Exploring Exploring

Lesson Overview

Lesson Summary

Students do not always realize that the steps in future exploration are built on a tradition of exploration that is as old as humankind. This lesson introduces the concept of exploration through basic ideas that express why humans have always been explorers; students determine these reasons for exploration through a class discussion. In the first activity, students use the Internet to examine the characteristics of past explorers and why they conducted their exploration. The students then examine why current explorers—including the students themselves—want to explore other worlds in the Solar System. By the end of the lesson, the students can conclude that no matter what or when we explore—past, present, or future—the reasons for exploration are the same; the motivation for exploration is universal.

Grade Level
5–8

Duration
Two 45-minute class periods

Essential Question

Why do we explore unknown environments?

Lesson 1
of the Grades 5-8
Component of the
Mission Design
Education Module

Figure 1. Exploration has always been an integral part of human history, from the exploration of the Earth across the oceans (modern-day replica of an ancient Polynesian voyaging canoe; top left) and over land (a map of the Lewis and Clark expedition over the Louisiana Purchase territory; top right), to exploration of the sky (photograph of the Wright Flyer; bottom right) and space (an artist's impression of the MESSENGER spacecraft investigating Mercury; bottom left.) (Picture credits: http://www.coris.noaa.gov/about/eco_essays/nwhi/media/voyaging_canoe400.jpg; http://www.loc.gov/exhibits/treasures/images/872m.jpg; http://www.grc.nasa.gov/WWW/K-12/aerosim/LessonHS97/WRIGHT.GIF; NASA/JHU-APL/CIW; http://messenger.jhuapl.edu/the_mission/artistimpression/artists_impression.html)

This lesson was developed by the National Center for Earth and Space Science Education (http://ncesse.org).

Objectives

Students will be able to do the following:

- Identify characteristics common to all explorers.
- State some of the basic reasons why people explore.
- Explain why humans should explore worlds outside of the Earth.

Concepts

- Explorers can be very different, but they share some common characteristics.
- The desire to explore is part of human nature, and it holds its foundation in our past.
- Space exploration has opened up a whole new area about which to ask questions and seek answers.

MESSENGER Mission Connection

The MESSENGER spacecraft is heading to Mercury so that humans can explore that world. Unveiling the mysteries of Mercury will not only provide a lot of information on this poorly known planet, but also help scientists learn more about the properties of other planets, including the Earth, and even provide clues to the formation of the Solar System. The reasons for exploring Mercury are the same reasons that have motivated explorers throughout human history.

Standards & Benchmarks

National Science Education Standards

Standard D3: Earth in the solar system

- The earth is the third planet from the sun in a system that includes the moon, the sun, eight other planets* and their moons, and smaller objects, such as asteroids and comets. The sun, an average star, is the central and largest body in the solar system.

Standard E2: Understanding about science and technology

- Many different people in different cultures have made and continue to make contributions to science and technology.

Standard G3: History of science

- Many individuals have contributed to the traditions of science. Studying some of these individuals provides further understanding of scientific inquiry, science as a human endeavor, the nature of science, and the relationships between science and society.

American Association for the Advancement of Science, Project 2061

Benchmark 1C/M1:

- Important contributions to the advancement of science, mathematics, and technology have been made by different kinds of people, in different cultures, at different times.

Benchmark 3A/M2:

- Technology is essential to science for such purposes as access to outer space and other remote locations, sample collection and treatment, measurement, data collection and storage, computation, and communication of information.

Benchmark 4A/M3:

- Nine planets* of very different size, composition, and surface features move around the sun in nearly circular orbits. Some planets have a variety of moons and even flat rings of rock and ice particles orbiting around them. Some of these planets and moons show evidence of geologic activity. The earth is orbited by one moon, many artificial satellites, and debris.

**Since the time these standards were written, the International Astronomical Union decided that there are only eight major planets in the Solar System. The former ninth planet, Pluto, is considered a dwarf planet.*

Science Overview

Humans have always had the desire to know, "What is out there?" It is easy to imagine our earliest ancestors being curious as to what was over the next hill, what was on the other side of this lake or over that mountain. However, in many cases, little is known about the early explorations since few records remain of them, except in stories that were handed down from one generation to the next. There are some human remains and tools that have been found around the Earth, so it is possible to track where the people lived and where they went. Cave drawings indicate what animals were hunted, and some of their bones have also been found in old human habitats. In addition to being curious, the early people tended to follow the source of their food (animals) in order to survive. Following the animals sometimes led the nomadic people to new areas that also contained other resources, such as better shelter or a source of water. In this way, the explorations also provided future generations a better place to live. Examples of human exploration throughout history show that even though the methods and tools of exploration may have changed, many of the basic reasons for exploration remain the same. Please note that human history offers stories of exploration too numerous to be described in detail here, and so the following paragraphs include just a handful of highlights of past and present exploration.

