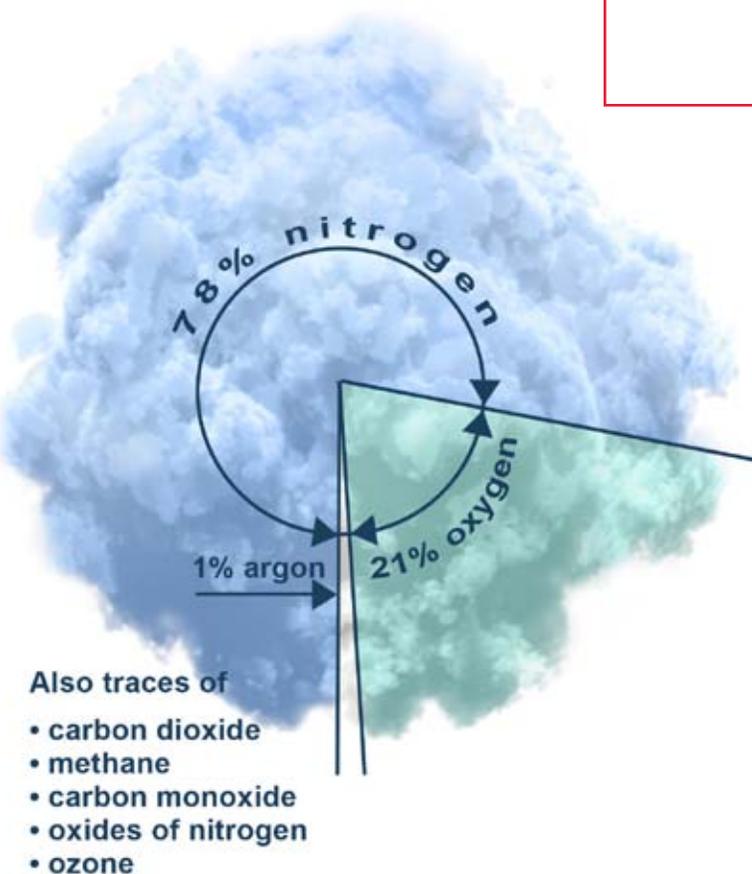
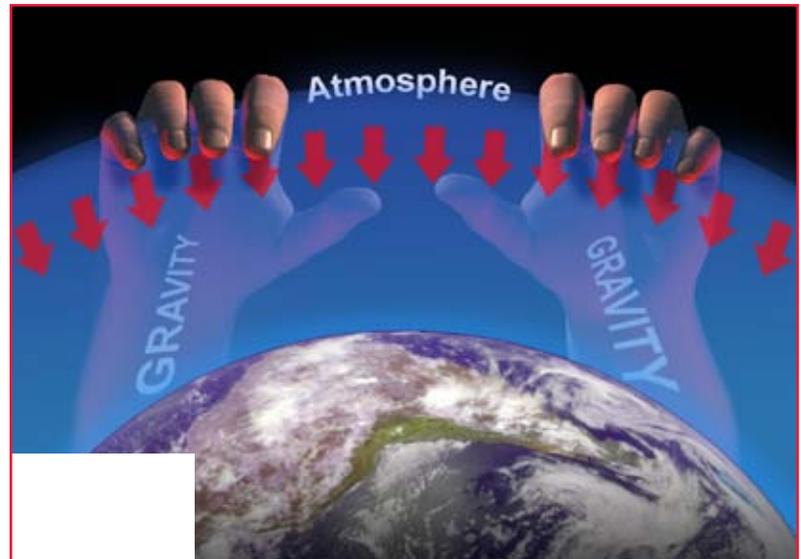
- It contains the gases we need to breathe.
- It protects the Earth by absorbing the harmful ultraviolet radiation from the Sun.
- It blankets the Earth to help keep heat from the Sun from escaping back into space.
- It is a major part of the water cycle.
- It maintains a moderate climate on Earth compared to that of other planets.





## The atmosphere does not drift into space.

Some planets and moons do not have enough gravity to keep an atmosphere. Fortunately for us, Earth does have enough gravitational pull to keep the atmosphere from drifting into space.

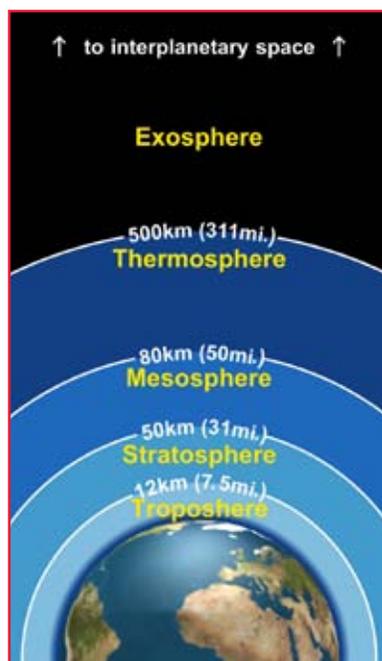


## The atmosphere is a mixture of gases.

The atmosphere is made of a mixture of gases. The main atmospheric gases are 78 percent nitrogen, 21 percent oxygen, and 1 percent argon. The atmosphere also contains water vapor and traces of carbon dioxide, methane, carbon monoxide, oxides of nitrogen, and ozone. Eighty-five percent of the atmosphere's mass is found in the troposphere, the lowest layer of the atmosphere.

## Scientists have divided the atmosphere into five layers.

Scientists defined five atmospheric layers based on whether the temperature is increasing or decreasing within the layer. Temperatures and conditions in the atmosphere vary over the course of years, months, and even days. So, the extent of the layers varies with time.



The layers of the atmosphere include, from lowest to highest, the troposphere, the stratosphere, the mesosphere, the thermosphere, and the exosphere. The height of the layers varies from the equator to the poles and from day to day. The following facts help to identify each layer.

### **Troposphere – From Earth' surface up to 12 kilometers (km) [or 7.5 miles (mi.)]**

1. This layer closest to the Earth is where we live.
2. Weather systems and clouds are found in this layer.
3. The bulk (about 85 percent) of the total mass of the atmosphere is found in the troposphere.
4. The temperatures decrease with altitude in this layer.
5. As the amount of gases in this layer decreases with altitude, the air becomes thinner. Therefore, the air pressure decreases with altitude.
6. In this layer, a strong, high-altitude wind called the jet stream generally blows eastward, horizontally in the northern hemisphere. The jet stream has a large impact on the weather at Earth's surface.
7. Many aircraft fly in this layer.

#### **Height of layers vary:**

- from the equator to the poles
- from day to day



## Lesson 1

### The Earth's Atmosphere



### Stratosphere – 12 to 50 kilometers (about 7.5 to 31 mi.)

1. The temperatures increase with altitude in this layer.
2. This layer contains about 15 percent of the total mass of the atmosphere with very little water vapor.
3. The stratosphere contains about 90 percent of the ozone in the atmosphere. Ozone is an important trace gas that acts as a shield for Earth's surface by absorbing harmful ultraviolet radiation from the Sun.
4. Weather balloons and many aircraft fly in the stratosphere.



### Mesosphere – 50 to 80 kilometers (31 to 50 mi.)

1. The temperatures decrease with altitude in the third layer, with the upper part of the mesosphere being the coldest region in the atmosphere.
2. Most meteors burn up in the mesosphere leaving fiery trails in the night sky. Some people call these trails “shooting stars.”
3. Aircraft cannot fly in the mesosphere because there is not enough air for airplanes to operate. Rocket propulsion is necessary for travel in this layer and above.





## Thermosphere – 80 to 500 kilometers (50 to about 311 mi.)

1. The temperatures increase and soar to over 1,200 degrees Celsius (2,192 degrees Fahrenheit) in the fourth layer of the atmosphere.
2. Air pressure is very low here and is about one ten-millionth of that at Earth's surface.
3. Most of the ionosphere is found in the thermosphere. The ionosphere contains electrically charged particles—positively charged ions and negatively charged electrons—that are important for radio communication.
4. Beautiful auroras, also known as the Northern and Southern lights, occur in the thermosphere.
5. A person must travel 80 kilometers (50 miles) away from the surface of the Earth to be considered an astronaut. This distance marks the beginning of the thermosphere.
6. The Space Shuttle and the International Space Station (ISS) fly in this layer.



## Exosphere – 500 kilometers (about 311 mi.) to interplanetary space

1. The outer region of the atmosphere is by far the largest layer in vertical extent.
2. The exosphere is the transitional region between the atmosphere and near-vacuum of interplanetary space.
3. Satellites orbit in this layer. Those that observe Earth are far enough away to capture good views of Earth. Satellites that observe space capture good views of the other planets and their moons, asteroids, comets, stars, and galaxies without being hindered by Earth's atmosphere.
4. The Space Shuttle flies in this layer, for example, when it services the Hubble Space Telescope.



## Lesson 1

### Homework Assignment: How High Can They Go?



## How High Can They Go?

1. Bring in a picture of an aircraft or a spacecraft (other than the Space Shuttle, the International Space Station (ISS), the Hubble telescope, or the Stardust spacecraft) that flies or orbits in the five layers of the atmosphere or that travels beyond these layers into interplanetary space. Cut out the craft from its background.
2. Write one or two sentences in your log describing how this vehicle is used. You will be asked to read this aloud in class.
3. Be sure to find out the approximate altitude in miles or kilometers at which the vehicle flies, or its destination in space, so that it can be placed in the correct region.
4. To help with this research, do the following:
  - 1) Read the information in “Flying Above the Earth” to help you decide what type of vehicle to research.
  - 2) You may use any printed source or look on the Internet to find and copy/print a picture of an aircraft, a spacecraft, a satellite, a space probe, or another vehicle that flies or has flown above Earth. You may want to find a vehicle that has been flown or launched by another country. If you choose an Earth observation satellite or a space observation satellite, try to bring in an image taken by that satellite, as well as a picture of the satellite.

**Due** \_\_\_\_\_ **(the next day of class)**



## Flying Above the Earth

Credit: Much of this information is taken from the NASA Educator Guide [How High Is It?](#)

### Human-made things found above Earth's surface include:

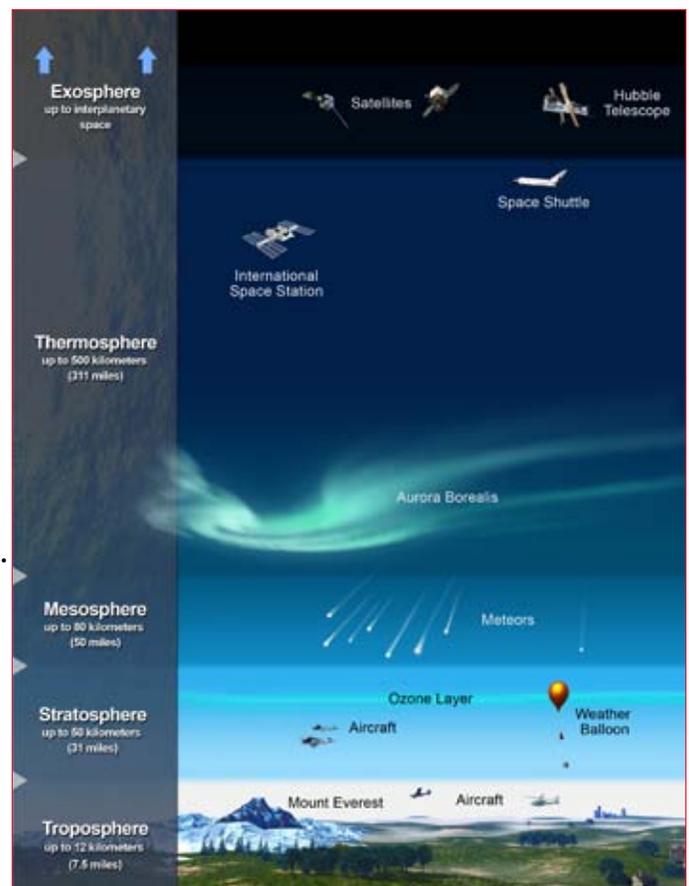
- Aircraft
- Crewed spacecraft
- Earth-orbiting satellites
- Research aircraft/rockets/spacecraft
- Orbital debris/space junk
- Deep space probes

### Aircraft

Aircraft means any machine or device, such as an airplane, helicopter, glider, or balloon, that can travel through the air and is supported either by its own buoyancy or by the action of the air against its surfaces.

### Crewed Spacecraft

Crewed spacecraft allow humans to travel above the lower two layers of the atmosphere. The Space Shuttle and the International Space Station (ISS) are examples of crewed spacecraft.



## Lesson 1

### Flying Above the Earth



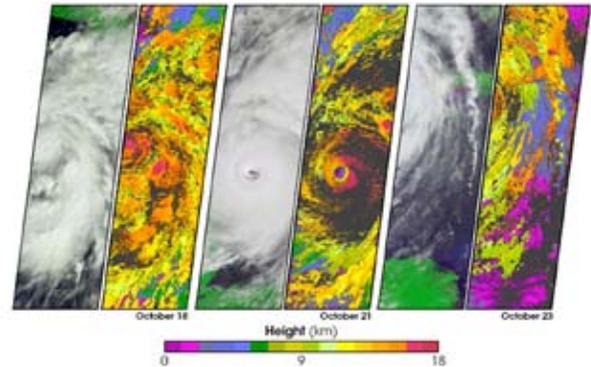
## Earth-orbiting Satellites

A satellite is any object that orbits a celestial body, such as Earth. Satellites can be natural or artificial. Earth has one natural satellite, the Moon, but there are thousands of spacecraft known as artificial satellites orbiting the Earth. Artificial satellites include the following:

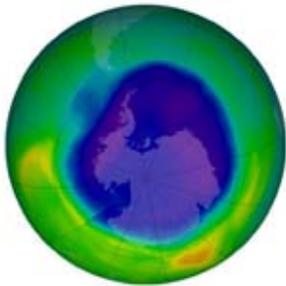
- Communication satellites – Communication satellites transmit news, television, Internet, and phone calls.
- Earth observation satellites – Earth observation satellites monitor different aspects of our planet, including water, land, and atmosphere, to better understand the health of the planet and to predict weather more accurately.



Fires over northern Washington state



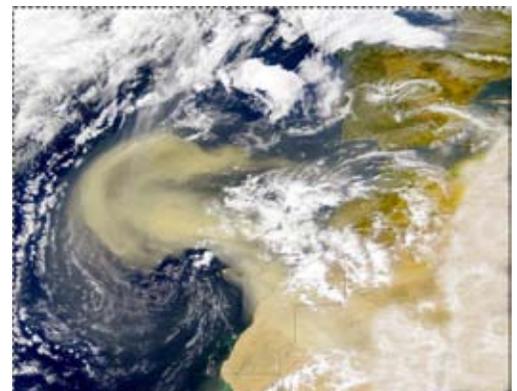
Special NASA cameras took images and measured the cloud-top heights of Hurricane Wilma in October 2005. Each pair of images has a photo-like view of the storm on the left and a matching color-coded image of cloud-top height on the right. Cloud-top heights range from 0 (purple) to 18 (red) kilometers in altitude. Areas where cloud heights could not be determined are shown in gray.



Data from NASA's Earth-observing Aura satellite show that the ozone hole peaked in size on Sept. 13, 2007, reaching a maximum area extent of 9.7 million square miles – just larger than the size of North America.



Deforestation in Mato Grosso, Brazil



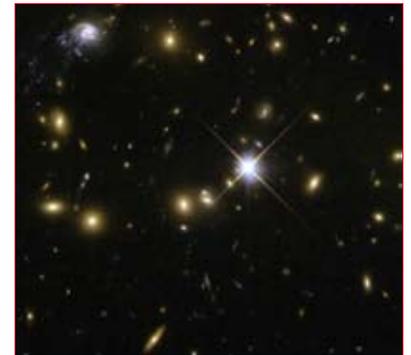
A massive sandstorm blowing off the northwest African desert has blanketed hundreds of thousands of square miles of the eastern Atlantic Ocean with a dense cloud of Saharan sand.



- Navigational satellites – Navigational satellites help ships and aircraft travel from place to place by pinpointing their precise location. Any type of Global Positioning System (GPS) device relies on these types of satellites, and even certain motor vehicles are equipped with a GPS device today.



Hubble telescope photo of the Barred Spiral Galaxy

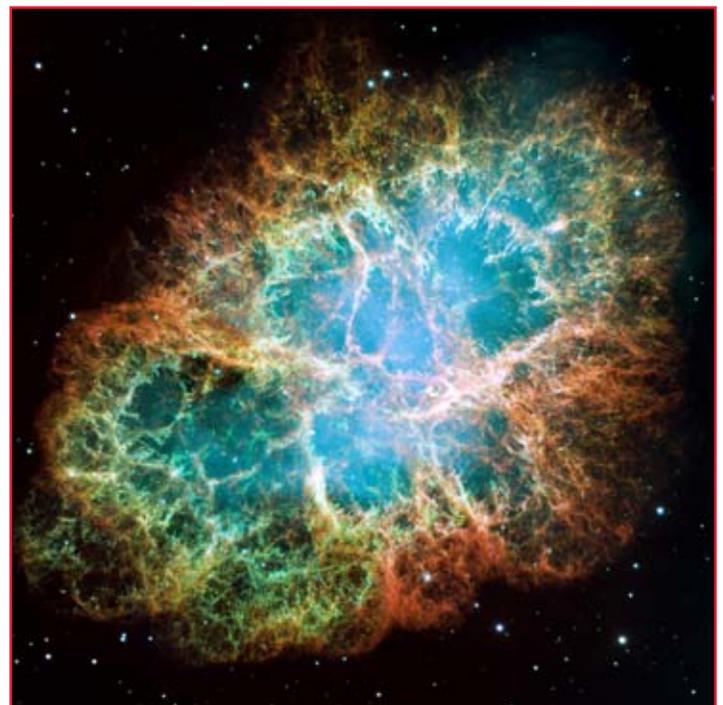


Hubble telescope image of the galaxies of cluster Abell 2667

- Space observatories – Space observatories, or space observation satellites, orbit Earth, but they point toward space to study objects in the solar system or elsewhere in the universe.

### **Research Aircraft/Rockets/Spacecraft**

All types of vehicles that launch from the ground, fly in the atmosphere to perform a task, and then return to Earth are included in this category.



Hubble telescope photo of the Crab Nebula

### **Orbital Debris/Space Junk**

Orbital debris is any human-made object that orbits Earth but no longer serves a purpose. Orbital debris is also called space junk or space trash. Examples of orbital debris include broken satellites, upper stages of rockets, debris from explosions or collisions of spacecraft, and smaller objects that separate from spacecraft. Some of the larger objects could threaten the lives of astronauts in a space shuttle or the International Space Station (ISS). Thousands of objects more than 1 centimeter in size are closely monitored to protect spacecraft and satellites. The NASA Orbital



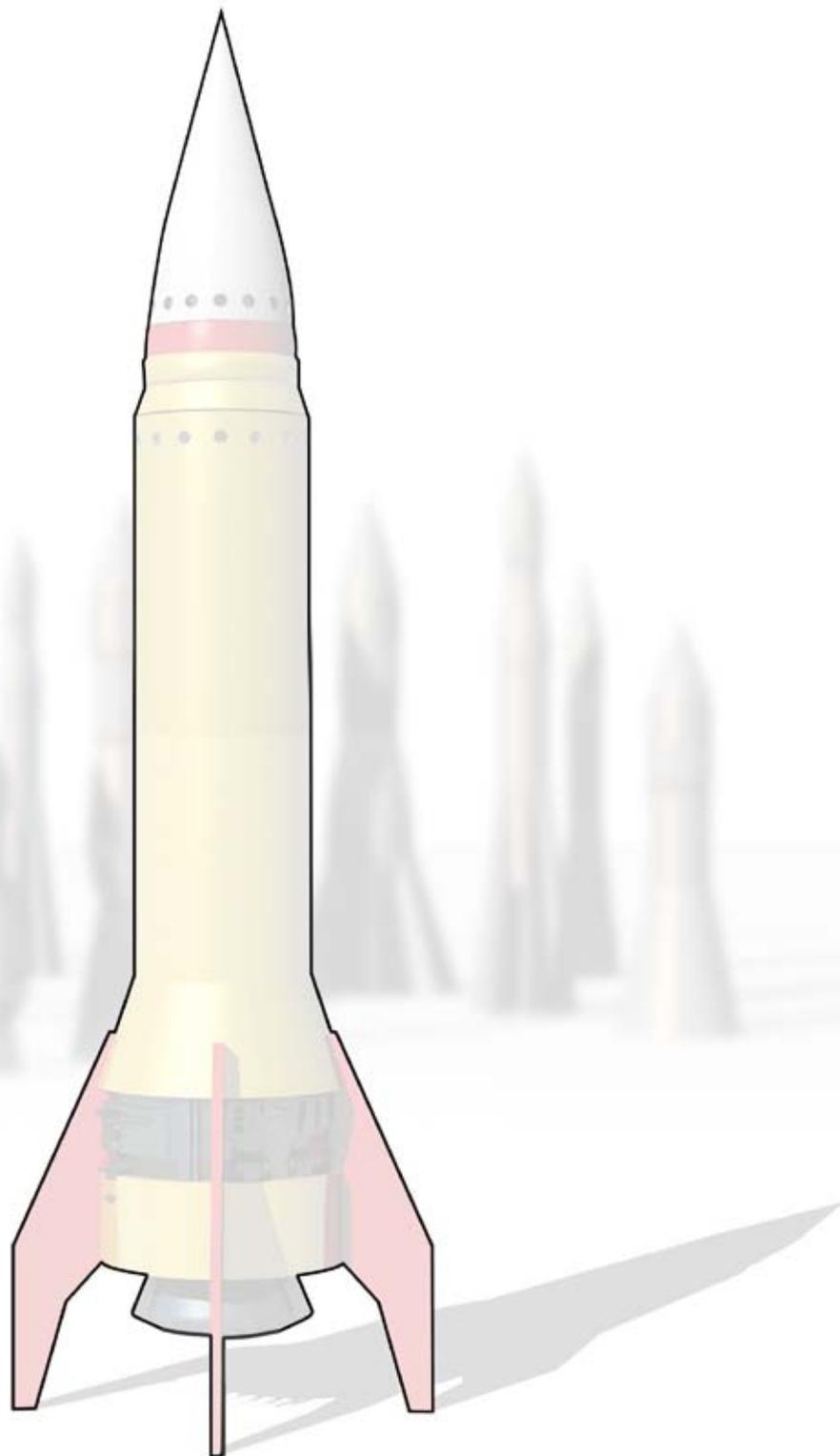
Debris Program Office is located at the Johnson Space Center and is the lead NASA Center for orbital debris research. Space junk is also tracked by the U.S. Space Surveillance Network. This agency tracks human-made objects larger than 4 inches (10 centimeters) in diameter orbiting the Earth (13,000 objects as of 2008). These include both operational spacecraft and debris such as derelict rocket bodies. In addition, there are hundreds of thousands of smaller objects in space. These include everything from pieces of plastic to flecks of paint.

## Deep Space Probes

Many spacecraft travel beyond Earth's orbit to explore other worlds where humans cannot travel. NASA has sent spacecraft to study the different celestial bodies in the solar system. Some deep space probes orbit the Sun, other planets, moons, and even asteroids. Some probes fly by these celestial bodies, while other probes have landed on their surfaces. The Stardust spacecraft is an example of a spacecraft that encountered comet Wild 2 (pronounced Vilt 2) in January 2004. Stardust collected samples of comet particles and took detailed pictures of Wild 2's pockmarked surface. Stardust returned the samples to Earth in January 2006 after traveling billions of miles. After the capsule's safe landing, the NASA Stardust Web site reported as follows:

“Scientists said they were delighted with Stardust samples returned from the tail of a comet after an almost three-billion-mile journey. Speaking at NASA's Johnson Space Center, Peter Tsou, Stardust deputy principal investigator, said researchers were ecstatic with the collection of the cometary and solar materials from outer space.”

Space probes usually do not return to Earth, so Stardust was very unusual in this way. Most keep going and some have even left the solar system.







## Lesson 2 – How Far Up Can We Go?

Credit: The idea for the NASA vehicles graphing activity comes from the NASA Education Guide [How High Is It?](#). However, all of the material has been updated to include current missions.

**Lesson prep time:** 20–25 minutes (for gathering materials and following pre-lesson instructions)

**Teaching time:** 1¼–1½ hours (Science, Technology)  
30–45 minutes (Math)

### Objectives

1. The students will identify the five layers of the Earth's atmosphere and recall certain characteristics of each layer.
2. The students will share their knowledge about aircraft and spacecraft and where they travel as they contribute to the "Layers of the Atmosphere" bulletin board.
3. The students will construct a model/graph of the layers of the Earth's atmosphere and graph the location of NASA aircraft and spacecraft that operate within Earth's atmosphere and beyond.
4. The students will assess the use of the NASA vehicles and make observations about how these vehicles impact their lives.

5. The students will recognize the difference between vehicles that need air to fly and vehicles that need rockets to fly in the absence of enough air.
6. The students will construct their own graph of the layers of the atmosphere.



*Image credit: NASA*

A concept image shows the Ares V Earth Departure Stage and the Altair lunar lander docked with the Orion Crew Exploration Vehicle in Earth orbit.

## National Standards

### Science

- Abilities necessary to do scientific inquiry – S2Ea, S2Ma
- Understandings about scientific inquiry – S2Eb, S2Mb
- Properties of objects and materials/Properties and changes in matter – S3Ea, S3Ma
- Position and motion of objects/Motion and forces – S3Eb, S3Mb
- Properties of Earth materials/Structure of the Earth system – S5Ea, S5Ma
- Objects in the sky – S5Eb
- Changes in Earth and sky/Earth in the solar system – S5Ec, S5Mc
- Abilities of technological design – S6Ea, S6Ma
- Understanding about science and technology – S6Eb, S6Mb
- Risks and benefits – S7Md
- Science and technology in local challenges/in society – S7Ee, S7Me
- Science as a human endeavor – S8Ea, S8Ma
- History of science – S8Mc

### Mathematics

- Understand patterns, relations, and functions – M4
- Use mathematical models to represent and understand quantitative relationships – M6
- Specify locations and describe spatial relationships using coordinate geometry and other representational systems – M9
- Use visualization, spatial reasoning, and geometric modeling to solve problems – M11
- Understand measurable attributes of objects and the units, systems, and processes of measurements – M12
- Apply appropriate techniques, tools, and formulas to determine measurements – M13
- Formulate questions that can be addressed with data and collect, organize, and display relevant data to answer them – M14
- Develop and evaluate inferences and predictions that are based on data – M16
- Understand and apply basic concepts of probability – M17
- Problem solving – M18
- Communication – M20

### Geography

- How to use maps and other geographic representations, tools, and technologies to acquire, process, and report information from a spatial perspective – G1
- How to use mental maps to organize information about people, places, and environments in a spatial context – G2
- The physical and human characteristics of places – G4
- The physical processes that shape the patterns of Earth's surface – G7
- How human actions modify the physical environment – G14
- How physical systems affect human systems – G15

### Language Arts

- Standards 1, 3, 4, 7, 8, 11, and 12 (See the Language Arts Matrix on page 22.)

### Technology – ISTE

- Students are proficient in the use of technology – I2
- Students develop positive attitudes toward technology uses that support lifelong learning, collaboration, personal pursuits, and productivity – I5
- Students use productivity tools to collaborate in constructing technology-enhanced models, prepare publications, and produce other creative works – I7
- Students use technology to locate, evaluate, and collect information from a variety of sources – I10
- Students employ technology in the development of strategies for solving problems in the real world – I14

### Technology – ITEA

- Relationships among technology and other fields – T3
- Cultural, social, economical, and political effects – T4
- Effects of technology on the environment – T5
- Role of society in the development and use of technology – T6
- Influence of technology on history – T7
- Engineering design – T9
- Role of troubleshooting, research and development, inventions and innovation, and experimentation in problem solving – T10
- Assess impact of products and systems – T13
- Information and communication technologies – T17
- Transportation technologies – T18

## Materials

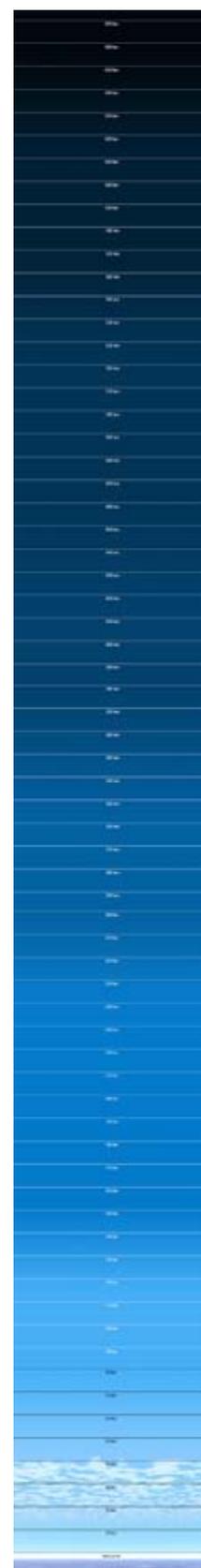
- Student logs
- The students' completed "How High Can They Go?" homework assignments
- "Layers of the Atmosphere" bulletin board
- Teacher Reference for the NASA Vehicles list
- One copy of the following for each group:
  - Altitude Chart (Print two extra copies to be used as demonstrators.)
  - Atmospheric Layers Table
  - NASA Vehicles Template
  - NASA Vehicle Altitude Table
- A 9- by 12-inch sheet of black construction paper for each group (optional)
- A clear tape dispenser for each group
- Scissors for each group
- Glue for each group
- A 12-inch ruler that also shows centimeters for each group
- A black felt pen or magic marker for each group
- A copy of the "Graphing the Layers of the Atmosphere" (Student copy) instructions for each student and the following materials for that activity:
  - A sheet of small-grid graph paper for each student
  - A compass for each student

## Pre-lesson Instructions

1. Divide the class into groups of two or three students each for making a model of the atmosphere.
2. Duplicate a copy of the following for each group.
  - Altitude Chart – Duplicate two additional copies of the Altitude Chart. This chart covers several sheets of paper. Before the lesson, tape the sheets of one of the charts together to be used as a finished example for the students. (Instructions for taping the sheets together are in Step 6 of the Procedure.) The other copy will be used to demonstrate connecting the sheets together as you explain the procedure to the class.
  - Atmospheric Layers Table
  - NASA Vehicles Template
  - NASA Vehicle Altitude Table
3. Because all of the vehicles will not fit on the graph,

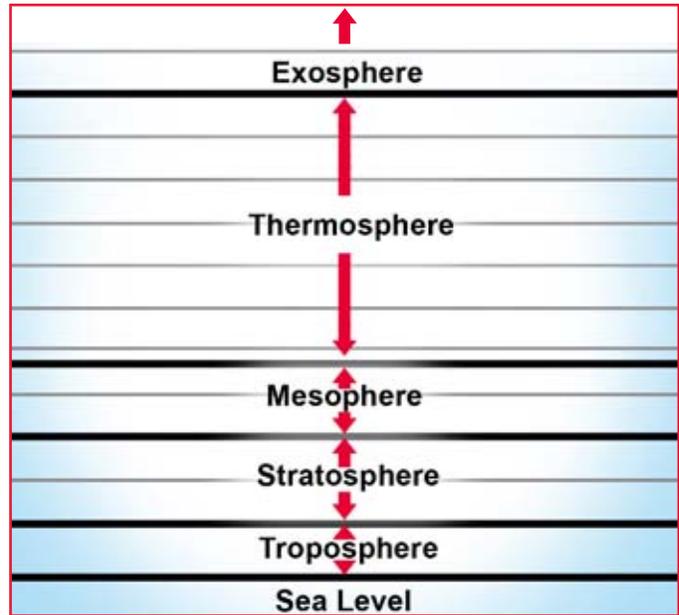
teachers may elect to tape a black sheet of construction paper to the top of the graph to represent the exosphere. Then, students can glue the vehicles operating in this layer onto the black paper. If this option is used, cut off the title "Altitude Chart."

4. Duplicate enough student copies of the math activity "Graphing the Layers of the Atmosphere" for each student and collect the materials needed for this activity. These materials are listed in the Teacher copy of the activity as well as in the materials list of Lesson 2.
5. Set out the tape dispensers, scissors, rulers, glue, and black pens or markers.



## Procedure

1. Direct the students' attention to the "Layers of the Atmosphere" bulletin board. Review the layers and ask the students to recall some of the characteristics of each. Emphasize that almost the entire mass of the atmosphere is in the first two layers.
2. Instruct the students to take out the pictures of the aircraft or spacecraft that they researched for homework. Tell them to get out their logs and turn to the description of their vehicle. Have each student show the picture of the vehicle and read the sentences describing its purpose and the altitude at which it flies. Then, help the student to place the picture at the correct altitude on the "Layers of the Atmosphere" bulletin board.
3. Next, show the class the completed Altitude Chart that has been taped together. Tell the students that they are going to make this model/graph of the layers of the atmosphere. Then, show the NASA Vehicles Template and tell them that they will be positioning these NASA vehicles in the correct layer on the model.
4. Assign the students to their groups.
5. Distribute the six-page Altitude Chart to each group. Distribute the tape dispensers around the room and have each group pick up scissors, a ruler, glue, and a black pen or marker.
6. Teachers should demonstrate each step as they explain the instructions. Instruct the students to cut off the bottom, or top, of each page on the line and then use the tape to connect the six pages end to end in the correct order. When connecting the pages, tell them to leave a space of almost 2 centimeters between the altitude line at the bottom of the page and the altitude line at the top of the next page.
7. When the charts are complete, display the completed chart again and emphasize that each horizontal line represents 10 kilometers.
8. Distribute an Atmospheric Layers Table to each group. Instruct the students to use this table to label each layer of the atmosphere in large letters on the chart. They should draw an arrow from the base of each layer to the top of each layer. Demonstrate this step on the completed Altitude Chart. When completing the exosphere, have the arrow go all the way to the top of the chart to show that it keeps going.
9. Next, distribute a NASA Vehicles Template to each group. Tell the students to cut out each vehicle and estimate where on the chart they think the vehicle flies. Tell them to place the vehicle in that area of the chart but not to glue it on yet. Allow about 5–8 minutes for the students to cut out and place the vehicles in the estimated areas.
10. Using the Teacher Reference for the NASA Vehicles, read the brief description of each vehicle. As you read about each vehicle, give the students a few seconds to change the vehicle's location on the graph based on its description.
11. As each vehicle description is read, allow the students to share their observations about the use of each vehicle and how it might impact their lives. Ask, "How do the people on Earth benefit from this vehicle? What does it accomplish, and how does that affect our lives?"



12. Tell the students that they will now assess their predicted locations for each vehicle. Explain that they will be comparing their estimated altitude to the actual altitude and then grading the estimates.
13. Distribute the NASA Vehicle Altitude Table. Tell the students to use this table to locate the correct area for each vehicle, but do not move the vehicle. On the Vehicle Altitude Table, have the students record the difference between the estimated altitude and the actual altitude by marking the symbols A, C, or NEC. (See the “NASA Vehicle Chart” on page 64.)
14. After they have rated their estimates, they should move their vehicles to the correct area on the chart and glue them in place.
15. Allow a few minutes for the students to discuss the accuracies and inaccuracies between the estimated and actual placement of the vehicles. Point out that aircraft with propeller, jet, or scramjet engines need air for thrust and that these vehicles are located in the two lower layers. All vehicles traveling above the stratosphere need rocket engines for propulsion.
16. By this time, students will have realized that not all of the NASA vehicles fit on the chart. Students will not be able to place the “A Train,” Chandra, GOES, Landsat, OSTM, Terra, and THEMIS on the graph. Explain to the students that this model of the atmosphere has limits because of the scale chosen to represent the distances. To accommodate the other vehicles, the model would have to use many more pages.
17. One option for accommodating these vehicles would be to tape a 9- by 12-inch sheet of black construction paper to the top of the graph to represent the rest of the exosphere. The vehicles that operate in this layer can be glued to this sheet of paper. If this option is used, cut off the title “Altitude Chart.”
18. After the discussion, tell the groups to formulate questions that can be answered by their graphs. Allow each group to ask one question to the class. Make sure the following questions are covered.

- 1) Which vehicles fly in the troposphere?

**The Blended Wing Body X-48B and the KC-135 fly in the troposphere. Both of these vehicles are powered by jet engines. A jet engine needs air to operate.**

- 2) Which vehicles fly mostly in the stratosphere?

**The F-15 ACTIVE, the Helios Prototype, SOFIA, the ULDB, and the X-43 fly in the stratosphere. The F-15 ACTIVE and SOFIA are powered by a jet engine and the X-43 by a scramjet. The ULDB is a helium-filled balloon and the Helios relies on a huge wing for lift. All of these vehicles need air to fly.**

- 3) Which vehicles fly in the mesosphere?

**None of these NASA aircraft, spacecraft, or satellites fly in the mesosphere.**

- 4) Which vehicles fly mostly in the thermosphere?

**The ISS, sounding rockets, the Space Shuttle, and TRMM fly in the thermosphere. The Ares rockets will fly in the thermosphere once they are put into service. Orion will fly solely in the thermosphere until it begins flights to the Moon. The Ares vehicles, sounding rockets and the Space Shuttle are rocket-powered vehicles. The ISS and the TRMM satellite were carried into space using rockets.**

- 5) Which vehicles fly mostly in the exosphere?

**The “A Train,” Chandra, GOES, the Hubble Space Telescope, Landsat, OSTM, Terra, and THEMIS orbit the Earth in the exosphere. All of these vehicles were carried into space by rockets or rocket-powered vehicles. Orion will fly in the exosphere and to interplanetary space when it begins its flights to the Moon.**

## Lesson 2

### Procedure

- 6) Why do you think the Hubble Space Telescope orbits in the exosphere?

**The higher a space telescope functions in the atmosphere, the less interference or obstruction the atmosphere causes in the data collected.**

- 7) Since the ISS orbits in the thermosphere, it is still in the atmosphere and bumps into air. This slows it down. What must be done to keep the ISS from slowing down too much?

**The ISS must be reboosted to prevent it from falling back to Earth.**

19. Display at least one of the completed Altitude Charts for future reference.

20. **Math Activity: “Graphing the Layers of the Atmosphere”**

This graphing activity can be done as a part of math class or as math homework. If students will be doing the graphing activity in class, distribute the instructions, graph paper, compasses, and colored markers. Read over the instructions and assist as needed. One option would be to let the students work in pairs.

## Teacher Reference for the NASA Vehicles

**“A-Train”** – The Afternoon, or “A-Train,” satellite constellation consists of six satellites flying in formation around the Earth. The satellites, which are a part of NASA’s Earth Observing System of satellites, will allow for studies of clouds, climate, water, atmosphere, and air quality.

**Ares** – NASA’s Ares rockets will return humans to the Moon and later take them to Mars and other destinations. Ares I is the rocket that will propel the Orion Crew Exploration Vehicle into orbit around the Earth. Ares V is a heavy lift launch vehicle that will be used to carry into Earth’s orbit the cargo and the components needed to go to the Moon and later to Mars.

**Blended Wing Body (BWB) X-48B** – The X-48B is an uncrewed test vehicle. The flying wing design provides additional lift with less drag which will cut down on fuel and noise.

**Chandra** – NASA’s Chandra X-ray Space Observatory is the world’s most powerful x-ray telescope. Scientists are using the x-ray images to understand the structure and evolution of the universe and to learn more about black holes, supernovae, quasars, and comets. Chandra’s resolving power is equal to the ability to read a 1-centimeter tall newspaper headline at the distance of a half-mile.

**F-15 ACTIVE Research Aircraft** – ACTIVE was a flight research program at NASA. An F-15 was modified so that the plane’s engine nozzles can redirect engine thrust, giving the aircraft thrust control in pitch (up and down) and yaw (left and right), or any combination of the two axes.

**Geostationary Operational Environmental Satellites (GOES)** – “Geostationary” describes an orbit in which a satellite is always in the same position with respect to the rotating Earth. This allows GOES to hover over one position on the Earth’s surface. These spacecraft help meteorologists observe and predict local weather events, track hurricanes, and support the search-and-rescue satellite-aided system (SARSAT).

**Helios Prototype** – The Helios Prototype was a remotely piloted, electrically powered, lightweight, flying wing. It achieved its first objective when it reached an altitude of almost 100,000 feet (19 miles or 30.5 kilometers), but did not meet its second objective to maintain flight above 50,000 feet (9.5 miles or 15.3 kilometers) for at least 4 days. Helios was designed as the forerunner of high-altitude unmanned aerial vehicles.

**Hubble Space Telescope** – This was the world’s first space-based optical telescope placed into orbit around Earth. Orbiting above Earth’s atmosphere, it is able to detect light from stars, galaxies, and other objects in space before that light is absorbed or distorted. The data sent back each week is equal to about 3,600 feet, or 1 kilometer, of books on a shelf.

**International Space Station (ISS)** – The ISS represents the partnership of 16 nations. NASA has the responsibility for developing and ultimately operating major elements and systems aboard the station. Research in the six state-of-the-art laboratories will lead to discoveries in medicine, materials, and fundamental science that will benefit people all over the world.

**KC-135** – The KC-135 was a microgravity research aircraft. Flying in parabolic arcs, these aircraft create 20 to 25 seconds of weightlessness so that the astronauts can experience the effects of “zero” gravity. The gut-wrenching effects aboard the aircraft earn it the famous nickname of “The Vomit Comet.” The C-9B Skytrain II replaced the KC-135 in 2004.

**Landsat** – Landsat satellites capture images of the Earth’s land mass, coastal boundaries, and coral reefs to ensure that sufficient data are acquired to support the observation of changes on the Earth’s land surface and surrounding environment.

**Orion** – NASA’s Orion Crew Exploration Vehicle will succeed the Space Shuttle as NASA’s primary vehicle

## Lesson 2

### Teacher Reference for the NASA Vehicles

for human space exploration. Orion will begin to carry crew and cargo to the International Space Station (ISS) by 2015. By 2020, it will carry crews to the Moon, and one day will dock with vehicles heading to Mars.

#### **Ocean Surface Topography Mission (OSTM)** –

The OSTM satellite, also known as Jason-2, will monitor global ocean circulation, discover the tie between the oceans and atmosphere, improve global climate predictions, and monitor El Niño/La Niña conditions.

#### **Stratospheric Observatory for Infrared Astronomy (SOFIA)** –

NASA's SOFIA is an airborne observatory that studies the universe in the infrared spectrum. A *Boeing 747SP* aircraft was modified to accommodate a 2.5-meter reflecting telescope that will help astronomers learn more about the birth of stars, the formation of solar systems, the origin of complex molecules in space, the nature and evolution of comets, how galaxies change with time, and even the nature of the mysterious black holes.

#### **Sounding Rocket** –

NASA uses sounding rockets to test instruments used on satellites and spacecraft and to provide information about the Sun, stars, galaxies, and Earth's atmosphere and radiation. The parabolic trajectories put scientific instruments in freefall to experience microgravity conditions for 6 to 10 minutes.

#### **Space Shuttle** –

The Space Shuttle is NASA's reusable launch vehicle that is used to conduct scientific research in Earth orbit and to help construct the ISS as well as transport its crews and supplies. The Shuttle also allows astronauts to service and repair satellites and observatories in space.

#### **Terra Satellite** –

Terra is NASA's flagship Earth-observing satellite. Terra produces land cover maps to show the distribution of Earth's ecosystems and land use patterns. The data is used to analyze relationships among Earth's lands, oceans, and atmosphere well enough to predict future climate conditions.

**THEMIS** – The THEMIS mission uses a constellation of five identical NASA satellites that are capable of being placed in any THEMIS orbit. The mission will help resolve the mystery of what triggers geomagnetic substorms that occur in the midst of the Northern Lights and the Southern Lights. The findings may help protect commercial satellites and humans in space from the adverse effects of particle radiation.

#### **TRMM Satellite** –

NASA's TRMM satellite monitors and studies rainfall in the tropics and subtropics of the Earth. TRMM will contribute to a better understanding of where and how much the winds blow, where the clouds form and rain occurs, where floods and droughts will occur, and how the winds drive the ocean currents.

#### **Ultra Long-Duration Balloon (ULDB)** –

ULDB is a project to fly balloons on missions lasting up to 100 days at the edge of space. As it circumnavigates the globe, the ULDB will take measurements with its scientific payload. The ULDB will offer a cheap alternative to certain kinds of low-Earth-orbiting satellite missions.

#### **X-43A** –

The X-43A is a hypersonic (a speed of Mach 5 and above), scramjet-powered research aircraft. In March 2004, the X-43A was carried to 95,000 feet (18 miles or 29 kilometers) by a Pegasus rocket and released to fly under its own power. The scramjet engine propelled the plane to fly just under Mach 7 (about 5,000 mph). In November 2004, the X-43A flew under its own power to reach an altitude of 110,000 feet (20.8 miles or 33.5 kilometers). It set a new speed record at Mach 9.6, or nearly 7,000 mph.

## Math Activity: Graphing the Layers of the Atmosphere (Teacher Copy)

**Teaching time:** 30–45 minutes

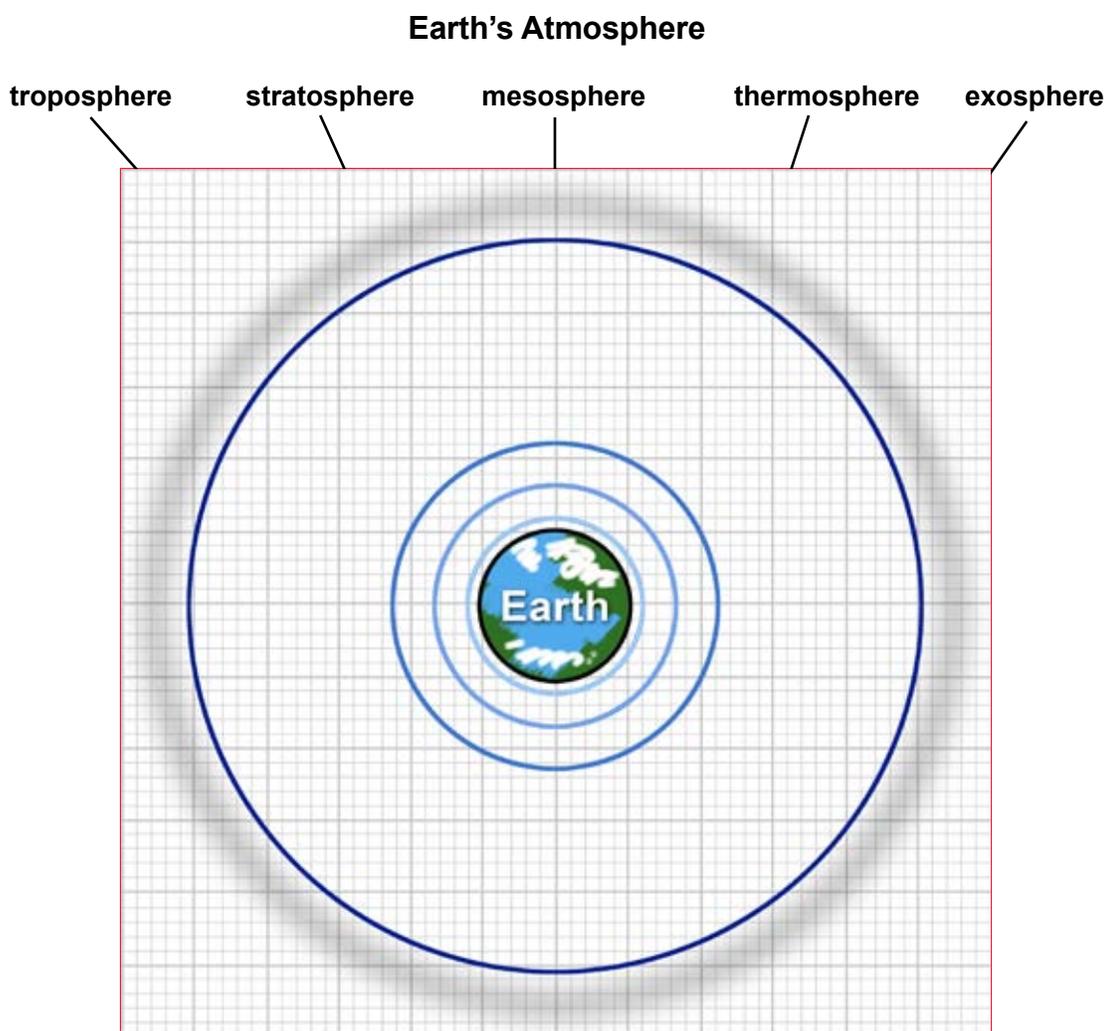
Note to the teacher: The graph below shows areas that are relatively correct, but not accurately scaled due to spacing. It is provided to give an idea of what a finished product should resemble.

### Materials

- Small-grid graph paper
- Compass for drawing a circle
- Pencil
- Colored markers

### Instructions

1. Create a scale to represent the altitude of the different layers of the atmosphere.
2. Draw a circle to represent Earth in the center of the graph paper.
3. Mark each layer of the atmosphere with dots according to the chosen scale.
4. Use a compass to connect the dots.
5. Label the layers of the atmosphere.
6. Color the layers if you wish.



# Altitude Chart

670 km

660 km

650 km

640 km

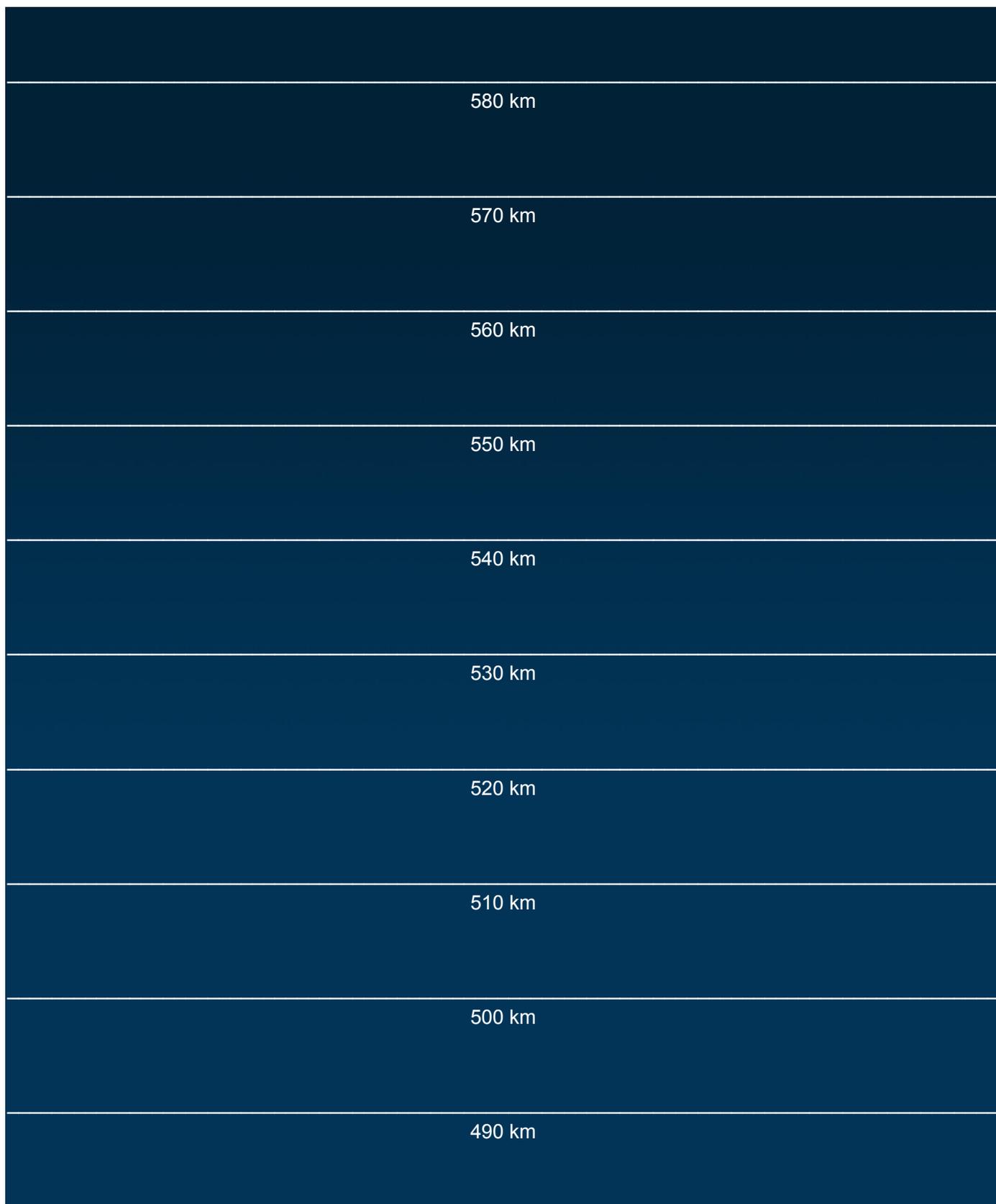
630 km

620 km

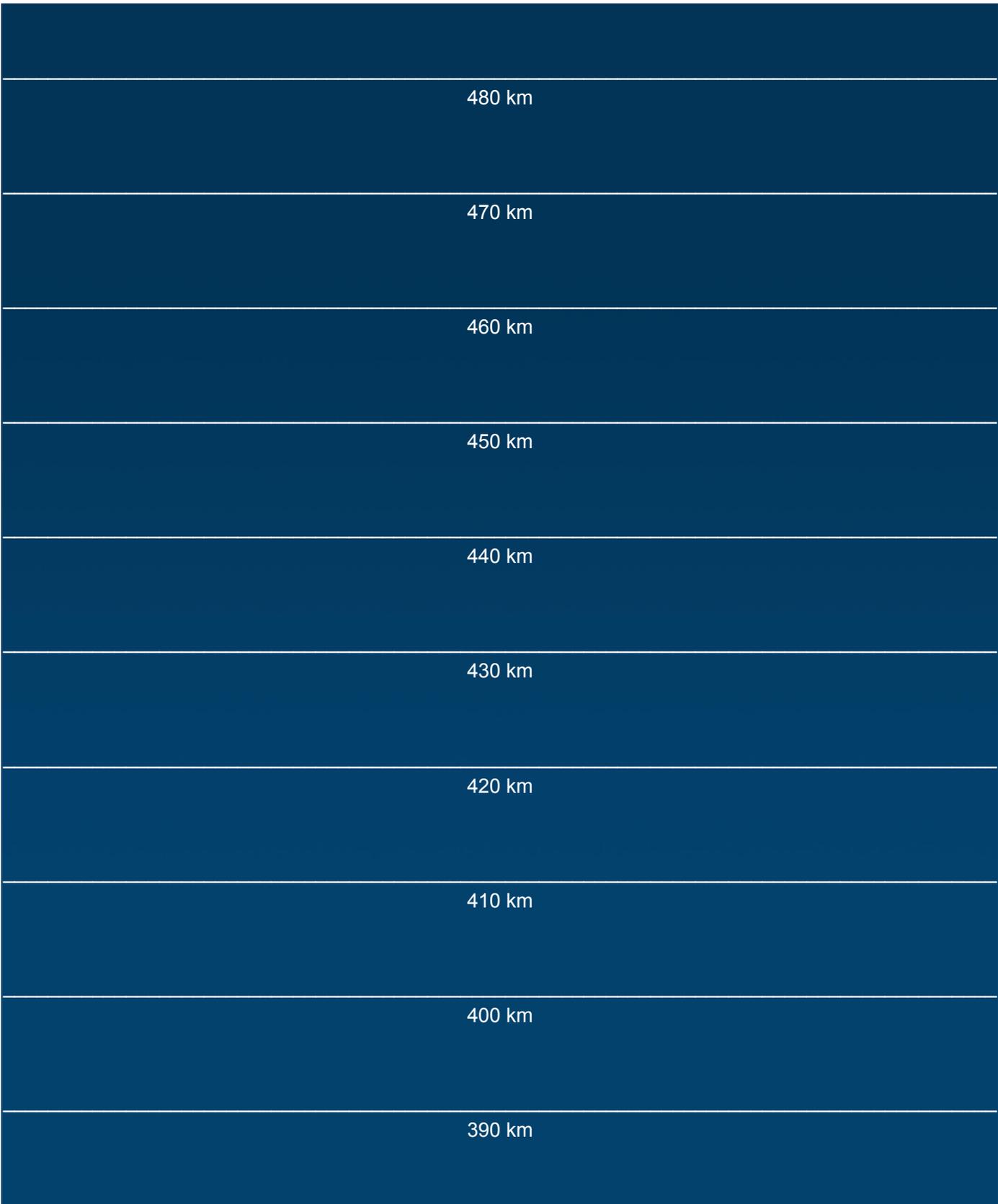
610 km

600 km

590 km

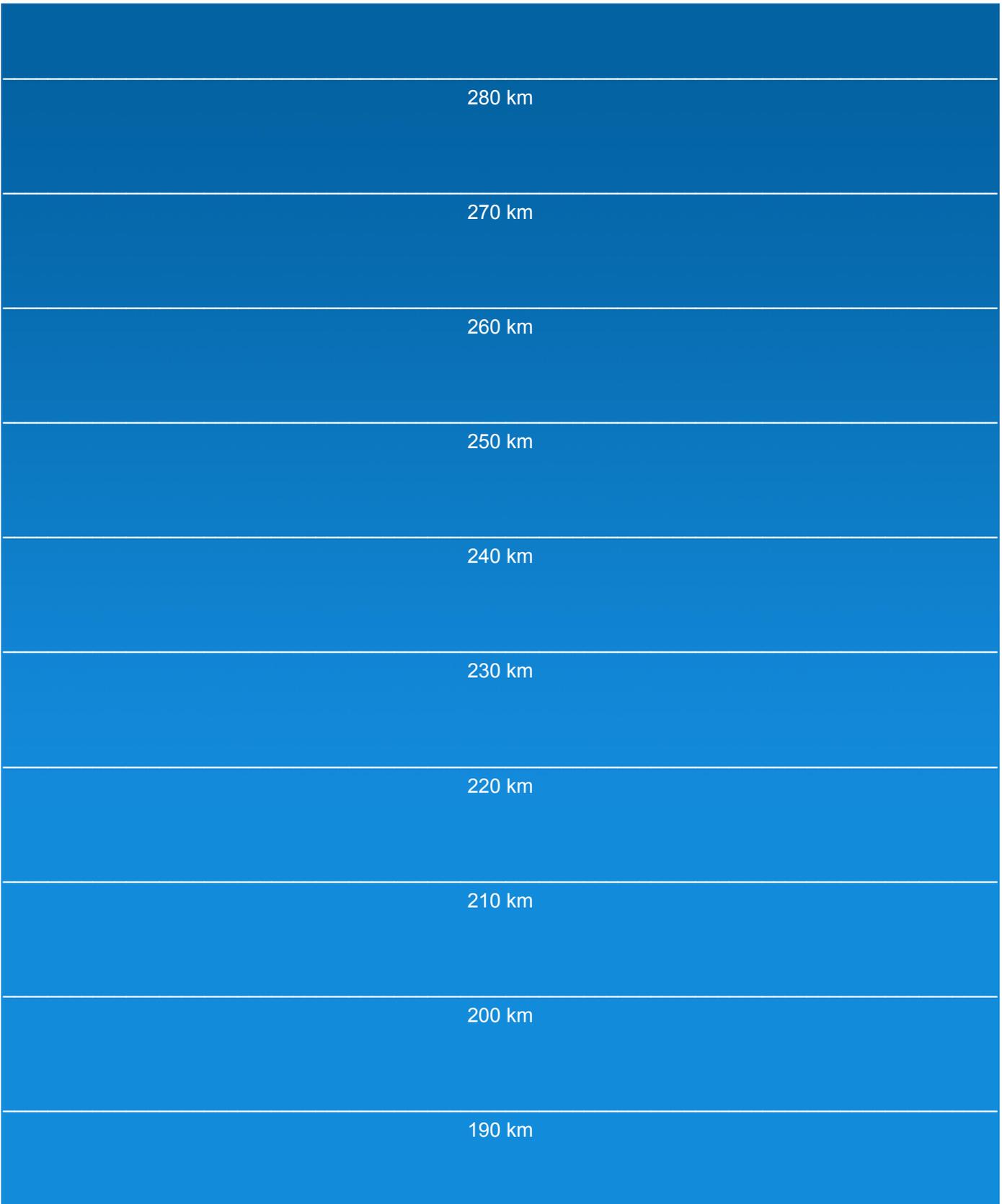


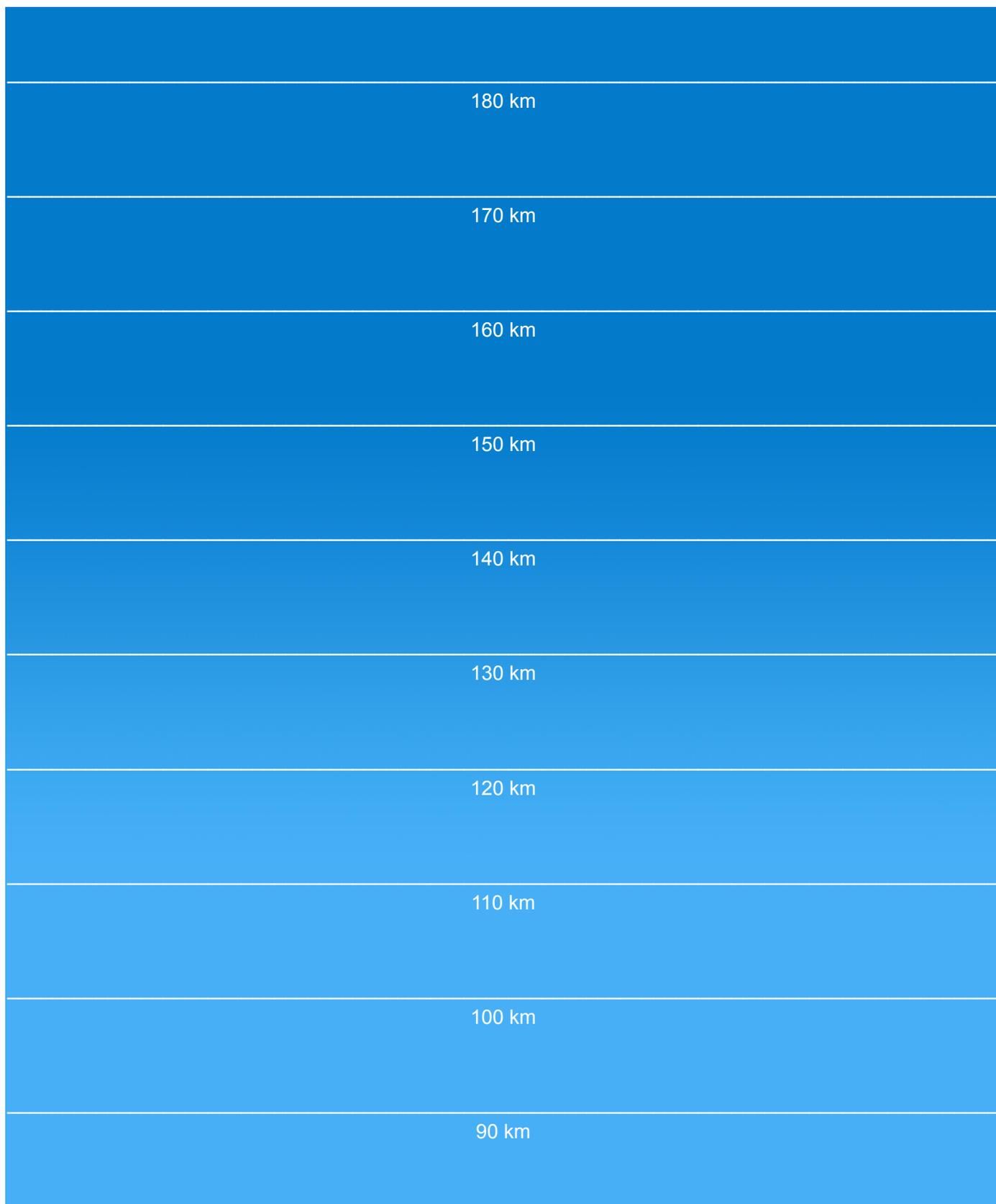
Lesson 2  
Altitude Chart



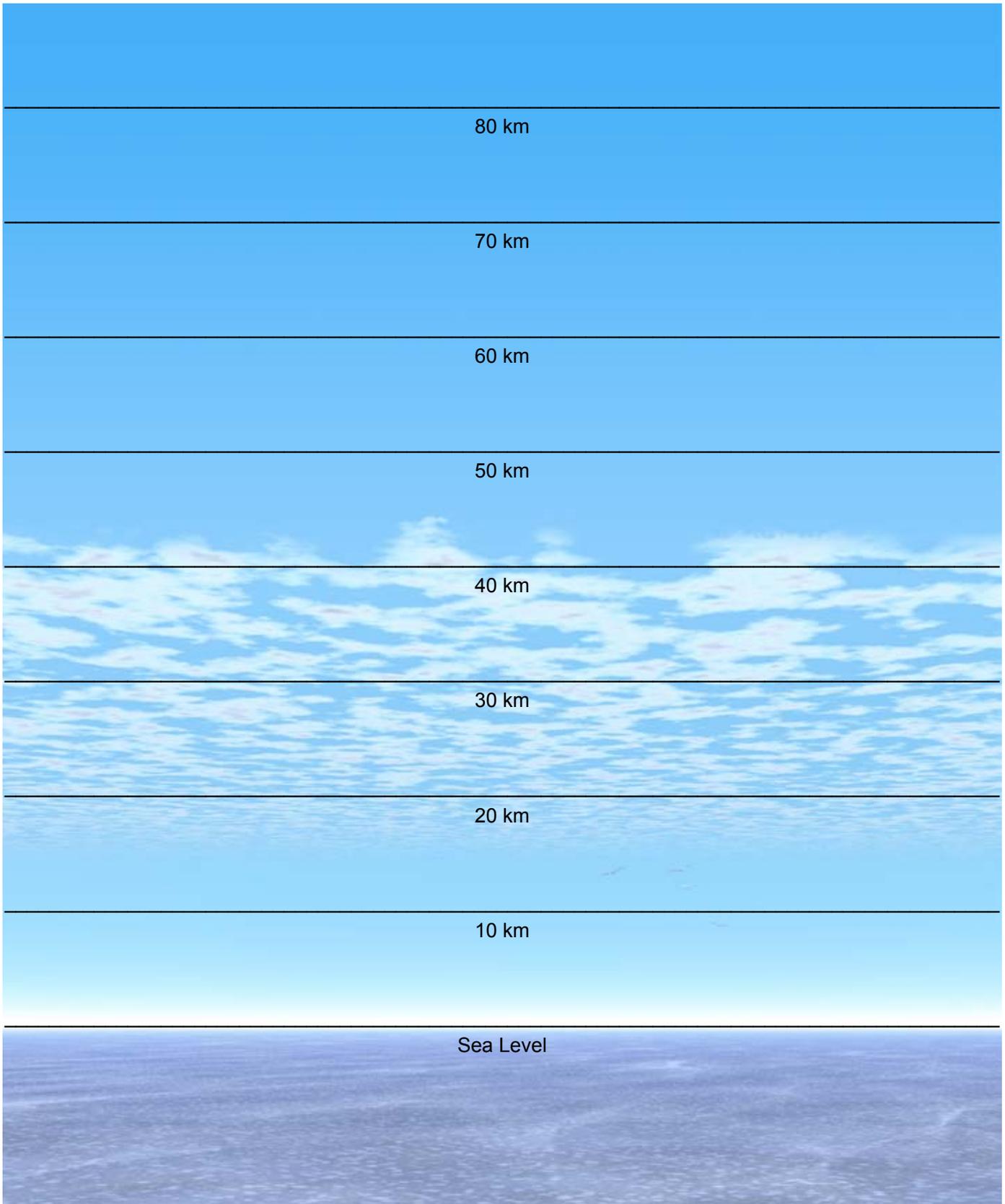


**Lesoon 2**  
Altitude Chart





Lesson 2  
Altitude Chart

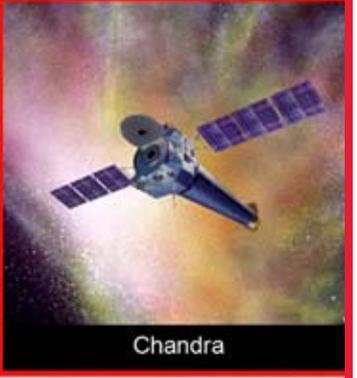
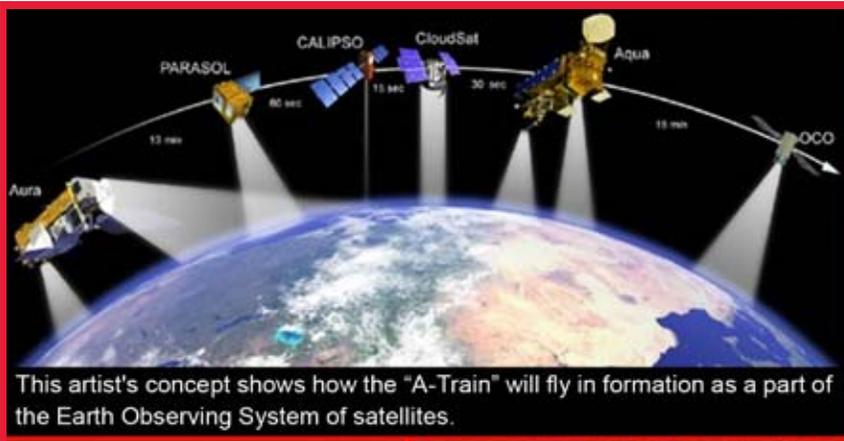


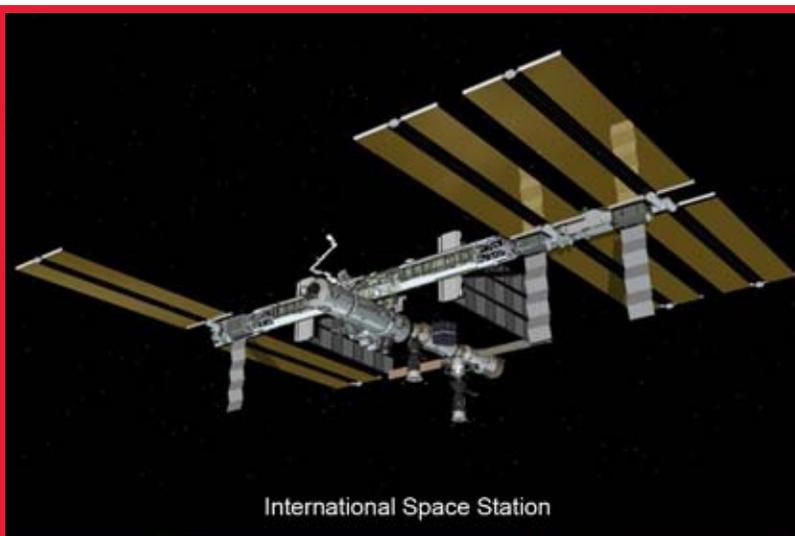


## Atmospheric Layers Table

Atmospheric Layer	Top Altitude
Troposphere	12 kilometers (7.5 miles)
Stratosphere	50 kilometers (31 miles)
Mesosphere	80 kilometers (50 miles)
Thermosphere	500 kilometers (311 miles)
Exosphere	To interplanetary space

Lesson 2  
NASA Vehicles

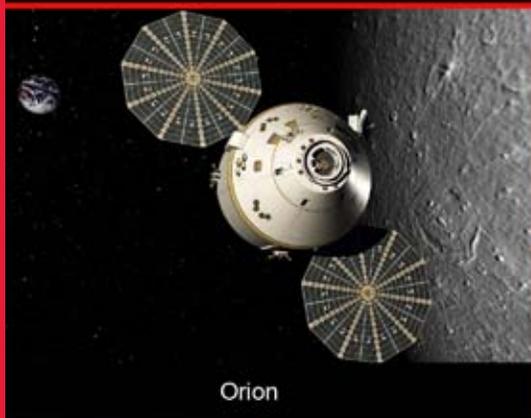




International Space Station



Hubble Space Telescope



Orion



SOFIA



X-43A



Sounding Rocket



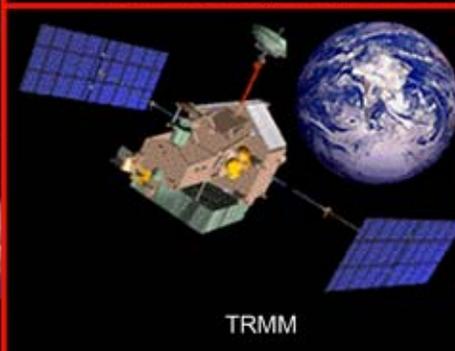
Space Shuttle



THEMIS



NASA Ultra-Long Duration Balloon



TRMM



Terra spacecraft

Lesson 2

NASA Vehicle Chart



# NASA Vehicle Chart

A	C	NEC	NASA Vehicle	Altitude (kilometers)
			"A-Train" Satellites	705
			Ares	Ares I – 185 Ares V Core – 174
			Blended Wing Body <i>X-48B</i>	3
			Chandra	16,000 to 133,000
			<i>F-15 ACTIVE</i>	18
			GOES	35,790
			Helios Prototype	31
			Hubble Space Telescope	589
			International Space Station (ISS)	309–463
			<i>KC-135</i>	8–11
			Landsat	705
			Orion	Through 2020 – Docks with ISS After 2020 – the Moon
			OSTM	1336
			SOFIA	13
			Sounding Rocket	209
			Space Shuttle	195–556
			Terra Satellite	705
			THEMIS	Probe 1 – 197,718 Probe 2 – 127,560 Probes 3 and 4 – 76,536 Probe 5 – 63,780
			TRMM	350
			Ultra Long-Duration Balloon	35
			<i>X-43A</i>	33.5

**A = Accurate**  
**C = Close**  
**NEC = Not even close**



## Graphing the Layers of the Atmosphere

### Materials

- Small-grid graph paper
- Compass for drawing a circle
- Pencil
- Colored markers

### Instructions

1. Create a scale to represent the altitude of the different layers of the atmosphere. (Use kilometers or miles, but indicate which you use on your graph.)
2. Draw a small circle to represent Earth in the center of the graph paper. This circle will not be to scale.
3. Mark each layer of the atmosphere with a dot according to the chosen scale using the information to the right.
4. Using a compass, draw a circle over each dot to represent each layer.
5. Label the layers of the atmosphere.
6. Color the layers if you wish.
7. Title the graph.

**Troposphere – From the surface up to 12 kilometers (about 7.5 mi.)**

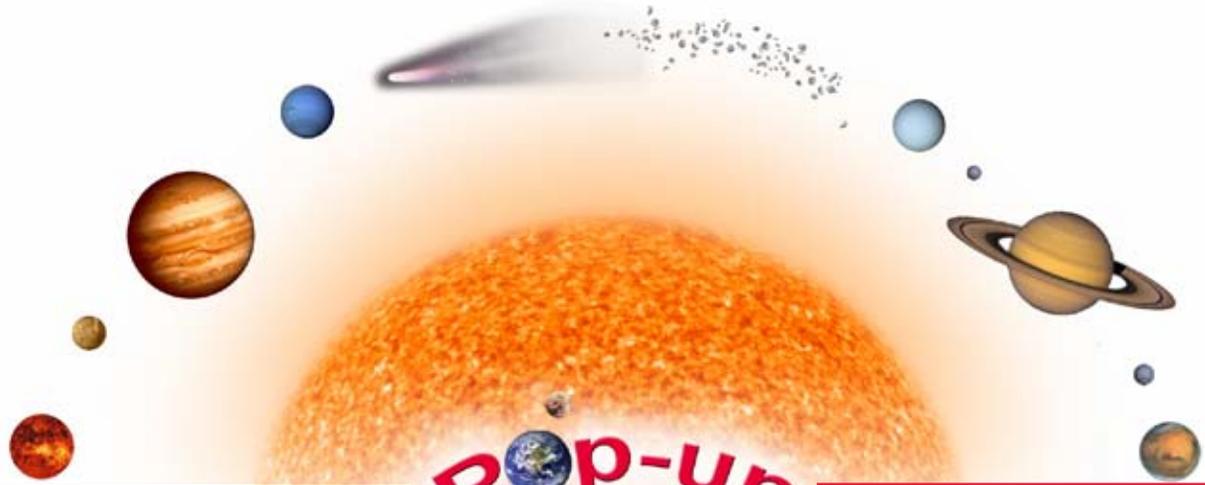
**Stratosphere – 12 to 50 kilometers (about 7.5 to 31 mi.)**

**Mesosphere – 50 to 80 kilometers (31 to 50 mi.)**

**Thermosphere – 80 to 500 kilometers (50 to about 311 mi.)**

**Exosphere – 500 kilometers (about 311 mi.) to interplanetary space**





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# The Solar System Pop-up Book Project

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This pop-up book project is an optional activity that provides a way for teachers to review facts and understandings about the solar system, as well as to build a knowledge base for those students who have had no previous teaching on the subject.

If a pop-up book seems too juvenile for your students, use the 12- by 18-inch sheets of paper as regular pages for a class book. An alternative idea is to distribute two 9- by 12-inch sheets of paper to each team and have them fold these together to make an eight-page book on their solar system body. The books could be presented to the class and then left out for students to read later.

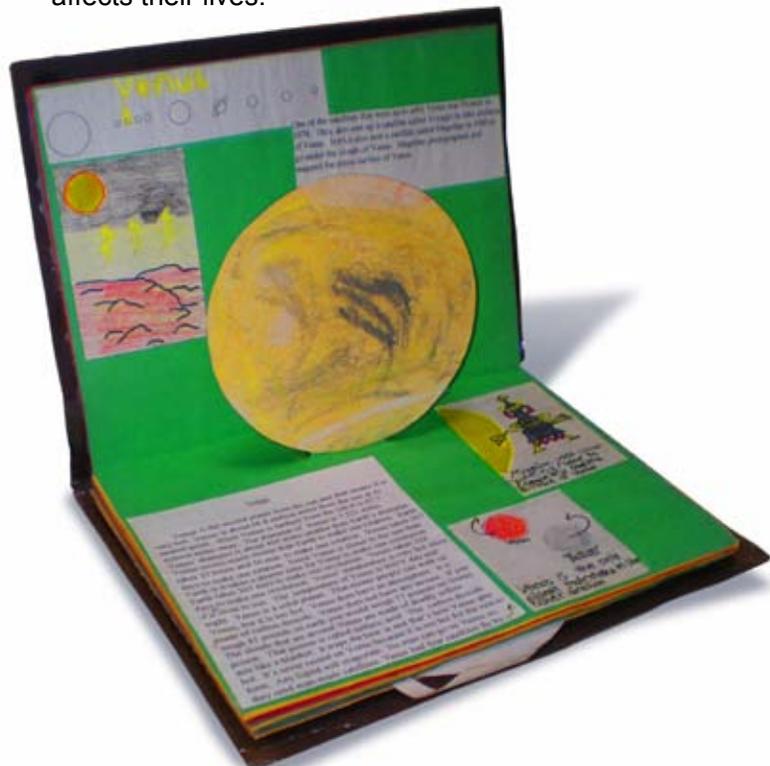
**Prep time:** 30–45 minutes

**Teaching time:** 3 days of 1–1½ hours each day (Science, Language Arts, Technology)

## Objectives

1. The students will conduct research on the celestial bodies of the solar system.
2. The students will use their research to write a short report and prepare informational illustrations about a solar system body.

3. The students will present their research to the class.
4. The students will discuss and compare the solar system bodies.
5. The students will identify the space probes that have been sent out to the solar system bodies and discuss how the data sent back to Earth by those probes affects their lives.



## National Standards

### Science

- Position and motion of objects/Motion and forces – S3Eb, S3Mb
- Properties of Earth materials/Structure of the Earth system – S5Ea, S5Ma
- Objects in the sky – S5Eb
- Changes in Earth and sky/Earth in the solar system – S5Ec, S5Mc
- Abilities of technological design – S6Ea, S6Ma
- Understanding about science and technology – S6Eb, S6Mb
- Risks and benefits – S7Md
- Science and technology in local challenges/in society – S7Ee, S7Me
- Science as a human endeavor – S8Ea, S8Ma
- History of science – S8Mc

### Mathematics

- Use mathematical models to represent and understand quantitative relationships – M6
- Understand measurable attributes of objects and the units, systems, and processes of measurements – M12
- Communication – M20

### Geography

- How to use maps and other geographic representations, tools, and technologies to acquire, process, and report information from a spatial perspective – G1
- How to use mental maps to organize information about people, places, and environments in a spatial context – G2

### Language Arts

- Standards 1, 3, 4, 5, 6, 7, 8, 11, and 12 (See the Language Arts Matrix on page 22.)

### Technology – ITEA

- Students are proficient in the use of technology – I2
- Students use productivity tools to collaborate in constructing technology-enhanced models, prepare publications, and produce other creative works – I7

- Students use telecommunications to collaborate, publish, and interact with peers, experts, and other audiences – I8
- Students use a variety of media and formats to communicate information and ideas effectively to multiple audiences – I9
- Students use technology to locate, evaluate, and collect information from a variety of sources – I10

### Technology – ITEA

- Relationships among technology and other fields – T3
- Cultural, social, economical, and political effects – T4
- Role of society in the development and use of technology – T6
- Influence of technology on history – T7
- Role of troubleshooting, research and development, inventions and innovation, and experimentation in problem solving – T10
- Use and maintain technological products and systems – T12
- Assess impact of products and systems – T13
- Information and communication technologies – T17
- Transportation technologies – T18

## Materials

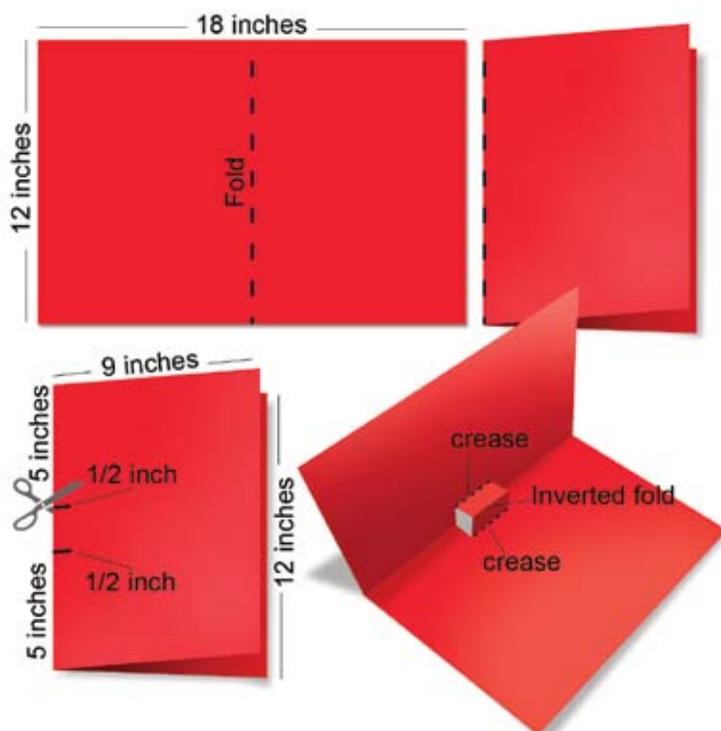
- Books on the solar system and the individual celestial bodies (the Sun, planets, moons, comets, asteroids, etc.) in the solar system
- Computers and printers (If possible, use colored printers for printing images from the Internet.)
- Chart of the solar system (A small chart is provided.)
- “Solar System Pop-up Book Instructions” sheet
- Multi-colored 12- by 18-inch construction paper – 1 per team
- White 12- by 18-inch drawing paper – 2 sheets per team
- Drawing and coloring materials, such as magic markers, colored chalk, and oil crayons for each group
- Black ink pens for captioning and labeling
- Glue
- Scissors

## Pre-activity Instructions

1. Gather many books about the solar system, including the Sun, planets, Earth’s Moon, asteroids, comets, and meteors. Use the school library, as well as a public library, to make sure that each group has several books for research and for finding illustrations.
2. Find a solar system chart that shows the relative sizes of the planets and their relative distances from the Sun. Many charts show the planets in a straight line out from the Sun, but, if possible, select a more realistic, chart of the solar system showing the planets in their orbits around the Sun. A small chart is provided at the end of the lesson.
3. Have several computers available to the class for research. The computers will also be used to type the paragraph, so each computer needs to be connected to a printer. The paragraph can also be handwritten.
4. Divide the class into pairs (teams).
5. Write the following topics in list form on the board or chart: “Sun, Mercury, Venus, Earth, Earth’s Moon, Mars, asteroids, Jupiter, Saturn, Uranus,

Neptune, Pluto/Charon, comets, and meteors.” Teachers should omit the last two items on the list if there are not enough students in the class, or allow some students to work alone so that each subject is covered. Display this list until the presentations are complete.

6. Each team will need one 12- by 18-inch colored sheet of construction paper. Fold each of these sheets in half to make a 9- by 12-inch folded sheet. Five inches from each end of the fold, make two 1½-inch incisions into the fold.
7. Open the sheet and invert the fold in this section. Make a crease at each end of this section. (The crease connects the ends of each incision.) The front of this section provides the surface on which the solar system body is glued and will pop-up when opened. Leave the sheets folded so that the inverted folds will be set.
8. Duplicate copies of the “Solar System Pop-up Book Instructions” sheet for each team.
9. Prepare small slips of numbered paper to decide the order that teams will choose their topics. (The total number of slips corresponds to the number of teams in the class.)



## Procedure – Day 1

1. Show the students the chart of the solar system. Using the list of topics, find each topic on the chart. Allow time for students to discuss the chart and ask questions.
2. Explain to the class that they will be conducting research on these topics to make a class solar system pop-up book and that they will be grouped in pairs to create a page of the book.
3. Assign the students in pairs (called teams) and give each team a few minutes to decide their first, second, and third choices of a topic to research.
4. Teachers should let each team draw a number to allow a fair order of choices.
5. When all the teams have selected their topic, distribute a “Solar System Pop-up Book Instructions” sheet to each team. Read over the “Conducting the Research” section that includes the list of required information they will need to research. Explain that some of the required research will not apply to their topics.
6. Show the students the books and explain that they will use the books and the computers to find information about their topic. Tell them to print any images that they may want to use for their page using the colored printer, if available.
7. Tell the class that, once their research is complete, they should use this information to construct sentences and write the first draft of a 2–3 paragraph report about their topic.
8. After the report is edited, tell the students that they will type the report on the computer and print it. Teachers should help the students set the margins, spacing, and font so that the finished paragraph is approximately a 6-inch square. (Paragraphs may be handwritten as well, but these may exceed the 6-inch square space.)
9. Explain that this report will be glued onto their page in the next lesson.





## Procedure – Day 2

1. After all of the reports have been edited and typed (or written) onto the 6-inch square paper, the students are ready to create their page. Instruct them to collect a sheet of the folded and cut colored construction paper, two white sheets of drawing paper, and drawing and coloring materials. Tell them that the colored sheet will be their page for the book and the white paper will be used for drawing their illustrations. Show the students the completed pages in the left column.
2. Ask the students to get out the “Solar System Pop-up Book Instructions” sheet.
3. Read over the “Creating a Page” section and allow them to ask questions.
4. Reiterate the following: The white paper is used to draw, cut out, and color their solar system body and other illustrations. They will not draw on the colored sheet. Colored chalk is recommended for coloring the solar system bodies because it can be blended into realistic colors. Tell them to refer to NASA images of the body taken by a space probe for the correct coloring of their solar system bodies.
5. As the solar system bodies are colored, laminate each one. Using a strong adhesive tape, help the students to adhere them into place so that they pop up on their pages.
6. After the illustrations are glued on the pages, lay the pages out to dry overnight.

## Procedure – Day 3

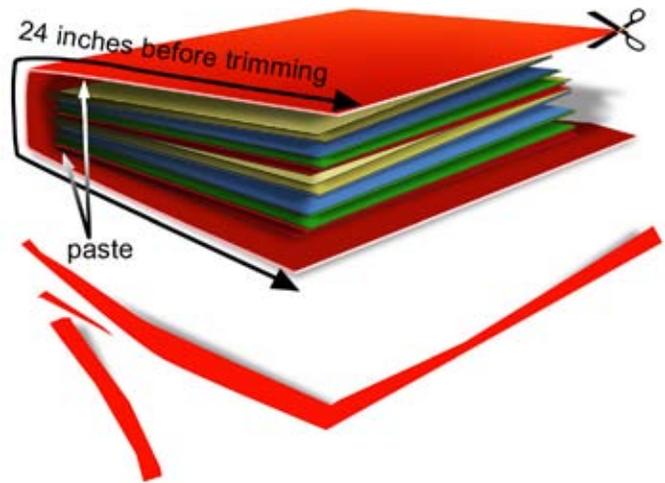
1. Ask the students to gather their pop-up pages and the books and Internet pictures that they used to prepare their research and illustrations.
2. Give the teams about 5–10 minutes to prepare a presentation about their topic. Tell them that they will read their paragraphs and explain the illustrations on their page. They should also show illustrations

## The Solar System Pop-up Book Project

### Procedure – Day 3

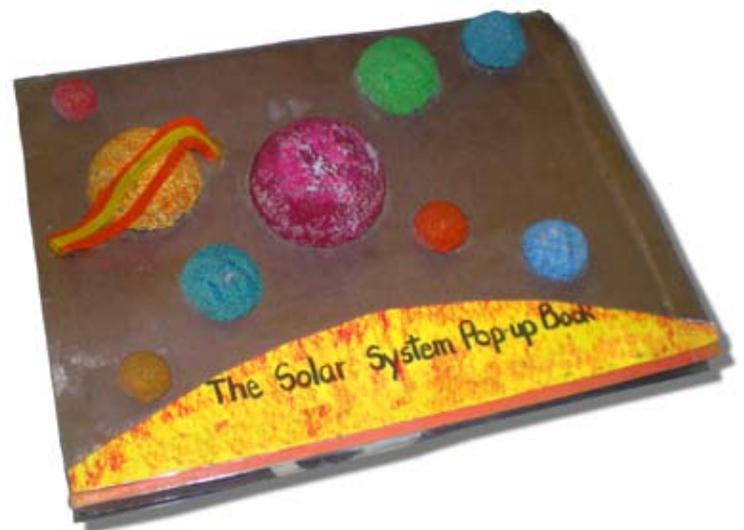
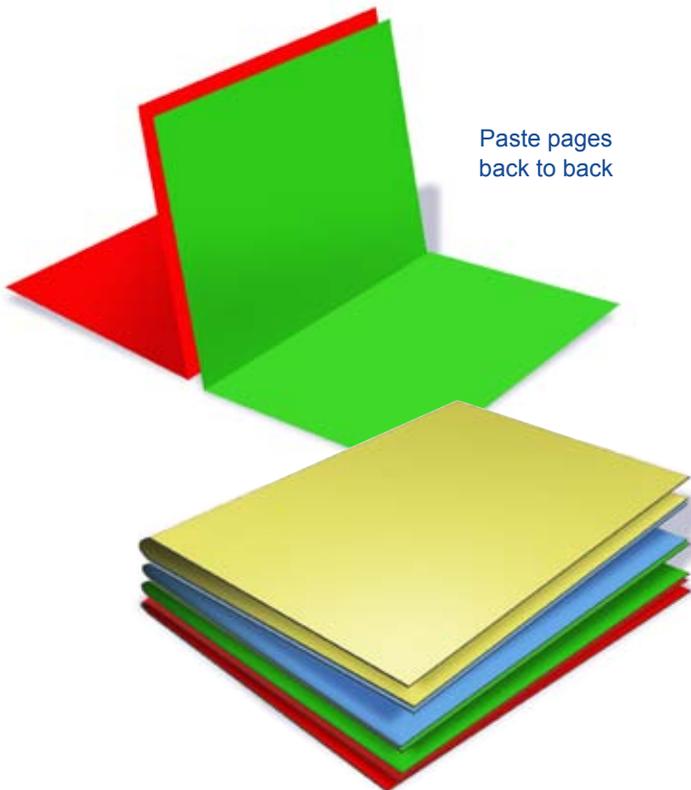
- from books or the Internet as they present their research on their topics.
3. Use the list of topics from Day 1 as the order for the presentations. After each presentation, allow the class to question the presenters.
  4. When the presentations are complete, have a short discussion to review the solar system bodies and answer questions. Compare and contrast the bodies as to inner and outer, gaseous and solid, temperatures, etc.
  5. Make a list of the solar system bodies that have been explored by space probes, noting which ones have been studied using flybys, orbiters, or landers. Ask the students how the knowledge about these solar system bodies affects their lives, if at all. Ask them if they would like to be a space tourist.
  6. Teachers may want to mount the pages on a bulletin board for a few weeks before pasting the pages together into a book.
  7. When making the book, paste the folded pages back to back with the folds placed on top of one another.
  8. For the cover, use a large sheet of construction paper (an 18- by 24-inch sheet) to cover the book. Paste it in place and trim the edges leaving a 1-inch margin around the perimeter.

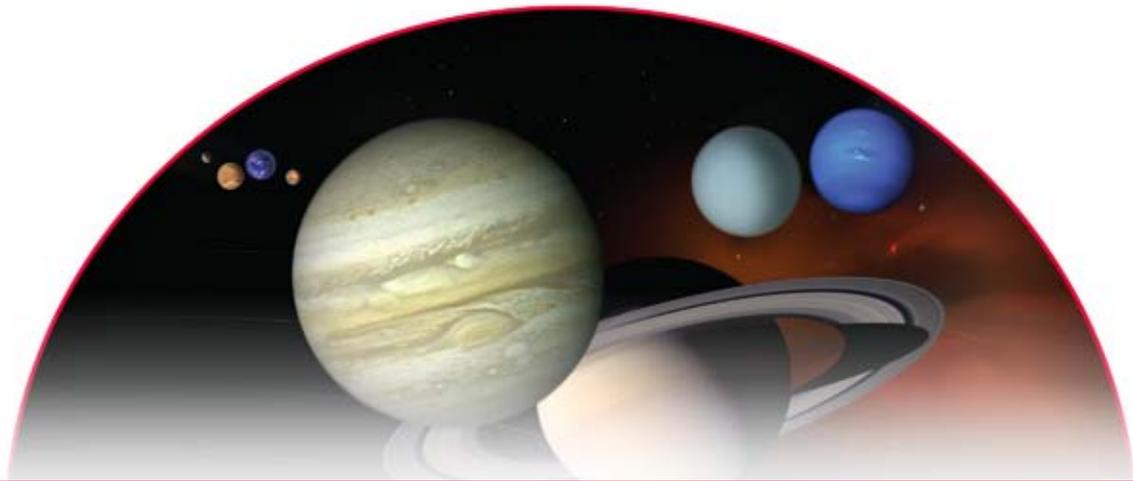
Trim edges for a  
1-inch overlap



9. Have some of the students illustrate and write the title on the cover.

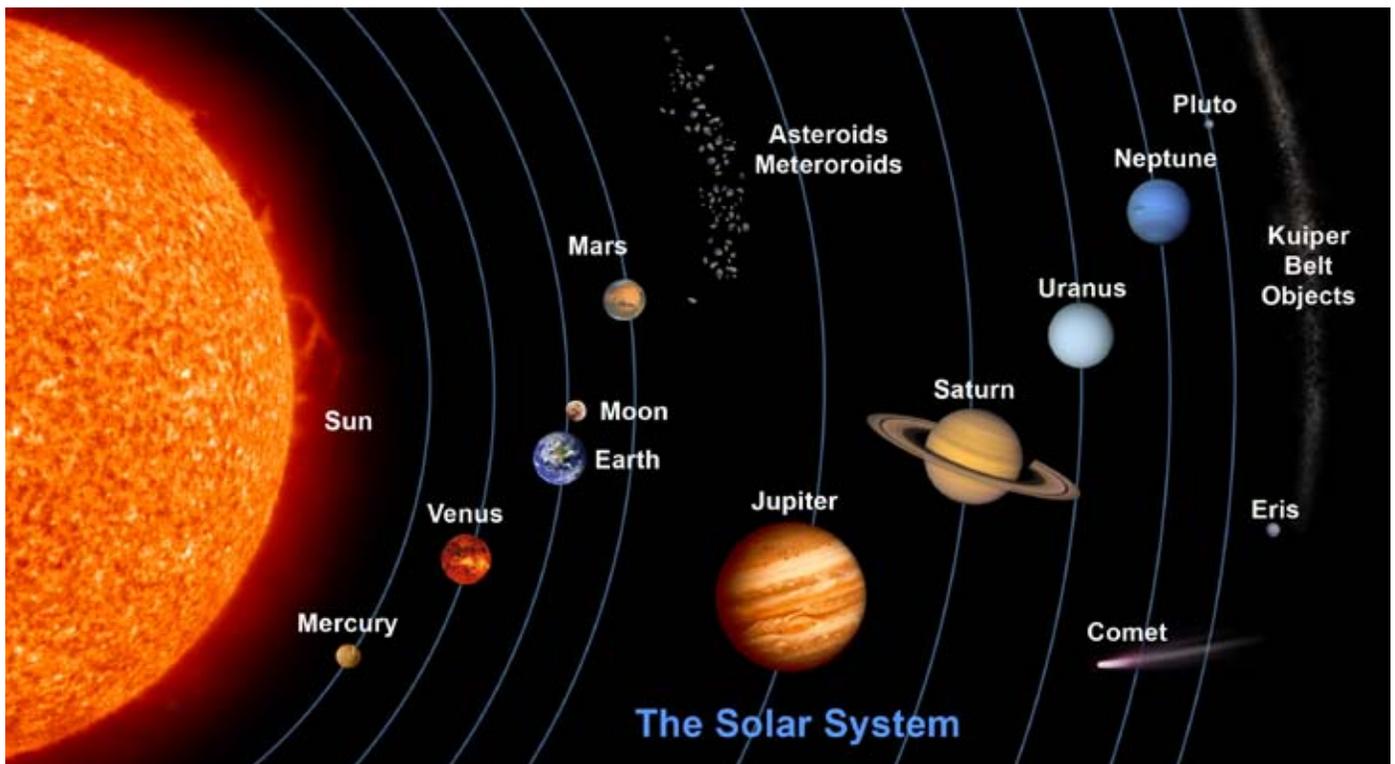
Paste pages  
back to back





## The Solar System Pop-up Book Instructions

Our solar system is nearly five billion years old. It is made up of eight planets, a few so-called dwarf planets, and more than 170 moons, as well as dust, gas, and thousands of asteroids and comets, all orbiting around a central Sun.





**Team members** \_\_\_\_\_

**Name of the solar system body** \_\_\_\_\_

## Conducting the Research

**Find and record the following information about your solar system body. Skip those entries that do not apply to your topic.**

Position of orbit around the Sun \_\_\_\_\_

Average distance from the Sun \_\_\_\_\_

Average speed in orbiting the Sun \_\_\_\_\_

Diameter and relative size compared to Earth \_\_\_\_\_

\_\_\_\_\_

Tilt of axis \_\_\_\_\_

Length of one revolution \_\_\_\_\_

Length of one rotation \_\_\_\_\_

Gravity \_\_\_\_\_

Temperatures (core, surface) \_\_\_\_\_

Surface and core materials and features

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

Atmosphere \_\_\_\_\_

\_\_\_\_\_

Interesting facts about this body

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_



Number of satellites (moons) \_\_\_\_\_

Names and features of any interesting moons

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Description of space probes to this body, including name of probe, its mission, and interesting data returned to Earth by the probe

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Interesting observations from Earth- and space-based telescopes about this body

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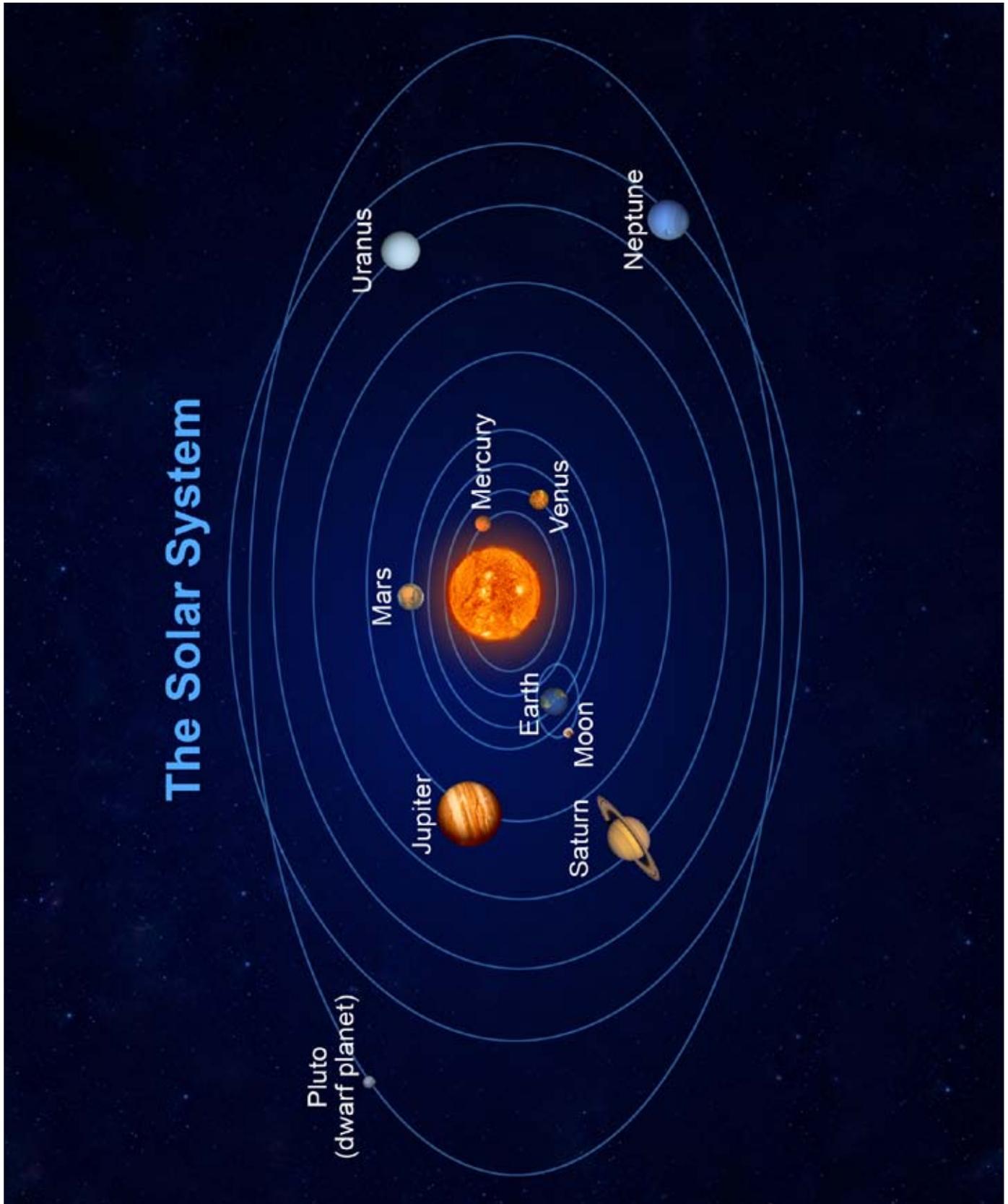


## Creating a Page

Follow these instructions for creating a page in the pop-up book.

1. Use your research to write the first draft of a two-to-three-paragraph report on your topic. Edit the paragraphs and make a final copy of the report using a computer. This final copy should be typed (or written) on paper approximately 6 by 6 inches in size. (Paragraphs may be handwritten if computers are not available.)
2. Draw your solar system body on white drawing paper. The diameter of circular bodies should be no more than  $6\frac{3}{4}$  inches. Rings will be added around some planets. Irregular shapes of asteroids can be glued on a black oval background approximately  $8\frac{1}{2}$  by 6 inches in size. Meteors can be drawn on a similar background. A comet can be an oblong shape the full length of the 12-inch page.
3. Refer to NASA images for the correct coloring of the solar system body. Use colored chalk to blend different colors to make it look realistic. Ask your teacher to laminate this. Adhere this to the page on the pop-up section using strong adhesive tape.
4. Choose four or five interesting facts about your topic to illustrate. Find pictures in the books and print out images from the Internet to help you draw your pictures. One of your illustrations should be the human-made space probe(s) that explored your solar system body. Another suggestion would be a cutaway of the body showing its core and different layers.









## Lesson 3 – Preparing for the Race

**Lesson prep time:** 45 minutes–1 hour (for gathering materials and following pre-lesson instructions)

**Teaching time:** 1 hour (Science, Geography, Technology)

### Objectives

1. The students will compare the 1903 *Wright Flyer I* to a *Boeing 787* (or the European *Airbus 380*) and discuss how progress in the field of aeronautics has impacted our lives.
2. The students will compare the *Freedom 7* capsule to the Space Shuttle orbiter (or the Orion capsule that will be used after the Space Shuttle retires) and discuss how progress in the field of spaceflight has impacted our lives.
3. The students will identify the acronyms NACA and NASA.
4. The students will list different kinds of races before they begin a study of the space race.
5. The students will locate the U.S. and the Union of Soviet Socialist Republics (USSR) on a world map dated before 1989 and recognize that the space race was between these two countries.
6. The students will review their knowledge of human exploration of the solar system.

7. The students will discuss their ideas about future space travel and generate a list of questions to address the problems of human spaceflight.
8. The students will conduct research and begin their own designs of the Orion Crew Exploration Vehicle and the Altair lunar lander that will transport and land humans on the Moon.



Alan Shepard made America's first human spaceflight in his *Freedom 7* Mercury capsule.

## National Standards

### Science

- Abilities necessary to do scientific inquiry – S2Ea, S2Ma
- Understandings about scientific inquiry – S2Eb, S2Mb
- Properties of objects and materials/Properties and changes in matter – S3Ea, S3Ma
- Position and motion of objects/Motion and forces – S3Eb, S3Mb
- Objects in the sky – S5Eb
- Changes in Earth and sky/Earth in the solar system – S5Ec, S5Mc
- Abilities of technological design – S6Ea, S6Ma
- Understanding about science and technology – S6Eb, S6Mb
- Risks and benefits – S7Md
- Science and technology in local challenges/in society – S7Ee, S7Me
- Science as a human endeavour – S8Ea, S8Ma
- History of science – S8Mc

### Mathematics

- Use visualization, spatial reasoning, and geometric modeling to solve problems – M11
- Understand measurable attributes of objects and the units, systems, and processes of measurements – M12
- Formulate questions that can be addressed with data and collect, organize, and display relevant data to answer them – M14
- Develop and evaluate inferences and predictions that are based on data – M16
- Problem solving – M18
- Communication – M20

### Geography

- How to use maps and other geographic representations, tools, and technologies to acquire, process, and report information from a spatial perspective – G1
- How to use mental maps to organize information about people, places, and environments in a spatial context – G2
- The physical and human characteristics of places – G4
- How culture and experience influence people's perceptions of places and regions – G6
- The patterns and networks of economic interdependence

on Earth's surface – G11

- How human actions modify the physical environment – G14
- How physical systems affect human systems – G15
- How to apply geography to interpret the past – G17
- How to apply geography to interpret the present and plan for the future – G18

### Language Arts

- Standards 1, 3, 4, 5, 6, 7, 8, 11, and 12 (See the Language Arts Matrix on page 22.)

### Technology – ISTE

- Students are proficient in the use of technology – I2
- Students develop positive attitudes toward technology uses that support lifelong learning, collaboration, personal pursuits, and productivity – I5
- Students use productivity tools to collaborate in constructing technology-enhanced models, prepare publications, and produce other creative works – I7
- Students use telecommunications to collaborate, publish, and interact with peers, experts, and other audiences – I8
- Students use technology to locate, evaluate, and collect information from a variety of sources – I10
- Students employ technology in the development of strategies for solving problems in the real world – I14

### Technology – ITEA

- Relationships among technology and other fields – T3
- Cultural, social, economical, and political effects – T4
- Effects of technology on the environment – T5
- Role of society in the development and use of technology – T6
- Influence of technology on history – T7
- Attributes of design – T8
- Engineering design – T9
- Role of troubleshooting, research and development, inventions and innovation, and experimentation in problem solving – T10
- Apply the design process – T11
- Use and maintain technological products and systems – T12
- Assess impact of products and systems – T13
- Transportation technologies – T18

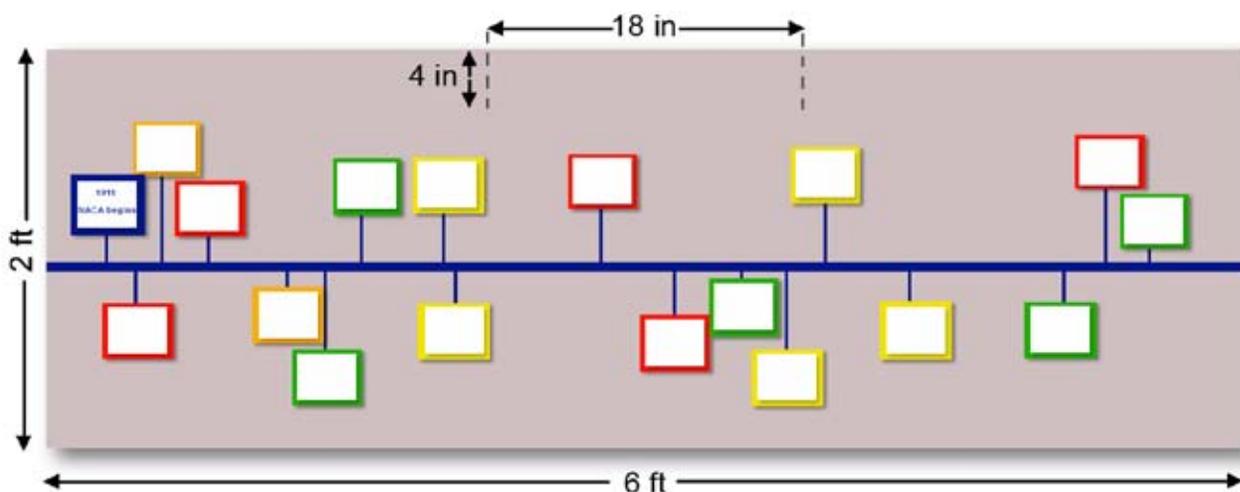
## Materials

- Books on the U.S. space program (See the Pre-lesson Instructions for a description of books.)
- Pictures of the 1903 *Wright Flyer I*, a *Boeing 787* (or the European *Airbus 380*), the *Freedom 7* capsule, the Space Shuttle orbiter (or Orion after the Space Shuttle retires), and the ISS (all provided)
- Timeline (as described in the Pre-lesson Instructions)
- Timeline Date Sheet (provided)
- Student logs
- World map showing the former USSR
- Current world map showing Russia
- Diagram of the solar system (small diagram provided)
- Picture of several galaxies (provided)
- Homework assignment – “Design the Orion Crew Exploration Vehicle and the Altair Lunar Lander”

**Note:** The following materials should be displayed throughout the study of this unit: the pictures of the *Wright Flyer I*, the space shuttle orbiter (or Orion if the Space Shuttle has been retired), the ISS, the timeline, both world maps, the diagram of the solar system, and the picture of the galaxies.

## Pre-lesson Instructions

1. Gather 40–50 picture books on NASA, the solar system, the exploration of space, the U.S. space program (including Projects Mercury, Gemini, and Apollo, the Space Shuttle, the International Space Station, and the current U.S. Space Exploration Policy), the lives of famous astronauts, and current and future spacecraft. These books, also recommended in the Pre-unit Instructions, will provide many of the pictures needed for this lesson.
2. Print or prepare to display pictures of the following: (All are provided at the end of the lesson.)
  - the 1903 *Wright Flyer I*
  - the *Boeing 787*
  - the European *Airbus 380*
  - the *Freedom 7* capsule
  - the Space Shuttle orbiter or Orion if the Space Shuttle has retired
  - the ISS
3. Duplicate an extra copy of the Timeline Date Sheet located at the end of this lesson to be used as a reference throughout the unit.
4. Prepare a timeline. This timeline will act more as a chronology where events are placed on a line in sequential order rather than a strict timeline of equal increments of time.



## Lesson 3

### Pre-lesson Instructions, Procedure

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- 1) The timeline will be filled in as the students read the student texts. In the lesson following each student text, students will be asked to enter on the timeline the important events they learned from the reading selection. Teachers should use the information on the Timeline Date Sheet to help with these dates.
  - 2) Post the entries on the timeline alternating between the top and the bottom of the line. Choose a way of inserting each entry in the timeline. One suggestion would be to cut out 2½- by 3-inch pieces of white drawing paper for writing the date and event. You may want to choose one color pen to write the U.S. events and another color to write the USSR/Russian events. You could also mount the pieces of white paper to 3- by 3½-inch pieces of multi-colored construction paper as a mat.
  - 3) It is recommended that you attach the entries to the butcher paper with small Velcro® squares or another non-permanent way (magnetic boards) so that they can be moved in case other entries are inserted. Do not write the entry directly onto the butcher paper since another entry may need to occupy that space.
  - 4) At the far left of the timeline, insert “1915: NACA begins.” On a sticky note (or another temporary way), write “1958: NASA begins.” Decide the approximate position of 1958 to place the sticky note. Later, a permanent entry for NASA will be added in the correct position. You may want to cut out the insignias (provided at the end of the lesson) of these agencies for these dates.
  - 5) The rest of the timeline should remain blank at this time. As dates are added, have students draw illustrations of some of the events on white paper and adhere these around the edges of the timeline as a type of border. Have the students add a caption and the date of the event to their illustrations.
5. Print or prepare to display a picture of several hundred galaxies to show a small part of the universe (provided at the end of the lesson) or search <http://hubblesite.org/> □ GALLERY □ PICTURE ALBUM □ GALAXIES or THE UNIVERSE. Some images show several hundred galaxies together.
  6. A diagram of the solar system can be found at most teacher stores as a poster or chart. Try to find one that shows correctly scaled pictures of the planets and their relative distances from the Sun. A diagram of the planets in a straight line is acceptable, but one with the Sun in the center and the planets at various places in their orbits is more realistic. (See the example provided at the end of the lesson.) If possible, try to find one that shows Earth’s Moon and some other planetary moons.
  7. Duplicate enough copies of the homework assignment “Design the Orion Crew Exploration Vehicle and the Altair Lunar Lander” for each student. Punch holes so that students can insert these in their logs.
  8. Teachers should research the Internet to see the Orion’s and Altair’s designs. The students are allowed to use similar shapes for their designs, but copies or near-copies of the interiors should not be accepted. Some Internet sites show a cutaway diagram that should not be duplicated.

## Procedure

1. Show the class a picture of the 1903 *Wright Flyer I*. Then, show a picture of the *Boeing 787* (or the European *Airbus 380*). After the students identify these, tell them that the *Wright Flyer I* was the first powered, heavier-than-air, aircraft to fly, and that the *Boeing 787* is one of the most recent U.S. passenger planes to be built.
2. Tape each of these pictures to the chalkboard side-by-side



so that they are at the top of two columns. Ask the students to compare the aircraft. Under each picture, list the comparisons made by the students. Some examples might include the following:

- the size
- wingspan
- materials they are made from
- engine types (propeller and jet)
- passenger capacity
- speed
- the controls
- the range without refueling

The *Boeing 787* is scheduled to begin service in 2009. It will have three different configurations that will carry from 210–330 passengers on routes up to 8,500 nautical miles and features fuel efficiency and increased comfort and convenience for passengers. The European *Airbus 380* is a double-decker passenger plane capable of carrying up to 800 passengers and can be reconfigured for use as a cargo plane.

3. Ask the students to discuss how the progress of aeronautics has impacted our lives. Have the students think in terms of personal travel, speedy delivery of cargo including the mail, and the use of aircraft by the media, medical community, law enforcement agencies, military, and business community. How do these groups use aircraft now? How did they accomplish their jobs before aircraft was used?

4. Next, show the class pictures of the *Freedom 7* capsule and the Space Shuttle orbiter (or Orion after the Space Shuttle retires) and ask the students to identify these. Tell them that *Freedom 7* was the first U.S. vehicle to carry a passenger (Alan Shepard) to and from space and the space shuttle orbiter (or Orion) is the most recent U.S. crewed spacecraft to travel to and from space.



5. Once again, tape each of these pictures to the chalkboard side-by-side so that they are at the top of two columns. Ask the students to compare the spacecraft. Under each picture, list the comparisons made by the students. Some examples might include the following:

- the size
- materials they are made from
- passenger capacity
- speed
- controls
- *Freedom 7* made a suborbital journey but the Space Shuttle orbiter (or Orion) can orbit the Earth at different altitudes.
- *Freedom 7* was not reusable, but the orbiter (or Orion) is reusable.
- *Freedom 7* landed by parachutes in the ocean, but the orbiter lands like an airplane on a runway (Orion will parachute to the ground or the ocean).
- The *Freedom 7* flight took only a few minutes but the orbiter can stay in space for several weeks (or Orion can stay in space for months).

6. Discuss how the progress of space travel has impacted our lives. Show the picture of the ISS and ask the students how this spacecraft affects them. **(Experiments**



**performed on the ISS provide new technology that improves our lives.)** Have the students recall what they learned about spacecraft in Lessons 1 and 2 **(satellites that provide communication, video from all over the world, weather forecasts, reports of global change, and GPS; knowledge of our solar system and the universe; benefits from the results of experiments performed aboard the Space Shuttle and the ISS, etc.)**. Tell the class that thousands of technology transfers have come out of the space program to benefit our everyday lives. Also tell them that they will be researching some of these technology transfers later in the unit.

7. Tell the students that, as they study this unit, they will learn how the U.S. progressed from flying the little *Wright Flyer I* to flying the powerful Space Shuttle (or Orion) which was used to build the ISS, largely because of a national agency known as NASA.

## Lesson 3

### Procedure

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8. Direct the students' attention to the untitled timeline showing only the origination of the NACA in 1915 and the beginning of NASA in 1958. Write "NACA – The National Advisory Committee for Aeronautics" and "NASA – National Aeronautics and Space Administration" on the board. Explain that aeronautics is a science dealing with the operation of aircraft and that the NACA research helped the U.S. develop and improve airplanes in the years between 1915 and 1958.
9. Ask the students why they think the NACA had to change into NASA. Let them share their ideas before telling them that they will be reading about this change in the next lesson. Next, tell them that they will fill in the timeline as they learn about the achievements of NASA. **Do not** tell them that it is also about a space race.
10. Instruct the students to take out their logs. Allow them a few minutes to list different kinds of races and some of the famous races in which people compete. Kinds of races might include car, horse, running, boat, or dog. Include achievement races such as selling the most, reading the most, or making the highest score. Famous races may include the Indianapolis 500, NASCAR, the Olympics, the Kentucky Derby, the America's Cup, the Tour de France, or the Iditarod. As they share their ideas, make a list on the board.
11. After making the list, tell the students that they will be learning about a space race. Ask if they know what a space race refers to. Then, explain that this was a race between the United States (U.S.) and the Union of Soviet Socialist Republics (USSR).
12. Write the terms "Union of Soviet Socialist Republics (USSR), Soviet Union, Soviets, and Soviet" on the board for clarification. Tell them that the USSR was also referred to as the Soviet Union and that the term "Soviets" or "Soviet" will refer to the government of the USSR or persons living in the USSR. This is similar to the use of the word "Americans" by foreigners. Sometimes foreigners use the word "American" to refer to the American (U.S.) government and sometimes the word refers to Americans, the citizens of the U.S.
13. Now fill in the title "The Space Race" on the timeline. Explain that, as they learn about the space race, they will plot the achievements of the U.S. in space, as well as some of the achievements of the USSR in space.
14. Using a world map dated before 1989 that shows the former USSR, ask a student to find this country on the map. Compare its size to the U.S. Explain that it was a powerful nation that had conquered and united many countries, but that it no longer exists today.
15. Show a current world map and focus on the area once occupied by the USSR. Point out that Russia is the country that now occupies much of the same area, and that Russia's capital city, Moscow, was also the capital of the USSR.
16. Next, show the diagram of the solar system as described in the Pre-lesson Instructions. Ask the nonsense question, "Which country was the first to land a spacecraft on Pluto?" As the students (hopefully) answer that no country has landed a spacecraft on Pluto, they will reveal what knowledge they have of the human exploration of space. Allow time for the students to share their knowledge about the spacecraft that have explored the solar system. (If the class made the Solar System Pop-up Book, this should be a very quick review of the space probes that have explored the solar system.)
17. Refer to the diagram of the solar system and ask the students to identify the bodies that have had a vehicle from Earth land on them. Then, emphasize that the U.S. has landed a crewed spacecraft on the Moon, but only uncrewed spacecraft called space probes have landed on other bodies including Mars and the asteroid Eros. With some help from NASA, the European Space Agency (ESA) built the Huygens probe which landed on Saturn's moon, Titan. The Soviets landed a probe on Venus.



18. Tell the students that these probes help scientists get information about our solar system. When a probe lands (lander), orbits (orbiter), or passes by a body (flyby), it sends back pictures and other data to help scientists learn about that body. Space probes have sent back data from the Sun, all of the planets, some asteroids, and some comets. In January 2006, NASA launched the *New Horizons* space probe on a 3-billion mile trip to Pluto, a dwarf planet. It is expected to reach Pluto on July 14, 2015.

19. Finally, show a picture of several galaxies in space. Ask the students if they know how scientists are finding



information about these distant bodies. Tell them that NASA has several ground telescopes and four space telescopes. At the time of this writing, these space telescopes include Hubble, Chandra, Spitzer, and Fermi. The space telescopes orbit the Earth and send back images of space that are thousands and millions of light years away. NASA is planning to launch the James Webb Space Telescope in 2013.

20. Start a brief discussion of future space travel by asking the following questions: “What do you think the future of space travel will be?” “If you were to explore the solar system, what kind of spacecraft would you like to have?” Ask the students to generate a list of questions to address the problems of crewed spaceflight. Write these questions down and provide the students with a copy to help them plan their designs of the Orion crew exploration vehicle.

21. Distribute the homework assignment “Design the Orion Crew Exploration Vehicle and the Altair Lunar Lander” and have the students insert this in their logs. Discuss the requirements and fill in a due date several school days from the present. Try to allow for a weekend to be included before the due date. Students should be ready to present their designs as a part of Lesson 7. If the students need more time to finish their designs, continue with the other lessons and come back to Lesson 7. Presentations will cover 1–1½ hours.

22. Try to arrange for an outside person to come in and review or even judge the Orion/Altair design presentations. In one classroom, the students were informed that this was a competition and that prizes would be given. A NASA engineer was invited to critique and judge the top entries that exhibited excellent work and reflected the best ideas. Astronaut patches were awarded to those students whose designs were chosen. Almost all of the designs were elevated to excellent standards because of the expectation of an outside commentator or judge. Teachers may not want this to be a competition, but, in real life, only the best design of a competition is chosen by a company.



## Design the Orion Crew Exploration Vehicle and the Altair Lunar Lander

NASA's Exploration Systems Mission Directorate has issued a Request for Proposal (a means by which companies submit their plans or ideas) for the Orion Crew Exploration Vehicle and the Altair lunar lander. Orion is the spacecraft that will carry astronauts to the International Space Station in 2015 and from the Earth to the Moon's orbit in 2020. Later, it will be equipped to support a human mission to Mars. On a Moon mission, Altair will separate from Orion and land the astronauts on the lunar (Moon's) surface. The astronauts will live in Altair while exploring the Moon.

The aerospace company you work for has asked its aerospace engineers (you) to submit a design for Orion and Altair. You also need to present a plan for using the vehicles for a human lunar landing. The following descriptions of each of the vehicles will help you with your design.

### Orion will

- provide a habitat (living area) for four crew members capable of supporting human life on a 16-day mission to the Moon that can later be modified for a trip to Mars;
- have its own propulsion system that will enable it to lunar orbit and return to Earth's surface;
- be equipped with control and communication systems





- be able to dock with Altair and the International Space Station (ISS); and
- provide an abort capability (that is, the ability to stop the mission and get the astronauts to safety) during all phases of flight.



### Altair will

- provide a habitat for the crew;
- have the ability to detach from Orion, leave lunar orbit, land on the lunar surface, and return to lunar orbit to dock with Orion;
- allow the crew to conduct science experiments; and
- allow the crew to exit the module to perform moonwalks.

### To prepare for the presentation, you must do the following:

1. Conduct research on Orion and Altair and their components. Use the Internet for the most up-to-date information on these subjects. You may use similar shapes for your design, but you must create your own original interior design. A NASA activity for designing an exploration vehicle can be found at [http://www.nasa.gov/pdf/146851main\\_Designing\\_a\\_CEV\\_Student.pdf](http://www.nasa.gov/pdf/146851main_Designing_a_CEV_Student.pdf).
2. Design a poster. On one side, draw individual diagrams of Orion and Altair and label the important parts. Show the dimensions of each. Each vehicle must have the capability to dock with other vehicles; so be sure to include a docking feature on each vehicle.
3. On the other side, draw cutaways of Orion and Altair and label the interior areas.



Lesson 3

Homework Assignment: Design the Orion Crew Exploration Vehicle and the Altair Lunar Lander



4. Prepare a written presentation that will be delivered orally to your company’s board of directors (your classmates) describing your designs for Orion and Altair. Computers and Microsoft PowerPoint presentations may be used, but printed copies must be made, as well. The written presentation should include the following information:

- Provide a description of each vehicle, including dimensions, approximate sizes, and capacities.
- Outline the capabilities of each vehicle.
- Identify the labeled parts of each vehicle and the function of each part.
- Describe the plan for using the vehicles for a human lunar landing.

5. **Optional:** Design a Cargo Delivery System. This uncrewed system will be used to deliver materials and supplies to the Moon to enable longer human stays on the Moon.
6. Students are encouraged to use as many technology tools as possible in their presentations, but this is not a requirement.



DUE DATE: \_\_\_\_\_



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**Parents, please sign this slip and return it to school. Thank you.**

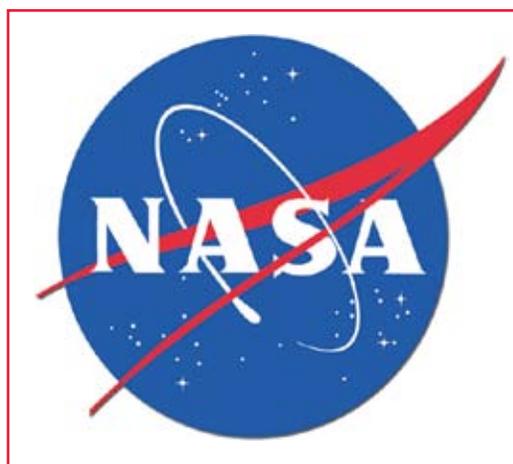
**I have read my child’s “Design the Orion Crew Exploration Vehicle and the Altair Lunar Lander” assignment.**

**Signature:** \_\_\_\_\_

Teachers, print and cut out the insignias and insert them in the correct position on the timeline.



**1915 – NACA begins**



**1958 – NASA begins**



*Wright Flyer I*



*Photo credit: Boeing*

**Boeing 787**



*Photo credit: Airbus*

**Airbus 380**



*Freedom 7 capsule*



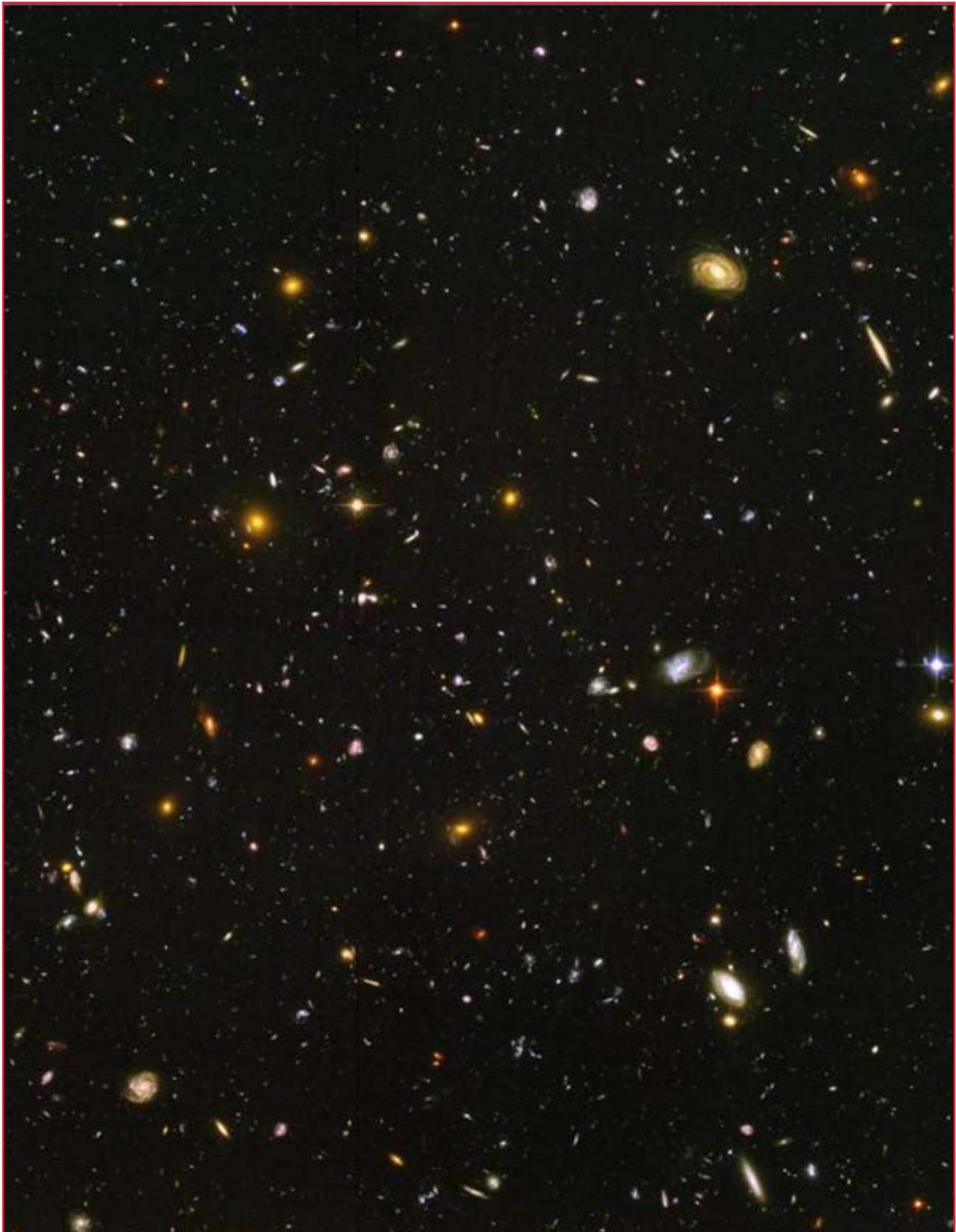
Space Shuttle Orbiter



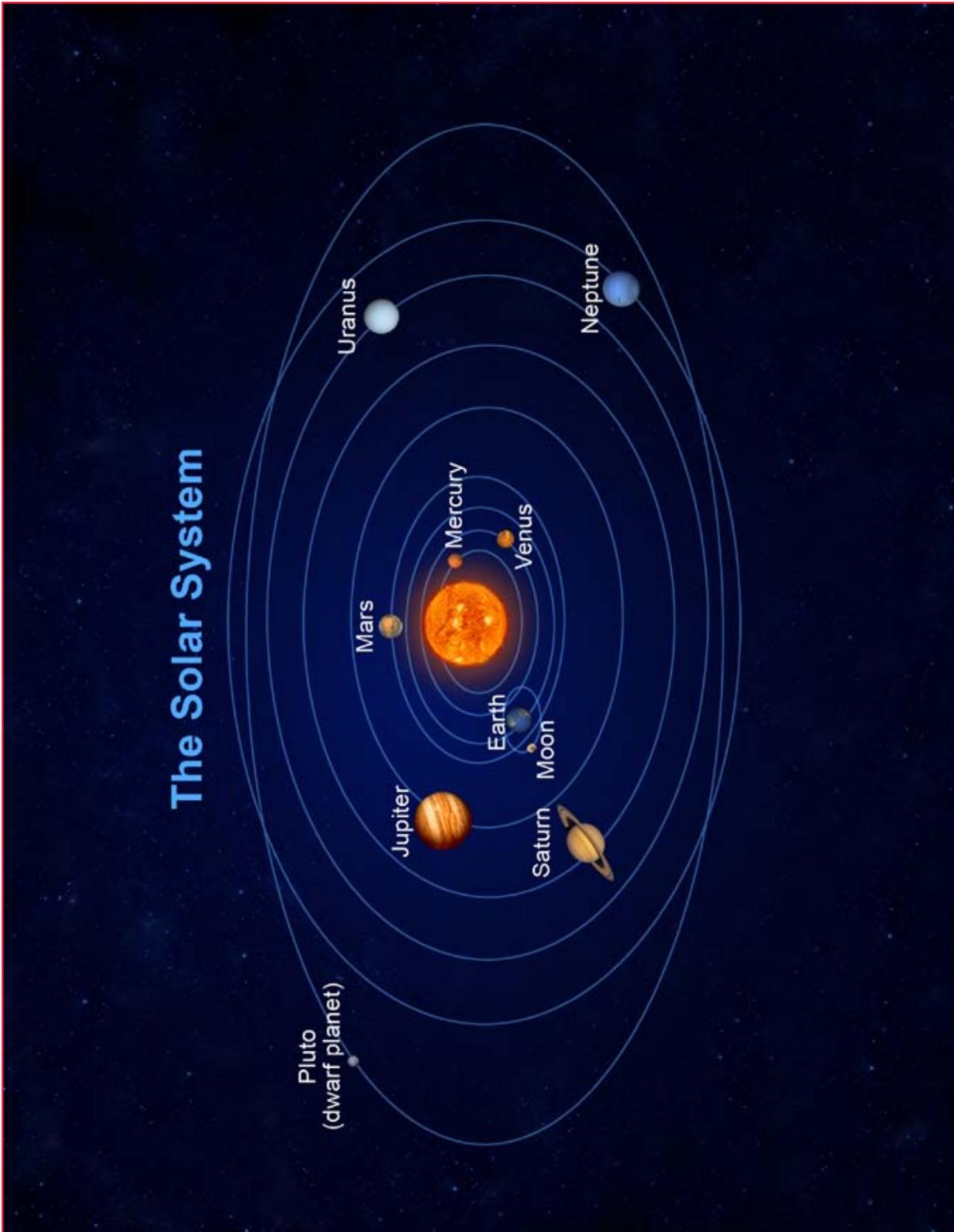
Orion Crew Exploration Vehicle



International Space Station



*Several hundred galaxies as seen by the Hubble Space Telescope*



## Timeline Date Sheet

- March 3, 1915** – The 12-member National Advisory Committee for Aeronautics (NACA is created by U.S. President Woodrow Wilson.
- July 17, 1917** – NACA breaks ground for the Langley Memorial Aeronautical Laboratory, the first U.S. civilian aeronautical research facility, near Hampton, Virginia.
- 1920s–1958** – NACA wind tunnel testing provided data to airplane manufacturers, which led to the designs of safer and faster planes.
- 1920s** – NACA cowling reduced the drag on a plane, which increased its airspeed and lowered the cost of flying.
- March 16, 1926** – Robert Goddard launches the world’s first liquid-fueled rocket.
- 1930s** – NACA’s airfoil tests gave manufacturers the ability to find the best shaped airfoil (wing) for a particular plane.
- 1930s** – NACA’s research led to the prevention of icing on wings and propellers.
- 1930s** – Drag tests on fixed landing gear led to the design of retractable landing gear.
- Sept. 1, 1939** – Germany invades Poland to begin World War II (WWII).
- 1940s** – NACA engineers worked closely with the *Bell X-1* design team to produce the plane that first broke the sound barrier
- 1940s** – NACA conducted research with rocket-powered models of new planes under development.
- May 8, 1945** – Victory in Europe (V-E) Day is celebrated signaling Germany’s defeat and the end of WWII in Europe.
- Aug. 6, 1945** – The world’s first atomic bomb is dropped on Hiroshima, Japan.
- Aug. 9, 1945** – The world’s second and last atomic bomb is dropped on Nagasaki, Japan.
- Aug. 15, 1945** – Victory in Japan (V-J) Day is celebrated signaling Japan’s defeat and the final end of WWII.
- 1950s** – A NACA transonic tunnel provided data for supersonic flight.
- 1950s** – NACA flew and tested many X-planes, the planes designed for flight experiments
- 1950s** – NACA produced some of the research that would lead to the human space program.
- July 1, 1957–Dec. 31, 1958** – The International Geophysical Year (IGY) is observed.
- Oct. 4, 1957** – *Sputnik I* is successfully launched.
- Nov. 3, 1957** – *Sputnik II* is successfully launched.
- Dec. 6, 1957** – *Vanguard TV3* explodes during launch.
- Jan. 31, 1958** – *Explorer I* is successfully launched.
- March 17, 1958** – *Vanguard I* is successfully launched.
- July 29, 1958** – U.S. President Dwight Eisenhower signed into law the National Aeronautics and Space Act of 1958.
- Oct. 1, 1958** – The National Aeronautics and Space Administration (NASA) is established.
- April 12, 1961** – Soviet cosmonaut, Yuri Gagarin, becomes the first human in space when he completes one full orbit of Earth.
- May 5, 1961** – Alan Shepard becomes the first American in space when he completes a suborbital flight in his *Freedom 7* Mercury capsule.
- May 25, 1961** – U.S. President John Kennedy announces the NASA mission to land a human on the Moon.
- Aug. 7, 1961** – Soviet Gherman Titov completes a 17-orbit flight.
- Feb. 20, 1962** – John Glenn completes three orbits in his *Friendship 7* Mercury capsule.
- May 15–16, 1963** – In the last Mercury flight, Gordon Cooper completes 22 orbits in 34 hours in his *Faith 7* capsule.
- March 18, 1965** – Soviet cosmonaut Aleksei Leonov becomes the first human to walk in space.
- June 3, 1965** – Edward White becomes the first American to walk in space.
- March 16, 1966** – The U.S. performs the first orbital docking of two spacecraft.
- April 3, 1966** – The Soviets achieve the first lunar orbit (uncrewed).

## Lesson 3

### Timeline Date Sheet

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- Nov. 16, 1966** – The last Gemini flight returns.
- Jan. 27, 1967** – Astronauts Chaffee, Grissom, and White were killed during a simulation aboard *Apollo 1*.
- Dec. 21–27, 1968** – The crew of *Apollo 8* makes the first crewed lunar orbit.
- July 20, 1969** – Americans Neil Armstrong and Edwin (Buzz) Aldrin become the first humans to walk on the Moon during the *Apollo 11* mission.
- April 11–17, 1970** – The flight of *Apollo 13* becomes a near-disaster mission.
- April 19, 1971** – The Soviets' *Salyut 1* becomes the first space station to be launched into orbit.
- Nov. 13, 1971** – *Mariner 9*, the first space probe to be sent to orbit another planet (Mars), is launched.
- Jan. 5, 1972** – U.S. President Nixon announces the decision to proceed with the development of a new space transportation system (the space shuttle).
- March 3, 1972** – *Pioneer 10* is launched to explore Jupiter.
- Dec. 7–19, 1972** – *Apollo 17* is the last of the six Apollo missions to the Moon.
- May 25–June 22, 1973** – The first U.S. astronaut crew lives in Skylab, the U.S. orbital workshop.
- July 15–24, 1975** – The Apollo-Soyuz Test Project is accomplished.
- July 20, 1976** – The *Viking 1* planetary lander lands on Mars after a voyage of almost a year.
- Aug. 18, 1976** – The uncrewed Soviet *Luna-24* lands on the Moon to collect soil samples which will be returned to Earth.
- Aug. 20, and Sept. 5, 1977** – *Voyager II* and then *Voyager I* are launched to explore Jupiter, Saturn, Uranus, and Neptune, as well as some of their moons.
- April 12, 1981** – Astronauts Crippen and Young pilot Space Shuttle *Columbia* on the first flight of the space transportation system (STS), STS-1.
- April 19, 1982** – *Salyut 7* becomes the last Soviet Salyut space station to be launched.
- June 18, 1983** – Sally K. Ride becomes the first U.S. woman astronaut during the STS-7 mission aboard Space Shuttle *Challenger*.
- Aug. 30, 1983** – Guion Bluford becomes the first U.S. African-American astronaut during the STS-8 mission aboard Space Shuttle *Challenger*.
- Jan. 28, 1986** – Space Shuttle *Challenger* explodes 73 seconds after the STS-51-L liftoff, killing all seven crew members including Christa McAuliffe who was to be the first teacher in space.
- Feb. 20, 1986** – The first element of Soviet Space Station *Mir* is launched.
- Sept. 29–Oct. 3, 1988** – The Space Shuttle returns to flight as *Discovery* completes the first mission since the *Challenger* disaster.
- April 24, 1990** – The Hubble Space Telescope is launched.
- Dec. 8, 1991** – The USSR is dissolved.
- Dec. 2, 1993** – Space Shuttle *Endeavour* is launched on a successful mission to repair the Hubble Space Telescope.
- Feb. 3–11, 1994** – Space Shuttle *Discovery* performs a historic mission with the first Russian cosmonaut to fly on a U.S. mission in space.
- June 27–July 7, 1995** – The U.S. Space Shuttle *Atlantis* docks with the Russian Space Station *Mir* for the first time.
- July 4, 1997** – *Mars Pathfinder* lands on Mars and a robotic rover named *Sojourner* departs the lander to explore the planet and send back data.
- Sept. 11, 1997** – The *Mars Global Surveyor* probe launched on Nov. 7, 1996, enters the Mars orbit.
- Oct. 15, 1997** – The *Cassini-Huygens* space probe bound for Saturn is launched.
- Jan. 29, 1998** – The ISS agreement among 15 countries is signed.
- Nov. 20, 1998** – The assembly of the ISS begins when Russia's Proton rocket puts the Russian *Zarya* control module in orbit.
- Dec. 4–12, 1998** – STS-88 Space Shuttle *Endeavour's* crew mates the U.S. *Unity* module with *Zarya*, connects the cables, and opens the hatches between the two modules of the ISS.
- May 27–June 6, 1999** – In STS-96, Space Shuttle *Discovery* becomes the first spacecraft to dock with the ISS on its mission to deliver supplies to the station.
- July 22–27, 1999** – Eileen Collins becomes the first woman shuttle commander on the STS-93 Space Shuttle *Columbia* mission to carry the Chandra X-ray Observatory to orbit.

- Oct. 31, 2000** – Expedition One, the first crew to inhabit the ISS, is launched.
- March 23, 2001** – Space Station *Mir* falls to Earth with fragments landing in the South Pacific Ocean.
- April 7, 2001** – The orbiter 2001 *Mars Odyssey* is launched.
- Oct. 23, 2001** – The *Mars Odyssey* enters the Mars orbit and begins to map the Mars surface in February 2002.
- Feb. 1, 2003** – Space Shuttle *Columbia* STS–107 breaks up as it enters the Earth’s atmosphere. All seven crew members are lost. Some of the 80 micro-gravity experiments on board were from K–12 school children.
- August 25, 2003** – The Spitzer Space Telescope, an infrared space observatory, was launched.
- Jan. 4, 2004** – The Mars rover *Spirit* lands on Mars.
- Jan. 14, 2004** – President George W. Bush announces the Vision for Space Exploration (now referred to as the U.S. Space Exploration Policy) to the nation and NASA begins to plan to go back to the Moon, then on to Mars, and beyond.
- Jan. 15, 2004** – *Spirit* rolls out onto the Mars soil to explore the surface and send back data.
- Jan. 25, 2004** – The Mars rover *Opportunity* lands on the opposite side of Mars from its twin, *Spirit*.
- Jan. 31, 2004** – *Opportunity* rolls onto Martian ground to explore the planet’s surface and send back data.
- June 30, 2004** – The *Cassini-Huygens* space probe enters Saturn’s orbit.
- Aug. 3, 2004** – The *Messenger* space probe was sent to Mercury to collect data on the planet’s surface and atmosphere. The probe will fly by Mercury three times before it slows down enough to enter Mercury’s orbit in March 2011.
- Jan. 14, 2005** – The *Huygens* probe successfully descends through the atmosphere of Titan, Saturn’s largest moon, to safely land on its surface.
- July 4, 2005** – The *Deep Impact* space probe slammed its impactor into the comet Tempel 1. In February 2006, NASA announced that *Deep Impact* had sent back definitive evidence of surface ice on the comet.
- Jan. 19, 2006** – The New *Horizons* space probe was launched to begin its mission to Pluto. The New Horizons spacecraft will cross the entire span of the solar system and conduct flyby studies of Pluto and Charon in 2015.
- March 10, 2006** – The *Mars Reconnaissance Orbiter* enters into low orbit around Mars.
- Sept. 27, 2007** – The *Dawn* spacecraft was launched on a journey to study a pair of asteroids. *Dawn* will begin its exploration of Vesta in 2011 and Ceres in 2015.
- May 25, 2008** – The *Phoenix* spacecraft successfully landed on the Mars surface.
- June 2–13, 2008** – NASA’s Constellation Program conducted tests on its new prototype vehicles in Moses Lake, Washington to prepare for future lunar expeditions.
- June 11, 2008** – The Fermi Gamma-ray Space Telescope was launched to perform gamma-ray astronomy observations from low Earth orbit.
- July 31, 2008** – NASA announced that *Phoenix* confirmed the presence of water ice on Mars





## Lesson 4 – The Race Begins

**Lesson prep time:** 10 minutes [(for gathering materials and following pre-lesson instructions) (Wind tunnel prep time is separate.)]

**Teaching time:** 1½ hours (Language Arts, Science, Technology)

### Objectives

1. The students will recognize the work of the National Aeronautics and Space Administration (NASA) and some of the contributions made by the Agency.
2. The students will list the ways the National Advisory Committee for Aeronautics (NACA) contributed to the progress of aeronautics from 1915 to 1958.
3. The students will read and discuss a selection about how the space race began and then list the steps that led to the beginning of the space race.
4. The students will identify how the space race would change the world forever.
5. The students will construct a wind tunnel and test a paper airplane of their own design in the wind tunnel to gain an understanding of how engineers test airplanes in wind tunnels.
6. The students will continue to conduct research, design Orion and Altair with each of their components, and prepare their presentations of these designs.



Newspaper image credit: The New YorkTimes

## National Standards

### Science

- Abilities necessary to do scientific inquiry – S2Ea, S2Ma
- Understandings about scientific inquiry – S2Eb, S2Mb
- Position and motion of objects/Motion and forces – S3Eb, S3Mb
- Properties of Earth materials/Structure of the Earth system – S5Ea, S5Ma
- Objects in the sky – S5Eb
- Changes in Earth and sky/Earth in the solar system – S5Ec, S5Mc
- Abilities of technological design – S6Ea, S6Ma
- Understanding about science and technology – S6Eb, S6Mb
- Risks and benefits – S7Md
- Science and technology in local challenges/in society – S7Ee, S7Me
- Science as a human endeavor – S8Ea, S8Ma
- History of science – S8Mc

### Mathematics

- Use visualization, spatial reasoning, and geometric modeling to solve problems – M11
- Understand measurable attributes of objects and the units, systems, and processes of measurements – M12
- Formulate questions that can be addressed with data and collect, organize, and display relevant data to answer them – M14
- Develop and evaluate inferences and predictions that are based on data – M16
- Understand and apply basic concepts of probability – M17
- Problem solving – M18
- Communication – M20

### Geography

- How to use maps and other geographic representations, tools, and technologies to acquire, process, and report information from a spatial perspective – G1
- The physical and human characteristics of places – G4
- How culture and experience influence people's perceptions of places and regions – G6

- The patterns and networks of economic interdependence on Earth's surface – G11
- How the forces of cooperation and conflict among people influence the division and control of Earth's surface – G13
- How human actions modify the physical environment – G14
- How to apply geography to interpret the past – G17
- How to apply geography to interpret the present and plan for the future – G18

### Language Arts

- Standards 1, 3, 4, 5, 6, 7, 8, 11, and 12 (See the Language Arts Matrix on page 22.)

### Technology – ISTE

- Students are proficient in the use of technology – I2
- Students develop positive attitudes toward technology uses that support lifelong learning, collaboration, personal pursuits, and productivity – I5
- Students use productivity tools to collaborate in constructing technology-enhanced models, prepare publications, and produce other creative works – I7
- Students use telecommunications to collaborate, publish, and interact with peers, experts, and other audiences – I8
- Students use technology to locate, evaluate, and collect information from a variety of sources – I10
- Students employ technology in the development of strategies for solving problems in the real world – I14

### Technology – ITEA

- Relationships among technology and other fields – T3
- Cultural, social, economical, and political effects – T4
- Effects of technology on the environment – T5
- Role of society in the development and use of technology – T6
- Influence of technology on history – T7
- Attributes of design – T8
- Engineering design – T9
- Role of troubleshooting, research and development, inventions and innovation, and experimentation in problem solving – T10
- Use and maintain technological products and systems – T12

- Assess impact of products and systems – T13
- Information and communication technologies – T17
- Transportation technologies – T18

## Materials

- Student logs
- A copy of the student text for Lesson 4 “The Race Begins” for each student
- Picture of astronauts on the Moon (provided)
- Pictures of U.S. planes used from 1915–1958 (Many pictures of these planes are found in the student text. Picture books such as Jane’s Aircraft Recognition Guide may also be used.)
- World map
- Copies of paper airplane patterns for students who may not want to make their own (Check your library for books on making paper planes and the Internet for different designs.)
- Newsprint (9- by 12-inch), notebook paper, and/or other paper suitable for making paper airplanes
- Wind Tunnel Directions (found on page 15)
- Lightweight string – 12 inches per student
- Notebook reinforcement rings – 2 per student

## Pre-lesson Instructions

1. Construct the wind tunnel, and make sure it is ready for use, even though it will not be used until the next lesson. Instructions for building the wind tunnel are found on page 15.
2. Duplicate enough copies of the student text for Lesson 4, “The Race Begins,” for each student. Punch holes so that students can insert this in their logs.
3. Duplicate several copies of simple paper airplane patterns. Search your school library for books on making paper airplanes and look on the Internet for some different designs. Then, print and copy some of the easiest to make.
4. Print or prepare to display a picture of Astronauts Armstrong and Aldrin on the Moon (provided at the end of the lesson).

5. Additional images of Vanguard, Explorer, and Sputnik can be found at <http://www.hq.nasa.gov/office/pao/History/sputnik/gallery.html>. A 30-minute video recounting all events leading up to and following the *Explorer I* launch and including the launch of *Sputnik* and the explosion of *Vanguard TV3* can be found at <http://www.redstone.army.mil/history/explorer/welcome.html>.

## Procedure

1. Review the location of the USSR on the world map. Now, locate it (or the area it covered) on the globe. Remind the students of the different names for this country: Union of Soviet Socialist Republics, USSR, or the Soviet Union.
2. Distribute copies of the student text for Lesson 4, “The Race Begins,” and have the students insert this in their logs. Before reading, direct their attention to the timeline and tell them that today they will learn about the period of time between 1915 and 1958. They will also learn why it was important for NASA to be established.
3. Show a picture of the astronauts on the Moon and ask the students to identify it. Place this picture with the picture of the space shuttle and the ISS. Ask the students what agency is responsible for all three of these missions. (**NASA**)
4. Introduce and teach the vocabulary in the same manner that you would for any guided reading.
5. Read and discuss the student text, “The Race Begins,” as you would any guided reading. As the class discusses the text, question their understanding and encourage their questions.
6. Before reading the section “What Is NASA?,” ask the students what they think of when they hear the word “NASA.” After reading the first paragraph, explain that



the illustration shows the Space and Rocket Center in Huntsville, Alabama, the home of Space Camp. Tell them that the Space and Rocket Center displays a full-size Saturn V rocket like the one that launched the astronauts to the Moon. Space exhibits and demonstrations fill the Center and outside displays include the space shuttle and many other rockets.

7. After reading the section “What Is NASA?,” instruct the students to observe and discuss the illustration “NASA technology touches our lives everyday,” which shows only a fraction of the contributions of NASA. Ask the students if they are familiar with other NASA contributions. Ask them what they think our world would be like if NASA had never existed.
8. As the students read the section “NACA, Not NASA,” point out the pictures of the first wind tunnel and the other wind tunnels built at the Langley Laboratory and then later at the Ames and Lewis Laboratories. Tell them that Lewis was later named Glenn Research Center to honor John Glenn, one of the first astronauts who later became a Senator from Ohio. Explain that Ames and Lewis were the two laboratories added to the NACA in 1940.
9. Read the questions “Have you ever flown on a plane?” and “How would you like to fly on a plane that had never been tested?” Then, allow a few minutes for the students to answer them. Help them to understand the importance of wind tunnel testing and how it contributes to the development of flight and the safety of passengers.
10. Next, read how NACA research helped to design and build all kinds of planes. Then, point out that all of the planes shown on these pages were helped by NACA research. If you have a book of planes, such as Jane’s Aircraft Recognition Guide, show pictures of some of the U.S. planes built during those years. Emphasize that all of the planes built in the U.S. between 1915 and 1958 were helped by NACA research.
11. After reading the paragraph about WWII, find Germany on a world map. Identify some of the other countries in Europe. Tell the students that the war was fought mainly in Europe and the Pacific Islands, including Japan, and that the U.S. did not join in the war until the Japanese bombed Pearl Harbor in December 1941. Find Japan and Pearl Harbor, Hawaii, on the map. Allow students to share any knowledge they may have of this war.
12. Finish reading the section “NACA, not NASA.” Ask the students to recall the ways NACA contributed to the progress of aeronautics from 1915 through 1958. List these on the board. This list should include the following:
  - **NACA shared its research results and information with the airplane manufacturers who used it to design and build safer and faster planes.**
  - **NACA’s research was used for every aircraft built in the U.S. from 1915 to 1958.**
  - **NACA cowling reduced the drag on a plane which increased its airspeed and lowered the cost of flying.**
  - **NACA’s airfoil tests gave manufacturers the ability to find the best shaped airfoil (wing) for a particular plane.**
  - **NACA’s research led to the prevention of icing on wings and propellers.**
  - **Drag tests on fixed landing gear led to retractable landing gear.**
  - **NACA engineers worked closely with the *Bell X-1* design team to produce the plane that first broke the sound barrier.**
  - **NACA conducted research on rocket-powered models of new airplane designs that helped to build planes that would fly faster and higher.**
  - **A NACA transonic tunnel provided data for supersonic flight.**
  - **NACA flew and tested many X-planes, the planes designed for flight experiments.**
  - **NACA produced some of the research that would lead to the human space program.**
13. Before reading the section “Going to Space,” ask the students to recall the meanings of orbit and satellite. Ask them to explain the difference between a natural satellite and a human-made satellite. (**Earth’s Moon**

is a natural satellite, and all of the other satellites now in orbit around the Earth, about 3,000 of them, are human-made.) Ask the students to share what they remember about satellites from Lessons 1 and 2.

14. Tell the students that they will read about the first human-made satellites put into Earth's orbit in the next section. Write "International Geophysical Year (IGY) – 1957–1958" on the board. Explain that it was a special year that really lasted for 18 months during the years 1957 to 1958.

15. Present an explanation of how a human-made object can be placed into an orbit around the Earth. Some students will understand this but many will not. All of the students should understand that, if a vehicle travels at a fast-enough speed away from Earth, it can go into orbit, and, if it travels at a much faster speed, it can break away from Earth's gravity and travel away from Earth. Duplicate the simple drawings on the board as you read and discuss the following steps which explain how spacecraft orbit the Earth and how they travel away from the Earth into space.



Bullet travels  
5 miles per second (mps)

enough forward velocity (like 5 miles per second), the bullet will still try to fall toward the Earth, but, because of its speed forward, the amount it drops toward the Earth's surface is equal to the same amount that the Earth's curvature bends away from it. The bullet is then following a path all the way around the Earth in a circular orbit.



Bullet travels  
above 5 but less than 7 mps

3) It is a little more complicated as we go to the next step. Fire the bullet faster than 5 miles per second but less than 7 miles per second, and the bullet climbs away from the Earth's curvature. But gravity still wins and brings the bullet around on a curved path (orbit) with the highest point being whatever the bullet climbed out to and the lowest point being the altitude it was shot from. This is an elliptical orbit.



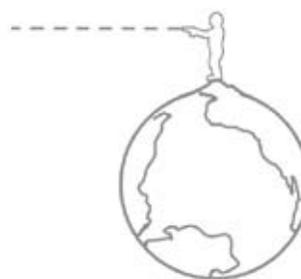
Bullet travels fast

1) Imagine standing on the tallest mountain on Earth, high above any obstacles in the distance, and above any air that may cause drag. Now imagine that you fire a gun that is pointed horizontally to the surface where you are standing. The bullet travels outward from the gun, but also downward toward the Earth's surface until it hits the ground.



Bullet travels faster

2) Now try a more powerful gun firing a more powerful bullet traveling at a higher velocity (speed of motion). It will travel farther outward on a curve before it hits the surface. When you fire the bullet with



Bullet travels  
faster than 7 mps

4) Now shoot the bullet (always straight out and parallel to the surface) faster than 7 miles per second. That velocity is high enough that Earth's gravity can no longer bring it back into its influence, and the Sun or other objects (the Moon) can win the tug of war and pull the bullet toward them. This is escape velocity.

5) With rockets, we first have to get above the dragging effects of the atmosphere. We can do that most quickly by accelerating straight up.



Rocket travels at 5 mps to enter Earth orbit

Then the vehicle is pitched over (arced) gradually as the atmosphere thins out, so that it gains forward velocity and eventually travels parallel to the Earth's surface. When it is high enough (above the major atmospheric effects) and fast enough (5 miles per second), it is in orbit and the engine can be shut off.

6) To do this around other celestial bodies, the velocity needed to achieve orbit is different because of their gravity. To orbit the Moon, we only need to fire the bullet at 1 mile per second to go into orbit because it has a lighter gravity pull.

16. Read only the first paragraph of the section "Going to Space." On the board, write "Navy – Vanguard" and "Army – Jupiter-C." Explain that Explorer and Vanguard were the names of the satellites that were carried into space, but the rockets often had different names. The Vanguard rocket (a modified Viking rocket) was used to launch *Vanguard TV3* and *Vanguard I*. A modified Jupiter-C rocket was used to launch the *Explorer I* satellite. Explain that people often used the satellite name to refer to the whole assembly.

17. Continue reading this section and also study the photos. As you look at the picture of *Explorer I*, tell the students that *Explorer I* carried the world's first experiment into orbit. It found the presence of a radiation belt around the Earth. The belt was named the Van Allen Belt in honor of James Van Allen who first predicted the existence of the belt and was responsible for the experiment on *Explorer I*. If time allows, show the *Explorer I* video mentioned in the pre-lesson instructions at this time.

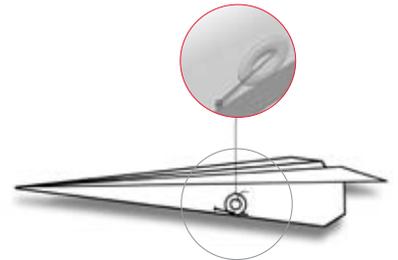
18. Continue reading to the end of the selection. Then, ask the students to recall the steps that led to the beginning of the space race. Ask how these events would change the world forever.

19. Have the students construct paper airplanes. (Be prepared for them to want to test them as well!) Provide a selection of paper airplane patterns. Put out newsprint, notebook paper, and other suitable paper to be used for constructing their paper airplanes. There are also books with directions for making paper airplanes where the students can find many models from which to choose.

20. Provide no advice for their paper airplanes, but remind them that they should be built for maximum lift. They should question and test their own designs for success.

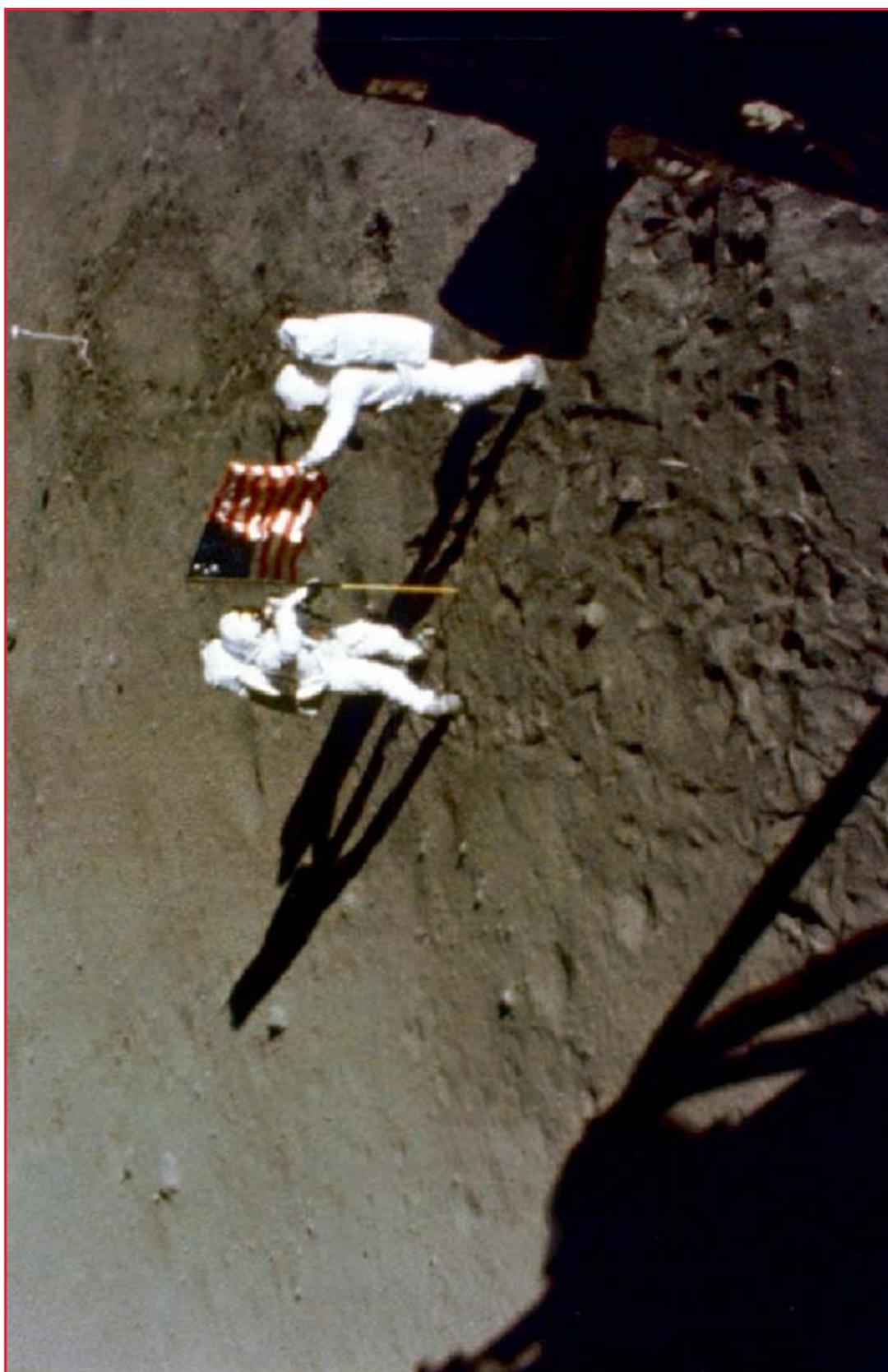
21. As students finish their planes, help them attach the string for suspending it in the wind tunnel. Use the following steps from "Building a Wind Tunnel" to prepare the plane for testing.

- 1) Tie a small loop in one end of a 12- to 15-inch piece of string. This will be used to slip over the cup hook.
- 2) Glue two notebook reinforcement rings together. Thread the other end of the string through the ring and tie a knot to secure it.
- 3) Teachers should anchor the ring with a straight pin below the wing at the center of gravity. DO NOT let the students perform this step.



22. Tell the students that testing in the wind tunnel will begin tomorrow. Have them put their names on their planes and provide a safe place for storage.

23. Homework assignment – Ask the students if they have any questions about their Orion/Altair assignment. Check to see that all parent-signed slips have been returned.



Astronauts Neil Armstrong and Buzz Aldrin on the lunar surface on July 20, 1969

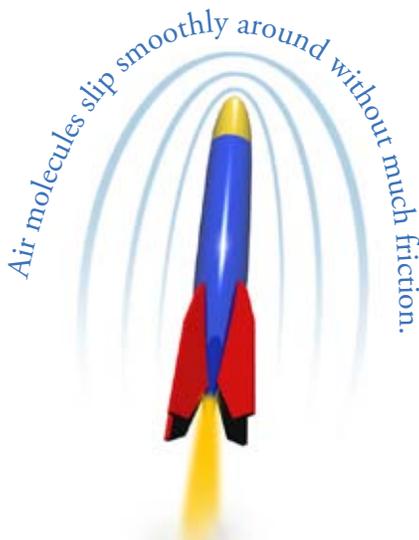


## Vocabulary



Housed in the NASA Headquarters building, the administration oversees NASA's programs and projects.

**administration** – a group of people who carry out the management of any office, business, or organization, giving direction for the work that needs to be done; the performance of executive duties



The aerodynamic shape of the rocket reduces drag.

**aerodynamic** – designed to reduce or minimize the drag caused by air as an object moves through the air, or by wind that strikes and flows around an object; designed in such a way so as to reduce wind drag on a vehicle

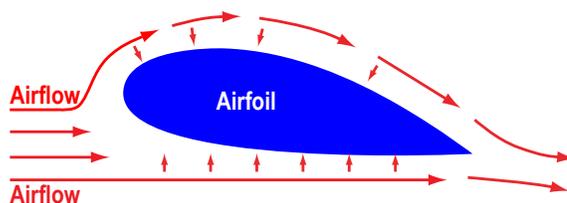
**aeronautics** – a science dealing with the operation of aircraft; the design and construction of aircraft



Aeronautics



**airfoil** – a section of a wing, rudder, or rotor blade used for testing the reaction from air through which it moves



Sketch of an airfoil



Astronaut Buzz Aldrin walked on the Moon on July 20, 1969.

**astronaut** – a person trained to pilot, navigate, or otherwise participate as a crew member of a spacecraft; a person who travels beyond the Earth's atmosphere. These people are called cosmonauts in Russia and taikonauts in China.

**aviation** – the design, development, production, operation, and use of aircraft, especially heavier-than-air aircraft

**Congress** – the chief lawmaking body of the United States, consisting of the Senate and the House of Representatives



The U.S. Senate chamber in the U.S. Capitol Building



The U.S. House of Representatives in the U.S. Capitol Building

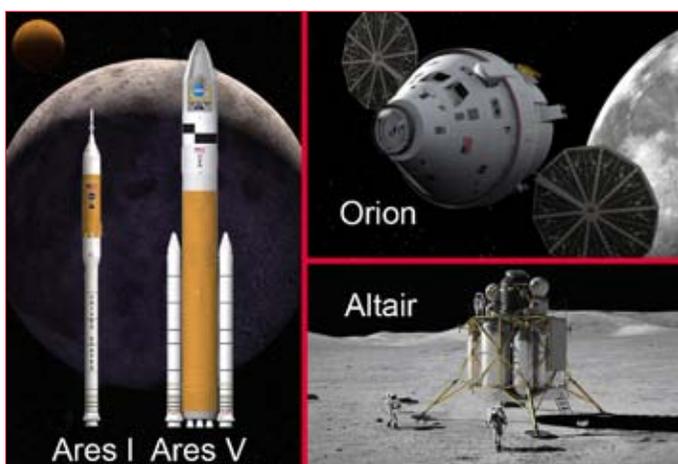


Image credit: NASA

Constellation Program's new spacecraft for human spaceflight

**Constellation Program** – Constellation is a NASA program to create a new generation of spacecraft for human spaceflight, consisting primarily of the Ares I and Ares V launch vehicles, the Orion Crew Exploration Vehicle, and the Altair lunar lander. These spacecraft will be capable of performing a variety of missions from delivering cargo and crew to the International Space Station (ISS) to landing on the Moon.



**cowling** – a streamlined metal housing or removable covering for an engine, especially an aircraft engine



This *Curtiss Hawk* has a NACA cowling covering its engine (November 1928).

**engineer** – a person who is trained in, or follows as a profession, a branch of engineering; a person who uses scientific knowledge to solve practical problems

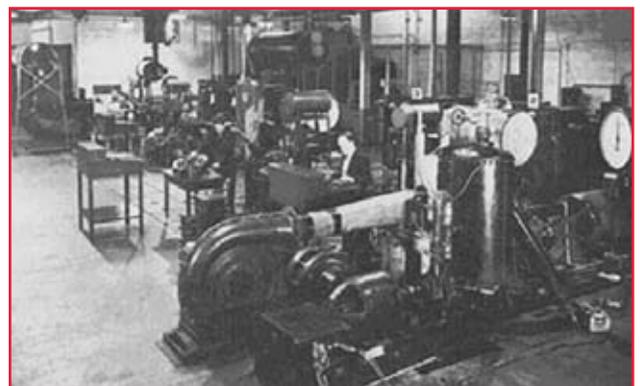


*Explorer I* – the first U.S. Earth satellite launched into orbit as part of the U.S. program for the International Geophysical Year (IGY), 1957–1958

William H. Pickering, James van Allen, and Werner von Braun hold up a model of *Explorer I*, America's first Earth satellite, launched January 31, 1958.

**International Geophysical Year (IGY)** – an international scientific effort that lasted from July 1, 1957 to December 31, 1958, in which scientists from 67 nations studied 11 different Earth sciences

**laboratory** – a room or building equipped for scientific experimentation or research



A NACA engine laboratory (1938)



**military** – of or relating to members of the armed forces (such as the U.S. Army, Navy, Air Force, Marines, or Coast Guard)

**missile** – an object or weapon that is fired at a target; a rocket carrying a warhead

A model German V-2 missile acted as the booster for this rocket launched in July 2000 to honor the first rocket launch at Cape Canaveral, Florida.



**orbiting** – the act of a celestial body or an artificial satellite as it revolves around another body

**premier** – the head of government in many nations; a position that is usually the same as that of a prime minister

**satellite** – a celestial body or a human-made vehicle intended to orbit a celestial body



Earth's Moon and approximately 3,000 artificial satellites orbit the Earth.



*Sputnik I* weighed 184 pounds (83 kilograms).

**Sputnik** – a USSR artificial satellite. Launched on October 4, 1957, *Sputnik I* was the first human-made satellite to orbit the Earth. *Sputnik II* was launched on November 3, 1957 and carried a dog named Laika on board.

**superpower** – an extremely powerful nation (such as the United States); a powerful nation able to influence events throughout the world

**supersonic** – relating to a speed greater than the speed of sound in a given medium, especially air

**transonic** – close to the speed of sound (Mach 1); moving at 700–780 miles per hour (1,127–1,255 kilometers per hour) at sea level

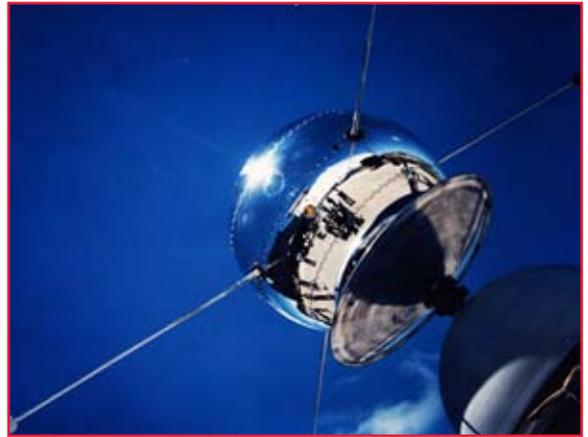
**universe** – all matter and energy, including the Earth, the galaxies, and the contents of intergalactic space, regarded as a whole

More than a thousand galaxies are captured in this Spitzer space telescope image.





**Vanguard** – the name of the U.S. program that was set to launch the first artificial satellite of the Earth. Vanguard was also the name given to the artificial satellites, as well as the rockets that launched them. In 11 attempts, only three Vanguard launches were successful. The first attempt, *Vanguard TV3*, failed on December 6, 1957. After the successful launch of *Explorer I*, *Vanguard 1*, launched on March 17, 1958, became the second artificial satellite (and the first solar-powered satellite) successfully placed in Earth orbit by the U.S. The other successful launches were *Vanguard 2*, launched on February 17, 1959, and *Vanguard 3*, launched on September 18, 1959.



The Vanguard satellite was the second U.S. satellite put into orbit.



The 16-foot transonic tunnel is one of 23 major wind tunnels at NASA's Langley Research Center.

**wind tunnel** – tubular structures or passages in which high-speed movements of air or other gases are produced. Objects such as aircraft, parts of aircraft, or models of these, are placed inside the wind tunnel so researchers can investigate the flow of air around them and the aerodynamic forces acting upon them.

**World War II (WWII)** – a war fought from 1939 to 1945, in which the Allied Forces (Great Britain, France, the USSR, the United States, China, and other countries) defeated the Axis Forces (Germany, Italy, and Japan)



## The Race Begins

### What is the National Aeronautics and Space Administration (NASA)?

What do you think of when you hear the word NASA? You might think of the Space Shuttle. Or you may think of **astronauts** landing on the Moon. Then again, you might think about the International Space Station (ISS) **orbiting** the Earth, where men and women live and work for months in space. Perhaps you have heard the news about NASA's plans to take humans back to the Moon and someday on to Mars and beyond. NASA is responsible for all of this and a whole lot more. NASA is the United States (U.S.) government agency that is leading us through the space age as it makes discoveries about our **universe** and directs the U.S. exploration of space.



Lesson 4

Student Text—The Race Begins



The name NASA is used so often that most people do not know what the letters stand for. The N stands for National. National comes from the word nation and our nation is the United States. The A is for **Aeronautics** which means the science of designing, building, and operating aircraft. The S is for Space, meaning the whole universe. The last A is for **Administration**. They are the people who manage all of the work at NASA.

**N**ational  
**A**eronautics and  
**S**pace  
**A**dministration

So, NASA hires a lot of people to do a lot of work that deals with flight. They help design better aircraft for the sky and spacecraft to take us into space. They build telescopes and robots to explore the universe. Their **satellites** collect data about Earth and their scientists use the data to help make Earth a better place. The technology developed in the space programs has been used in countless ways to enrich our lives and even to save lives.



NASA technology touches our lives everyday.



Right now, NASA is preparing to send humans back to the Moon and then on to Mars and beyond. NASA's **Constellation Program** is building the vehicles that will accomplish that mission. NASA is a world leader in the air and space business and people all over the world admire and respect what NASA does. But how did NASA achieve this respect? Let's look back.

## NACA, Not NASA

We know that the Wright Brothers were Americans who flew the first airplane at Kitty Hawk, North Carolina, in 1903. But Americans did not appreciate the Wrights, nor did they recognize the importance of their invention. At first, America was not even interested in flight and ignored this new machine called an airplane. But it was not that way in Europe. Europeans were working hard to improve airplanes. The U.S. soon realized that they were being left behind in this new and important business of airplane transportation.



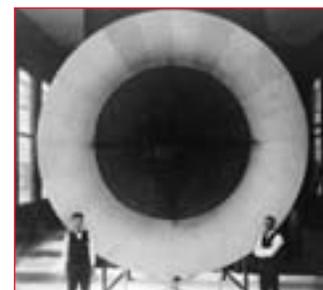
## The National Advisory Committee for Aeronautics

So **Congress** passed a bill and created an agency that would take **aviation** in the U.S. to the same level that it was in Europe. In 1915, the National Advisory Committee for Aeronautics (NACA) was formed. NACA was a committee of 12 men that would advise the President. It would find out all it could about aeronautics and study the problems of flight. Then, it would try to solve these problems through research and testing. NACA had to get busy because the U.S. had to catch up with the Europeans.

NACA's first job was to build the Langley **Laboratory** in Hampton, Virginia. Many of the best scientists and **engineers** in the U.S. came to work there. They studied aeronautical research from the U.S. and Europe. In 1920, the first **wind tunnel** was built at Langley.



The first major U.S. wind tunnel was built in 1920 at NACA's Langley Laboratory in Hampton, Virginia.



This photo shows the air intake section of Langley Laboratory's first wind tunnel.

## Lesson 4

### Student Text—The Race Begins



Wind tunnels are used to test airplane designs or parts of planes. In flight, the airplane moves through relatively stable air. But in a wind tunnel, the air moves over the fixed airplane. Usually a model of a plane or a part of a plane is tested, but some wind tunnels are large enough to test the whole plane. Engineers observe what happens and collect data. The wind tunnel tests helped NACA engineers and scientists design better planes and improve the materials used to build planes.



The Variable Density Tunnel, the world's first wind tunnel in which air pressures could be varied, was built at the Langley Laboratory in 1922.



The X-48B was tested in the full-scale wind tunnel at NASA's Langley Research Center.



Langley built many wind tunnels. The engineers tested models of airplanes in the wind tunnels. But sometimes they tested actual parts of a plane in the tunnels. They could test a wing, an engine, a propeller, or some other part. They would see if the part was right for the plane. They even had a tunnel to test a full-size plane. As Langley grew, it became the best research laboratory of its kind in the world. In 1940, NACA added two more research laboratories. One was located in California and the other was in Ohio. Later, two flight centers for **aerodynamic** and high-speed flight research were added to NACA.



This photo shows the NACA Langley Laboratory high-speed tunnel in Hampton, Virginia (January 1936).



This January 1931 photo shows NACA Langley Laboratory's original hangars. Notice the airplane and the cars in the photo.



An aerial view of the wind tunnels at the NACA Ames Laboratory in California was taken in February 1947.



This May 1944 photo shows the Wind Tunnel Aircraft Engine Research Laboratory at the NACA Lewis Research Laboratory in Cleveland, Ohio. Notice the parked cars.

## Lesson 4

### Student Text—The Race Begins



*Boeing B-17 Flying Fortress*



*Curtiss JN-4H Jenny*



*Vought F4U-1D Corsair*



*Grumman F-11*

Have you ever flown on a plane? How would you like to fly on a plane that had never been tested? You would not know if the wings were shaped to give lift. You would not know if the engine worked correctly. NACA's wind tunnel testing helped to design and build planes that were safe and fast.

NACA-led flight research in the U.S. for more than 40 years. During this time, NACA conducted testing and research on commercial and **military** planes. One of NACA's most



*Vought O3U*



*Douglas X-3*



*Bell X-5*



*Pitcairn Autogyro*



*Beechcraft D-18*



*Curtiss Hawk AT-5A*



*Grumman F4F Wildcat*



*Sperry Messenger*



*Boeing B-29 Superfortress*



*Republic P-47 Thunderbolt*



*Lockheed P-38 Lightning*

important contributions was that it shared its research results and information with the airplane manufacturers. The manufacturers used NACA's research to design and build safer and faster planes. Some of these planes were built for the military to move soldiers and equipment and fight wars. Some were built for commercial use and transported people and cargo all over the world. NACA's research was used for every aircraft built in the U.S. from 1915 to 1958.



*Douglas D-558-1 Skystreak*



*Northrup X-4*



*Brewster XF2A-1 Buffalo*



*Curtis P-40*



*North American F-86 Sabre*



*Boeing 247*



*P-51 Mustang*



*Piper Cub J-3*



*Bell X-1*



*Douglas DC-3*



*Thomas Morse MB-3*

## Lesson 4

### Student Text—The Race Begins



The NACA research led to the development of many improvements for aircraft. Some of these improvements included the following:

- An airplane engine **cowling** reduced the drag on a plane which increased airspeed and lowered the cost of flying. (1920s)
- A catalogue of 78 **airfoils**, each with specific properties, allowed manufacturers to pick the right airfoil (wing) for a particular plane. These airfoils are still used on modern aircraft including the new *F-22 Raptor* jet fighter. (1930s)
- Refrigerated wind tunnel tests led to the prevention of icing on wings and propellers. (1930s)
- Drag tests on fixed landing gear led to retractable landing gear. (1930s)
- The *Bell X-1*, the plane that first broke the sound barrier flying faster than the speed of sound or Mach 1, was built with the help of NACA engineers. (1947)
- Rocket-propelled models of new airplane designs helped to build planes that would fly faster and higher. (1940s)
- A **transonic** tunnel for high-speed testing led to many planes that could achieve **supersonic** flight, or above Mach 1. (1950s)
- Many X-aircraft, the planes designed for flight experiments, were tested and flown at NACA's California High-Speed Flight Station. (1950s)
- Research was conducted that led to the human space program. (1950s)



Experimental aircraft were an important part of the NACA research. The High-Speed Flight Station in Edwards, California, became a testing facility for airplanes to fly higher and faster.



In 1939, war broke out. Germany invaded Poland, and this started World War II (WWII). WWII was fought from 1939 to 1945. Most of the countries with a strong military force fought in this war. The U.S. fought on the side of the Allies, and NACA went to work to help the U.S. win the war. Much of NACA's work during this war was to help the airplane companies build better planes. NACA did research and testing for new fighter planes and bombers.



A mass formation of more than 1,200 aircraft flew over the U.S. fleet anchored in Tokyo Bay on September 2, 1945, to signal the end of World War II. The battleship *Missouri* is in the foreground.