Figure 2. A view from the surface of Mars recorded by the robotic Spirit rover. What is on the other side of this hill? The question is an example of the kind of curiosity that has motivated explorers throughout history. (Picture credit: NASA/JPL-Caltech; http://marsrovers.jpl.nasa.gov/gallery/press/spirit/20060505a/Sol810A_P2536_L257F-A810R1_br2.jpg)

Ancient Explorers

One important reason for exploration has been to establish trade to improve the local economy. A good example is a group of people called the Minoans. They lived on the island of Crete off the coast of Greece in the Aegean Sea, with their civilization at its height from about 2600 to 1450 BCE. Since the Minoans lived on an island, they became great seafarers and established a trade network across the Mediterranean. Their explorations reached as far as mainland Greece, Cyprus, Egypt, and even Spain, to trade for supplies. The Minoans spoke a language that little is known about, and they wrote in a script that has not been deciphered. Therefore, many aspects of the Minoan culture remain unknown today and provide opportunities for archaeologists to make future discoveries.

The famous Norwegian explorer Thor Heyerdahl thought that people from South America could have settled Polynesia in the south Pacific in ancient times. He was curious to know if Stone Age people could have made the long trip across the ocean with the technology and the materials they had available. Heyerdahl gathered a small team and traveled to Peru to explore this possibility. The team constructed a balsawood raft in a style based on the illustrations made by Spanish conquistadors of old Incan rafts. Calling the raft Kon-Tiki, the team sailed for 101 days over 6,900 km (4,300 miles) across the Pacific Ocean before arriving at the Tuamotu Islands on August 7, 1947. While the exploration team had modern equipment such as a radio, as well as food and fresh water, they also were able to catch fish from the sea, as the raft attracted lots of marine life. As a result, in addition to showing that there were no technological constraints for the people of South America to make the journey across the Pacific, along the way, the exploration provided a lot of information about life in the sea. Even though modern linguistic, physical and genetic evidence suggests that the Polynesian islands were settled from South Asia instead of from South America, Heyerdahl's journey is an important example of modern exploration into ancient cultures by showing that the stone age people with limited technology could have made the long trip over open oceans of the South Pacific.

Perhaps because of the large distances between the islands on which they lived, Polynesians became excellent seafarers and used canoes (see Fig. 3) to journey across open seas hundreds of years ago. The people within the Polynesian triangle, cornered by Hawaii, Rapa Nui (Easter Islands) and Aotearoa (New Zealand), traveled frequently across the vastness of oceans with the help of skilled canoe crews. Of particular importance for these journeys were the navigators, who used their knowledge of the oceans, winds, and astronomy to guide the canoes safely even at times when the shoreline was no longer visible. In other parts of the world, gathering the courage to travel across open seas took centuries longer. In addition to basic curiosity, the journeys were driven by a desire to find more resources and new lands on which to settle. Frequent ocean journeys were later performed for commerce between the islands, and sometimes for conquering islands from earlier settlers.

Figure 3. A modern-day replica of an ancient Polynesian voyaging canoe. Polynesian voyagers used canoes to travel across the open oceans of the southern Pacific, reaching all the way to Hawaii. (Picture credit: http://www.coris.noaa.gov/about/eco_essays/nwhi/media/voyaging_canoe400.jpg)

Another group of great early explorers are the Vikings, who roamed the oceans of the North Atlantic from the late 8th century to the 11th century. While the Vikings usually are thought of only as the people who raided the coasts of Europe (and especially the British Isles), they were also merchants. They traveled from their native Scandinavian lands all around Europe, all the way to Northern Africa and the Middle East. They also ventured out to open seas, traveling to the islands across the North Atlantic, establishing a settlement in Greenland, and even to North America. Leif Erikson is the first European known to have traveled to North America, reaching Newfoundland in around the year 1000. The Vikings originally thought of settling into the area, which they called Vinland, but the idea was later abandoned, perhaps because of conflicts with the Native Americans living in the area already.

The Dawn of the Age of Discovery

Christopher Columbus is one of the best-known explorers of all time. He was instrumental in ushering in the so-called Age of Discovery, which was a period from the early 15th century to the early 17th century, during which European ships traveled around the world. They were exploring with an economic purpose in mind—to find new ways to reach desired trade destinations, as well as discover new trade partners—but along the way, the explorers discovered many new places and people. Columbus was an Italian explorer who, funded by Spanish monarchs, sailed across the Atlantic Ocean in 1492, hoping to find a new route to India and China to trade for goods such as silk and spices. Finding a new route was an important goal at the time to solve the problems that had arisen with the old land route called the Silk Road. Columbus made four trips to the Caribbean and South America during the years 1492-1504. He visited the Bahamas, Cuba, Central America, South America, and Hispaniola (now Dominican Republic) though not the North American mainland; he never found the route to India. However, he met new people and visited new places, and helped bring about a new era of exploration by opening a whole continent for European exploration, and, unfortunately, also for exploitation. Some of the other major explorers during the Age of Discovery include Vasco da Gama, who was the first person to sail directly from Europe to India by sailing around the southernmost point of Africa; Giovanni Caboto (also known as John Cabot), who was the first modern European to have arrived at the North American mainland; Yermak Timofeyevich, who explored Siberia; Ferdinand Magellan, who led the first expedition to sail around the world; and Willem Janszoon, who is thought to be the first European to have seen the coast of Australia.

The Lewis and Clark Expedition

After the lay of the lands and the continents on the face of the Earth was discovered, much remained to be learned about the interior of the continents. A good example of this type of exploration is the expansion of the Unites States in the early 19th century.

After the United States purchased the Louisiana Territory from France in 1803, President Thomas Jefferson was curious to know more of the new land west of the Mississippi River. He also thought that if there was a waterway from the Mississippi to the Pacific Ocean (called "the Northwest Passage"), whoever controlled it would control trade across the continent. Captain Meriwether Lewis and William Clark were chosen to lead an expedition to explore the new territory and to search for the waterway. The expedition was to keep a detailed diary of the people, plant life, animals, minerals, and the geography of the explored areas. Lewis and Clark spent months planning the expedition, since limited information about what they could expect on the journey made it difficult to decide what kind of supplies to bring along. The 33-member team left St. Louis, MO, in May 1804 for the journey and returned in September 1806 after reaching the Pacific Ocean. One of the key members of the expedition was Sacagawea, a Shoshone woman who joined the group in North Dakota and accompanied the team to the Pacific Ocean and back. She acted as a guide and an interpreter as the expedition traveled among the Native American tribes, located crucial resources when the team crossed the Rocky Mountains, and even rescued the expedition's journals, which had fallen into a river from a capsized boat. Even her mere presence in the team was important to the success of the expedition: it conveyed to the tribes the expedition encountered that the travelers did not have hostile intentions, but were on a peaceful journey of exploration, instead. While the Lewis and Clark expedition did not find the Northwest Passage waterway to the Pacific Ocean, it returned with a wealth of information about the new lands west of the Mississippi River.

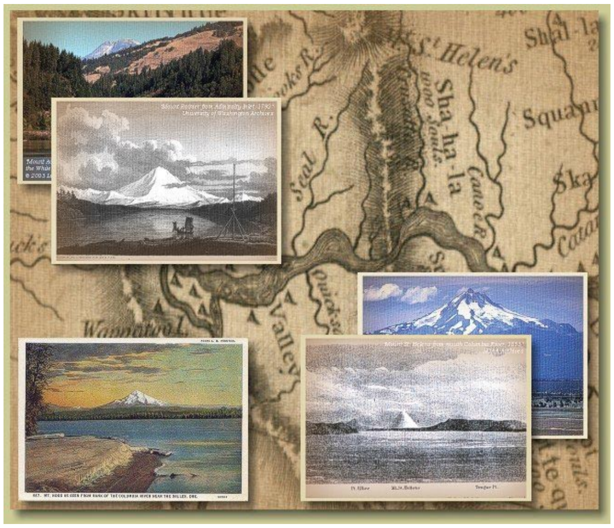


Figure 4. Pictures of some of the volcanoes encountered during the Lewis and Clark expedition over the Louisiana Purchase territory overlain on a map drawn during the journey. Expeditions over land and water were the main way of exploring unknown environments until the development of aircraft. (Picture credit: http://vulcan.wr.usgs.gov/LivingWith/Historical/LewisClark/SiteImages/beginning_image.jpg)