Besides new aircraft, many other new inventions contributed to the war effort. Radar and the computer were invented. Large rockets and jet engines were built. Then, the U.S. invented the atomic bomb. When it was used against Japan, the war ended.



After the war, Japan and most of the countries in Europe were in ruins. However, two other countries came out of the war as very strong nations. The U.S. and the Union of Soviet Socialist Republics (USSR) became **superpowers**. These two countries were on opposite sides of the Earth, but each one wanted to be more powerful than the other. They both set out to build bigger rockets and bigger **missiles**. They built bigger bombs and more advanced planes. NACA helped the U.S. in this effort. NACA conducted missile research and high-speed research, but all of this power-buildup on Earth was not enough. Each nation then wanted to conquer space.



## Going to Space

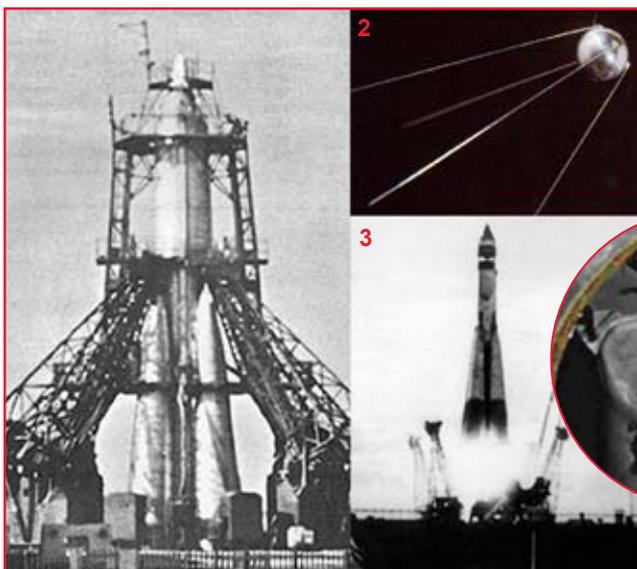
Before the year 1957, no country on Earth had sent anything into space, but the U.S. had been studying how to do this. They wanted to put a satellite into orbit as a part of the International Geophysical Year (IGY). This special year really lasted 18 months from July 1957 to December 1958. Scientists from 67 countries took part in it, and each nation did something to study the Earth. That is why the U.S. wanted to put up a satellite with an experiment on board. The USSR then said that it would send up a satellite, too. The space race had begun.



The U.S. got right to work. Three groups submitted their ideas for building a rocket and putting the satellite into orbit. The Navy designed the **Vanguard** rocket. The Army designed a modified Jupiter-C rocket. The Air Force had an idea, but it would take too long. Of the three plans, the Navy's idea was chosen. The U.S. was trying to beat the USSR into space, and the Navy's rocket was almost ready. The first test firing of the rocket would be held soon. But on October 4, 1957, all work in the U.S. stopped. Radio operators all over the world picked up a "beep, beep." It was made by *Sputnik I* in space! The USSR had beaten the U.S. in

the race to launch the first satellite. Their rocket had successfully put *Sputnik I*, Earth's first artificial satellite, into orbit. *Sputnik I* weighed 184 pounds (83 kilograms). *Sputnik II* carried the first living animal, a dog named Laika, into orbit a month later. *Sputnik II* weighed 1,100 pounds (499 kilograms).

The U.S. rocket was planning to lift only a 31-pound (14-kilogram) satellite.



- 1) The USSR Sputnik (R-7) rocket launched the world's first satellite.
- 2) *Sputnik I* was made of polished aluminum and was 23 inches in diameter. Four long whip antennae were attached to the sphere.
- 3) *Sputnik I* was launched on October 4, 1957.
- 4) Laika rode in *Sputnik II*.



People in the U.S. realized how powerful the Soviet rockets were. Many people were afraid because they knew the U.S. was getting behind. They realized that the powerful Soviet rockets could send nuclear weapons to U.S. soil. So again, the U.S. had to work hard to catch up. The Navy's design had been chosen, but now the Army was told to get its rocket ready too.

By December 1957, *Vanguard TV3* was ready to be launched. It rose only 3 feet before it shook, exploded, and fell over in flames. People in the U.S. felt shaken too. Now they were worried more than ever.

On January 31, 1958, the U.S. finally put its first satellite in orbit. It was called *Explorer I* and weighed only 30.7 pounds. However, it was the Army's modified Jupiter-C rocket that took *Explorer I* into space, not the Navy's rocket.

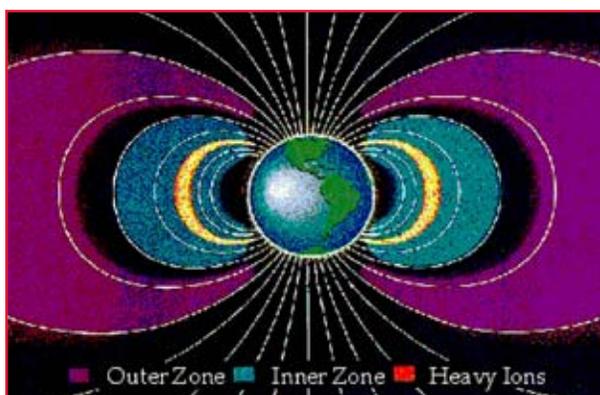
The *Explorer I* satellite, designed by the Jet Propulsion Laboratory (JPL), carried the first space experiment that proved that radiation bands surround the Earth. These bands were called the Van Allen Belt to honor the man that developed the test. This was the first major scientific discovery of the space age. Finally, in March, the Navy successfully launched *Vanguard I*. It joined *Explorer I* in orbit.



*Vanguard TV3* on the launch pad, December 6, 1957



*Vanguard TV3* in flames, December 6, 1957



The Van Allen radiation belts are regions of high-energy particles, held captive by the magnetic influence of the Earth.



Image credit: Huntsville Times

The local newspaper praised the team of scientists responsible for the Jupiter-C rocket that lifted the first U.S. satellite into orbit. The modified Jupiter-C was designed, built, and launched by the Army Ballistic Missile Agency in Huntsville, Alabama under the direction of Dr. Wernher von Braun.



However, the U.S. was still in trouble. The USSR was clearly ahead in the space race. The Soviet **premier** had called *Explorer I* “the grapefruit satellite” to show how much more advanced and powerful the Soviet rockets were. The U.S. needed a space program, and NACA, with a plan to get to space already in place, was chosen to run it. NACA already had a strong research team, and they also had a plan for space research. But a whole new agency needed to be formed.



The National Aeronautics and Space Administration (NASA) was created on October 1, 1958, to perform civilian research related to space flight and aeronautics. President Eisenhower, middle, commissioned Dr. T. Keith Glennan, right, as the first administrator for NASA and Dr. Hugh L. Dryden as deputy administrator (January 1, 1959).

Congress passed another bill, and, on October 1, 1958, NASA was created. NACA was 43 years old when it was transformed into NASA. Now NACA’s 8,000 people, three laboratories, and two flight centers would be a part of NASA. In addition to this, many of the people who had worked on rockets were put under NASA.

A week after NASA was created, it got some special orders. The Agency was told to put a human into space. NASA was in for a wild ride, and the space race was just getting started.



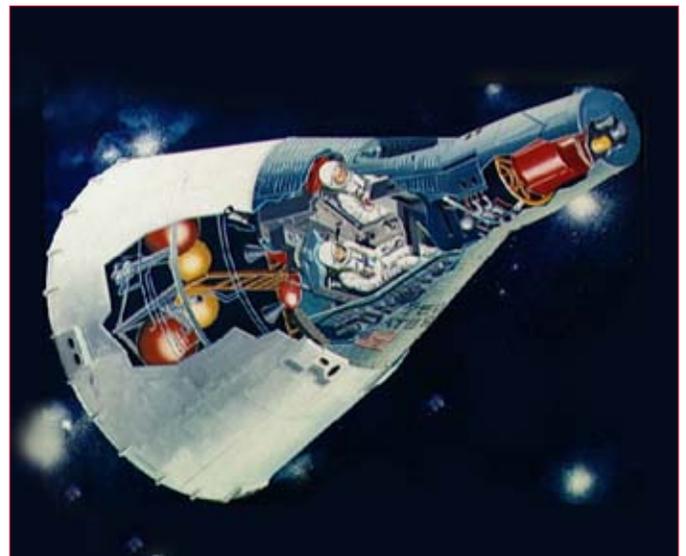
## Lesson 5 – Humankind in Space

**Lesson prep time:** 20 minutes (for gathering materials and following pre-lesson instructions)

**Teaching time:** 1¼–2 hours (Language Arts, Science, Math, Technology)

### Objectives

1. The students will understand the significance of Robert Goddard's invention of the liquid-fueled rocket.
2. The students will identify the contributions of NACA.
3. The students will create a timeline showing the achievements of NACA and the establishment of NASA, the U.S. space agency that competed with the USSR in the space race.
4. The students will recognize that the competition of the space race with the USSR helped to push the U.S. space program forward.
5. The students will explain the significance of the Mercury and Gemini programs as they read a selection about the early U.S. space program.
6. The students will predict the performance of their paper airplanes, test their planes in a wind tunnel, and gain an understanding of how engineers perform tests on airplanes.
7. The students will compare the performance of their planes to their predictions.
8. The students will construct and test different paper airplane designs to compete in a paper airplane contest.
9. The students will graph Alan Shepard's Mercury flight.
10. The students will continue to conduct research, design Orion and Altair with each of their components, and prepare their presentations of these designs.



An artist's concept of the two-man Gemini spacecraft in flight

## National Standards

### Science

- Abilities necessary to do scientific inquiry – S2Ea, S2Ma
- Understandings about scientific inquiry – S2Eb, S2Mb
- Position and motion of objects/Motion and forces – S3Eb, S3Mb
- Objects in the sky – S5Eb
- Changes in Earth and sky/Earth in the solar system – S5Ec, S5Mc
- Abilities of technological design – S6Ea, S6Ma
- Understanding about science and technology – S6Eb, S6Mb
- Risks and benefits – S7Md
- Science and technology in local challenges/in society – S7Ee, S7Me
- Science as a human endeavor – S8Ea, S8Ma
- History of science – S8Mc

### Mathematics

- Understand patterns, relations, and functions – M4
- Analyze change in various contexts – M7
- Specify locations and describe spatial relationships using coordinate geometry and other representational systems – M9
- Use visualization, spatial reasoning, and geometric modeling to solve problems – M11
- Understand measurable attributes of objects and the units, systems, and processes of measurements – M12
- Apply appropriate techniques, tools, and formulas to determine measurements – M13
- Formulate questions that can be addressed with data and collect, organize, and display relevant data to answer them – M14
- Develop and evaluate inferences and predictions that are based on data – M16
- Understand and apply basic concepts of probability – M17
- Problem solving – M18
- Communication – M20

### Geography

- How to use maps and other geographic representations, tools, and technologies to acquire, process, and report

information from a spatial perspective – G1

- The physical and human characteristics of places – G4
- How human actions modify the physical environment – G14

### Language Arts

- Standards 1, 3, 4, 5, 6, 7, 8, 11, and 12 (See the Language Arts Matrix on page 22.)

### Technology – ISTE

- Students are proficient in the use of technology – I2
- Students develop positive attitudes toward technology uses that support lifelong learning, collaboration, personal pursuits, and productivity – I5
- Students use productivity tools to collaborate in constructing technology-enhanced models, prepare publications, and produce other creative works – I7
- Students use telecommunications to collaborate, publish, and interact with peers, experts, and other audiences – I8
- Students use technology to locate, evaluate, and collect information from a variety of sources – I10
- Students employ technology in the development of strategies for solving problems in the real world – I14

### Technology – ITEA

- Relationships among technology and other fields – T3
- Cultural, social, economical, and political effects – T4
- Effects of technology on the environment – T5
- Role of society in the development and use of technology – T6
- Influence of technology on history – T7
- Attributes of design – T8
- Engineering design – T9
- Role of troubleshooting, research and development, inventions and innovation, and experimentation in problem solving – T10
- Apply the design process – T11
- Use and maintain technological products and systems – T12
- Transportation technologies – T18

### Materials

- Student logs
- A copy of the student text for Lesson 5, “Humankind

in Space” for each student

- Timeline, Timeline Date Sheet, and blank entry cards
- Picture books on the Mercury Program, including pictures of the Mercury Seven astronauts, the capsules, the launches, and the recoveries from the ocean
- Picture books on the Gemini Program, including pictures of the astronauts, the capsules, the launches, and the recoveries from the ocean
- A picture of Robert Goddard in 1926 with the first liquid-fueled rocket and an entry card of this event for the timeline (both provided)
- Homework Assignment – “The Paper Airplane Contest”
- Wind tunnel with fan (See wind tunnel directions.)
- Students’ paper airplanes

Teachers, paste this picture of Robert Goddard on an entry card for the timeline.



## Pre-lesson Instructions

1. Duplicate enough copies of the student text for Lesson 5, “Humankind in Space,” for each student. Punch holes so that students can insert these in their logs.
2. Duplicate enough copies of the homework assignment “The Paper Airplane Contest” for each student. Punch holes so that students can insert these in their logs.
3. Be sure that 40+ picture books on the U.S. space program are now in your classroom. The books on Project Mercury and Project Gemini will provide many of the pictures needed for this lesson.
4. Cut out and glue the small picture of Robert Goddard and his rocket on an entry card. Print the larger version (provided at the end of the lesson) to show the class or search [http://en.wikipedia.org/wiki/Robert\\_Goddard\\_\(scientist\)](http://en.wikipedia.org/wiki/Robert_Goddard_(scientist)).
5. More images of the Mercury Program can be found at <http://spaceflight.nasa.gov/gallery/index.html>. Find “More Galleries” (on the left side of the page)  “NASA Programs”  “Mercury” for a broad search of the Mercury Program. Additional pictures can be found under “NASA Programs” (on the right side of the page)  “Mercury.” Search both sites for images of the Mercury astronauts, capsules, launches, and recoveries.
6. More images of the Gemini astronauts, capsules, launches, and recoveries can be found at <http://spaceflight.nasa.gov/gallery/index.html>. Find “More Galleries” (on the left side of the page)  “NASA Programs”  “Gemini” for a broad search of the Gemini Program. Additional pictures can be found under “NASA Programs” (on the right side of the page)  “Gemini.” A video of the launch and the recovery of *Gemini XI* can also be found at this site.

## Procedure

1. Ask the students to take out their logs and turn to the student text for Lesson 4, “The Race Begins.” Next, direct the students’ attention to the timeline. Tell the students that, in 1926, Robert Goddard flew the world’s first liquid-fueled rocket. Show the enlarged picture but wait until this date comes up in Procedure Step 3 to add the entry card to the timeline.
2. Teach the class the following information: Goddard named his rocket “Nell.” The flight lasted only 2.5 seconds, rose just 41 feet, and ended in a cabbage field, but it was an important demonstration that liquid-fuel propellants were possible. Before this time, rockets used only solid propellants, usually black powder (a combination of charcoal, sulphur, and potassium nitrate) and could not travel long distances. Liquid-fuel propellants were capable of creating a much greater thrust which allowed humans to go to space. The rockets used to launch the first satellites, as well as to send the first men to the Moon, were liquid-propelled.
3. Using the text for “The Race Begins,” ask the students to recall the NACA accomplishments and the important events that need to go on the timeline. Write the event and the date on the entry card and fill in the dates from 1915 to 1958. Use the Timeline Date Sheet to corroborate the students’ answers and to get the exact dates. (Research and development often takes years to produce reliable data so many of these dates represent time spans.) Remind the students that these were the years of NACA.
4. Read aloud to the students the following excerpt from an article on wind tunnels from the Centennial of Flight website.

“For years, wind tunnels were used as a less expensive way of testing an airplane than having to build the full-size plane. But wind tunnel research was and still is expensive. It costs millions of dollars to test a new airplane design in a wind tunnel. As a result, aircraft designers have begun to use computers and a method called computational fluid dynamics (air, after all, is a

fluid, like water). This method simulates airflow entirely within a computer. Computing power is relatively cheap, and computer models can be changed much more easily than physical models made of plastic, metal, and wood.”

“Today, wind tunnels are used less and less and the giant wind tunnels that were used by so many aeronautical research centers starting in the 1930s and 1940s are now often called upon only to serve as backups to the computer simulations, to prove that their predictions are sound. In several important cases, however, aircraft designers have had to use wind tunnels to test their designs after computer simulations have proven inadequate. For example, the Pegasus XL air-launched rocket suffered an in-flight aerodynamic failure that was not predicted by a computer-generated aerodynamic model. But in a matter of years, most of the large NACA-built wind tunnels may become totally silent, their roar replaced by the hum of supercomputers.”

5. Tell the students that the rest of the unit will be about the U.S. Government Agency NASA. Explain that, even though NASA continues to carry out research in aeronautics which contributes to the design and improvement of airplanes, it is NASA’s space programs that have captured the public’s attention and the newspaper headlines since the Agency began.
6. Explain that thousands of people work for NASA, but when a program, or project, begins, a certain group within that workforce is selected to be responsible for that program. Many others may contribute, but the core group will work full-time on the program. NASA’s efforts in exploring space were usually known by their program or project name. Then, tell them that the first program to put a human into space was called Mercury. Ask the students why they think that name was chosen. (**In Roman mythology, the god Mercury sped across the heavens to deliver messages to the other gods.**)
7. Introduce and teach the vocabulary in the same manner that you would for any guided reading.

8. Distribute the student text for Lesson 5, “Humankind in Space” and have the students insert this in their logs. Read and discuss this selection as you would any guided reading activity. As the class discusses the text, question their understanding and encourage their questions.
9. After reading the first paragraph, have the students observe the top illustration on the page. It depicts the capsules and the astronaut patches of the six Mercury space flights. Each capsule was specially painted with the name and insignia given to it by the astronaut who flew that mission. The names of the capsules were, from left to right: *Freedom 7*, *Liberty Bell 7*, *Friendship 7*, *Aurora 7*, *Sigma 7*, and *Faith 7*. Ask the students why they think each of the capsules had a “7” in their name. **(The first seven astronauts were named the “Mercury 7.” Each “7” refers back to that team.)**
10. Now, have the students observe the bottom illustration. Instruct them to find Alan Shepard and ask if they know why he is famous.
11. Continue reading until the students get to the picture of Alan Shepard waiting in *Freedom 7* to be launched. Tell the students to try and imagine themselves in that capsule. How would they feel about being the first American to rocket into space? Would they trust the people responsible for the rocket and the spacecraft to keep them safe?
12. After reading about the launch and recovery of Shepard and the capsule, have the students look at the picture of the launch and the flight path of the capsule. Explain that this path is a suborbital flight. *Freedom 7* did not go into orbit around the Earth, but it did enter space before it returned to Earth.
13. Next, ask the students to look at the pictures that show the Mercury capsule parachuting down to the ocean and the recovery of Shepard as he is pulled up into the helicopter. Explain to the students that this was how the U.S. brought all of the capsules back from space before 1981 when the Space Shuttle was made to reenter the atmosphere and land like a plane.
14. Find Cape Canaveral, Florida, on a map. Tell the students that Shepard landed in the Atlantic Ocean only 303 miles from the Cape.
15. Direct the students’ attention to the Altitude Chart that was made in Lesson 2. Mark the altitude achieved by Shepard’s *Freedom 7* capsule.
16. After reading about Yuri Gurgarin and President Kennedy, explain that Americans were not only disappointed, but that they were also fearful. Americans realized that these very powerful rockets could also be armed with ballistic missiles that could be pointed toward the U.S. Explain that this time in history was known as the Cold War in which both the U.S. and the USSR were competing for military and technological dominance. Explain that this is why President Kennedy tried to encourage the American people.
17. After reading “More Mercury Flights,” tell the students that an extensive search for *Liberty Bell 7* took place, but the capsule was not recovered until 1999.
18. Then, point out that John Glenn’s flight was the first to orbit the Earth. Mention that John Glenn became a U.S. senator and that NASA’s Lewis Research Center in Ohio was renamed Glenn Research Center to honor him.
19. Before reading “The Gemini Step to the Moon,” introduce Project Gemini as NASA’s second space program. Explain that Project Gemini had several objectives but there were two main objectives. The first main objective was to practice the different maneuvers for operating in space that would be necessary for a successful Moon landing and return to Earth. The second main objective was to keep NASA in the news, thereby maintaining the public’s interest and attention. Ask the students why they think the project was named “Gemini.” **(The Gemini capsule held two people. Gemini, Latin for “the twins,” is the name of a constellation in which the two brightest stars are named Castor and Pollux, twins in a Greek myth.)**

20. Finish reading and discussing the section, “The Gemini Step to the Moon.” Discuss the pictures of the Gemini capsule and Edward White performing the first spacewalk by an American astronaut. Make sure the students understand the maneuvers of rendezvous and docking and explain the multiple exposure picture of the Rendezvous Docking Simulator.
21. Have the students observe the illustration on page 147. Tell them to look carefully at the sky. (**The shapes of the spacecraft in the top border are hidden in the sky.**)
22. If possible, show the video of the launch and recovery of *Gemini XI*. Ask the students if they have any questions or if there is anything that they would like to discuss.
23. Turn the students’ attention to the wind tunnel and their paper airplanes. If the students have been taught the NASA educator guide The Courage to Soar, they should have no problem understanding the force of lift on the plane in the wind tunnel. If they have not had any instruction on lift, conduct the following simple activity.

**Activity** – Instruct the students to take out a sheet of notebook paper and cut a 2-inch vertical strip off of one side. Show them how to hold the paper against their chins then ask the following question: “What will happen if you blow across the top of the paper?” After the students have given their answers (their hypotheses), tell them to hold the paper up to their chins and blow hard across the top of the paper. The result will be that the paper will lift up. Tell them that the paper lifted because of the force of lift. Explain that when you blow across the top of the paper, the faster moving air has less pressure (it pushes less) than the stable (standing still) air underneath. Since the stable air underneath pushes harder, it caused the paper to lift up.



24. Instruct the students to turn to a clean sheet of notebook paper in their logs. Tell them to title the page “Wind Tunnel Tests” and draw lines to create three columns underneath. Write the headings Low, Medium, and High above each column leaving several spaces under each heading to record the prediction and result for each of the fan settings. (Teachers may want to draw the following table on the board.)

**Wind Tunnel Tests**

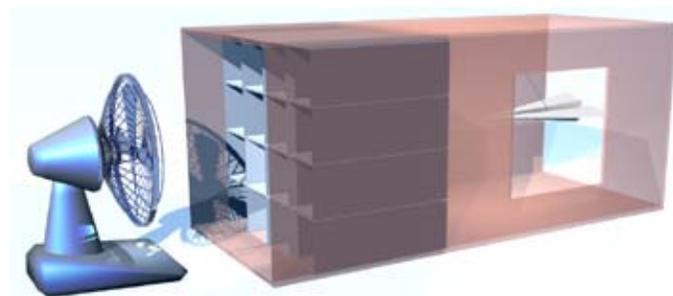
Low	Medium	High
Prediction: The plane will	Prediction: The plane will	Prediction: The plane will
Test: The plane	Test: The plane	Test: The plane

25. Give the students a few minutes to make predictions of what their plane will do at each fan speed. “What will the plane do on low speed? Medium speed? High speed? Then, explain that they will be recording data about their plane. After their plane is tested in the wind tunnel, they should record how their plane performed at these different speeds.
26. Tell the students to gather around the wind tunnel. Explain that the wind tunnel is a tunnel through which air is forced at controlled speeds to study the airflow around the object suspended within it. Also explain that the milk (or juice) carton separators straighten the swirling air currents from the electric fan.

27. Begin to test each airplane using the directions from “Building a Wind Tunnel” printed below. Remind the students to record in their logs the results of their own plane at each fan speed.

### Testing the Planes

- 1) Slip the loop at the end of the string over the cup hook.
- 2) Turn the fan on low and observe the results.
- 3) Then, turn the fan on medium and observe the results.
- 4) Finally, turn the fan on high and observe the results.
- 5) Record how the plane performed at each setting.



28. After each plane has been tested, ask the students to share their results. How did their planes perform compared to their predictions? Remind them that this is how NACA engineers tested aircraft and that this is how NASA still tests some aircraft today. NASA also tests spacecraft components in high-speed, high-temperature wind tunnels. The Space Shuttle tiles were tested in a high-speed, high-temperature wind tunnel.
29. Tell the students that in the next lesson they will take part in a paper airplane contest, using the planes that they tested as well as one more plane that they will make in class. Distribute the homework assignment, “The Paper Airplane Contest,” and read it aloud to the class.
30. Explain again that they should learn how to make the plane but they are not allowed to bring it in to class. They will be given 5 minutes to make it in class right before the contest. Tell the students that they will be testing their wind tunnel planes as well as the new plane to decide which one they want to fly in the contest. (If students receive help from

home, it will be limited to helping with the design of the plane. This kind of “help” is encouraged as being instructional.) Allow the students to ask questions about the assignment.

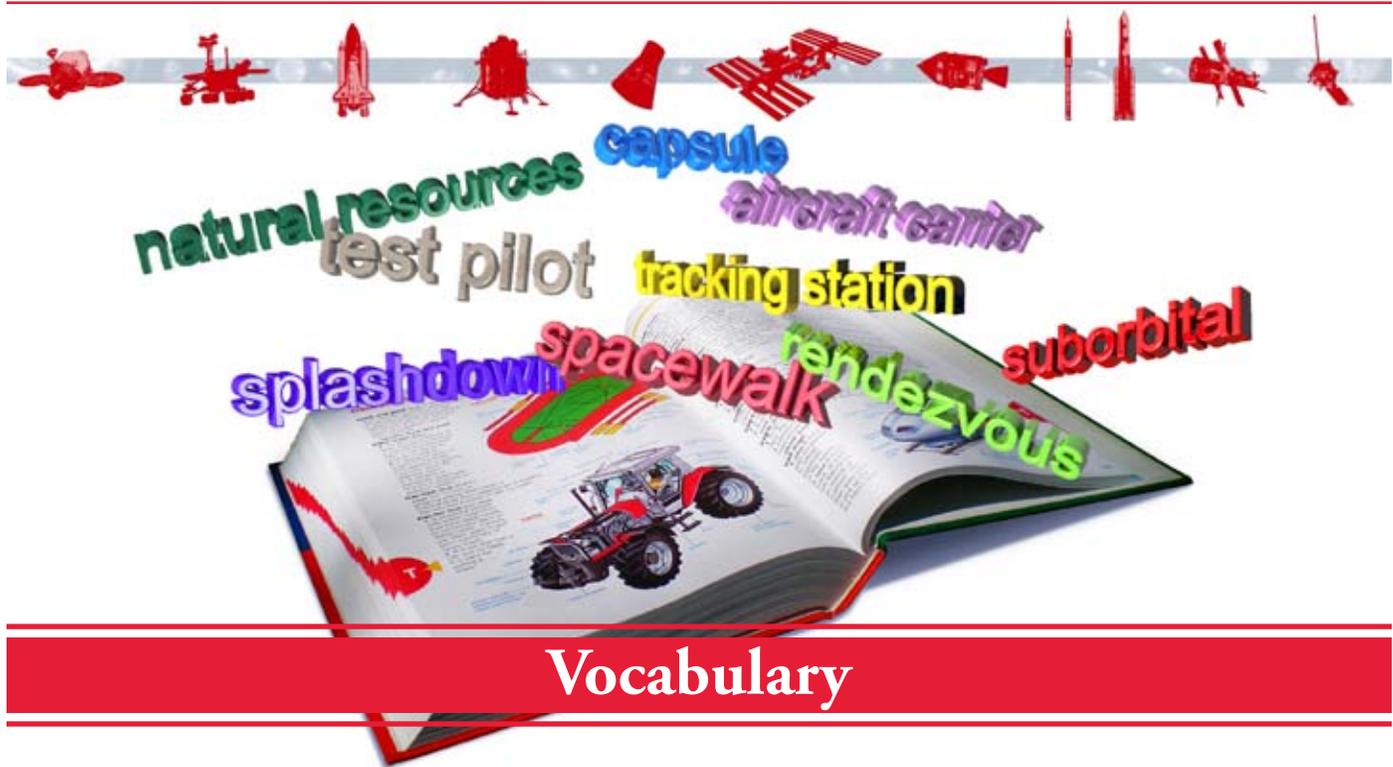
31. **Optional Math Activity:** Students can visualize Alan Shepard’s flight path in his *Freedom 7* capsule with a simple graphing activity. Distribute small-lined graph paper to each student or have the students work in pairs. Write the following information on the board:

Altitude – 116 miles (187 kilometers)

Distance downrange – 303 miles (488 kilometers)

Then, tell the students that Shepard’s capsule made a parabolic arc across the sky reaching an altitude of 116 miles (187 kilometers) and landing in the Atlantic Ocean 303 miles (488 kilometers) downrange from the Cape Canaveral launch site. Tell them that except for small deviations during the launch and also during the parachute ride, the capsule traveled in a symmetrical arc.

Note: Younger students may need help in determining the value of each square.



**aircraft carrier** – a large, naval ship with a long flat deck from which airplanes can take off and on which they can land



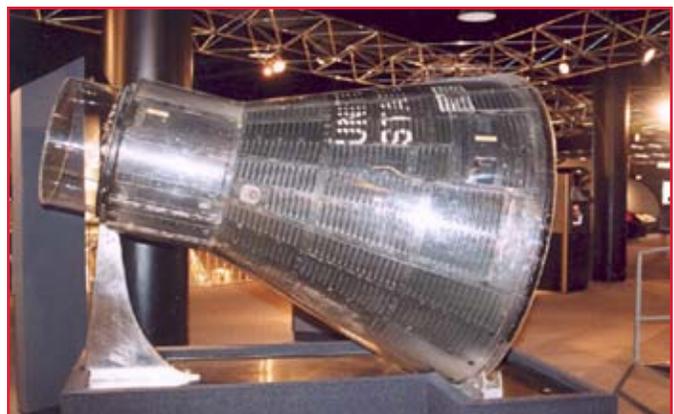
The crew of the aircraft carrier USS Kearsarge stood in a formation to spell out "MERCURY 9" on the flight deck while on their way to the recovery area to pick up Gordon Cooper and the *Faith 7* capsule.

**applicant** – one who applies for something; a person who requests or seeks something

**capsule** – a spacecraft designed to transport people and support human life in outer space



Orion, NASA's new crew capsule, will hold a crew of six.



A Project Mercury capsule could carry only one person into space.



**cosmonaut** – an astronaut of the Soviet or Russian space program

**crewed** – transported, operated by, or performed by a human; having a crew

**decade** – a period of 10 years



*Image Credit: NASA*  
Artist's impression of Russian Cosmonaut Mikhail Tyurin driving a golf ball from the International Space Station



Cosmonaut Pavel Vinogradov



Nose of *Gemini XI* spacecraft and Agena Target Vehicle while docked

**docked** – to mechanically join two or more spacecraft in space

**hold** – a delay in a countdown; a halt in the pre-launch countdown, either planned or unexpectedly called, to allow correction of one or more faults in the spacecraft and/or launch system

**maneuver** – a clever or skillful move or action; a movement or procedure involving skill and dexterity

**mph** – an abbreviation for “miles per hour”

**natural resources** – resources (actual and potential) supplied by nature, such as land, forests, water, minerals, coal, oil, and natural gas



Some of Earth's natural resources



**parachute** – a device for slowing the descent of a person or object through the air that consists of a usually umbrella-shaped, light fabric canopy beneath which the person or object is suspended

**rendezvous** – an orbital maneuver between two spacecraft where the two arrive at the same orbit, make the orbital speeds the same, and travel close together, typically within 100 meters (330 feet); an approach maneuver that may or may not include docking



A parachute slows the descent of the *Gemini XII* capsule.



The first U.S. rendezvous in space was made by *Gemini VI* and *Gemini VII*.



Edward White performs America's first space walk from *Gemini IV*.

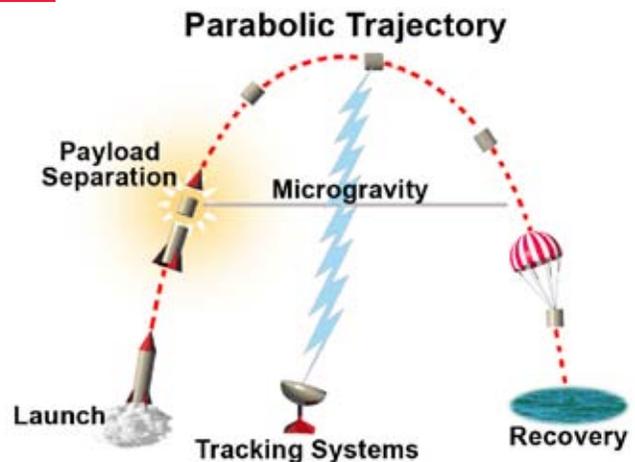


The *Gemini X* capsule splashdown

**spacewalk** – any kind of physical activity by an astronaut outside a spacecraft in space, sometimes called an extravehicular activity (EVA)

**splashdown** – a landing of a spacecraft in the sea at the end of a space flight

**suborbital** – a spacecraft not in orbit; having or following a trajectory (curved path) of less than one orbit



Suborbital flight



**test pilot** – a pilot who flies aircraft of new or experimental design to test them



A NASA tracking station



The Mercury Seven astronauts were all test pilots.



Mercury Control Center (Notice the flight paths on the screen.)

**tracking station** – a station for observing the path of and maintaining contact with an object in the atmosphere or in space especially by means of radar or radio

**uncrewed** – having no crew (or no human) aboard



## Humankind in Space

### The Mercury Seven

Alan Shepard was a very special man. He was one of the Mercury Seven, the group of men chosen by NASA to be the first astronauts. These seven men were going to work for Project Mercury, NASA's first space program. Project Mercury's goal was to put a spacecraft with a human aboard into orbit around the Earth, and bring both the human and the spacecraft back safely.



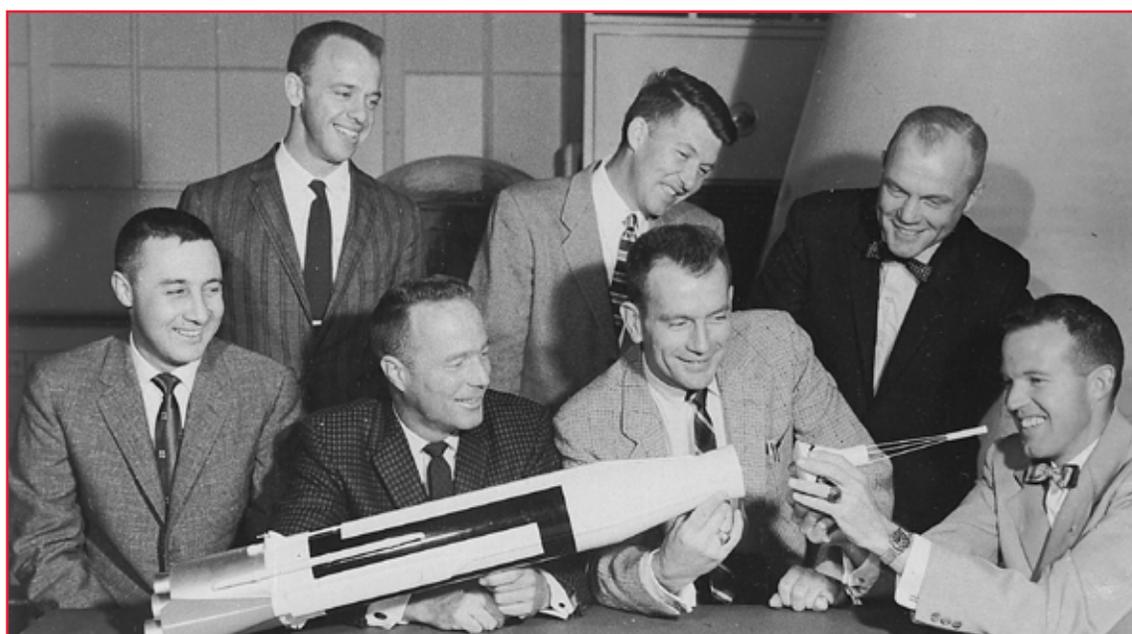


Actually, all of the first astronauts were special men. They had been chosen from hundreds of **applicants**. Every one of them was a **test pilot** in the military. They all had families, and they all had college degrees. They had also passed some very difficult tests to show that they were physically and mentally fit. This fitness was necessary for the demanding task of space travel.



Alan Shepard in his pressure suit just before launch

The Mercury Seven soon became famous. They even had a movie, The Right Stuff, made about them. The movie was based on the book with the same title written by Tom Wolfe. Wolfe said that he wrote the book to find out why the astronauts accepted the danger and risks of space flight. The title referred to the character of the astronauts. Because they were smart, brave, strong, and daring, they had the right stuff to become astronauts. Of these seven men, Alan Shepard was chosen to be the very first American to travel into space.



(1959) — The original Mercury astronauts are pictured around a table admiring a model of the Atlas rocket. Standing, left to right, are Alan B. Shepard, Jr., Walter M. Schirra, Jr., and John H. Glenn, Jr. Sitting, left to right, are Virgil I. Grissom, M. Scott Carpenter, Donald Slayton, and L. Gordon Cooper, Jr.

## Lesson 5

### Student Text—Men in Space



NASA had done all it could to prepare for the first **crewed** flight. Thousands of scientists, engineers, and many other workers had labored to complete the dream of sending a human into space. They had conducted many

tests to prove that the **capsule** and rocket were safe. Twenty **uncrewed** flights were made to help solve a lot of problems. But one of these flights was not exactly uncrewed. That's because Ham was aboard the Mercury-Redstone 2 (MR-2) mission.



Ham and a technician look over equipment.



Biosensors are attached to Ham's body before his trip.



Ham tries out his combination couch and life support system.

In January 1961, NASA launched a chimpanzee into space. His name was Ham. After the flight, Ham's capsule landed in the ocean and was picked up by a helicopter. The helicopter carried the capsule to the deck of a ship. When Ham came out of the capsule, he happily ate an apple and half an orange. Ham became almost as

famous as the Mercury Seven!

Ham's mission paved the way for the launch of America's first human in space. Finally, NASA felt that a crewed space flight would be safe.



Ham is greeted by the recovery ship commander.



Ham reaches for an apple following his brief space ride.



## The First U.S. Space Flight

On the morning of May 5, 1961, Alan Shepard was perched high atop a Redstone rocket. He felt snug in *Freedom 7*, his one-person capsule. He was nervous, of course, but he also felt confident. Even though he sat all alone on the launch pad, he was surrounded by people. He could hear his team talking to him through his headset. Hundreds of reporters and writers were there to announce the flight to the world. Thousands of people all over the U.S. were sitting in front of their TV sets. The first American would soon zoom into space, and no one wanted to miss this important event!



Astronaut Alan B. Shepard, Jr., awaits liftoff in *Freedom 7*.

Shepard sat waiting in the capsule for 4 hours and 14 minutes, enduring several “**holds.**” NASA wanted to be sure that it was safe. When it was time for him to blast off, he soared 116 miles (186.7 kilometers) high and reached a speed of over 5,000 **mph**. The capsule made a giant arc in the sky. With the help of a **parachute**, it landed in the ocean, where helicopters were hovering nearby. They lifted the astronaut to safety and hoisted the capsule out of the water. Then, both were taken to the deck of an **aircraft carrier**.



The launch of MR-3



Astronaut Alan Shepard is rescued by helicopter at the end of his MR-3 flight. Notice the Mercury capsule in the water.



The *Freedom 7* capsule recovery.



The ride was only 15 minutes long. Shepard had not gone into orbit, but he went into the history books. His **suborbital** flight made him the first American in space. The U.S. was thrilled with Shepard's success. Many people were displeased with the U.S. space program. The USSR had beaten the U.S. by putting the first human in space a month before. The **cosmonaut's** name was Yuri Gagarin, and he had actually orbited the Earth. The U.S. was behind once again.

*Image credit: Huntsville Times*



On April 12, 1961, Russian cosmonaut Yuri Gagarin became the first human in space, making an orbital flight in his *Vostok 1* spacecraft.



John F. Kennedy delivers his "Send a man to the Moon before the end of the decade" speech.

However, this was a big challenge. The announcement put a lot of pressure on NASA because the race for the Moon was to start right away. NASA had barely gotten one person into space. Now they were supposed to land a man on the Moon!

A few weeks after Shepard's flight, President John F. Kennedy tried to lift the country's spirits. In a speech to Congress, he set the U.S. space program on a new and daring course. "I believe that this nation should commit itself to achieving the goal, before this **decade** is out, of landing a man on the Moon and returning him safely to the Earth." NASA and the rest of the nation were thrilled. The U.S. would be doing all it could to win the space race.





## More Mercury Flights

In the meantime, five more Mercury flights took place. The second Mercury flight took place in July. Gus Grissom was launched on a 15-minute suborbital flight in the *Liberty Bell 7*. His rescue in the ocean turned scary when the hatch blew off and his capsule was filled with water. The capsule sank, but Grissom was safe.



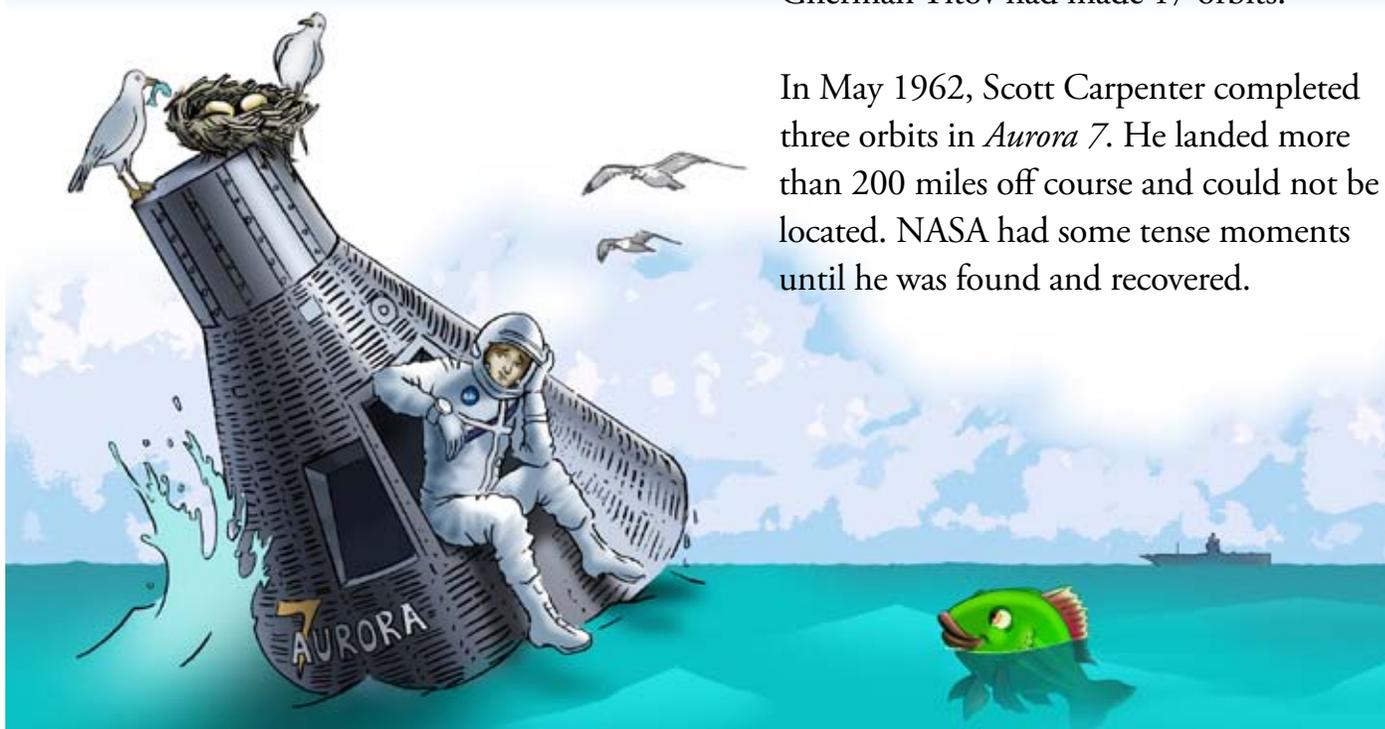
Gus Grissom became the second American to reach space on July 22, 1961.



John Glenn enters his *Friendship 7* capsule.

In February 1962, a powerful Atlas rocket pushed John Glenn's *Friendship 7* into orbit. Glenn made three orbits and became the first American to orbit the Earth. Once again, though, the USSR had beaten the U.S. Six months earlier, Cosmonaut Gherman Titov had made 17 orbits.

In May 1962, Scott Carpenter completed three orbits in *Aurora 7*. He landed more than 200 miles off course and could not be located. NASA had some tense moments until he was found and recovered.



## Lesson 5

### Student Text—Men in Space



Wally Shirra made six orbits in *Sigma 7* the following October. The last Mercury flight took place in May 1963, when Gordon Cooper made 22 orbits in *Faith 7*. He traveled almost 18,000 mph and performed eleven experiments. **Tracking stations**, located all over the world, talked to him as he passed high above. The flight lasted 34 hours and 20 minutes. Project Mercury was over, and all of its goals were met.

Now, America turned its attention to landing an astronaut on the Moon. The name of the program would be Apollo. It was going to be an extraordinary task, but NASA was up to the challenge. The world would soon know that the U.S. was the leader in science and technology. NASA and the U.S. were going to land a human on the Moon, and they were going to make sure that they would be the “first” to do it this time.



The Rocket Garden at Kennedy Space Center



## The Gemini Step to the Moon

NASA had many good ideas for a Moon landing, but all of these ideas needed to be tested. So, after Mercury, NASA developed a project to help with the testing that would be needed for a successful Moon mission. The project was named Gemini, and its 10 crewed flights took place in 1965 and 1966.

Project Gemini had several objectives. NASA wanted to test the effects of putting a human in space for up to two weeks. They wanted the astronauts to **rendezvous** and dock with other space vehicles, and they wanted to perfect ways of entering the atmosphere and landing. The project successfully put more astronauts in space. People all over the U.S. watched the launches and the **splashdowns** on TV. NASA knew it was important to keep the country's space efforts in the news.



The Gemini VII capsule



Project Gemini kept the U.S. space effort in the news.

## Lesson 5

### Student Text—Men in Space



During Project Gemini, NASA gained a lot of experience that would help with landing an American on the Moon. The Gemini capsule was made for two people. The extra weight caused NASA to use a more powerful rocket. So a huge, powerful, Titan rocket lifted each of the crewed Gemini capsules into space. These flights gave the ground crew practice in taking humans to and from space. *Gemini 3* carried the first pair of astronauts into space.



Astronauts Edward White and James McDivitt inside the *Gemini IV* spacecraft



Edward White performs the first U.S. spacewalk during the *Gemini IV* mission.

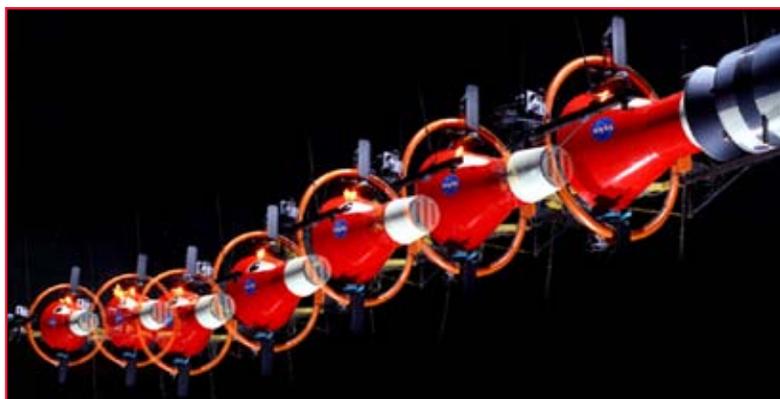
In December 1965, the astronauts in *Gemini VII* spent 14 days in space. While in orbit, the *Gemini VII* capsule was met by *Gemini VI* to perform the first rendezvous in space. The two spacecraft remained together for five hours at distances from one foot (.30 meters) to 295 feet (90 meters). The U.S. had finally accomplished a “first” in space.



*Gemini VII* is photographed from the hatch window of *Gemini VI* during the first space rendezvous.



*Gemini VIII* performed the first successful docking of two spacecraft when they joined the Gemini capsule with the Agena target vehicle seen in this photograph.



This multiple exposure (several images superimposed over the first image) of NASA's Rendezvous Docking Simulator shows the Gemini spacecraft on the left being guided by the astronaut inside into a docking position.

Then, in March 1966, *Gemini VIII* performed another first when it **docked** with another spacecraft, the Agena target vehicle.

They were the first two spacecraft to join in space, a **maneuver** that would be needed for a trip to the Moon. The plan called for the two spacecraft to remain docked all night. But, after 30 minutes, the two began to spin out of control. Astronaut Neil Armstrong undocked his capsule, but it was some time before he was able to control the capsule. He finally fired a reentry rocket and made an emergency landing. Later, Gemini flights perfected the rendezvous and docking of two space vehicles.



Astronaut Dick Gordon straddling an Agena target vehicle to attach a tether



The *Gemini XII* spacecraft receives preflight preparation.

## Lesson 5

### Student Text—Men in Space



During *Gemini XII*, Edwin “Buzz” Aldrin spent a record 5 hours and 28 minutes outside the spacecraft in three separate trips. Aldrin completed 19 tasks during the longest single spacewalk of 2 hours and 6 minutes.

Besides all of the advances in technology, Gemini also helped U.S. scientists. The Gemini astronauts took many photos of Earth. These were the first color photos taken



A view of Cape Canaveral, home to Kennedy Space Center, from the *Gemini V* capsule



The Himalayas in Asia

of Earth from various altitudes. When the scientists looked at the pictures, they were able

to study the surface of the Earth. The photos showed that many of the Earth’s **natural resources** were being reduced, and the scientists started to worry.



Nicaragua and Honduras



The Imperial Valley in California



The Nile Delta in Egypt



After the last Gemini capsule splashed down, most people forgot about this project. But Gemini was a very important step on the way to the Moon. All of its goals had been met but one. NASA had hoped to set the capsule down on land instead of splashing in the ocean, but this did not happen.

NASA and the whole U.S. now turned all of their energy and attention to one goal. All efforts turned to the Apollo Program that would land a man on the Moon. The U.S. had to beat the Soviets there. The space race had to be won, and the U.S. had to be the winner!





## The Paper Airplane Contest

Practice making paper airplanes at home this evening for a paper airplane contest that will be held in class tomorrow. Try several different designs to discover which design flies the longest distance. You may receive help with your design, but do not bring the airplane into class. Be sure to learn how to make the design so that you can remake it in class. You will be given about 5 minutes to make your plane in class tomorrow.

Reminder: The Orion/Altair designs and presentations are due in two class periods.



Robert Goddard holds the launching frame of his invention — the first liquid-fueled rocket (March 16, 1926).





## Lesson 6 – The Paper Airplane Contest and Apollo

**Lesson prep time:** 25–30 minutes (for gathering materials and following pre-lesson instructions)

**Teaching time:** ½ hour (Science, Math, Technology)

### Objectives

1. The students will test their planes and record data about each flight.
2. The students will participate in a paper airplane contest and discuss their observations of the best designed planes.
3. The students will perform simple computations using the flight distances of their paper airplanes.
4. The students will create a timeline showing the achievements of NASA as the U.S. Agency competed with the USSR in the space race.
5. The students will observe and discuss pictures and computer videos about NASA's Apollo Program.
6. The students will identify each section of the Apollo spacecraft.
7. The students will continue to conduct research and design Orion and Altair with each of their components and prepare their presentations of these designs.



AS-203, the third Saturn IB launch vehicle developed by the Marshall Space Flight Center, lifts off from Cape Canaveral, Florida (July 5, 1966).

## National Standards

### Science

- Abilities necessary to do scientific inquiry – S2Ea, S2Ma
- Understandings about scientific inquiry – S2Eb, S2Mb
- Position and motion of objects/Motion and forces – S3Eb, S3Mb
- Objects in the sky – S5Eb
- Changes in Earth and sky/Earth in the solar system – S5Ec, S5Mc
- Abilities of technological design – S6Ea, S6Ma
- Understanding about science and technology – S6Eb, S6Mb
- Risks and benefits – S7Md
- Science and technology in local challenges/in society – S7Ee, S7Me
- Science as a human endeavor – S8Ea, S8Ma
- History of science – S8Mc

### Mathematics

- Compute fluently and make reasonable estimates – M3
- Use mathematical models to represent and understand quantitative relationships – M6
- Analyze change in various contexts – M7
- Use visualization, spatial reasoning, and geometric modeling to solve problems – M11
- Understand measurable attributes of objects and the units, systems, and processes of measurements – M12
- Apply appropriate techniques, tools, and formulas to determine measurements – M13
- Formulate questions that can be addressed with data and collect, organize, and display relevant data to answer them – M14
- Develop and evaluate inferences and predictions that are based on data – M16
- Problem solving – M18
- Communication – M20

### Language Arts

- Standards 1, 3, 4, 5, 6, 7, 8, 11, and 12 (See the Language Arts Matrix on page 12.)

### Technology – ISTE

- Students are proficient in the use of technology – I2
- Students develop positive attitudes toward technology uses that support lifelong learning, collaboration, personal pursuits, and productivity – I5
- Students use productivity tools to collaborate in constructing technology-enhanced models, prepare publications, and produce other creative works – I7
- Students use telecommunications to collaborate, publish, and interact with peers, experts, and other audiences – I8
- Students use a variety of media and formats to communicate information and ideas effectively to multiple audiences – I9
- Students use technology to locate, evaluate, and collect information from a variety of sources – I10
- Students employ technology in the development of strategies for solving problems in the real world – I14

### Technology – ITEA

- Relationships among technology and other fields – T3
- Cultural, social, economical, and political effects – T4
- Effects of technology on the environment – T5
- Role of society in the development and use of technology – T6
- Influence of technology on history – T7
- Attributes of design – T8
- Engineering design – T9
- Role of troubleshooting, research and development, inventions and innovation, and experimentation in problem solving – T10
- Apply the design process – T11
- Use and maintain technological products and systems – T12
- Transportation technologies – T18

## Materials

- Newsprint, notebook paper, and/or other paper for paper airplanes
- Copies of paper airplane patterns and/or books for making paper airplanes (from Lesson 4)
- Student logs and pencils
- Flying area for paper airplane contest (Prepare a wide lane for each group.)
- Two paper airplanes per student
- One 50-foot measuring tape per group
- Timeline, Timeline Date Sheet, and blank entry cards
- Picture books on the Apollo Program
- Many pictures and a few computer videos of the Apollo Program
- A picture of the Apollo spacecraft atop a Saturn V rocket on the launch pad (provided at the end of the lesson)
- A diagram of the Apollo spacecraft atop a Saturn V rocket showing each of the components (provided at the end of the lesson)

## Pre-lesson Instructions

1. Divide the students into groups of 3 or 4 per group for testing and flying their airplanes. Assign a recorder for each group.
2. Be sure to have copies of paper airplane patterns and/or books for making paper airplanes for those students who received no help with, or were not able to do, their homework. These can be the same as the patterns and books used for Lesson 4.
3. Prepare the flying area for the paper airplane contest before class. If it is windy outside, choose a place indoors like a cafeteria or gym so that the wind will not be a variable. Make sure that the area is spacious and that nothing will interfere with the flights. Prepare a wide flying lane (8- to 10- feet wide or wider) for each group and designate a starting line for each lane so that all groups can conduct their test flights at once.
4. Optional: Create a sign or banner for the winner. Choose a phrase such as, "Congratulations to \_\_\_\_\_, the

Paper Airplane Contest Winner." Also prepare a paper badge or ribbon for the top winners and a special one for the overall winner.

5. Find books on the Apollo Program with pictures to enhance the student text in Lesson 8 as well as the discussion about Apollo in this lesson. Videos and additional pictures of the Apollo Program can be found at the following Web sites.

<http://www.nasm.si.edu/collections/imagery/apollo/apollo.htm>

<http://www.apolloarchive.com> Choose "Apollo Image Gallery" for images and "Apollo Multimedia" for videos.

<http://nix.nasa.gov/> Choose "Space Flights" then "Apollo."

<http://grin.hq.nasa.gov/> Choose "Browse by Subject," then "Space," then "Apollo Spacecraft" or "Lunar Module."

<http://science.ksc.nasa.gov/history/apollo/apollo.html>

<http://spaceflight1.nasa.gov/gallery/>

<http://kids.yahoo.com/directory/Science-and-Nature/Astronomy-and-Space/Human-Spaceflight/Apollo-Missions>

6. Print both the picture of the Apollo spacecraft atop a Saturn V rocket on the launch pad and the diagram of the Apollo spacecraft atop a Saturn V rocket showing each of the components (provided at the end of the lesson).

## Procedure

1. Begin the lesson with the paper airplane contest. If there are any students who did not learn to make another paper airplane, tell them to use one of the patterns or books for making their plane.

## Lesson 6

### Procedure

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2. Direct the students' attention to the newsprint, notebook paper, and other paper for making paper airplanes. Tell them to choose a piece of paper to make their second airplane. Ask them to consider making it out of a different paper from the one made for the wind tunnel test. Give the students 5–10 minutes to complete their second plane.
3. Have the students gather their wind tunnel planes. Tell them to name each of their planes and label them with their own names as well as the name of the plane. This will help to identify their planes among so many similar planes.
4. Assign the students to their groups and identify the recorder of each group.
5. Next, explain the procedure for the contest. Tell the students that they will fly each of their planes twice. In the four test flights, each owner will fly his/her own plane, another student will mark where it lands, and the third student in the group will be responsible for helping to measure the distance. The owner of the plane should record the name of the plane and the distance of each test flight in his/her own log. From these four test flights, each student will choose which of the two planes to fly in the group contest.
6. Then, the contest will begin within each group. Each student will fly his/her plane once, the qualifying flight, and the recorder of each group will record the distance. Teachers will use these distances to identify the 6–8 longest flights in the class to compete for the longest flight award.
7. If students seem uncertain about these instructions, the teacher should model this procedure and record the distance of each flight on the board. Explain again that each student should fly both of their planes twice (thus, four test flights) and record the data in their logs. From these flight tests, students should choose the plane they want to enter the contest. Be sure to point out that only one flight will be allowed in the group contest (the qualifying flight).
8. Then, ask them to gather their logs, pencils, and planes, and proceed to the flying area.
9. Assign each group an area, or lane, for flying. Then circulate among the groups as the test flights and the qualifying flights take place.
10. When the qualifying flights are complete and their distances are recorded, call the class to attention. Determine the 6–8 longest flights from all of the flights in the class. (One group may have several winners, but another group may have none.) Let these students fly their planes once to determine a winner. Instruct the students to observe the planes in flight and take note of the designs of the planes that flew successful flights.
11. As each plane is flown, be sure to record the name and distance of each participant. Give all of the winners a ribbon and the final winner a special ribbon.
12. When the class returns to the room, write the winner's name in the blank of the sign or banner, and display it in the room a few days before letting him/her take it home.
13. Then, conduct a brief discussion of the paper airplane flights. Ask them to share their observations about which designs remained in flight the longest or flew the longest and straightest flights. What details about the winner's plane caused it to win? Tell them that the ability to observe and interpret data is an important characteristic of an engineer.
14. Have the students do simple computation problems using the distances of their own flights. They could find
  - the difference between the shortest and longest flight of each plane;
  - the difference between the shortest and longest flight of both planes;
  - the difference between the longest flight of their plane and the longest flight of the winner's plane;
  - the sum of the flights of each plane; and/or
  - the sum of the flights of both planes.

15. Next, direct the students' attention to the timeline. Ask them to take out their logs and turn to the student text for Lesson 5, "Humankind in Space." Using the text, have them recall the important events that need to go on the timeline. Fill in the dates from 1958–1966, the year of the last Gemini flight. Use the Timeline Date Sheet to corroborate the students' answers and to get the exact dates.
16. Explain that, after Gemini, NASA and the whole U.S. (and even the world) were focused on landing a human on the Moon. Introduce the students to the story of Project Apollo, the program that took NASA's astronauts to the Moon. Use picture books, pictures, and computer videos to bring this story to life and help them to understand the marvelous accomplishments of the U.S. Moon missions.
17. For a video of the *Apollo 11* launch and of Neil Armstrong's first step on the Moon, search <http://www.apolloarchive.com>. Choose "Apollo Multimedia" for videos. Find "[video of Apollo 11 liftoff](#)" and "[Armstrong steps onto the Moon's surface](#)." This site has other videos of Project Apollo as well.
18. Show the picture of the Apollo spacecraft atop a Saturn V rocket on the launch pad. Explain that a Saturn V was needed for the powerful thrust it took to break free from Earth's gravity.
19. Show the diagram of the Apollo spacecraft atop a Saturn V rocket showing each of the components, and explain each Apollo component: the command module, the service module, and the lunar module. Tell the students that they will learn about the job of each module when they read about the Apollo Program, NASA's mission to the Moon, in Lesson 8.
20. Remind the students that their Orion/Altair designs and presentations are due tomorrow (or the next class period). Ask if they have any questions about tomorrow's presentations.

Lesson 6

*Apollo 17* on the launch pad

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*Apollo 17* on the launch pad

## The Apollo Spacecraft and the Saturn V Launch Vehicle

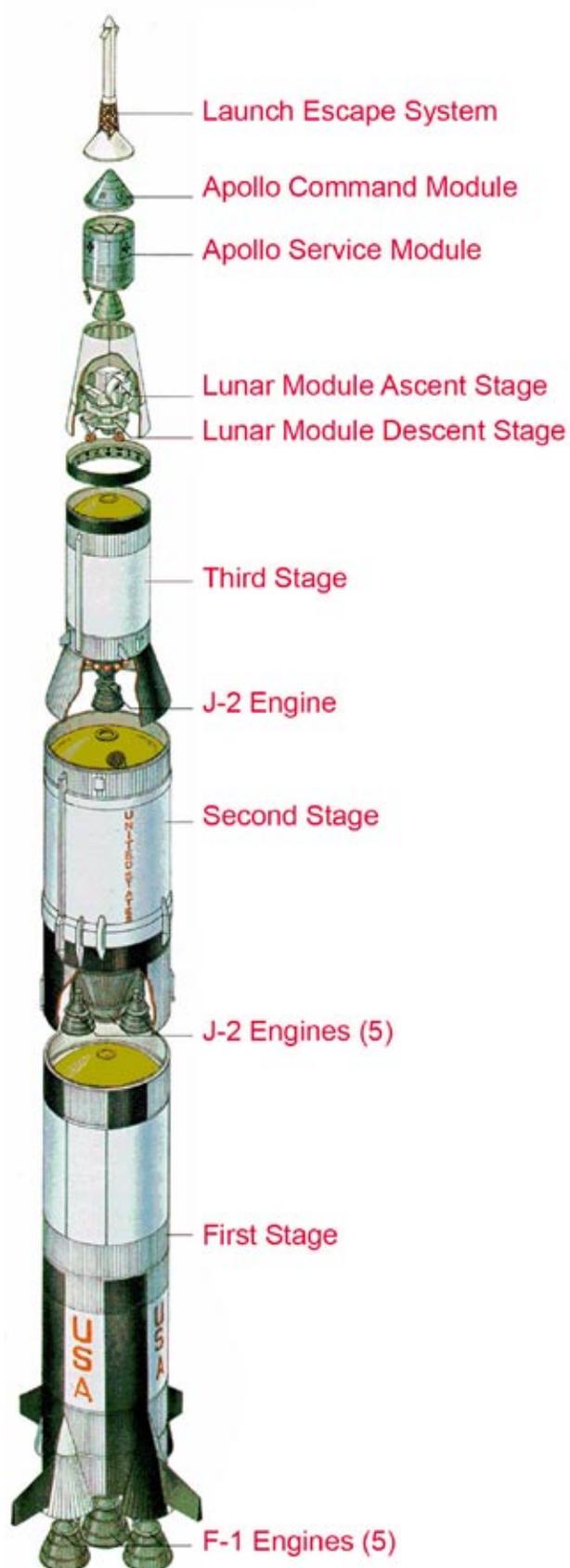






Image credit: NASA

## Lesson 7 – The Orion and Altair Design Presentations

**Lesson prep time:** 5–10 minutes (for gathering materials and following pre-lesson instructions)

**Teaching time:** 1–1½ hours

### Objectives

1. The students will present their designs of Orion and Altair, explain the function of each of the labeled parts, and describe their plans for using the vehicles for a human lunar landing.
2. The students will participate in their pretend roles as members of the board of directors for their company as they listen to the presentations of their classmates and question and/or make suggestions to the presenter about his/her design.
3. The students will identify the best components of each design to be used in a final Orion and Altair composite design.



Image credit: NASA

Shown is an artist's concept of the Ares I Crew Launch Vehicle and the Ares V Cargo Launch Vehicle. Ares I will carry the Orion Crew Exploration Vehicle with an astronaut crew to Earth orbit. Ares V will deliver large-scale hardware to space. This includes the Altair lunar lander, the Earth Departure Stage, materials for establishing an outpost on the Moon, and the vehicles and hardware needed to extend a human presence beyond Earth orbit.

## National Standards

### Science

- Abilities necessary to do scientific inquiry – S2Ea, S2Ma
- Understandings about scientific inquiry – S2Eb, S2Mb
- Properties of objects and materials/Properties and changes in matter – S3Ea, S3Ma
- Position and motion of objects/Motion and forces – S3Eb, S3Mb
- Objects in the sky – S5Eb
- Abilities of technological design – S6Ea, S6Ma
- Understanding about science and technology – S6Eb, S6Mb
- Risks and benefits – S7Md
- Science and technology in local challenges/in society – S7Ee, S7Me
- Science as a human endeavor – S8Ea, S8Ma

### Mathematics

- Use visualization, spatial reasoning, and geometric modeling to solve problems – M11
- Understand measurable attributes of objects and the units, systems, and processes of measurements – M12
- Apply appropriate techniques, tools, and formulas to determine measurements – M13
- Formulate questions that can be addressed with data and collect, organize, and display relevant data to answer them – M14
- Develop and evaluate inferences and predictions that are based on data – M16
- Problem solving – M18
- Communication – M20

### Language Arts

- Standards 4, 5, 6, 7, 8, 11, and 12 (See the Language Arts Matrix on page 12.)

### Technology – ISTE

- Students are proficient in the use of technology – I2
- Students develop positive attitudes toward technology uses that support lifelong learning, collaboration, personal pursuits, and productivity – I5
- Students use productivity tools to collaborate in constructing technology-enhanced models, prepare publications, and produce other creative works – I7
- Students use telecommunications to collaborate, publish, and interact with peers, experts, and other audiences – I8
- Students use a variety of media and formats to communicate information and ideas effectively to multiple audiences – I9
- Students use technology to locate, evaluate, and collect information from a variety of sources – I10
- Students employ technology in the development of strategies for solving problems in the real world – I14

### Technology – ITEA

- Relationships among technology and other fields – T3
- Cultural, social, economical, and political effects – T4
- Effects of technology on the environment – T5
- Role of society in the development and use of technology – T6
- Influence of technology on history – T7
- Attributes of design – T8
- Engineering design – T9
- Role of troubleshooting, research and development, inventions and innovation, and experimentation in problem solving – T10
- Apply the design process – T11
- Use and maintain technological products and systems – T12
- Assess impact of products and systems – T13
- Transportation technologies – T18

## Materials

- Student designs and presentations of Orion and Altair
- A quiet location for the presentations
- A stand or place for the students to display their posters as they make their presentations
- Any necessary pieces of equipment for technology uses

## Pre-lesson Instructions

1. Teachers may want to invite the school principal, a pilot, or an engineer from the community to listen to the Orion and Altair presentations. An invited guest adds a tone of seriousness to these presentations and helps to prepare students for real-life situations.
2. Be sure that the location (classroom or elsewhere) of the presentations provides a quiet and undisturbed environment and that every student in the audience can see and hear the speaker clearly.

## Procedure

1. Prepare the class for listening to the Orion and Altair design presentations. Tell them that when they become adults, they will probably have to present their research on many occasions. Encourage them to pretend that they are presenting their designs to a board of directors and they should try and persuade this board that their design is the best.
2. Instruct the class to be professional and positive as they listen to the presentations, ask questions, and make suggestions. Tell them that they may have a job one day that requires them to be knowledgeable members of an audience listening to their co-workers' presentations and reports.
3. After all of the designs have been presented, conduct a discussion to identify the best components for an Orion

and Altair design. Some examples might be to identify the best ideas for the crew living quarters, method or area for storing food, cockpit, experiment section, etc. Some of the students may want to incorporate the best ideas to design another Orion and Altair. Perhaps extra credit could be given for this project.

4. Find a place in the room or hall to display the Orion and Altair designs.





## Lesson 8 – The Giant Leap for Mankind

**Lesson prep time:** 30 minutes (for gathering materials and following pre-lesson instructions)

**Teaching time:** 1½ hours (Language Arts, Science, Math, Technology)

### Objectives

1. The students will read a selection to develop an understanding of the Apollo Program and realize what a tremendous accomplishment it was to take humans to the surface of the Moon and back.
2. The students will become familiar with the contributions of the National Aeronautics and Space Administration (NASA).
3. The students will recognize that the competition of the space race with the Soviet Union helped to push the U.S. space program forward.
4. The students will identify the name and function of each component of the Apollo/Saturn spacecraft.
5. The students will understand that becoming an astronaut requires hard work and, perhaps, the ultimate sacrifice.
6. The students will research NASA's technology transfers and prepare a presentation of this research.
7. The students will perform calculations to determine the distance from the Earth to the Moon using the diameters of different planets.



During each Moon landing, the Apollo crew set up experiments on the lunar surface.

## National Standards

### Science

- Abilities necessary to do scientific inquiry – S2Ea, S2Ma
- Understandings about scientific inquiry – S2Eb, S2Mb
- Properties of objects and materials/Properties and changes in matter – S3Ea, S3Ma
- Position and motion of objects/Motion and forces – S3Eb, S3Mb
- Objects in the sky – S5Eb
- Changes in Earth and sky/Earth in the solar system – S5Ec, S5Mc
- Abilities of technological design – S6Ea, S6Ma
- Understanding about science and technology – S6Eb, S6Mb
- Risks and benefits – S7Md
- Science and technology in local challenges/in society – S7Ee, S7Me
- Science as a human endeavor – S8Ea, S8Ma
- History of science – S8Mc

### Mathematics

- Compute fluently and make reasonable estimates – M3
- Understand patterns, relations, and functions – M4
- Use mathematical models to represent and understand quantitative relationships – M6
- Analyze change in various contexts – M7
- Investigate, describe, and reason about the results of subdividing, combining, and transforming shapes – 8EUc
- Specify locations and describe spatial relationships using coordinate geometry and other representational systems – M9
- Use visualization, spatial reasoning, and geometric modeling to solve problems – M11
- Understand measurable attributes of objects and the units, systems, and processes of measurements – M12
- Apply appropriate techniques, tools, and formulas to determine measurements – M13

- Formulate questions that can be addressed with data and collect, organize, and display relevant data to answer them – M14
- Problem solving – M18
- Communication – M20

### Geography

- How to use maps and other geographic representations, tools, and technologies to acquire, process, and report information from a spatial perspective – G1
- How to use mental maps to organize information about people, places, and environments in a spatial context – G2
- The physical and human characteristics of places – G4
- How culture and experience influence people's perceptions of places and regions – G6
- The patterns and networks of economic interdependence on Earth's surface – G11
- How human actions modify the physical environment – G14
- How physical systems affect human systems – G15
- How to apply geography to interpret the past – G17

### Language Arts

- Standards 1, 3, 4, 5, 6, 7, 8, 11, and 12 (See the Language Arts Matrix on page 12.)

### Technology – ISTE

- Students are proficient in the use of technology – I2
- Students develop positive attitudes toward technology uses that support lifelong learning, collaboration, personal pursuits, and productivity – I5
- Students use productivity tools to collaborate in constructing technology-enhanced models, prepare publications, and produce other creative works – I7
- Students use telecommunications to collaborate, publish, and interact with peers, experts, and other audiences – I8
- Students use a variety of media and formats to communicate information and ideas effectively to multiple audiences – I9
- Students use technology to locate, evaluate, and collect information from a variety of sources – I10

- Students employ technology in the development of strategies for solving problems in the real world – I14

### Technology – ITEA

- Relationships among technology and other fields – T3
- Cultural, social, economical, and political effects – T4
- Effects of technology on the environment – T5
- Role of society in the development and use of technology – T6
- Influence of technology on history – T7
- Attributes of design – T8
- Engineering design – T9
- Role of troubleshooting, research and development, inventions and innovation, and experimentation in problem solving – T10
- Use and maintain technological products and systems – T12
- Assess impact of products and systems – T13
- Transportation technologies – T18

### Materials

- A copy of the student text for Lesson 8, “The Giant Leap for Mankind” for each student
- Picture books on the Apollo Program
- A few computer videos of the Apollo Program (the same as Lesson 6)
- Pictures of the *Apollo 11* crew, the first footprint on the Moon, “The Blue Marble,” and “The Near Side of Earth’s Moon” (provided at the end of the lesson)
- A diagram of the Apollo spacecraft atop the Saturn V rocket showing each of the components (the same as in Lesson 6)
- Student calculators

### Pre-lesson Instructions

1. Duplicate enough copies of the student text for Lesson 8, “The Giant Leap for Mankind” for each student. Punch holes so that students can insert these in their logs.

2. Choose a few videos of the Apollo Program. Use the following Web sites:

<http://www.apolloarchive.com> Click “Apollo Multimedia” for videos.

<http://spaceflight1.nasa.gov/gallery/> Under “NASA Programs” on the right, choose “Apollo.” Under “Multimedia Types” choose video.

<http://kids.yahoo.com/directory/Science-and-Nature/Astronomy-and-Space/Human-Spaceflight/Apollo-Missions> Under “Top Categories” choose “Videos.”

3. Print the pictures of the *Apollo 11* crew, the first footprint on the Moon, “The Blue Marble,” and “The Near Side of Earth’s Moon” (all provided at the end of the lesson).
4. Have available the diagram of the Apollo spacecraft atop the Saturn V rocket showing each of the components (the same diagram as in Lesson 6).
5. Duplicate enough copies of the homework assignment “Technology Transfers” for each student. Punch holes so that students can insert this in their logs.

## Procedure

1. Ask the students to share what they have learned so far about NASA's Apollo Program, America's first Moon missions.

2. Show the students the photos of the first footprint on the Moon and "The Blue Marble." Tell them that of the thousands of photographs taken during the Apollo Program these are two of the most famous. The footprint was made during the *Apollo 11* mission and belongs to Astronaut Neil Armstrong, the first human to step on the Moon. "The Blue Marble" photo was taken by the crew of *Apollo 17*, the last mission to the Moon.



3. Find Cape Canaveral, Florida, on a U.S. map. Remind the students that all of the U.S. crewed spacecraft today are launched from the Cape at Kennedy Space Center (KSC). This coastal area of Florida is known as the "Space Coast." Hundreds of companies that support the space business are located here, and millions of visitors come here each year to visit the KSC Visitors Center. The operations of KSC are miles away from public lands and the warm climate allows launches year round. (Later, students will learn how climate affects the launches. They will learn of the *Challenger* disaster caused by the failure of an O-ring seal on the Solid Rocket Booster. Exceedingly low air temperatures were thought to be the major contributor of the failure of the O-ring to seal properly.)

4. Introduce and teach the vocabulary in the same manner that you would for any guided reading. Use the diagram of the Apollo spacecraft atop the Saturn V rocket as you teach these vocabulary words.

5. Show the pictures of the *Apollo 11* crew and point out Astronauts Neil Armstrong and Edwin "Buzz" Aldrin.

Identify them as the first and second men to walk on the Moon. Identify the third astronaut as Michael Collins and tell them that they will read about what he did on this mission.



6. Show the diagram of the Apollo spacecraft on the Saturn V. On the board, write "command module – CM, lunar module – LM, service module – SM, command service module – CSM." Once again, point out each of these components on the diagram and tell the students that each part will be identified by its initials in the student text.

7. Write the word "lunar" on the board and show the picture of the first footprint on the lunar surface. Emphasize that the word "lunar" always refers to the Moon. Also remind the students of the meaning of the word "orbit." Tell them that they will be reading about an Earth orbit and a lunar orbit in the student text.

8. Distribute the copies of the student text for Lesson 8 "The Giant Leap for Mankind" and instruct the students to insert these in their logs.

9. Read and discuss "The Giant Leap for Mankind" as you would any guided reading. As the class discusses the text, question their understanding and encourage their questions.

10. On the first page of the student text, have the students observe the picture above the title and ask them to identify what they see. Tell them that this is a composite picture and the astronaut is Alan Shepard, the first American in space. It is hard to see, but he has a golf club in his hand. Then, ask them if they recognize the video that is being shown in the bottom picture. This is the actual footage of Neil Armstrong stepping off the ladder onto the Moon's surface. The crew had positioned the TV camera before coming down the ladder to capture the first steps for the whole world to see on live television.

11. As the class reads “Apollo/Saturn Gets Ready for Launch” and “Apollo/Saturn Journeys to the Moon and Back,” be sure to stop and read the captions for the pictures. These give a step-by-step description of Apollo/Saturn from its assembly to its recovery from the ocean.

12. After reading the first two paragraphs in “Preparing for the Landing,” you may want to take a few minutes to discuss the *Apollo 1* tragedy. Let the students express their feelings about this accident. You may want to explain that astronauts know that hard work and risks are associated with their jobs, yet every astronaut feels that their mission with NASA is worth it.

13. Finish reading the section “Preparing for the Landing.” Review how each mission is numbered. *Apollo 1* was named to honor the crew that lost their lives in the fire. There was no mission designated for *Apollo 2* or *3*. *Apollo 4*, *5*, and *6* were all uncrewed missions. The student text will explain the *Apollo 7–17* crewed missions.

14. The students may enjoy a brief discussion about nicknames. Ask them if they have ever nicknamed their bicycles or other vehicles. The astronauts of the *Apollo 9–17* missions nicknamed the command module and the lunar module. Below is a list of their nicknames. The command module is listed first, and the lunar module is listed second.

- Apollo 9 – Gumdrop and Spider*
- Apollo 10 – Charlie Brown and Snoopy*
- Apollo 11 – Columbia and Eagle*
- Apollo 12 – Yankee Clipper and Intrepid*
- Apollo 13 – Odyssey and Aquarius*
- Apollo 14 – Kitty Hawk and Antares*
- Apollo 15 – Endeavor and Falcon*
- Apollo 16 – Casper and Orion*
- Apollo 17 – America and Challenger*

15. Before reading the next section, “The *Eagle* Has Landed,” show the class “The Near Side of Earth’s Moon” chart. Read the caption that tells how the

areas of the Moon got their names. Then, point out the Mare Tranquillitatis, the Latin name for the Sea of Tranquility. This is where the *Apollo 11* LM, *Eagle*, landed.



16. You may need to remind the students that the LM had two parts: a descent stage and an ascent stage. Both stages landed on the Moon, of course. When the astronauts finished their work on the Moon, they reboarded the ascent stage. On takeoff, the descent stage remained on the Moon, and the ascent stage blasted back up to join the CSM. (Since the Moon’s gravity is 1/6 of the Earth’s gravity, less thrust is needed.) Since the SM is jettisoned into space just before entering Earth’s atmosphere, the CM is the only part of Apollo/Saturn that comes back to Earth. These seven command modules are in museums across the country. For their exact locations, see <http://nssdc.gsfc.nasa.gov/planetary/lunar/apolloloc.html>

17. FYI: The present plans for a 2020 Moon landing will use technology similar to the Apollo Program for landing a man on the Moon. As students understand how these vehicles worked and interacted in the Apollo Program, they will be current with NASA’s planning for a future Moon and Mars mission which will be discussed in Lessons 18 and 19.

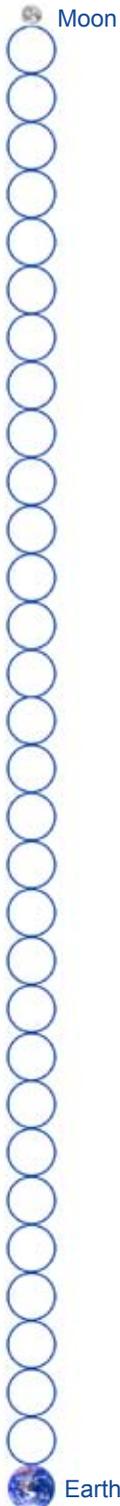
18. Finish reading and discussing “The *Eagle* Has Landed.” After reading the section “More Moon Missions,” show the short video of “The Hammer and the Feather” found at [http://nssdc.gsfc.nasa.gov/planetary/lunar/apollo\\_15\\_feather\\_drop.html](http://nssdc.gsfc.nasa.gov/planetary/lunar/apollo_15_feather_drop.html). Then, finish reading the selection.

19. Tell the students that they will be making and launching their own rockets in the next lesson.

20. Distribute the homework assignment “Technology Transfers” to the students. Answer any questions the class may ask. Encourage them to find NASA technology transfers that affect their lives.

### Math Activity: How far away is the Moon?

1. Distribute the calculators and draw the following sketches on the board.



2. Tell the class that the Moon is 238,855 miles (384,400 kilometers) from the Earth. With a diameter of approximately 8,000 miles (3,475 kilometers), it would take about 30 Earths set side-by-side to cover the distance from the Earth to the Moon. Using a calculator and the diameters of the other planets, determine approximately how many of each planet set side-by-side would be needed to reach the Moon from Earth. Write the diameters of each of the planets in miles and/or kilometers on the board.

- Mercury – 3,032 mi. (4,879 km)
  - Venus – 7,521 mi. (12,104 km)
  - Mars – 4,222 mi. (6,794 km)
  - Jupiter – 88,846 mi. (142,984 km)
  - Saturn – 74,898 mi. (120,536 km)
  - Uranus – 31,764 mi. (51,118 km)
  - Neptune – 30,776 mi. (49,538 km)
  - Pluto (included here, but not considered a planet by the International Astronomical Union) – 1430 mi. (2302 km)
- For more details on Pluto, search <http://solarsystem.nasa.gov/planets/profile.cfm?object=Pluto>.

3. Now, have the students create and name their own planet. Using paper and pencil, tell the students to draw a determined number of circles, from 10–50, in a line. Using the distance to the Moon from Earth of 238,855 miles (384,400 kilometers) and the number of circles, ask them to calculate the diameter of their planets in miles and kilometers.

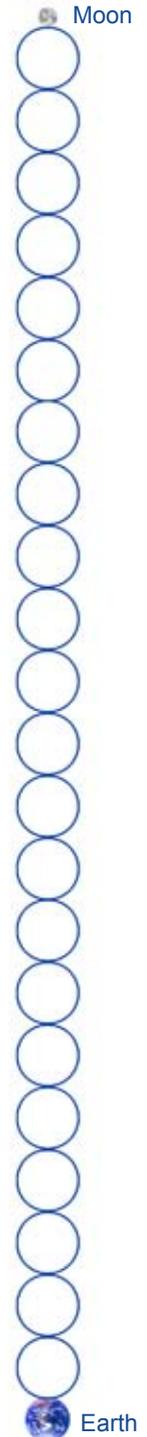
4. Use the example to the right as a demonstration. It takes 22 of the planet Kaboom to span between Earth and Earth's Moon.

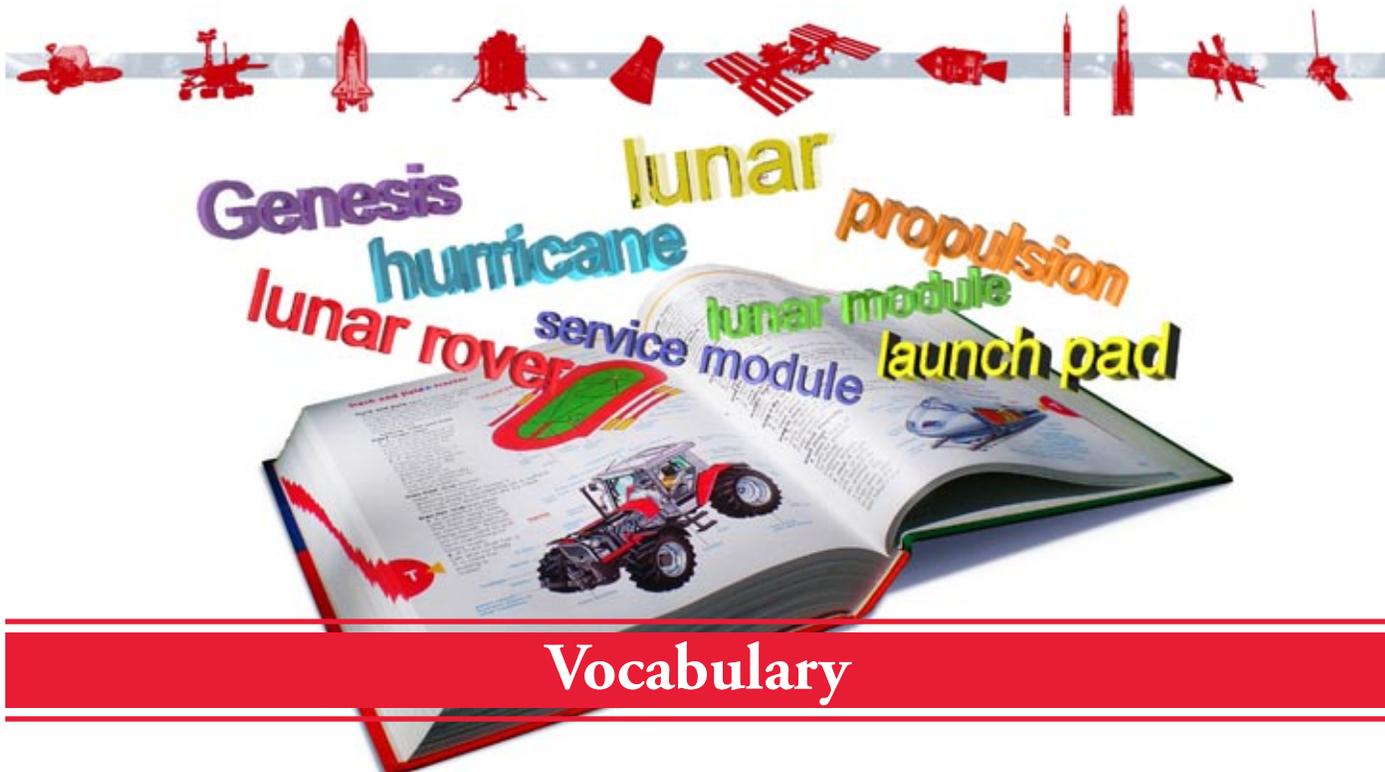
5. In the example of 22 circles, the diameter of Kaboom would be

$$238,855 \div 22 = 10,857 \text{ miles}$$

or

$$384,400 \div 22 = 17,472.7 \text{ kilometers.}$$





## Vocabulary

**ascent stage** – the part of the lunar module (LM) that contains the crew cabin; an equipment bay; the ascent rocket engine and fuel to return to the lunar orbit; and the components for instrumentation, guidance, navigation, life support, and communications



The ascent stage of the LM



The CM over the lunar surface

**command module (CM)** – the part of a space vehicle designed to carry the crew, the chief communications equipment, and the equipment to travel through Earth’s atmosphere. The Apollo CM remained in lunar orbit and did not descend to the lunar surface

**descent stage** – the part of the LM that contains the landing gear; landing radar antenna; descent rocket engine and fuel to land on the Moon; and several cargo compartments used to carry surface tools, lunar sample collection boxes, some parts of the lunar rover, a surface television camera, and supplies for an extended lunar visit by the crew



The descent stage is the bottom half of the LM and includes the “legs.”



**device** – a piece of equipment or a mechanism designed or invented for a particular purpose

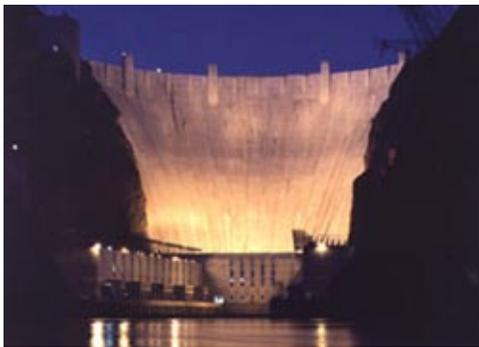
**EVA** – means extravehicular activity; an activity or maneuver performed by an astronaut outside a spacecraft in space

**forecasting** – predicting a future condition or occurrence; calculating in advance a prediction, especially as to the weather

**Genesis** – the first book of the Bible

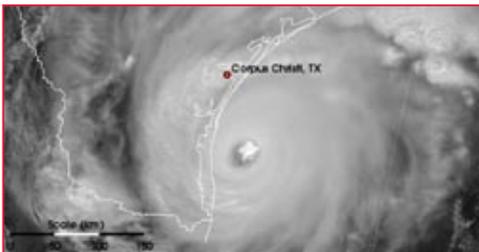


Astronaut Harrison Schmitt during an EVA



Hoover Dam

**Hoover Dam** – The Hoover Dam is one of the world's largest dams. The concrete dam on the Colorado River stands 726 feet (221 meters) high and is 1,244 feet (379 meters) long. The 17 turbine generators generate a maximum of 2,080 megawatts (1 megawatt = 1 million watts) of hydroelectric power.



A GOES image of Hurricane Bret as it nears the Texas coast

**hurricane** – a cyclone formed in the tropics with winds of 74 miles (119 kilometers) per hour or greater, usually accompanied by rain, thunder, and lightning

**launch pad** – the base or platform from which a rocket or space vehicle is launched



The launch pad for the Saturn V launch vehicle and the Apollo spacecraft



**lunar** – of or relating to the Moon

**lunar module (LM)** – the part of a space vehicle designed to carry astronauts from the command module to the surface of the Moon and back; also known as the lunar lander



The LM *Eagle* begins its descent to the Moon.



The lunar rover was used by astronauts on the *Apollo 15, 16, and 17* missions.

**lunar rover** – an electric vehicle designed to operate in the low-gravity vacuum of the Moon and to be capable of traversing the lunar surface

**maneuver** – a clever or skillful move or action; a movement or procedure involving skill and dexterity

**plaque** – a flat plate, slab, or disk inscribed as a memorial or marker

**propulsion** – a driving or propelling force; forward motion of a body produced by the forces resulting from the rearward discharge of a jet of fluid



Each Apollo mission to the Moon left behind a plaque affixed to the leg of the LM's descent stage. This plaque was left by the crew of *Apollo 17*, the last Moon mission.