Exploration of Ocean Depths

Some of the areas of the Earth that are the least explored today are the depths of the Earth's oceans. While mapping out the sea floor in 1951, a British survey ship Challenger II located a deep depression at the bottom of the Pacific Ocean now known as the Mariana Trench, just east of the Mariana Islands. The bottom of the feature is about 11 km (7 miles) below sea level. What was at the bottom of the Mariana Trench? In 1960, the famous French underwater explorer, Jacques Piccard, and U.S. Navy Lt. Donald Walsh descended in the U.S. Navy bathyscaphe (a type of deep-sea exploration vehicle) Trieste to find out. The water pressure at the bottom of the trench is enormous, over 1000 times the standard atmospheric pressure at sea level. To their surprise they found organisms that could live at that depth. What was originally a curiosity about the shape of the sea floor led to the discovery of a deep trench, and curiosity about the new feature led to the discovery of organisms in a place where none was expected. Scientists now know that there is a lot of life at the depths of the oceans, and continued explorations of strange environments such as hydrothermal vents reveal many strange life forms in places scientists once thought no living beings could exist.

Exploration of Flight

One of the greatest achievements of human technological exploration is the first successful flight with a powered aircraft. On December 17, 1903, Wilbur and Orville Wright made four brief flights at Kitty Hawk, NC, with the aircraft they had designed (Fig. 5.) Even though these flights were short (the longest covering 262 meters, or 859 feet), they started the journey toward the development of modern airplanes.

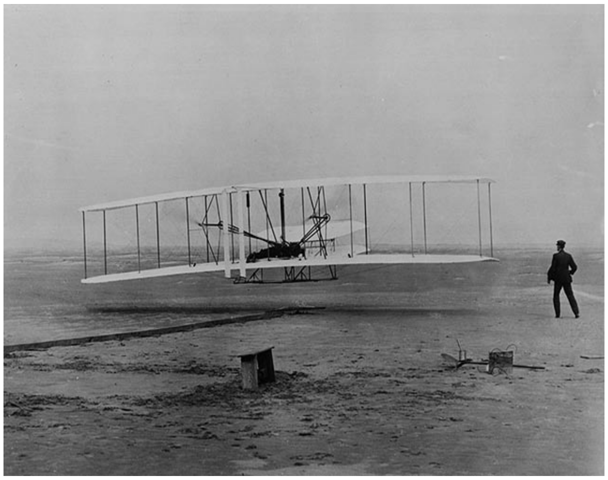


Figure 5. The Wright Flyer was the first modern airplane. Built by the brothers Wilbur and Orville Wright, the Flyer became the first heavier-than-air machine to fly a powered and controlled flight on December 17, 1903. (Picture credit: http://www.grc.nasa.gov/WWW/K-12/aerosim/LessonHS97/WRIGHT.GIF)

Another important aviation milestone was reached when Charles Lindbergh made the first solo nonstop flight across the Atlantic Ocean with the Spirit of St. Louis aircraft, flying from New York to Paris on May 20-21, 1927. The first flight across the Atlantic by a heavier-than-air aircraft had been performed earlier by the crew of the NC-4 in May 1919, but they made their journey in stages, and it took the crew 19 days to cross the Atlantic Ocean.

Amelia Earhart's name became a household word in 1932 when she became the first woman (and the second person ever) to fly solo across the Atlantic, on the fifth anniversary of Charles Lindbergh's feat, flying a Lockheed Vega from Harbor Grace, Newfoundland to Londonderry, Ireland. On June 1, 1937, she and Fred Noonan, her navigator, took off on an attempt to fly around the world starting from

Miami, FL. After numerous stops in South America, Africa, the Indian Subcontinent and Southeast Asia, they arrived at Lae, New Guinea on June 29. About 35,000 km (22,000 miles) of the journey had been completed. On July 2, 1937, Earhart and Noonan took off from Lae. Their intended destination was Howland Island, a tiny piece of land a few kilometers long, 6 meters (20 ft) high, and 4,113 km (2,556 miles) away. They never reached the island. A coordinated search by the Navy and Coast Guard was organized, but no physical evidence of the flyers or their plane was ever found.

On October 14, 1947, the Bell X-1 became the first airplane to fly faster than the speed of sound. Piloted by U.S. Air Force Capt. Charles E. "Chuck" Yeager, the X-1 reached a speed of 1,127 kilometers (700 miles) per hour, Mach 1.06, at an altitude of 13,000 meters (43,000 feet).

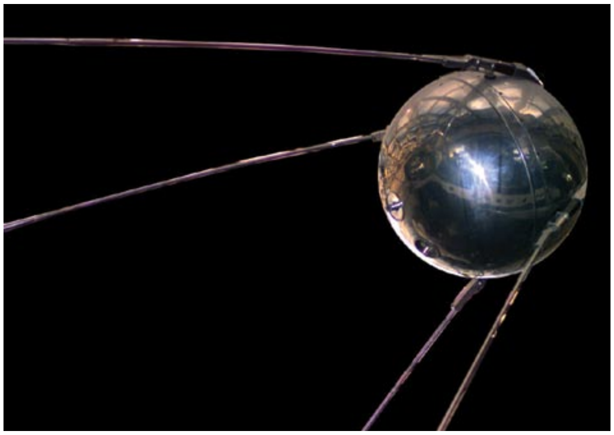


Figure 6. Sputnik 1 became the first human-made object to orbit the Earth in October 1957. (Picture credit: NASA Space Science Data Center; http://nssdc.gsfc.nasa.gov/planetary/image/sputnik_asm.jpg)

Exploration of Space

In October 1957 the Soviet Union announced the landmark launch of the satellite Sputnik (Fig. 6) into orbit around the Earth. The satellite was small—only 58 cm (23 inches) in diameter and weighed about 84 kg (185 lbs)—but powerful enough to transmit signals back to Earth, announcing to the whole world that the first human-made object had been sent to space. In this manner, Sputnik 1 opened a brand new frontier for human exploration. The first spacecraft launch was soon followed by others, including the first successful satellite launch by the United States in 1958.

Because the Sputnik launch occurred at the height of the Cold War, the American public became concerned about the Soviet space program. Politicians feared that Soviet superiority in space could threaten American national security. In response, the U.S. government formed the National Aeronautics and Space Administration (NASA) in 1958 to conduct all U.S. nonmilitary exploration of space. In October 1958, within its first week, NASA announced Project Mercury, its first manned space program. However, the Soviet Union also won this chapter of the so-called space race. In 1961, Yuri Gagarin became the first human to travel into space, as well as orbit the Earth, a few months before Alan Shepard, Jr., became the first American in space, and John Glenn the first American to orbit the Earth. The first woman in space was the Soviet cosmonaut Valentina Vladimirovna Tereshkova on the Vostok 5 mission in 1963. The first American woman in space was Sally Ride in 1983.

After the first human ventures into space, landing the first person on the Moon became the prized goal of both Soviet and U.S. space exploration. In 1961, President John F. Kennedy announced that the United States was planning a mission to land the first human beings on the Moon before the decade was over. This extraordinary milestone in human exploration took place on July 20, 1969, when Neil Armstrong and Buzz Aldrin landed safely on the surface of the Moon (see Fig. 7.) This historic moment forever changed the way humans look at the Universe. For the first time, a human being had set foot on a world other than our own!

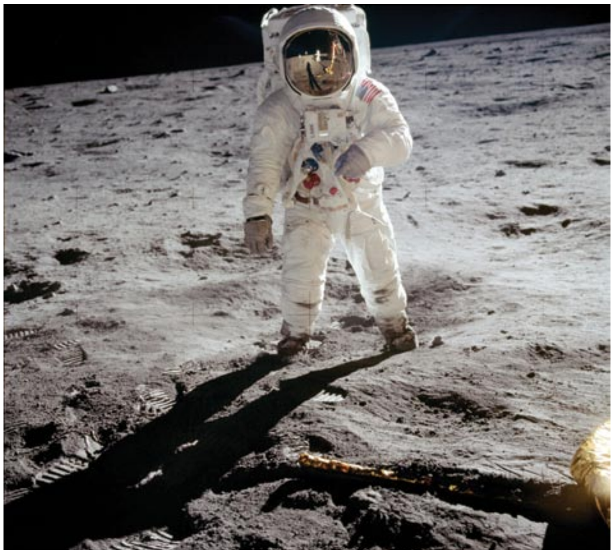


Figure 7. Picture of the lunar module pilot Buzz Aldrin taken by the Apollo 11 commander Neil Armstrong (whose reflection can be seen on Aldrin's helmet visor.) Armstrong and Aldrin became the first human beings to set foot on another world in the Solar System besides the Earth on July 20, 1969. (Picture credit: NASA Project Apollo Archive/Apollo Image Gallery, scanned by Kipp Teague, AS11-40-5903; http://www.apolloarchive.com/apollo_gallery.html)