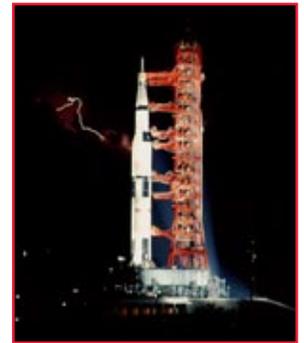
**Saturn (rockets)** – Saturn I, the first U.S. rocket specifically developed for spaceflight, was a two-stage vehicle. The Saturn I and the **Saturn IB** placed uncrewed and crewed versions of Apollo spacecraft into Earth orbit and launched uncrewed satellites. **Saturn V** was the largest launch vehicle ever built by the U.S. and was used to launch the lunar missions of Apollo and the Skylab Space Station.



The launch of a Saturn I rocket



The launch of a Saturn IB rocket



The Saturn V rocket on the launch pad

**service module (SM)** – the part of a space vehicle containing oxygen, water, fuel cells, fuel tanks, and the main rocket engine

**technology transfer** – the National Aeronautics and Space Administration’s (NASA’s) technology transfer is the process by which space technology developed by NASA is transferred to businesses for another purpose. As NASA scientists and engineers explore the frontiers of aeronautics and space, they find that their work will have applications to problems on Earth, so the technology is transferred to the public and is known as a technology transfer. Sometimes NASA uses the word “spinoff” and defines a spinoff as a commercialized product that incorporates NASA technology or NASA “know-how” and benefits the public.



The CM and SM are joined to become the CSM.

**vehicle** – something used to transport persons or goods



**Wright Brothers** – Wilbur and Orville Wright invented and flew the world’s first controlled, heavier-than-air, powered airplane, the *Wright Flyer I*, in 1903.

The Wright Brothers flew the *Wright Flyer I* at Kitty Hawk, North Carolina.



## The Giant Leap for Mankind

### We're Going to the Moon!

Are you aware of the famous words spoken by Astronaut Neil Armstrong as he made the first footprint on the Moon? On July 20, 1969, after a four-day and almost seven-hour trip, he climbed out of the **lunar module (LM)** and started down the ladder. As his foot stepped off the bottom rung of the ladder and touched the **lunar** soil, he spoke the words, **“That’s one small step for man, one giant leap for mankind.”** Armstrong was right. What a giant leap of progress it represented! The **Wright Brothers** had flown the first airplane only 65 years earlier. Now, a human had walked on

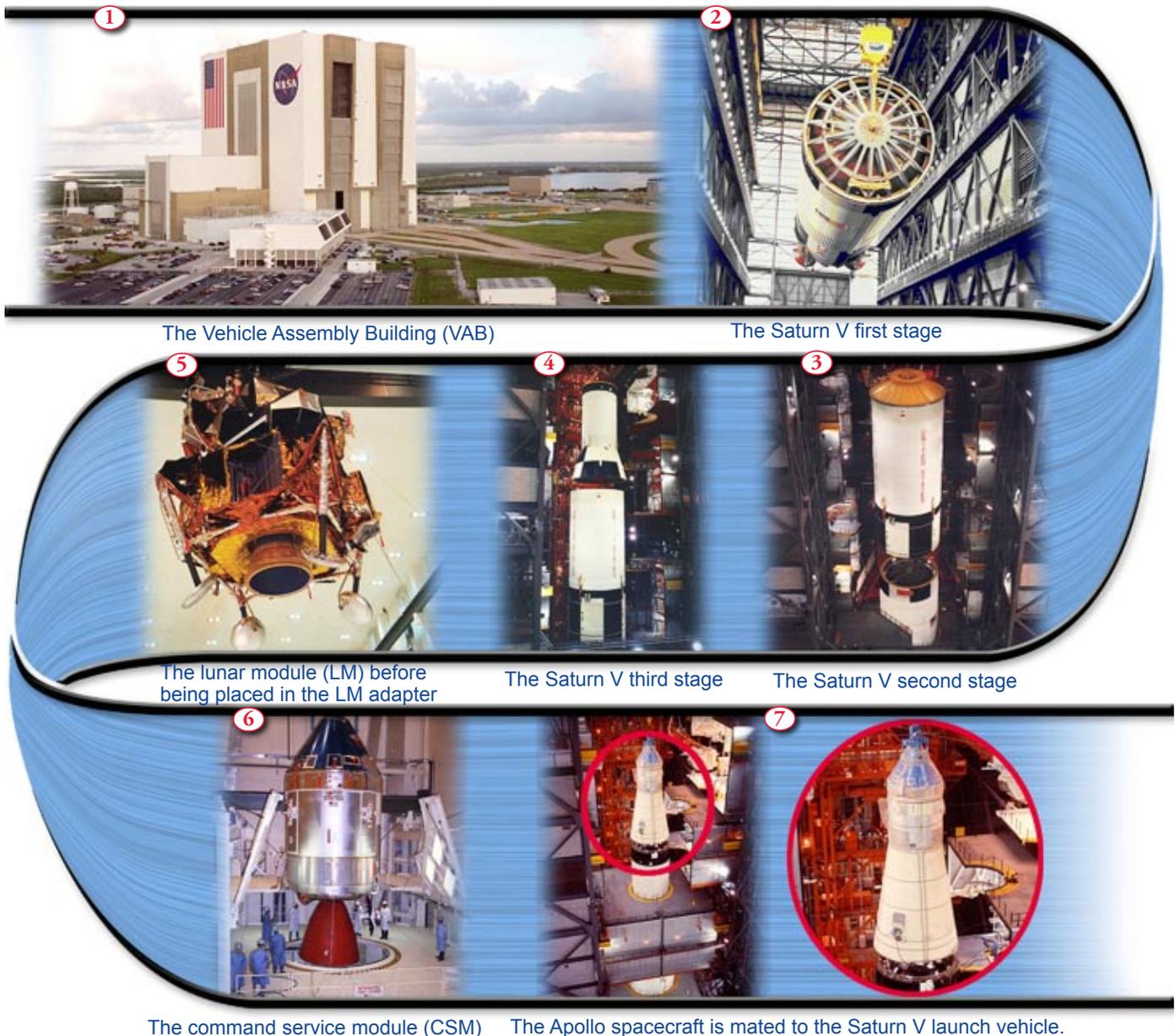


A television camera captured the first step on the Moon for a world-wide audience.



## Apollo/Saturn Gets Ready for Launch

Getting Astronauts Armstrong and Aldrin to the Moon was no easy task. When President Kennedy called for the U.S. to put Americans on the Moon by the end of the decade, no rocket in the country could take a craft to the Moon. But Wernher von Braun and his team at Marshall Space Flight Center answered the challenge. The result was the towering **Saturn V**, the most powerful vehicle ever designed. At 363 feet (110.6 meters) high, it stood 60 feet taller than the Statue of Liberty. At liftoff, the three-stage rocket had the power equal to the energy created by 85 **Hoover Dams**.



1

2

The Vehicle Assembly Building (VAB)

The Saturn V first stage

5

4

3

The lunar module (LM) before being placed in the LM adapter

The Saturn V third stage

The Saturn V second stage

6

7

The command service module (CSM)

The Apollo spacecraft is mated to the Saturn V launch vehicle.



Stacked on top of the Saturn V rocket was the Apollo spacecraft. First on the stack was the LM, the part that would take the astronauts to the surface of the Moon. The LM was made up of a **descent stage** and an **ascent stage** to land and take off from the Moon. Next on the stack was the **service module (SM)** for the support systems and the **propulsion**. On the top of the stack, but still below the launch escape system, sat the **command module (CM)**. It contained the crew compartment and the controls. Apollo/Saturn was more than giant as it sat on the **launch pad**.



The crawler transporter

The mobile launcher



Ready to launch

Traveling up to pad 39-A.

The rollout



The Apollo 11 crew heads to the launch pad.

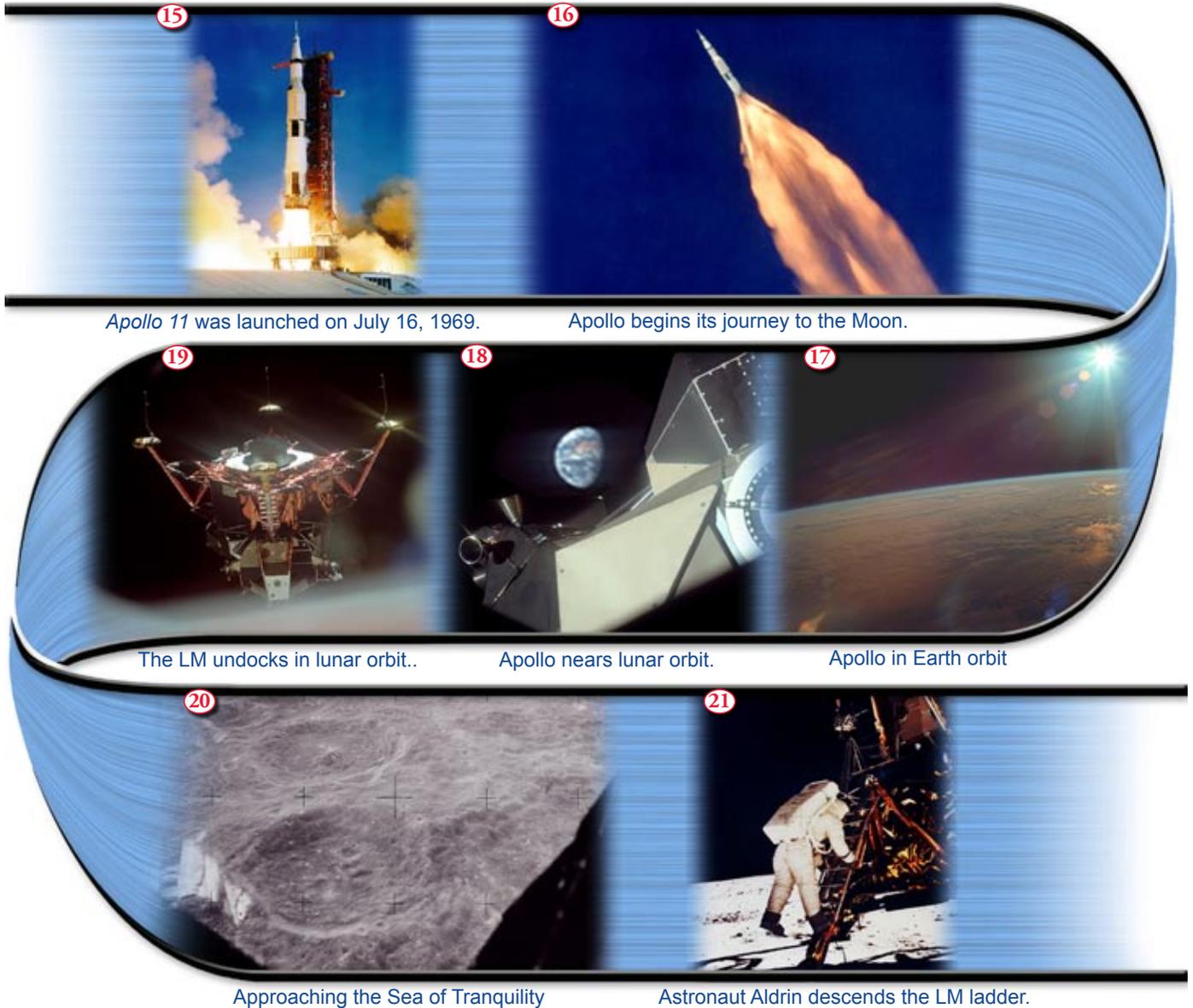
The Apollo 11 crew crosses the access walkway.

Lesson 8

Student Text—The Giant Leap for Mankind



After a Moon launch, the first two stages of the Saturn V dropped off as the propellant tanks were emptied. About 11 minutes after launch, the third stage of the rocket fired itself and the Apollo spacecraft into Earth orbit. Once all systems were ready, the third stage fired again, and the Apollo stack left Earth orbit on a course to the Moon. After some time, the command service module (CSM) separated from the third stage, turned around, and docked with the LM. After a secure docking, the CSM pulled the LM from the third stage. Then, the Apollo spacecraft continued until they were captured by the Moon's gravity. In lunar orbit, two of the astronauts got into the LM, separated from the CSM, and descended to the surface of the Moon. The CSM, with the third astronaut aboard, remained in lunar orbit.





Each Apollo crew stayed on the lunar surface for different time periods, allowing them to perform a series of tasks. Once these tasks were completed, the crew boarded the ascent stage of the LM. At launch, they ascended to dock with the CSM in lunar orbit. Finally, the astronauts climbed back into the CM, ditched the LM into space, and began the journey home. Nearing the Earth, the crew would ditch the SM and parachute into the ocean where a recovery team would be waiting. The CM, carrying the astronauts, would be the only part of the whole stack that would come back to Earth.





## Preparing for the Moon Landing

There had been many years of hard work leading up to landing a human on the Moon. Project Gemini had tested several **maneuvers** needed for a successful Moon landing. Then, the first Apollo flights were flown. The uncrewed flights of *Apollo 4*, *5*, and *6* tested ideas and systems. They also tested the rockets and the spacecraft.



An exterior view of the *Apollo 1* CM after the fire

In January 1967, NASA was getting ready for the first crewed Apollo flight when a terrible thing happened. Three astronauts were seated in the CM practicing for a launch. Suddenly, a fire broke out inside the module, and the smoke killed the men before the rescuers could get to them. This mission was later called *Apollo 1* to honor the men who died in the fire.

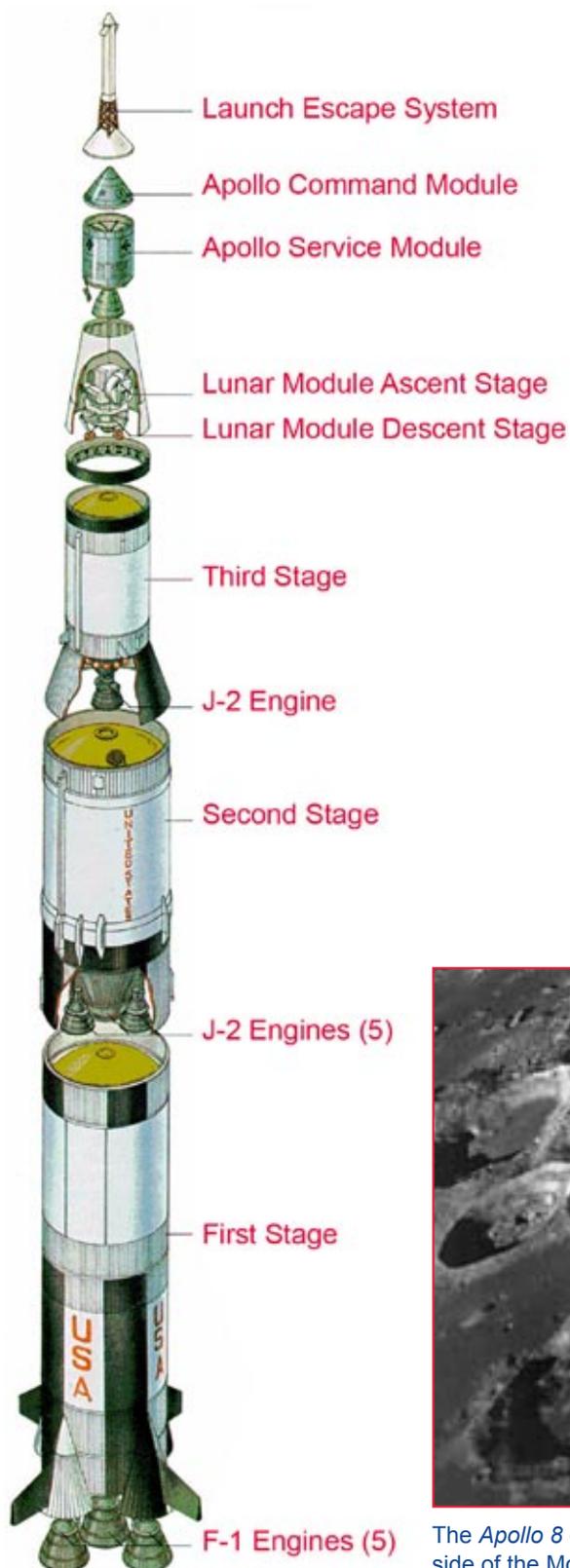


The *Apollo 1* crew trains in the CM. Seated from left to right are Astronauts Roger B. Chaffee, Edward H. White, and Virgil I. (Gus) Grissom.

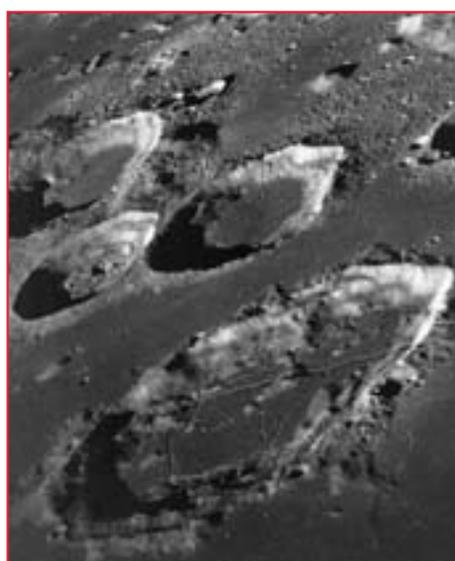


After 18 months of investigations and redesign, a safer CM was built. In October 1968, NASA tried again. The crew of *Apollo 7* made the first crewed flight test. NASA used a **Saturn IB** rocket to launch *Apollo 7* into Earth's orbit where it stayed for 11 days. The flight tested the CSM, the spacesuits, and even the food. It also tested the mission support crew and ground equipment. The *Apollo 7* crew gave us our first live TV show from space.

The *Apollo 7* crew arrives aboard the recovery ship *U.S.S. Essex*. Standing from left to right are Astronauts Walter M. Schirra, Donn F. Eisele, R. Walter Cunningham.



On December 21, 1968, the Saturn V rocket carried its first Moon-bound crew into space. The *Apollo 8* mission was history's first crewed flight to another planetary body. On Christmas Eve, the *Apollo 8* astronauts became the first humans to orbit the Moon. Looking back at the Earth and being filled with emotion on that special evening, the astronauts made a live television broadcast as they orbited the Moon. They showed pictures of the Earth and Moon as seen from lunar orbit. Jim Lovell shared his personal thoughts as he spoke these words: "The vast loneliness is awe-inspiring, and it makes you realize just what you have back there on Earth." They ended the broadcast with the crew taking turns reading from the book of **Genesis**. Frank Borman then added, "And from the crew of *Apollo 8*, we close with good night, good luck, a Merry Christmas, and God bless all of you, all of you on the good Earth." After ten orbits, the crew headed back to Earth. *Apollo 8* proved that a spacecraft could safely make the trip to and from the Moon.



The *Apollo 8* crew photographed the far side of the Moon.



The crew of *Apollo 8* witnessed the Earth rising as they gave a live TV broadcast.

## Lesson 8

### Student Text—The Giant Leap for Mankind



An Apollo 9 astronaut wore the new spacesuit during an EVA.

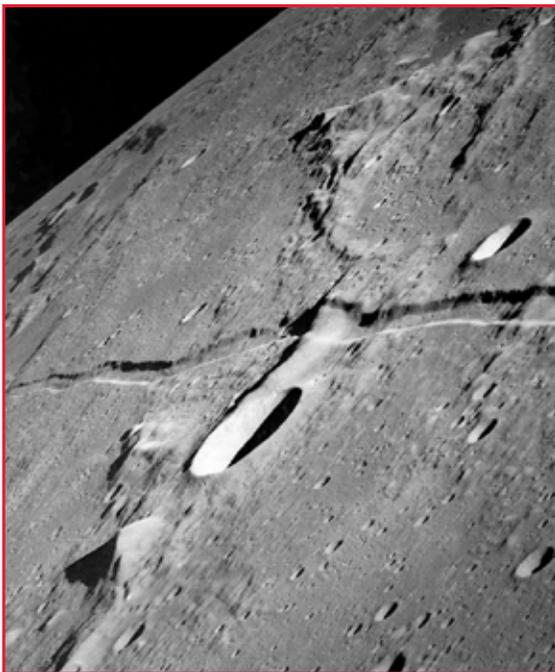


Apollo 9 Astronaut Dave Scott during an EVA



During the first crewed test of Apollo's LM, *Spider* was photographed by *Gumdrop*.

*Apollo 9* stayed in orbit around the Earth for 10 days. The crew practiced undocking and docking the LM with the CSM. It was the first crewed flight of the LM in space. The new spacesuit with its own life support system was tested during the first Apollo **extravehicular activity (EVA)** on this mission.



The Apollo 10 LM "Snoopy" descended to within 9 miles of the lunar surface.

*Apollo 10* was a complete dress rehearsal for a Moon landing, but it did not land on the Moon. *Apollo 10* was launched into Earth orbit with the Saturn V rocket. After three days, it entered the Moon's orbit. In lunar orbit, the LM separated from the CSM and started down to the Moon's surface. However, it did not land. The LM was only 9 miles (14 kilometers) from the lunar surface. Can you imagine how much the crew wanted to land right then? Instead, the crew took the LM back to lunar orbit to dock with the CSM. All three crew members flew safely back to Earth and splashed down in the Pacific Ocean. The whole world had watched much of the mission on TV. With the success of this mission, NASA knew it was ready to land the first human on the Moon. The people in the U.S. could not wait.

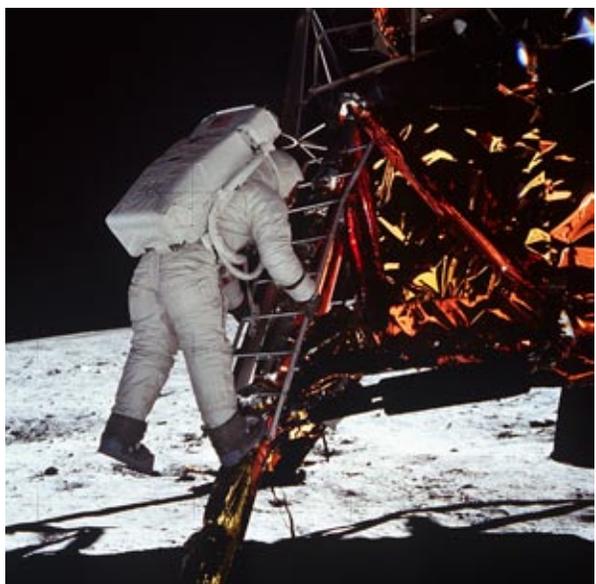


## The *Eagle* Has Landed

The wait was not very long. Two months later, on July 16, 1969, *Apollo 11* was launched at Kennedy Space Center. Four days later, the men at NASA's mission control in Houston were on the edge of their seats. The LM *Eagle* was flying above the Sea of Tranquility on the lunar surface, but it could not find a suitable place to land.



The Sea of Tranquility as viewed from the LM just after touchdown



Astronaut Edwin E. Aldrin, Jr., prepares to step on the Moon.

After searching the surface, the LM had only a few seconds of fuel left. Finally, mission control heard the words they had been waiting for: “Houston, Tranquility Base here. The *Eagle* has landed.” These words brought huge sighs of relief from the team before they all erupted in shouts of celebration! One of the controllers told the *Apollo 11* crew, “You got a bunch of guys about to turn blue; we’re breathing again.” The crew was safe on the Sea of Tranquility. The TV cameras showed the whole scene to the world. They watched the NASA workers celebrate. Then, they watched as Neil Armstrong stepped onto the lunar soil and gave us the famous words about the step and the leap. Armstrong’s famous footprint was soon joined by Buzz Aldrin’s.



Astronaut Michael Collins photographed *Eagle* from the CM.



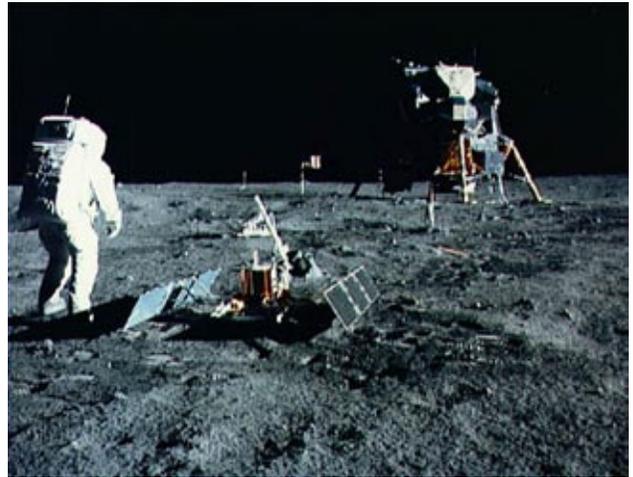
Mission Control during the *Apollo 11* EVA

## Lesson 8

### Student Text—The Giant Leap for Mankind



The two men explored the lunar surface for 2½ hours that day. They collected rock and soil samples, they set up experiments that would be left on the Moon, and they took pictures. These same tasks would be done by the next 10 astronauts who landed on the Moon. In all, 836 pounds of lunar rock and soil samples would be brought back to the Earth. Hundreds of experiments would be performed, and thousands of pictures would be taken. Armstrong and Aldrin also left behind a patch honoring the fallen *Apollo I* crew.



The Early Apollo Scientific Experiments Package is set up on the lunar surface.



Astronaut Neil Armstrong placed the first footprint on the Moon on July 20, 1969.

Once Armstrong and Aldrin had joined Collins in *Columbia*, the three men soared toward home. After a splashdown in the Pacific Ocean, America's first vision for space exploration was completed. In a post-flight press conference, Armstrong called the flight “a beginning of a new age.” Michael Collins looked farther out into time and space. He talked about journeys to Mars. Today, NASA is finally sharing his vision.

When the astronauts' work was finished, they entered the LM. After 21 hours on the lunar surface, the ascent stage launched the two men to lunar orbit. Once in lunar orbit, they docked with the CSM, *Columbia*. Michael Collins had been orbiting the Moon in the CSM since the *Eagle* had separated. While the *Eagle* was on the Moon, Collins was taking pictures and conducting experiments in *Columbia*. On later missions, the astronaut left behind in the CSM would also repeat these jobs.



Mission Control celebrated the successful conclusion of the *Apollo 11* mission.



## More Moon Missions

The U.S. made five more Moon landings. It would have been six more, but *Apollo 13* had to return to Earth before it got to the Moon. An oxygen tank in the SM exploded. We almost lost our three astronauts in that flight, but courage, brains, and teamwork brought the crew home. The movie *Apollo 13* was made about this heroic flight.

*Apollo 12* landed on the Ocean of Storms. Astronauts Pete Conrad and Alan Bean made two Moonwalks to collect rocks and set up experiments. Alan Shepard went to the Moon on *Apollo 14*. From the Moon's surface, he used his golf club to hit a golf ball. With so little gravity, the ball sped out of sight. Shepard reported that the ball sailed for “miles and miles.”



“The Hammer and the Feather” is an acrylic painting on Masonite by Astronaut Alan Bean.

The *Apollo 15* crew conducted the experiment of “The Hammer and the Feather” in front of the TV camera. Astronaut David Scott dropped a hammer and a falcon feather at the same time. In the absence of air, they both hit the lunar surface at the same time. The experiment proved that Galileo was right. In the absence of air resistance, all objects fall with the same velocity.



*Apollo 13*'s severely damaged SM after separation



*Apollo 12* Astronaut Al Bean descends the LM ladder.



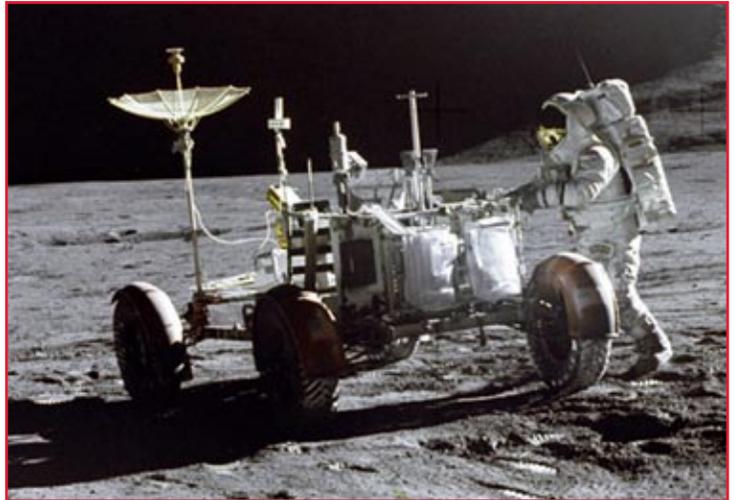
*Apollo 14* Astronaut Alan Shepard hits the first golf ball on the moon.

## Lesson 8

### Student Text—The Giant Leap for Mankind



The *Apollo 15* crew was the first to travel in the lunar roving **vehicle**. The **lunar rover** looked like a little car, but it could be folded up inside the LM. On earlier trips, the astronauts had just walked on the Moon's surface and could not venture too far from the LM. With the lunar rover, the astronauts unfolded the little vehicle and took off on the Moon's surface to cover a large area. The crews of *Apollo 16* and *17* also used a lunar rover to explore the Moon's surface.



Astronaut James Irwin works at the lunar roving vehicle during the *Apollo 15* mission.



High school and college students compete each spring in the Great Moonbuggy Race at the Space and Rocket Center in Huntsville, Alabama. See [http:// moonbuggy.msfc.nasa.gov](http://moonbuggy.msfc.nasa.gov).



An *Apollo 17* astronaut collects samples of rocks and rock chips with a lunar rake.



*Apollo 17* Astronaut Jack Schmitt

*Apollo 17* made the last flight to the Moon. Finishing the last EVA, Astronaut Eugene Cernan put the last footprint there as he stepped on the ladder to enter the LM for the final time. The *Apollo 17* crew returned to Earth in December 1972. Apollo was over. The space race had been won. The U.S. had proven to the world that they were the super superpower.

### Sharing the Wealth

Many books for both children and adults were written about the U.S. trips to the Moon. So much was learned and so many things were invented as a result of the Apollo Program and NASA research. NASA found 30,000 ways for the public to use what it had learned. These were known as **technology transfers**, and many of these changed our world.

NASA satellites changed the way people live. They allowed us to talk to someone across the ocean at



*Apollo 17* splashes down, ending the Apollo mission.





any time. We could see a live TV show from anywhere on Earth. We could even see astronauts in space as they talked to the ground crews on Earth. It had not been that long since television had come into people's homes, so this technology was really amazing to them. Meteorologists used satellites for weather **forecasting**. This was especially helpful for the people who lived in the paths of **hurricanes**. Scientists used satellite pictures to help study the Earth. These observations helped us to take better care of the planet. Some satellites are used by government agencies to spy on other nations.

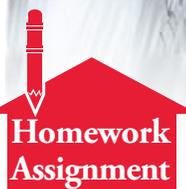
During the Apollo Program, NASA invented hundreds of medical **devices** to keep track of the astronauts' health. Many lives have been improved and saved because NASA passed these on to public health care. NASA also shared technology to help solve our energy problems. Even our flashlight batteries last longer because of Apollo technology.



Plaque affixed to the leg of the LM *Eagle* signed by President Nixon, Neil A. Armstrong, Michael Collins, and Edwin E. Aldrin, Jr.

If you went to the Moon today, you would see some things left there by the Apollo astronauts. Six descent stages of the LMs, each with a **plaque** on one of the legs, and three lunar rovers are sitting there. Many experiments, tools, and equipment were left behind. The U.S. flags from each mission are there too, and so are the footprints. You could read the plaque left by the *Apollo 11* crew. “Here Men From Planet Earth First Set Foot Upon the Moon. July 1969 A.D. We Came In Peace For All Mankind.”





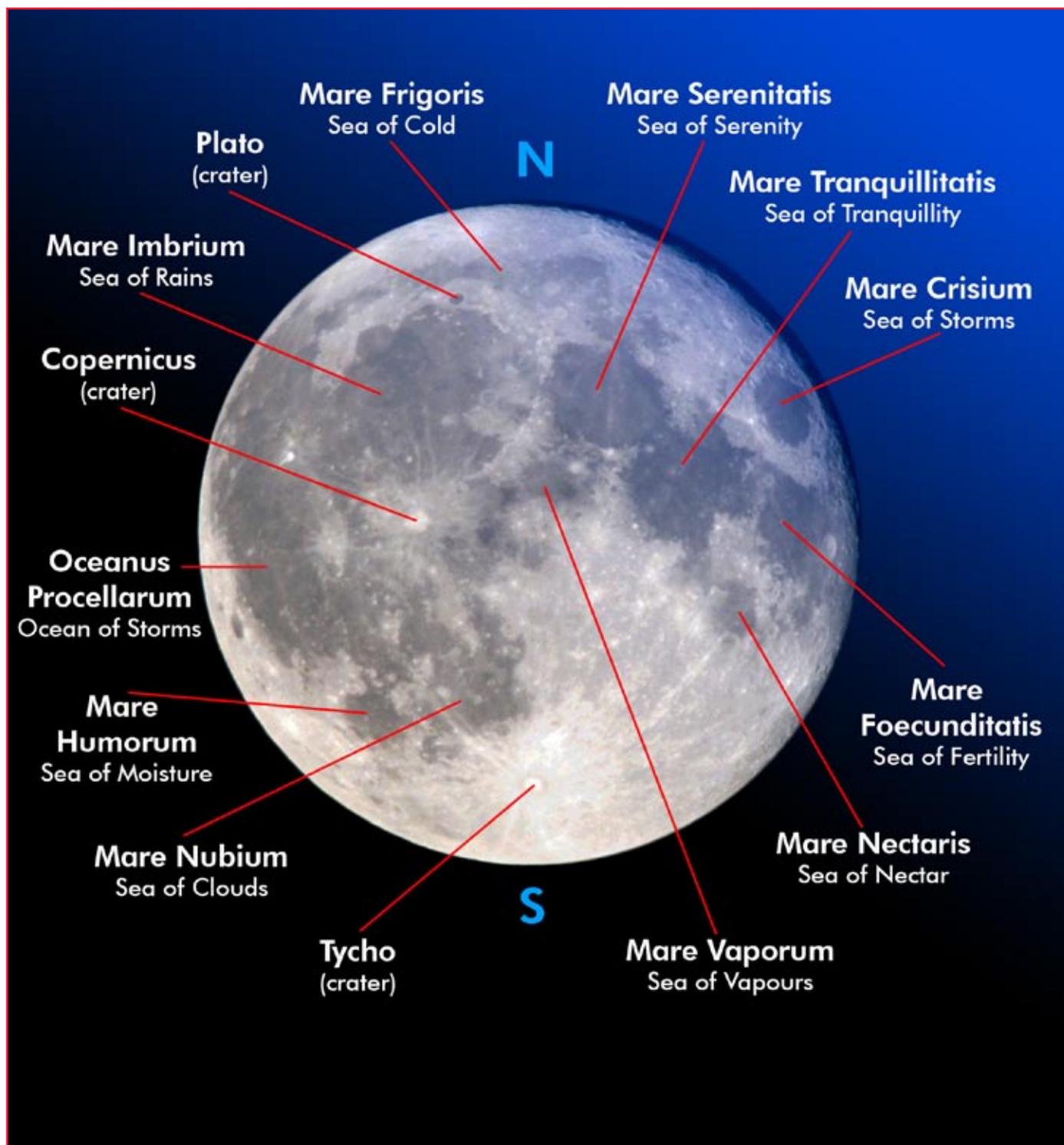
## Technology Transfers

Identify and describe in a one-paragraph report a technology transfer (sometimes known as a spin-off) given to the public by NASA. (Do not use Tang or Tempur®-Pedic mattress.) Be prepared to present your research to the class and provide a picture of the NASA technology transfer. Computers and Microsoft PowerPoint® presentations may be used, but printed copies must be made, as well. Use sources such as the Internet to research these products. Begin your research at <http://www.sti.nasa.gov/tto/>.

**Due date:** \_\_\_\_\_ (Due in two class periods)



The Blue Marble



The Near Side of Earth's Moon



*Apollo 11 Crew*  
Left to right: Astronauts Neil A. Armstrong, commander; Michael Collins, command module pilot;  
and Edwin E. Aldrin, Jr., lunar module pilot (May 1, 1969)



Astronaut Neil Armstrong placed the first footprint on the Moon on July 20, 1969.





## Lesson 9 – Rocket Power

**Lesson prep time:** 25–30 minutes (for gathering materials and following pre-lesson instructions)

**Teaching time:** 1½–2 hours (Language Arts, Science, Math, Technology)

### Objectives

1. The students will create a timeline showing the achievements of National Aeronautics and Space Administration (NASA) as the Agency competed with the United Soviet Socialist Republic (USSR) in the space race.
2. The students will understand the power of rockets as they read a short history of rockets

4. The students will visit a Web site to discover and/or review Newton's Three Laws of Motion.
5. The students will identify the uses of rockets.
6. The students will conduct experiments to demonstrate rocket liftoff and draw conclusions as they vary the procedure of the experiments.
7. The students will explain how Newton's Laws apply to their rockets.
8. The students will perform calculations to analyze data and graph the variations of an experiment.
9. The students will continue to research NASA technology transfers and prepare a presentation of this research.



A Titan IV Centaur rocket launch

*Photo credit: U.S. Air Force*

## National Standards

### Science

- Abilities necessary to do scientific inquiry – S2Ea, S2Ma
- Understandings about scientific inquiry – S2Eb, S2Mb
- Properties of objects and materials/Properties and changes in matter – S3Ea, S3Ma
- Position and motion of objects/Motion and forces – S3Eb, S3Mb
- Objects in the sky – S5Eb
- Changes in Earth and sky/Earth in the solar system – S5Ec, S5Mc
- Abilities of technological design – S6Ea, S6Ma
- Understanding about science and technology – S6Eb, S6Mb
- Risks and benefits – S7Md
- Science and technology in local challenges/in society – S7Ee, S7Me
- Science as a human endeavor – S8Ea, S8Ma
- History of science – S8Mc

### Mathematics

- Compute fluently and make reasonable estimates – M3
- Understand patterns, relations, and functions – M4
- Use mathematical models to represent and understand quantitative relationships – M6
- Analyze change in various contexts – M7
- Specify locations and describe spatial relationships using coordinate geometry and other representational systems – M9
- Use visualization, spatial reasoning, and geometric modeling to solve problems – M11
- Understand measurable attributes of objects and the units, systems, and processes of measurements – M12
- Apply appropriate techniques, tools, and formulas to determine measurements – M13
- Formulate questions that can be addressed with data and collect, organize, and display relevant data to answer them – M14
- Select and use appropriate statistical methods to analyze data – M15

- Develop and evaluate inferences and predictions that are based on data – M16
- Understand and apply basic concepts of probability – M17
- Problem solving – M18
- Reasoning and proof – M19
- Communication – M20

### Geography

- How to use maps and other geographic representations, tools, and technologies to acquire, process, and report information from a spatial perspective – G1
- The physical and human characteristics of places – G4
- How human actions modify the physical environment – G14

### Language Arts

- Standards 1, 3, 4, 5, 6, 7, 8, 11, and 12 (See the Language Arts Matrix on page 12.)

### Technology – ISTE

- Students are proficient in the use of technology – I2
- Students develop positive attitudes toward technology uses that support lifelong learning, collaboration, personal pursuits, and productivity – I5
- Students use productivity tools to collaborate in constructing technology-enhanced models, prepare publications, and produce other creative works – I7
- Students use telecommunications to collaborate, publish, and interact with peers, experts, and other audiences – I8
- Students use a variety of media and formats to communicate information and ideas effectively to multiple audiences – I9
- Students use technology to locate, evaluate, and collect information from a variety of sources – I10
- Students employ technology in the development of strategies for solving problems in the real world – I14

### Technology – ITEA

- Relationships among technology and other fields – T3
- Cultural, social, economical, and political effects – T4

- Role of society in the development and use of technology – T6
- Influence of technology on history – T7
- Attributes of design – T8
- Engineering design – T9
- Role of troubleshooting, research and development, inventions and innovation, and experimentation in problem solving – T10
- Apply the design process – T11
- Use and maintain technological products and systems – T12
- Assess impact of products and systems – T13
- Transportation technologies – T18

## Materials

- Timeline, Timeline Date Sheet, and blank entry cards
- A copy of the student text for Lesson 9, “Rocket Power” for each student
- Student logs
- A baseball (or another solid ball)
- World map
- U.S. map
- Picture of Robert Goddard with the 1926 liquid-fueled rocket (provided in Lesson 5)
- Computers
- Diagram of a rocket (included with student text)
- Calculators for each pair or group
- Graph paper
- The words to all of the verses of “The Star-Spangled Banner” (A Web site is provided for these verses.)
- Materials needed for constructing the 3–2–1 Pop Rockets for each pair or group:
  - Instruction sheet for making the 3–2–1 Pop Rockets
  - Two 9- by 12-inch sheets of colored construction paper
  - Plastic 35-mm film canister with an internal-sealing lid
  - Scissors
  - Clear plastic tape
  - 12-inch ruler
  - Compass for drawing a circle
  - Protractor

- Materials needed for the “Rocket Experiment 3–2–1 Pop”
  - A student copy of the “Rocket Experiment 3–2–1 Pop” for each group
  - A teacher copy of the “Rocket Experiment 3–2–1 Pop” for each adult
  - “Educator Information for the Rocket Experiment 3–2–1 Pop” sheet
  - Launch area with a high ceiling (at least 5 meters)
  - Table to be used as a launch pad
  - Measuring tape with English and metric units extending to at least 5 meters (16.4 feet)
  - Student-made rockets
  - Protective eyewear (safety glasses) for each member of the group
  - Water
  - Paper towels for clean-up
  - ½ effervescent tablet such as Alka-Seltzer® for each group (Have 10–12 extra tablets for class experiments.)

## Pre-lesson Instructions

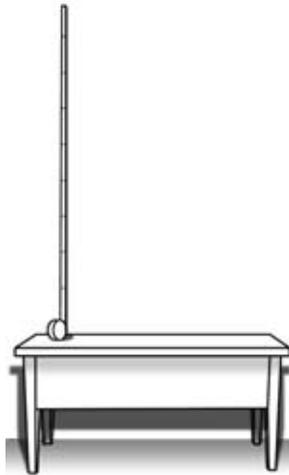
1. **Important: Begin collecting film canisters with internal-sealing lids several weeks ahead of this lesson. Some canisters may be found at a camera shop where photographic processing takes place. Some of these businesses recycle the canisters and may donate them for educational use. These are harder to find now that digital cameras are being used, but camera shops still carry these. Also, many portrait studios still use this type of film.**
2. Duplicate enough copies of the student text for Lesson 9, “Rocket Power” for each student. Punch holes so that students can insert these in their logs.
3. Divide the class into pairs or groups for the “Rocket Experiment 3–2–1 Pop.” The number of students in each group will be determined by the number of film canisters collected, but pairs are preferable.
4. Duplicate enough copies of the “Instructions for Making a 3–2–1 Pop Rocket” for each pair or group.

## Lesson 9

### Pre-lesson Instructions, Procedure

5. Duplicate enough student copies of the “Rocket Experiment 3–2–1 Pop” for each pair or group.
6. Duplicate enough teacher copies of the “Rocket Experiment 3–2–1 Pop” for each adult.
7. Gather the materials needed for constructing the rockets, and lay them out so that each group can collect what they need when it is time to construct the rockets.
8. Gather the materials needed for the experiment and be sure to have extra effervescent tablets, water, and enough safety glasses (one pair for each member of the group) ready to carry to the launch area.

9. Reserve an inside area with a high ceiling (at least 5 meters) for a launch area. Set up the launch area with the table and the measuring tape. Place the table beside the wall and attach the measuring tape vertically up the wall starting from the table surface. Mark each foot and meter vividly to help with judging the vertical distance. Remember that the rockets can shoot 5 meters (16.4 feet) or more in the air.



10. Read and become familiar with the “Educator Information for the Rocket Experiment 3–2–1 Pop.” (You may want to duplicate this.)
11. Ask another adult (parent volunteer) to attend the launch to judge and record the height of each rocket. One judge for all of the launches will give a more constant and impartial measurement of the height reached by the rockets. Consider locating this judge on a ladder or some other elevated position to provide a straight and accurate view of the highest altitude of the rocket.
12. Find all of the verses of “The Star-Spangled Banner.” (A Web site is provided to find these verses.)

## Procedure

1. Ask the students to take out their logs and turn to the student text for Lesson 8, “The Giant Leap for Mankind.” Then, direct their attention to “The Space Race” timeline. Have the students fill in the events from 1966–1972 using the student text for Lesson 8. Use the Timeline Date Sheet for the exact dates.
2. Teach the vocabulary in the same manner that you would for a reading assignment. Teach and elaborate on the proper nouns in the text. Find and pronounce Los Angeles, Wan-Hu, Sir Isaac Newton, Francis Scott Key, Robert Goddard, and Wernher Von Braun (pronounced “brown”), so the students will be familiar with them as they read. Find Fort McHenry (near Baltimore, Maryland) on the U.S. map.
3. Distribute the copies of the student text for Lesson 9, “Rocket Power” and instruct the students to insert these in their logs.
4. Before reading the text, give the class a short explanation of how spacecraft break free of Earth’s gravitational pull. Toss a baseball straight up into the air. Explain that the baseball keeps rising until Earth’s gravitational pull overcomes the force that is put into the throw, and it falls back to the ground. Toss the baseball harder to show that a greater force sends the ball higher, but Earth’s gravity will always cause the ball to fall back to the ground. Write the following on the board: 7 miles per second, or 25,000 miles per hour. Tell the students that, if you could toss the ball hard enough to reach a speed of 7 miles per second, or 25,000 miles per hour, the ball will keep going into outer space. This is known as the “escape velocity.” At that speed, the force of gravity can never be stronger than the force causing the ball to rise, so it will escape the gravitational bonds of Earth. Of course, the best baseball pitchers can only throw at a velocity of 95–100 miles per hour, which is why you don’t see baseballs in orbit. Rockets, however, can reach escape velocity to propel spacecraft beyond Earth’s gravitational pull and send them to other celestial bodies.

5. Read and discuss this selection as you would any guided reading activity. As the class discusses the text, question their understanding and encourage their questions.
6. After reading the first paragraph, stop and find New York and Los Angeles on a U.S. map. Tell the students that it would take about 5¼ hours airtime to make a non-stop flight between these two cities today. With the rocket speed mentioned, it would take less than 10 minutes for the trip.
7. When you get to the paragraph about Sir Isaac Newton, you may want to stop here and discuss his Three Laws of Motion. If so, a simple explanation of Newton's Laws of Motion suitable for younger students can be found at the following Web site: <http://teachertech.rice.edu/Participants/louviere/Newton/index.html>. This Web site is also included in the "Educator Information for the Rocket Experiment 3–2–1 Pop" and can wait to be viewed when the students are ready to perform the rocket experiments.
8. After reading the third paragraph, stop to find Great Britain (England, Scotland, and Wales) on the world map. Read the paragraph about the battle at Fort McHenry (actually a part of The Battle of Baltimore) and then teach the following about the War of 1812.
 

Many people in the U.S. are not aware of another war with Great Britain after winning the Revolutionary War. This war was declared by the United States on Great Britain, because the British were boarding American ships in order to return British deserters to their fleet, often taking American sailors as well. The Battle of Baltimore occurred in September of 1814, and the British retreated, having failed to take the city of Baltimore. By December, a peace treaty had been signed. However, since word traveled so slowly, a final battle was fought two weeks later in New Orleans, where Andrew Jackson defeated the British.
9. When the class reads the paragraph about Robert Goddard, show the picture of Robert Goddard, the father of modern rocket propulsion. For a video of a later Goddard launch, go to [http://en.wikipedia.org/wiki/Robert\\_Goddard](http://en.wikipedia.org/wiki/Robert_Goddard) and scroll down until you see "Robert Goddard footage."
10. Before reading the last paragraph of "Early Rockets," remind the students that they read about *Explorer I* in the student text for Lesson 4, "The Race Begins." Ask the students to recall what they learned about *Explorer I* from that text.
11. Before reading the section "Lots of Power," study the diagram of a rocket. Then, finish reading and discussing the selection. Ask the students to review how rockets have changed the world. Visit [http://www.aeronautics.nasa.gov/fap/students\\_1.html](http://www.aeronautics.nasa.gov/fap/students_1.html) to see how rockets work.
12. Tell the students that now they will be making and launching their own rockets. A short explanation of Newton's Laws of Motion should be given at this time. Use the "Educator Information for the 3–2–1 Pop Rocket" sheet to help explain them. A simple explanation of the three laws suitable for students can be found at the following Web site: <http://teachertech.rice.edu/Participants/louviere/Newton/index.html>.
13. Divide the students into pairs or groups. Distribute the "Instructions for Making the 3–2–1 Pop Rocket" and the "Rocket Experiment 3–2–1 Pop" to each pair or group.
14. Direct the students to collect the materials and follow the directions on the instruction sheet for making their rockets. Circulate among the groups and assist as needed.
15. When all of the rockets are assembled, instruct the class to turn to the "Rocket Experiment 3–2–1 Pop" sheet. Read the problem, and allow time for each group to write a hypothesis.
16. Gather the effervescent tablets, water, and safety glasses to take to the launch area.

## Lesson 9

### Procedure

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17. At the launch area, call up one group at a time to follow the experiment procedure. **Be sure the members of the group are wearing protective eyewear as they perform the launch.** If possible, have another adult judge and record the height of each launch. Tell the students to record this number on their worksheets.
18. After all of the groups have launched their rockets, vary the experiment as suggested in the Follow-up Activities. Record the height and conditions of each launch. These will be needed for a class discussion.
19. Ask the students to come up with other variations of the experiment. Perform the experiment several more times as a class to test their suggestions and questions. Record the height and conditions of each launch.
20. Return to the classroom to discuss the results of the student experiments and the variations of the activity. Instruct the students to fill in the results and conclusion on their experiment sheets. Use some of the discussion questions in the Educator's Information, and create other questions based on the class experiences.
21. Math activities using calculators (or not) might include the following:
  - Find the mean, median, and average heights of the rocket flights.
  - Find the difference between the highest and lowest height reached by the rockets. Discuss what may have caused this difference.
  - Find the difference between the height of your team's rocket and the highest height reached of all the rockets. Why did your team's rocket fly higher or lower?
  - Use graph paper to graph the heights of the rocket when different amounts of effervescent tablets were used. Let the class decide on the increments of each space on the graph.
22. Read aloud to the class all of the verses of "The Star-Spangled Banner." Find all four verses at the following Web site: <http://www.americanhistory.si.edu/starspangledbanner/the-lyrics.aspx>.
23. **Homework reminder:** Remind the students that their NASA technology transfer report is due the next class period.

## Educator Information for the Rocket Experiment 3–2–1 Pop

This experiment is a simple, but exciting, demonstration of Newton's Laws of Motion, so be prepared to teach these laws to your students. It is especially necessary that the students understand the Third Law of Motion which helps define thrust. The Third Law states: "For every action there is an equal and opposite reaction." For more information and a simple explanation of Newton's Laws of Motion suitable for students, find the following Web site: <http://teachertech.rice.edu/Participants/louviere/Newton/index.html>.

### Newton's Laws of Motion are as follows:

**First Law:** An object at rest will remain at rest, unless acted on by an unbalanced force. An object in motion continues in motion with the same speed and in the same direction unless acted upon by an external force. (This law is often called "the law of inertia.")

**Second Law:** Acceleration is produced when a force acts on a mass. The greater the mass (of the object being accelerated), the greater the amount of force needed (to accelerate the object).

**Third Law:** For every action, there is an equal and opposite reaction. In other words, if object A exerts a force on object B, then object B also exerts an equal and opposite force on object A. The statement means that, in every interaction, there is a pair of forces acting on the two interacting objects. The size of the force on the first object equals the size of the force on the second object. The direction of the force on the first object is opposite to the direction of the force on the second object. Forces always come in pairs.

### Newton's Laws of Motion in the Rocket Experiment

In this experiment, the rocket lifts off because it is acted upon by an unbalanced force (First Law). This is the force produced when the lid blows off the canister. The rocket travels upward with a force that is equal and opposite

to the downward force propelling the water, gas, and lid (Third Law). The amount of force is directly proportional to the mass of water and gas expelled from the canister and how fast it accelerates (Second Law).

### Class Discussion

Use the following questions for a class discussion after the experiments and Follow-up Activities have been performed:

1. How does the amount of water placed in the canister affect how high the rocket will fly?
2. How does the temperature of the water affect how high the rocket will fly?
3. How does the amount of the tablet used affect how high the rocket will fly?
4. How does the length of the body tube or the canister without the body tube (in other words, the weight of the rocket) affect how high the rocket will fly?
5. How do Newton's Laws of Motion apply to this rocket? (See explanation above.)

## Rocket Experiment 3–2–1 Pop (Teacher copy)



**Note to teacher:** These rockets can shoot 5 meters (16.4 feet) or more into the air.

**Problem:** What will happen when an effervescent tablet is added to a “rocket film canister” filled  $\frac{1}{3}$  full of water, and the lid is immediately snapped on tightly?

**Hypothesis:** The rocket will \_\_\_\_\_  
\_\_\_\_\_.

### Materials:

- Launch area with a high ceiling
- Table to be used as a launch pad
- Measuring tape with English and metric units extending to at least 5 meters (16.4 feet) attached vertically to one wall beginning from a table surface beside the wall
- Student-made rockets
- Protective eyewear (safety glasses)
- Water
- Effervescent tablet, such as Alka-Seltzer® ( $\frac{1}{2}$  for each student experiment)

### Procedure:

1. All participants should put on eye protection before beginning the experiment.
2. Have a parent volunteer or another adult positioned to judge the height of the launched rocket.
3. Hold the rocket upside down, and fill the canister  $\frac{1}{3}$  full of water.

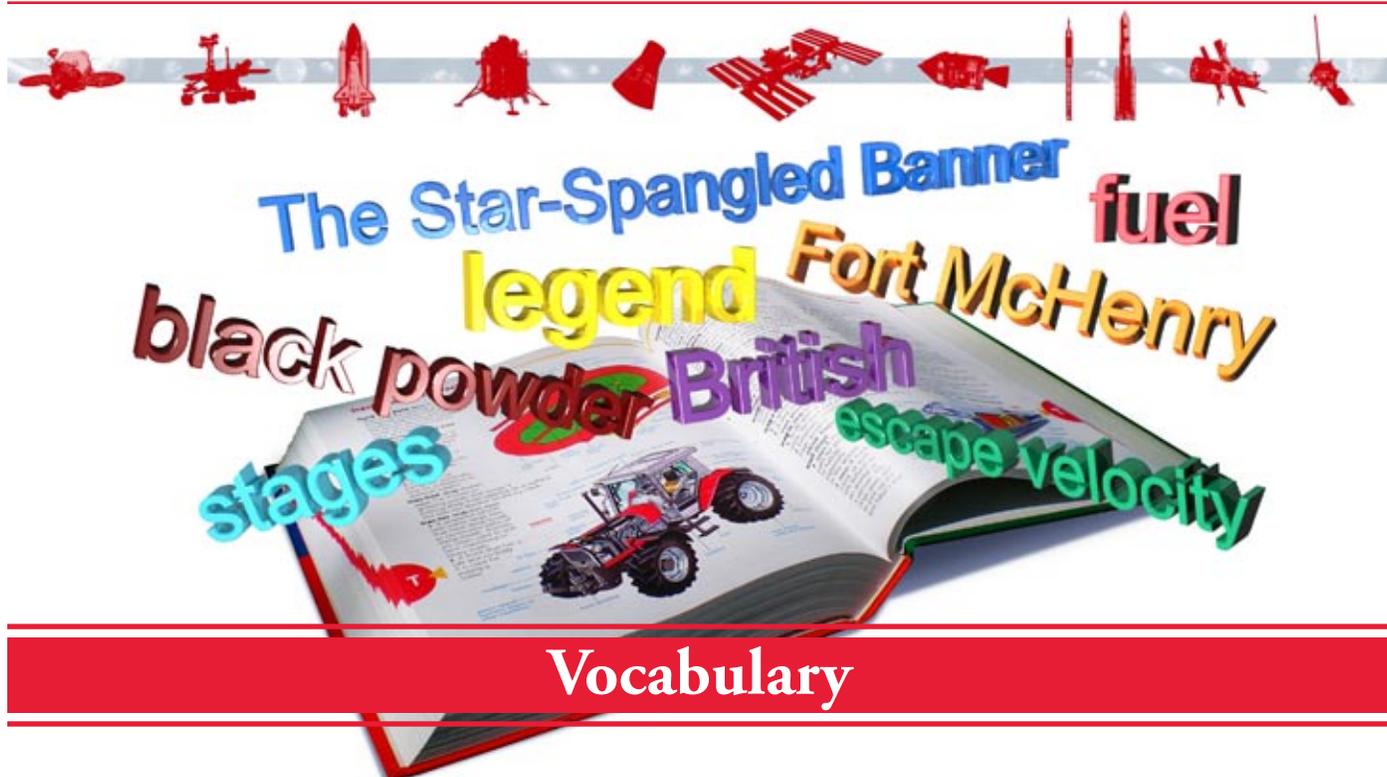
4. Moving very quickly, drop in  $\frac{1}{2}$  of an effervescent tablet, and immediately snap the lid on tight.
5. Stand the rocket in an upright position on the table.
6. Step back to observe.
7. Record the height of the launch. \_\_\_\_\_

**Results:** The rocket will lift up into the air.

**Conclusion:** The rocket is propelled according to the principle stated in Newton’s Third Law of Motion: “For every action there is an opposite and equal reaction.” Gas pressure builds inside the film canister due to the mixing of the effervescent (Alka-Seltzer®) and water, which releases carbon dioxide. This action continues until enough pressure builds to blow the canister apart from its lid. The reaction is the launch of the rocket.

### Follow-up Activities:

1. Vary the amount of water keeping the size of the tablet constant.
2. Increase and/or decrease the temperature of the water.
3. Increase the size of the tablet beginning with  $\frac{1}{4}$ , then  $\frac{1}{2}$ ,  $\frac{3}{4}$ , a whole tablet, and then  $1\frac{1}{4}$ ,  $1\frac{1}{2}$ , etc., if time allows. Be sure to keep the amount of water constant. (Try  $\frac{1}{2}$  full of water.)
4. Remove the rocket covering, and launch only the canister.



**bamboo** – a tropical, tall, woody, plant with strong hollow stems



Bamboo

**black powder** – a type of gunpowder consisting of a mixture of charcoal, sulfur, and potassium nitrate (saltpeter)



THE BRITISH PEOPLE ARE CITIZENS OF England, Scotland, and Wales.

**British** – the people of Great Britain (England, Scotland, and Wales)

**deep space** – the regions of space beyond the gravitational influence of Earth encompassing interplanetary and interstellar space

**escape velocity** – the minimum velocity that a moving body (such as a rocket) must have to escape from the gravitational field of a celestial body (as the Earth) and move outward into space



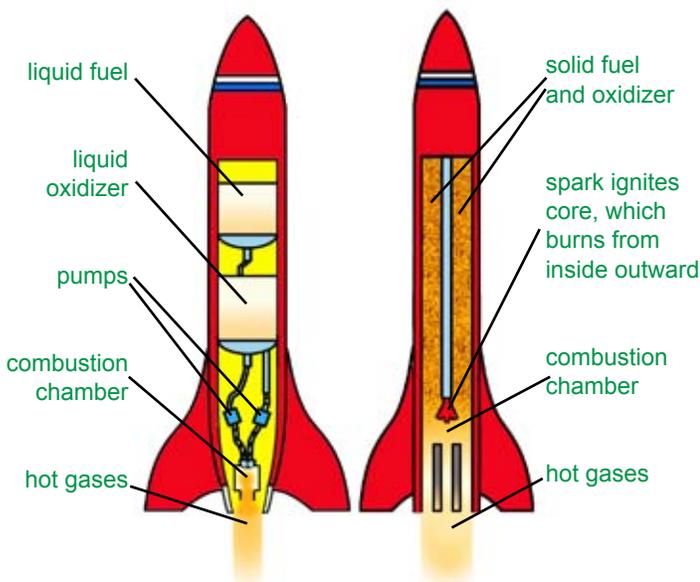
**Fort McHenry** – the site of a fort in Baltimore, Maryland, that was bombarded by the British fleet in 1814. The fort later became famous because Francis Scott Key wrote “The Star-Spangled Banner” after he witnessed the bombardment. Today, Fort McHenry is a major tourist attraction in Baltimore.



*Photo credit: NPS*

Fort McHenry is a major tourist attraction in Baltimore.

Liquid-Fuel Rocket    Solid-Fuel Rocket



Rocket fuel can be a liquid or a solid. As the fuel burns, it gives off gases that push the rocket forward.

**gases** – a fluid (such as air) that has no fixed shape and tends to expand without limit

**fuel** – a material (such as coal, wood, oil, or other materials) that can be burned to produce heat or power. Rockets use a solid fuel or a liquid fuel such as kerosene or liquid hydrogen.



As the fuel burns inside the rocket, hot gases are produced. The gases rush out the bottom of the rocket and create a force.



**gravity** – a force of attraction that makes objects fall toward Earth or any other celestial body

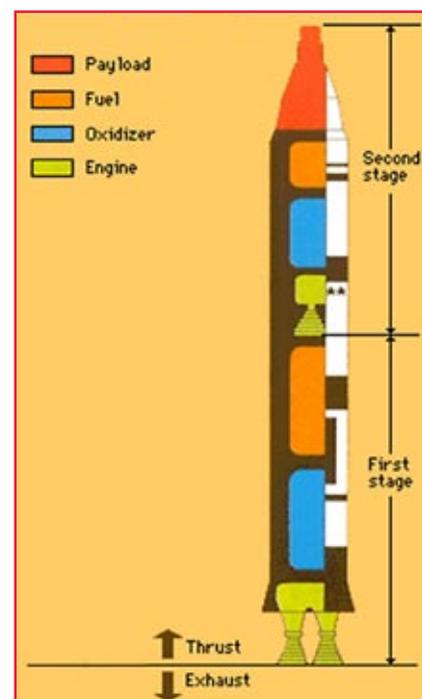
**legend** – a story handed down from the past whose truth is popularly accepted but cannot be checked



This Delta II rocket launched NASA's Gamma-ray Large Area Space Telescope (later renamed Fermi) spacecraft into Earth orbit.

**rocket** – a flying object that is pushed forward by the force of burning gases; a vehicle that obtains thrust by the reaction to the ejection of fast-moving exhaust gas from within its engine. The engine operates independent of the need for atmospheric air, therefore allowing it to operate in the vacuum of space.

**stages** – one of two or more sections of a rocket, each having its own fuel and engine



*Image credit: NASA*

A two-stage rocket carries a propellant and one or more rocket engines in each stage. The first stage launches the rocket. After burning its supply of propellant, the first stage falls away from the rest of the rocket. The second stage then ignites and carries the payload into Earth orbit or even farther into space.





*"And the rockets' red glare, the bombs bursting in air,  
Gave proof thro' the night, that our flag was still there."*

## Rocket Power

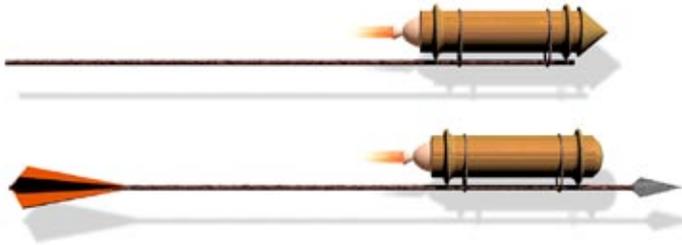
Can you imagine going 25,000 miles per hour? That's how fast our astronauts travel when they journey to **deep space**. A **rocket** must fly at this speed to escape the gravitational bonds of Earth. This is known as "**escape velocity**." At that speed, the force of **gravity** can never be stronger than the force causing the rocket to rise. If you could fly that speed on Earth, you would be traveling seven miles per second. You could travel from New York to Los Angeles in less than 10 minutes. You would be able to circle the Earth in one hour. Of course, you could not really do that. If you traveled at that speed you would end up in outer space. That is the power of rockets. Rockets can reach escape velocity. So we use rockets to send spacecraft beyond Earth's grasp to explore the other celestial bodies in our solar system. The airplanes that you and I travel on today do not use rockets, but one day they could.





## Early Rockets

Exactly when the first rockets appeared is unclear, but most historians credit the Chinese as the first people to use rockets. These first century rockets were **bamboo** tubes filled with **black powder**. When they were lit with fire, they would take off! At first, the Chinese used these as fireworks for religious festivals. Later, they attached the bamboo tubes to arrows and used this rocket power for weapons. Called fire arrows, they were a simple form of a solid-propelled rocket.



The Chinese began experimenting with the gunpowder-filled tubes. At some point, they attached bamboo tubes to arrows and launched them with bows.



A stick acted as a simple guidance system.



*Image courtesy of Wikipedia*

A Fourth of July fireworks display at the Washington Monument shows one use of rockets.

The Chinese also have a **legend** about an official named Wan-Hu. Wan-Hu made a rocket-powered flying chair to use for travel. He attached 47 rockets to the chair. At his command, his rocket assistants lit all of the rockets at the same time. When the smoke cleared, Wan-Hu and the flying chair were gone.

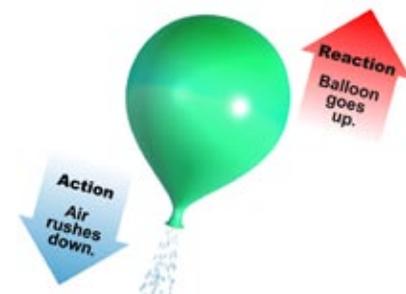


*Image credit: U.S. Civil Air Patrol/MSFC*

Wan-Hu and his rocket-powered chair



More than 300 years ago, an English scientist named Sir Isaac Newton tried to explain how rockets work. Newton had discovered and wrote about three laws of motion. His Third Law of Motion states that, “For every action there is an opposite and equal reaction.” This law helps us to understand **thrust**, but people who want to build rockets must understand all three laws.



For every action there is an opposite and equal reaction.

During the 18th and 19th centuries, rockets were used as weapons of war. The **British** used rockets against the United States in the War of 1812. The British fleet had sailed up the river to attack **Fort McHenry**, the U.S. fort near Baltimore. Before the battle, Francis Scott Key, an American lawyer, went on board one of the British ships to try to gain the release of an American doctor. They were held against their will and forced to watch British warships fire rockets on the fort all through the night. However, the Americans held the fort, and Key could see “by the rockets’ red glare” that “our flag was still there.” The Stars and Stripes remained on the flagstaff “thro’ the perilous fight.” The sight of the large American flag (30- by 42-feet) flying over Fort McHenry in “the dawn’s early light” inspired Francis Scott Key to write the poem “**The Star-Spangled Banner.**” The poem was put to music and became the U.S. national anthem in 1931.



*Photo credit: Smithsonian Institute*

The flag that flew over Fort McHenry after its bombardment by the British, is displayed at the National Museum of American History.



The bombardment of Fort McHenry

## Lesson 9

### Student Text—Rocket Power



Robert Goddard was an American who conducted experiments with rockets. He flew the first rocket to use liquid **fuel** in 1926. The rocket flew 41

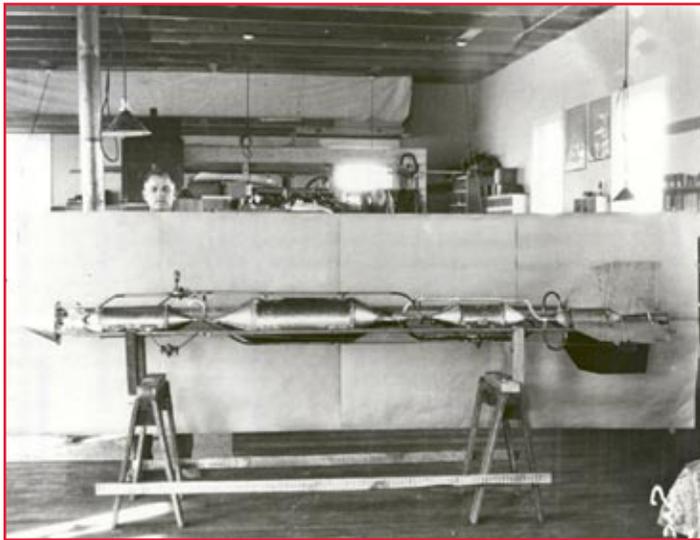
feet (12.5 meters) high and landed in a cabbage patch. This 2½-second event did not seem important, but later his rockets got bigger and flew higher. With the liquid-fueled rocket, a whole new era of rocket flight began.



Dr. Robert H. Goddard (1882–1945) stands with one of his earlier rockets. He was the first U.S. scientist to realize the potential of missiles and space flight.

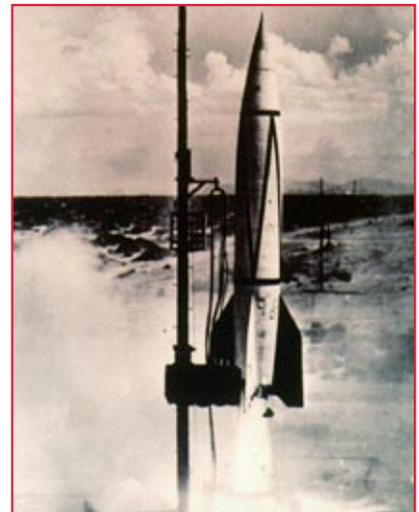


Goddard and his crew moved from Massachusetts to Roswell, New Mexico, to conduct research and perform test flights away from the public eye. This rocket was one of many that he launched in Roswell from 1930–1941.



This rocket was the first Goddard rocket to be used at Roswell, New Mexico (December 30, 1930). The rocket attained an altitude of about 2,000 feet and a speed of about 500 mph.

During World War II (WWII), a team of German scientists under the leadership of Wernher von Braun built and flew the V–2 rocket. This was the most advanced rocket of its time and was the first rocket capable of going into space. The Germans used the V–2s against England and other Allied



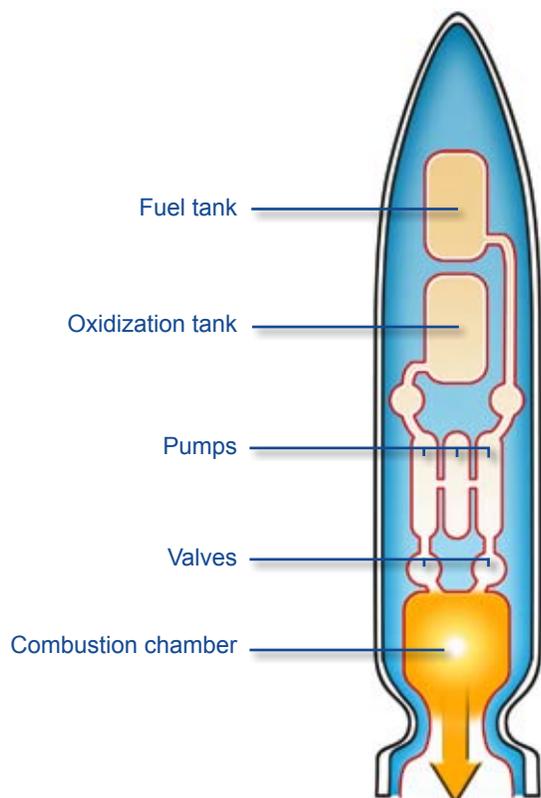
The 46-foot V–2 rocket used alcohol and liquid oxygen as fuel and could carry a 1,650 pound warhead 225 miles. It is estimated that, by the end of WWII, the Germans had fired nearly 3,000 V–2 weapons against England and other targets.



targets. They carried bombs that could wipe out whole city blocks. After the war, this team came to the U.S. to join American rocket scientists. They built the rocket that carried *Explorer I*, the first U.S. satellite, into orbit. Later, von Braun led the team that developed the Saturn V, the rocket that pushed Apollo towards the Moon.

### Lots of Power

A rocket has the most powerful engine of any flying machine. The fuel is burned inside the rocket, typically at the bottom. As the fuel burns, hot **gases** are produced. The hot gases press on the inside walls.



Dr. Wernher von Braun served as NASA Marshall Space Flight Center's (MSFC's) first director from July 1, 1960, until January 27, 1970. Following WWII, von Braun and his German colleagues arrived in the United States under Project Paperclip to continue their rocket development work. In 1950, von Braun and his rocket team were transferred to Huntsville, Alabama, to work for the Army's rocket program at Redstone Arsenal and later at NASA's MSFC. Under von Braun's leadership, Marshall developed the Saturn V launch vehicle which took Apollo astronauts to the Moon. This photo shows von Braun in his office at MSFC.

The gases also rush out the bottom of the rocket and create a force. The force presses on the inside of the rocket and downward. This force, called thrust, lifts the rocket off the ground.

## Lesson 9

### Student Text—Rocket Power



For a rocket to go into deep space, it must create enough thrust to escape Earth's gravitational pull. In this case the spacecraft must travel at 25,000 miles (40,234 kilometers) per hour, the escape velocity. To go into orbit, it must create enough thrust to balance Earth's gravity. A spacecraft must travel at 17,500 miles (28,164 kilometers) per hour, or 5 miles per second, to stay in orbit around the Earth. These speeds apply only to Earth. If a vehicle wants to orbit a

different celestial body, the speed to stay in orbit will change. This is because the pull of gravity of each celestial body is different. To orbit the Moon, a spacecraft must fly at 3,600 miles (5,794 kilometers) per hour or 1 mile per second. The slower speed is because the Moon has a lighter gravity pull.



A rocket and its fuel are heavy, so rockets are built in **stages**, or parts. This makes the lifting easier. Each stage has its own fuel supply. When a stage uses all of its fuel, it drops off. This makes the rocket lighter. Then, it can travel faster with less thrust.





The Saturn V rocket at the Davidson Center for Space Exploration

*Photo credit: U.S. Space and Rocket Center*



*Image credit: NASA*

Rockets took the first human into space and later launched capsules that took astronauts to the Moon. They lift the Space Shuttle. They carry parts and supplies to the International Space Station (ISS). They send satellites into orbit and probes out to the planets and beyond. They have sent robots to land on planets. One day, rockets will send humans back to the Moon, to Mars, and beyond. No one really knows where rockets will take us one day. Space is waiting for us to find out.

## Lesson 9

### Instructions for Making a 3–2–1 Pop Rocket



## Instructions for Making a 3–2–1 Pop Rocket

(This activity comes from the NASA Educator Guide *3–2–1 Liftoff*.)

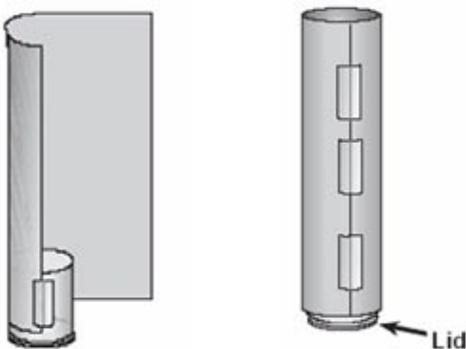
### Materials for each pair or group

- Two 9- by 12-inch sheets of colored construction paper
- Plastic 35-mm film canister (with internal seal)
- Scissors
- Clear plastic tape
- 12-inch ruler
- Compass for drawing a circle
- Protractor

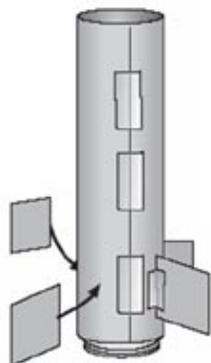


### Assembly Instructions

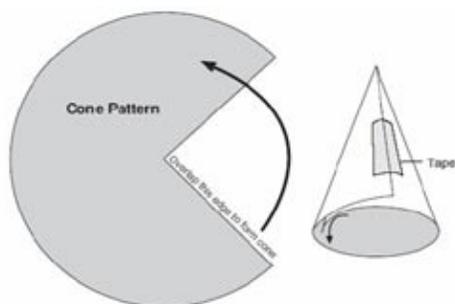
1. Stand the ruler vertically against the film canister to decide the height (optional) of the rocket. Measure and mark this height along both 12-inch sides of the paper and draw a line connecting these two points.
2. Cut along this line. This will be the body tube of the rocket.



3. With the **lid of the film canister down**, tape the edge of the paper to the film canister. Position the paper from the bottom of the canister so that the paper **does not touch the lid**. Then, wrap the tube of paper around the canister, cut off the excess paper, and tape it in place. It is **very important that the paper is firmly taped to the canister** and that it **does not touch the lid**. The lid must be free to snap off.



4. Cut out four same-sized fins and tape them to the sides of the rocket, so that they are equal distances apart.



5. Use the compass to draw a circle on the second sheet of construction paper. With the protractor, measure a  $90^\circ$  angle and cut this out of the circle.

6. Curl the paper into a cone, so that its circumference fits the top of the body tube of the rocket, and tape it in this position.

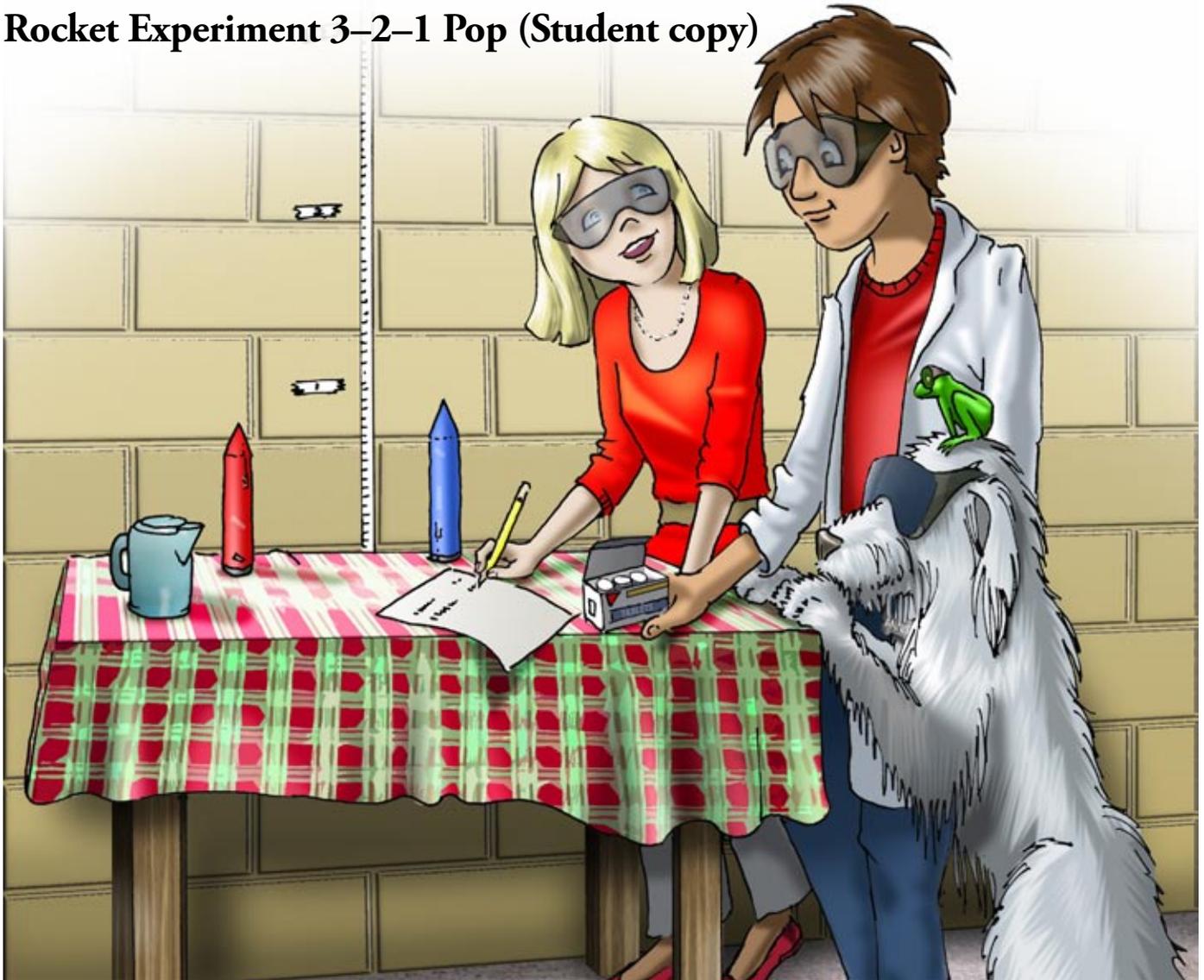


7. Tape the cone to the upper end of the rocket to form a nosecone for the rocket.





## Rocket Experiment 3–2–1 Pop (Student copy)



**Problem:** What will happen when an effervescent tablet is added to a “rocket film canister” filled  $\frac{1}{3}$  full of water and the lid is immediately snapped on tightly?

**Hypothesis:** The rocket will \_\_\_\_\_.

### **Procedure:**

1. All participants should put on eye protection before beginning the experiment.
2. Have a partner positioned to observe the height of the launched rocket.



3. Hold the rocket upside down and fill the canister  $\frac{1}{3}$  full of water.
4. Moving very quickly, drop in  $\frac{1}{2}$  of an effervescent tablet and immediately snap the lid on tight.
5. Stand the rocket in an upright position on the table.
6. Step back to observe.
7. Record the height of the launch. \_\_\_\_\_

**Results:** The rocket \_\_\_\_\_.

**Conclusion:** \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_

### Follow-up Activities:

1. Vary the amount of water keeping the size of the tablet constant.
2. Increase and/or decrease the temperature of the water.
3. Increase the size of the tablet beginning with  $\frac{1}{4}$ , then  $\frac{1}{2}$ ,  $\frac{3}{4}$ , a whole tablet, then  $1\frac{1}{4}$ ,  $1\frac{1}{2}$ ,  $1\frac{3}{4}$ , and 2. Be sure to keep the amount of water constant. (Try  $\frac{1}{2}$  full of water.)
4. Remove the rocket covering and launch only the canister.





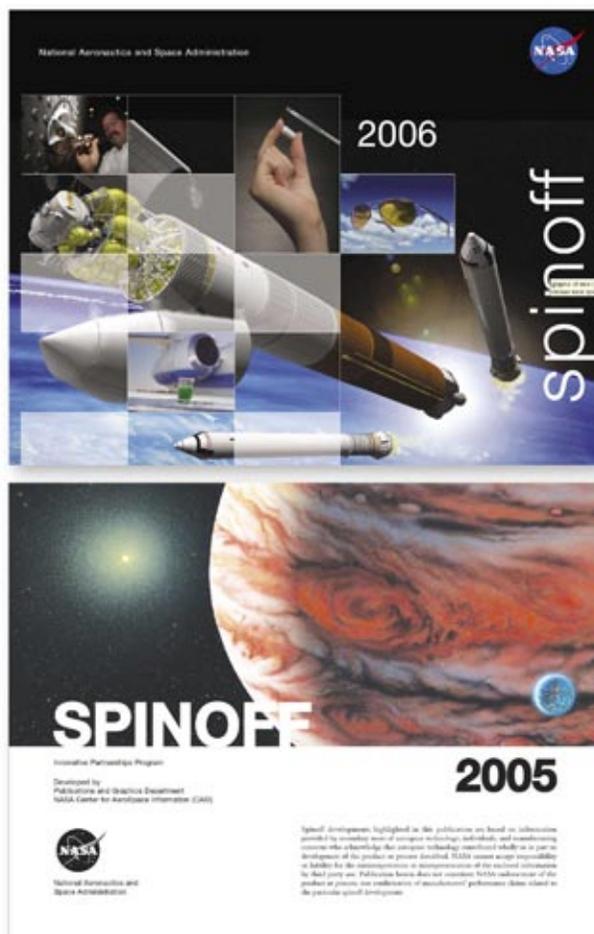
## Lesson 10 – NASA Technology Transfers (Spinoffs)

**Lesson prep time:** 30 minutes (for optional bulletin board)

**Teaching time:** 1 hour (Language Arts, Science, Technology)

### Objectives

1. The students will present their research on NASA technology transfers, also known as NASA spinoffs, to the class.
2. The students will identify technology transfers that have been given to the public by NASA.
3. The students will recognize the benefits of the space program as influencing their own lives and impacting technologies in many other areas.



## National Standards

### Science

- Abilities necessary to do scientific inquiry – S2Ea, S2Ma
- Understandings about scientific inquiry – S2Eb, S2Mb
- Properties of objects and materials/Properties and changes in matter – S3Ea, S3Ma
- Position and motion of objects/Motion and forces – S3Eb, S3Mb
- Objects in the sky – S5Eb
- Changes in Earth and sky/Earth in the solar system – S5Ec, S5Mc
- Abilities of technological design – S6Ea, S6Ma
- Understanding about science and technology – S6Eb, S6Mb
- Risks and benefits – S7Md
- Science and technology in local challenges/in society – S7Ee, S7Me
- Science as a human endeavor – S8Ea, S8Ma
- History of science – S8Mc

### Mathematics

The presentations and discussions of NASA technology transfers will probably meet the following mathematics standards.

- Use mathematical models to represent and understand quantitative relationships – M6
- Analyze change in various contexts – M7
- Use visualization, spatial reasoning, and geometric modeling to solve problems – M11
- Understand measurable attributes of objects and the units, systems, and processes of measurement – M12
- Formulate questions that can be addressed with data and collect, organize, and display relevant data to answer them – M14
- Develop and evaluate inferences and predictions that are based on data – M16
- Problem solving – M18
- Communication – M20

### Geography

- The physical and human characteristics of places – G4
- How culture and experience influence people's perceptions of places and regions – G6
- The patterns and networks of economic interdependence on Earth's surface – G11
- How human actions modify the physical environment – G14

### Language Arts

- Standards 1, 3, 4, 5, 6, 7, 8, 11, and 12 (See the Language Arts Matrix on page 12.)

### Technology – ISTE

- Students are proficient in the use of technology – I2
- Students develop positive attitudes toward technology uses that support lifelong learning, collaboration, personal pursuits, and productivity – I5
- Students use productivity tools to collaborate in constructing technology-enhanced models, prepare publications, and produce other creative works – I7
- Students use telecommunications to collaborate, publish, and interact with peers, experts, and other audiences – I8
- Students use a variety of media and formats to communicate information and ideas effectively to multiple audiences – I9
- Students use technology to locate, evaluate, and collect information from a variety of sources – I10
- Students employ technology in the development of strategies for solving problems in the real world – I14

### Technology – ITEA

- Relationships among technology and other fields – T3
- Cultural, social, economical, and political effects – T4
- Effects of technology on the environment – T5
- Role of society in the development and use of technology – T6
- Influence of technology on history – T7
- Attributes of design – T8
- Engineering design – T9

- Role of troubleshooting, research and development, inventions and innovation, and experimentation in problem solving – T10
- Apply the design process – T11
- Use and maintain technological products and systems – T12
- Assess impact of products and systems – T13
- Information and communication technologies – T17
- Transportation technologies – T18

The presentations and discussions of NASA technology transfers could also meet the following standards.

- Medical technologies – T14
- Agricultural and related biotechnologies – T15
- Energy and power technologies – T16
- Manufacturing technologies – T19
- Construction technologies – T20

## Materials

- None – This class period will be used for the student presentations of their research on NASA technology transfers.
- Optional – A bulletin board for displaying the pictures of the NASA technology transfers after the presentations

## Pre-lesson Instructions

1. Choose a location (classroom or elsewhere) for the presentations that provides a quiet and undisturbed environment, and make sure that every student in the audience can see and hear the speaker clearly.
2. Since the students have pictures of the NASA technology transfers, you may want to prepare a bulletin board or another area for them to be displayed. These pictures would be a good reminder of the benefits of the space program.

## Procedure

1. Prepare the class for listening to the NASA technology transfer presentations. Remind them that they will probably have to present their research on many occasions when they become adults. Many NASA engineers and scientists present their research at conferences attended by other engineers and scientists from all over the world.
2. Instruct the class to be professional and positive as they listen to the presentations, ask questions, and make suggestions. Tell them that they may have a job one day that requires them to be knowledgeable members of an audience listening to their co-workers' presentations and reports.
- 3 Call on each student to present their research. After each presentation, give the class an opportunity to ask questions and discuss how that technology transfer might affect them.
4. If you have planned a bulletin board or other display area, let the students place the pictures of their technology transfers in this area after they have completed their presentations.





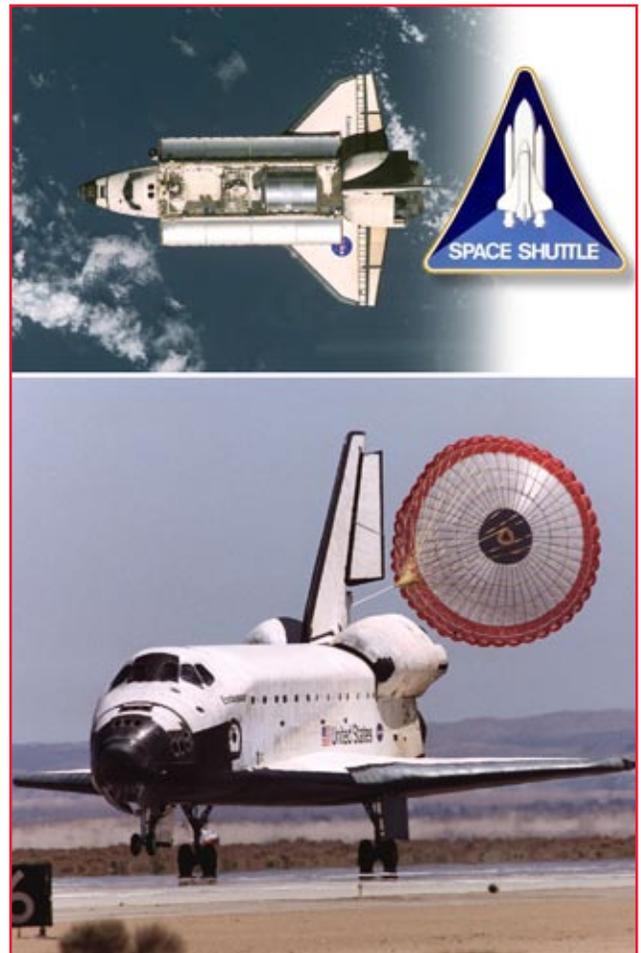
## Lesson 11 – The Space Shuttle

**Lesson prep time:** 20–25 minutes (for gathering materials and following pre-lesson instructions)

**Teaching time:** 1–1¼ hours (Science, Language Arts, Technology)

### Objectives

1. The students will compare the risks taken by astronauts to the risks taken by other explorers as they traveled into unknown territories.
2. The students will recognize the dangers faced by astronauts.
3. The students will describe the process from landing to launch that makes the Space Shuttle a reusable space vehicle.
4. The students will identify some of the Space Shuttle components and their functions.
5. The students will participate in a simple reenactment of a launch and landing of the Space Shuttle.
6. The students will begin to research and design an advanced model of the Personal Satellite Assistant (PSA) for the astronauts on Mars.