NASA's Space Shuttle, officially called Space Transportation System (STS), has been the U.S. government's launch vehicle for human spaceflight since the 1980s. The winged Shuttle orbiter is launched strapped to an external fuel tank, carrying between five and eight astronauts into low Earth orbit, to a height of 185-643 kilometers (115-400 miles) from the Earth's surface. After completing its mission, the Shuttle re-enters the atmosphere and makes an unpowered gliding horizontal landing. During the program's history there have been five Shuttles used in the program. Two have been destroyed in accidents: Challenger, seconds after liftoff in 1986, and Columbia during reentry to the Earth's atmosphere in 2003. After each incident, Shuttle flights were suspended for about 2.5 years to investigate the disasters and fix the problems found, in order to avoid losing additional lives in future flights. The exhaustive investigations and the resumption of Shuttle flights after the disasters demonstrate NASA's dedication to human spaceflight. The remaining Shuttles—Atlantis, Discovery, and Endeavour—have been used mainly to construct and supply the International Space Station (ISS.) The fleet will be retired in 2011, after which NASA will rely on Russian spacecraft to carry astronauts to the ISS. NASA is planning to develop new spacecraft to carry humans even farther into space, but the state of these plans is uncertain at this time (June 2010.)

Robotic Exploration of Space

While human exploration of space is exciting because it involves actual human beings traveling to space, the space environment makes this mode of exploration challenging, dangerous, and expensive. As a result, humans have only traveled as far as the Moon and not any farther into space. Instead, robotic spacecraft have become invaluable in the exploration of the Solar System, providing us with information on our cosmic backyard. The history of the robotic exploration of the Solar System is long and full of interesting stories and discoveries, but instead of describing every milestone, the following paragraphs discuss just a handful of recent spacecraft missions.

A great example of current exploration of the inner Solar System is NASA's MESSENGER mission to Mercury (Fig. 8.) The spacecraft was launched in 2004 and after three flybys of its target planet in 2008 and 2009, it will go into orbit around Mercury in 2011. MESSENGER is only the second spacecraft ever to visit, and the first to orbit, the innermost planet of the Solar System. MESSENGER will provide a lot of information about the properties of the planet, the space environment near Mercury, and even the Sun. Its results will provide answers to a wide range of science questions, from the origin and evolution of Mercury to the formation of the Solar System and the properties of other planets, including the Earth.

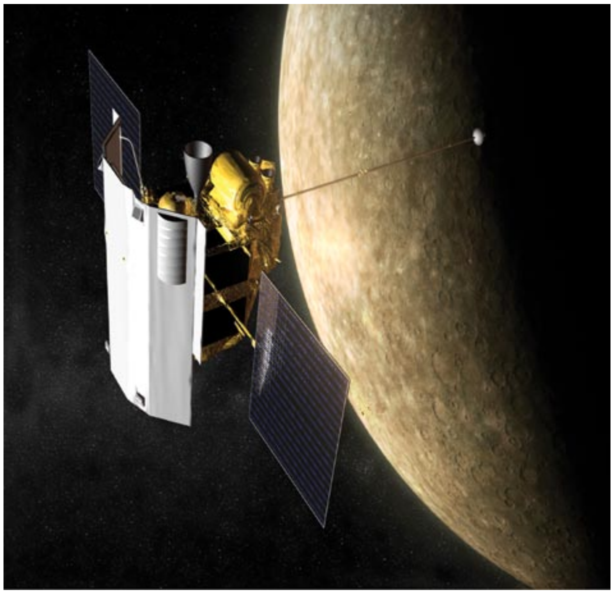


Figure 8. An artist's impression of the MESSENGER spacecraft exploring Mercury. MESSENGER is the first spacecraft to explore the innermost planet in the Solar System since the 1970s, and the first spacecraft ever to investigate the planet from orbit. (Picture credit: http://messenger.jhuapl.edu/the_mission/artistimpression/artists_impression.html)

Two robotic rovers (Spirit and Opportunity; known together as Mars Exploration Rovers) landed on Mars in January 2004. One of their main goals was to look for evidence of liquid water on the surface of Mars in the past. Finding signs of water is important, since one of the basic requirements for life as we know it is liquid water. If Mars had water on its surface in the past, perhaps it could have supported life at some point. Currently, Mars is a dry planet with only a very thin atmosphere consisting of mainly carbon dioxide. While previous spacecraft exploring the planet had shown that there used to be rivers on the Martian surface, the rovers were the first to find evidence showing that in the past Mars had lots of liquid water on its surface, in the form of lakes and oceans. Where did the water go? Why did the Martian environment change so that the surface featuring lakes and oceans became the dry wasteland we see today? While scientists are still trying to find answers to these questions, one possible answer to where the water vanished was provided by the spacecraft 2001 Mars Odyssey, which discovered that there is water frozen underneath the Martian surface near its south pole. Could there be life on the ice? That seems like a strange possibility to even consider. However, there are some microorganisms on Earth that can survive in ice by extruding a chemical that melts just enough ice around them to allow them to live. There are other forms of bacteria that survive in ice by going into a suspended state and being revived when the ice melts. To answer the questions of the history of water on Mars, and the possible presence of life there in the past or in the present, there are plans to send several other robotic missions to Mars in the next several years, including a mission that will return samples of the Martian soil to the Earth.

The Cassini-Huygens spacecraft mission is a joint project by NASA and the European Space Agency (ESA.) Since its arrival at Saturn in 2004, the spacecraft has been exploring the Saturn system, providing a wealth of new information about the planet, as well as its rings, magnetosphere, and moons. One of the central parts of the Cassini mission was the delivery of the Huygens probe to Saturn's moon Titan. Huygens entered Titan's atmosphere on January 14, 2005, and sent back pictures and other data for about three hours as it descended and landed on the surface. The probe provided an unprecedented look at Titan's surface, which had been previously hidden by the thick atmosphere's haze and clouds. The surface seems to be geologically active, and appears to have liquids flowing at least occasionally on its surface, though instead of water, the flowing liquid on the cold moon is methane. Titan, which has an atmosphere that in many ways resembles that of the early Earth, could be a possible host for life, if it was not so cold that no living beings that we know of could survive on its surface. As it is, it is unlikely any living beings ever could have survived on the surface of Titan.

The New Horizons spacecraft was launched by NASA in January 2006 to explore the outer reaches of the Solar System. It will be the first spacecraft ever to visit Pluto, when it flies by this small world in 2015. At present, we do not know much about Pluto, and the mission will reveal a lot of information about it and its three moons. After flying by Pluto, the robotic spacecraft will continue its exploration further out in the Solar System, where many icy worlds similar to Pluto reside. These worlds, the first of which was discovered in

1992, now include more than 1,000 known objects, and there are probably thousands more awaiting discovery. Most of these objects are smaller than Pluto, but a world called Eris, discovered in 2003, is a little larger than Pluto. This discovery led to the new classification of Solar System objects in 2006, when the International Astronomical Union (IAU) passed a resolution that Pluto, Eris, and other Solar System objects that are large enough to be spherical in shape but do not meet all the criteria of an actual planet belong to a class of objects called dwarf planets. Most of the objects in the region of the Solar System beyond the orbit of Pluto are not large enough to be called dwarf planets; they are just large chunks of ice and rock orbiting the Sun in the far reaches of the Solar System. Until the IAU resolution, Pluto had been known as the ninth planet, and many people were upset over what some saw as a demotion of Pluto. However, the initial furor has passed, and it appears that Pluto will be known as a dwarf planet from now on, unless some new discovery requires changes in the classification of Solar System objects again.

In addition to planets and their moons, as well as the newly classified dwarf planets, there are other objects in the Solar System that are interesting targets of exploration. One example of robotic space missions to these kinds of objects is NASA's Stardust mission to Comet Wild 2. The spacecraft flew by the comet in 2004, coming within 250 km (155 miles) of the nucleus of the comet at closest approach. The spacecraft took images of the nucleus and captured samples of comet material. The collected samples were returned to the Earth in 2006. Understanding the composition of different kinds of comets, which are thought to be leftovers from the formation of the Solar System, provide important clues to what the conditions in the Solar System were like during its formation, and how they have changed during its history.

Exploration of the Universe

Human curiosity and the desire to explore have always reached beyond the bounds of Earth. Even in ancient times, people wondered what lay beyond the Earth, but it has only been in the last few centuries, and especially in the last few decades, that technology has provided proper tools for our investigations. One of the great milestones in this process was the development of the telescope, which took place in about 1608. There is some dispute as to exactly who made the first telescope, but the feat is usually attributed to Hans Lippershey. However, there is little dispute about who was the first person to use the telescope for significant astronomical discoveries. Though other people may have used the new instrument to look at the sky, Galileo Galilei not only used (and improved) the telescope in the early 17th century to observe celestial objects no human had ever seen in such detail before, but also reported on his discoveries. In so doing, Galileo started the era of detailed astronomical observations not possible with the unaided eye.