## National Standards

### Science

- Abilities necessary to do scientific inquiry – S2Ea, S2Ma
- Understandings about scientific inquiry – S2Eb, S2Mb
- Position and motion of objects/Motion and forces – S3Eb, S3Mb
- Objects in the sky – S5Eb
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- Understanding about science and technology – S6Eb, S6Mb
- Risks and benefits – S7Md
- Science and technology in local challenges/in society – S7Ee, S7Me
- Science as a human endeavor – S8Ea, S8Ma
- History of science – S8Mc

### Geography

- How to use maps and other geographic representations, tools, and technologies to acquire, process, and report information from a spatial perspective – G1

### Language Arts

- Standards 1, 3, 4, 5, 6, 7, 8, 11, and 12 (See the Language Arts Matrix on page 12.)

### Technology – ISTE

- Students are proficient in the use of technology – I2
- Students develop positive attitudes toward technology uses that support lifelong learning, collaboration, personal pursuits, and productivity – I5
- Students use productivity tools to collaborate in constructing technology-enhanced models, prepare publications, and produce other creative works – I7
- Students use telecommunications to collaborate, publish, and interact with peers, experts, and other audiences – I8
- Students use technology to locate, evaluate, and collect information from a variety of sources – I10

- Students employ technology in the development of strategies for solving problems in the real world – I14

### Technology – ITEA

- Relationships among technology and other fields – T3
- Cultural, social, economical, and political effects – T4
- Effects of technology on the environment – T5
- Role of society in the development and use of technology – T6
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- Engineering design – T9
- Role of troubleshooting, research and development, inventions and innovation, and experimentation in problem solving – T10
- Apply the design process – T11
- Use and maintain technological products and systems – T12
- Assess impact of products and systems – T13
- Information and communication technologies – T17
- Transportation technologies – T18

### Materials

- A picture book on the Space Shuttle with pictures and information on the process that makes the Space Shuttle a reusable space vehicle
- A toy model of the Space Shuttle that shows how the orbiter, external tank, and solid rocket boosters (SRB) fit together
- A picture of the Space Shuttle configuration (provided at the end of the lesson)
- The flowchart “The Space Shuttle from Landing to Launch” showing the process that makes the Space Shuttle a reusable space vehicle
- Pictures of the Space Shuttle flying piggyback and the Space Shuttle crews of STS–1, the first Space Shuttle mission; and STS 51–L and STS–107, the *Challenger* and *Columbia* crews who were lost (provided at the end of the lesson)
- Videos of a Space Shuttle launch and landing
- Audio wake-up calls to the Space Shuttle crews
- Short videos giving descriptions of several functions of the Space Shuttle

- “Orbiter Cutaway” diagram (provided at the end of the lesson). There is also a cutaway of the Space Shuttle orbiter in the book Stephen Biesty’s Incredible Cross-Sections. See the Resources section of this guide.
- Map of the U.S.
- Globe
- Homework assignment—“The Personal Satellite Assistant” (including the “Background Information for the Personal Satellite Assistant” and the “Parent’s Page”)

## Pre-lesson Instructions

1. Find a picture book on the Space Shuttle. Look for one that has pictures and information on the process that makes the Space Shuttle a reusable space vehicle, such as I Am Space Shuttle. I Love To Fly! by Becky Cross. (See the Resources section of this guide.)
2. Purchase a small toy model (3–4 inches high) of the Space Shuttle with components (orbiter, external tank, SRBs) that can be disassembled. Amazon.com has one for about \$4.00.
3. Find and be prepared to show a launch and a landing of the Space Shuttle. Use <http://science.ksc.nasa.gov/>. Under “Space Shuttle Information” choose “Photo/Movie Archive.”
4. Find and be prepared to play some of the audio wake-up calls to the astronauts as they are flying aboard the Shuttle. Use <http://spaceflight.nasa.gov/gallery/images/shuttle/index.html>. Choose a mission under “Audio.”
5. Preview short videos, each about 1½ minutes long, which give descriptions of several functions of the Space Shuttle. Find these at <http://www.nasa.gov/returntoflight/multimedia/index-how-it-works.html>. Choose a few for the class to view, especially the following:
  - “Orbiter Processing”
  - “Space Shuttle Main Engines”
  - “Parachutes”
  - “Solid Rocket Boosters”
  - “External Fuel Tank”
6. Duplicate enough copies of the flowchart “The Space Shuttle from Landing to Launch” for each student. Punch holes, so that students can insert these in their logs.
7. Duplicate enough copies of the “Orbiter Cutaway” diagram for each student. Punch holes, so that students can insert these in their logs.
8. Duplicate enough copies of the homework assignment “The Personal Satellite Assistant” (including the “Background Information for the Personal Satellite Assistant” and “Parent’s Page”) for each student. Punch holes, so that students can insert these into their logs.
9. Print, or be prepared to display, the pictures of the Space Shuttle configuration; the crews of STS–1, STS 51–L, and STS–107; and the Space Shuttle flying piggyback.
10. Additional pictures and videos of the Space Shuttle program can be found at the following Web sites:
 

<http://nix.nasa.gov/> Under “Browse Subject Categories,” choose “Space Flights” and then “Space Shuttle.”

<http://spaceflight1.nasa.gov/gallery/> Search both sides of the page for Space Shuttle images and videos.

<http://science.ksc.nasa.gov/> Under “Space Shuttle Information,” choose “Photo/Movie Archive.”
11. Divide the class into four Mars Expedition Teams so that all teams are as equal as possible in academic strength. Assign a leader for each team. Designate a storage area for team members to store their Mars colony materials as they are brought to class.

## Procedure

1. Introduce the lesson by reading and discussing a picture book about the Space Shuttle that has pictures and information on the process that makes the Space Shuttle a reusable space vehicle. Describe the steps taken by NASA workers to prepare the reusable Space Shuttle orbiter from landing to launch.

2. After discussing the book, ask the students the following questions:

- 1) Do you think it takes a special kind of person to know and accept the dangers of going into unknown territory where most others would fear to go? What kind of person would this be?
- 2) Do you think some people are meant to be explorers? What character traits do you think most explorers have?
- 3) How do the dangers astronauts face today compare to the dangers faced by explorers of the past? (Think about Marco Polo, Christopher Columbus, Magellan, Daniel Boone, James Cook, Lewis and Clark, and others who have gone into unknown territory.)
- 4) Knowing the dangers of traveling in space, would you sign up to be an astronaut? Why or why not?
- 5) Even though two Shuttle crews have been lost, do you think the human exploration of space should continue? Why or why not?

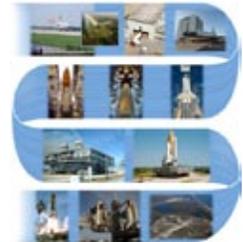
3. Show the class the toy model or the picture of the Space Shuttle configuration. Teach the following information:



- 1) No NASA spacecraft before the space shuttle was reusable. None of the capsules or rockets in the Mercury, Gemini, or Apollo programs could be used more than once. When NASA developed the Space Shuttle, it became the world's first reusable spacecraft.
- 2) The Space Shuttle consists of three major components: the orbiter, the large external tank, and two SRBs. All of the components are reused except for the external fuel tank, which burns up in the atmosphere after launch.

3) The Shuttle launches like a rocket, maneuvers in Earth orbit like a spacecraft and lands like an airplane. Each of the orbiters now in operation, *Discovery*, *Atlantis*, and *Endeavour*, is designed to fly at least 100 missions.

4. Distribute the flowchart "The Space Shuttle from Landing to Launch" and have the students insert this in their logs. Discuss each frame and use the information below to explain some of the stops on the journey.



- **Shuttle Landing Facility** – includes one of the longest runways in the world at 15,000 feet (4,572 meters) long
- **Orbiter Processing Facility (OPF)** – where the orbiter is fully inspected, tested, and refurbished for its next flight
- **Vehicle Assembly Building (VAB)** – where the Space Shuttle orbiter is lifted to a vertical position, connected to the SRBs and the external tank, and lowered onto the mobile launcher platform. The VAB is one of the largest buildings in the world and has enough volume to hold nearly four Empire State Buildings. It stands 525 feet (160 meters) tall.
- **Crawler Transporter** – picks up the mobile launcher platform with the assembled Space Shuttle and carries it to the launch pad at a speed of 1 mph
- **Mobile Launcher Platform** – a two-story steel structure that provides a transportable launch base for the space shuttle
- **Launch Pad** – where the Space Shuttle is launched

5. Show the crew pictures of STS-1, the first crew to fly the Space Shuttle into space, and the crews of STS 51-L and STS-107, the *Challenger* and *Columbia* crews who were lost. Note that the first few missions carried a crew of only two members. Allow a few minutes for the students to discuss the *Challenger* and



*Columbia* tragedies. Many students may not realize that two of the crews were lost. Allow the students who know about these tragedies to share their knowledge of these events.



- Remind the students that all Shuttle launches and most Space Shuttle orbiter landings take place at Kennedy Space Center (KSC). The workers at KSC are responsible for getting each orbiter inspected, tested, and refurbished to prepare it for its next launch. Find KSC at Cape Canaveral, Florida, on the U.S. map.

- Explain that from 1981–1991 most of the orbiters landed at Edwards Air Force Base in California and were flown piggyback to KSC atop a *Boeing 747*. Show the picture of the piggyback configuration. Later, the long runway at KSC was used so the orbiter would not have to be hauled across the country. Certain weather conditions can still force a landing at Edwards.



- View some of the NASA shuttle videos at <http://science.ksc.nasa.gov/>. Under “Space Shuttle Information,” choose “Photo/Movie Archive.” Try to watch a launch and a landing.

- The students would also probably enjoy listening to an audio of the music used to wake the astronauts each day. Selections are chosen by the astronauts and their families. At the end of the music, there is dialogue between Mission Control and the astronaut who selected the music. To listen, use <http://space-flight.nasa.gov/gallery/images/shuttle/index.html>. Choose a mission under “Audio.”

- Display the toy model and/or the picture of the Space Shuttle configuration again. Once again, point out the three main components of the Space Shuttle: the SRBs, the external tank, and the orbiter. Consider showing some of the short videos listed in the pre-lesson instructions that give descriptions of

several functions of the space shuttle. Find these at <http://www.nasa.gov/returntoflight/multimedia/index-how-it-works.html>. Then, teach the following:

- **SRBs** – The main job of the SRBs is to lift the Shuttle off the launch pad. After about two minutes, their solid fuel is used up, and the boosters fall away from the Shuttle. Parachutes carry them safely back to Earth where they land in the ocean. Ships are waiting nearby to tow them back to the U.S. to be refurbished and used again.
- **External Tank** – The external tank holds the liquid propellants that power the shuttle’s main engines. Approximately eight minutes after takeoff, the main engines shut off and the external tank falls away, burning up in the atmosphere. The external tank is the only component of the Shuttle that is not reusable.
- **Orbiter** – The orbiter contains the crew compartment and the payload (cargo) bay. The Shuttle main engines are located on the aft, or rear, of the orbiter. Although many people refer to the orbiter as the Shuttle, this is incorrect.

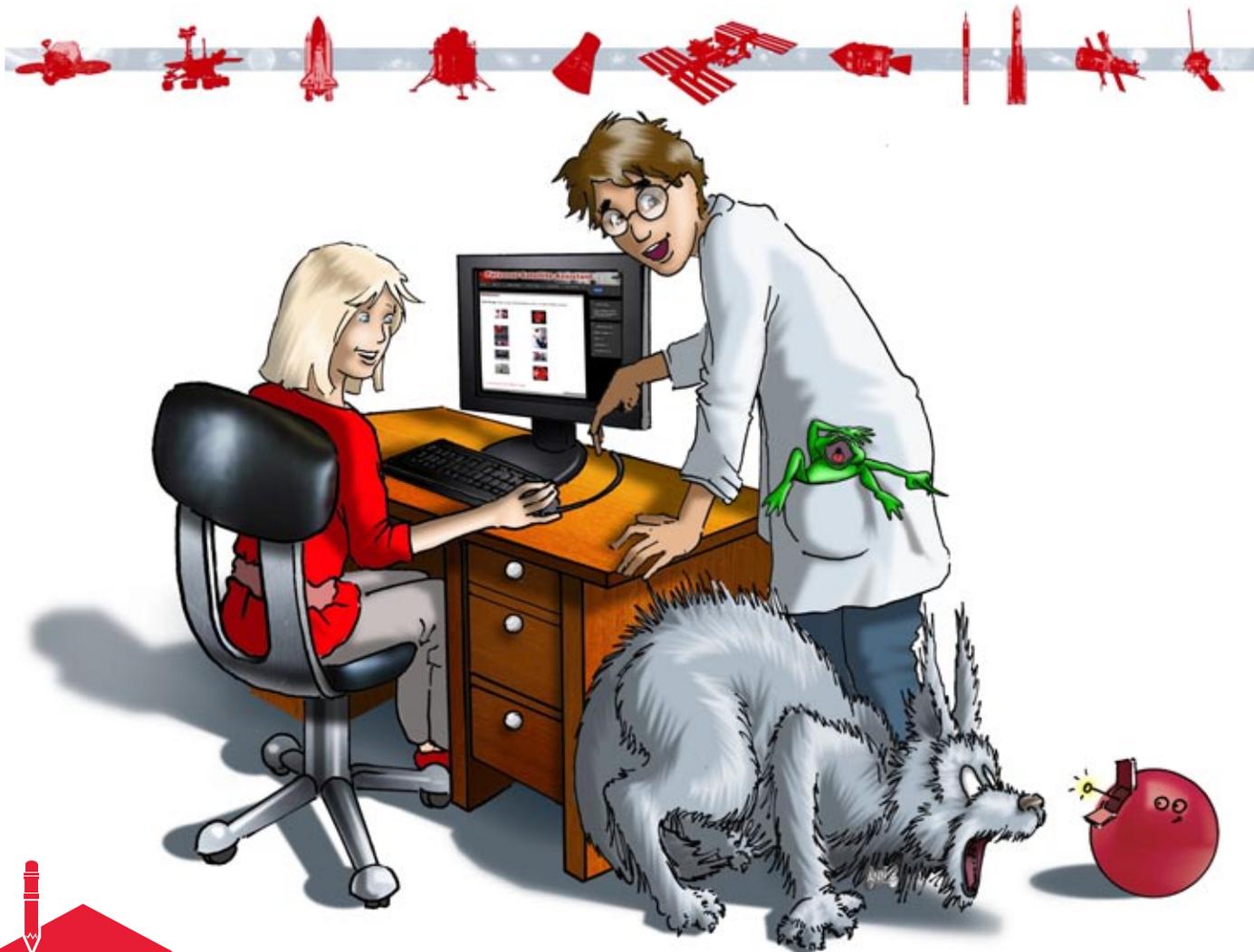
- Next, distribute the “Orbiter Cutaway” diagram and have the students insert this in their logs. Tell



the students that the **crew compartment** (or **crew module**), located in the forward fuselage, has three parts. Then, teach the following about each:

- **Flight deck** – The crew compartment’s top level is the flight deck, or cockpit. During launch and landing, the pilot and commander control the flight of the Space Shuttle from the flight deck. More than 2,000 separate displays and controls are located here.
- **Mid deck** – The mid deck, or crew quarters, is where the crew works, sleeps, eats, and relaxes. It includes the galley (kitchen), storage (for equipment, food, clothing, etc.), the bathroom, an exercise area, and sleep stations. Small experiments can be conducted there, as well.

- **Airlock** – The airlock is located next to the payload bay. The airlock has two airtight doors, called hatches. When the astronauts need to make a spacewalk, they go into the airlock and dress in their spacesuits. Once the astronauts are dressed and ready for the spacewalk, the hatch between the crew cabin and the airlock is sealed. Then, the airlock is depressurized until the pressure is reduced to zero, and the hatch to the outside is opened.
12. The Space Shuttle's mid-fuselage consists of the **payload (cargo) bay**. The payload bay is adaptable to hundreds of tasks and is large enough to hold a tour bus that measures 60 by 15 feet (18 by 4.6 meters). It is used to do the following:
    - carry and deploy satellites in orbit;
    - retrieve, service, and repair orbiting satellites;
    - carry scientific experiments, such as Spacelab;
    - return previously deployed spacecraft to Earth; and
    - help build and maintain the ISS by delivering modules, components, and supplies.
  13. Find KSC at Cape Canaveral, Florida, on the globe. (On a globe, look for the land that juts out on the central east coast of Florida.) Using the toy model of the Space Shuttle, simulate a launch using the following steps:
    - 1) Position the toy model over KSC on the globe. Direct the students to begin the countdown, "T-10, 9, 8..."
    - 2) At T-6, shout out, "Main engines ignite."
    - 3) At T-0, lift the Shuttle up as if it were being launched. Arc it over the Atlantic Ocean.
    - 4) Tell the students that the SRBs burn for about two minutes. These give the powerful thrust to lift the Shuttle from the launch pad and accelerate it to a high altitude. After the solid rocket boosters have used up their fuel, they separate from the orbiter and land in the Atlantic Ocean. Then U.S. ships recover them and tow them to land to be used again. As you say this, remove the SRBs from the orbiter.
  - 5) Take the toy model higher. Explain that, after the SRBs are released, the Shuttle main engines are using the rest of the fuel from the external tank. After about eight minutes of flight, all of the fuel is used from the external tank, and it separates from the orbiter. As you say this, separate the external tank from the orbiter. Explain that it falls back to Earth and burns up as it goes through the Earth's atmosphere.
    - 6) Approximately 40 minutes later, the orbiter's engines fire to put the orbiter in orbit. It continues to orbit the Earth until its mission is finished.
    - 7) When the mission is finished, the orbiter returns to Earth. It starts re-entry by firing maneuvering engines (located near the main engines) to slow the orbiter down. It soars through the atmosphere and glides until it touches down on the runway at KSC. A parachute slows it down until it stops.
    - 8) At Kennedy, the orbiter will go through several months of servicing until it is ready to fly again. It is a reusable launch vehicle.
  14. If time allows, watch a NASA video chronicling the Shuttle from landing to launch. View this video at [http://www.nasa.gov/mission\\_pages/shuttle/launch/index.html](http://www.nasa.gov/mission_pages/shuttle/launch/index.html). Choose "Space Shuttles Call Kennedy Space Center Home."
  15. Distribute the homework assignment "The Personal Satellite Assistant" and have the students insert this in their logs. Read through the assignment and assign a due date. (Presentations are due for Lesson 16.) Then, read the "Background Information for the Personal Satellite Assistant" offering explanations as you read. Answer any questions from the students.
  16. Next, read over the "Parent's Page" with the class. Assign the students to their Mars Expedition Teams and name the leaders of each team so they will know who they are working with to construct their colonies. Assign each team a location in the classroom where they can store their materials as they bring them to school. Tell them that more information on the Mars colony project will follow.



## The Personal Satellite Assistant

NASA's Spaceflight Mission Directorate has issued a Request for Proposals (RFP) for an advanced model of the Personal Satellite Assistant (PSA). An RFP is a means by which companies submit their plans or ideas for a project. The PSA is an astronaut support device designed to move and operate independently in the microgravity environment of space-based vehicles. Currently, the PSA will assist astronauts who are living and working aboard the space shuttle and the space station. However, NASA has issued this RFP for an advanced model of the PSA to be used by the first inhabitants of Mars, where it must operate in the Martian environment.

The robotics firm for which you work has asked its engineers to submit a design for this advanced PSA model and prepare a short explanation of its capabilities to be presented to a group of NASA engineers who are also working on this project.

**To prepare for the presentation you must do the following:**

1. Conduct research about the environment on Mars and decide on some of the needed capabilities of the PSA in that environment, as well as the design that would function best on the Martian terrain. (Think about the recent robotic landers on Mars.) For example, the present PSA models are shaped like a volley ball to be used in microgravity. The gravity on Mars is one-third that of Earth, so the PSA will not float on Mars. Therefore, advanced models will need to operate in a Martian environment with greater capabilities, and a totally different design must be considered.
2. Read the “Background Information for the Personal Satellite Assistant.” Then, use the Internet to conduct research on the PSA and to find the most up-to-date information on this subject. Remember that the advanced model will use the same concept to assist the astronauts, but the design and capabilities must be different.
3. Design a poster. Draw a picture of the PSA, label the important parts, and provide dimensions where applicable. List several of the capabilities of the PSA as if the poster were an advertisement for your design. The poster will be used in your oral presentation.
4. Using your poster design, prepare a written presentation that can be delivered orally in three to five minutes to a group of NASA engineers (your classmates). Computers and Microsoft PowerPoint presentations may be used, but printed copies must be made as well. The written presentation should include the following information.
  - Provide a description of the PSA design.
  - Identify the labeled parts, the function of each part, and give dimensions where applicable.
  - Outline the capabilities of the PSA. Outline the capabilities of the PSA. Include features on the PSA that the astronauts will use while inside a habitat and also while outside in the Martian environment.
  - Describe the plan for using the PSA in the Martian environment.

**Due Date:** \_\_\_\_\_

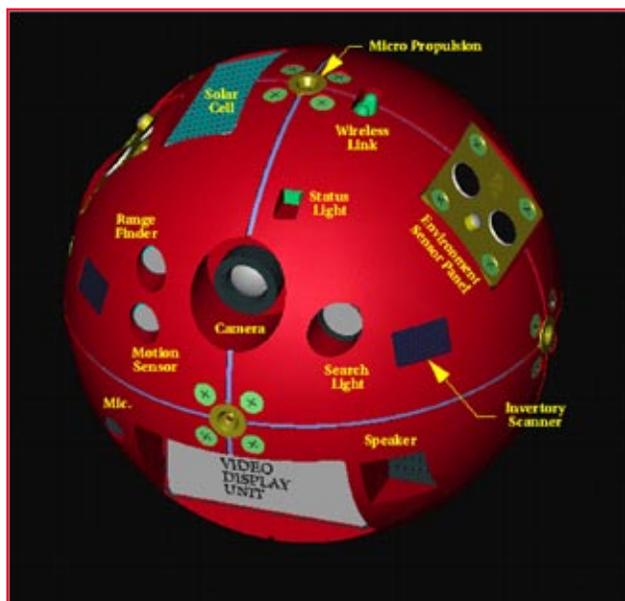


## Background Information for the Personal Satellite Assistant

The background information for the Personal Satellite Assistant was taken from the Ames Research Center Web site <http://psa.arc.nasa.gov/about.shtml>.

The PSA is a volleyball-sized robot that was prototyped in 2003–2004 to operate on a wide variety of spacecraft and could even go to Mars. The goal was to provide the astronauts with a robot assistant to help them with their daily tasks, to monitor the environment on the space vehicle, and to venture into situations that might be too dangerous for humans.

The PSA was designed to move and operate independently with eight small fans or impellers (with vents and louvers) and float effortlessly in microgravity on the space station. Like the fictional tricorder on *Star Trek*, the PSA had sensors that could detect the pressure and temperature of the air, as well as concentrations of gases, such as carbon dioxide. For astronauts living in a sealed aluminum can in the vacuum of space, this kind of information is essential.



The PSA would communicate with computers on the spacecraft and alert the astronauts and Mission Control if there was a problem. The PSA was planned to connect to computers using a wireless network. This would enable the PSA to access information about hardware, inventory, crew schedules, and science experiments. The information could then be shown on a small liquid crystal display (LCD) on the PSA, or spoken. If crew members had a question, they could simply ask the PSA through microphones on their headsets. The PSA was designed to have advanced voice-recognition and artificial intel-

## Lesson 11

### Background Information for the Personal Satellite Assistant

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ligence technologies that would allow it to understand spoken questions and commands. In addition, the PSA would provide audio and video communication, so that scientists on Earth could monitor experiments on the spacecraft and have conferences with the astronauts.

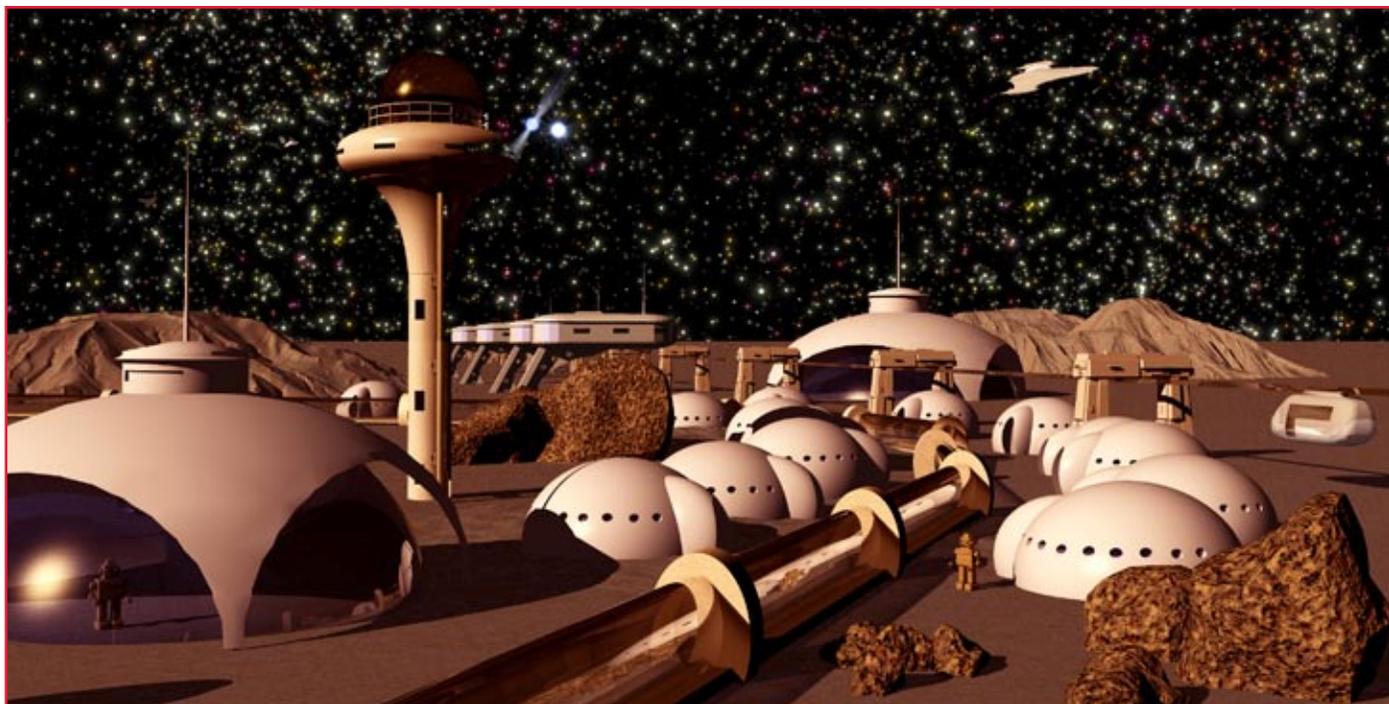
The PSA was also designed to assist the astronauts by keeping track of their schedules, tasks, and scientific experiments, and by monitoring supplies on the spacecraft. When the astronauts would repair something, the PSA could get the information from the main computer and give the astronauts step-by-step instructions. The PSA could also use its video camera to show the ground crew on Earth what is happening on the spacecraft.

The PSA is a complicated system made of parts that allow it to communicate, navigate around various spacecraft, detect heat or gas levels, “see” its environment, and store a lot of data. The robot prototype was designed and built at NASA Ames Research Center in Mountain View, California.

**Inspiration:** Part of the inspiration for the design of the PSA came from the movie *Star Wars*, where Luke Skywalker did lightsaber training with a small floating sphere. The astronauts asked for a device like a tricorder on the TV show *Star Trek* that checks the atmosphere on alien planets. So the scientists and engineers at NASA are designing a volleyball-sized robot that floats and has sensors to check the atmosphere—the PSA!



## Parent's Page



**Dear Parents,**

In a week or so, your child's Mars Expedition Team I will begin to build a model of the first Martian colony. Even though the work will be done in class, the teams need to collect materials beforehand to be used as structures for their model colony. Please help your child collect materials for this project. Each team will need at least seven items to be used as structures. Boxes can and will be used, but help your child to be creative. Think of domes, tents, metal cans, inflatable structures, etc. Imagine attachments to the buildings that serve some purpose. Each colony will be laid out on a 3- by 4-foot sheet of paper. Boards or any rigid surface cut to this size would also be appreciated. Thank you.

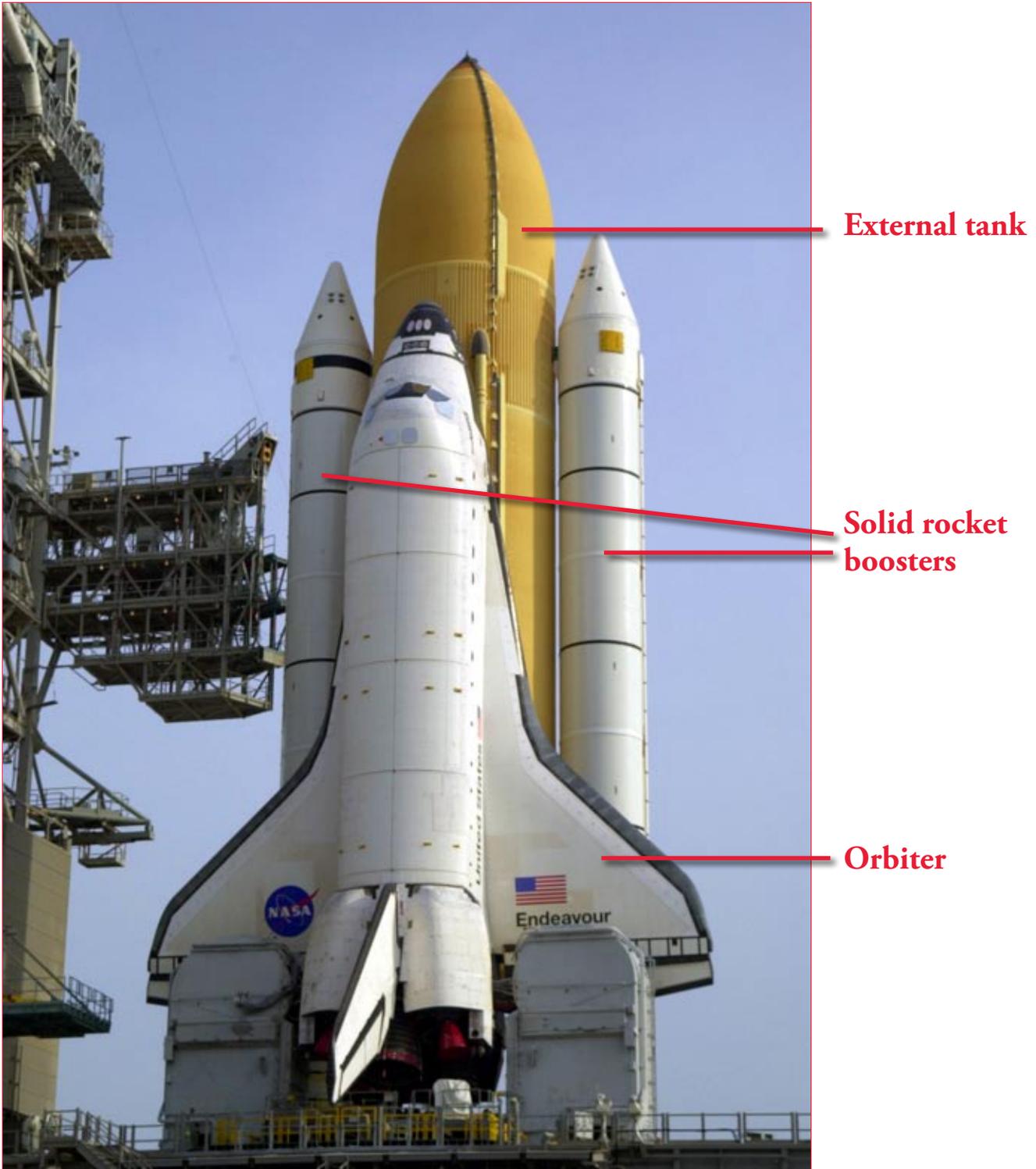


.....  
Parents, please sign this slip and return it to school. Thank you.

I have read my child's "Personal Satellite Assistant" assignment and background information, as well as the notice about the need for Mars colony materials.

Signature \_\_\_\_\_

## Space Shuttle Configuration





## The Space Shuttle from Landing to Launch



Shuttle Landing Facility



Orbiter Processing Facility (OPF)



From the OPF to the Vehicle Assembly Building (VAB)



The Space Shuttle in the VAB begins rollout.



Mating the Space Shuttle components



Cranes lift the orbiter in the VAB.



The Space Shuttle rolls out to the launch pad.



Launch Complex 39 at KSC



The Space Shuttle is prepared for launch.



The mobile launcher platform and the crawler transporter leave the launch area.



Space Shuttle launch from pad 39—A

## The STS-1 *Columbia* Crew



On April 12, 1981, the STS-1 crew, Commander John W. Young (left) and Pilot Robert L. Crippen, piloted Space Shuttle *Columbia* in the first Space Shuttle mission to be launched into space.

## The STS 51-L *Challenger* Crew



The STS 51-L crewmembers standing in the back row (left-right) are Mission Specialist Ellison S. Onizuka, Teacher in Space Participant Sharon Christa McAuliffe, Payload Specialist Greg Jarvis, and Mission Specialist Judy Resnik. Seated in the front row (left-right) are Pilot Mike Smith, Commander Dick Scobee, and Mission Specialist Ron McNair. On January 28, 1986, *Challenger* broke apart 73 seconds into its flight, leading to the deaths of its seven crew members.

## The STS-107 *Columbia* Crew



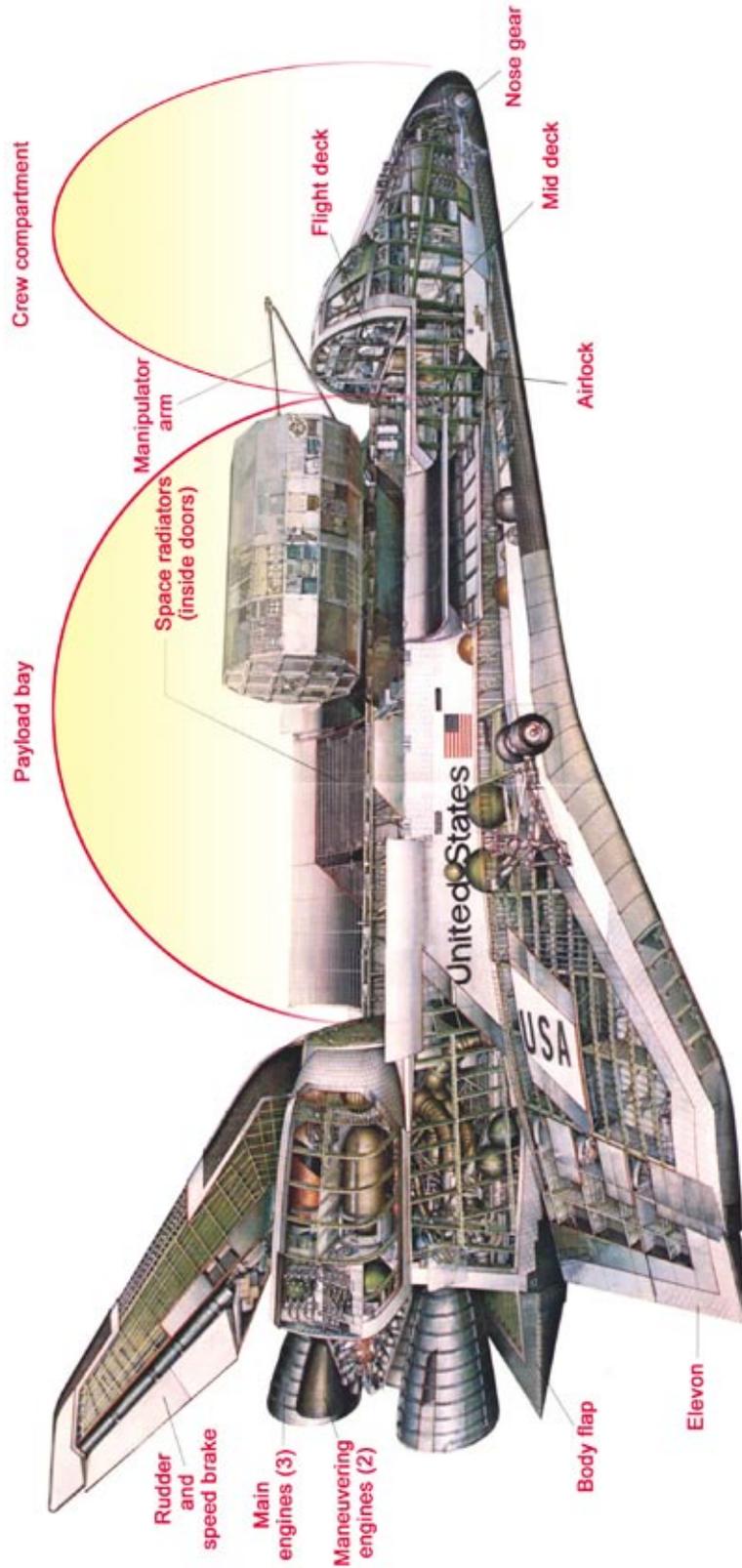
The STS-107 mission of Space Shuttle *Columbia*'s last journey flew from January 16 to February 1, 2003. From the bottom left are Astronauts Kalpana Chawla, mission specialist; Rick D. Husband, mission commander; Laurel B. Clark, mission specialist; and Ilan Ramon, payload specialist. From the top left are Astronauts David M. Brown, mission specialist; William C. McCool, pilot; and Michael P. Anderson, payload commander. On February 1, 2003, the seven crewmembers were lost with the Space Shuttle *Columbia* reentry over North Texas.

## Space Shuttle Flying Piggyback



The Space Shuttle flying piggyback atop a *Boeing 747*

# Orbiter Cutaway





STS-93 released Chandra into orbit.

## Lesson 12 – To Space and Back

**Lesson prep time:** 1 hour (for gathering materials and following pre-lesson instructions, including 40 minutes to preview The Dream Is Alive)

**Teaching time:** 1–1½ hours (Language Arts, Science, Technology)

### Objectives

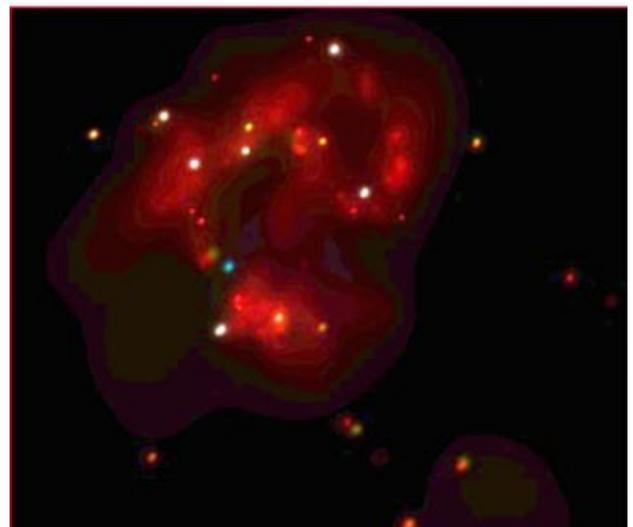
1. The students will become familiar with the space contributions of NASA.
2. The students will understand the function of satellites and space probes and learn how the data they return to Earth is used by scientists.
3. The students will identify some of the purposes of the Shuttle.
4. The students will realize the dangers of space travel as they read about the loss of *Challenger* and *Columbia*.
5. The students will acquire knowledge of a launch and of living on the space shuttle as they view the IMAX movie, The Dream Is Alive.
6. The students will continue to research and design an advanced model of the Personal Satellite Assistant (PSA) for the astronauts on Mars.



The Chandra X-ray Telescope in *Columbia*'s payload bay



Chandra just before deployment



This Chandra X-ray Observatory image reveals two colliding galaxies.

## National Standards

### Science

- Abilities necessary to do scientific inquiry – S2Ea, S2Ma
- Understandings about scientific inquiry – S2Eb, S2Mb
- Position and motion of objects/Motion and forces – S3Eb, S3Mb
- Objects in the sky – S5Eb
- Changes in Earth and sky/Earth in the solar system – S5Ec, S5Mc
- Abilities of technological design – S6Ea, S6Ma
- Understanding about science and technology – S6Eb, S6Mb
- Risks and benefits – S7Md
- Science and technology in local challenges/in society – S7Ee, S7Me
- Science as a human endeavour – S8Ea, S8Ma
- History of science – S8Mc

### Geography

- How to use maps and other geographic representations, tools, and technologies to acquire, process, and report information from a spatial perspective – G1

### Language Arts

- Standards 1, 3, 4, 5, 6, 7, 8, 11, and 12 (See the Language Arts Matrix on page 12.)

### Technology – ISTE

- Students are proficient in the use of technology – I2
- Students develop positive attitudes toward technology uses that support lifelong learning, collaboration, personal pursuits, and productivity – I5
- Students use productivity tools to collaborate in constructing technology-enhanced models, prepare publications, and produce other creative works – I7
- Students use telecommunications to collaborate, publish, and interact with peers, experts, and other audiences – I8
- Students use technology to locate, evaluate, and collect information from a variety of sources – I10

- Students employ technology in the development of strategies for solving problems in the real world – I14

### Technology – ITEA

- Relationships among technology and other fields – T3
- Cultural, social, economical, and political effects – T4
- Effects of technology on the environment – T5
- Role of society in the development and use of technology – T6
- Influence of technology on history – T7
- Attributes of design – T8
- Engineering design – T9
- Role of troubleshooting, research and development, inventions and innovation, and experimentation in problem solving – T10
- Apply the design process – T11
- Use and maintain technological products and systems – T12
- Assess impact of products and systems – T13
- Information and communication technologies – T17
- Transportation technologies – T18

### Materials

- Student logs
- A copy of the student text for Lesson 12, “To Space and Back” for each student
- The IMAX movie [The Dream Is Alive](#) (37 minutes)
- TV with DVD player
- A set of questions for students to answer as they watch the movie and a set of questions or topics for discussion after viewing the movie

### Pre-lesson Instructions

1. Purchase the IMAX movies *The Dream Is Alive* for Lesson 12, *Destiny in Space* for Lesson 13, and *Space Station* for Lesson 15 in DVD form. (Amazon.com carries these videos.) Ask your administrator or librarian for help with payment.
2. Reserve a TV set with a DVD player for the film *The Dream Is Alive*.

- Preview the film *The Dream Is Alive*, and make notes on specific questions or topics that you want to discuss. Prepare two or three questions for the students to answer as they watch the film. Prepare several additional questions or topics for a discussion after the students watch the film.
- Duplicate enough copies of the student text for Lesson 12, “To Space and Back” for each student. Punch holes, so that students can insert these in their logs.
- Additional pictures can be found at the following Web sites:

For *Skylab*, *Viking*, and Apollo-Soyuz, use <http://nix.nasa.gov/> and <http://grin.hq.nasa.gov/>.

For a few satellites, and some pictures of the Earth taken by satellites, use <http://photojournal.jpl.nasa.gov/targetFamily/Earth>.

For the Hubble Space Telescope and pictures taken of space by the Hubble, use <http://hubblesite.org/>. Choose “Gallery,” and then “Picture Album.”

For space probes and pictures taken by some of the probes, use the following Web sites:  
<http://nssdc.gsfc.nasa.gov/planetary/chronology.html>

<http://photojournal.jpl.nasa.gov/gallery/universe>

<http://www.jpl.nasa.gov/index.cfm>

<http://starchild.gsfc.nasa.gov/docs/StarChild/StarChild.html>

- Just before teaching the lesson, find the following Web sites so they will be ready to play at the end of the lesson.
  - After the *Challenger* disaster, John Denver wrote “Flying for Me” to honor the fallen astronauts. A video on You Tube <http://www.youtube.com/watch?v=LaMbky66-38> shows videos of Apollo/Saturn and the *Challenger* and crew (not the disas-

ter), while John Denver performs the song.

- The song “You Raise Me Up” by Rolf Lovland and Brendan Graham was performed by Josh Groban at the 2003 Super Bowl as a tribute to *Columbia*. To hear Josh Groban sing “You Raise Me Up,” use <http://ladynewavsone.com/raisemeup.html> or <http://www.creationsbydawn.net/cards/misc/raiseup.html>

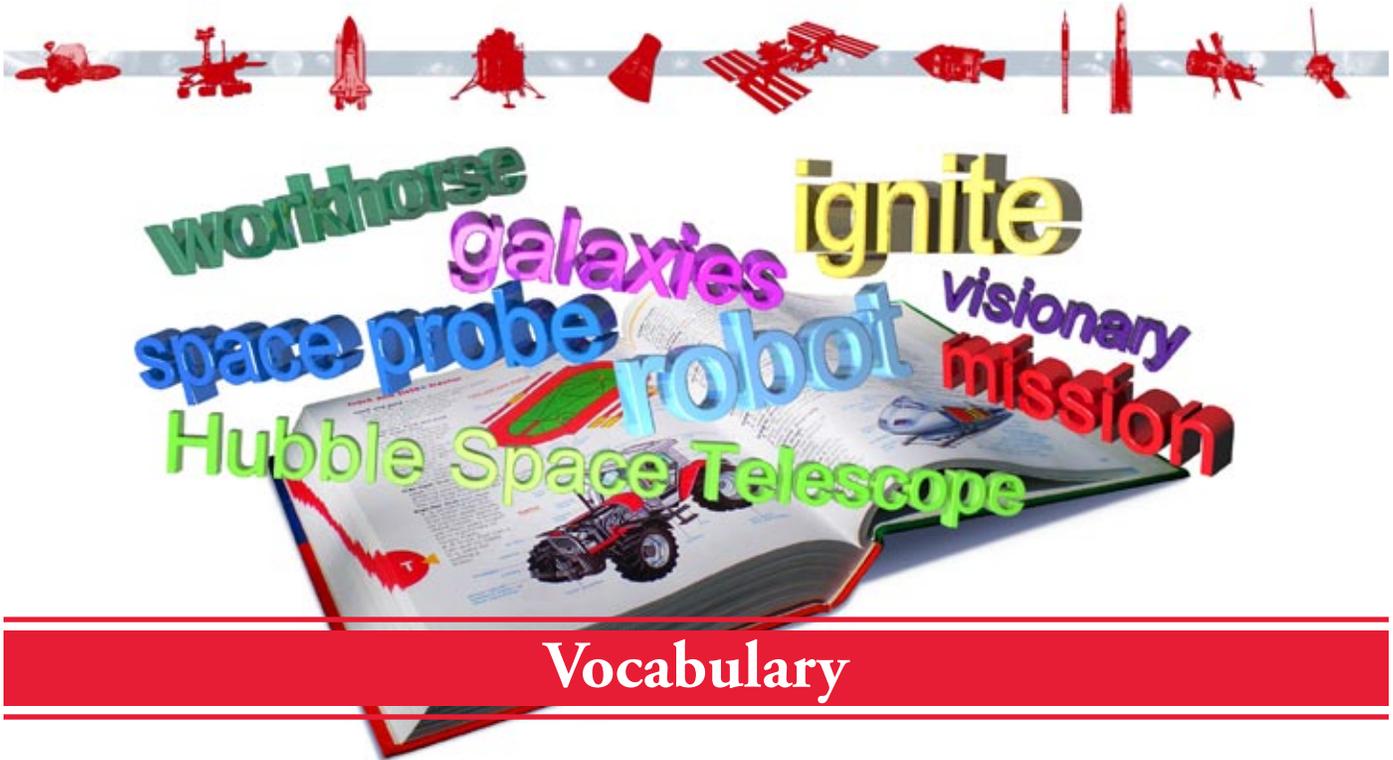
## Procedure

- Teach the vocabulary in the same manner that you would for a guided reading assignment. Once again, find Cape Canaveral and KSC, as well as Johnson Space Center near Houston, Texas, on a U.S. map.
- Distribute the student text for Lesson 12, “To Space and Back,” and have the students insert this in their logs. Read and discuss this selection as you would any guided reading. As the class discusses the text, question their understanding and encourage their questions.
- On the first page of the student text, have the students observe the science fiction spacecraft above the title. Then, look at the title of the first section “Visionaries.” Identify Christopher Columbus as a visionary. Let the students briefly share their knowledge of Columbus. Emphasize that he and his crew sailed from Spain to the New World using a route that no human had sailed before. This is what explorers do. They go into unknown or little known territory for the purpose of discovery. Ask the class to identify other visionaries. (**Explorers, scientists, researchers, writers, inventors, etc.**)
- Next, discuss the picture showing the early concepts for the Space Shuttle. Tell the students that it is a long, hard process to develop a new spacecraft and that thousands of ideas are considered before the final design concept is complete.

5. Read and discuss the section “Satellites, Space Probes, and Other Spacecraft.” Be sure the students understand the difference between a human-made satellite that orbits the Earth and a space probe that is sent away from the Earth to study other bodies in our solar system. Remind the students that GPS stands for Global Positioning System. Ask them if their parents have this system in their cars. Study the pictures taken of the Earth by satellites and discuss how these satellites help the Earth.
6. Tell the students that the most famous satellite at this time is the Hubble Space Telescope. Thousands of photos have been taken by the Hubble and many can be found at <http://hubblesite.org/>.
7. Read and discuss the next paragraph about space probes. NASA has sent up many probes for planetary exploration. Most of the pictures and other data about the solar system have come from these probes. Some probes only flew by a planet and took pictures and data. Some orbited the planet for years taking pictures, collecting data, and mapping almost the whole planet. A few probes were landers that landed on the surface to take pictures and collect data. Some were landers with robots that wheeled over the surface. A quick overview of each program includes the following probes:
  - There were eight different Mariner probes. *Mariners 2–8* studied Mars and Venus and most were flybys. *Mariner 9* was a Mars orbiter.
  - *Pioneer 10* was a Jupiter flyby and *Pioneer 11* was a Jupiter/Saturn flyby.
  - *Viking 1* and *Viking 2* went to Mars. Each had an orbiter and a lander.
  - *Voyager 1* was a Jupiter/Saturn flyby.
  - *Voyager 2* was a Jupiter/Saturn/Uranus/Neptune flyby.
  - *Pioneer Venus 1* was an orbiter and *Pioneer Venus 2* was a probe.
  - *Magellan* was an orbiter that mapped 98% of Venus’ surface.
  - *Galileo* was a Jupiter orbiter.
  - *Mars Global Surveyor* was a Mars orbiter.
  - *Mars Pathfinder* was a Mars lander and rover.
  - *Cassini Huygens* was sent to Saturn. Once in Saturn’s orbit, *Huygens*, (built by the European Space Agency) separated and landed on Saturn’s moon, Titan.
  - *Spirit* and *Opportunity* were Mars rovers.
  - *Mars Reconnaissance Orbiter* was a Mars orbiter.
  - *New Horizons* was launched in 2006 to Pluto and is scheduled to arrive on July 14, 2015.
  - *Phoenix* was a Mars lander.
8. Read the title of the next section, “April 1981 and the World’s First Reusable Launch Vehicle.” Remind the students that no spacecraft was used more than once before the Space Shuttle. The spacecraft used by NASA before the Space Shuttle are called expendable spacecraft.
9. Have the students turn their chairs on their backs and then carefully “sit” in them. Tell them to just sit quietly for a minute and think about how the astronauts must feel knowing that they will soon be blasted into space. After a minute, ask them how they feel. Explain that the astronauts are given medicine to help with headaches and nausea if needed.
10. Having seen the videos of the Space Shuttle launch, the next few paragraphs should be easy for the students to comprehend. Perhaps there is someone in the class who has actually been to a Shuttle launch and would share their experience with the rest of the class. Point out that the clouds are mostly water vapor. Most people think they are smoke. When the main engines are ignited, thousands of gallons of water are poured on the launch pad causing the water vapor. Plus, the main engines burn oxygen and hydrogen creating water vapor as well. After clearing the tower, most of the clouds from the launch vehicle are made up of smoke from the SRBs.
11. After reading the paragraph about the *Challenger* and *Columbia* disasters, allow the students to share their feelings about these. Then, finish reading the selection.
12. Tell the students that they will be watching the movie *The Dream Is Alive*. Display or ask the questions

that students should answer as they watch the film. If teachers have not previewed the film, they may want to take notes on specific questions or topics that they will want to discuss afterwards.

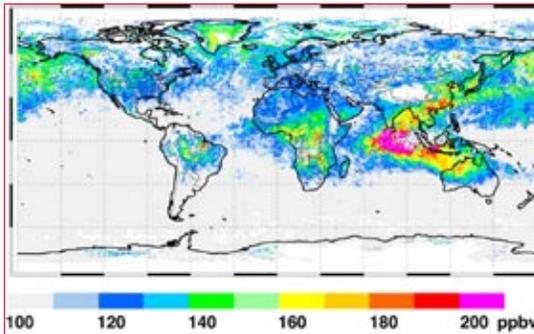
13. Show the IMAX movie *The Dream Is Alive*. After the movie, discuss the answers to the questions that the students were given before showing the film. Encourage the students to ask questions and participate in a discussion about the film.
14. Tell the students that after the *Challenger* disaster, John Denver wrote “Flying for Me” to honor the fallen astronauts. A video on You Tube <http://www.youtube.com/watch?v=LaMbky66-38> shows videos of Apollo/Saturn and *Challenger* and crew (not the disaster) while John Denver performs the song.
15. The song “You Raise Me Up” by Rolf Lovland and Brendan Graham was performed by Josh Groban at the 2003 Super Bowl as a tribute to *Columbia*. Try <http://ladywavsone.com/raisemeup.html> or <http://www.creationsbydawn.net/cards/misc/raiseup.html> to hear Josh Groban sing “You Raise Me Up.”



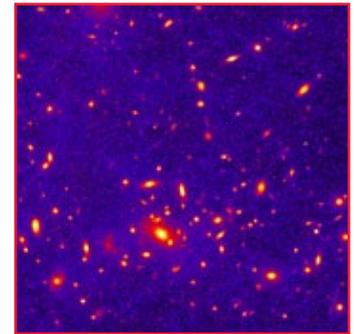
## Vocabulary

**data** – facts about something that can be used in calculating, reasoning, or planning

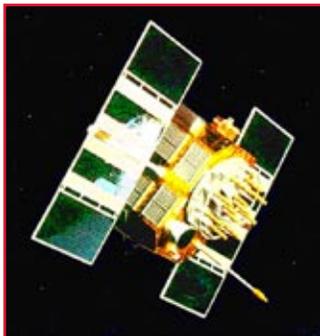
**galaxies** – very large groups of stars and other matter that are found throughout the universe



NASA satellite data shows global carbon monoxide pollution.



A cluster of galaxies



GPS is made possible by 24 NAVSTAR satellites.

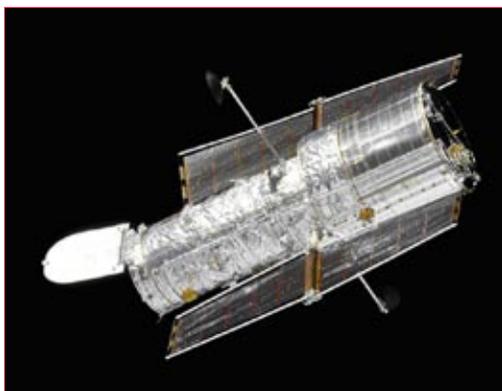


The USGS uses GPS devices to track earthquakes.

**GPS** – Global Positioning System; a navigation system that uses satellite signals to find the location of a radio receiver on or above the Earth's surface



**Hubble Space Telescope** – The Hubble Space Telescope is a space-based telescope that was launched in 1990 by the Space Shuttle. From its position 380 miles above the Earth’s surface, the Hubble has expanded our understanding of star birth, star death, and galaxy evolution, and has proven that black holes exist. It has recorded hundreds of thousands of images. The Hubble is about the size of a school bus and spins around the Earth every 97 minutes at a speed of 5 miles per second (8 kilometers per second).



Hubble Space Telescope



The Hubble Telescope captured this image of the “Cat’s Eye Nebula.”



The International Space Station

**ignite** – to cause (a fuel mixture) to burn

**ISS** – The International Space Station is the vehicle that stays in space, is shared by 16 countries, and orbits the Earth so that experiments can be done.

**mission** – a task or job that is assigned; a definite military or aerospace task such as a space mission

**reusable** – capable of being used again or repeatedly

**robots** – machines that act like a human; devices that automatically perform tasks that are complicated and often continuously repeated



A NASA robot practiced a Moon survey in the Arctic Circle.



A NASA humanoid robot may help astronauts during an EVA.



*Image credit: NASA*  
NASA sent the robots *Spirit* and *Opportunity* to Mars.



**space probe** – Space probes are uncrewed vehicles made to conduct science experiments and help scientists get information about our solar system. Most probes are not designed to return to Earth. Some have landed on other planets. Others have flown past the planets and taken pictures of them for scientists to see. There are even some space probes that go into orbit around the Sun or other planets and study them for a long time. The information they gather is used to help us understand the weather and other changes that occur on planets other than the Earth. This information is important in helping to plan other space missions.



The *Cassini* space probe was sent to Saturn.



*Image credit: NASA*  
An artist's interpretation of the Mercury-bound space probe, *Messenger*



The launch of the Space Shuttle

**Space Shuttle** – a spacecraft system designed to transport people and cargo between Earth and space which has parts that can be used repeatedly

**space station** – an artificial satellite designed to stay in orbit permanently and be occupied by humans for long periods



*Skylab* was the first U.S. space station.

**visionary** – a person having unusual foresight and imagination

**workhorse** – comes from the term for a draft horse, but used as an expression that refers to a machine, one that performs dependably under heavy, prolonged use; or a person, who works tirelessly at difficult, time-consuming tasks; something that is useful, durable, or dependable



*Photo credit: Maffei-Albers Photography  
Rimrock Cove Ranch, Arizona.*

“Workhorse” is a term that refers to the draft horse—a dependable, gentle, working horse.



## To Space and Back

### Visionaries

Visionaries are people who love to dream about the future. They want to explore the unknown. They want to find out about things. They imagine things that do not exist, although those things might exist in the future. Christopher Columbus was a **visionary**, yet many people in his time thought he was crazy. Why would he want to explore an unknown sea? Why would he risk such danger? Americans are probably very thankful that Columbus had a vision to explore. His vision led to the establishment of a great nation.

Throughout history, there have been many people with this kind of vision. Like Columbus, they have led us into the unknown. Each time, the unknown has been conquered.



*Photo credit: Library of Congress*

Christopher Columbus kneeling in front of Queen Isabella I



*Photo credit: Library of Congress*

Columbus' ships arrive on North America.



*Photo credit: U.S. Capitol Building*

Landing of Columbus



Space has always been a great unknown. Ever since humans gazed at the stars, they have dreamed of going there. Many people have felt that this unknown needed to be conquered. Some even had visions of winged spacecraft that could fly to space and back. These ideas were science fiction only a few years ago, but the National Aeronautics and Space Administration (NASA) had a vision to make these ideas real. NASA wanted a winged spacecraft that could be used over and over. The spacecraft would be able to leave Earth, go into space, and return to be used again and again. As astronauts were walking on the Moon, NASA was looking ahead with a vision for the future. The Agency would begin to build a **reusable** Space Transportation System (STS). Today, we know this as the **Space Shuttle**.



Many early space shuttle concepts preceded the final design.

## Satellites, Space Probes, and Other Space Vehicles

The work on the Space Shuttle began in the early 1970s, but it would take nine years of work before it flew. In the meantime, NASA was busy with several other projects. Many people were working on the shuttle, but a lot of other work was happening too. NASA was exploring space by sending up satellites, probes, and other space vehicles.



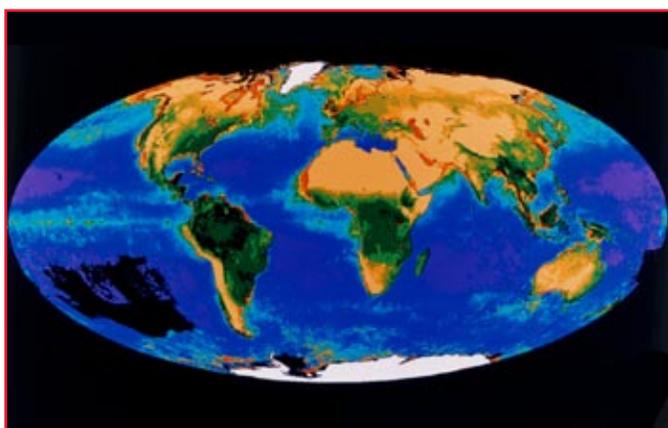
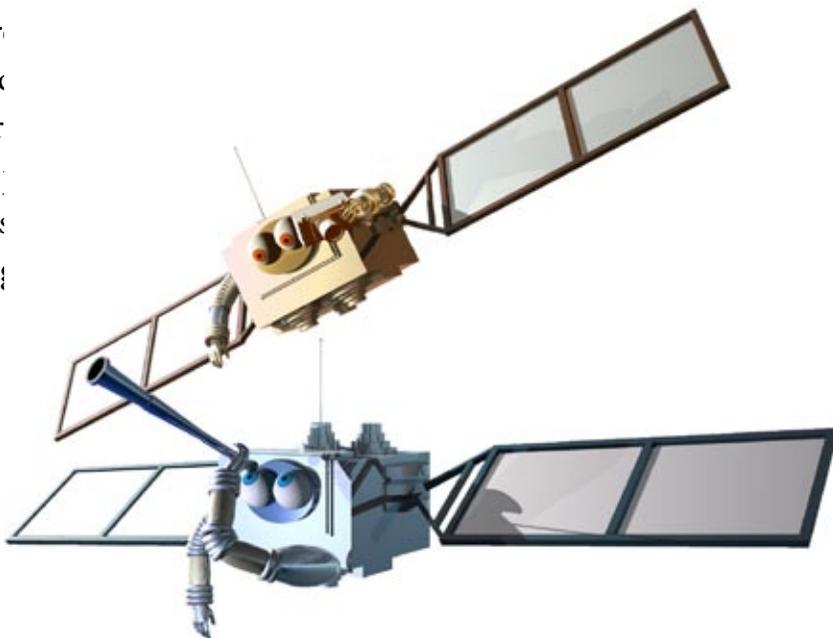
Have you ever had the feeling that you were being watched? Well, you are. The “eyes” are hundreds of satellites that orbit the Earth. NASA has launched hundreds of them. They have no eyes, but some of them “look down” on us with cameras. Others “look out” into space using telescopes. Still others do not “look” at all. They just relay signals.

Some of the satellites that “look down” on us are a part of NASA’s Earth Observing System of satellites. Using different cameras, they study the Earth by taking a



A spy satellite

lot of pictures. The pictures sent back to Earth is used to study crops, forests, the oceans, air, and living things. They help us to see how the Earth has changed. Many of the satellites that “look down” to the Earth are used for weather forecasting. Others are used to help keep our nation safe by spying on enemy nations.



A composite of two satellites over a period of three years shows concentrations of marine phytoplankton and land vegetation.



A Geostationary Operational Environmental Satellite (GOES) captures Hurricane Fran.

## Lesson 12

### Student Text—To Space and Back



The satellites with telescopes “look out” to study space. They look at many things in our solar system, and they look far beyond the solar system into the rest of the universe. They study the stars, **galaxies**, and even black holes. This data is also sent back to Earth for scientists to study.



This nebula is a cloud of gas ejected from the hot star visible in its center.



An encounter between two spiral galaxies



Image credit: NASA

Tracking and relay data system satellite

However, the satellites that do not “look” at all affect our lives the most. These satellites relay the signals that work our cell phones and long distance calls. They also work our computers for email and the Internet. Our TVs use these, too. We can see events as they happen from any place on Earth. Some of these satellites contain a **GPS**. GPS devices are found on cars, boats, and planes, and some can even be held in our hands. GPS devices show us where we are located on Earth. With GPS, we can never be lost.



The black hole in the center is about 70 million times more massive than the Sun.

NASA has also sent out many **space probes**. Like satellites, they are uncrewed. Probes have been sent to the farthest parts of the solar system. Some fly by the planets to conduct experiments and take pictures. Some orbit a planet for a long time conducting experiments



Image credit: NASA

Mariner 2 was the world's first successful interplanetary spacecraft.



Image credit: NASA

Voyager 2 flew by Jupiter, Saturn, Uranus, and Neptune.



and taking pictures. Some have even landed on the planets and traveled on their surfaces to take photographs and perform experiments. Most probes do not come back to Earth. Instead, they send back pictures and other data. Could you imagine going 50 times the speed of a bullet? That is how fast *Voyager 2* flew. Some NASA space probes have traveled out into space for so long that they have left the solar system.



A montage of *Voyager 2* images: Neptune, Uranus, Saturn, Jupiter

In 1975, NASA sent out two space probes that became rather famous. The probes *Viking I* and *Viking II* traveled to Mars. The way these probes worked was similar to Apollo in that they used an orbiter and a lander. Part of the probe stayed in orbit while the other part separated and landed on the surface of Mars. The Viking landers were like huge **robots**. Their “eyes” were cameras that took hundreds of pictures. Their “arms” scooped up soil samples and dumped them in the lander’s “mouth.” The “mouth” studied the samples and sent data back to Earth. From high above, the Viking orbiters took pictures of the entire surface of Mars. The Viking project taught scientists a lot about Mars. For example, they learned that Mars’ soil is rich in iron, which causes the soil to be red in color. This is why Mars is called the Red Planet. Besides satellites and probes, NASA worked on two other important **missions** during this time.



The *Viking 2* lander

Image credit: NASA



*Viking 1* on Mars



Astronaut Charles Conrad Jr. in the *Skylab* training simulator



Astronaut Alan Bean in sleep compartment reading a book



Astronaut Charles Conrad Jr. undergoes a dental examination.



Astronaut Jack Lousma takes a hot bath in the crew quarters of *Skylab*.



Astronauts Carr and Pogue jokingly demonstrate weight training in zero-gravity.



Arabella, one of two *Skylab* spiders, and her web



The *Skylab* astronauts controlled the solar physics telescope from this console.

In 1973, NASA sent *Skylab* into orbit. This was the first U.S. **space station**. [The United Soviet Socialist Republic (USSR) had already put up *Salyut I*, the world's first space station.] *Skylab* was a science laboratory in orbit where three different crews spent time living in space. Together they performed almost 300 experiments. The last crew set a new record spending 84 days in orbit. *Skylab* was proof that the U.S. could build a space station for humans to live and work for long periods of time.



*Skylab*, America's first space station



Astronaut Gerald Carr demonstrates the effects of zero-gravity in *Skylab*.



Then, in 1975, the world got a big surprise. After all those years in competition, a U.S. spacecraft docked with a USSR spacecraft. Some people think that this mission marked the end of the space race. The docking of these two vehicles was called the Apollo-Soyuz Test Project (ASTP). The two crews spent two days together completing special tasks. After this mission, both countries hoped to accomplish more things together in space.



The ASTP historic handshake in space



A recreation of the Apollo-Soyuz rendezvous

*Photo credit: NASM*

One of the American crewmen on ASTP was Astronaut Donald “Deke” Slayton, one of the original Mercury Seven astronauts. Due to a heart condition, Deke had previously been unable to go into space, but a review of his medical status made him eligible for spaceflight.



## April 1981 and the World's First Reusable Launch Vehicle



After many years of hard work, the Space Shuttle was ready. This time the whole world was watching as *Columbia* sat on the launch pad. They wanted to see *Columbia* soar into the sky. Watching a Space Shuttle launch is an amazing sight. As you wait for the countdown, the excitement grows. You can see the Shuttle stacked on the launch pad. The orbiter looks like a plane sitting with its nose pointed to the sky. Its three main engines look down at the launch pad. The huge external tank towers above the orbiter. It is filled with propellant and acts like a gigantic gas tank for the orbiter's main engines. A tall rocket stands on each side of the external tank. These are the solid rocket boosters (SRBs). On takeoff, they provide most of the thrust to lift the Shuttle skyward.



The astronauts sit inside the crew compartment. They are waiting for the final seconds to pass before liftoff. They have been strapped in their seats for at least three hours. Getting into these seats was a bit tricky. Remember, the orbiter is sitting with its nose up. Try turning your chair or desk on its back. Now sit in it for a few minutes. How do you feel?



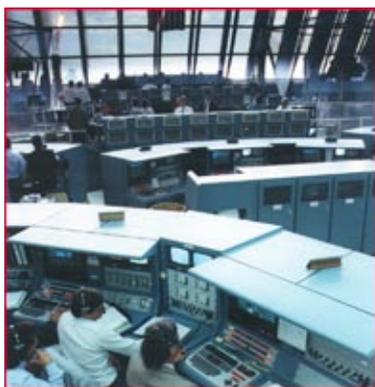
In the White Room on Launch Pad 39A, the closeout crew helps the astronauts adjust their launch and entry suits just before liftoff.



Space Shuttle *Endeavour* on the launch pad



People from all over the world come to watch a Space Shuttle launch.



The Launch Firing Room at KSC



Space Shuttle liftoff

If you ever want to see a launch, you must go to Cape Canaveral, Florida. This is where Kennedy Space Center is located. You will need to get there a few hours before liftoff, but know that the launch team has been working there for many days. The team checks the Space Shuttle's systems over and over. They make sure that everything is working just right. They make sure that everything is safe. They begin the countdown four days before the launch. When the countdown approaches T-10 seconds, you almost hold your breath. At T-6.6 seconds, the main engines are **ignited**. At T-0 seconds, the SRBs ignite, and the Shuttle has liftoff. For a second or so, clouds of steam hide everything from view. Then you can see the Shuttle lift up from the clouds. A glowing orange tail flows out from the bottom. The roar is deafening.



You will probably get goose bumps. Some people cry. Others scream and jump up and down. The Shuttle has been launched so many times, but each launch is still a very exciting event. Right after the liftoff, a new team takes over. The new team is Mission Control located at Johnson Space Center in Houston, Texas. This team will talk to the astronauts throughout the whole mission. They take data and watch every little thing about the shuttle for its entire flight. They also take data on the astronauts and monitor their health while they are on board the orbiter.



Mission Control Center in Houston, Texas



The solid rocket boosters fall off.



The external tank falls off.

About two minutes after launch, the SRBs' solid fuel is used up and they fall away from the Shuttle. They parachute into the ocean to be picked up and used again. At 8½ minutes after launch, the emptied external tank falls off and is burned up as it reenters the atmosphere. Then, the Shuttle fires its orbital maneuvering engines to enter its desired orbit.

Have you ever wondered why the U.S. has a space shuttle? What do the astronauts do on these missions? One of their main jobs is to conduct experiments and research in space. The astronauts also put new satellites in orbit and service and repair older satellites. A good example of this was the repair of the **Hubble Space Telescope**. Hubble did not work when it was first put into orbit, but astronauts were able to correct the problem on one of their flights. In the late 1990s, the Shuttle began to take the crew and supplies to *Mir*, the Russian



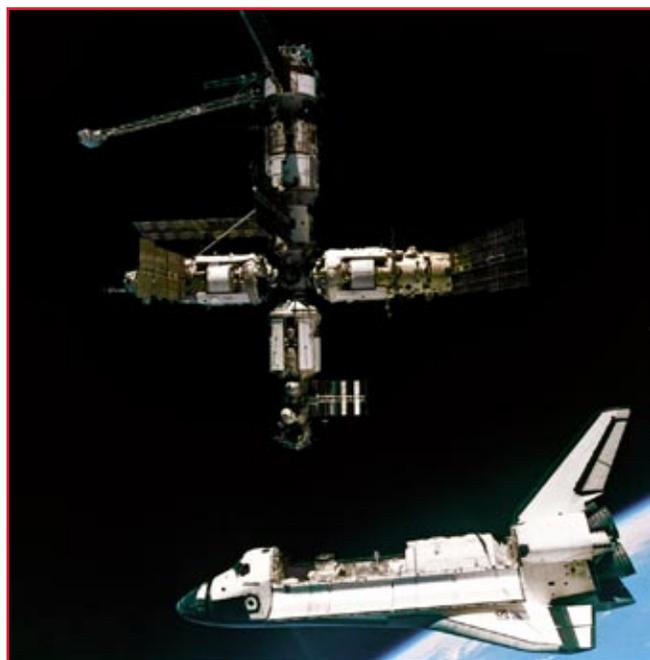
Attached to the "robot arm" the Hubble Space Telescope is unberthed and lifted up into the sunlight after being serviced.



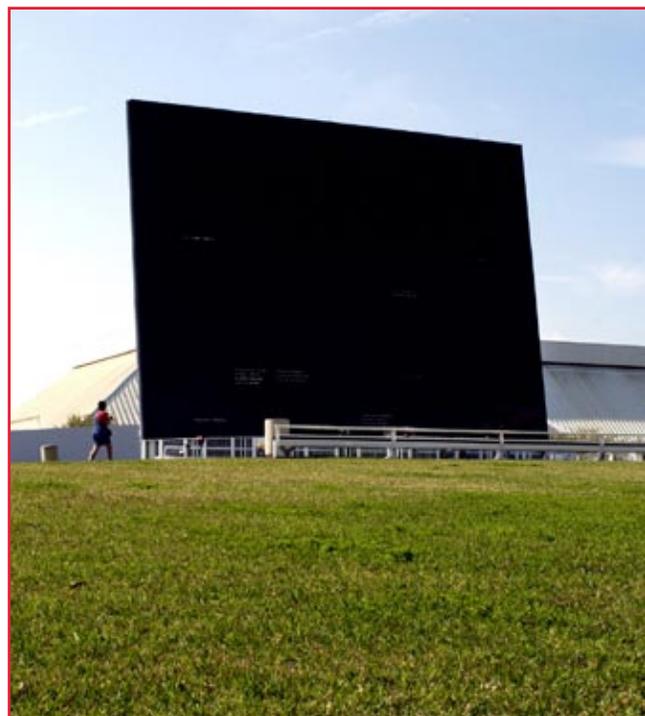
During the STS-88 mission, three EVAs were performed to connect the U.S. *Unity* module to the Russian *Zarya*, the first component of the ISS.

space station. Then, the Shuttle began to transport the parts to build the **International Space Station (ISS)**. Because of their size and weight, each module of the ISS had to be taken up alone. As the Space Shuttle carried each part to space, the astronauts would connect them together. Once the ISS was able to support human life, the Shuttle had another job. It had to deliver the crew and supplies to the ISS.

The Space Shuttle has flown over a hundred times, and dozens of safe missions have been completed. On two of the Shuttle missions, the crew did not make it home. One cold day in January 1986, *Challenger* was sitting on the launch pad. School children were watching this launch on TVs in classrooms all over the U.S. They were excited because Christa McAuliffe was on board. McAuliffe was a school teacher, and she was going to teach a lesson from space.



The Space Shuttle *Atlantis* departs the *Mir* Russian Space Station.



The Astronaut Memorial Space Mirror is a national tribute to American astronauts who gave their lives for space exploration.

## Lesson 12

### Student Text—To Space and Back



At 73 seconds after takeoff, the *Challenger* exploded. It took the lives of all onboard. After this, the Space Shuttle did not fly for almost three years. Then, 17 years later, on February 1, 2003, *Columbia* broke apart as it was reentering Earth's atmosphere. Once again, all of the crew members were lost. Like *Challenger*, this had been a special science mission for students. The *Columbia* astronauts had spent the week conducting almost 80 experiments. Some of the experiments were submitted by students here on Earth, and they were eagerly awaiting the results.

Each year NASA pays tribute to the fallen astronauts of *Apollo I*, *Challenger*, and *Columbia* with a “Day of Remembrance.” The day is set aside to “honor those who have given their lives in the selfless pursuit of knowledge, discovery, and exploration.”



The Astronaut Memorial Space Mirror honors those astronauts who have sacrificed their lives for the Nation and the space program.



Space Shuttle *Discovery* was launched on July 26, 2005, safely returning the shuttle fleet to flight. It had been almost 30 months since the loss of *Columbia*. Even then, NASA remained very cautious. Even after *Discovery's* successful flight, it was a whole year later before the Space Shuttle flew again. The country and NASA were seeing the terrible risks of space flight. They were focused more than ever on safety.



The STS 51-L (*Challenger*) mission patch



The STS-107 (*Columbia*) mission patch



As space shuttle *Endeavour* waits for launch, the U.S. Air Force *Thunderbirds* fly past in commemoration of NASA's 50th anniversary year.

By now, NASA had made the decision to retire the Shuttle in 2010. This date allowed the U.S. to fulfill its promise to the partners of the ISS. The space station would be completed. NASA has other plans on the horizon. A whole new spaceship was in the works and plans were being made to explore even farther into the depths of space. The Space Shuttles *Discovery*, *Atlantis*, and *Endeavour* would still fly. NASA would keep America's **workhorse** in space for a few more years.

## Lesson 12

### Student Text—To Space and Back



It will be a sad day when the orbiter's wheels touch down for the last time. The Shuttle will have flown almost three decades. The Shuttle astronauts have had the courage to soar higher in spite of the risks. They all say it is worth it. In their eyes, the benefits far outweigh the risks. They will be looking toward the future with the rest of us. Exciting days are ahead for America's space travelers and those who wish them well.



NASA will look forward to Ares I when the space shuttle retires in 2010.

*Ares I image credit: NASA*



## Lesson 13 – It Takes A Team

**Lesson prep time:** 1 hour (for gathering materials and following pre-lesson instructions including 40 minutes to preview the video [Destiny in Space](#))

**Teaching time:** 2 hours (Science, Math, Technology)

### Objectives

1. The students will create a timeline showing the achievements of NASA through the year 2003.
2. The students will understand some of the functions of the Space Shuttle as they view the film [Destiny in Space](#) and see teamwork in action.
3. The students will realize some of the functions of space probes as they view the film [Destiny in Space](#) and see teamwork in action.
4. The students will work together in teams to solve math problems to experience how engineers, scientists, and other workers at NASA work together in teams to solve problems.
5. The students will explain the solutions to their problems in a class presentation.
6. The students will continue to research and design an advanced model of the PSA for the astronauts on Mars.



An unusual sight: two Space Shuttles on their launch pads awaiting their individual countdowns.

## National Standards

### Science

- Abilities necessary to do scientific inquiry – S2Ea, S2Ma
- Understandings about scientific inquiry – S2Eb, S2Mb
- Properties of objects and materials/Properties and changes in matter – S3Ea, S3Ma
- Position and motion of objects/Motion and forces – S3Eb, S3Mb
- Objects in the sky – S5Eb
- Changes in Earth and sky/Earth in the solar system – S5Ec, S5Mc
- Abilities of technological design – S6Ea, S6Ma
- Understanding about science and technology – S6Eb, S6Mb
- Risks and benefits – S7Md
- Science and technology in local challenges/in society – S7Ee, S7Me
- Science as a human endeavor – S8Ea, S8Ma
- History of science – S8Mc

### Mathematics

- Compute fluently and make reasonable estimates – M3
- Understand patterns, relations, and functions – M4
- Use mathematical models to represent and understand quantitative relationships – M6
- Analyze change in various contexts – M7
- Use visualization, spatial reasoning, and geometric modeling to solve problems – M11
- Apply appropriate techniques, tools, and formulas to determine measurements – M13
- Formulate questions that can be addressed with data and collect, organize, and display relevant data to answer them – M14
- Understand and apply basic concepts of probability – M17
- Problem solving – M18
- Reasoning and proof – M19
- Communication – M20

### Geography

- How to use maps and other geographic representations, tools, and technologies to acquire, process, and report information from a spatial perspective – G1
- The physical and human characteristics of places – G4
- How human actions modify the physical environment – G14

### Language Arts

- Standards 1, 3, 4, 5, 6, 7, 8, 11, and 12 (See the Language Arts Matrix on page 12.)

### Technology – ISTE

- Students are proficient in the use of technology – I2
- Students develop positive attitudes toward technology uses that support lifelong learning, collaboration, personal pursuits, and productivity – I5
- Students use productivity tools to collaborate in constructing technology-enhanced models, prepare publications, and produce other creative works – I7
- Students use telecommunications to collaborate, publish, and interact with peers, experts, and other audiences – I8
- Students use technology to locate, evaluate, and collect information from a variety of sources – I10
- Students employ technology in the development of strategies for solving problems in the real world – I14

### Technology – ITEA

- Relationships among technology and other fields – T3
- Cultural, social, economical, and political effects – T4
- Effects of technology on the environment – T5
- Role of society in the development and use of technology – T6
- Influence of technology on history – T7
- Attributes of design – T8
- Engineering design – T9
- Role of troubleshooting, research and development, inventions and innovation, and experimentation in problem solving – T10
- Apply the design process – T11
- Use and maintain technological products and systems – T12

- Assess impact of products and systems – T13
- Information and communication technologies – T17
- Transportation technologies – T18

## Materials

- Student logs
- Timeline, Timeline Date Sheet, and blank entry cards
- IMAX movie Destiny in Space (40 minutes)
- TV with a DVD player
- A set of questions for students to answer as they watch the movie and a set of questions or topics for discussion after viewing the movie
- “Problems for Tiger Team” worksheets
- Some method for displaying the math worksheets to the class

## Pre-lesson Instructions

1. Reserve a TV set with a DVD player for the film Destiny in Space.
2. Preview the film Destiny in Space, and make notes on specific questions or topics that you want to discuss. Be sure to include questions about Mars, since the students will be building a Mars colony. Prepare two or three questions for the students to answer as they watch the film. Prepare several additional questions or topics for a discussion after the students watch the film.
3. Duplicate a copy of the “Answer Sheet for Tiger Team Problems” if needed.
4. Duplicate one copy of each of the “Problems for Tiger Team” worksheets. There are 12 different worksheets.
5. As each team presents their solutions to the class, they will need to display the problems. Provide a way for the worksheet to be projected or displayed in the classroom so that it is visible to all students. Try to have one or two extra worksheets not given to a team. These can be displayed in the classroom for teams to work on as they wait for all of the groups to finish.
6. Divide the class into teams with three students per team. Assign a leader, recorder, and reporter for each team. The leader will read the problems and guide the problem-solving work. The recorder will record all of the solutions. The reporter will report the findings to the class.

## Procedure

1. Ask the students to take out their logs and turn to the student text for Lesson 12, “To Space and Back.” Direct the students’ attention to “The Space Race” timeline. Have the students fill in the events from 1972–2003 based on the student text from Lesson 12. Use the Timeline Date Sheet for the exact dates. (Exclude the dates for the ISS, but leave room for these to be filled in later.)
2. Tell the students that they will be watching the IMAX movie, Destiny in Space. Part of this film features the astronauts on board the shuttle as they deploy and repair the Hubble Space Telescope. Other parts take the viewer millions of miles beyond Earth to soar above the surfaces of Venus and Mars. This tour is made possible by the space probes that mapped Venus and Mars. Tell them that they should pay close attention to the part on Mars, since they will be building a Mars colony later in the unit.
3. Display or ask the questions that students should answer as they watch the film. If teachers have not previewed the film, they may want to take notes on specific questions or topics that they will want to discuss afterwards.
4. Show the IMAX movie Destiny in Space. After the movie, discuss the questions that the students were asked before showing the film. Encourage the students to ask questions and participate in a discussion about the film. Make sure that students understand that, even though the tours of Venus and Mars appear animated, these are accurate mappings of both planets due to the space probes that orbited each planet.
5. Explain that every accomplishment that they saw in the film was made possible by teamwork. Teams of engineers, scientists, and other NASA workers are constantly involved in problem solving. Sometimes these teams are called Tiger Teams because they are put together to “attack” a problem.
6. Tell the class that today they will be working in Tiger Teams to solve some math problems. Assign the students to their teams and give each student the job of leader, recorder, or reporter. Explain the responsibility of each job.

## Lesson 13

### Procedure

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- The leader will read the problems and guide the problemsolving work.
  - The recorder will record all of the solutions.
  - The reporter will report the findings to the class.
7. If the class has never used “Play 24,” do a few problems together to teach them how to play. (See example problems below.) You can add, subtract, multiply, and divide. You must use all four numbers, but use each number only once. You can use the answer of an operation only once, as well. Tell them that a good strategy is to try and find factors of 24 and addends to make a sum of 24.
  11. When all teams have finished reporting, ask if any team solved the class problems. If so, let them explain their solutions. If not, solve these problems together as a class.
  12. Remind the class that their Personal Satellite Assistant (PSA) designs are due in a few days and that they should also be collecting materials to be used to build their Mars colonies. Answer any questions they might have about these assignments.

### Example Problems

- 1) For 7, 8, 4, 5:  
 $7-5=2$      $8+4=12$      $2 \times 12=24$   
or  
 $[7-5=2 \times (8+4) =24]$
  - 2) For 7, 7, 7, 3:  
 $7 \div 7=1+7=8 \times 3=24$
  - 3) For 2, 2, 5, 7:  
 $7 \times 2=14$      $5 \times 2=10$      $14+10=24$   
or  
 $[7 \times 2=14+ (5 \times 2) =24]$
8. Display the class problem worksheet(s). Tell the students to “attack” this when they have finished their own problems.
  9. Distribute the “Problems for Tiger Team” worksheets. Tell the students to decide quickly on a name for their group other than the 1A, 2B, etc., names on the worksheets and write this name in the blank at the top of their page. Tell them that they will have about 15–20 minutes to solve the problems. Allow time for all teams to finish. Walk around and provide assistance as needed.
  10. When all of the teams are finished, let each reporter present the team’s solutions. Instruct each team to display their set of problems and explain how they solved each one. Even though the reporter takes the lead, the other team members should stand and help as necessary.

## Answer Sheet for Tiger Team Problems

“Play 24” problems may have multiple solutions.

### Tiger Team – 1A

- For 7, 1, 4, and 7:  $7+1=8$      $7-4=3$      $8 \times 3=24$
- For 5, 3, 2, and 3:  $5+2=7$      $7 \times 3=21$      $21+3=24$
- Grapes 9 lbs., Cantaloupe 12 lbs., Bananas 4 lbs.,  
Total 43 lbs.
- Ruthie, Rod, Robbie, Reba, Rosie, and Raul

### Tiger Team – 2B

- For 7, 2, 4, and 5:  $7+5=12$      $4-2=2$      $2 \times 12=24$
- For 6, 9, 2, and 2:  $2 \times 9=18$      $18-6=12$      $12 \times 2=24$
- Hannah could have used 6 different groups of coins.
- 36 different routes

### Tiger Team – 3C

- For 7, 2, 6, and 8:  $6-2=4$      $7-4=3$      $3 \times 8=24$
- For 7, 3, 3, and 1:  $7 \times 3=21$      $21+3=24$      $24 \div 1=24$
- Whirlpool Rapids River is 16 miles long.
- Ron should stop on step 160 to look for the loose tile.

### Tiger Team – 4D

- For 8, 8, 9, and 7:  $9-7=2$      $2 \times 8=16$      $16+8=24$
- For 2, 5, 2, and 3:  $2 \times 5=10$      $10-2=8$      $8 \times 3=24$
- There are 17 habitats on Mars.
- The tribe numbers are from left to right 15, then 25, then 9, then 12, then 7

### Tiger Team – 5E

- For 7, 9, 6, and 1:  $7+1=8$      $9-6=3$      $8 \times 3=24$
- For 6, 7, 5, and 8:  $7+5=12$      $8-6=2$      $2 \times 12=24$
- Nick paid \$11 and Caroline paid \$26.
- 

Ernie	Pat
Becky	Bob
Sheila	Ginny

or

Pat	Ernie
Bob	Becky
Ginny	Sheila

### Tiger Team – 6F

- For 4, 5, 8, and 9:  $9-5=4$      $4 \times 4=16$      $16+8=24$
- For 2, 2, 7, and 6:  $7+2=9$      $9 \times 2=18$      $18+6=24$
- 30 people petted John, and 75 people petted Vicky.
- 

orange	red
blue	pink
green	yellow

### Tiger Team – 7G

- For 3, 6, 6, and 1:  $3 \times 6=18$      $1 \times 6=6$      $18+6=24$
- For 4, 5, 7, and 1:  $4 \times 7=28$      $5-1=4$      $28-4=24$
- 6 crayfish, 4 turtles; or 4 crayfish, 9 turtles; or 2 crayfish, 14 turtles
- Twelve planets are in the star system. Zenith lives on the sixth planet from Zion.

### Tiger Team – 8H

- For 5, 3, 4, and 3:  $3 \times 4=12$      $5-3=2$      $2 \times 12=24$
- For 4, 7, 3, and 2:  $7-3=4$      $4+2=6$      $4 \times 6=24$
- The meowie will weigh 6 lbs., and the barkstra will weigh 18 lbs. in October.
- Each day, they give out 12 more than the previous day for 7 days.

### Tiger Team – 9I

- For 1, 1, 6, and 9:  $1+1=2$      $2 \times 9=18$      $18+6=24$
- For 5, 2, 3, and 4:  $5+3=8$      $8+4=12$      $2 \times 12=24$
- Richard spent 6 days on the Moon. He would have 72 blue Moon rocks.
- The creepy cactus will be three times higher on Friday. By next Monday, the star burst will be 8 ft. high, and the cactus will be 21 ft. high.

## Lesson 13

### Answer Sheet for Tiger Team Problems

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#### Tiger Team – 10J

1. For 2, 2, 7, and 8:  $2+2=4$       $7-4=3$       $3 \times 8=24$

2. For 8, 8, 4, and 7:  $8-7=1$       $4-1=3$       $3 \times 8=24$

3.

r	b	w
w	r	b
b	w	r

r	w	b
w	b	r
b	r	w

Other combinations are acceptable.

4. Patty and Jane saw 36 puppies, 12 kittens, 6 birds, and 9 rabbits. They saw 63 animals in all.

#### Tiger Team – 11K

1. For 2, 2, 4, and 7:  $7 \times 4=28$       $2+2=4$       $28-4=24$

2. For 6, 5, 8, and 4:  $6-5=1$       $4-1=3$       $3 \times 8=24$

3. They bought six toads for \$18 and four frogs for \$20.

4. The monster ate 45 cakes.

#### Tiger Team – 12J

1. For 3, 4, 7, and 1:  $3 \times 7=21$       $4-1=3$       $21+3=24$

2. For 2, 5, 8, and 6:  $5 \times 6=30$       $8-2=6$       $30-6=24$

3. Tom must dust 34 sides and tops. On Tuesday he will dust 44 in all.

4. They can plan their day in 27 different ways.



## Problems for Tiger Team 1A

### PLAY 24

Use all four numbers, but use each number only once to make 24. You can add, subtract, multiply, or divide. Use the result of an operation only once.

**EXAMPLE:** For 9, 2, 6, and 4:  $2 \times 4 = 8$   $9 - 6 = 3$   $3 \times 8 = 24$

For 6, 2, 4, and 7:  $2 \times 7 = 14 + 4 = 18 + 6 = 24$

1. Use **7** **1** **4** **7** to make 24.

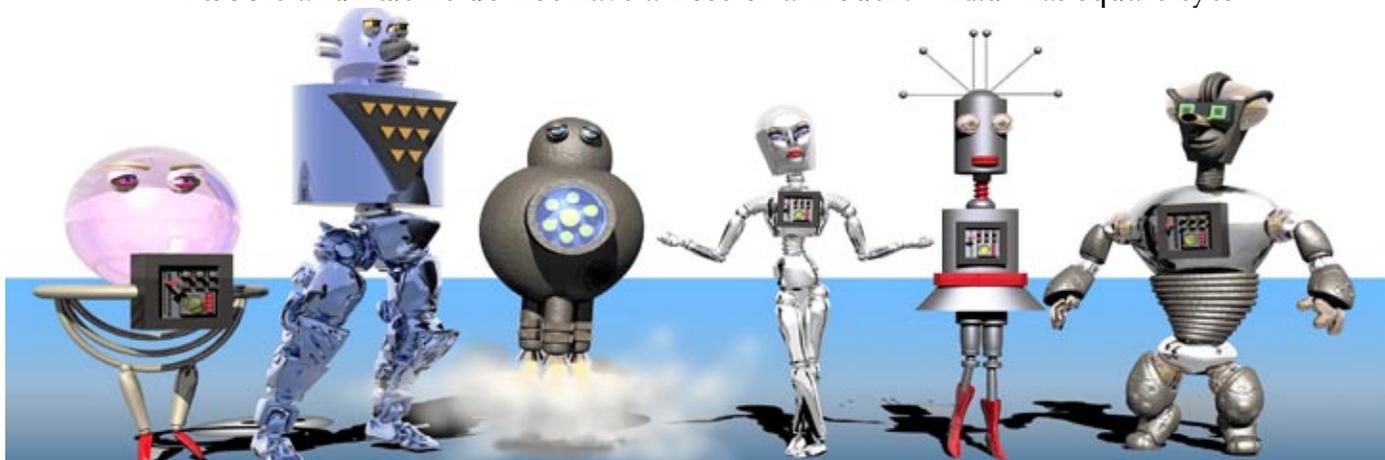
2. Use **5** **3** **2** **3** to make 24.

3. When Melissa got back to Earth, she weighed some of the fruits that she had grown on the space station. She weighed a watermelon, a bunch of grapes, a cantaloupe, and a bunch of bananas. The bananas were eight pounds less than the cantaloupe, and the cantaloupe was three pounds more than the grapes. The grapes weighed half as much as the watermelon. The watermelon was 18 pounds! How much did each of the other fruits weigh? What was the total weight of the fruits?



4. In a far off galaxy, the Ruby family has just bought six new robots. Their names were Reba, Rosie, Raul, Rod, Robbie, and Ruthie. On the way home their name tags fell off. Can you help the Ruby family find the name of each robot?

- Rod and Robbie do not have square control panels.
- Reba and Raul have arms.
- Robbie and Ruthie do not have a nose or a mouth.
- Raul has square eyes





## Problems for Tiger Team 2B

### PLAY 24

Use all four numbers, but use each number only once to make 24. You can add, subtract, multiply, or divide. Use the result of an operation only once.

**EXAMPLE:** For 9, 2, 6, and 4:  $2 \times 4 = 8$   $9 - 6 = 3$   $3 \times 8 = 24$   
 For 6, 2, 4, and 7:  $2 \times 7 = 14 + 4 = 18 + 6 = 24$

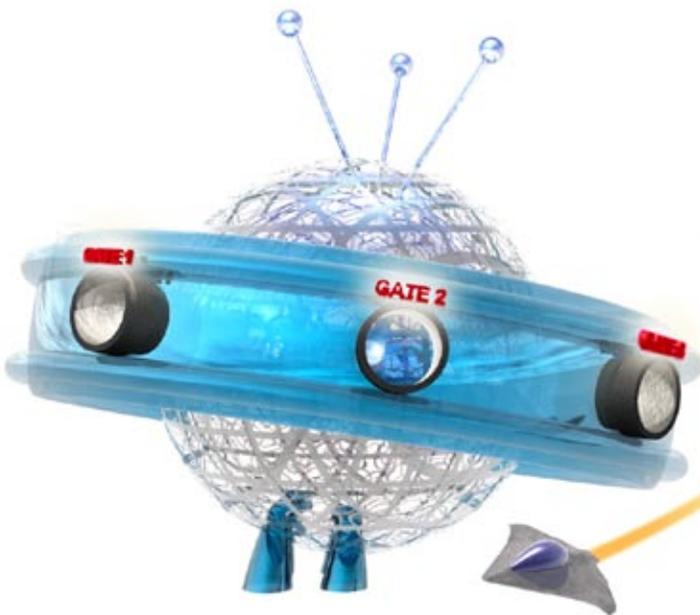
1. Use **7** **2** **4** **5** to make 24.

2. Use **6** **9** **2** **2** to make 24.

3. Hannah got on the space elevator ride and dropped her coins into the money meter. Her space elevator ride fare was 15¢. How many different groups of coins could Hannah have used to pay for her subway fare?



4. Charlie the Alien lived in a spaceship with a radar screen around it. If anyone wanted to see Charlie, they could enter through three different gates. Once inside the outer ring of the ship, they could enter the ship through four different doors. Finally they could go through three different hatches to enter the command module where Charlie lived. How many different routes could an Earthling take from outside the spaceship to Charlie's command module?





## Problems for Tiger Team 3C \_\_\_\_\_

### PLAY 24

Use all four numbers, but use each number only once to make 24. You can add, subtract, multiply, or divide. Use the result of an operation only once.

**EXAMPLE:** For 9, 2, 6, and 4:  $2 \times 4 = 8$   $9 - 6 = 3$   $3 \times 8 = 24$   
 For 6, 2, 4, and 7:  $2 \times 7 = 14$   $14 + 4 = 18$   $18 + 6 = 24$

1. Use **7** **2** **6** **8** to make 24.
2. Use **7** **3** **3** **1** to make 24.

3. When the Expedition Crew landed on the planet Hydra, they named and explored Whirlpool Rapids River. They started out at Circle Rapids and paddled seven miles south to one end of the river. The next day they paddled nine miles north to Seven Falls. When a storm came up, they turned around and paddled five miles south to Swirling Waters and set up camp for the night. The next day they paddled 12 miles to the other end of the river. How many miles long is Whirlpool Rapids River on the planet Hydra?



4. Ron has a treasure map of an abandoned launch site. When he gets to the launch tower, the directions tell him to climb a certain number of steps. When he has climbed this certain number of steps, he should look for a loose tile where further instructions are hidden. The map gives clues about the number of steps but it does not tell how many.
  - There are more than 125.
  - There are less than 180.
  - If you count by 5s, you say the number's name.
  - The number can be divided evenly by 4 and 8.
 How many steps should Ron climb before he stops to look for the loose tile?





### Problems for Tiger Team 4D

#### PLAY 24

Use all four numbers, but use each number only once to make 24. You can add, subtract, multiply, or divide. Use the result of an operation only once.

**EXAMPLE:** For 9, 2, 6, and 4:  $2 \times 4 = 8$   $9 - 6 = 3$   $3 \times 8 = 24$   
 For 6, 2, 4, and 7:  $2 \times 7 = 14 + 4 = 18 + 6 = 24$

1. Use **8** **8** **9** **7** to make 24.
2. Use **2** **5** **2** **3** to make 24.

3. Garry and the Mars Expedition Team have inflated their individual habitats in a row on First Street. Garry needs to assemble some of the team for a meeting. First, he goes down the street four habitats to get Nate. Nate lives in the first habitat on the street. Then, Garry goes up the street six habitats to find Ben. From here he goes back down the street three habitats to find Zack. Next, he goes up the street 13 habitats to get Elijah. Elijah lives in the last habitat on the street. How many habitats are built on Mars?



4. Planet Nike has five different tribes living there. All of the tribesmen in each tribe look alike, and each tribe has a number. Daniel is trying to tell which tribe is which. He knows that Tribes 7, 9, 12, 15, and 25 are on Nike.

- Tribes 9 and 7 have smiling faces.
- Tribes 25 and 7 have pointed ears.
- Tribe 15 has freckles.

Can you help Daniel put a number with each tribesman?





## Problems for Tiger Team 5E \_\_\_\_\_

### PLAY 24

Use all four numbers, but use each number only once to make 24. You can add, subtract, multiply, or divide. Use the result of an operation only once.

**EXAMPLE:** For 9, 2, 6, and 4:  $2 \times 4 = 8$   $9 - 6 = 3$   $3 \times 8 = 24$   
 For 6, 2, 4, and 7:  $2 \times 7 = 14 + 4 = 18 + 6 = 24$

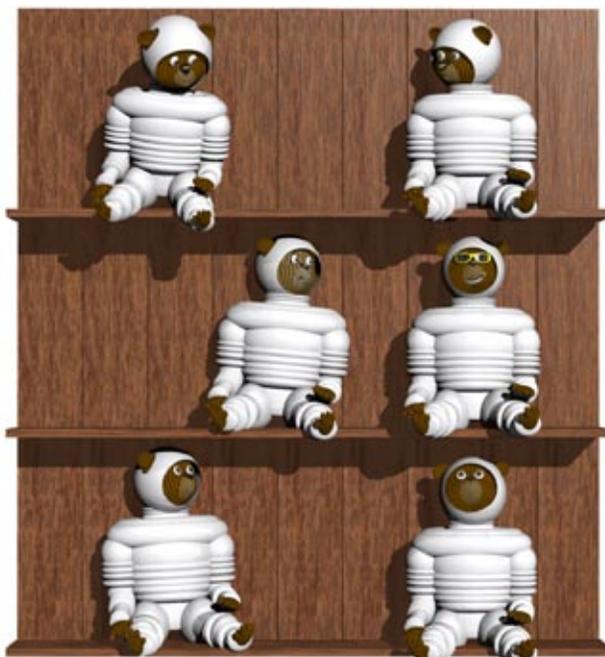
1. Use **7** **9** **6**

**1** to make 24.

2. Use **6** **7** **5**

**8** to make 24.

3. Nick and Caroline wanted to buy a model rocket for their garden. They both took out their money. Together, they paid \$37 for the model rocket. Caroline paid \$15 more than Nick. How much did each pay?



4. Dory was putting six new astronaut bears in the display case at the space shop. The case had three shelves, one on top of the other, with two spaces on each shelf. Each bear had a name: Ginny, Ernie, Becky, Pat, Bob and Sheila. Dory put Becky next to Bob and above Sheila. She did not put Ernie next to Bob or Sheila. She did not put Ginny next to Ernie. Where did Dory place each of the astronaut bears?



## Problems for Tiger Team 6F

### PLAY 24

Use all four numbers, but use each number only once to make 24. You can add, subtract, multiply, or divide. Use the result of an operation only once.

**EXAMPLE:** For 9, 2, 6, and 4:  $2 \times 4 = 8$   $9 - 6 = 3$   $3 \times 8 = 24$

For 6, 2, 4, and 7:  $2 \times 7 = 14 + 4 = 18 + 6 = 24$

1. Use **4** **5** **8** **9** to make 24.

2. Use **2** **2** **7** **6** to make 24.

3. Vicky and John are special sheep. They have been to space and back on the Space Shuttle. Now they live at the Space and Rocket Center. They like to count their visitors and the number of people who pet them. After visiting hours on Saturday, Vicky reported that 105 people in all had petted both of them. Vicky bragged that  $2\frac{1}{2}$  times as many people petted her as petted John. How many people petted Vicky and how many petted John?



4. Beth bought six colored boxes to store materials for her Moon Colony Project. She put them in two stacks on the shelf. She put three boxes in each stack. She put the green box under the blue box. She put the yellow box on the right side of the green box. She put the orange box on top of the blue box. Finally, Beth put the pink box between the yellow box and the red box. How did Beth arrange the six boxes?





## Problems for Tiger Team 7G

### PLAY 24

Use all four numbers, but use each number only once to make 24. You can add, subtract, multiply, or divide. Use the result of an operation only once.

**EXAMPLE:** For 9, 2, 6, and 4:  $2 \times 4 = 8$   $9 - 6 = 3$   $3 \times 8 = 24$   
 For 6, 2, 4, and 7:  $2 \times 7 = 14 + 4 = 18 + 6 = 24$

1. Use **3** **6** **6** **1** to make 24.
2. Use **4** **5** **7** **1** to make 24.

3. Pluto Pond on Farmer Howard's farm is filled with crayfish and mud turtles. His wife, Guen, says she doesn't know how many turtles and crayfish there are, but she has counted 76 legs in all. Each crayfish has 10 legs, and each turtle has four legs. How many crayfish and how many turtles could there be in Pluto Pond? Find two of the three solutions.



4. Zenith is looking for friends to play space ball. All of his friends live in his star system. Zenith leaves his planet and flies five planets west to get Zeke. Zeke lives on the first planet from the star Zion, their sun. Then, Zenith flies east eight planets to get Zorpa. From here he flies west six planets to find Zerk. Then he flies east nine planets for Zuck. Zuck lives on the last planet in the star system. How many planets are in Zenith's star system? In what position is Zenith's planet from Zion?





## Problems for Tiger Team 8H

### PLAY 24

Use all four numbers, but use each number only once to make 24. You can add, subtract, multiply, or divide. Use the result of an operation only once.

**EXAMPLE:** For 9, 2, 6, and 4:  $2 \times 4 = 8$     $9 - 6 = 3$     $3 \times 8 = 24$   
 For 6, 2, 4, and 7:  $2 \times 7 = 14 + 4 = 18 + 6 = 24$

1. Use **5** **3** **4** **3** to make 24.
2. Use **4** **7** **3** **2** to make 24.



3. Laurie and Mike live on Spectra. Laurie's pet meowie weighs two pounds in June. Mike's barkstra weighs 14 pounds in June. Both pets are gaining about a pound a month. If they keep on gaining weight like that, the barkstra will soon weigh three times more than the meowie. How many pounds will the meowie and the barkstra weigh then? What month will it be?

4. Bill's mother is campaigning for the office of Grand Hanuka on planet Hanuka. Bill and Gena are handing out buttons for Bill's mother. They start the first day with 500 buttons and hand out 50 buttons. On the second day they hand out 62 buttons. On the third day they hand out 74 buttons. If they hand out all the buttons at this rate, how many days will it take them to give out all of the buttons?





## Problems for Tiger Team 9I \_\_\_\_\_

### PLAY 24

Use all four numbers, but use each number only once to make 24. You can add, subtract, multiply, or divide. Use the result of an operation only once.

**EXAMPLE:** For 9, 2, 6, and 4:  $2 \times 4 = 8$     $9 - 6 = 3$     $3 \times 8 = 24$   
 For 6, 2, 4, and 7:  $2 \times 7 = 14 + 4 = 18 + 6 = 24$

1. Use **1** **1** **6** **9** to make 24.
2. Use **5** **2** **3** **4** to make 24.

3. On the first EVA of his Moon mission, Richard found two blue Moon rocks. He put them in a special sack. On the next day, he found four blue Moon rocks and put them in his sack. On each day of the mission, Richard found two more blue Moon rocks than he had found the day before. On the last day of his mission, he had 42 blue Moon rocks in the sack. How many days did Richard's Moon mission last? How many blue Moon rocks would he have if he stayed two more days on the Moon?



4. The space cadets had some very weird plants growing in their greenhouse. They raised star burst plants that grow one foot a day and creepy cactus plants that grow two feet a day. On Monday, the cadets found that they had a star burst plant one foot high and a creepy cactus plant seven feet high. On what day will the creepy cactus be three times as high as the star burst? How high will the plants be the following Monday?





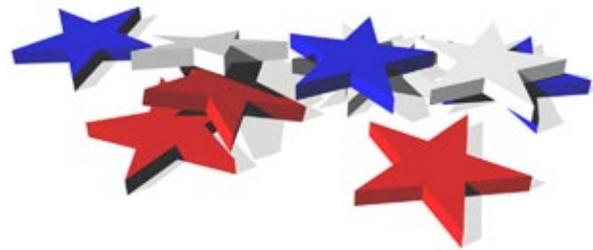
## Problems for Tiger Team 10J

### PLAY 24

Use all four numbers, but use each number only once to make 24. You can add, subtract, multiply, or divide. Use the result of an operation only once.

**EXAMPLE:** For 9, 2, 6, and 4:  $2 \times 4 = 8$     $9 - 6 = 3$     $3 \times 8 = 24$   
 For 6, 2, 4, and 7:  $2 \times 7 = 14 + 4 = 18 + 6 = 24$

1. Use **2** **2** **7** **8** to make 24.
2. Use **8** **8** **4** **7** to make 24.



- b. Larry is making a big banner to hang on the wall of his Moon habitat. He has three red stars, three blue stars, and three white stars to put on the banner. He is going to put the stars in three rows and three columns. How can he place the stars so that he has a red star, a blue star, and a white star in each row and each column?

4. Patty and Jane were trying to decide what kind of pet they wanted to take on their tour of the solar system. They looked at a lot of animals at Tyson's Pet Store. They looked at three more rabbits than birds. They saw  $\frac{1}{2}$  as many birds as kittens. There were  $\frac{1}{3}$  as many kittens as puppies. They took a long look at the 36 adorable puppies. How many of each kind of animal did they see? How many animals did they look at altogether?





## Problems for Tiger Team 11K

### PLAY 24

Use all four numbers, but use each number only once to make 24. You can add, subtract, multiply, or divide. Use the result of an operation only once.

**EXAMPLE:** For 9, 2, 6, and 4:  $2 \times 4 = 8$     $9 - 6 = 3$     $3 \times 8 = 24$   
 For 6, 2, 4, and 7:  $2 \times 7 = 14 + 4 = 18 + 6 = 24$

1. Use **2** **2** **4** **7** to make 24.
2. Use **6** **5** **8** **4** to make 24.

3. Steve and Marquita saw an ad that read:

#### WANTED:

**Warty Toads and Smooth Frogs for Space Shuttle Experiment**  
**I will pay \$3 for each toad and \$5 for each frog.**

#### Professor Quarles

Steve and Marquita caught 10 toads and frogs and brought them to the professor. The professor gave them \$38. How many frogs and how many toads did they take to the professor? What was the total payment for the frogs? For the toads?



4. Slowly Katie peeked around the Moon Base cafeteria door. The huge monster wiped its mouth, smiled, went to sleep, and started to snore. Katie had been watching while the monster ate the cakes in the cafeteria. The first hour, it ate  $\frac{1}{2}$  of all the cakes in the cafeteria. The second hour, it ate  $\frac{1}{2}$  of all the cakes left. The third hour, it ate  $\frac{1}{2}$  of what was left. And the fourth hour, it ate  $\frac{1}{2}$  of the cakes left again. Now, there are three cakes left. How many cakes did the monster eat?





## Problems for Tiger Team 12L

### PLAY 24

Use all four numbers, but use each number only once to make 24. You can add, subtract, multiply, or divide. Use the result of an operation only once.

**EXAMPLE:** For 9, 2, 6, and 4:  $2 \times 4 = 8$     $9 - 6 = 3$     $3 \times 8 = 24$   
 For 6, 2, 4, and 7:  $2 \times 7 = 14 + 4 = 18 + 6 = 24$

1. Use **3** **4** **7** **1** to make 24.
2. Use **2** **5** **8** **6** to make 24.

3. Karen and Tom sell square tins of Space Toffee in their shop. On Monday, they had 12 tins in the shop. They stacked the tins on a shelf, two tins in a stack, and the stacks touched sides. That night, Tom dusted the tops and the sides of the tins that are not touching the shelf or another tin. How many sides and tops together did he dust on 12 tins of Space Toffee? On Tuesday they get six more tins and sell two. How many sides and tops together did he dust on the tins of Space Toffee on Tuesday night?



4. On Saturday afternoon, David and his friends are trying to decide what to do. They are going to ride their space mobiles, walk, or hovercraft to the park. They can swim, play ball, or fly a kite at the park.



Then, they can eat pizza, burgers, or tacos. How many different ways can David and his friends spend their day?



## Lessons 14 and 15 – Research Project – Astronauts at Work

**Lesson prep time:** 15–20 minutes (for gathering materials and following pre-lesson instructions)

**Teaching time:** 1–2 hours each for 2 days (Language Arts, Science, Technology)

### Introduction for Lessons 14 and 15

“Astronauts at Work” is a team research project requiring about two class periods. Students will work in teams of three or four on six different aspects in the life of an astronaut. Topics include Astronaut Training, Going to Space, Working in Space, Living in Space, Returning to Earth from Space, and Life Aboard the International Space Station (ISS). The topics Going to Space, Working in Space, Living in Space, and Returning to Earth from Space refer to experiences aboard the space shuttle. Once the Orion crew exploration vehicle comes into service, these topics will refer to experiences aboard Orion.

### Objectives

1. The students will use multiple sources to research their topics about astronauts at work.
2. The students will practice the research skills of using the Table of Contents, using an index, and finding information on the Internet.
3. The students will read non-fiction materials to acquire information.
4. The students will gather and evaluate information.
5. The students will apply their knowledge of language to write a report about their topic.
6. The students will apply the knowledge gained from their research to illustrate their pages of a class book about astronauts at work.
7. The students will make a presentation to the class to share their research.
8. The students will continue to research and design an advanced model of the Personal Satellite Assistant for the astronauts on Mars.

## National Standards

### Science

- Abilities necessary to do scientific inquiry – S2Ea, S2Ma
- Understandings about scientific inquiry – S2Eb, S2Mb
- Position and motion of objects/Motion and forces – S3Eb, S3Mb
- Objects in the sky – S5Eb
- Changes in Earth and sky/Earth in the solar system – S5Ec, S5Mc
- Abilities of technological design – S6Ea, S6Ma
- Understanding about science and technology – S6Eb, S6Mb
- Risks and benefits – S7Md
- Science and technology in local challenges/in society – S7Ee, S7Me
- Science as a human endeavor – S8Ea, S8Ma
- History of science – S8Mc

### Language Arts

- Standards 1, 3, 4, 5, 6, 7, 8, 11, and 12 (See the Language Arts Matrix on page 12.)

### Technology – ISTE

- Students are proficient in the use of technology – I2
- Students develop positive attitudes toward technology uses that support lifelong learning, collaboration, personal pursuits, and productivity – I5
- Students use productivity tools to collaborate in constructing technology-enhanced models, prepare publications, and produce other creative works – I7
- Students use telecommunications to collaborate, publish, and interact with peers, experts, and other audiences – I8
- Students use a variety of media and formats to communicate information and ideas effectively to multiple audiences – I9
- Students use technology to locate, evaluate, and collect information from a variety of sources – I10
- Students employ technology in the development of strategies for solving problems in the real world – I14

### Technology – ITEA

- Relationships among technology and other fields – T3
- Cultural, social, economical, and political effects – T4
- Effects of technology on the environment – T5
- Role of society in the development and use of technology – T6
- Influence of technology on history – T7
- Attributes of design – T8
- Engineering design – T9
- Role of troubleshooting, research and development, inventions and innovation, and experimentation in problem solving – T10
- Apply the design process – T11
- Use and maintain technological products and systems – T12
- Assess impact of products and systems – T13
- Information and communication technologies – T17
- Transportation technologies – T18

### Materials

- Six or more computers to be used for research and printing
- Many picture books on astronauts, the Space Shuttle (or Orion when it comes into service), and the ISS so that each team has access to several books on their topic
- Student logs
- 30–40 sheets of 12- by 18-inch (or 9- by 12-inch) white construction or heavy drawing paper (9- by 12-inch paper is recommended if there are time restraints.)
- Drawing and coloring materials, such as magic markers, colored chalk, oil crayons, etc.
- 25+ sheets of 9- by 12-inch white drawing paper for captions

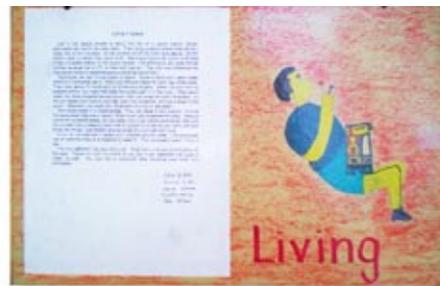
### Pre-lesson Instructions

1. Try to have at least six computers available for research and printing during both class periods.
2. Gather many picture books for this project. Even when computers are used for research, picture books will help with the research, illustrations, and explanations. (These books should already be in the classroom.) Use your local public library, as well as your school library.

3. Make a decision on the size of the book, either 12- by 18-inch or 9- by 12-inch, to determine which size paper to use. Put out the drawing and coloring materials such as magic markers, colored chalk, oil crayons, etc. Have all of the materials laid out and ready to be used before the lesson begins.
4. Divide the class into six teams for the “Astronauts at Work” project. Assign a leader and a recorder to each one.
5. Duplicate the “Guidelines and Suggestions for Research for Astronauts at Work” sheet for each group.
6. If adult volunteers are needed to help the students with their research, arrange for them to be at school at a designated time.
4. Decide whether the book will be bound at the top or on the left side. Each page will need a  $\frac{3}{4}$ -inch margin either on the side or at the top. This space will be used for punched holes to bind the book. Demonstrate measuring and drawing a line for the margin.
5. Hand out the “Guidelines and Suggestions for Research for Astronauts at Work” sheet for each topic. Explain that all of the suggestions do not have to be researched. These are just guidelines to get started. Assist each group as needed as they research and write their reports. Adult volunteers could also be used to assist the groups with their reports.

## Procedure—Lesson 14

1. Write the title “Astronauts at Work” and the six topics on the board — Astronaut Training, Going to Space, Working in Space, Living in Space, Returning to Earth from Space, Life Aboard the International Space Station (ISS). Tell the class that they will be divided into teams to research each of these topics.
2. Assign the students to their teams and appoint a leader and a recorder for each one. Let them meet for about three minutes to decide their first, second, and third choices for a topic. While the groups are meeting, write the numbers 1–6 on small sheets of paper. Then, fold them and place them in a container. Let each group leader draw a sheet of paper from the container. This will determine the order in which the topics are chosen. Call on each team until every team has selected their topic.
3. Explain that they will be producing a class book divided into six sections (their topics). The first page of each section will be a written report of their research. They can type this on a computer or write it by hand. This will be glued to a sheet of construction paper. From this information, each team member will use another sheet to illustrate and provide a **caption** for one part of the report, so that one team will have a written page followed by three or four (or more) picture pages. Each student should illustrate at least one page. Part of each page may use a color picture (or pictures) printed from the computer, but it should be enhanced by the students’ own artwork.



6. After the reports have been written, each team member will choose a part of the report to illustrate. For example, a student in the Training group might choose to draw the astronauts practicing in the Neutral Buoyancy Laboratory or a student in the Living group might show the astronauts eating their dinner. Each picture should have a one- or two-sentence caption.
7. Time may not allow for the students to finish their illustrations, so have them put their illustrations in a safe place until the next class period.

### Procedure—Lesson 15

1. Allow time for each of the students to complete their illustrations.
2. When all of the illustrations are complete, have each team present their work to the class. Ask the leader

of each team to read the report. Then, each member should display his/her illustration, read the caption, and provide any extra information as needed.

3. Laminate all the pages.
4. Display all of the pages on a bulletin board for a few weeks before binding them in a book. Ask a group of students to design and illustrate a cover for the book.
5. Remind the students that their Personal Satellite Assistant designs and presentations are due the next class period and that they will need the materials to begin building the Mars colonies for Lesson 18. Allow time for the Mars Expedition Teams to meet, discuss their plans, and assess their materials needs.





## Guidelines and Suggestions for Research for Astronauts at Work



### Astronaut Training

- Background requirements for the astronauts (education, etc.)
- Classroom work
- Learning to fly the *T-34* and the *T-38*
- Practice in the Neutral Buoyancy Laboratory
- Practice in the Weightless Wonder, NASA's name for the Vomit Comet (currently a *C-9B Skytrain II*)
- Practice in the orbiter simulator
- Practice using the robotic arm
- Emergency escape training
- Training in mock-ups
- Survival training in remote and harsh environments
- Use the following website: <http://www.nasa.gov/>. Under "Find It @ NASA," type in "Astronaut Training Timeline."



## Guidelines and Suggestions for Research for Astronauts at Work



### **Going to Space (in the Space Shuttle until Orion comes into service)**

- Vehicle Assembly Building
- Crawler ride to the launch pad
- Positioning Shuttle on the launch pad
- Countdown (begins 4 days before launch)
- Getting the astronauts ready on launch day
- Liftoff
- Mission Control
- Solid Rocket Booster separation and retrieval
- External Tank separation
- Astronaut experience during launch
- Entering orbit



## Guidelines and Suggestions for Research for Astronauts at Work

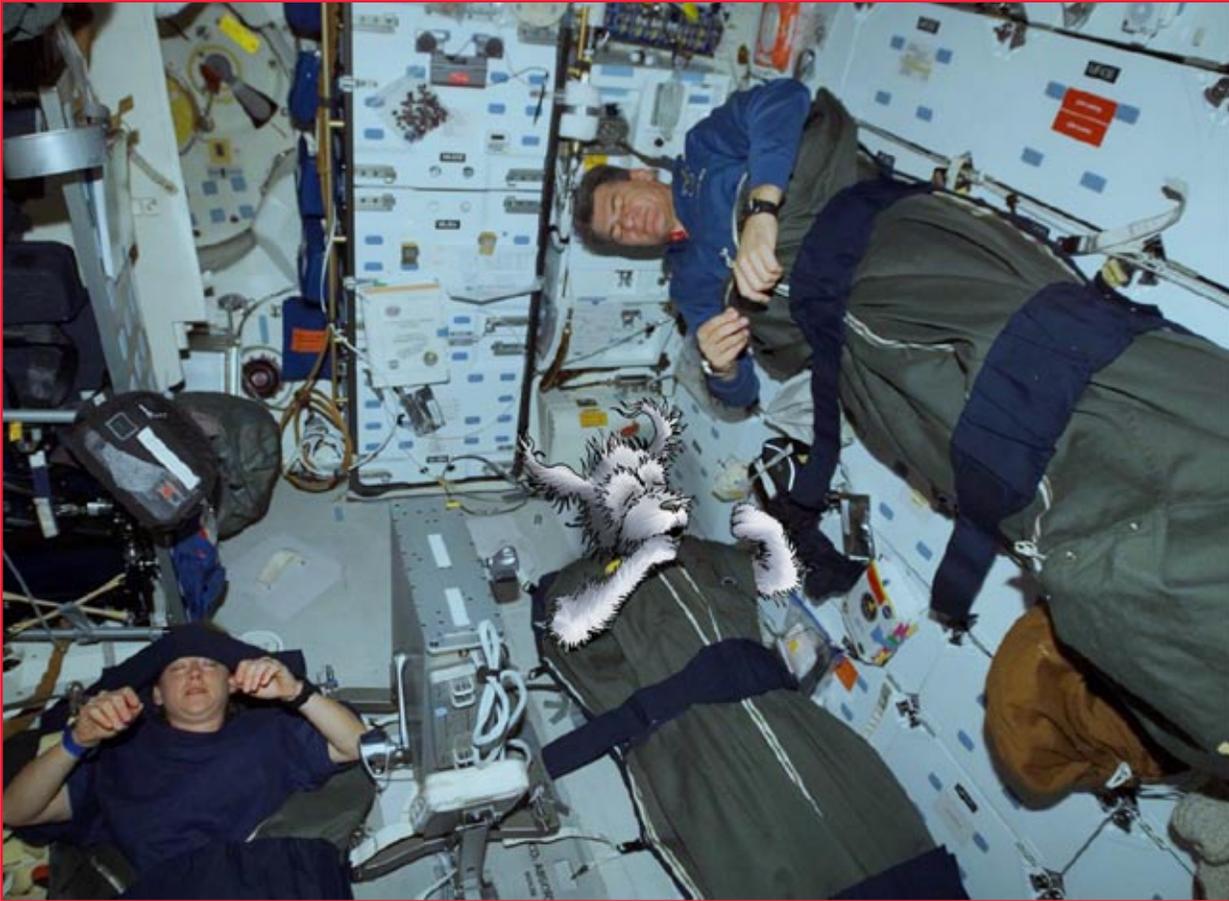


### **Working in Space (in the Space Shuttle until Orion comes into service)**

- Photographing the Earth
- Operating the robotic arm
- Putting satellites in orbit
- Repairing satellites
- Performing spacewalks
- Performing experiments
- Communicating with Mission Control
- Constructing the ISS



## Guidelines and Suggestions for Research for Astronauts at Work



### Living in Space (in the Space Shuttle until Orion comes into service)

- Living quarters
- Eating
- Sleeping and wake-up calls
- Exercise
- Personal hygiene
- Clothing
- Free time



## Guidelines and Suggestions for Research for Astronauts at Work



### Returning to Earth from Space (in the Space Shuttle until Orion comes into service)

- Preparing the orbiter
- Astronauts prepare for landing
- Re-entering the atmosphere
- Landing at Cape Canaveral (Kennedy Space Center in Florida)
- Alternate landing at Edwards Air Force Base in California and flying piggyback to Kennedy Space Center in Florida
- Orbiter Processing Facility
- Astronaut checkups and debriefing



## Guidelines and Suggestions for Research for Astronauts at Work



*Destiny laboratory on the International Space Station (ISS)*

### **Life Aboard the International Space Station (ISS)**

- Maintaining the ISS
- Experiments
- Photography
- Communication – Mission Control, family, friends, school groups
- Unloading cargo ships
- Spacewalks
- Dexter the robot
- Exercise
- Personal time



## Lesson 16 – The Personal Satellite Assistant Presentations

**Lesson prep time:** 35 minutes (for gathering materials and preparing an optional bulletin board)

**Teaching time:** 1¼ hours (Language Arts, Science, Technology)

### Objectives

1. The students will observe and recognize the harsh environment on Mars as they consider designs for the Personal Satellite Assistants (PSAs) that will be used by the first astronauts to visit the planet.
2. The students will present their designs of a PSA, explain the function of each of the labeled parts, outline its capabilities, and describe the plan for using the PSA in the Martian environment.
3. The students will participate in their pretend roles as NASA engineers as they listen to the presentations of their classmates and question and/or make suggestions to the presenter about his/her design.
4. The students will identify the best components of each design and apply these to a final PSA composite design.
5. The students will predict ways in which the PSA might one day be used in the public domain.
6. The students will conduct research on the planet Mars and find available research about surviving there.

## National Standards

### Science

- Abilities necessary to do scientific inquiry – S2Ea, S2Ma
- Understandings about scientific inquiry – S2Eb, S2Mb
- Position and motion of objects/Motion and forces – S3Eb, S3Mb
- Objects in the sky – S5Eb
- Changes in Earth and sky/Earth in the solar system – S5Ec, S5Mc
- Abilities of technological design – S6Ea, S6Ma
- Understanding about science and technology – S6Eb, S6Mb
- Risks and benefits – S7Md
- Science and technology in local challenges/in society – S7Ee, S7Me
- Science as a human endeavor – S8Ea, S8Ma
- History of science – S8Mc

### Mathematics

- Use visualization, spatial reasoning, and geometric modeling to solve problems – M11
- Understand measurable attributes of objects and the units, systems, and processes of measurement – M12
- Apply appropriate techniques, tools, and formulas to determine measurements – M13
- Problem solving – M18
- Communication – M20

### Language Arts

- Standards 1, 3, 4, 5, 6, 7, 8, 11, and 12 (See the Language Arts Matrix on page 12.)

### Technology – ISTE

- Students are proficient in the use of technology – I2
- Students develop positive attitudes toward technology uses that support lifelong learning, collaboration, personal pursuits, and productivity – I5

- Students use productivity tools to collaborate in constructing technology-enhanced models, prepare publications, and produce other creative works – I7
- Students use telecommunications to collaborate, publish, and interact with peers, experts, and other audiences – I8
- Students use a variety of media and formats to communicate information and ideas effectively to multiple audiences – I9
- Students use technology to locate, evaluate, and collect information from a variety of sources – I10
- Students employ technology in the development of strategies for solving problems in the real world – I14

### Technology – ITEA

- Relationships among technology and other fields – T3
- Cultural, social, economical, and political effects – T4
- Role of society in the development and use of technology – T6
- Influence of technology on history – T7
- Attributes of design – T8
- Engineering design – T9
- Role of troubleshooting, research and development, inventions and innovation, and experimentation in problem solving – T10
- Apply the design process – T11
- Use and maintain technological products and systems – T12
- Assess impact of products and systems – T13
- Information and communication technologies – T17

### Materials

- Optional – Display area for PSA design posters
- Project assignment – “Building a Mars Colony”

## Pre-lesson Instructions

1. Be sure that the location (classroom or elsewhere) of the presentations provides a quiet and undisturbed environment and that every student in the audience can see and hear the speaker clearly.
2. Optional – Prepare a bulletin board or another area for the posters to be displayed.
3. Duplicate enough copies of the project assignment, “Building a Mars Colony,” for each student. Punch holes so that students can insert these in their logs.

## Procedure

1. Prepare the class for listening to the PSA presentations. Remind them that they will probably have to present their research on many occasions when they become adults. Explain that, in many cases, their job success will depend on the strength of their abilities to present their ideas.
2. Instruct the class to be professional and positive as they listen to the presentations, ask questions, and make suggestions. Tell them that they may have a job one day that requires them to be knowledgeable members of an audience listening to their co-workers’ presentations and reports.
3. Call on each student to present their research. After each presentation, give the class an opportunity to ask questions and make suggestions.
4. After all of the designs have been presented, conduct a discussion to identify the best components for an advanced PSA design. Some examples might be to identify the best ideas for assisting the astronaut to deal with the harsh Martian environment, the best design for traveling on the Martian terrain, etc. Some of the students may want to incorporate the best ideas to design another PSA. Perhaps extra credit could be given for this project.
5. Discuss how the use of PSAs might one day be used in the public domain. “Do you think PSAs may be common objects like cell phones?” “How would they be used?”
6. Distribute the project assignment “Building a Mars Colony” and have the students insert this in their logs. Read and discuss the assignment. Tell the students that they have been identified as Mars Expedition Team I because they will be the first humans on Mars. Explain that they will build the colony in class with their teammates beginning with Lesson 18. (Assign the actual day this will begin.)
7. Instruct the students to begin the research as homework tonight either individually or together, and to be sure to take notes. Encourage the students to share this project with their parents and get their ideas and help. Explain that the more information they bring to class, the easier the project will be for their team. Answer any questions from the students.
8. Allow the teams to meet for about five minutes to discuss their plans. Tell them that they must use a Mars map when they name their landing site.



## Building a Mars Colony

Colony name: \_\_\_\_\_

Members: \_\_\_\_\_

Crew Exploration Vehicle name: \_\_\_\_\_

Mars lander name: \_\_\_\_\_

Landing site name: \_\_\_\_\_

Structures to be built:

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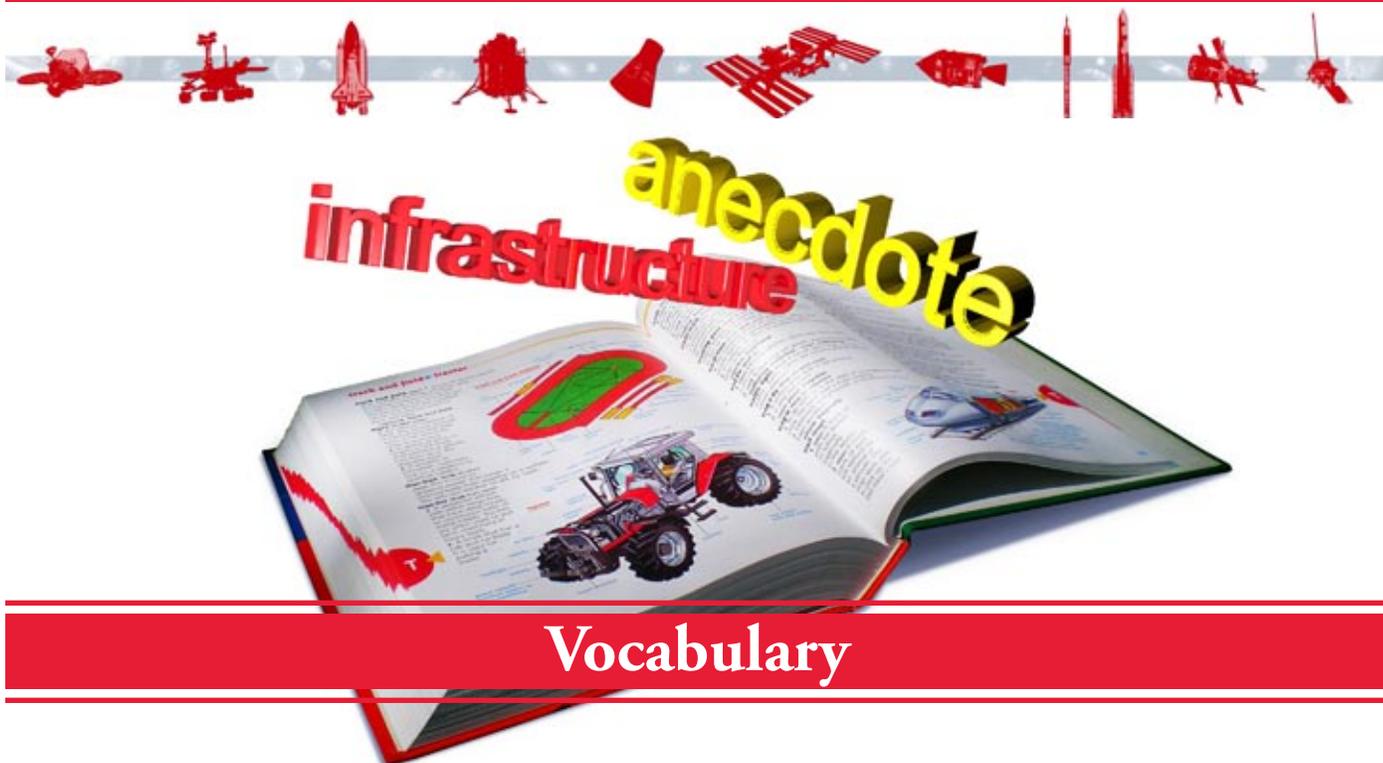
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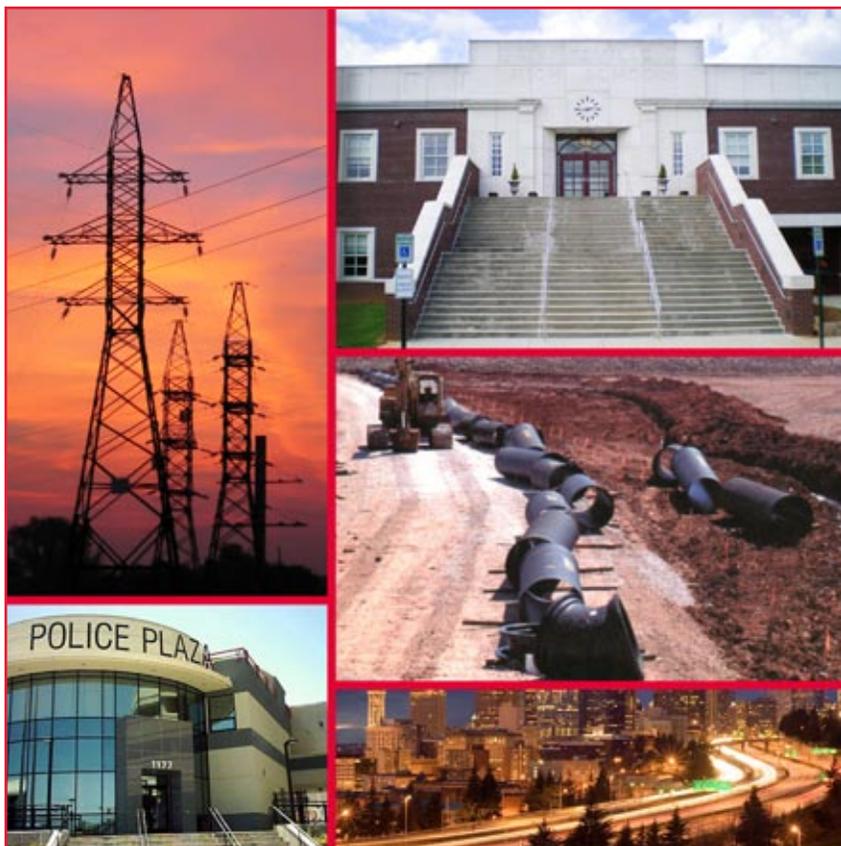
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## Vocabulary

**anecdote** – a short account of an interesting or humorous incident

**infrastructure** – the basic facilities, services, and installations needed for the functioning of a community or society, such as transportation and communications systems, water and power lines, and public institutions including schools, post offices, hospitals, law enforcement buildings, etc.



Some examples of infrastructure



## The Mars Expedition Team I Tasks

Your team will be the first humans to land on Mars. You will be responsible for building a colony that will be used for many years by other teams from Earth. You must set up the **infrastructure** that will be needed for human survival in a self-supporting colony.

Scientists on Earth have chosen a landing site based on the data from robotic missions. One robotic mole has drilled and found liquid water on this site. Another robotic mole has detected and drilled for fuel there.

Your job will include the following tasks:

1. Conduct research on the planet Mars to find out as much as possible about the planet's hostile environment. Find research that is already available about surviving there. Take notes in your student log on your research to help write your team's seven-day journal. Print or sketch ideas for the Martian structures. Some Internet sites are listed at the end of this assignment. Start by taking a virtual tour of the future colonization of Mars at the Mars Project site.
2. Find colored images of the surface of Mars. Use these images to prepare the landing site. (Your team will color a 3- by 4-foot sheet of paper that poses as the surface of Mars.) Use the map of Mars and determine a suitable landing site.
3. Build the colony. Use your research and your knowledge of survival needs, life on the Space Shuttle, and life on the ISS to plan and build the colony. Also, consider the services provided by your community. (Ask your parents about the utility bills they receive each month.) Each colony must have at least seven structures that will protect the site resources and keep your team and future residents alive for long periods on Mars. Robots have delivered the necessary building materials (the materials collected by you and your teammates) for these structures.

**Optional:** Construct figures of you and your teammates, models of your PSA robots, a model of the Mars rover, a model of the Mars lander, rocks, etc.



4. Write a seven-day journal (scientific and creative) about your daily work as your team completes the colony. Computers and Microsoft PowerPoint® presentations may be used, but printed copies must be made, as well. Journal entries will be titled as Martian days Sol 1, Sol 2, etc., and must include a daily report of the following:
- Describe your team's daily activities, including discoveries, experiments that are set up, any special events or meals, communication with Mission Control, etc. (Sol 1 should include a description of the landing area, including hills, volcanoes, valleys, rocks, etc.)
  - Give a report of the weather for the day, as well as observations of the immediate vicinity (sunrise, sunset, night sky, outside temperature, wind conditions, etc.).
  - Provide a description of the structure that was built that day, including the type of materials used, its size, its purpose, etc.
  - Give an account of the daily trips taken on the Mars rover and include a description of the surroundings (rock formations, canyons, mountains, valleys, etc.). Use the map of Mars to identify specific locations that can be used as rover destinations. Try to measure in miles, and compute the approximate distances traveled each day.

Other subjects that may be included are:

- successes, failures, and disasters;
  - personal experiences, interactions, observations, and communications with home;
  - physical/medical problems or changes; or
  - intrusions (from a decision-making robot perhaps?).
5. Prepare an oral presentation to be given to the class by the whole team.
- First, identify your landing site on the Mars map.
  - Then, describe your colony. Identify each building and tell its purpose. Add any details that you think would be of interest to the class.
  - Next, read your journal entries. Be prepared to show the routes of your daily rover excursions on the Mars map.
  - Allow time between each day for team members to add oral, personal **anecdotes** to the written entry. Team members should be thinking of personal creative elements about their experience on Mars to share during this time. Notes may be used.



## Mars/Earth Comparison

	Mars	Earth
Average Distance from Sun	142 million miles	93 million miles
Average Speed in Orbiting Sun	14.5 miles per second	18.5 miles per second
Diameter	4,220 miles	7,926 miles
Tilt of Axis	25 degrees	23.5 degrees
Length of Year	687 Earth Days	365.25 Days
Length of Day	24 hours 37 minutes	23 hours 56 minutes
Gravity	0.375 that of Earth	1 g*
Temperature	Average -81 degrees F	Average 57 degrees F
Atmosphere	mostly carbon dioxide; some water vapor	nitrogen, oxygen, argon, others
Number of Moons	2	1

\*Earth's gravity, denoted by g, refers to the gravitational attraction that the Earth exerts on objects on or near its surface.



### Internet sites for research:

<http://www.marsproject.com/>

<http://www.antarcticconnection.com/antarctic/science/index.shtml>

<http://themis.asu.edu/projects/>

<http://www.marsonearth.org/about/devon.html>

<https://ngm.nationalgeographic.com/ngm/0102/feature2/media2.html>



## Lesson 17 – A Home Above the Sky

**Lesson prep time:** 1–1½ hours (for gathering materials and following pre-lesson instructions including 50 minutes to preview the IMAX film Space Station)

**Teaching time:** 2–2½ hours Fourth graders may need two days for the reading selection. (Language Arts, Science)

### Objectives

1. The students will compare the character traits of astronauts to their own character traits.
2. The students will present their concept drawing of a space station.
3. The students will compare their homes to the home aboard the International Space Station (ISS).
4. The students will understand why the space station is an international space station.
5. The students will become familiar with the contributions of the National Aeronautics and Space Administration (NASA) as the Agency worked with Russia and 14 other nations to build the ISS.
6. The students will compare the relationship of the U.S. and the USSR in space during the period between the 1950s and 1993 to the relationship of the U.S. and Russia in space during the period between 1993 and the present.

7. After reading a selection and viewing the film Space Station, the students will list the risks and benefits of having a space station.
8. The students will continue to conduct research on the planet Mars and find available research about surviving there.



One special visitor to the ISS was Educator Astronaut Barbara R. Morgan (foreground). Barbara was selected as the backup candidate for the NASA Teacher in Space Program in July 1985. After two decades of waiting, she flew on STS-118 in August 2007 to visit the ISS.

## National Standards

### Science

- Abilities necessary to do scientific inquiry – S2Ea, S2Ma
- Understandings about scientific inquiry – S2Eb, S2Mb
- Position and motion of objects/Motion and forces – S3Eb, S3Mb
- Objects in the sky – S5Eb
- Changes in Earth and sky/Earth in the solar system – S5Ec, S5Mc
- Abilities of technological design – S6Ea, S6Ma
- Understanding about science and technology – S6Eb, S6Mb
- Risks and benefits – S7Md
- Science and technology in local challenges/in society – S7Ee, S7Me
- Science as a human endeavor – S8Ea, S8Ma
- History of science – S8Mc

### Mathematics

- Understand patterns, relations, and functions – M4
- Use mathematical models to represent and understand quantitative relationships – M6
- Formulate questions that can be addressed with data and collect, organize, and display relevant data to answer them – M14
- Problem solving – M18
- Communication – M20

### Geography

- How to use maps and other geographic representations, tools, and technologies to acquire, process, and report information from a spatial perspective – G1
- The physical and human characteristics of places – G4
- How culture and experience influence people's perceptions of places and regions – G6
- How human actions modify the physical environment – G14

### Language Arts

- Standards 1, 3, 4, 5, 6, 7, 8, 11, and 12 (See the Language Arts Matrix on page 22.)

### Technology – ISTE

- Students are proficient in the use of technology – I2
- Students develop positive attitudes toward technology uses that support lifelong learning, collaboration, personal pursuits, and productivity – I5
- Students use productivity tools to collaborate in constructing technology-enhanced models, prepare publications, and produce other creative works – I7
- Students use telecommunications to collaborate, publish, and interact with peers, experts, and other audiences – I8
- Students use a variety of media and formats to communicate information and ideas effectively to multiple audiences – I9
- Students use technology to locate, evaluate, and collect information from a variety of sources – I10
- Students employ technology in the development of strategies for solving problems in the real world – I14

### Technology – ITEA

- Relationships among technology and other fields – T3
- Cultural, social, economical, and political effects – T4
- Effects of technology on the environment – T5
- Role of society in the development and use of technology – T6
- Influence of technology on history – T7
- Attributes of design – T8
- Engineering design – T9
- Role of troubleshooting, research and development, inventions and innovation, and experimentation in problem solving – T10
- Apply the design process – T11
- Use and maintain technological products and systems – T12
- Assess impact of products and systems – T13
- Information and communication technologies – T17
- Transportation technologies – T18

## Materials

- Student logs
- A sheet of 9- by 12-inch drawing paper for each team
- A copy of the student text for Lesson 17 “A Home Above the Sky” for each student
- World map
- Large-block graph paper
- A list of the 16 countries that participated in the planning and building of the ISS (See the Pre-lesson Instructions.)
- IMAX film *Space Station* (47 minutes)
- TV with a DVD player

## Pre-lesson Instructions

1. Divide the students into teams of two or three students each to brainstorm a design of a space station.
2. Duplicate enough copies of the student text for Lesson 17, “A Home Above the Sky” for each student. Punch holes so that students can insert these in their logs.
3. Display in the following order the list of the 16 countries that participated in the planning and building of the ISS: United States, Russia, Canada, Japan, Brazil, Germany, France, Italy, United Kingdom, Netherlands, Denmark, Belgium, Sweden, Norway, Switzerland, and Spain.
4. Reserve a TV set with a DVD player for the film Space Station.
5. Preview the film Space Station and make notes on specific questions or topics that you want to discuss. Prepare two or three questions for the students to answer as they watch the film.

## Procedure

1. Instruct the students to take out their logs. Since they have completed the “Astronauts at Work” research lessons, they should be familiar with many of the tasks that astronauts perform. On the board, write the heading “Character Traits.” Under this heading, make two columns. Write the heading “Astronauts” over one side and “Me” over the other. Tell the students to copy this in their logs.



2. Have the students identify some of the character traits of astronauts. As the astronaut character traits are given, write these in the “Astronaut” column and tell the class to copy this list. Then, give the students a few minutes to put checks in the “Me” column beside those traits that they think they possess. Encourage the students to share their own character traits as well as some they would like to possess. Ask the students if they would like to work for NASA. Ask how many would like to become an astronaut. How have they changed their minds since first beginning the unit?
3. Assign the students to their teams and distribute the 9- by 12-inch drawing paper. Tell the students that they will have about 10 minutes to brainstorm their designs of a space station and label as many parts as time allows. Tell them to be prepared to explain the function of each labeled part. Remind the students that, in a brainstorming activity, all ideas are accepted, and that these are just space station concepts that may or may not be technologically correct.

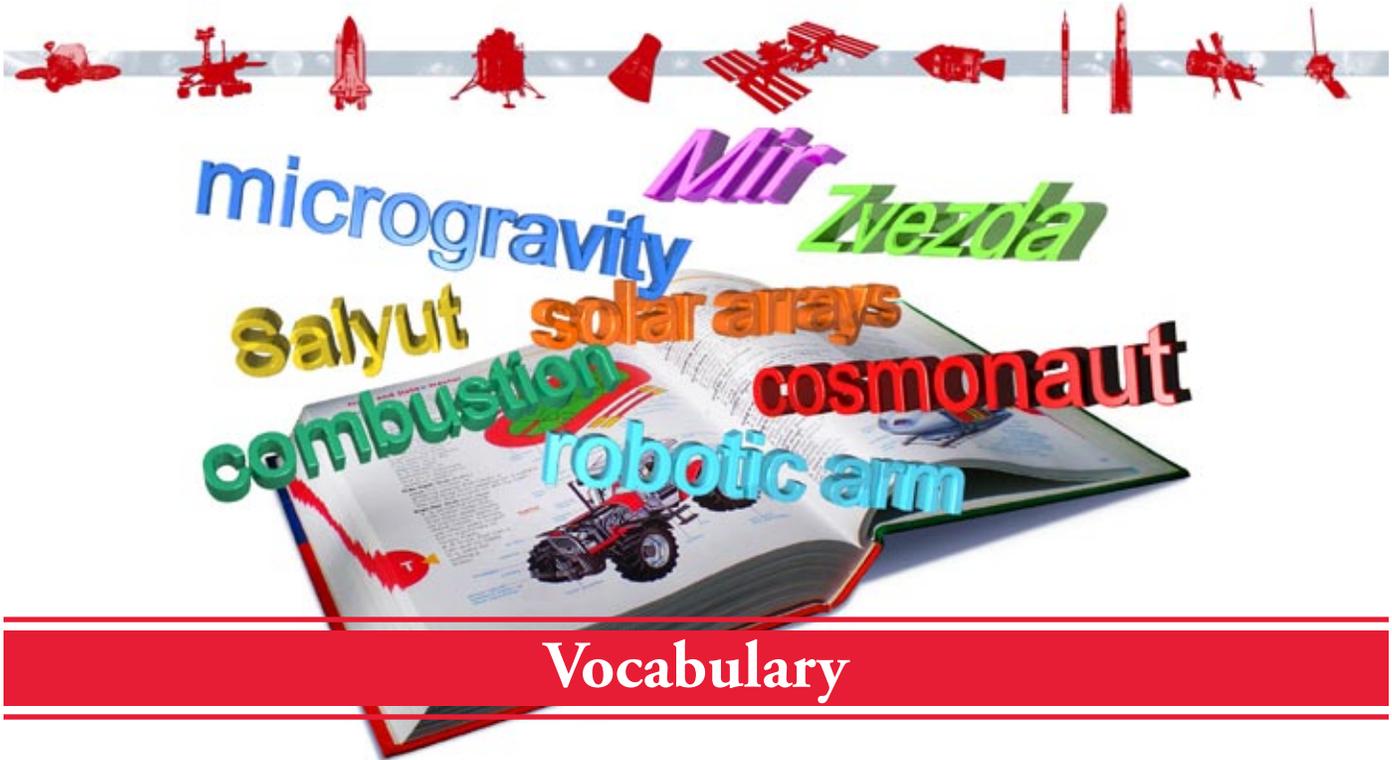
## Lesson 17

### Procedure

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4. Have each team display their drawing and explain the different functions of the labeled parts. Allow a short time for questions or a discussion of each concept. Consider a permanent display of these concepts to remind the students of their own space station designs as they read the reading selection.
5. Teach the vocabulary in the same manner that you would for a guided reading assignment. This may be a good time to explain that the USSR collapsed into independent nations in 1991, and the countries it had captured returned to independent countries. The large country of Russia, with Moscow as its capital, continued with the space program.
6. Locate Houston, Texas, in the U.S. and Moscow and Korolev (near Moscow) in Russia on a world map. Tell the students that Moscow is the capital of Russia like Washington, DC, is the capital of the U.S. Korolev is the location of Korolev Rocket and Spacecraft Corporation Energia and the Russian Federal Space Agency's Mission Control.
7. Ask the students to share information about the places they have lived as well as places they have visited or might wish to live or visit. Tell them that, in this lesson, they will read about living on the space station and see the film Space Station. (Reading the student text precedes the film because so much history and background are given in the reading selection.)
8. Distribute the student text for Lesson 17, "A Home Above the Sky" and have the students insert this in their logs. Read and discuss this selection as you would any guided reading. As the class discusses the text, question their understanding and encourage their questions.
9. Read the first section "Where Would You Want To Live?" Take a poll asking students to vote for the beach, mountains, city, or the ISS as their choice for a home for a year. Write the results of the poll on the board.
10. Distribute the graph paper. Instruct the students to make a pictograph using the data on the board. Allow about 10–15 minutes for this activity.
11. Next, read the section "Early Space Station Concepts." Compare these drawings with the students' designs and discuss similarities and differences.
12. Then, read the section "Lessons Learned from Previous Stations." In the second paragraph, the students will read about the cosmonauts who lost their lives as their spacecraft was returning to Earth. Allow time for the students to talk about these deaths, and remind them again of the risks of space exploration.
13. Look again at the pictures of the *Salyut*, *Skylab*, and *Mir* space stations. Tell the students that these space stations orbited the Earth at one time, but have since fallen back to the Earth through the atmosphere and burned up. Explain that the experiences on these stations provided valuable knowledge for the planning and building of the ISS.
14. Next, point to the list of nations that have helped to plan and build the ISS. Find each of these on a map. Tell the class that the last eleven nations belong to the European Space Agency (ESA). Tell them that this is why the space station is an international one. International means it involves two or more nations. Then, tell them they will find out how different countries have helped to build the ISS in the next section.
15. Before reading "A Big Team Builds a Big Home in Space," ask the students to think back on what they have learned about the space race. Have them describe the relationship between the U.S. and Russia. Then, read this section.
16. Before reading "A Home in Orbit," ask the students to share their experiences of moving into a new home. What important things have to be done first? Have you ever thought about the chores in your home being a matter of life and death? Ask the students to think of other ways a home in orbit is different from theirs. Then, read the section.

17. After reading “A Home in Orbit,” ask the students to compare the relationship of the U.S. and the USSR in space during the period between the 1950s and 1993 to the relationship of the U.S. and Russia in space during the period between 1993 and the present. Ask them how they would feel if they lived on the ISS with a Russian. (**Be sure the students understand the common interests of the astronauts and cosmonauts on the station.**) Have the students answer the question asked earlier in the text: “Have you ever had an old enemy turn into a new friend?”
18. Next, read and discuss the section “Living on the ISS.” Be sure to read the captions that explain how the ISS crew members spend their days.
19. Before reading “Research to Help Earthlings,” tell the students to list the reasons our world does or does not need a space station. Record their answers on the board. After reading the selection, ask them if their minds have been changed as to whether or not our world needs the station.
20. Tell the students that they will be watching the film Space Station. Display or ask the questions that students should answer as they watch the film. If teachers have not previewed the film, they may want to take notes on specific questions or topics that they will want to discuss afterwards.
21. Show the IMAX film Space Station. After the film, discuss the questions that the students were asked before showing the film. Encourage the students to ask questions and participate in a discussion about the film. Finally, ask the students to list the risks and benefits of the space station.
22. Remind the students that they will begin to build their Mars colonies tomorrow and that they should continue their research in order to be knowledgeable members of their teams. Tell them that you will be checking their individual research notes in their student logs tomorrow. Ask them to share anything interesting that they have found so far. Answer any questions they may have about the project.
23. Allow about 5–10 minutes for team members to discuss their Mars Colony Projects. Instruct them to assess what materials they have and decide on what materials they still need. Tell them to look at the worksheet for entries for names and structures. They are not to start this worksheet until Lesson 18, but they should start thinking of names for these things. Remind them that the Apollo astronauts named their command module and the lunar lander, and they should do the same.

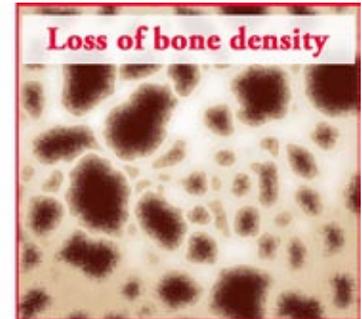


## Vocabulary

**bone density** – a measurement of the bone mass; referring to the compactness of material in the bone

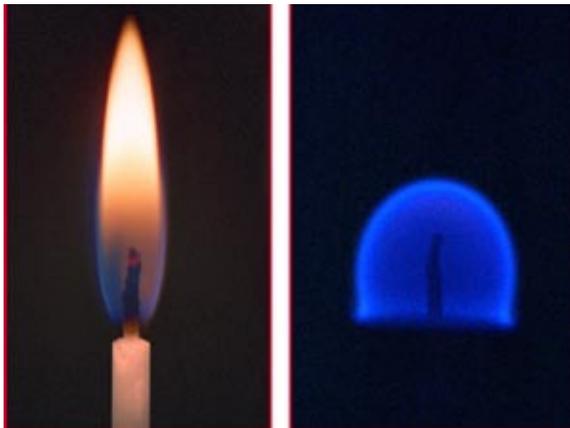


Normal bone



Loss of bone density

Loss of bone density is a problem for astronauts.



These two images of a candle flame, the left in Earth's gravity and the right in microgravity, show the difference in the processes of combustion in microgravity.

**combustion** – an act or instance of burning

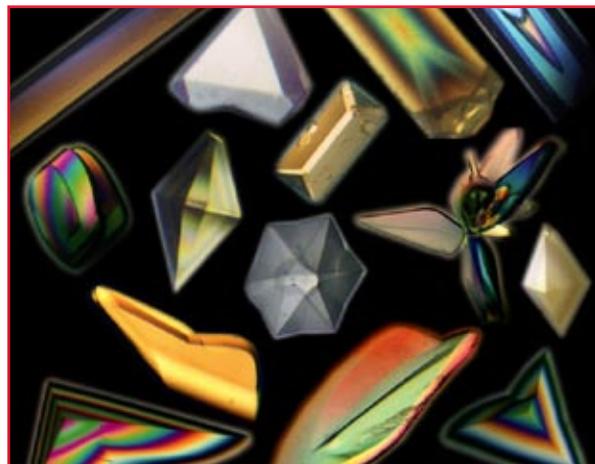
**cosmonaut** – a Soviet or Russian astronaut



Astronaut Edward Lu and Cosmonaut Yuri Malenchenko made up the ISS Expedition 7 crew.



**crystals** – a solid form of a substance that has a regularly repeating internal arrangement of its atoms and often external plane faces; a crystalline material used in electronics as a frequency-determining element as in a clock or watch; a quartz that is transparent or nearly so



Students grew crystals from biological solutions in their classrooms and prepared solutions that formed crystals on board the space station *Mir*. When the crystals were returned to Earth, the students compared crystals grown on Earth to those grown in space.



Space shuttle *Atlantis* (bottom) docks with the ISS at the ISS docking port.

**docking port** – an area where one space vehicle joins with another



An astronaut holds onto a hatch door handle on the ISS.

**hatch** – a small door or opening (as in an airplane or spacecraft)

**Houston** – a city in southeast Texas; one of the centers of the U.S. aerospace industry and the home of Johnson Space Center, the location of Mission Control for all U.S. crewed spaceflights beginning with *Gemini IV*



Johnson Space Center (JSC)



Mission Operations Control Room at JSC



**Korolev** – a city near Moscow; the center of Russia’s aerospace industry where the crewed space program and mission control are located. Korolev is also the home of S.P. Korolev Rocket and Space Corporation Energia, the Russian manufacturer of spacecraft and space station components.



The Expedition I cosmonaut called Russian Mission Control Central in Korolev.



The NASA KC-135 uses a special parabolic pattern to create brief periods of microgravity which gives astronauts a preview of weightlessness in spaceflight.

**metal alloy** – a substance consisting of two or more metals, or of a metal and a nonmetal united usually by being melted together

**microgravity** – when the force of gravity is so slight it is barely measurable; near weightlessness; almost zero gravity

**Mir** – The United Soviet Socialist Republics (USSR) launched the core module of the *Mir* space station in February 1986. It was enlarged several times so that it could accommodate a crew of up to six cosmonauts. It was also home to seven American astronauts before it fell to Earth in 2001.

**Moscow** – the capital city of Russia and the capital city of the former USSR



The Russian space station *Mir*



**node** – a point at which other parts originate or center

**republic** – a government having a chief of state who is not a monarch and who in modern times is usually a president



The *Harmony Node 2* is a pressurized component that acts as a junction between the station's U.S. laboratory and laboratories from Japan and Europe.



A view of *Harmony's* location on the ISS



Space shuttle *Endeavour's* robotic arm (left) moves away following the hand-off of an external stowage platform to the station's robotic arm while docked with the ISS.

**robotic arm** – an automatic, mechanical arm designed for grabbing, holding and pulling objects. A robotic arm is onboard the space shuttle and the ISS.

**Salyut** – The Salyut program was the first space station program undertaken by the Soviet Union. It consisted of a series of nine single-module space stations launched over a period of eleven years from 1971 to 1982. Six were scientific, and three were secret military. It was intended as a project to carry out long-term research into the problems of living in space and a variety of astronomical, biological, and Earth-resources experiments.



*Salyut 7*



**solar arrays** – panels that collect energy from the Sun for conversion to electricity

A 115-foot solar array wing containing 32,800 solar cells produces 32 kilowatts of electricity (enough to power 16 homes) for the ISS as it orbits 240 miles above Earth.

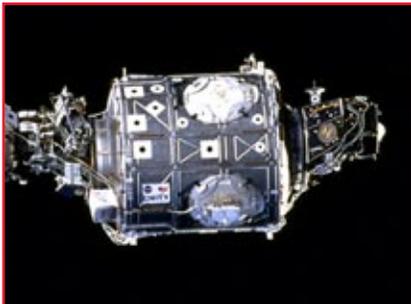


**Soyuz** – a series of spacecraft launched by the Soyuz launch vehicle (the Soyuz rocket), as part of the Soyuz program. These spacecraft were later used to carry cosmonauts to and from the Salyut space stations and *Mir*, and upgraded versions now carry cosmonauts and astronauts to the International Space Station (ISS).



Soyuz, the longest serving crewed spacecraft design in history (1967– ), is upgraded regularly.

**tissue culture** – the process or technique of making body or plant tissue grow in a culture medium outside the organism; the growth of cells (tissue) separate from the organism. This term usually is used in the context of animal tissue culture, while the term “plant tissue culture” is used for plants.



ISS *Unity* module (NASA) was connected to *Zarya* in December 1998.

***Unity*** – the first U.S.-built component of the ISS; the connecting module with six berthing locations facilitating connections to other modules

***Zarya*** – This was the first module launched for the ISS. *Zarya* provided electrical power, storage, propulsion, and guidance to the ISS during the initial stage of assembly. It is officially owned and paid for by the United States, but it was built and launched in Russia since the cost of building and launching it there was less than half the cost of building it in the U.S.

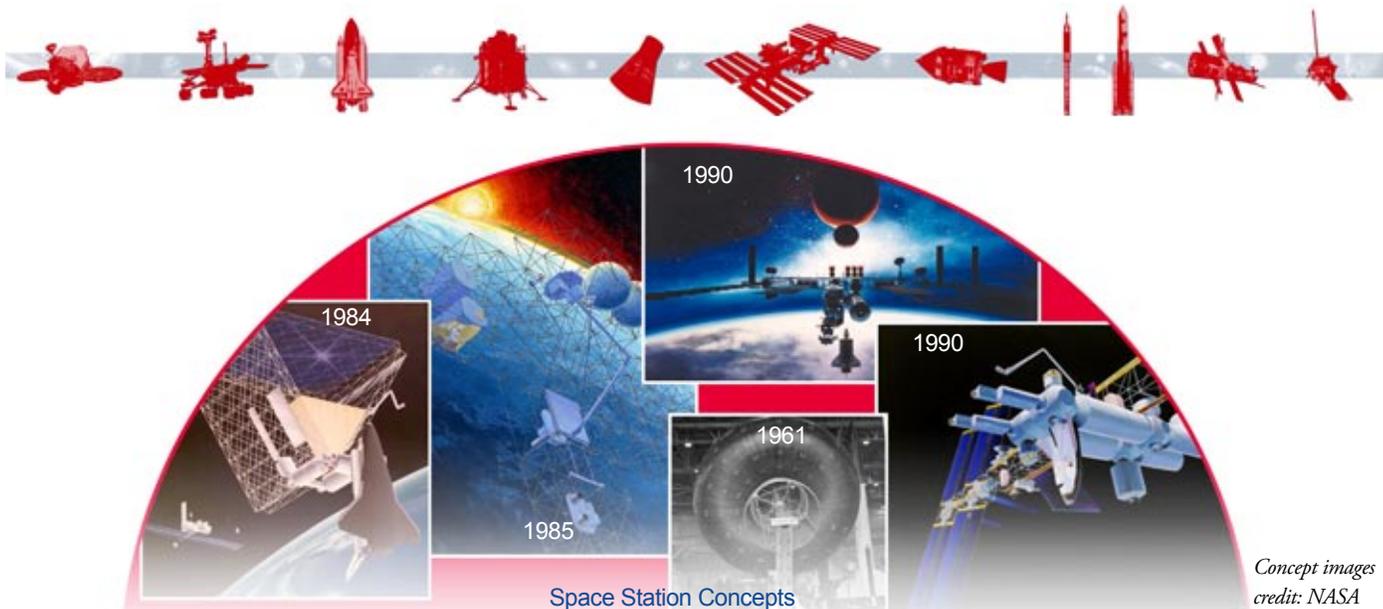


The ISS *Zarya* was the first module to be placed into orbit.

***Zvezda*** – a Russian service module for the ISS. *Zvezda* provided early living quarters, a life support system, a communication system, electrical power distribution, a data processing system, a flight control system, and a propulsion system.



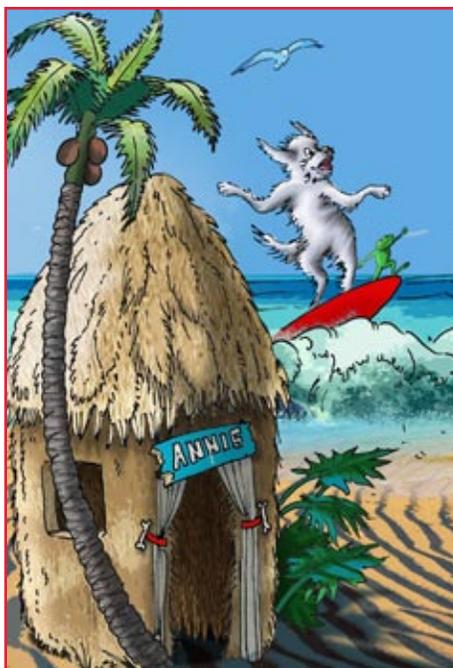
The *Zvezda* Service Module trainer/mockup was used by astronauts and cosmonauts in training for ISS expeditions.



## A Home Above the Sky

### Where Would You Want to Live?

If you could pick any place to live, where would you want to go? Some of you would say a mountain top, so you could see for miles around. Others of you might choose to live at the beach to watch waves pound against the shore. Some may want to live on the top floor of a skyscraper. The views of the city would be amazing.





But would any of you want to live in space? Think about those views from the window. If you lived on the ISS, you could see a huge part of the Earth at once, or you could look out into the heavens. No cloud could block your view.

Who in the world would want to live out of this world? The answer is thousands of people. Right now, the best way to get to live in space is to become an astronaut. So, every year, thousands of people apply to be one. They all dream of riding a spacecraft into space. They all hope for a chance to live in the space station or even beyond. You may think this would be a brave thing to do. Yes, astronauts



have to be brave, but, more importantly, they are believers. They truly believe that what they do helps other people. This is why they go through such hard training. This is why they are willing to spend months away from their homes and families. This is why they risk their lives. It is their belief that their work in space makes our home on Earth a better place. Besides, they think all this work is fun!



Jules Verne's 1865 science fiction novel

### Early Concepts of Space Stations

Long before the ISS existed, a permanent space station where people live and work existed in the minds of science fiction writers and the imaginations of those who read their books. Jules Verne and H.G. Wells were famous for their science fiction books, and millions have enjoyed their visions of the future. In fact, the 1938 radio broadcast of Well's book, The War of the Worlds, seemed so real that it caused a major panic. Many listeners believed that an actual Martian invasion was in progress! Some of the early



concepts for space stations were illustrated in these science fiction works and even in comic books, but to really believe such wild notions was a huge step for real scientists. The public would not take them seriously. Even fellow scientists would shun their beliefs. After all, access to space was still a dream.

Regardless of how others viewed them, certain visionaries in the early part of the 20th century wrote about a station in space. They knew that one day humans would have the ability to explore space and foresaw an Earth-orbiting space station. They viewed a space station as a jumping-off point to the Moon and the planets. A permanently occupied space station was a necessary outpost in the new frontier of space. Except for a very few, most people considered these ideas “loony.”



An illustration by Warwick Goble in H.G. Wells' 1898 [The War of the Worlds](#)



Image credit: NASA

An artist's impression of the “Brick Moon”

It was acceptable for Edward Hale to describe an Earth-orbiting space station in 1869. It was only a short story meant to entertain the readers of [The Atlantic Monthly](#), a popular magazine of the time. “The Brick Moon” told of a satellite that would be used by mariners to aid in navigation. The story becomes more interesting when the “moon” is accidentally launched with 37 people aboard.

One of the few scientists seriously thinking about the exploration of space was Hermann Oberth. Oberth, a German physicist, presented the first serious proposal for a space station in 1923. In one of his papers, he proposed building an orbiting structure that would serve as a station to launch and refuel spacecraft traveling into deep space.

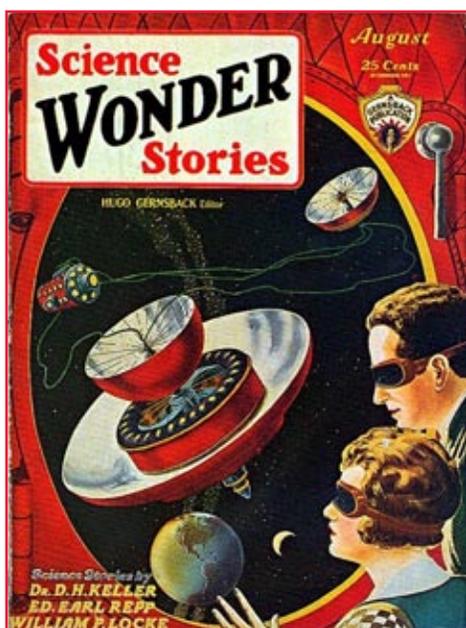
Another serious thinker was Konstantin Tsiolkovsky, a Russian rocket scientist. He published hundreds of works on space travel, including the design and construction of space rockets



Tsiolkovsky's circular Earth-orbiting space station design that would provide artificial gravity



and space stations. In his 1926 Plan of Space Exploration (an unthinkable concept at the time), he listed “Constructing large orbital habitats around the Earth” as a step in which humans would eventually conquer space.



Noordung's space station on a magazine cover

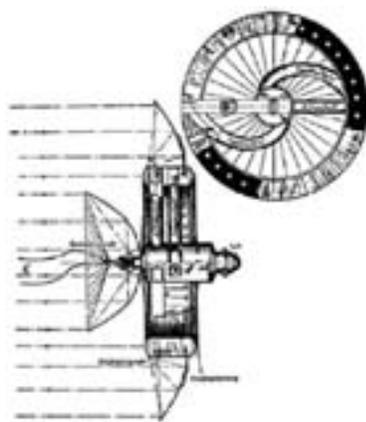
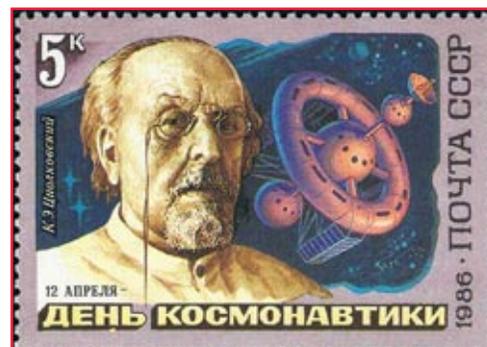


Image credit: *The California Institute of Technology*  
Noordung's sketches show the habitat ring, the first example of the rotating ring which would provide artificial gravity by centrifugal force. Noordung also drew a spiral staircase.

As a youth in Germany, Wernher von Braun read the science fiction of Jules Verne and H.G. Wells as well as the science works of Hermann Oberth. He was so inspired by the dream of space travel that he devoted his life to space science and rocketry. In 1952, Collier's magazine published von Braun's ideas and a drawing of his vision of a space station. It was a wheel-shaped rotating structure that would orbit 1,075 miles above the Earth. Von Braun envisioned several purposes for the station, including weather forecasting and navigation support. He also saw the station serving as a military outpost, a spaceport, and a launching platform for travels into deeper space.



A 1986 Soviet postage stamp honored Tsiolkovsky.

Then, the Austrian engineer Herman Noordung (the pseudonym for Potocnik) stirred a great deal of interest with actual images seen by the public. In 1928, he published the first detailed, technical drawings of a space station. He drew a three-unit space station with a habitat, a machine room, and an observatory, all connected by strong wires.



Artist's credit: *Chesley Bonestell*  
The front cover of Collier's magazine that contained the space station article by Von Braun



Von Braun supposedly encouraged NASA to build a space station prior to sending a man to the Moon, but President Kennedy decided that the Apollo program should be the earlier mission.

During the 1960s, the U.S. Air Force (USAF) began research on a Manned Orbiting Laboratory. They hoped to use it for weather observation and for spying on enemy nations. They actually got as far as a test flight, but the program was cancelled after satellites began to do much of this work.



Artist's credit: Chesley Bonestell  
The first page of von Braun's article "Crossing the Last Frontier" in *Collier's* magazine



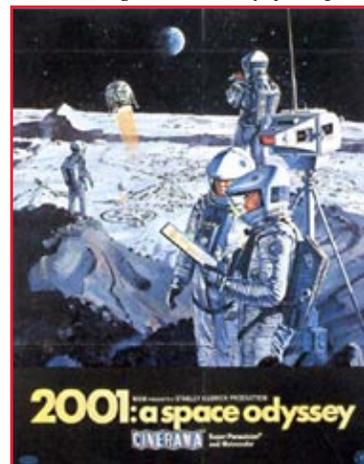
Image credit: NASA  
The USAF Manned Orbiting Laboratory (MOL)

The USAF test launch of the MOL from Cape Canaveral, FL (1966)

In the meantime, the concept of a space station was kept alive by the 1968 movie *2001: A Space Odyssey*. Stanley Kubrick's science fiction film featured a spinning double-wheel station. Space planes flew people up to the station from which they could catch a ferry to the Moon.

Image credit: Courtesy of Wikipedia

The original movie poster



The classic space station image from the movie *2001: A Space Odyssey*





Almost as soon as NASA was created, it began to study several space station strategies. In 1959, NASA printed a brochure titled “Space, The New Frontier.” The space station images inside still looked like those from science fiction articles. Even as NASA was deep in the Apollo Program, it studied space station designs. As the Space Shuttle flew dozens of missions, the space station concepts kept changing.

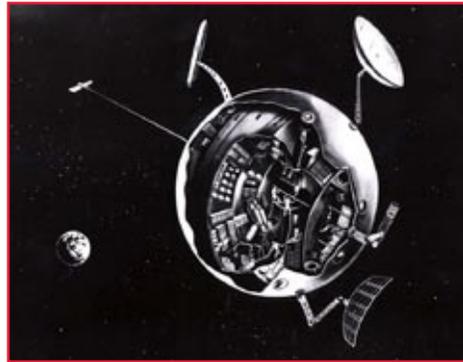


Image credit: NASA

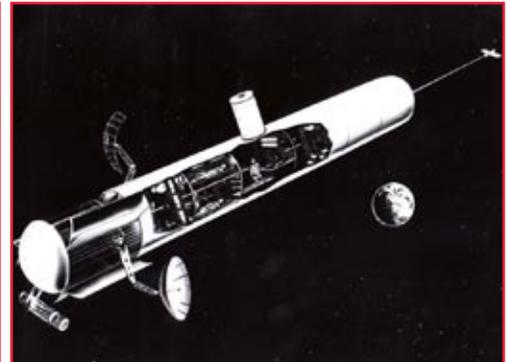


Image credit: NASA

These early space station concepts appeared in the NASA brochure “Space, the New Frontier.”



Image credit: NASA

An artist's concept of the three-radial-module space station (1960)

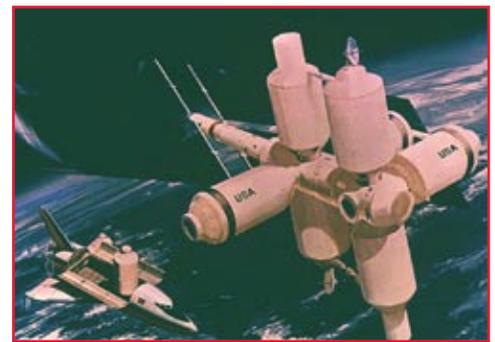


Image credit: NASA

An artist's concept of a modular space station (1970)

Finally, in a 1984 address to the nation, President Reagan directed NASA to build a space station within the decade.



Image credit: NASA

An artist's concept of the “Power Tower” space station (1985)

He also invited U.S. allies to be a part of the program. By 1985, NASA saw the station as a “power tower” with modules positioned at the bottom and solar arrays attached to the top, but that concept changed when NASA considered a dual-keel structure which positioned the modules in the center. In 1988, the Agency decided on a design called Space Station Freedom. Freedom was to be a station that



Image credit: NASA

An artist's concept of the Spider Space Station (1977)

was to be a station that



attempted to bring together the U.S., Canada, Japan, and nine European nations. Due to budget problems, the project collapsed. Instead, in 1993, the original partners, as well as Russia, pooled their resources to create a space station. At first it was named International Space Station Alpha, but later the term Alpha was dropped, and it became known as the International Space Station.



*Image credit: NASA*  
An artist's concept of the dual keel space station (1986)



*Image credit: NASA*  
An artist's concept of Space Station Freedom



*Image credit: NASA*  
An artist's concept of International Space Station Alpha



The ISS as of June 2008

## Lessons Learned from Previous Stations

Scientists have known for a long time that experiments done in space are special. They give us knowledge that could not be discovered here on Earth. That is why the USSR went into the space station business so long ago. At first, they made a lot of mistakes. Mistakes helped them to learn. They found out what works and what does not work.



The first space station was the *Salyut 1*.

While the U.S. worked with space station concepts, the USSR launched the first space station into orbit. A Proton rocket lifted *Salyut 1* to orbit in 1971. Then, a **Soyuz** spacecraft carrying the first crew docked with the station. But the station door was stuck and they were forced to return to Earth. Can you imagine going to your home in space and not being able to open the door? A better **hatch** that was easier to open had to be built. The next crew got in and lived there 23 days. On their way back, the spaceship leaked air. The

## Lesson 17

### Student Text—A Home Above the Sky



A Soyuz T spacecraft

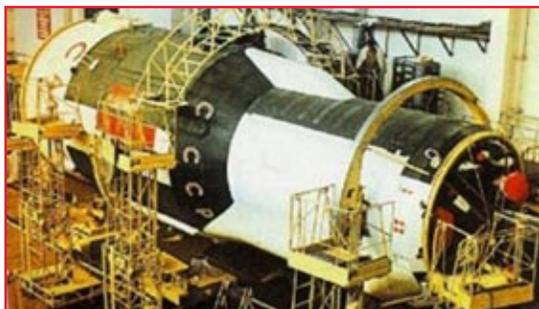
crew did not make it back to Earth alive. Future **cosmonauts** were required to wear a spacesuit in flight. The spacesuits provide air to prevent another accident like this from happening. The USSR launched three more stations, but they failed to reach orbit or broke up in orbit before crews could reach them. From these losses, the Soviets learned to make better engines.

In 1973, U.S. astronauts began to live in space when a Saturn V rocket launched *Skylab* into orbit. *Skylab* was built to be a workshop in space. NASA never meant for it to be a permanent home for the astronauts. Three different crews enjoyed three missions in *Skylab*. A fourth crew was scheduled to live in *Skylab*, but the Space Shuttle was not ready in time to carry the crew. After 6 years, *Skylab* fell back to Earth. Space stations have to be boosted back into their orbit every so often. Atmospheric drag causes them to be pulled slowly back towards Earth. So, without a boost, *Skylab* fell.



Image credit: NASA

Artist's concept of Skylab space station cluster in Earth's orbit



The Salyut 3 space station (circa 1974)

In the late 1970s, the U.S. was busy building the Shuttle, so plans for a space station were put off. However, the USSR had recovered from their earlier failures. In addition to military spy programs and scientific experiments, the USSR was learning how to build a better space station. Cosmonauts lived on *Salyut 3–7*. These stations had many problems, but the Soviets



worked hard to solve each one. They learned that a space station needed two **docking ports**. One port was used for their return, or escape, ship, and the other was for a cargo supply ship. The cargo ship would leave with the trash and burn up when it fell back to Earth.



Mir space station

In 1991, the USSR collapsed as a nation. The **republics** who formed the old USSR were now separate countries. One of these countries was Russia. A Russian space agency took over the space activities of the old USSR. Have you ever had an old enemy turn into a new friend? That is kind of what happened to the U.S. and Russia. They decided to work together as friends in space.

In 1986, the USSR put up the first part of space station *Mir*. *Mir* was built to be a permanent home in space. It was made so that parts could be added. Six new parts, called modules, made *Mir* the biggest station ever built at that time. Better engines allowed *Mir* to stay in orbit. For the first time, a human spent more than a year in space. The USSR had learned a lot about space stations. All of these lessons were later shared with the U.S. and would help NASA to plan and build a space station.



Photo credit: NASM

The final Salyut space station was the *Salyut 7*, launched in 1982.



Fish-eye view of the space shuttle *Atlantis* as seen from the Russian *Mir* space station during the STS-71 mission.



The assembly of the International Space Station has been compared to building a giant Lego toy in space.

## A Big Team Builds a Big Home in Space

When the U.S. began to plan a space station, it invited Russia and 14 other nations to join them. Although it was an international space station, NASA took the lead and was responsible for building the station. NASA built many of the ISS parts and most of the **solar arrays**. NASA used its Space Shuttle to carry most of the parts and the crew to the station. It was usually the U.S. astronauts who performed the spacewalks to connect the new parts to the ISS. Since the first crew went aboard, they have depended on NASA to operate most of the systems.

Russia was a major partner in the planning and building of the ISS. Its many years of experience with space stations helped the ISS team in the planning and design stage. Russia also built several parts, some solar arrays, and the modules for spaceships to dock. Canada built the **robotic arm**. Japan built the *Kibo* laboratory with an outside platform for experiments to



be performed in the harsh space environment. The European Space Agency (ESA) built the Columbus laboratory and a cargo supply ship. Italy, a member of ESA, built two cargo modules. Brazil helped the U.S. with some of its work.

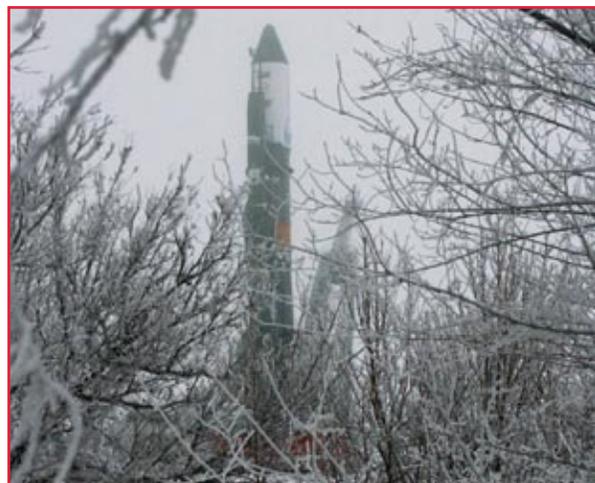


At the Baikonur Cosmodrome, the *Soyuz TMA-12* spacecraft lifts off carrying the Expedition 17 crew.

Although the Space Shuttle delivers most of the ISS parts, crews, and supplies, Russia plays an important role in maintaining the ISS. Its Proton rocket carries parts to the ISS, and its Progress cargo ship carries supplies. Russia's Soyuz spacecraft transport crew and supplies to the ISS. When the space shuttle cannot fly, Soyuz is the only spacecraft that can deliver crews to the ISS (until Orion/Ares is ready).



Space shuttle *Discovery* delivered Japan's *Kibo* laboratory to the ISS. *Kibo* is seen here in *Discovery's* cargo bay.



Roll out of the Russian Progress cargo ship



The Russian Progress spacecraft is the longest serving unmanned cargo spacecraft (1978–).



The *Soyuz TMA-5* spacecraft is mated to its booster rocket in a processing hangar at the Baikonur Cosmodrome.



While the ISS was being planned, Russia invited NASA to visit *Mir*. Seven U.S. astronauts took turns living on *Mir* with the Russian cosmonauts. The U.S. gained a lot of knowledge from these visits. Being on board *Mir* helped the U.S. to plan and make many good decisions. The U.S. learned a lot from the Russians. One thing they learned was that the U.S. astronauts did not like Russian food. The crews learned to live and work together. In 1997, a fire broke out, and the station filled with smoke.



Space shuttle *Atlantis* docked to *Mir*



Crewmembers of STS-71, Mir-18, and Mir-19

The crew worked quickly to put it out. Later that year, a Progress supply ship crashed into *Mir* causing air to rush out. Once again, astronauts and cosmonauts worked together to save the station.

In 1998, Russia put the first piece of the ISS into orbit. Its name was *Zarya*, which means sunrise. A U.S.-built module named *Unity*, taken up by the Space Shuttle, was the second piece. Astronauts performed a spacewalk to connect the two pieces. *Unity* had six berthing locations allowing for the connection of other modules. Sometimes referred to as **Node 1**, *Unity* was the first of three connecting modules in the completed space station.



However, nobody could live on the ISS yet. Russia ran out of money and could not get the third piece up. Its name was *Zvezda*, and it was the living area. It was almost two years before *Zvezda* was put in place. Then, the shuttle took up supplies and equipment. It was far from complete, but the new home above the sky was ready for humans to live there. The first crew came aboard in November 2000.

### A Home in Orbit

In early November 2000, the Expedition 1 crew brought the ISS to life. It was like setting up a new home on Earth. Astronaut Bill Shepherd was the commander. Cosmonauts Yuri Gidzenko and Sergei Krikalev made up the rest of the crew. Each one had been in training for years to do their special tasks.

Their first tasks were just like those of any new home owner. First, they got the food warmer to work. Next, they set up their sleeping areas. Then, they all called home. In this case, it was a



Astronaut Bill Shepherd and Cosmonaut Yuri Gidzenko work on the food warmer.



In view from top to bottom are *Unity*, *Zarya*, *Zvezda*, and the docked Progress M1-3 spacecraft.

call made back to Earth. They called Mission Control in **Houston** and in **Korolev**, a city outside of **Moscow** in Russia. Now that's a long distance phone call!



The Expedition I crew got the ISS ready for future residents.

## Lesson 17

### Student Text—A Home Above the Sky



During the next four months, the crew worked hard. They had to get the computers to work and the systems working. These were life and death tasks. These systems gave them oxygen, cleaned the air, and provided water. The crew also got the medical center and the exercise equipment working. These are needed to keep humans healthy in space. These were all some major assembly instructions! Three shuttle flights brought equipment and supplies, and three Progress ships brought supplies. The parts and supplies had to be unloaded and stored. The crew set up the first laboratory, the U.S. *Destiny* module. They had to perform spacewalks to put parts of the station in place. They also had to do some research. Future crews were very thankful for these three men. They had set up a space home for humans to use for at least the next 15 years.



The crew still found time to photograph the Earth.



The treadmill exercise device had to be assembled.



The crew had to help set up the U.S. *Destiny* laboratory brought up by STS-105.



The crew worked so hard they sometimes had to combine work and eating.



However, this home was quite a bit different from those on Earth. The completed ISS is about 360 feet (110 meters) wide and 290 feet (88 meters) long. It is about the size of two football fields placed side by side. (A football field is 160 feet wide and 300 feet long.) What a huge home! That is why it had to be taken up in parts. The station is in orbit about 240 miles (386 kilometers) from Earth. And this home moves! In fact, it moves at a speed of 17,500 mph (28,164 km per hour)! The ISS does not get power from the city power lines. Instead, it is powered by an acre of solar arrays which trap energy from the sun. (An acre is about half the size of a soccer field.) Batteries are also used since the ISS is in the shadow of Earth a lot of the time. The arrays also provide the electrical power to run six different laboratories. Research from all over the world is done here.

The ISS is scheduled to be completed in 2010. It will eventually consist of 14 pressurized modules with a living volume of around 15,000 cubic feet (425 cubic meters). These modules include laboratories, docking compartments, airlocks, nodes, and living quarters. Each module is launched either by the Space Shuttle, a Proton rocket, or a Soyuz rocket.



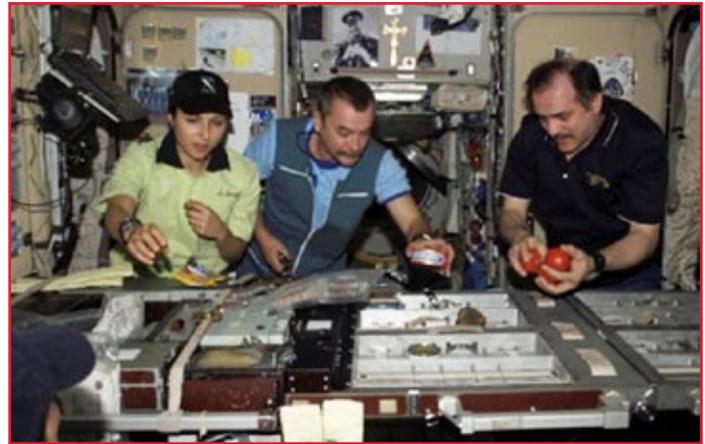
The ISS as of June 2008

## Lesson 17

### Student Text—A Home Above the Sky



Teleconferencing with Mission Control



Sharing a meal



The flags represent visitors to the ISS.



In-flight maintenance



Emailing and reading



Spacewalks

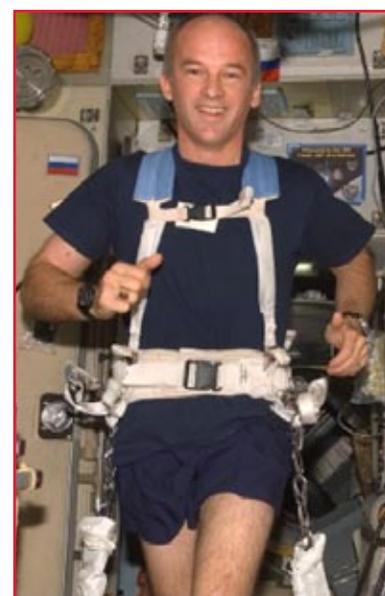
Astronauts on the ISS are working to improve life on Earth and to extend life beyond their home planet. Throughout the day they are busy performing so many tasks. Some tasks involve conducting experiments. Some involve personal time, but a great deal of time goes into keeping the station safe. Then there are the times that a new module is delivered, and the crew must devote a lot of time connecting it to the station. If you lived on the ISS, you would never have time to be bored.



Crew members talk with school children on the Amateur Radio on the International Space Station (ARISS).



Controlling the Canadarm2



Exercising 2 hours daily



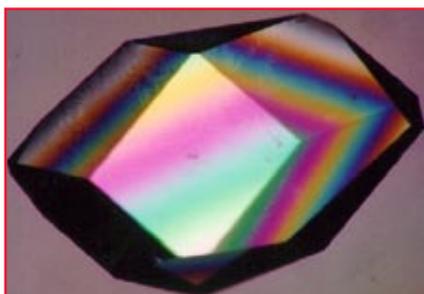
## Space Research to Help Earthlings

Research is the main purpose of the ISS. The research done in space will help people living on Earth. This brings us back to why the astronauts believe in what they do, because they know that their work helps others. The experiments on the ISS are performed in **microgravity**. This means that there are hardly any effects of gravity on the ISS. Science done without gravity opens up a whole new world of knowledge.



Working with sample tubes

The crews on the ISS work with the experiments in space. Many scientists study the data and images sent back to Earth. Here are some of the studies they are working on.



Scientists hope to use the microgravity of space to grow the large, nearly perfect crystals they need for molecular lock-picking, the first step in designing drugs that can treat a broad range of diseases and disorders.



A close up view of sodium chloride crystals in a water bubble

1. They are growing near-perfect **crystals**. The crystals, more valuable than gems, contain the blueprints for biological substances that make up humans, plants, animals, and even viruses. The protein crystal growth study will help us find better drugs to fight diseases. Other types of crystals can be used for super fast computers.
2. They are studying **combustion**, the act of burning, is being studied. Scientists are studying fire prevention; detection and suppression; incineration of solid wastes; power generation; and flame spread. They hope to build better furnaces and reduce air pollution.



The Combustion Integrated Rack is designed to support the long-term study of flames and their behavior in space.



3. They are studying plants. For many years, NASA has been seeking ways to make closed spaces on the Moon or Mars more livable. Plants could provide oxygen and



Checking the progress of pea plants growing in the greenhouse

remove carbon dioxide in space. Scientists are also looking at ways to grow better food. This will help future explorers to stay longer in space. Studies by NASA show that houseplants are remarkably efficient filters of common and dangerous pollutants.



A plant grown aboard the ISS



Plant experiments on the ISS use the principles of aeroponics, growing plants in an air/mist environment with no soil and very little water.

4. They are studying humans. Without gravity, our muscles get weaker and we lose **bone density** in space. Our hearts, arteries, and veins are affected. Exercise helps. That is why astronauts exercise every day. However, if we want to travel further out in



The Human Research Facility houses equipment to investigate the effects of microgravity on humans.



This human-torso-like device is designed to help scientists understand the exposure of astronauts to radiation.

space, we have to know more. These studies are also giving scientists insight into the aging process. They hope to find ways to prevent some of the physical effects of aging.



5. Scientists are conducting **Tissue culture** research is being done. This will bring new treatments for cancer patients. Astronauts who experience a wound while in space will also benefit from these studies.



A Quad Tissue Culture Module Assembly will be used to grow human cells on the ISS.



The Materials Science Research Rack – Researchers can better isolate chemical and thermal properties of materials from the effects of gravity.

6. Scientists are hoping to create better **metal alloys** and materials. This means that spacecraft and satellites will last longer. They are hoping to find better materials for computer chips and even better fabrics. Some materials will be placed outside of the station to study the effects of space on them.

7. Scientists are studying the Earth through observation. Remember that the ISS is in orbit 240 miles from Earth. Its orbital paths allow the astronauts to view 75 percent of Earth's land area. It also allows a view of 95 percent of the people on Earth. Thousands of photos of Earth have been taken from the ISS.



The eruption of the Chaitan Volcano in southern Chile



These photos help scientists to monitor the changes on Earth. They are studying the climate and the air. They map vegetation, land use, and minerals. They check the health of rivers, lakes, and oceans. The data helps us to understand



Viedma Glacier – Scientists are using photographs taken from the ISS to monitor the effects of global climate changes on glaciers worldwide.



The Basin fire in central California as photographed by the ISS crew (July 2008)

the Earth. It also helps us to see how humans have affected the Earth. We have polluted the air and the water. Millions of acres of forests have been cut. Oil spills have caused death and ruined our waters. The cameras record the Earth surface changes over time. They also record certain events like storms, floods, fires, and volcanic eruptions. Scientists can see all of these things and how much the Earth has changed.

8. Scientists are doing space research on the ISS with telescopes. These give us clear views of the Moon, Sun, planets, and stars. No clouds or smog can block the view. The telescopes on the ISS are easy to repair and change. Think about how we have to service the Hubble Space Telescope. Hubble is farther away from Earth than is the ISS, so servicing it is a difficult and dangerous task for the astronauts.



A photo of the Moon from the ISS

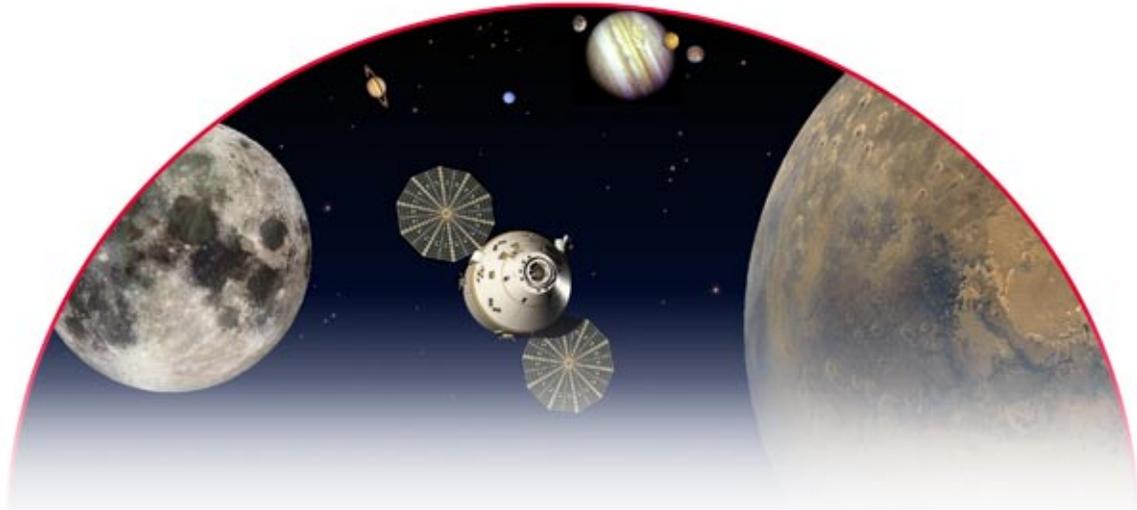
Thanks to the leadership of NASA, we have a home in space. Thanks to the home in space, we have a better understanding of Earth. Research from the space home helps us to take better care of our Earth home. It also helps us to take better care of ourselves. The products developed from this research will help the people on Earth. The discoveries will also help us to explore other worlds. One day, the ISS may be used as a spaceport for launches out into deep space. Many things in your future will change because of the work on the ISS today. Are you ready?

Lesson 17

Student Text—A Home Above the Sky



Annie remembers the days she had the courage to soar higher on the ISS.



## Lessons 18 and 19 – NASA Goes Far Out

**Lesson prep time:** 30 minutes (for gathering materials and following pre-lesson instructions for both lessons)

**Teaching time:**

Lesson 18: Two hours (Science, Language Arts, Technology)

Lesson 19: Two hours (Science, Language Arts, Technology)

### Objectives

1. The students will create a timeline showing the achievements of NASA.
2. The students will generate questions about the universe, the Moon, and Mars.
3. The students will describe the U.S. Policy for Space Exploration, the plan for humans to explore the Moon, Mars, and beyond.
4. The students will share their research on Mars with their team members and collaborate to develop a plan for a model colony on Mars.
5. The students will build a model of a Mars colony.
6. The students will write a seven-day journal about the experience of exploring Mars and building a colony there.
7. The students will prepare an oral presentation to describe their model Mars colonies and read their seven-day journal.
8. The students will prepare personal anecdotes for each day of their seven-day journal.



*Image credit: NASA*

Artist's concept of possible exploration of the surface of Mars

## National Standards

### Science

- Abilities necessary to do scientific inquiry – S2Ea, S2Ma
- Understandings about scientific inquiry – S2Eb, S2Mb
- Properties of objects and materials/Properties and changes in matter – S3Ea, S3Ma
- Position and motion of objects/Motion and forces – S3Eb, S3Mb
- Objects in the sky – S5Eb
- Changes in Earth and sky/Earth in the solar system – S5Ec, S5Mc
- Abilities of technological design – S6Ea, S6Ma
- Understanding about science and technology – S6Eb, S6Mb
- Risks and benefits – S7Md
- Science and technology in local challenges/in society – S7Ee, S7Me
- Science as a human endeavor – S8Ea, S8Ma
- History of science – S8Mc

### Mathematics

- Compute fluently and make reasonable estimates – M3
- Investigate, describe, and reason about the results of subdividing, combining, and transforming shapes – 8EUc
- Use visualization, spatial reasoning, and geometric modeling to solve problems – M11
- Understand measurable attributes of objects and the units, systems, and processes of measurement – M12
- Apply appropriate techniques, tools, and formulas to determine measurements – M13
- Problem solving – M18
- Communication – M20

### Geography

- How to use maps and other geographic representations, tools, and technologies to acquire, process, and report information from a spatial perspective – G1
- How to use mental maps to organize information

about people, places, and environments in a spatial context – G2

- The physical and human characteristics of places – G4
- The processes, patterns, and functions of human settlement – G12
- How human actions modify the physical environment – G14
- How physical systems affect human systems – G15
- How to apply geography to interpret the present and plan for the future – G18

### Language Arts

- Standards 1, 3, 4, 5, 6, 7, 8, 11, and 12 (See the Language Arts Matrix on page 22.)

### Technology – ISTE

- Students are proficient in the use of technology – I2
- Students develop positive attitudes toward technology uses that support lifelong learning, collaboration, personal pursuits, and productivity – I5
- Students use productivity tools to collaborate in constructing technology-enhanced models, prepare publications, and produce other creative works – I7
- Students use telecommunications to collaborate, publish, and interact with peers, experts, and other audiences – I8
- Students use a variety of media and formats to communicate information and ideas effectively to multiple audiences – I9
- Students use technology to locate, evaluate, and collect information from a variety of sources – I10
- Students employ technology in the development of strategies for solving problems in the real world – I14

### Technology – ITEA

- Relationships among technology and other fields – T3
- Cultural, social, economical, and political effects – T4
- Effects of technology on the environment – T5
- Role of society in the development and use of technology – T6
- Influence of technology on history – T7
- Attributes of design – T8
- Engineering design – T9

- Role of troubleshooting, research and development, inventions and innovation, and experimentation in problem solving – T10
- Apply the design process – T11
- Use and maintain technological products and systems – T12
- Assess impact of products and systems – T13
- Information and communication technologies – T17
- Transportation technologies – T18

## Materials

- Student logs
- Timeline, Timeline Date Sheet, and blank entry cards
- A copy of the student text for Lessons 18 and 19, “NASA Goes Far Out” for each student
- Picture books on Mars, the Moon, the Apollo Moon landings, and the U.S. Policy for Space Exploration
- A surface map of Mars (A small one is provided at the end of Lesson 19.)
- A way to record student questions about the Moon and Mars
- Boxes, cans, domes, and other objects to be used for structures on Mars (These should have been collected by the team members and stored in the classroom.)
- White 3- by 4-foot sheets of butcher paper or other paper suitable for use in depicting the Martian surface (one for each team)
- Sand, gravel, and rocks to be used in depicting Martian terrain
- Art materials, such as paint (thick for painting structures), colored chalk, oil crayons, magic markers, scissors, clear tape, etc.

## Pre-lesson Instructions

1. Duplicate enough copies of the student text for Lessons 18 and 19, “NASA Goes Far Out” for each student. Punch holes, so that students can insert these in their logs.
2. Find picture books about the Apollo missions and pick out a few illustrations that show the lunar surface.
3. Find a non-fiction picture book on Mars, and pick out a few illustrations that show the Martian terrain.

4. Find a surface map of Mars. Teacher stores may have a large chart or use the map provided at the end of Lesson 19.
5. Set up a computer to view the videos of *Spirit* and *Opportunity* on the surface of Mars. Locate the NASA website at [http://www.nasa.gov/mission\\_pages/mer/index.html](http://www.nasa.gov/mission_pages/mer/index.html) to see the rover video. (Note: These videos may be removed from this site at a later time.)
6. Make sure each team has at least seven items to be used as structures.
7. Cut the white 3- by 4-foot sheets of butcher paper that will be used as the Martian surface so that each team has a sheet.
8. Gather the art supplies listed in the materials list and place them so that students will have access to them.
9. Assign an area for each team to build their colony.
10. Plan a special celebration to mark the end of The Courage to Soar Higher. Ask for parent volunteers to prepare space-themed foods and activities for the students. Schedule this as a part of Lesson 20, after the students give their Mars colony presentations.

**Lesson 20 will be taught three to five days after Lesson 19 to allow time for students to complete their Mars colonies.**

## Procedure – Lesson 18

1. Ask the students to take out their logs and turn to the student text for Lesson 17, “A Home Above the Sky.” Then, direct their attention to “The Space Race” timeline. Have the students fill in the events relating to space stations using the student text for Lesson 17. Use the Timeline Date Sheet for the exact dates.
2. Tell the students to imagine themselves outside at night looking up into the starry sky. Remind them that our Sun is the nearest star and that the stars are huge bodies of gas like our Sun. Ask them what questions about the universe come to their minds.

3. As the students share their questions, record them on the board or chart paper or some other way for future reference. Do not erase them until Lesson 19 is complete. Add the following questions if they are not already recorded.
  - Are there planets like Earth revolving around other stars?
  - Does life exist elsewhere in the universe?
  - Has life ever existed elsewhere in our solar system?
  - What can we learn from other planets that can help us to understand our own?
  - What else can we learn about our own planet? Do we have any unexplored frontiers left on Earth?
  - Will humans ever leave Earth to live on another planet? Why? When?
4. Allow the students to discuss their thoughts and answers to the questions. Explain that questions like these are on the minds of people at NASA. By sending spacecraft, rockets, and people into space, NASA is not only opening up new frontiers, but whole new avenues of knowledge and discovery. NASA believes that, “Exploration and discovery are, as they always have been for humanity, the pathways to our future.”
5. Distribute the student text for Lessons 18 and 19 “NASA Goes Far Out” and have the students insert this in their logs. For Lesson 18, read and discuss through the section “So Many Questions... About the Moon” as you would any guided reading. The rest of the text will be read as a part of Lesson 19. As the class discusses the text, question their understanding and encourage their questions.
6. Teach the vocabulary in the same manner that you would for a guided reading assignment.
7. Read the quote spoken by President George W. Bush. Explain that these words were a part of a nationally televised speech he made about the Vision for Space Exploration. This vision changed NASA’s direction and focused the Agency’s attention on the plan to return to the Moon and then to explore Mars and beyond.
8. Have the class observe the pictures of *Spirit* and *Opportunity* on the surface of Mars. Tell the class that each rover is 5.2 feet long, 4.9 feet tall, and weighs 384 pounds. Then, read “The Rovers” section and allow a few minutes for the students to enjoy the cartoons celebrating the success of the Mars’ rovers. If possible, go to the NASA website [http://www.nasa.gov/mission\\_pages/mer/index.html](http://www.nasa.gov/mission_pages/mer/index.html) to see a rover video. This will also give students a better image of the terrain to help them prepare the Mars’ surface and describe their Mars rover trips.
9. Show a surface map of Mars. Conduct a short discussion comparing the surface and atmosphere of Earth to the surface and atmosphere of Mars. It is recommended that teachers use a Venn diagram and record these comparisons. This can be used for a quick review in Lesson 19. Students should comprehend the vast differences between the two planets and start to visualize the harsh environment our astronauts will face when they land there.
10. Finish reading through the section “First Things First.” Then, show the students pictures of the earlier Moon landings that show the Moon’s terrain and the Apollo vehicles that landed there. Ask them to recall some of the things they learned about those missions when they read “The Giant Leap for Mankind.”
11. Ask the class to pretend that they are scientists who work for NASA as the Agency prepares to return to the Moon. What questions about the Moon would they want answered by these future missions? Record the students’ questions for future reference.
12. Read and discuss the 10 questions and answers about the Moon in the section “So Many Questions... About the Moon.” After reading the answer to Question 1, refer back to the Global Exploration Strategy Poster and read over the international community answer as to why humans should go back to the Moon. In addition to NASA, space exploration experts from Australia, Canada, China, the European Space Agency, France, Germany, Great Britain, India, Italy, Japan, Russia, South Korea, and Ukraine participated in this strategy.

13. After reading the answer to Question 4, ask the students if they would like to be among the first to live at the lunar outpost.
  14. Finish reading the section “So Many Questions... About the Moon.” Check the students’ questions to see if any of them were answered in this section. Then, try to answer the students’ unanswered questions about the Moon.
  15. Tell the students that they will read about Mars and NASA’s new vehicles and exploration plans in the next class period.
  16. Then, have the students turn to the Mars colony worksheet in their logs. Remind them that the Apollo astronauts named their command module and lunar lander, and that they should do the same by naming their crew exploration vehicle and the Mars lander. Tell them to also decide on a name for their colony.
  17. Next, direct their attention to the Structures section of the worksheet. Tell them that they are required to “build” at least seven structures, and pretend that one structure is built each sol (a Martian day). They will have to write a journal entry describing the activities of each sol including the description of constructing a building. Explain that robots have delivered the materials in earlier Mars’ missions and that robots will probably help with construction.
  18. Some teachers will stop here and let the students create their own colony, relying on their research. Other teachers may need to guide the students’ thinking to the kind of structures that will be needed to survive.
    - 1) Remind them that the Mars atmosphere contains carbon dioxide. Ask what living things on Earth need carbon dioxide. How would establishing huge greenhouses or Martian fields on Mars help with human survival?
    - 2) Tell them that some of the structures should protect the water and fuel (power) supply.
    - 3) Remind them of the space shuttle and the ISS. What areas were needed by the astronauts (i.e., living quarters, places for communication, laboratories for experiments, etc.)?
  19. Assign an area for each team to build their model colony.
  20. Distribute the white butcher paper that will be used as the Martian surface. Discuss how to prepare the surface. Some suggestions would be to mix sand in paint for a gravel-like texture. Rocks and gravel could be painted to match the soil.
  21. Teachers should feel free to advise the teams about having a strategy to attack these tasks. But, above all, encourage the students to plan and set out a strategy. The team leader should assign tasks to each team member before proceeding. Tell them that they can finish building the colony before writing the journal, or they can write as they go along. The journal should be written as a team.
  22. Allow the students about one hour to work on their Mars colonies. Walk around and assist the groups as needed.
- ## Procedure – Lesson 19
1. Have the students take out their logs and turn to the student text for Lessons 18 and 19, “NASA Goes Far Out.” Before reading, ask the class to once again pretend that they are scientists who work for NASA, but this time as the Agency prepares to land humans on Mars. What questions about Mars would they want answered by these missions? Record the students’ questions for future reference.
  2. Review the vocabulary words.
  3. Show some of the pictures from the book on Mars and let the students discuss what they observe. Ask the students to recall some of the comparisons they found in Lesson 18 between the surface of Mars and the surface of Earth. Use the Venn diagram made in Lesson 18.

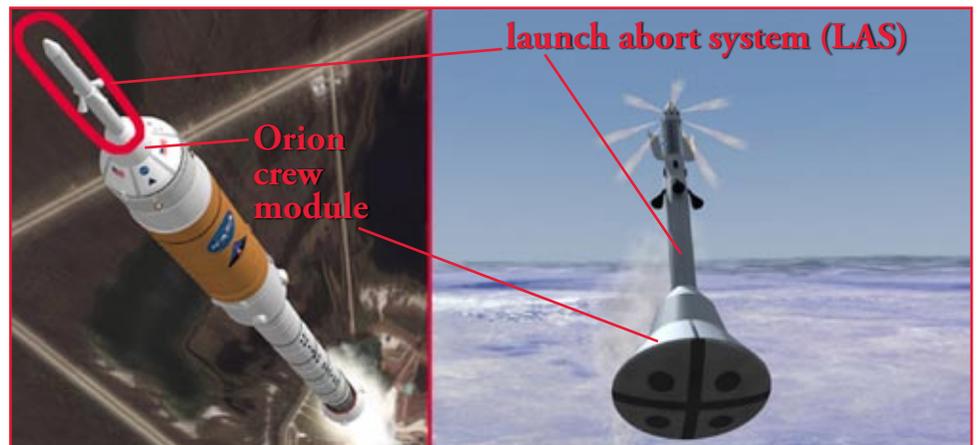
4. Read the rest of the student text beginning with the section “So Many Questions... About Mars.” Read and discuss this as you would any guided reading. As the class discusses the text, question their understanding and encourage their questions.
5. Read and discuss the 10 questions and answers about Mars. Check the students’ questions to see if any of them were answered by this section. Find Antarctica and Iceland on a World Map. A similar environment exists on the Mars polar caps, but Mars is colder, has no oxygen, and has greater amounts of radiation! Answer any questions the students may have about this section.
6. After reading the section “Traveling to the Moon, Mars, and Beyond,” remind the students of their own Orion/ Altair designs. Ask how NASA’s designs are different from their designs.
7. Next, ask the students to give a description of how the Apollo spacecraft went to the Moon and back. (Use the terms command module, lunar lander, descent stage, and ascent stage.) Tell them that Orion’s trip to the Moon will be similar to the Apollo command module. Then, read “To the Moon and Back.” Compare Apollo’s journey to the new launch and Moon journey that NASA is now recommending. **(NASA will use two separate launch vehicles to launch the Orion crew capsule and the Altair lunar lander. Then, Orion and Altair, with the Earth Departure Stage, will dock in low Earth orbit before continuing onto the Moon.)**
8. Finish reading the section “The NASA Mission.” Allow time for the students to discuss their perceptions of NASA, their appreciation of astronauts, or whatever they would like to share about the text they have just read.
9. Before the students return to building their Mars colonies, check to see if they have any questions or concerns. Then, allow one hour for them to work on their colonies and journals.
10. Teachers should realize that several days will pass before the class is ready for Lesson 20. Students will need more class time to finish their colonies and their journals.
11. Write the following URL on the board for the students: <http://lunar.gsfc.nasa.gov/outreach.html>. Tell them to look under the “For Kids” section for activities they can do at home.
12. If you have planned a special celebration to mark the end of The Courage to Soar Higher, complete those preparations and make sure that plans are being carried out.

**Lesson 20 will be taught three to five days after Lesson 19 to allow time for students to complete their Mars colonies.**



## Vocabulary

**abort** – the act of terminating an operation or procedure, as with a project, missile, airplane, or space vehicle, before completion



*Images Credit: NASA*

Orion's launch abort system has a solid rocket motor above the capsule that can pull it out of harm's way in case of an emergency.



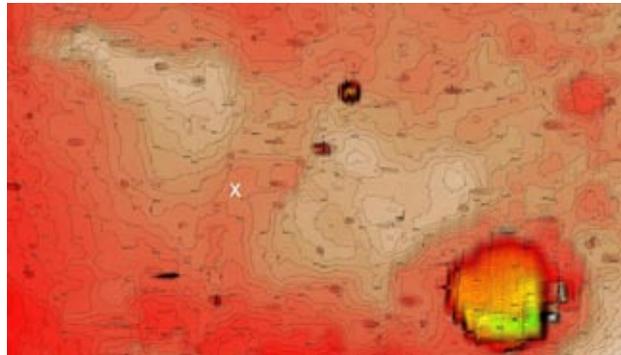
Two boosters (white) are attached to the Delta II rocket (blue) and a third booster waits to be attached.

**booster** – a rocket stage used to give the rest of the launch vehicle the acceleration it needs for launch at liftoff; a strap-on rocket (either a solid rocket booster or liquid rocket booster) used to provide additional lift capability of a core launch vehicle



**Cargo Launch Vehicle** – NASA’s rocket, named Ares V, that will launch the Altair lunar lander, or other cargo, and the Earth Departure Stage into Earth’s orbit

**contour** – a line drawn on a map connecting points of equal measurements such as height, temperature, and pressure



Contours are one of several common methods used to denote elevation. This contour map made by Mars Global Surveyor shows the *Opportunity* landing site area on Mars.



*Image credit: NASA*  
The Ares V cargo launch vehicle

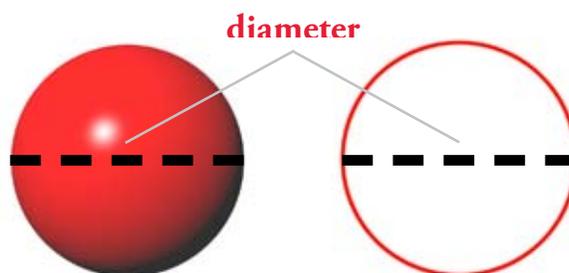


*Image credit: NASA*  
The Altair lunar lander (left) will be larger than its Apollo counterpart (right) as seen when comparing the size of the astronauts to each lander.

**counterpart** – one thing that has the same functions and characteristics as another

**Crew Launch Vehicle** – NASA’s rocket, named Ares I, that will launch the Orion Crew Exploration Vehicle into Earth’s orbit

**diameter** – a straight line passing through the center of a circle or sphere and meeting the circumference or surface at each end



*Image credit: NASA*  
The Ares I crew launch vehicle



**entrepreneur** – one who organizes, manages, and assumes the risks of a business or enterprise



Astronauts endured the harsh lunar environment.



Martian environment

**environment** – the surrounding conditions or forces (as soil, climate, and living things) that influence the form and the ability to survive of a plant or animal or ecological community



Images courtesy of Wikipedia  
Earth has many different environments.

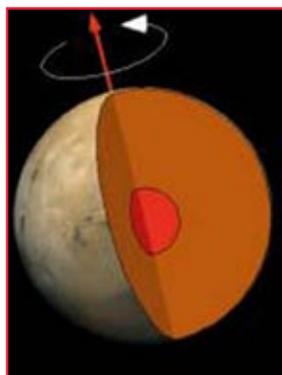


Image credit: NASA

Through geophysics, scientists learn such things as the densities, temperatures, and depths of boundaries of the planet's crust, mantle, and core, as seen in this diagram of Mars.

**geophysics** – the physics of the Earth (or the Moon or Mars) and its environment, including the physics of fields such as meteorology, oceanography, volcanology, magnetism, radioactivity, and seismology

**habitat** – the place or type of place where a plant or animal lives or grows



Artist's concept credit: John Fasanito for NASA  
A lunar habitat has been assembled out of materials delivered by automated cargo flights.



Image courtesy of Wikipedia  
A rainforest provides a habitat for many animals.



**hostile** – very unfavorable to life or growth; forbidding



*Opportunity* captured the hostile environment of Mars with this composite photo of Victoria Crater.

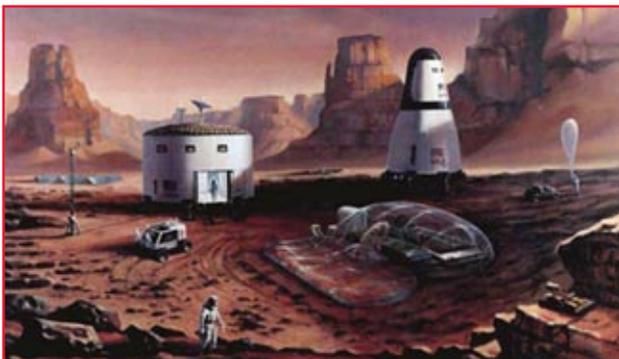


*Image credit: Pat Rawlings for NASA*

A future lunar colony will make use of in-situ resources found on the Moon such as water and lunar soil.

**microscopic** – invisible or indistinguishable without the use of a microscope

**outpost** – an outlying or frontier settlement



*Image credit: Robert Murray for NASA*

An artist's concept of a future Mars outpost



*Image credit: NASA*

The Mars Science Laboratory will collect and analyze soil and rock samples to determine the existence of microscopic life now or in the past.



*Image Credit: NASA*

An artist's concept of a small lunar outpost



**oxidizer** – a substance that oxidizes (supplies oxygen) to another substance, especially one that supports the combustion of rocket fuel

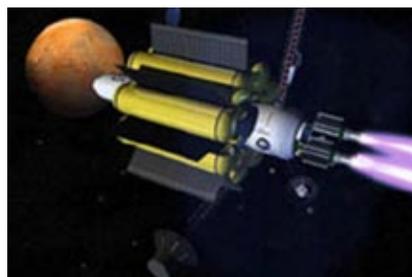


*Photo credit: International Polar Foundation*

Cross-section view of permafrost

**permafrost** – a permanently frozen layer below the surface in frigid regions of a planet and other celestial bodies; permanently frozen subsoil

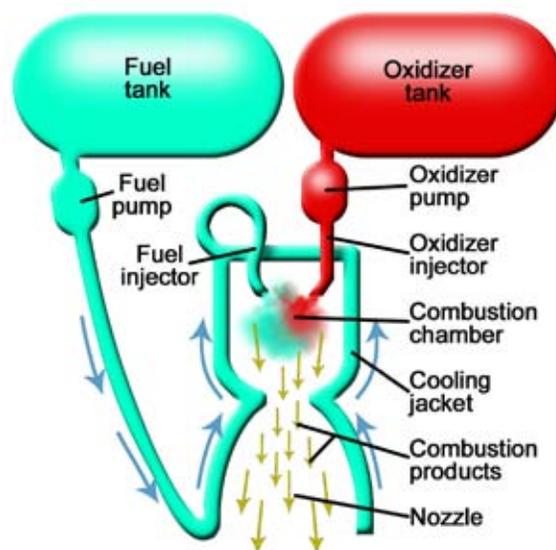
**propellant** – something, such as an explosive charge or a rocket fuel, that propels or provides thrust



*Image credit: NASA*

NASA is working on new propulsion systems to allow spacecraft to travel at higher speeds.

**proving ground** – a place for scientific experimentation or testing; a place where something is developed or tried out



A liquid-propellant rocket carries fuel and an oxidizer in separate tanks.



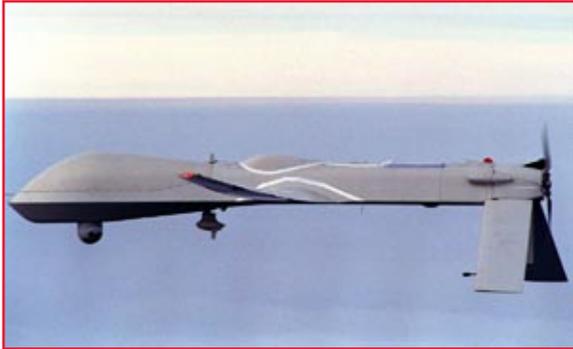
The Space Shuttle solid rocket motor is the largest solid propellant motor ever developed for space flight. It contains more than 1,000,000 pounds (450,000 kilograms) of propellant.



NASA will use the Moon as a proving ground for testing new technology that will be used to explore Mars and beyond.



**radiation** – energy given off in the form of waves or particles



An unmanned aerial vehicle (UAV), such as this Predator, can be used for reconnaissance missions over enemy nations.



A human-torso-like experiment on the ISS is designed to better understand the exposure of astronauts to radiation.

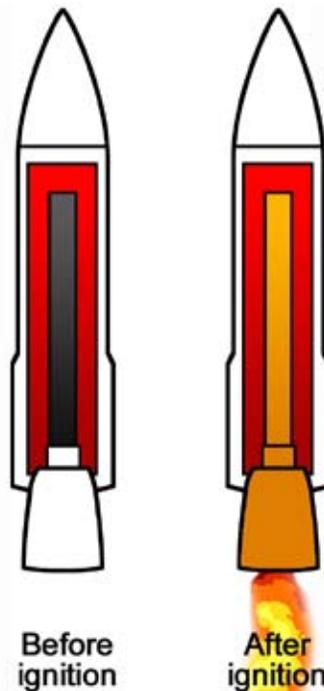


*Image credit: NASA*

An artist's concept shows the *Mars Reconnaissance Orbiter* searching for evidence that water persisted on the surface of Mars for a long period of time.

**reconnaissance** – an inspection or exploration of an area, especially one made to gather information

**solid rocket** – a rocket that uses solid fuel (a fuel that is a powder or solid material and contains its own supply of oxygen)



The solid fuel, shown in red, has a tube in the middle.



The solid rocket booster (left) provides most of the thrust for the space shuttle launch.



**technology** – the use of science in solving problems

**USGS** – The United States Geological Survey (USGS) is a scientific agency of the United States government. The scientists of the USGS study the landscape of the United States, its natural resources, and the natural hazards that threaten it.



*Images credit: NASA*

NASA will use new technology to return humans to the Moon for habitation and exploration.



In the past, Mars was a very volatile planet with many volcanoes including Olympus Mons, the largest known volcano in the solar system.

**volatile** – likely to change suddenly or quickly; tending to erupt into violence; explosive



## NASA Goes Far Out

### Far Out

“Mankind is drawn to the heavens for the same reason we were once drawn into unknown lands and across the open sea. We choose to explore space because doing so improves our lives and lifts our national spirit.”

President George W. Bush  
January 14, 2004

### The Rovers

In early 2004, two little robots thrilled the world. One was named *Spirit*, and the other was named *Opportunity*. The little rovers were many millions of miles away, but the people on Earth cheered them on. They rolled around on opposite sides of Mars and relayed pictures of the Red Planet back to Earth that made us gasp. They drilled into rocks and sent back data. The data told us that water had once been on Mars. This was a huge discovery. The more the two little rovers told us, the more questions we had.



The Mars rovers, *Spirit* and *Opportunity*

Images credit: NASA





## The Vision for Space Exploration

A few days after the robots landed on Mars, President Bush made a very important announcement. He told the nation that we were going to send humans back to the Moon. Then, after the Moon, we would go on to Mars. Plans were being made to answer our questions about the Red Planet.

These were some mighty big plans. NASA created a whole new group that would work only with exploration. It was known as the Exploration Systems Mission Directorate (ESMD). They looked to see what was already being done. Then, they looked at what needed to be done. They knew



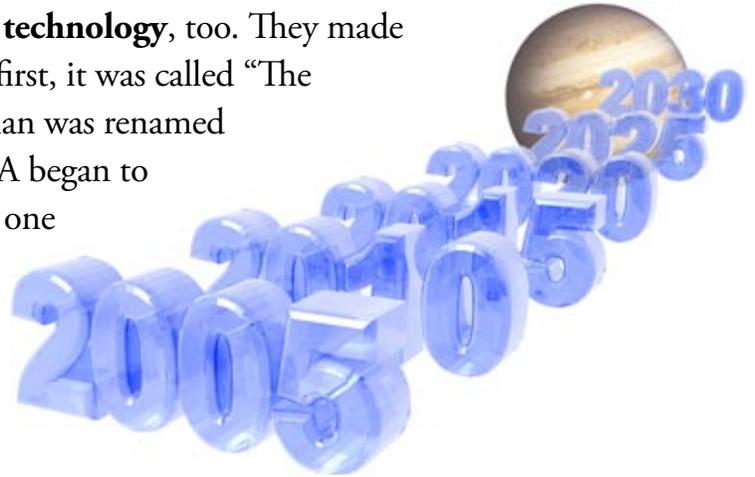
Workers at Kennedy Space Center (KSC) watch President George W. Bush at NASA Headquarters in Washington, DC, stating his goals for NASA's new mission.

- Complete the International Space Station
- Safely Fly the Space Shuttle Until 2010
- Develop and Fly Orion (CEV) No Later Than 2014
- Return to the Moon No Later Than 2020
- Extend Human Presence Across the Solar System and Beyond
- Implement a Sustained and Affordable Human and Robotic Program
- Develop Supporting Innovative Technologies, Knowledge, and Infrastructures
- Promote International and Commercial Participation in Exploration

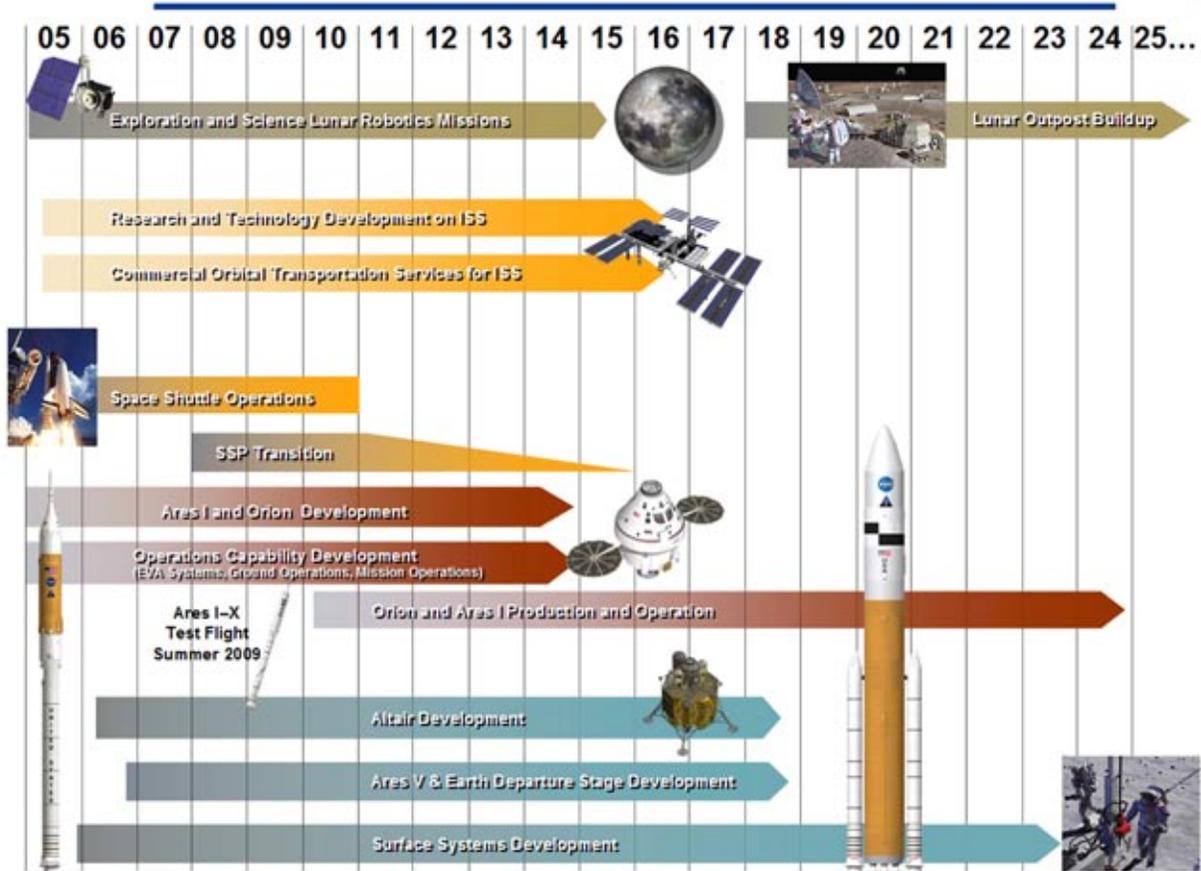
The Exploration Systems Mission Directorate's goals



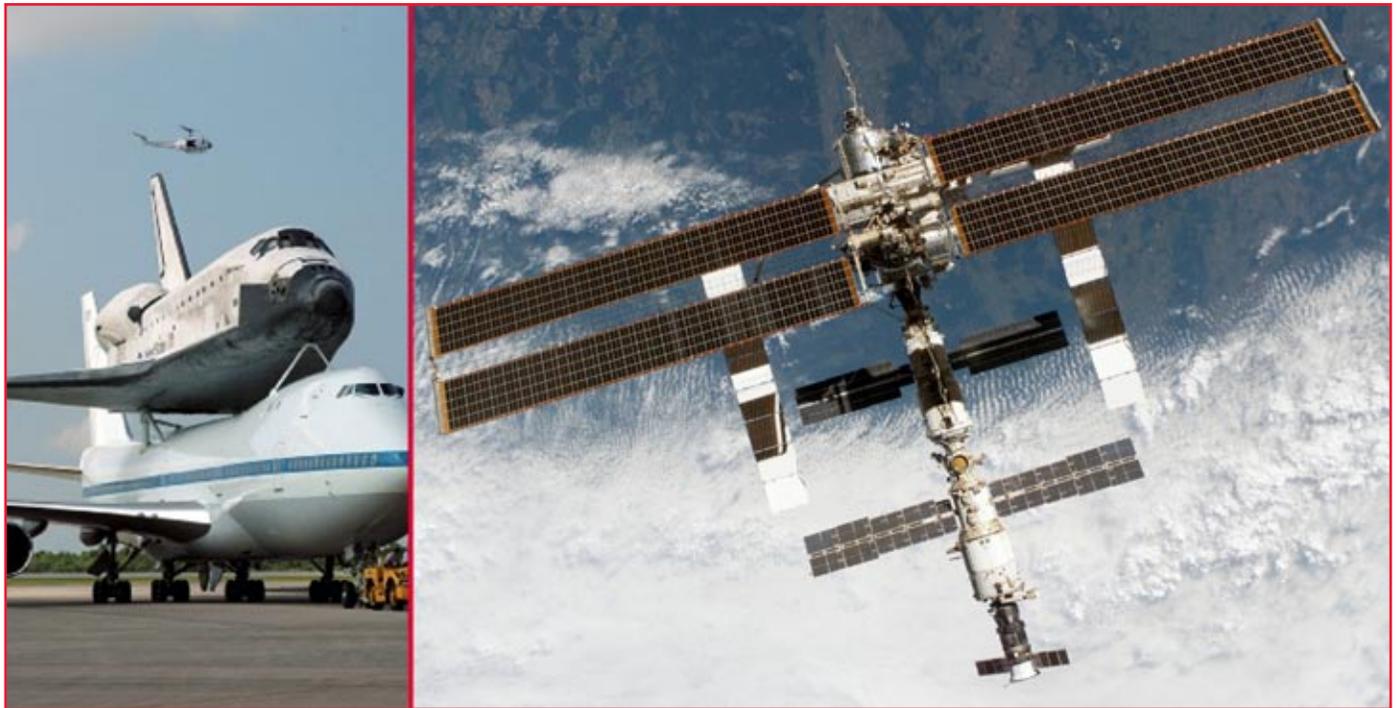
we would need new vehicles. We needed new **technology**, too. They made a timetable that reached to the year 2030. At first, it was called “The Vision for Space Exploration,” but later the plan was renamed the “U.S. Policy for Space Exploration.” NASA began to plan for humans to go back to the Moon and one day on to Mars. Plans were also made to explore the moons of Jupiter and other outer planets. This was a long way out, but 2030 was a long way off.



## NASA’s Exploration Roadmap



NASA’s Exploration Roadmap for future space exploration is updated to reflect the latest vehicle design and target dates.



The Shuttle Carrier Aircraft brought *Discovery* home to KSC after completing the historic STS-114 Return to Flight mission.

The space shuttle *Discovery* captured this image of the International Space Station.

### First Things First

When the President told the Nation about the plans to explore the solar system, the workers at NASA were excited. It had been a hard year for NASA. Since the *Columbia* accident in February 2003, the Space Shuttle had not flown. The ISS assembly was on hold, since only the Space Shuttle could carry the new modules and other large parts. The new crews and supplies to the ISS had to be taken up on the Russian Soyuz and Progress spacecraft. Plans for the Space Shuttle to return to flight were still a long way off.

Now NASA had a new vision, and a new “can do” spirit returned to the Agency. The first item on every list was to get the Space Shuttle flying again. Then, NASA had to finish the ISS and keep their promises to the ISS partners. Behind those two items was a mad and wonderful scramble. NASA had to get started on the new age of exploration.

In April 2006, NASA laid out its Global Exploration Strategy. People from NASA, 13 other space agencies, and other experts were involved. Their answers to “Why should we return to the Moon?” gave us six broad reasons for this mission. NASA took these six ideas and made a poster.



National Aeronautics and Space Administration



## The Global Exploration Strategy Poster

# WHY THE MOON?

*THE DAWN OF THE TRUE SPACE AGE LIES AHEAD OF US.*

In the not too distant future, people around the world will be able to look through a telescope and see evidence of human and robotic exploration on the Moon. In 2004, President Bush directed NASA to send humans back to the lunar surface – this time to stay – and to get ready for a journey to Mars. Since then, we've determined what transportation we'll need, set goals for our activities, identified real benefits of exploring the Moon, and even started building the spacecraft to get us there. We'll spend 2007 maturing our ideas on the equipment that future lunar explorers will need to accomplish these exciting plans.

*WHATEVER WE DO, IT WILL BE FOR THE BENEFIT OF ALL MANKIND.*



### Human Civilization

Extend human presence to the Moon to enable eventual settlement.



### Global Partnerships

Provide a challenging, shared, and peaceful activity that unites nations in pursuit of common objectives.



### Scientific Knowledge

Pursue scientific activities that address our fundamental questions about the history of Earth, the solar system, and the universe – and about our place in them.



### Economic Expansion

Expand Earth's economic sphere and conduct lunar activities with benefits to life on the home planet.



### Exploration Preparation

Test technologies, systems, flight operations, and exploration techniques to reduce the risks and increase the productivity of future missions to Mars and beyond.



### Public Engagement

Use a vibrant space exploration program to engage the public, encourage students, and help develop the high-tech workforce that will be required to address the challenges of tomorrow.



# BECAUSE HUMANS EXPLORE

*"The Earth is the cradle of mind, but one cannot forever live in a cradle."*

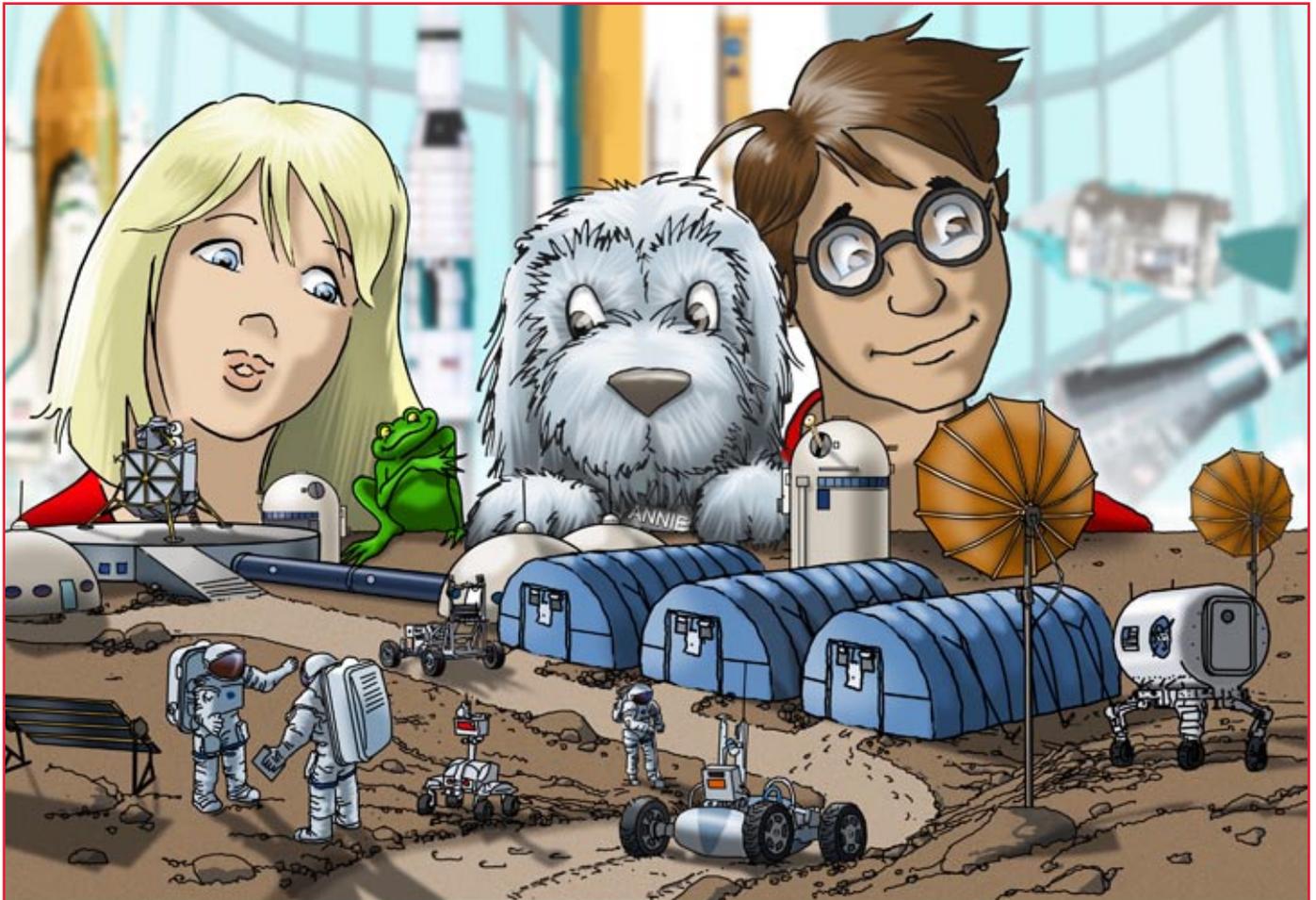
– Konstantin Tsiolkovsky, 1896

[www.nasa.gov](http://www.nasa.gov)



## So Many Questions... About the Moon

When NASA announced its plans for exploring the Moon, Mars, and beyond, everyone began to ask questions. Some of the answers will help us understand all that is happening.



NASA wants to build a permanent base on the Moon.

### 1) **Why are we going back to the Moon? We've been there and done that!**

NASA's main goal is to explore Mars and the rest of the solar system. To explore that far out, we will have to develop and test new technology. However, we need a place away from Earth to test our ideas, so we will go to the Moon and test them out there. We will find ways to survive long-term stays on other worlds by going to the Moon first. It takes only three days to get to the Moon. Astronauts will learn to live and work in a **hostile environment** before they head off to distant places, so the Moon is a perfect **proving ground**. Then, we will be more confident to venture on to Mars.



NASA's inflatable habitat structure is being tested in Antarctica and may support future explorers on the Moon.



*Image credit: NASA*  
An artist's concept of a lunar outpost with an inflatable habitat

## 2) What will the astronauts do on the Moon?

They will test NASA's new technology. This will include activities that will prepare NASA to make human missions to Mars and beyond. Some of their tasks will include the following:

- For the very first time, set up a **habitat** on another world.
- Learn to “live off the land.”



NASA may use this planetary surface habitat and airlock unit in a lunar base.



*Image credit: Pat Rawlings and Doug McLeod for NASA*  
An artist's concept of a deep drill team obtaining cores for studies of the lunar soil, called regolith, shows how astronauts will live off the land.



*Image credit: NASA*  
This Hobot, or robotic habitat, looks like the real lunar habitat. This artist's concept image shows a lunar base that can travel on wheels, or even legs.



*Image credit: Pat Rawlings for NASA*  
An artist's concept of a lunar habitat shows a mining operation that will allow astronauts to live off the land.

Lessons 18 and 19

Student text—NASA Goes Far Out



NASA will be testing its new vehicles on the Moon. From left to right are a lunar crane, a drilling rover, a lunar truck, two K10 robots, and a lunar ATV.



NASA is developing new spacesuits for a lunar mission.

- Test new spacesuits and new rovers and vehicles.
- Try out new ways for protecting humans from deadly **radiation**.
- Learn to operate life support and power systems to stay alive.
- Learn to adapt to the absence of normal gravity on the body.
- Learn to **interact** with robots.

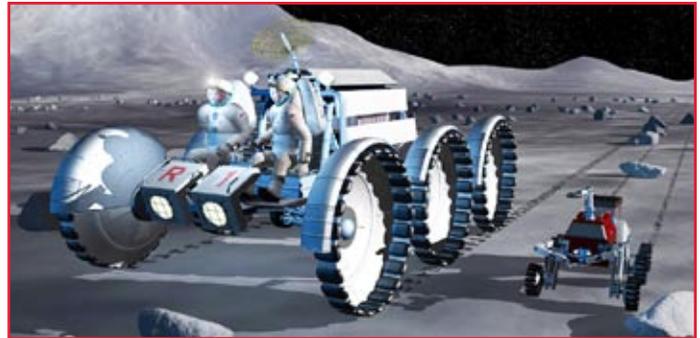


Image Credit: NASA

Aided by their robotic work assistant traveling at their side, the astronauts will be able to achieve scientific and exploratory objectives, as shown in this artist's concept.



Credit: Pat Rawlings for NASA

In this artist's concept, astronauts must learn to operate this lunar oxygen production plant to refine oxygen for rocket propulsion.

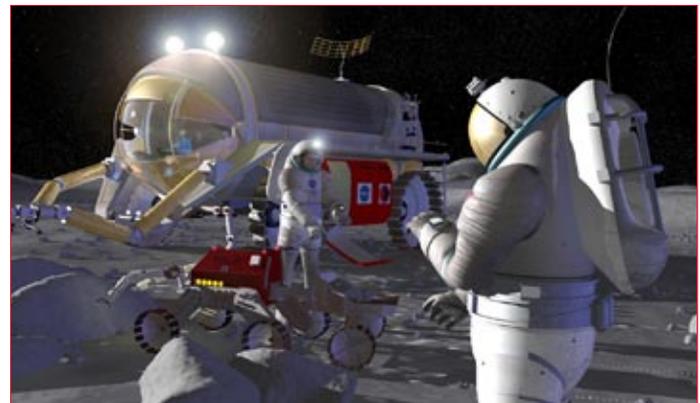


Image credit: NASA

An artist's concept of astronauts and robots working together

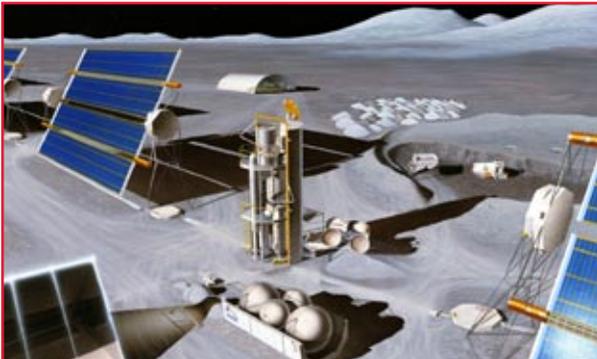


Image credit: Mark Dowman for NASA

The artist's concept shows a pilot plant designed to produce an oxygen propellant derived from lunar raw materials.



Image credit: NASA

In an artist's conception, two NASA astronauts watch as a drill bores down into the top layers of the lunar surface.

### 3) How can astronauts live off the land? There is nothing there.

Actually, there is something there. The robots and astronauts will explore the Moon to find hidden resources. The Moon is a good testing ground for **in-situ** resource uses. They will look beneath the lunar surface for oxygen, water, and even fuel. Scientists already know that the lunar soil, called regolith, contains oxygen and hydrogen. That is a good start for keeping humans alive and also for making rocket fuel. We just have to know how to get to it and extract it.



The Autonomous Drilling Rover is equipped with a drill designed to find water and oxygen-rich soil on the Moon.

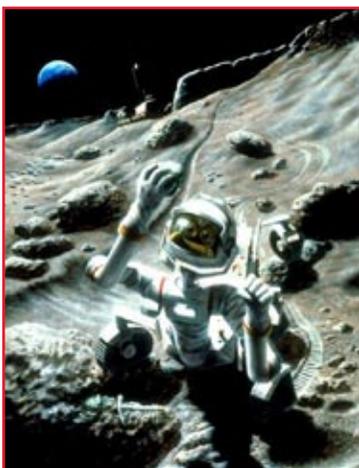


Image credit: Pat Rawlings for NASA

Left: This concept robot will dig into the lunar soil (regolith) to extract oxygen, which makes up 40 percent of the lunar soil.

Right: This artist's concept of lunar mining operations illustrates the production of liquid oxygen.



Image credit: Pat Rawlings for NASA



*Image credit: John Frassanito and Associates for NASA*

In this artist's concept, a pressurized lunar rover is unloaded from an automated cargo lander. The rover will provide a temporary habitat for lunar crews, as well as extended exploration trips.



A lunar ATV, a robot known as Athlete, is multi-wheeled to allow robots or humans to load, transport, or deposit payloads to almost any site on the lunar surface.

4) **When will the first astronauts go to the Moon? How long will they stay there?**

Right now, the first human flight by NASA is set for 2020. The current plan is to begin base construction with four-person crews. The first missions will last only four to seven days, until the basic necessities are in place. In addition to human flights, landers will deliver cargo. NASA is hoping to send up two crewed missions a year. Crews will stay longer with each visit and they will look for

resources. NASA believes it will take several years before a permanent **outpost** is ready. Right now, they are looking at 2024. Once the lunar outpost is ready, a new crew will come up to stay every six months. Students sitting in classrooms today may be future residents of the Moon.



### 5) What will be built on the Moon?

When NASA returns to the Moon, it intends to stay. Plans call for building the following:

- Outposts to pave the way for journeys to Mars and beyond.



*Image credit: Pat Rawlings for NASA*

This artist's concept shows part of a future spaceport. Beneath the lander an astronaut begins the process of changing an engine. A crane removes a small canister.



*Image credit:*

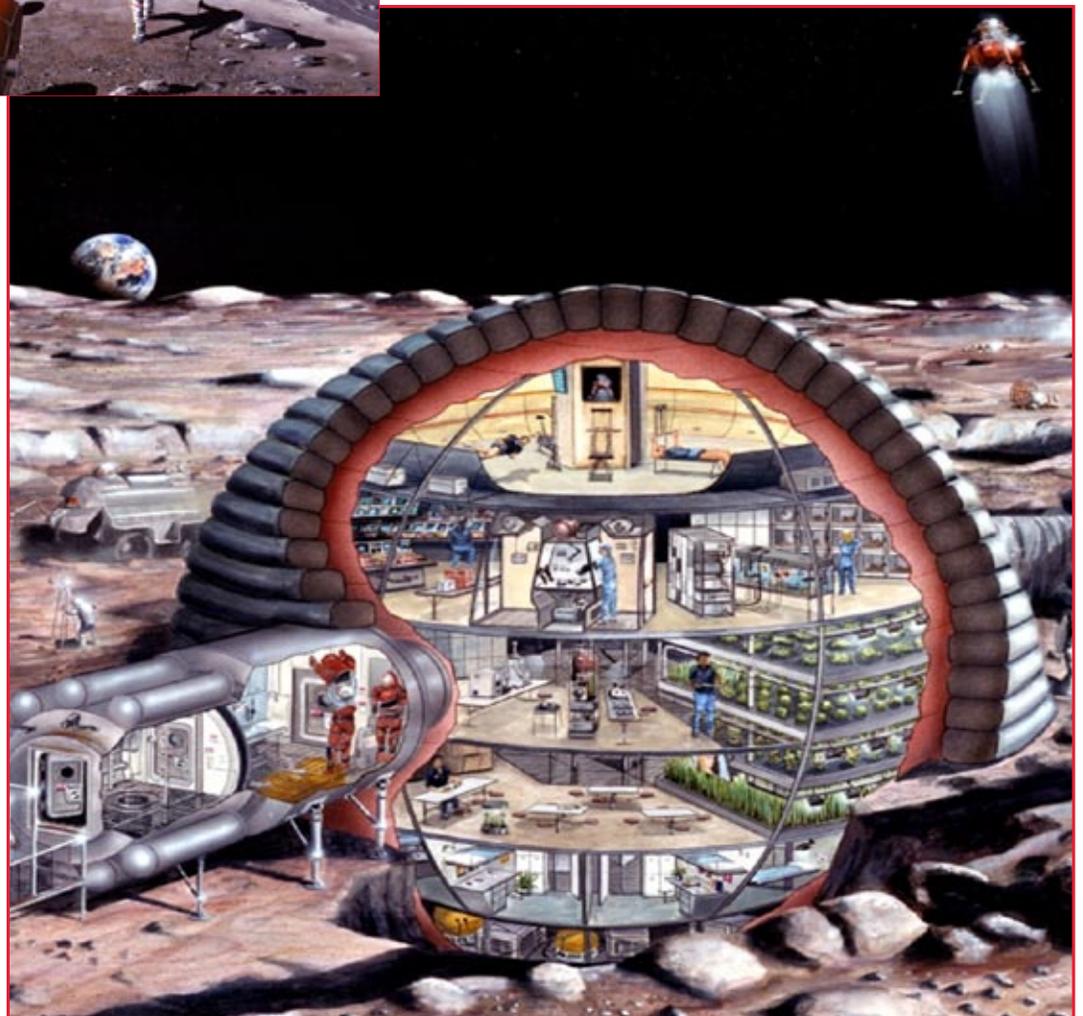
*Dennis Davidson for NASA*

An artist's concept of a lunar base with a spaceport and launch site (background)

*Image credit: NASA*

A lunar outpost may include an inflatable habitat that could accommodate the needs of several astronauts living and working on the surface of the Moon. This artist's concept pictures

- astronauts exercising;
- a base operations center;
- a pressurized lunar rover;
- a small clean room;
- a fully equipped life sciences lab;
- a lunar lander;
- hydroponic gardens (the growing of plants in nutrient solutions with or without soil);
- a wardroom;
- private crew quarters;
- dust-removing devices for lunar surface work; and
- an airlock.



Lessons 18 and 19

Student text—NASA Goes Far Out



*Image credit: NASA*

An artist's concept of astronauts establishing a field site for scientific data collection



*Image credit: NASA*

An artist's concept of astronauts setting up a lunar telescope array



*Credit: Pat Rawlings for NASA*

An artist's concept of a science laboratory on the Moon

- A science station that will search for how the Earth and the solar system began.
- A post for tracking meteors and asteroids that could bombard Earth.

NASA has given some consideration to building a spaceport for launching spacecraft and an observatory that gives much clearer views of the universe.



*Image credit: Pat Rawlings for NASA*

A space telescope on the lunar surface uses an advanced walking mobility platform in this artist's concept.



*Image credit: Rick Guidice for NASA*

This artist's concept shows a NASA design for a solar-powered lunar base. This lunar colony interior could be used as a tracking center.



### 6) **Where will we build an outpost?**

NASA needs more data in order to decide this. NASA will send more robots to explore the Moon and send back data. Scientists will use that data to help NASA find the best sites. Right now, NASA is looking at the Moon's polar locations, especially the south pole, for several reasons:

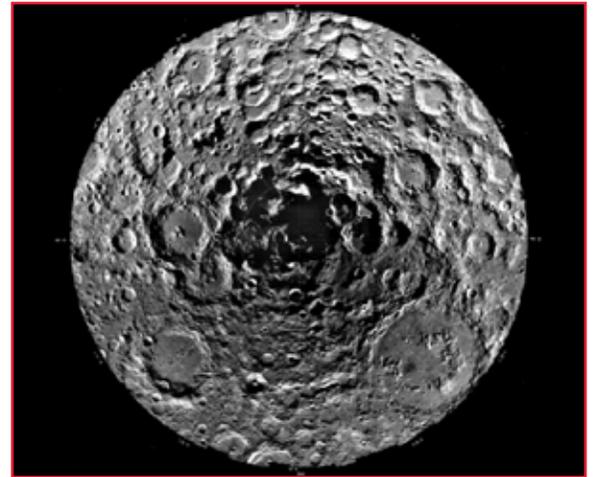
- The Moon has two weeks of light followed by two weeks of darkness. However, the poles receive near constant sunlight. This would make them good locations for solar arrays to power a lunar outpost.
- Polar temperatures are relatively moderate. Other regions on the Moon tend to be extremely hot or cold.
- The poles contain craters whose slopes may be permanently in the shadows. This is an indication that water ice and other potentially useful chemicals may be there.

### 7) **Why would we build a spaceport on the Moon instead of launching the spacecraft from Earth?**

Spacecraft will need a lot less fuel because there is so little gravity to overcome. NASA is still discussing the best way to launch spacecraft to Mars.



*Image credit: Dennis Davidson for NASA*  
An artist's concept of a lunar base with a launch site (background)



This composite photo of the lunar south pole shows a possible site for future outposts. There is evidence of water frozen in deep dark south polar craters. Water can be split into oxygen to breathe and hydrogen to burn as rocket fuel, or astronauts could simply drink it.



*Image credit: NASA*

This concept drawing provides a solution to periods of lunar darkness. During the daytime, the solar arrays electrolyze water. Then, the hydrogen and oxygen are liquefied and stored in insulated cryogenic tanks. Over the night time, the hydrogen and oxygen are recombined to provide power to run the base.



### 8) How will the robots help?

Before humans go back to the Moon, robots will be sent to prepare the way. Some robots will stay in low orbit around the Moon. Other robots will land on the Moon. Their job will be to study, map, and learn about the lunar surface. The robots will send back data to help NASA decide where humans will land. They will look for resources such as oxygen, water, metals, and fuel.



Image credit: NASA

Robots will learn about the lunar surface and send back data to help NASA decide where humans will land.



Image credit: NASA

Robotic sample collections will search for oxygen, water, metals, and fuel.



The LRO undergoes testing.



Image credit: NASA  
An artist's concept of the LRO in lunar orbit

The first robot will take off for the Moon in 2009. This will be the Lunar **Reconnaissance** Orbiter (LRO). On board the orbiter will be the Lunar Orbiter Laser Altimeter, (LOLA). LOLA will create a three-dimensional map of the Moon's surface. LOLA's map will be very accurate. We will know the **contours** of the Moon better than we know some remote areas of Earth. Astronauts will be able to use it like a **USGS** hiking map, so, if astronauts ride out on their rovers, they will not get lost. The LRO will also use sensors to look for resources under the lunar soil. It will find mining sites for oxygen, hydrogen, and water.

A hitchhiker will be launched with the LRO. The smaller Lunar Crater Observation and Sensing Satellite (LCROSS) will ride along with the LRO. LCROSS will separate from the LRO on the way to the Moon and carry out its own mission. Its mission is to crash into the Moon in search of water.



Image credit: NASA  
LCROSS will begin the search for water. This is an artist's concept of the separation.



On the way to the Moon, the two main parts of LCROSS will stay together. As they get near the Moon's south pole, one part will separate and crash into a lunar south pole crater. The tremendous impact will create a plume, or large cloud, of debris. Then, the other part will fly through the cloud to analyze it for signs of water and other materials. Other instruments on Earth will also study the plume. If water ice is found there in large amounts, the astronauts could use it for rocket fuel or for drinking.



*Image credit: NASA*  
An artist's concept shows the LCROSS probe hitting the Moon.

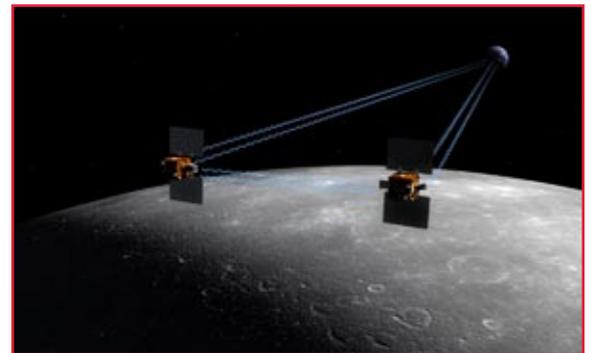


*Image credit: NASA*  
A concept image of LADEE approaching the Moon

### 9) Will other robots be sent to the Moon?

In a single launch, NASA plans to send two robotic spacecraft to orbit the Moon in 2011. The Lunar Atmosphere and Dust Environment Explorer (LADEE) will study the Moon's atmosphere and the dust above the lunar surface. These studies will help NASA scientists assess the lunar environment. This will give our explorers a clearer understanding of what they will be up against as they set up the first outpost. The Gravity Recovery and Interior Laboratory (GRAIL) will use gravity field mapping to determine the

Moon's interior structure. GRAIL will fly twin satellites to x-ray the Moon from crust to core. This will reveal the Moon's subsurface structures and its thermal history. LADEE and GRAIL will separate on their way to the Moon.



*Image credit: NASA*  
A concept image of the GRAIL spacecraft

NASA is also studying a robot that will land on the Moon's surface. This robot will test the ability to land at targeted places on the Moon. It will search for resources that could sustain humans living there. The lander will be able to gain access to the deep craters at the lunar poles. What it finds may help scientists discover the presence of water ice in these craters. It will also assess dangers, such as the effect of low lunar gravity and high radiation levels. The data and



discoveries of this lander will give scientists the answers to many questions. Look for these answers in the news as the robots send back their discoveries.

Future plans call for other robots to visit the Moon. NASA is working on building smarter robots. These robots will be able to make decisions that are normally made by humans back on Earth. This will allow the robot to complete a task much more quickly. It will not have to wait for a human to tell it what to do. Robots that think and make decisions! That may be a little scary. This sounds like something out of our present-day science fiction movies.



NASA's K10 robot looks a little like PIXAR's WALL-E, or does WALL-E look like the K10? K10 will be used for tasks such as lunar site mapping and science reconnaissance, not garbage collection!

### 10) **How can NASA afford to do all of this?**

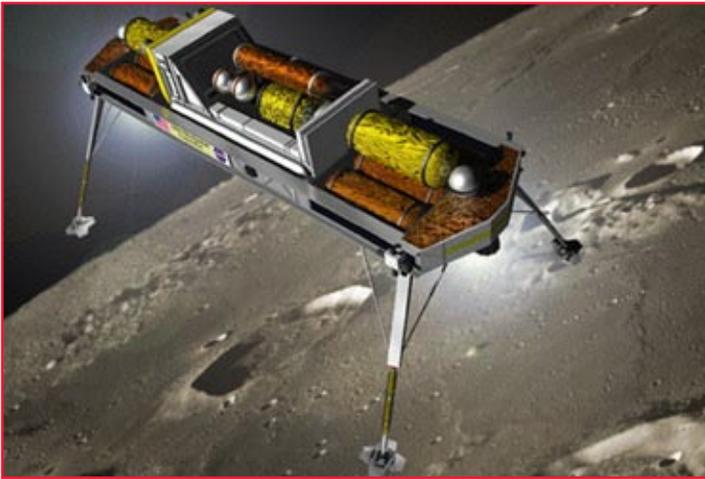
NASA realizes that, with the high cost of space exploration, the Agency cannot afford to colonize the Moon by itself. NASA's 2006 Global Exploration Strategy meeting included **entrepreneurs** and business leaders to discuss ways they could participate in future space missions to the Moon. Inviting companies to help construct a Moon base and do business on the Moon is still far in the future.



*Image credit: NASA*

An artist's concept shows commercial mining of the Moon's regolith.

In the meantime, some companies are already dreaming of how to make money on the Moon. There will be spaceships to build, Moon metals to mine, and resources to use. The Moon's surface material, regolith, contains oxygen and hydrogen. Commercial use of regolith can be used to manufacture rocket fuel. This could lower the cost of space exploration. Regolith also contains silicon that can be used to create panels that help generate solar power. Other companies could construct buildings that meet NASA's needs for shelter on the Moon.



*Image credit: John Frassanito and Associates for NASA*

A commercially operated automated cargo lander delivers an oxygen production plant to the surface of the Moon in this artist's concept.



*Image credit: John Frassanito and Associates for NASA*

A commercial teleoperated lunar oxygen plant begins production in this artist's concept. Remotely driven surface vehicles mine and transport lunar soil to the plant where the oxygen is extracted, liquefied, and pumped into waiting storage tanks.

Some other businesses have imagined ways they could cash in with media deals. Video cameras on robotic spacecraft could beam high-definition imagery down to Earth for advertising. Lots of money could be made by beaming live low-gravity sports events such as volleyball, soccer, racquetball, and golf. One day there could even be a broadcast of new extreme lunar sports! And then there would be movies to make and low-gravity games to create. People used to think that the only way to go to space was to be an astronaut. In the future, there may be transport companies that take people to the Moon as tourists or members of a sports team. When people are given a chance to make money, it seems that the sky is not the limit. One day a company may have you in a soccer match on the Moon.

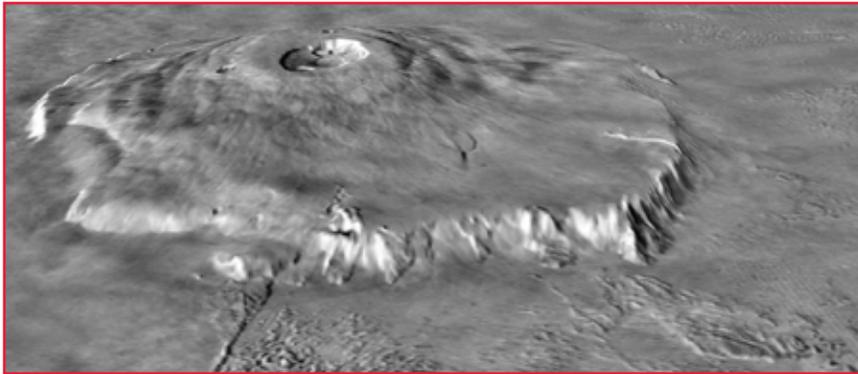


*Image credit: Pat Rawlings and Bill Gleason for NASA*

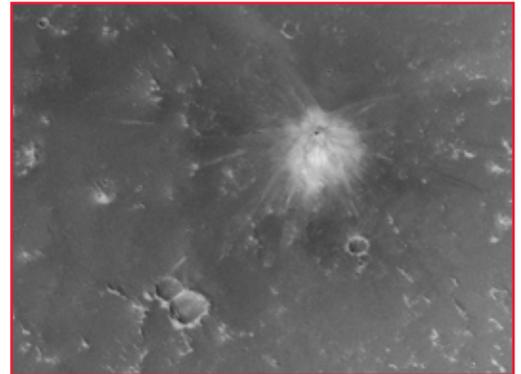
Routine 24-hour flights to the Moon could employ detachable crew modules atop nuclear thermal transfer vehicles, as shown in this artist's concept.



Philip imagines how lunar sports will be played.



Mars is covered with volcanoes. Olympus Mons is the highest known volcano in the solar system.



Meteors make deep craters on Mars.

## So Many Questions... About Mars

### 1) Is Mars like Earth?

Mars has several features like those on Earth. Mars has polar caps like Earth. It also has clouds, seasons, wind, and weather patterns. Its surface has volcanoes and canyons, but our robots have shown us that Mars is very cold. It was once a **volatile** world in which volcanoes raged and meteors made deep craters. Flash floods rushed over its land.



The north polar region of Mars is gouged by deep canyons.



This Mars canyon may have been formed by flowing water like those on Earth.



This image of Mars' southern hemisphere shows its south pole.

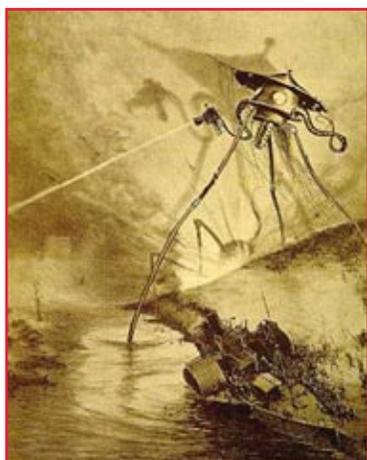
Mars is famous for large, planet-wide dust storms. Three storms are visible in this image.





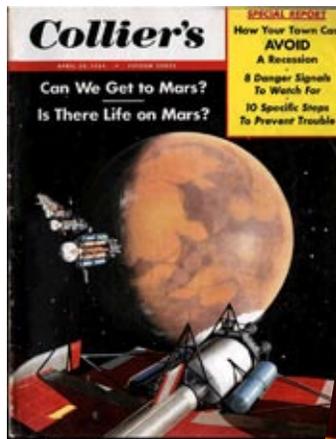
## 2) Why on Earth would we want to go to Mars?

For a long time, Mars has sparked the human imagination. The Romans named the planet after their god of war. Stories told of Martians, monsters, and battles on Mars. At one time, people actually believed there were canals on Mars. An astronomer saw dark lines on the planet through his telescope. People thought the lines

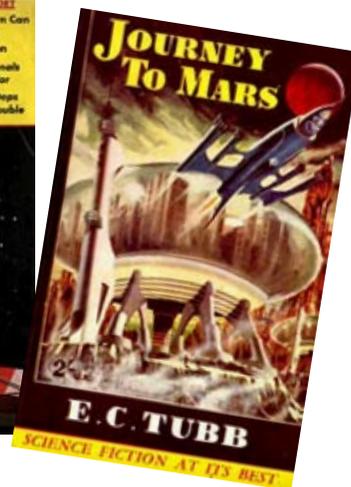


[The War of the Worlds](#), the 1898 science fiction novel by H. G. Wells, describes an invasion of England by aliens from Mars.

were canals bringing water from the ice caps at the poles to the desert areas.



Artist's credit: Chesley Bonestell  
Collier's Space Flight Series (1952–1954)



However, by the mid-1970s, images from NASA's Mariner and Viking spacecraft had put an end to these myths. The early Mars' orbiters and landers sent back photos of a dusty, barren, planet with huge geologic features. Later, scientists saw evidence of water. Now, scientists want to know if life ever existed there.

To help understand the past, present, or future potential for life on Mars, NASA has set four science goals. Robots and humans will help NASA achieve them:

- Find out if life ever existed on Mars.
- Study the climate of Mars.
- Study the geology of Mars.
- Prepare for human exploration of Mars.



Images credit: John Frassanito and Associates for NASA

Image credit: NASA

These artists' concepts show robots and humans exploring Mars to find out if life ever existed there.

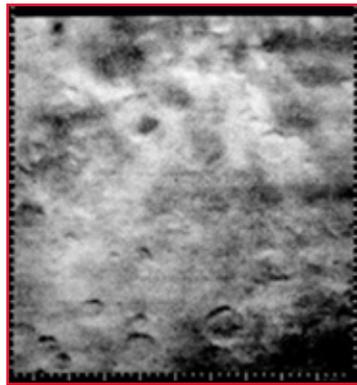


### 3) What kind of robots has NASA already sent to Mars?

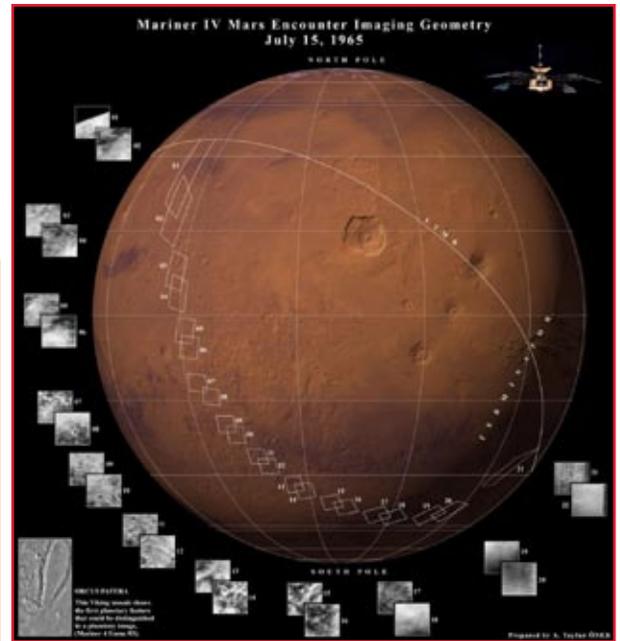
NASA has been sending space probes, or robots, to Mars for many years. Some flybys and orbiters took data from far above Mars giving us global images and information. The landers and rovers on Mars' surface have photographed and analyzed the surface of Mars. These Mars robots include the following spacecraft:

#### Flybys

- *Mariner 4* collected the first close-up photographs of another planet in 1965. It disproved the myths of canals and Martians.
- In 1969, *Mariners 6* and *7* analyzed the Martian atmosphere and surface and recorded and relayed images back to Earth.



*Mariner 4* took the first photo showing Mars' craters



The route of *Mariner 4*



*Mariner 9* took this image of Olympus Mons, the largest volcano in the solar system.

#### Orbiters

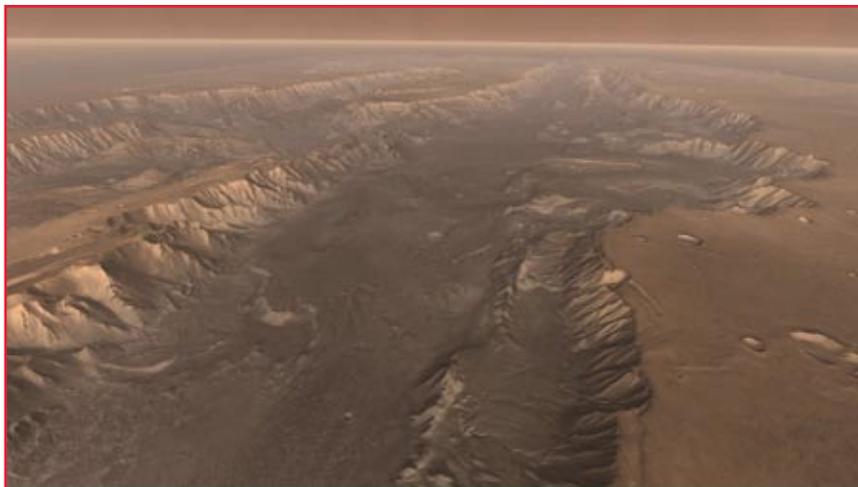
- *Mariner 9*, arriving in Mars' orbit in 1971, was the first spacecraft to orbit another planet. It photo-mapped 100 percent of the planet's surface with images that amazed people on Earth. It observed a global dust storm, gigantic volcanoes, and a huge canyon stretching 3,000 miles (4,800 kilometers). The spacecraft also provided the first close-up pictures of the two small, irregular Martian moons, Phobos and Deimos.
- The *Viking I* and *II* orbiters arrived in 1976. Their main job was to transport the landers to Mars and



locate landing sites for them. Then, they acted as communications relays for the landers, took photos, and performed their own scientific investigations.

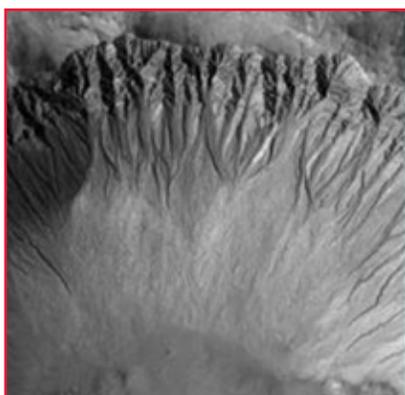


This composite photo of Valles Marineris, the great canyon of Mars, was made from Viking orbiter images.

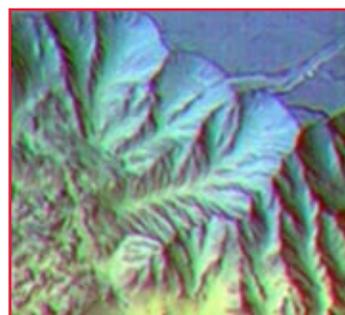


The Grand Canyon of Mars is over 100 miles wide. This image is a composite using the Mars Orbiter Laser Altimeter (MOLA), an instrument on *Mars Global Surveyor*.

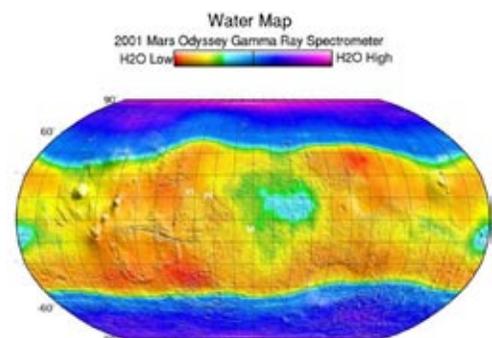
- *Mars Global Surveyor* arrived at Mars in 1997. It studied the entire Martian surface, as well as the atmosphere and interior. It observed repeatable weather patterns and gullies and debris flows which suggest the presence of liquid water at one time.
- *Mars Odyssey* entered Mars' orbit in 2001. It has collected more than 130,000 images and continues to send information to Earth about Martian geology, climate, and mineralogy. It also identified regions with a plentiful amount of buried water ice.



*Mars Global Surveyor's* discovery of many gullies on a crater wall suggests erosion of flowing water on Mars.



*Odyssey's* infrared cameras reveal chemical elements like carbon and iron and other minerals.



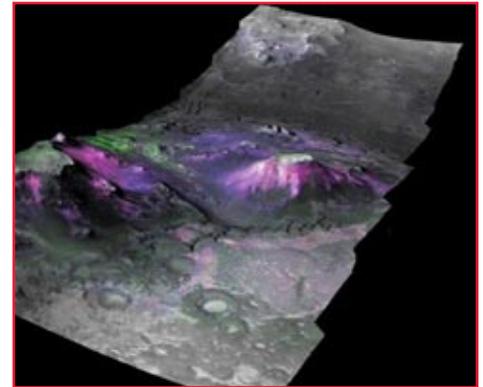
A special camera on *Mars Odyssey* shows regions high in hydrogen at the poles. The areas in blue and violet are believed to consist of 50% water ice.



- The *Mars Reconnaissance Orbiter* (MRO) arrived at Mars in 2006. MRO carried a very powerful camera that can spot an object the size of a dinner plate. This ability helps identify obstacles that could jeopardize the safety of future landers and rovers. Instruments aboard MRO will try to find subsurface water and surface minerals. This data

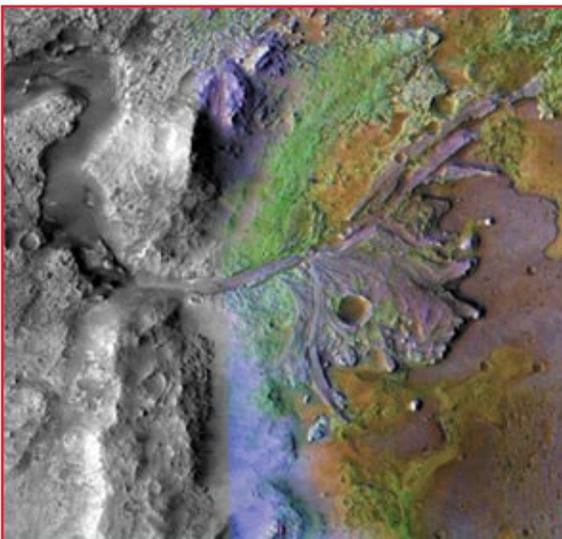


Gullies with characteristics of water-carved channels



This 3-D image from the MRO shows a mineral called phyllosilicates (in magenta and blue hues), evidence that water played a large role in the planet's early history.

is helping to pick sites that can be used for in-situ purposes. A site that has water will likely be chosen for a landing site for human exploration. A student reading this today could one day be landing at a site chosen by the MRO. Other instruments are studying how dust and water are transported in the Martian atmosphere. Two studies based on MRO data have revealed that the Red Planet once hosted vast lakes, flowing rivers, and a variety of other wet environments that had the potential to support life.



This color-enhanced image of the delta in a crater shows that it once held a lake.



MRO's HiRISE camera is examining more than two dozen landing sites for the Mars Science Laboratory rover.



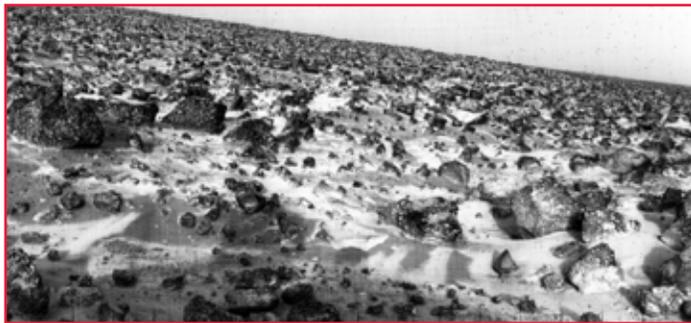
## Landers

- The *Viking I* and *II* landers set down on Mars in 1976. They took photographs and collected other science data from the atmosphere and soil on the Martian surface. They discovered the presence of water vapor and **permafrost**. They also conducted three biology experiments designed to look for possible signs of life, but no sign of life was found. Over 50,000 photos of Mars were obtained from the Viking Project.



Image credit: NASA

A Viking lander



This *Viking II* photo shows a thin coating of water ice on the rocks and soil.

- *Pathfinder* landed on Mars in 1997. Its main job was to deliver the rover *Sojourner*. It also took photos and sent back data on winds and other weather factors. Findings from the lander and the rover suggest that, in its past, Mars was warm and wet, with liquid water, and had a thicker atmosphere.

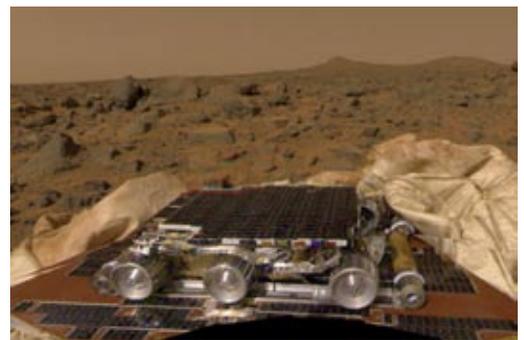


The first color picture taken by *Viking II* showed a rocky reddish surface.



Image credit: NASA

An artist's concept of the *Pathfinder* lander and *Sojourner* rover on Mars



The *Sojourner* rover and undeployed ramps onboard the Mars *Pathfinder* spacecraft



- *Phoenix* landed on Mars in 2008. Its robotic arm dug to expose water ice below the surface. It also checked samples of soil and ice for evidence of past life. Other instruments enabled the identification of local minerals and a scan of the atmosphere up to 12.4 miles (20 kilometers) in altitude.

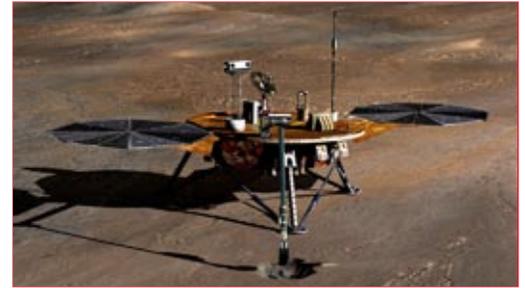


Image credit: NASA

An artist's concept of the *Phoenix* lander



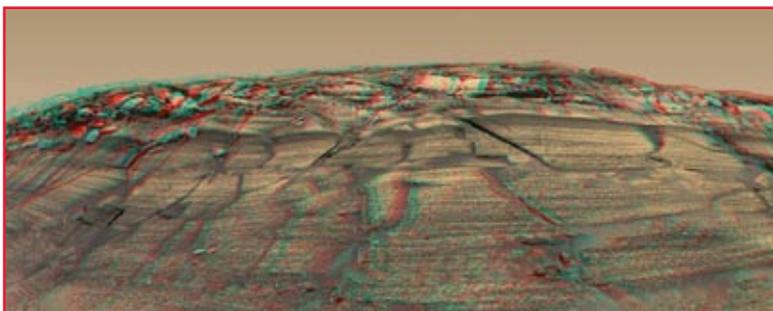
*Sojourner* is taking its Alpha Proton X-ray Spectrometer measurement of the Yogi Rock.

## Rovers

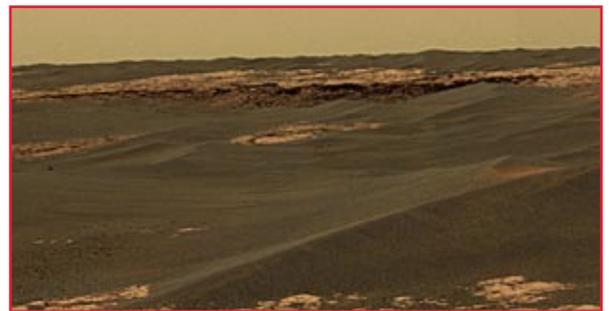
- *Sojourner* was NASA's first Mars' rover, landing on the surface in 1997 with *Pathfinder*. The day after *Pathfinder* landed on Mars, the little robot rolled down its ramp. The robot crossed the Martian soil and bumped into rocks. Barnacle Bill, Yogi, and Scooby Doo were names given to a few of the rocks by NASA scientists. *Sojourner* sent back chemical analyses of rocks and soil.
- *Spirit* and *Opportunity* were two robotic geologists who landed on opposite sides of Mars in 2004. They operated for years, making NASA scientists feel like they were their friends. The twin rovers traveled for miles across the Martian surface, analyzing the soil and rocks and making atmospheric observations. They sent more than 100,000 spectacular, high-resolution, full-color images of Martian terrain as well as detailed **microscopic** images of rocks and soil surfaces to Earth.



*Spirit* captures a bumpy boulder



You need 3-D glasses to see *Opportunity's* image of Burn's Cliff.



The upper portion of *Opportunity's* composite image shows part of the rim of Erebus Crater.



4) **Do we really expect to find life on Mars?**

NASA does not expect to find little green men on Mars, but there may be some form of life. Almost everywhere we find water on Earth, we find life. Because evidence shows that Mars had huge amounts of water and now has water ice, we may find that it once had life. Scientists want to know if there might still be some microscopic life forms there; therefore NASA’s strategy is to “follow the water.”



Image credit: NASA

Astronauts and robots explore Mars searching for evidence of past life in this artist’s concept.

5) **Is there water on Mars now?**

NASA says there is, but you would not want to go for a swim. The air temperature on Mars is rarely above freezing. NASA scientists have been gathering data for years to determine the existence of water on Mars. In 1998, *Mars Global Surveyor* found hematite, an iron mineral that can form in the presence of water. On the other side of Mars, data showed that water may once have flowed into and through a crater. The *Mars Express* (sent by ESA and aided by NASA) discovered kieserite, a water-bearing mineral. In 2002, *Mars Odyssey* found the presence of hydrogen in Mars’ polar region.

Image credit: CartoonStock. Used with permission



LOOK WHAT FOLLOWED ME HOME MOM. CAN I KEEP IT AND CALL IT ROVER ?

Image credit: CartoonStock. Used with permission

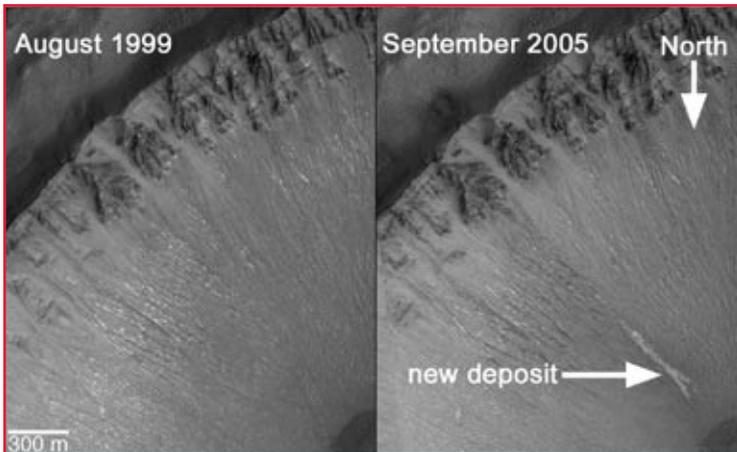


"I thought I told you to take your new pet outside. Now it's drilling holes in the furniture!"

Image credit: CartoonStock. Used with permission



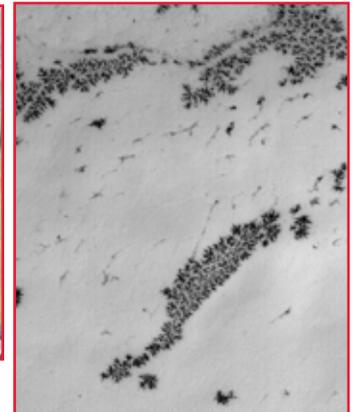
"Wow! We've been sent free earth donuts!"



NASA before-and-after photographs have revealed bright new deposits seen in two gullies on Mars that suggest water carried sediment through them sometime during the past 7 years.



Red and yellow indicate the presence of hematite on Mars.



Another sign of water is this image of a frost-covered surface in the south pole region. Those areas already defrosted appear dark in the image.

The only real source of hydrogen would be water in the form of frozen ice. From this, scientists believed that water ice lay just beneath the surface. *Opportunity* took some photographs of rock layers that were likely formed by flowing water. Then, in 2005, the *Mars Global Surveyor* took photos of a new gully deposit in a crater. All the data pointed to water, but there was still no absolute proof.

Using all of this evidence, NASA decided to go beneath the surface of Mars to look for liquid water. By now, they believed that water existed in the polar regions of Mars. In Antarctica and Iceland, water is stored in a layer of permafrost. Beneath that, there is liquid water. Therefore, even if the surface water on Mars had evaporated, NASA believed there were reservoirs of water in the subsurface at the Martian poles. In 2008, their beliefs were confirmed. Scientists found water on Mars!



Image credit: CartoonStock. Used with permission

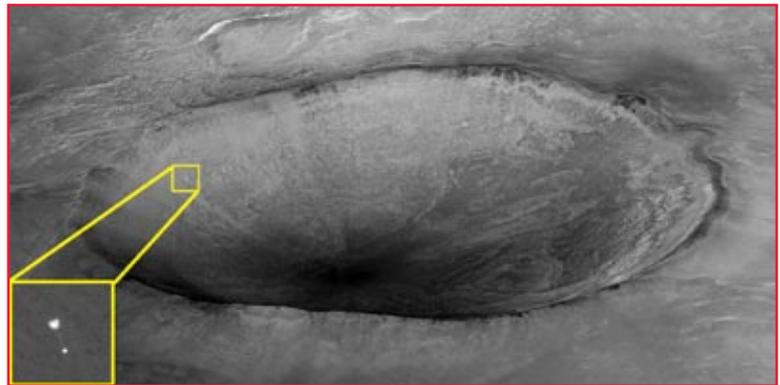


Image credit: CartoonStock. Used with permission



### 6) How did NASA find water?

In 2002, the *Mars Odyssey* orbiter discovered hydrogen at the Mars poles. That discovery caused NASA to believe that water ice lies just beneath the surface in the arctic plains of Mars. NASA, therefore, knew exactly where to land the Mars *Phoenix* lander in 2008.



MRO's HiRISE camera took this image of *Phoenix* hanging from its parachute as it descended to the Martian surface.

After landing, *Phoenix* used its 7.7-foot (2.3-meter) arm to dig into the icy soil. Images came back to Earth showing that *Phoenix* had uncovered something white. After four days, the white had disappeared. Scientists knew then that it was ice. Next, *Phoenix's* arm placed the samples into its instruments. *Phoenix* began to taste and sniff those fistfuls of Martian soil and buried ice, analyzing the samples. On July 31, 2008, NASA announced that water had been found on Mars. Laboratory tests aboard *Phoenix* identified water in a soil sample.



Image credit: NASA

Pulsed rocket engines control *Phoenix's* speed during the final seconds of descent to the arctic plains of Mars.



*Phoenix's* 7.7-foot (2.3-meter) arm scooped up samples of soil and underground ice. The spacecraft will collect samples up to 20 inches (½ meter) deep using its robotic arm.



Image credit: NASA

*Phoenix's* arm dug into the Martian soil to reveal a white subsurface.

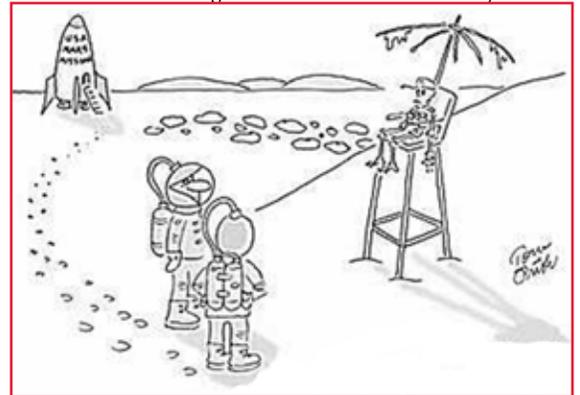
The mission was named after the Phoenix, a mythological bird that is repeatedly reborn from its own ashes. Many students will recognize the name because of Fawkes, the phoenix in the Harry Potter books. The spacecraft will continue to look for microbial life on Mars. It will also determine whether or not this frosty region will support a future human presence.



### 7) What does “follow the water” mean?

“Follow the ...whatever” is a phrase used when people are searching for something. They follow the clues in hopes of finding what they are looking for. NASA knows that finding liquid water is the key to finding evidence of life on the planet. They want to explore dry riverbeds and ice in the polar caps. They will study rock types that only form when water is present. They will look for hot springs, thermal vents, and water reserves deep in the ground. They want to know if there was once a vast ocean on ancient Mars. If there was once an ocean, why is Mars so dry and dusty today? They want to find out how, when, and why Mars changed to become the hostile planet that it is today. They want to know if life was ever on Mars. Robots have begun the search.

Image credit: CartoonStock. Used with permission



Signs of water discovered on Mars

### 8) How will other robots explore Mars?

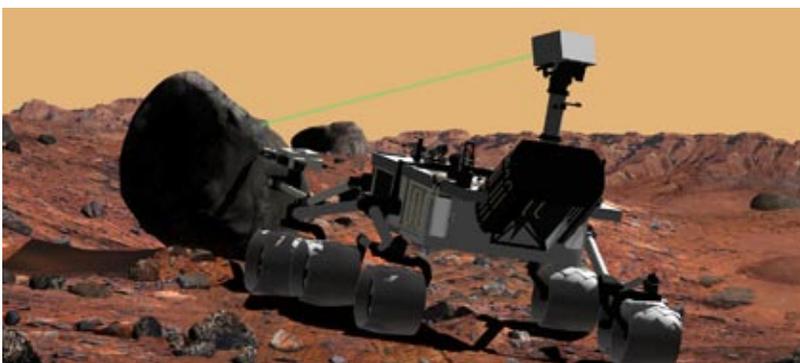


Image credit: NASA

This artist's concept of the *Mars Science Laboratory* shows the use of the ChemCam used to identify the chemical composition of a rock sample on the surface of Mars.



Image credit: NASA

This artist's concept shows that the next generation rover, *Mars Science Laboratory*, is much larger than *Spirit* and *Opportunity*.

The *Mars Science Laboratory* will arrive at Mars in 2010. This rover is much bigger than the 2004 robots. It will collect soil samples, crush them, and put them in a test chamber. They will be examined for compounds that may have supported life. It will also carry a laser and a very powerful drill for analyzing rocks. Some of the tools on board are from other countries. A detector for finding water comes from Russia. Tools for studying the weather and climate come from Spain. A tool to measure light waves comes from Canada.



NASA has a long-term program to explore Mars over the next two decades. They will build on what they have learned from earlier missions to plot the course for future missions. Future robots are a part of the strategy to follow the water. They will look for signs of present or past life on Mars. They will take data on the climate and the history. The more we know about Mars, the safer our astronauts will be when they get there. NASA is studying some new technologies that will give us a closer look at Mars.

- The Mars airplane might be used to fly over valleys and mountains. It would be able to get closer images of the ground than an orbiter. It could cover more land than a rover.



*Image credit: NASA*

An artist's concept of the Mars Scout Plane



*Image credit: NASA*

An artist's concept of the Mars airplane

- Balloons can fly 100 times closer to the surface of Mars than orbiters. They can travel 1,000 times further than a rover. They would be used to image the surface and gather data. They could also provide a slow landing for small craft in unsafe landing places.
- An Astrobiology Field Lab would conduct a robotic search for evidence of past or present life.



*Image credit: Robert Michelson for NASA*

In this artist's concept, entomopters exploring Mars would be able to land, takeoff, and hover.



*Image credit: NASA*

Directed Aerial Robot Explorers (DARE) are autonomous balloons that can send out swarms of miniature probes over multiple target areas in this artist's concept.

- Radar and robotic “moles” will be used. These robots are called moles because they will dig under the ground. NASA is now developing a mole that will be able to drill hundreds of meters down. NASA engineers are still solving a lot of problems with drilling on Mars. The Mars drill will even have to make



*Image credit: NASA*

An artist's concept of an Astrobiology Field Lab



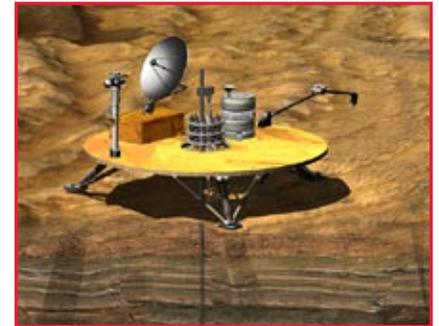
its own decisions. On Earth, drills can get stuck very quickly so a Mars robotic drill must know how to recognize, avoid, and solve problems on its own.



*Image credit: NASA*

An artist's concept of the Mars Sample Return Mission ascent vehicle on its way back to Earth

- A Mars Sample Return mission would use a robot and an ascent rocket. It would collect and send rocks, soil, and atmosphere back to Earth. Then, we could study the Red Planet close-up here on Earth.



*Image credit: NASA*

Artist's concept of a deep-drill lander

## 9) Will humans go to Mars?

Some time in the future, humans will go to Mars. The timing of the first human mission will depend on what the robots find out. It will also depend on the new technology to get humans safely there and back. Will someone or something be there to greet them when they land? We must find out.



*Image credit: John Frassanito and Associates for NASA*

In this artist's concept, two astronauts are preparing a robot to collect samples from the Martian surface.



*Image credit: John J. Olson for NASA*

Artist's concept for a future base on Mars



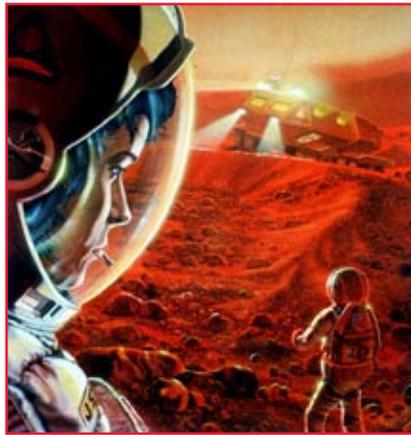
*Image credit: NASA*

Artist's concept of human exploratory drilling for in-situ resources on Mars

*Image credit: Pat Rawlings for NASA*

Artist's concept of *Sojourner* being discovered many years after its mission





*Image credit: Paul DiMare for NASA*  
The hostile environment on Mars will require special technologies and systems such as these durable suits for protection against the dust storm in this artist's concept.



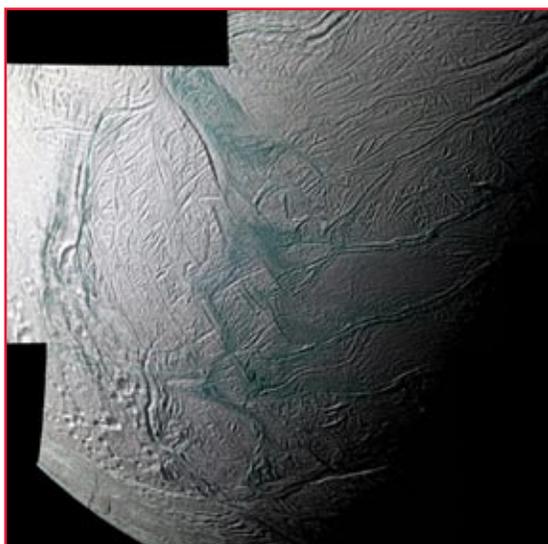
*Image credit: NASA*  
An artist's concept of a Martian greenhouse, an essential part of any future human colony on the Red Planet

### 10) What are NASA's plans for research beyond Mars?

NASA's mission is to pioneer the future in space exploration and scientific discovery and research. NASA will always lead the exploration of space. Right now, the *Cassini* orbiter is sending back pictures and data from Saturn. The *Huygens* probe, built by ESA with NASA participation, separated from *Cassini* and landed on Saturn's moon, Titan. *Messenger* was sent to Mercury to map the entire planet in color. Instruments on board will be



*Image credit: NASA*  
Fractures, or "tiger stripes," where icy jets erupt on Saturn's moon Enceladus was the target of a close flyby by the Cassini spacecraft, as shown in this artist's concept.



NASA's *Cassini* spacecraft has pinpointed precisely where the icy jets erupt from the surface of Saturn's moon, Enceladus. Newspaper articles questioned whether Enceladus was a frozen iceball or a hidden ocean.

able to determine the components of Mercury's surface and atmosphere. The *New Horizons* probe was sent on a 10-year journey to Pluto. The spacecraft will cross the entire span of the solar system. It will conduct flyby studies of Pluto and Charon. *Juno* will be sent to Jupiter in 2010 and reach the planet in 2016. *Dawn* was launched in 2007 to orbit the asteroids Ceres and Vesta. *Dawn* will reach Vesta in 2011 and Ceres in 2015.



## Traveling to the Moon, Mars, and Beyond

Now that we have learned about going to the Moon, Mars, and beyond, let's look at NASA's plans for getting there. NASA's Constellation Program is developing the new spacecraft that will return humans to the Moon and blaze a trail to Mars and beyond. These new spacecraft include Orion and Altair. The Orion capsule is the crew exploration vehicle that functions as a crew habitat. The Altair lunar lander will carry humans to the Moon's surface. Orion and Altair will be sent into Earth orbit by separate launch vehicles. Orion will be launched by Ares I, the **Crew Launch Vehicle**. Altair and the Earth Departure Stage (EDS) will be carried into orbit by Ares V, the **Cargo Launch Vehicle**.



### Orion, NASA's Crew Exploration Vehicle

Orion is NASA's new vehicle for carrying humans into space. Its shape will be very much like the Apollo capsule. Orion includes a command module (CM), a service module (SM), and a launch **abort** system. The Orion CM will support the launch and the return of the crew and provides

the living space they will need. It is designed to carry four astronauts to and from the Moon. It will also support a crew of six on their missions to the ISS and to Mars. The CM will have a **diameter** of 16.4 feet (5 meters). Its volume will be almost three times larger than the Apollo CM,



A mockup of Orion comes together.



Image credit: NASA

An artist's concept of Orion and Altair in lunar orbit

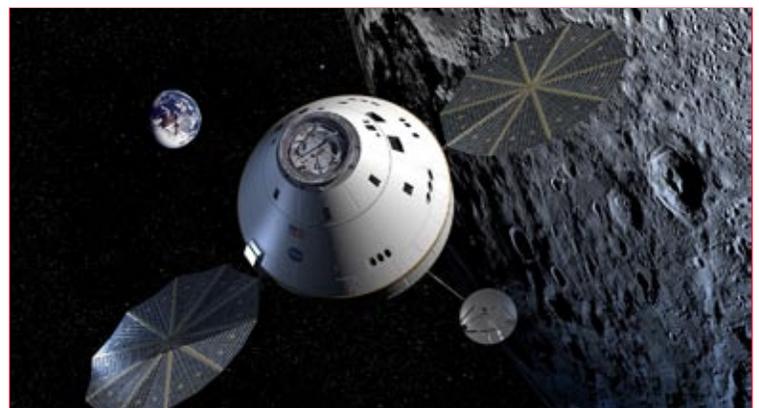


Image credit: NASA

Orion will remain in lunar orbit after Altair separates to descend to the lunar surface. This artist's concept shows how Orion's disc-shaped solar arrays will track the Sun to provide power.



so Orion's crew will ride in style on their way to the Moon. When the CM is in orbit around the Moon, an astronaut will not need to stay behind like the Apollo missions. This will allow all of the astronauts to descend to the lunar surface.

Orion's SM will supply the ship with **propulsion** and power. It will have all of the support systems to meet the needs of a crew on a mission. Solar panels will provide power for inside the vehicle.

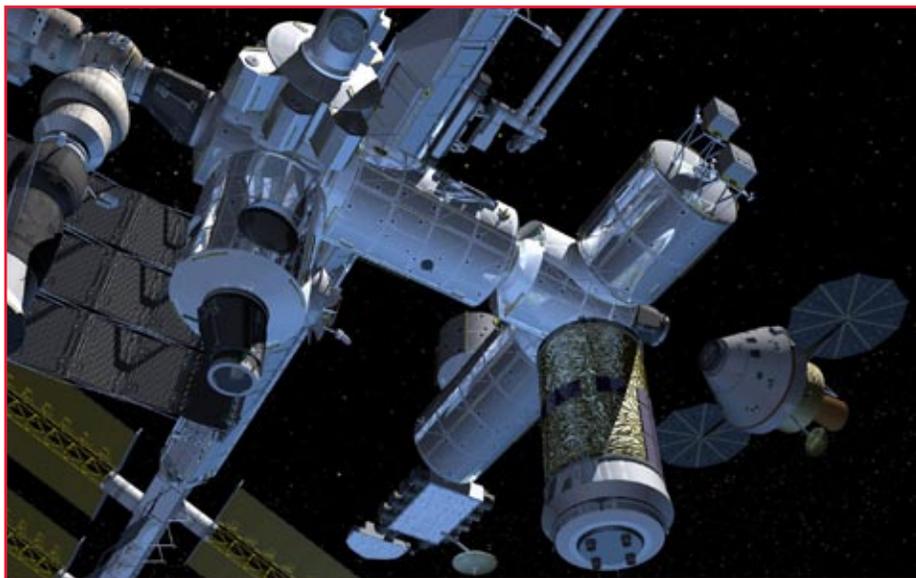
Orion will have a launch abort system. If trouble occurs during a launch, the astronauts will be taken to safety. A **solid rocket** motor above the capsule can pull it out of harm's way in case of an emergency. This makes Orion much safer than the Space Shuttle.



*Image credit: NASA*

Orion's launch abort system is designed to pull the crew module to safety in an emergency, as shown in this artist's concept.

Before Orion carries a crew to the Moon, the capsule will carry the crew and supplies to the ISS. Up to six crew members can be taken to and from the ISS. When Orion is not carrying a crew, it can be used as a cargo ship. Workers will remove the parts needed for a crew and install parts to support the cargo. Since the Space Shuttle is scheduled to retire in 2010, NASA is working hard



*Image Credit: NASA*

This artist's concept shows Orion preparing to dock with the ISS in Earth orbit.

to get Orion ready. They are hoping to avoid a long time gap between Orion and the retired Space Shuttle. On ISS missions, Orion can remain docked in an inactive state up to six months. This means that the crew on the ISS can return to Earth in case of an emergency. Plans call for Orion to make up to five trips a year to the ISS.



As Orion returns to Earth, the SM will separate and the CM will be flying alone. The CM has its own propulsion system to control its position as it re-enters Earth's atmosphere. Early plans called for Orion to use parachutes and airbags to land on dry land. Now, the primary landing will be a splashdown into the ocean. NASA will still prepare for a ground landing as a backup option. Once Orion is recovered from the water, it will be carefully examined to determine which parts might be used again.



For return to Earth, Orion will be equipped with a system of parachutes for a splashdown into the ocean. Shock absorbers (air bags) have also been tested to prepare for a backup ground landing.

*Image credit: NASA*

## The Altair Lunar Lander

Please note that the concept images for the Altair lunar lander are not precise. As of this writing, NASA currently is seeking input from industry experts and is developing conceptual designs for Altair.

The Altair lunar lander is much like the lunar lander from the Apollo program. It will have a descent stage and an ascent stage. An airlock will give the astronauts the ability to go in and out of the cabin. Like Orion, Altair is bigger than its Apollo **counterpart**. It will be able to carry a crew of four to the Moon's surface and back to lunar orbit.



*Image credit: NASA*

An artist's concept of the lunar lander on the lunar surface

NASA will also use Altair as an all-purpose lander that can carry a large amount of cargo to the Moon in a single trip. NASA compared the lander to a pickup truck: "You can put what you want in the bed. You can take it to wherever you want, and you can deliver cargo and crew. You can do it robotically or with humans aboard. The more you can land the better it is."



Altair will begin its journey to the Moon on a separate launch vehicle from Orion. It will be put into low Earth orbit (LEO) by a powerful Ares V rocket. In LEO, Orion will dock with Altair before heading for the Moon.

After a three-day trip, Orion and Altair will reach the lunar orbit. Once the crew transfers from Orion into Altair, Altair will separate from Orion and descend to the lunar surface. Altair will carry enough fuel to land at any site on the Moon. The mission control team in Houston will not be turning blue on Orion missions like it did with the *Eagle* in the *Apollo 11* mission.



Image credit: NASA

The Ares V Earth Departure Stage in LEO, shown in this artist's concept with the Orion capsule docked with the Altair lander, is needed to escape Earth's gravity and send Orion and Altair on their way to the Moon.

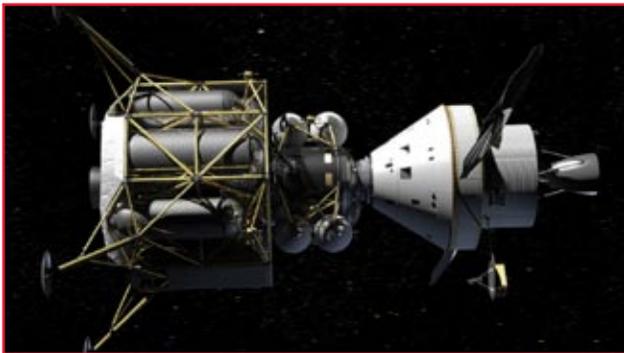


Image credit: NASA

Altair flies in space while docked with the Orion capsule in this artist's concept.

Once on the Moon, Altair will provide a home for the crew for up to seven days. Along with the crew, Altair will be able to carry 1,100 pounds (500 kilograms) of payload. Without a crew, it can deliver 4,800 pounds (2,200 kilograms) of payload to the surface. This will allow NASA to build an outpost with parts being sent over several missions. Humans will be aboard some missions, but only cargo will be delivered on other missions.

Part of the first cargo will be a rover. Using the rover, the crew will be able to travel as far as 9–12 miles (15–20 kilometers) from the lander. The crew will be performing three main activities. The first will be to conduct lunar science activities such as geology, **geophysics**, astronomy, and Earth observations. The second will be to look for resources such as water. The third will be to test the technology that will be used on future missions to Mars.



The lunar truck can go sideways, forward, backward, and any direction in between.



At the end of the mission, the crew will launch Altair's ascent stage into lunar orbit. In lunar orbit, it will dock with Orion. The crew will enter Orion and discard Altair's ascent stage before heading back to Earth. Just before landing, the SM will be discarded, and only Orion's CM will land on Earth's surface.

A concept image of a crew being launched from the Moon's surface in the ascent stage of Altair



Image credit: John Frassanito and Associates for NASA

When people are asked today what they think of NASA's plans to return to the Moon, many reply, "It's about time." NASA thinks so, too. NASA is working at top speed to fulfill this mission. What do you think you will be doing when the next astronaut steps on the Moon? Many students today will be a part of that mission tomorrow. Maybe one of them will be you.

## The New Launch Vehicles



The Ares logo

Getting from Earth's surface into orbit is most often the hardest part of space travel. Orion and Altair will need a mighty big boost to escape Earth's gravity. NASA is developing those launch vehicles in Huntsville, Alabama, at the Marshall Space Flight Center (MSFC). Hundreds of engineers are working on this project. MSFC was the NASA Center that produced the Saturn V rocket. The Center is also responsible for the Space Shuttle propulsion systems. The solid rocket **boosters**, the external tank, and the space shuttle main engines were developed at MSFC.

The engineers at MFSC are now working to design and build two different launch vehicles for Orion and Altair. They are using some of the best technology from Apollo and the space shuttle for the new vehicles, but the new vehicles will be getting a big upgrade. They will be safer and more reliable. These new launch vehicles will be used for the Moon missions, as well as the missions to the ISS and future missions to Mars. They were given the names Ares I and Ares V. The "I" and "V" were given to Ares to honor the Saturn I and Saturn V rockets that were a part of the Apollo program.



An aerial view of MFSC with the rocket test stands in the foreground



## Ares I, NASA's Crew Launch Vehicle

The Ares I Crew Launch Vehicle will carry the Orion crew capsule into orbit. Ares I is a two-stage launch vehicle. The first stage is a five-segment solid rocket booster (SRB). This makes it taller than the Space Shuttle SRBs. NASA had to add a fifth segment rather than making the diameter larger. The diameter is fixed since each segment travels by train from where they are made in Utah to the Kennedy Space Center (KSC) in Florida. If the rocket were any wider, it would not fit through the many railroad tunnels on the journey. Workers at KSC will put the segments together in a stack.



Image credit: NASA

Launch Pad 39B at KSC will be modified to support future launches of Ares I and the Orion spacecraft, as shown in this artist's concept.

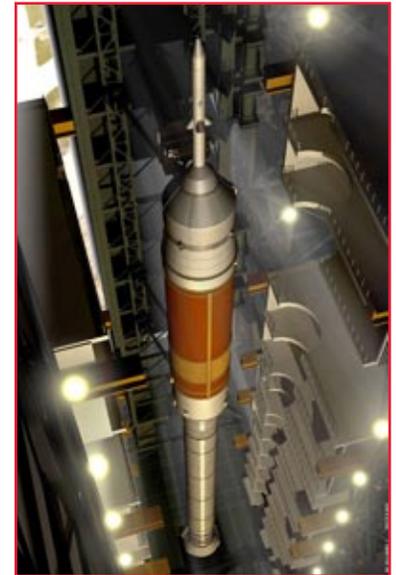


Image credit: NASA

An artist's rendition of Ares I being stacked in the Vehicle Assembly Building (VAB)



The locomotive and rail cars carrying solid rocket booster motor segments



One segment of a solid rocket booster



Image credit: NASA

A concept image of an Ares I launch

The SRB will propel the entire vehicle with Orion off the launch pad to high altitude. It will burn for two minutes and then separate and fall back to Earth. Parachutes will ease its landing into the ocean. Then, it will be picked up, cleaned, inspected, and shipped back to Utah. Workers there will reload it with **propellant**, and it will be ready to be used again.



Once the SRB drops off, the second stage, or upper stage, ignites. The upper stage will be powered by a new J-2X engine. This rocket uses two liquid propellants. Liquid oxygen will be the **oxidizer** and liquid hydrogen will be the fuel. This is the most powerful combination of liquid propellants. Once the J-2X takes Orion from high altitude to LEO, it drops off, burns up, and its debris lands in the ocean. Then, Orion's own propulsion systems will take over.



A J-2X engine is installed on a test stand.

Ares I can carry a payload of 56,000 pounds (25 metric tons) into LEO. It will be 10 times safer than the space shuttle. This safety factor is due to its in-line design (one tall stack) and its abort system. By sitting on top of the stack, Orion can separate from the rocket below and make a safe landing. At first, Ares I will launch Orion's crews and supplies to the ISS. Later, it will get some very powerful help to get Orion to the Moon.

## Ares V, NASA's Cargo Launch Vehicle



Image credit: NASA

A model of Ares V shows two five- and one-half-segment SRBs on either side of the core tank, and the Earth Departure Stage above the core.

Ares V is NASA's Cargo Launch Vehicle. NASA has been focusing on an all-cargo version of the Space Shuttle for many years. Ares V is the result of that focus. Its main propulsion will be a modified shuttle external tank with two SRBs. The tank will be 33 feet in diameter. It will provide the fuel for six RS-68 engines. The RS-68 is the most powerful liquid oxygen/liquid hydrogen rocket engine in existence.



Engineers conduct an RS-68 engine hardware test for Ares V at NASA MSFC in Huntsville, Alabama. Six RS-68 engines will power the core stage of Ares V.



Each SRB will have five and one-half segments. Sitting atop the core will be the Earth Departure Stage (EDS). This stage carries liquid oxygen and liquid hydrogen fuel for a J-2X engine. Ares V will stand 381 feet (116 meters) tall and can lift 413,800 pounds (187.7 metric tons) to LEO for a lunar mission.



*Image credit: NASA*

A concept image of an Ares V launch



*Image credit: John Frassanito and Associates for NASA*

In this artist's concept, Ares V places a monolithic 8-m UV-visual telescope on a path to study the Sun.

The main task of the Ares V rocket will be to lift the Altair lunar lander and the EDS into low Earth orbit. It will also be used to deliver hardware and materials for a Moon base. Once the base is ready for humans to live there, Ares V will launch cargoes of food, fresh water, and other staples needed by the Moon

residents. Ares V will also be able to launch robotic probes to explore the solar system. NASA has ways to increase the propulsion on Ares V to meet the different needs of sending objects into space. The lift capability numbers will change as needs change.

The six RS-68 engines and the SRBs will lift the rocket from the launch pad. The SRBs will burn for two minutes before they separate and fall into the ocean. Like the SRB on Ares I, they will be picked up to be used again. The core stage will continue to burn for three and one half minutes. Then, it will separate and burn up, and the remaining parts fall into the ocean. The EDS will ignite and place Altair into low Earth orbit.



*Artist's concept image credit: NASA*

The Ares V cargo launch vehicle will work in tandem with the Ares I crew launch vehicle to deliver the power to explore the Moon and beyond.



Together, they will orbit the Earth to wait for Orion. Once Orion docks with Altair, the EDS ignites again. This will send the astronauts on their way to the Moon.

### To the Moon and Back

Orion's crew will travel for three days before it goes into lunar orbit. Apollo's CM stayed in orbit while the lunar lander went to the lunar surface. The separation of Orion and Altair will

be very similar. Altair will separate and descend to the lunar surface. Orion will remain in an uncrewed lunar orbit. This will allow all four astronauts to explore the Moon. The length of time on the Moon will depend on the mission. Once the mission is completed, the astronauts will reenter the ascent stage of Altair. They will launch the ascent stage into lunar orbit where they will dock with Orion. When the astronauts are aboard Orion, the service module main engine will provide the power that Orion needs to break out of the lunar orbit and head home to Earth. One day, in the near future, Orion will return to Earth from its trip to Mars.



Image credit: NASA

This artist's concept shows the EDS with engines firing to take Orion and Altair further into space.



Artist's concept image credit: NASA

The service module supports Orion until the two modules separate just before reentering Earth's atmosphere.



Orion returns to Earth.

Artist's concept image credit: NASA



Artist's concept image credit: NASA

With the use of parachutes, Orion will safely return the astronauts to Earth.



Some people may question a repeat Moon mission, but this time, the Moon is only a first step. This time we will build a base there. One day, we will travel far beyond the Moon. In unveiling the Vision for Space Exploration, President Bush addressed the need to return to the Moon: “This cause of exploration and discovery is not an option we choose; it is a desire written in the human heart.” The footprints of Apollo are ready for company, and Mars awaits the first steps of the next giant leap for humankind.

### **The NASA Courage**

In a 2008 “Day of Remembrance” message to the workers at Marshall Space Flight Center, Center Director David King delivered the following statement: “NASA belongs to the American people, for we are their space program. We share with America a sense of high esteem for our astronauts. They are brilliant and daring, a special breed of people all their own. They are our friends, our families, our heroes. And the nation mourns with us when one of them falls. What we do at NASA embodies the best of the American spirit — the unquenchable desire to explore, to bravely unlock the doors of discovery, to pursue the betterment of all. It is not an easy task. Nor is it without risk.”

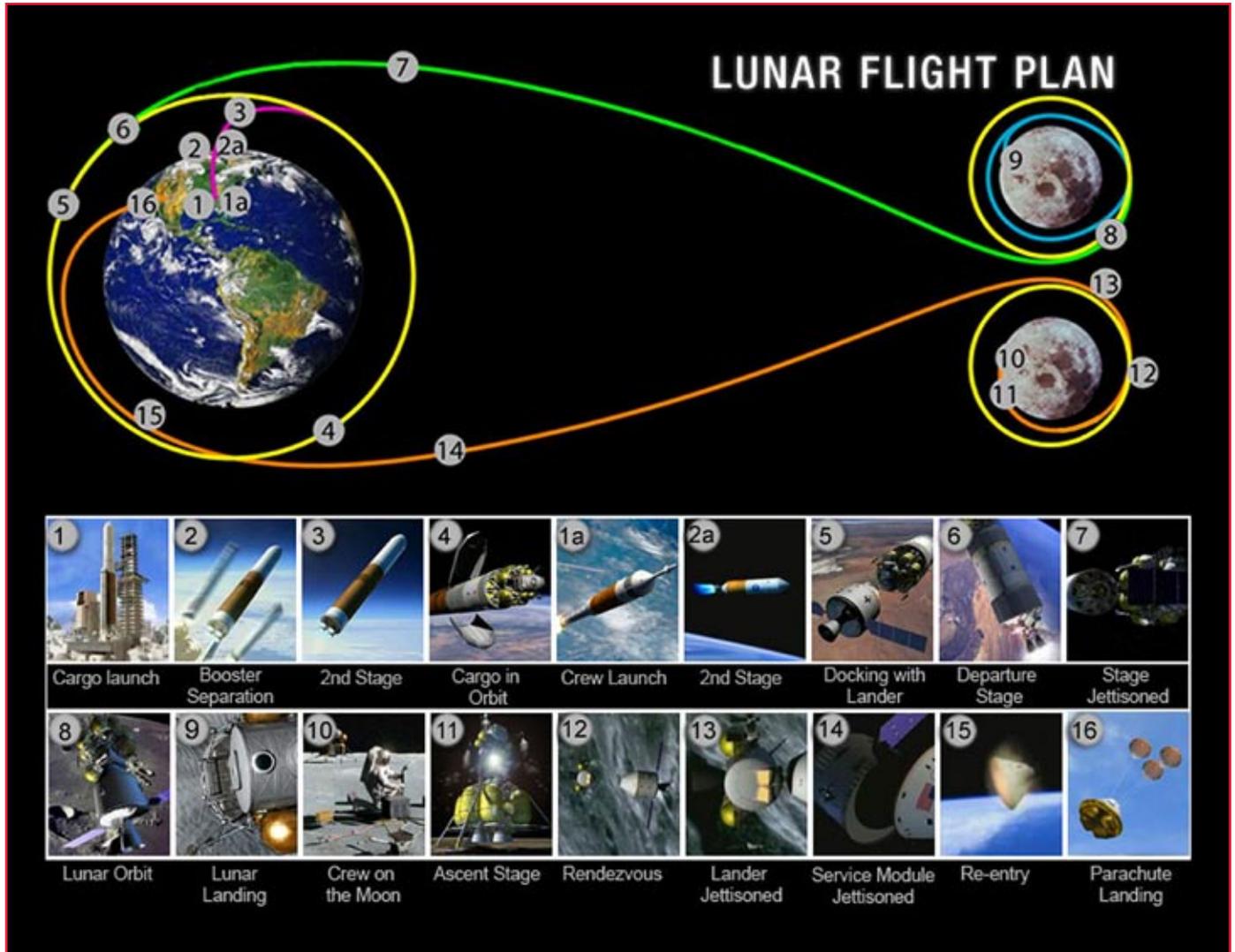
As we look back at the progress of the 20th century, it is hard to imagine what lies ahead in the next 100 years. For the first time in the history of humanity, humans may be sent out to explore the far reaches of the solar system and even beyond. The possibilities of new technologies and discoveries are endless. We can thank NASA for leading the way in our pursuit to unlock those doors of discovery in our universe. Who knows what lies behind them. But, with the courage to soar higher, we will soon find out.



Wow! Space Camp is great, but wouldn't it be cool to work for NASA when we grow up! <http://www.spacecamp.com/>

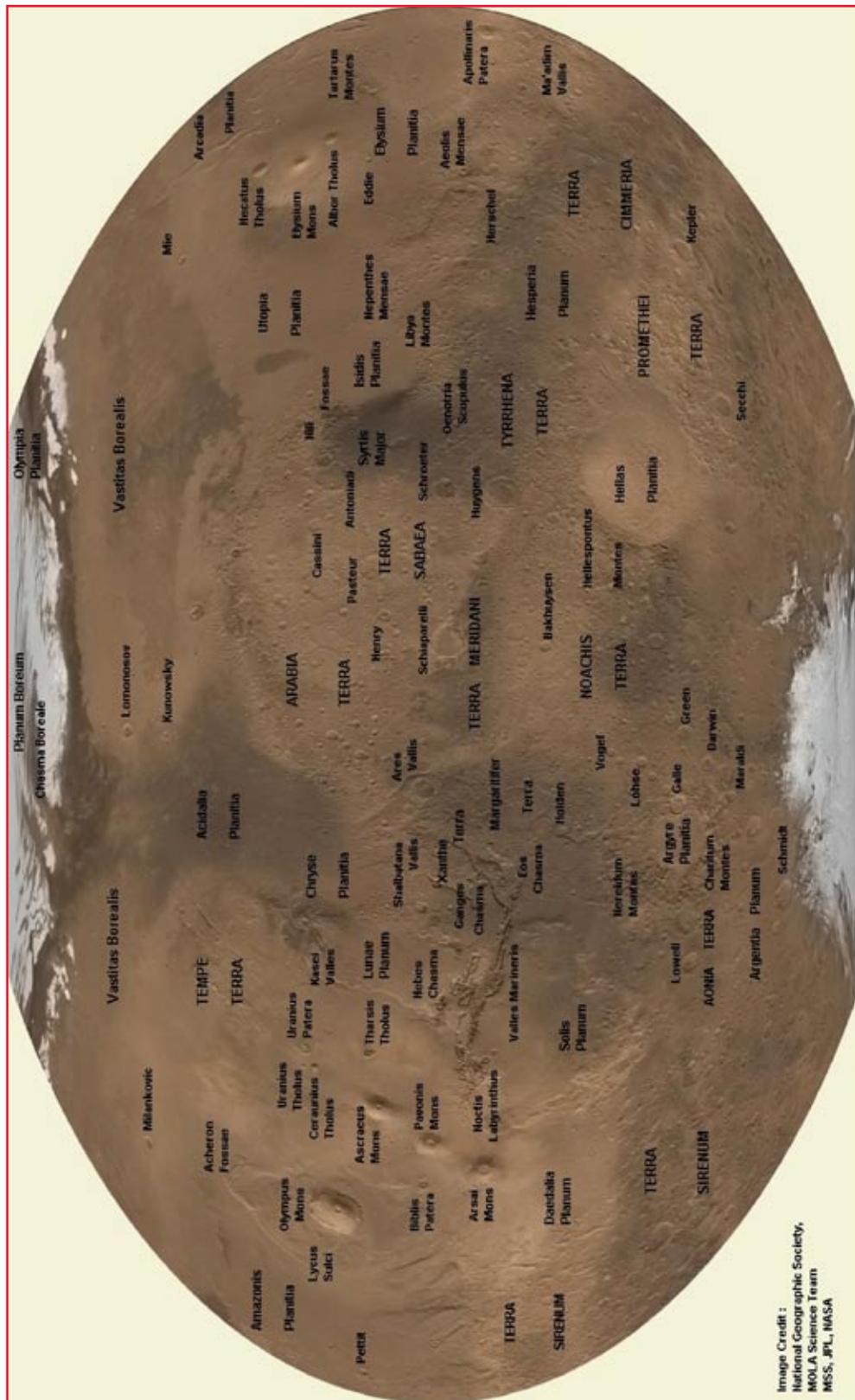
Lessons 18 and 19

NASA's plan to send humans to the Moon and back



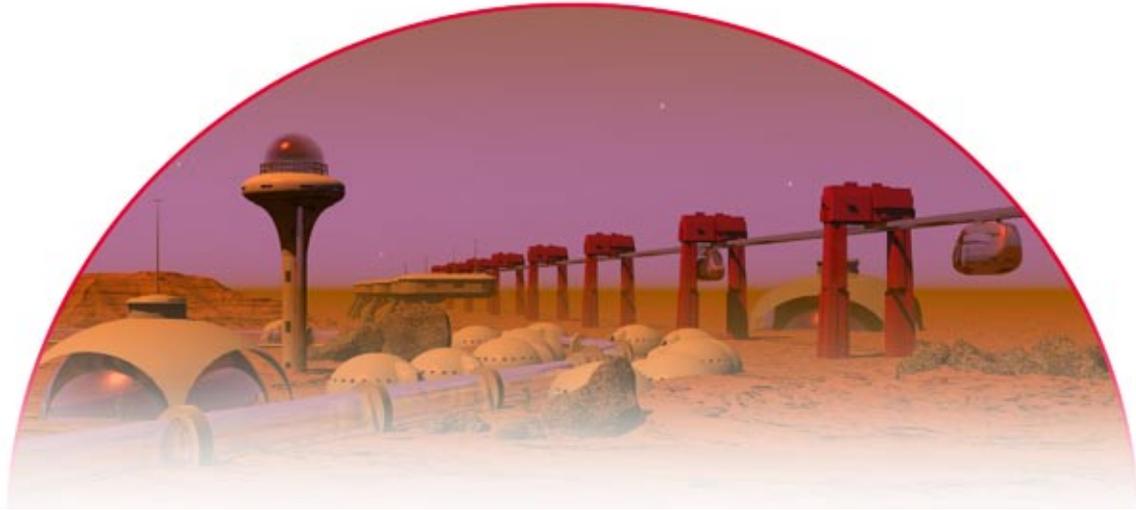
NASA's plan to send humans to the Moon and back

*Image credit: NASA*



The surface of Mars





## Lesson 20 – The Mars Colony Presentations

**Note to the teacher:** Several days will transpire between Lessons 19 and 20, so that the students can finish their Mars Colony assignment.

**Lesson prep time:** 5–10 minutes (for gathering materials and following pre-lesson instructions)

**Teaching time:** Two hours (including the optional celebration)

### Objectives

1. The students will explain why this unit was titled The Courage to Soar Higher and recall the people who demonstrated the courage to soar higher.
2. The students will share the knowledge they have learned about space exploration as they complete the KWL chart.
3. The students will deliver oral presentations to the class describing their Mars colonies.
4. The students will read their seven-day journal entries and share personal anecdotes about each day.
5. The students will listen to the presentations of their classmates and question and/or make suggestions to the presenters about their designs and journals.

6. The students will assess the impact a Mars colony would have on their own planet.
7. The students will compare their views of space travel to those of the author of the poem “Courage to Soar.”
8. The students will create a travel brochure for future tourists to Mars.



## National Standards

### Science

- Abilities necessary to do scientific inquiry – S2Ea, S2Ma
- Understandings about scientific inquiry – S2Eb, S2Mb
- Properties of objects and materials/Properties and changes in matter – S3Ea, S3Ma
- Position and motion of objects/Motion and forces – S3Eb, S3Mb
- Objects in the sky – S5Eb
- Changes in Earth and sky/Earth in the solar system – S5Ec, S5Mc
- Abilities of technological design – S6Ea, S6Ma
- Understanding about science and technology – S6Eb, S6Mb
- Risks and benefits – S7Md
- Science and technology in local challenges/in society – S7Ee, S7Me
- Science as a human endeavor – S8Ea, S8Ma
- History of science – S8Mc

### Mathematics

- Compute fluently and make reasonable estimates – M3
- Investigate, describe, and reason about the results of subdividing, combining, and transforming shapes – 8EUc
- Use visualization, spatial reasoning, and geometric modeling to solve problems – M11
- Understand measurable attributes of objects and the units, systems, and processes of measurement – M12
- Apply appropriate techniques, tools, and formulas to determine measurements – M13
- Problem solving – M18
- Communication – M20

### Geography

- How to use maps and other geographic representations, tools, and technologies to acquire, process, and report information from a spatial perspective – G1

- How to use mental maps to organize information about people, places, and environments in a spatial context – G2
- The physical and human characteristics of places – G4
- The processes, patterns, and functions of human settlement – G12
- How human actions modify the physical environment – G14
- How physical systems affect human systems – G15
- How to apply geography to interpret the present and plan for the future – G18

### Language Arts

- Standards 1, 3, 4, 5, 6, 7, 8, 11, and 12 (See the Language Arts Matrix on page 22.)

### Technology – ISTE

- Students are proficient in the use of technology – I2
- Students develop positive attitudes toward technology uses that support lifelong learning, collaboration, personal pursuits, and productivity – I5
- Students use productivity tools to collaborate in constructing technology-enhanced models, prepare publications, and produce other creative works – I7
- Students use a variety of media and formats to communicate information and ideas effectively to multiple audiences – I9
- Students use technology to locate, evaluate, and collect information from a variety of sources – I10
- Students employ technology in the development of strategies for solving problems in the real world – I14

### Technology – ITEA

- Relationships among technology and other fields – T3
- Cultural, social, economical, and political effects – T4
- Effects of technology on the environment – T5
- Role of society in the development and use of technology – T6
- Influence of technology on history – T7
- Attributes of design – T8
- Engineering design – T9
- Role of troubleshooting, research and development,

inventions and innovation, and experimentation in problem solving – T10

- Apply the design process – T11
- Use and maintain technological products and systems – T12
- Assess impact of products and systems – T13
- Information and communication technologies – T17
- Transportation technologies – T18

## Materials

- Student logs
- Timeline, Timeline Date Sheet, and blank entry cards
- The KWL chart on Space Exploration
- Students' completed model Mars colonies
- Students' completed journals
- A copy of the poem "Courage to Soar" for each student
- A copy of the homework assignment "Come Explore the Red Planet" for each student
- A 9- by 12-inch sheet of drawing paper for each student
- A few travel brochures (three panels on each side to be used as an example)
- Food and activities for the students and guests if a celebration was planned

## Pre-lesson Instructions

1. Find a few travel brochures like those found in hotels or highway rest stops. Try to find those that are divided into three panels on each side to use as an example for the homework assignment.
2. Duplicate enough copies of the homework assignment, "Come Explore the Red Planet," for each student. Punch holes so that students can insert these in their logs.
3. Duplicate enough copies of the poem, "Courage to Soar," for each student. Punch holes so that students can insert these in their logs.
4. Teachers are encouraged to invite the school principal, parents, and/or a member of the community who has worked in a space-related field to listen to the Mars

colony presentations. An invited guest adds a tone of seriousness to these presentations and helps to prepare students for real-life situations.

5. Plan for how the presentations will be given. If guests have been invited, the presentations may need a larger area. Should the students move the colonies to an auditorium, the front of the classroom, or leave them where they were built? Take into consideration whether or not the colonies may be moved.
6. Plan for the celebration if one is to be given. If parent volunteers are used, set up a meeting to plan the celebration. Encourage a "space" theme.

## Procedure

1. Ask the students why they think this unit was titled The Courage to Soar Higher. Ask them to recall the people who demonstrated the courage to soar higher.
2. Direct the students' attention to the timeline. Ask the students if there are any more dates that they want to add to this, including future dates.
3. Direct the students' attention to the KWL chart "Space Exploration." Review what the students wanted to know about space exploration. Let the students share these answers first and begin to fill in the What We Learned column. Then, proceed to write the other facts that the students have learned through this study. Use student logs, student displays, the timeline, and charts for review.
4. Distribute the 9- by 12-inch sheets of drawing paper and tell the class that they will be creating travel brochures for Mars. Show the class several three-panel travel brochures as an example of what they need to create. Then, show the students how to fold the drawing paper in thirds so that three equal panels are present. Instruct them to fold their paper into three equal panels and provide assistance if needed. Explain that they need to cover all six panels on the front and back like a real brochure. Then, distribute the homework assignment "Come Explore the Red

Planet” to the students and have them insert this in their logs. Read over the assignment and answer any questions. Fill in the due date (two or three class periods from now). You may want to suggest that they illustrate and describe the mode of transportation to Mars and even the types of lodging that they may be residing in during their stay.

5. Prepare the class for listening to the Mars colony presentations. Tell them that when they become adults they will probably have to listen to the presentations of others on many occasions. Encourage the class to be professional and respectful as they listen.
6. After all presentations have been given, conduct a short discussion about how a colony on Mars will influence life on Earth. Ask the students what technology derived from the Mars visits and colonization might be transferred to the public. How will this program help/harm our planet?
7. Distribute the poem, “Courage to Soar,” to the students and have them insert this in their logs. Have the students read the poem silently. Then, ask them how reading this makes them feel. Do they share the author’s feelings? What modes of space travel mentioned in the poem would be impossible today? What parts of the poem are science fiction and what parts are real? Then, read the poem aloud. Ask the students if they believe they have “All the Right Stuff” and the “Courage to Soar.” Ask them if they have changed their minds about their desire to travel in space.
8. Introduce any guests and begin the presentations.
9. Allow the students to ask questions about each of the presentations.
10. Invite the guests to stay for the celebration and have fun celebrating.



## "Come Explore the Red Planet"

Using your knowledge of the planet Mars, make a travel brochure for future tourists to Mars. Pretend you are a Martian travel agent. What would tourists from Earth need to bring to visit Mars? How would you describe the weather? What are the most exciting places to visit? What could tourists expect to see and do during their visit to Mars? Use text and captioned illustrations to entice visitors to the Red Planet. Create your own title for the brochure.



## COURAGE TO SOAR

Ever since I can remember, I would stare up at the sky,  
Watch the stars as they would flicker, follow clouds as they passed by.  
I would greet the sun each morning, then the moon at fall of night,  
And, dreaming, swear that I could almost feel myself in flight.

I began to read the stories: men and women who would face  
Unknown adventures in strange places as they traveled into space;  
Touching planets never touched, and feeling air where no one's been.  
And the more I dream, the more I'm sure, I want to be like them.

I don't know if I have what some folks call "All the Right Stuff."  
Yet I know that dreams and watching clouds would not be quite enough.  
Could I really ride a capsule to uncertain destinations?  
And see up close the stars whose names I've heard in constellations?





What do they have? These astronauts, who leave this galaxy?  
 And can I find what's found in them deep down inside of me?  
 A spirit of adventure, the ability to learn,  
 And sheer determination, all of these they have for sure.

They must possess a sense of calm, when what they feel is stress.  
 And when others might say, "No, I can't," their answer will be "yes."  
 Their strength must be external, for they must have great endurance.  
 Inside they must be confident, and rely on self assurance.

I've heard it said that I can be what I have dreamt to be.  
 So I'll work toward making sure that all these things are true of me.  
 A dream's only worth dreaming if you make your dream come true.  
 And you must know for sure your dream is the right dream for you!

How do I know that this is what my life is purposed for?  
 For though I marvel at the earth, for me, there must be more.  
 I feel no fear of taking off, just thrilled right to my core.  
 And filled inside with what I know is Courage, now, to Soar.

~ Colleen Boyle







## Resources

### Related Links

#### General Links

The *NASA Portal* serves as the gateway for information regarding content, programs, and services offered by NASA. The collection of educational information has been divided into categories for kids, students, educators, and the media. The students' and educators' categories are further divided to give an overview of resources available for K–4, 5–8, 9–12, and post-secondary users. <http://www.nasa.gov/home/index.html?skipIntro=1>

*NASA Images* is a service of Internet Archive (<http://www.archive.org>), a non-profit library, to offer public access to NASA's images, videos, and audio collections. These collections include images of the universe, solar system, Earth, aeronautics, and astronauts. It also includes a spaceflight timeline with images of Explorer, Mercury, Gemini, Apollo, Pioneer, Skylab, Viking, Voyager, Space Shuttle, Galileo, Hubble, Pathfinder, Cassini Huygens, the International Space Station, and the Mars Rovers. <http://www.nasaimages.org/>

The *Image of the Day Gallery* is a collection of NASA images sent out electronically each day to subscribers. The images with descriptive details feature current NASA events and archived images to honor past events. <http://www.nasa.gov/multimedia/imagegallery/iotd.html>

The *NASA Image Exchange (NIX)* is a search engine that pulls images from across NASA's Web space. <http://nix.nasa.gov/>

*Great Images in NASA (GRIN)* is a selection of the best and best-known images from a half-century of exploration and discovery containing over 1,000 images of significant historical interest. <http://www.grin.hq.nasa.gov/>

The *Human Spaceflight Gallery* is a collection of excellent photos taken during human spaceflight missions. The collection features images, videos, and audios covering all of the NASA programs from Mercury through the Space Shuttle Program and the Constellation Program. Search both sides of the page to find specific missions for each of the programs. <http://spaceflight1.nasa.gov/gallery/>

The *Kennedy Multimedia Gallery* contains images and video from the Kennedy Space Center, including shuttle launches and landing, crew training, and satellite launches. <http://mediaarchive.ksc.nasa.gov/index.cfm>

The *JSC Digital Image Collection* consists of more than 9,000 NASA press release photos spanning American human spaceflight from the Mercury program to the STS-79 Shuttle mission. Choose “Earth From Space” to link to *The Gateway to Astronaut Photography of Earth* Web site. This site hosts the best and most complete online collection of astronaut photographs of the Earth (770,668 images as of 9/1/2008). <http://images.jsc.nasa.gov/index.html>

*The Planetary Photojournal* is a Jet Propulsion Laboratory site that has the latest images of planets available. <http://photojournal.jpl.nasa.gov/index.html>

*The Apollo Image Gallery* is an extensive collection of high-quality Apollo images, featuring images scanned for Eric Jones’ Apollo Lunar Surface Journal. [http://www.apolloarchive.com/apollo\\_gallery.html](http://www.apolloarchive.com/apollo_gallery.html)

### Rocket Links

The *Team America Rocketry Challenge* (TARC) is an annual competition that provides 7th through 12th grade students a realistic experience in designing a flying aerospace vehicle that meets a specified set of mission and performance requirements. Students work together in teams the same way aerospace engineers do. Students in grades 4–6 are not eligible, but following this competition could cause interest and enthusiasm for their futures. <http://www.rocketcontest.org/>

*NASA Rocket Classroom Activities* is a Web page listing various experiments, games, and activities dealing with rockets and how they work. <http://exploration.grc.nasa.gov/education/rocket/TRCRocket/RocketActivitiesHome2.html>

The *National Association of Rocketry* has a list of local rocketry clubs where teachers may find volunteers willing to demonstrate a rocket launch. This site also has a listing of where NAR rocket launches are being held. <http://www.nar.org/>

*Homer Hickam Online* is a Web site for educators and students interested in Hickam’s books. It encourages reading and studying the stories of the “rocket boy” and provides a springboard for getting students interested in rocketry. <http://www.homerhickam.com/>

### Links for Kids

*NASA Kid’s Club* is a Web site filled with science-related games and activities for kids. <http://www.nasa.gov/audience/forkids/kidsclub/flash/index.html>

*NASA Quest* connects K–12 classrooms with people, research, and science through mission-based interactions and activities. <http://quest.arc.nasa.gov/>

*NASA Science for Kids* is a Web site where kids can play, learn and explore the world around them. This site provides an exciting way to look at our Sun and Earth, our solar system, and the universe beyond. <http://nasascience.nasa.gov/>

*NASA Space Place* is a Web site where science is made fun through games, projects, and activities, and where science information is presented in exciting and kid-friendly ways. <http://spaceplace.nasa.gov/en/kids/>

*StarChild* is a Web site that presents science information in activity and game form that can be used to engage, excite, and educate students in classrooms. <http://starchild.gsfc.nasa.gov/docs/StarChild/StarChild.html>

## Suggested Reading

Allen, John Logan, Barry M. Gough, and E. Julius Dasch. (1998), *Explorers: From Ancient Times to the Space Age, Vol. 3*. Macmillan Library Reference. ISBN: 0-0286-4893-5. Spans time and distance through the stories of the diverse men and women who ventured into uncharted territory.

Anderson, Dale. (2004), *The First Moon Landing*. World Almanac Library, Milwaukee, WI. ISBN: 0-8368-5406-3. Describes the background, planning, accomplishment, and aftermath of *Apollo 11*, the first manned mission to land on the Moon.

Asimov, Isaac and Francis Reddy. (1995), *Exploring Outer Space*. Gareth Stevens, Milwaukee, WI. ISBN: 0-8368-1193-3. Discusses how rockets, probes, and satellites have increased our knowledge of the solar system and beyond.

Asimov, Janet and Isaac Asimov. (1986), *The Norby Chronicles*. (Fiction) Ace Books, New York, NY. ISBN: 0-4415-8634-1. This book is a compilation of the humorous first two science fiction stories for children in the Norby series: “Norby, the Mixed-Up Robot” (first published in 1983) and “Norby’s Other Secret” (published in 1984). The first tale introduces the reader to a 14-year-old Space Academy cadet, Jeff Wells, and his unusual robot, Norby, as they foil a plot of a villain to take over the solar system. In the second story, the robot discovers his origin, a dragon-inhabited planet, and some new abilities: traveling through time and telepathy.

Bailey, Gerry. (2004), *Journey Into Space*. Picture Window Books, Minneapolis, MN. ISBN: 1-4048-1042-0. Discusses a wide subject area about space, including artificial satellites, multi-stage rockets, space capsules, space suits, the Moon, the lunar rover, space probes, the space shuttle, pulsars and quasars, space telescope, and black holes.

Baker, David. (1988), *I Want to Fly the Shuttle*. Rourke Enterprises, Vero Beach, FL. ISBN: 0-8659-2406-6. Discusses the origins of the space shuttle program,

qualifications and training of the astronauts, and the lift-off, in-flight activities, and the landing of the space shuttle.

Baker, David. (1989), *Living in Space*. Rourke Enterprises, Vero Beach, FL. ISBN: 0-8659-2401-5. Traces the history of manned space flights from Mercury to the shuttle program, examines the medical effects of weightlessness on astronauts, the difficulties of eating, working, sleeping, and cleaning oneself on board, and future plans for a space station.

Barrett, Norman S. (1990), *The Picture World of Space Shuttles*. Franklin Watts, New York. ISBN: 0-5311-4056-3. Describes how space shuttles work and looks at various missions.

Berger, Melvin and Gilda. (2000), *Can You Hear a Shout in Space?* Scholastic, Inc. New York. ISBN: 0-4391-4879-0. Provides answers to commonly asked questions about space exploration.

Biesty, Stephen and Richard Platt. (1992), *Stephen Biesty’s Incredible Cross-Sections*. Alfred A. Knopf, New York. ISBN: 0-6798-1411-6. Cross-sectional illustrations explore the inner working of real machines and buildings including a galleon, a steam train, an ocean liner, a submarine, a helicopter, a jumbo jet, and the space shuttle.

Bizony, Piers. (2006), *Space 50*. Harper Collins Publishers Inc., New York. ISBN-10: 0-0608-9010-X. This Smithsonian Book recounts, in text and beautiful imagery, the first half-century of space exploration.

Branley, Franklin M. (1998), *Floating in Space*. Harper Collins Publishers, New York. ISBN: 0-0644-5142-9. Examines life aboard a space shuttle, describing how astronauts deal with weightlessness, how they eat and exercise, some of the work they do, and more.

Branley, Franklin M. (2000), *The International Space Station*. Harper Collins Publishers, New York. ISBN: 0-0644-5209-3. Explains the construction and purpose of the International Space Station and the life of the astronauts on board.

Bredeson, Carmen. (1998), *Neil Armstrong: A Space Biography*. Enslow Publishers, Springfield, NJ. ISBN: 0-8949-0973-8. A biography of the first man on the Moon, covering his youth, his career as an astronaut, and his life after NASA.

Bredeson, Carmen. (1999), *Our Space Program*. Millbrook Press, Brookfield, CT. ISBN: 0-7613-1349-4. Examines the U.S. space program from the development of the first rockets after World War II to the formation of NASA, the lunar landing, unmanned space probes, and space stations of the future.

Bredeson, Carmen. (2000), *John Glenn Returns to Orbit*. Enslow Publishers, Inc. Berkeley Heights, NJ. ISBN: 0-7660-1304-9. Describes the activities aboard the Space Shuttle *Discovery* during its historic flight when John Glenn, at age 77, returned to space.

Bredeson, Carmen. (2000), *NASA Planetary Spacecraft*. Enslow Publishers, Inc. Berkeley Heights, NJ. ISBN: 0-7660-1303-0. Discusses the roles of several NASA spacecraft that carried our probes during exploration of the planets.

Briggs, Carole S. (1999), *Women in Space*. Lerner Publications Company, Minneapolis, MN. ISBN: 0-8225-4937-9. Profiles some of the women including two Russians who have had important roles in space exploration and provides a brief history of the U.S. space program.

Busby, Peter. (2003), *First to Fly: How Wilbur and Orville Wright Invented the Airplane*. Crown, New York. ISBN: 0-3758-1287-3. A look at the lives of the Wright Brothers, from their childhood interest in flight, through their study of successful gliders and other flying machines, to their triumphs at Kitty Hawk and beyond.

Campbell, Peter A. (1995), *Launch Day*. Millbrook Press, Brookfield, CT. ISBN: 1-5629-4611-0. Describes preparation, launch, and return of the *Atlantis* space shuttle at Kennedy Space Center in Florida.

Clemens, Peter. (1991), *Super Wings the step-by-step Paper Airplane Book*. RGA Publishing Group, Inc., USA.

ISBN: 0-9299-2387-1. Gives step-by-step directions and simple diagrams for making paper airplanes.

Cole, Michael D. (1995), *Challenger, America's Space Tragedy*. Enslow Publishers, Inc. Berkeley Heights, NJ. ISBN: 0-8949-0544-9. Recounts the tragic *Challenger* disaster with special attention to the lives of *Challenger's* passengers and the cause of the explosion.

Cole, Michael D. (1995), *Friendship Seven: First American in Orbit*. Enslow Publishers, Springfield, NJ. ISBN: 0-8949-0540-6. Describes the flight of the first American to orbit the Earth, John Glenn, in his *Friendship 7* capsule.

Cole, Michael D. (2000), *NASA Space Vehicles: Capsules, Shuttles, and Space Stations (Countdown to Space)*. Enslow Publishers, Springfield, NJ. ISBN: 0-7660-1308-1. A survey of NASA spacecraft, from the Mercury capsule to the International Space Station.

Cole, Michael D. (2000), *Space Emergency: Astronauts in Danger*. Enslow Publishers, Inc. Berkeley Heights, NJ. ISBN: 0-7660-1307-3. Captures the excitement and bravery of the astronauts involved in the space emergencies of *Apollo 13*, *Friendship 7*, *Gemini 8*, and *Mir* missions.

Cole, Michael D. (2003), *The Columbia Space Shuttle Disaster*. Enslow Publishers, Inc. Berkeley Heights, NJ. ISBN: 0-7660-2295-1. Tells the story of Space Shuttle *Columbia's* first and last missions.

Crewe, Sabrina and Dale Anderson. (2004), *The First Moon Landing*. Gareth Stevens Pub. Milwaukee, WI. ISBN: 0-8368-3397-X. Explores the amazing achievement of the Apollo program, which pushed space technology to new heights.

Cross, Becky. (2003), *I Am a Space Shuttle. I Love to Fly*. Perspective Books L.L.C. Shirley, MA. ISBN: 0-9701-7361-X. A photo journal of the space shuttle from inception to launch and back again.

Dick, Stephen and Robert Jacobs, Constance Moore, Anthony Springer, and Bertram Ulrich. (2007),

*America in Space, NASA's First Fifty Years.* Harry N. Abrams Inc. New York. ISBN 13: 9780-8109-9373-0. Tells the story of America's space age with more than 400 photographs.

Eugene, Toni. (1999), *Exploring Space.* National Geographic Society, Washington, DC. ISBN: 0-7922-9426-2. Explains the different ways we learn about outer space and shows astronauts at work.

Fraser, Mary Ann. (1993), *One Giant Leap.* H. Holt, New York. ISBN: 0-8050-2295-3. A moment-by-moment recreation of the first space flight to the Moon, culminating in Neil Armstrong's step onto its surface.

Green, Carl R. (2004), *Apollo 11 Rockets to the Moon.* Enslow Publishers, Inc. Berkeley Heights, NJ. ISBN: 0-7660-5164-1. Discusses the astronauts and the mission of the first humans to walk on the Moon.

Green, Carl R. (2004), *The Gemini 4 Spacewalk Mission.* Enslow Publishers, Inc. Berkeley Heights, NJ. ISBN: 0-7660-5163-3. Describes the *Gemini 4* mission in 1965 when astronauts Edward White and James McDivitt carried out the first extravehicular activity in the U.S. manned space program.

Hayhurst, Chris. (2001), *Astronauts: Life Exploring Outer Space.* The Rosen Publishing Group, Inc. New York. ISBN: 0-8239-3364-4. Discusses the qualities and training of astronauts and their journeys into space.

Holden, Henry M. (2004), *Living and Working Aboard the International Space Station.* Enslow Publishers, Inc. Berkeley Heights, NJ. ISBN: 0-7660-5168-4. Explains the construction and purpose of the International Space Station and the life of the astronauts on board.

Holden, Henry M. (2004), *Triumph Over Disaster Aboard Apollo 13.* Enslow Publishers, Inc. Berkeley Heights, NJ. ISBN: 0-7660-5167-6. Relates events of the April 1970 flight of *Apollo 13*, the third mission to the Moon, which was aborted after an explosion critically damaged the command module and nearly claimed the lives of the three men aboard.

Irvine, Mat. (1984), *Satellites and Computers.* Franklin Watts, New York. ISBN: 0-5310-4817-9. Describes various kinds of man-made satellites and their uses. Includes a glossary of terms.

Johnstone, Michael. (1999), *The History News in Space.* Scholastic, Inc. New York. ISBN: 0-7636-0490-9. Presents significant events in space exploration as exciting breaking news in newspaper article form beginning with the year 140 A.D. through NASA's *Pathfinder* mission.

Kerrod, Robin. (2005), *Dawn of the Space Age.* World Almanac Library, Milwaukee, WI. ISBN: 0-8368-5712-7. Tells the story of the development of spacecraft from the earliest rocket designs and satellite launches in the 1950s to the first landing on the Moon in 1969.

Kerrod, Robin. (2005), *Space Pioneers.* World Almanac Library, Milwaukee, WI. ISBN: 0-8368-5714-3. Tells the stories of the first men and women who traveled into space.

Kerrod, Robin. (2002), *Space: Present Knowledge Future Trends.* Franklin Watts, London. ISBN: 1-5834-0351-5. Describes the history and development of space stations and the exploration of our solar system as well as the possibility of some day settling on the Moon and traveling to Mars.

Kerrod, Robin. (2005), *Space Probes.* World Almanac Library, Milwaukee, WI. ISBN: 0-8368-5715-1. Illustrates how the technology of space probes provides us with astonishing facts about the celestial bodies in our solar system and also examines how these craft help us explore the universe by detecting black holes, star clusters, and nebulae.

Kerrod, Robin. (2005), *Space Shuttles.* World Almanac Library, Milwaukee, WI. ISBN: 0-8368-5709-7. Explores the many successes of the space shuttle program as well as the two tragedies.

Kerrod, Robin. (2005), *Space Stations.* World Almanac Library, Milwaukee, WI. ISBN: 0-8368-5717-8. Discusses the history of space stations from the Russian *Salyuts*, through *SkyLab*, *Mir*, and the International Space Station.

Maze, Stephanie and Catherine O'Neill Grace. (1997), *I Want to be an Astronaut*. Harcourt Brace, San Diego, CA. ISBN: 0-1520-1300-8. Describes what it is like to be an astronaut, some of the ways to prepare for this career, and the work in various related jobs.

McNeese, Tim. (2003), *The Challenger Disaster*. Children's Press, New York. ISBN: 0-5162-4222-9. Recounts events surrounding the explosion of the Space Shuttle *Challenger* in 1986, the first shuttle to carry a civilian passenger, and discusses the impact of this disaster on the U.S. space program.

McNeese, Tim. (2003), *The Space Race*. Children's Press, New York. ISBN: 0-5162-4201-6. Discusses the race between the United States and the Soviet Union to be the first nation to send a man into space and to land on the Moon, including a glimpse of historical, technological, and human factors involved.

McNulty, Faith. (2005), *If You Decide to Go to the Moon*. (Fiction) Scholastic, New York. ISBN: 0-5904-8359-5. Readers accompany a boy on a fascinating excursion to the Moon, including a description of trip preparations, what to expect en route, and after disembarking, a visit to *Apollo 11*'s landing site, and the thrill of homecoming.

Murphy, Patricia J. (2004), *Exploring Space with an Astronaut*. Enslow Publishers, Inc. Berkeley Heights, NJ. ISBN: 0-7660-2268-4. Briefly explains the work of astronauts and scientists who travel on the space shuttle to study outer space and to conduct experiments.

Nettleton, Pamela Hill. (2004), *Sally Ride*. Picture Window Books, Minneapolis, MN. ISBN: 1-4048-0189-8. A brief biography that highlights some important events in the life of the first American woman in space.

Rau, Dana Meachen. (2005), *The International Space Station*. Compass Books, Minneapolis, MN. ISBN: 0-7565-0852-5. Takes readers on a tour of the International Space Station with the American and Russian crew to find out what their daily life is like.

Rau, Dana Meachen. (2005), *Space Walks*. Compass Books, Minneapolis, MN. ISBN: 0-7565-0851-7. Describes all aspects of walking in space including the training astronauts receive for a particular mission, their suits, and the jobs they do outside their spacecraft.

Richards, Jon and Simon Tegg. (1998), *Space Vehicles*. Copper Beech Books, Brookfield, CT. ISBN: 0-7613-0728-1. Examines different types of machines used in space exploration, including probes, satellites, space shuttles, and rockets, and describes the work that they do.

Schomp, Virginia. (1998), *If You Were an Astronaut*. Benchmark Books, New York. ISBN: 0-7614-0618-2. Describes the training and experience of astronauts who fly the space shuttle.

Schyffert, Bea Uusma. (1999), *The Man Who Went to the Far Side of the Moon*. Chronicle Books, San Francisco, CA. ISBN: 0-8118-4007-7. A biography of Astronaut Michael Collins who circled the Moon in the *Apollo 11* space capsule while his colleagues Neil Armstrong and Buzz Aldrin landed the lunar lander and walked on the Moon.

Scieszka, Jon and Lane Smith. (2001), *Baloney, (Henry P.)*. (Fiction) Viking, New York. ISBN: 0-6708-9248-3. A young alien uses his imagination to tell a story of a rocket ride.

Scott, Elaine. (1998), *Close Encounters. Exploring the Universe with the Hubble Space Telescope*. Scholastic, Inc. New York. ISBN: 0-5902-0005-4. Tells the story of the Hubble Space Telescope and uses beautiful photography from Hubble's lens to present information about the universe.

Shearer, Deborah A. (2002), *Astronauts at Work*. Capstone Press, Mankato, MN. ISBN: 0-7368-1142-7. Explains the different jobs NASA astronauts do on the space shuttles.

Shearer, Deborah A. (2002), *Mission Control*. Capstone Press, Mankato, MN. ISBN: 0-7368-1143-5. Describes the role of NASA engineers, technicians, and other specialists who stay on the ground in Houston, Texas, supporting astronauts as they journey on the space shuttle.

Simon, Seymour. (2003), *The Moon*. Simon and Schuster, New York. ISBN: 0-6898-3563-9. From *Apollo 11*'s first landing to the mystery of moonquakes and the genesis of craters. This stunning introduction to our nearest neighbor in space describes the Moon and its all-important relationship to Earth in full-color photography with descriptive, informative text.

Simon, Seymour. (2004), *Destination: Mars*. Harper Collins, New York. ISBN: 0-0605-4638-7. Presents stunning photos and discusses facts and information on Mars from data and photos sent back to Earth by NASA probes to Mars in the late 1990s and the Hubble Space Telescope.

Sipiera, Diane M. and Paul P. Sipiera. (1997), *Project Gemini*. Children's Press, New York. ISBN: 0-5162-0441-6. Highlights the accomplishments of the 12 missions of the Gemini Program including the first manned flight and the first extravehicular activity (EVA), or walk in space.

Sipiera, Diane M. and Paul P. Sipiera. (1997), *Project Mercury*. Children's Press, New York. ISBN: 0-5162-0443-2. Describes early space exploration and the six missions of Project Mercury that constituted America's first step toward the Moon.

Spangenburg, Ray and Kit Moser. (2001), *Artificial Satellites*. Franklin Watts, New York. ISBN: 0-5311-3971-9. Describes the wide array of different types of satellites that have been placed in orbit since the launch of *Sputnik I* in 1957 and the various functions they perform, from communications and weather forecasting to astronomy and spy tasks.

Spangenburg, Ray and Kit Moser. (2002), *Onboard the Space Shuttle*. Franklin Watts, New York. ISBN: 0-5311-5568-4. Examines what it is like for the crews living and working on the American space shuttles.

Spangenburg, Ray and Kit Moser. (2001), *Project Apollo*. Franklin Watts, New York. ISBN: 0-5311-3972-7. Describes the planning, development, missions, and accomplishments of Project Apollo which took the U.S. to the Moon.

Spangenburg, Ray and Kit Moser. (2001), *Project Gemini*. Franklin Watts, New York. ISBN: 0-5311-3973-5. Discusses the importance of the 12 Gemini space flights that laid the foundation for the U.S. exploration of the Moon.

Spangenburg, Ray and Kit Moser. (2000), *The History of NASA*. Franklin Watts, New York. ISBN: 0-5311-6511-6. Surveys the history of the National Aeronautics and Space Administration, describing the major spacecraft and missions launched.

Stille, Darlene R. (2002), *Satellites*. Compass Point Books, Minneapolis, MN. ISBN: 0-7565-0137-7. Describes different types of artificial satellites and their functions.

Stille, Darlene R. (2004), *Space Shuttle*. Compass Point Books, Minneapolis, MN. ISBN: 0-7565-0609-3. A simple introduction to the space shuttle, describing its equipment, parts, uses, and journey into space.

Stott, Carole. (1999), *Moon Landing: The Race for the Moon*. Dorling Kindersley, New York. ISBN: 0-7894-3958-1. An illustrated account of humanity's exploration of the Moon, from our first observations and attempts to the first landing and later expeditions.

Stott, Carole. (2000), *Space Exploration*. Dorling Kindersley, New York. ISBN: 0-7894-5858-6. Describes rockets, exploratory vehicles, and other technological aspects of space exploration, satellites, space stations, and the life and work of astronauts.

Tocci, Salvatore. (2003), *NASA*. Franklin Watts, New York. ISBN: 0-5311-5598-6. Examines the function of NASA and discusses its various exploration programs and achievements.

Tocci, Salvatore. (2002), *Space Experiments*. Scholastic, Inc. New York. ISBN: 0-5162-6997-6. Describes what it is like to be an astronaut during the launch, space travel, and landing, and includes eight experiments for students such as “Building a Rocket,” “Floating in Space,” and “Landing Gently.”

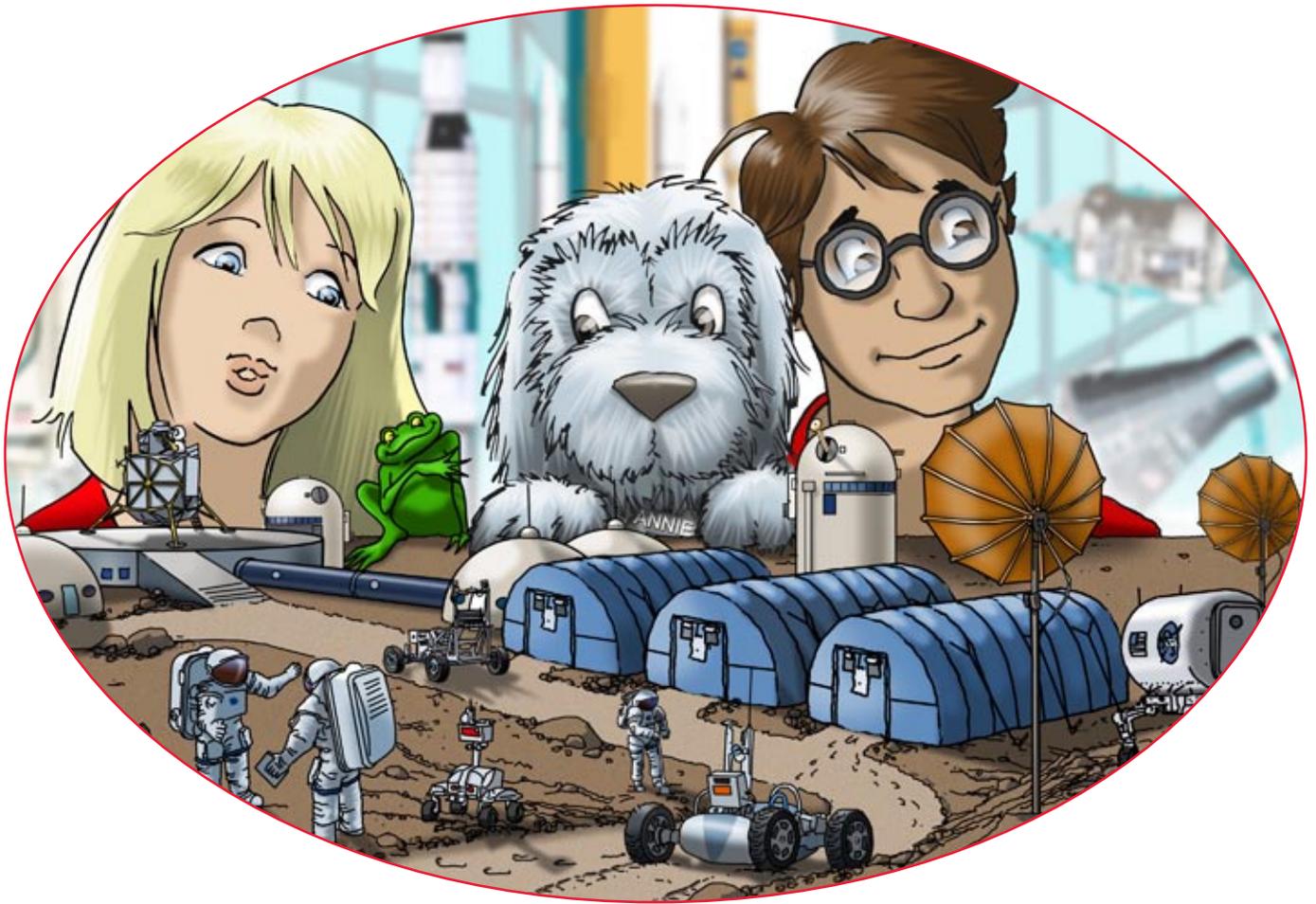
Vogt, Gregory L. (2000), *Apollo Moonwalks*. Enslow Publishers, Inc. Berkeley Heights, NJ. ISBN: 0-7660-1306-5. Discusses the six Apollo missions that landed on the Moon, describing the work performed there, what it is like to walk on the Moon, and the collection of Moon rocks.

Vogt, Gregory L. (1999), *Rockets*. Bridgestone Books, Mankato, MN. ISBN: 0-7368-0198-7. Describes different types of rockets and how they work, including Delta rockets, the Saturn V, and the space shuttle.

Vogt, Gregory L. (2000), *Spacewalks*. Enslow Publishers, Inc. Berkeley Heights, NJ. ISBN: 0-7660-1305-7. Describes the training and preparation for spacewalking, the hazards faced by astronauts, as well as the construction of spacesuits.

Vogt, Michael and Mark Vogt. (1994), *Paper Airplane Power*. Publications International, Ltd., Lincolnwood, IL. ISBN: 0-7853-1764-3. Provides patterns and step-by-step directions for making paper airplanes.

Wunsch, Susi Trautman. (1998), *The Adventures of Sojourner*. Mikaya Press, New York, NY. ISBN: 0-9650-4935-3. Tells the story of the mission that placed the *Sojourner* remote-controlled rover on Mars on July 4, 1997.



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