Telescopes are the basic tool of observational astronomy, and they have become ever more accurate in modern times, when new ways to use this venerable tool have been developed. In 1923, German scientist Hermann Oberth suggested using a rocket to carry a telescope to space, and in 1946, the American astrophysicist Lyman Spitzer, Jr., wrote a detailed paper proposing a space observatory. He proposed placing a large telescope into space where it would be able to observe objects in space without having to deal with the blurring effects of the Earth's atmosphere. In 1975 NASA, along with the European Space Agency, began the development of the telescope that would later be known as the Hubble Space Telescope (HST). The telescope was named after the American astronomer Edwin Hubble, who is considered the founder of modern cosmology. In 1990 HST was placed into orbit around the Earth by the Space Shuttle. While it wasn't the first space telescope, the hundreds of thousands of pictures of more than 25,000 astronomical targets it has taken has made HST possibly the most important telescope in the history of astronomy. To honor the contributions of Lyman Spitzer, Jr., to the development of space telescopes, NASA named an infrared space telescope launched in 2003 after him; the Hubble and Spitzer Space Telescopes are part of NASA's Great Observatories program.

One of the technological advances that has made space telescopes possible is a camera that does not use film. Instead, space telescope use electronic devices known as Charge Coupled Devices (CCDs). These detectors can see objects that are a billion times fainter than what the unaided eye can see. These devices are also at the heart of every digital camera; while commercial digital cameras are built differently, they use the same CCD technology. This is a great example of how the desire to explore the Universe benefits from (and in return can influence the work of engineers working on more Earthly problems). The information captured by the HST's cameras are sent to the control centers on Earth (at Goddard Space Flight Center in Greenbelt, MD, and the Space Telescope Science Institute in Baltimore, MD) where computers are used to actually form the pictures we see on Web sites and in newspapers.

Learning More about Explorations in the Past

The paragraphs above offer just a brief glimpse into the history of exploration, and they cannot cover all the details, or even mention all the important stories from our history. Fortunately, finding out information on past explorations is easy with the help of the Internet. However, it is good to remember that even though the Internet has become an invaluable method of sharing information, sometimes the information may not be accurate. Anyone can publish a Web page discussing a topic of their choice, and it is entirely possible that the contents of the Web page are biased or inaccurate. As a result, it is important to consider the source of the information when doing

Internet research. The best sources of information on the Internet are usually government agencies, universities and affiliated research institutions, or well-known encyclopedias, though even they are not always 100% accurate.

When reporting on Internet research, it is important to cite as much of the information on the Web site as possible, including:

- The name of the author or editor
- The name of the Web site
- The posting date
- The name of the Web site publisher
- The date you accessed the material
- URL (Uniform Resource Locator); the standard way to describe Web page addresses.

using the format:

> Editor, author, or compiler name. *Name of the Site.* Posting date. Name of Web site publisher. Date of access. URL.

Note that not every Web site includes all the information, but it is always advisable to include as much information as possible. For example, if you are referring to information published on January 10, 2010, on the NASA home page that you read on January 12, 2010, you would give the citation as:

> Editor, author, or compiler name. *NASA Home Page.* January 10, 2010. NASA. Accessed on January 12, 2010. http://www.nasa.gov.

By documenting the source of information, anyone questioning the accuracy of the report can check the source themselves.

Exploration in the Future

As a child grows up and begins to crawl, the desire to investigate things (usually by putting new things into his or her mouth) begins. The method of investigation changes with age, but the basic curiosity is still there. After we learn that the lights in the sky are the Moon, planets, and stars, we begin to wonder what they are like. In this manner, the growth of the child follows the pattern the human race has taken. Humans were first curious about their immediate surroundings, traveling by land and by sea to explore their neighborhood. The first steps of exploration led humans to travel across the Earth and to investigate our home planet as a whole. In recent decades, human exploration has reached beyond the bounds of Earth into space. Humans have observed objects in space with telescopes, sent robotic spacecraft to explore different environments of the Solar System, and even landed humans on the Moon (a total of six times in 1969-1972.) There is little doubt that the human journey of exploration will continue in the future. Exploration is an essential part of human nature, and as far as the technological advances will allow, the human race will push the boundaries of exploration to see what the other neighborhoods in the Universe are like, and how they compare with our own neck of the woods.

Lesson Plan

Warm-Up & Pre-Assessment

1. Ask the students to think about past explorers. You can ask them to name a few past explorers and what they explored. Ask the students why they think these people wanted to explore. Write down the answers on the chalkboard or overhead projector. Stop when the list includes seven entries. The students may come up with many more reasons, but stop at seven, so that there are as many entries as letters in the word "explore" used in Step 3 below.

2. Ask the students to name a few present-day explorers, or careers that modern-day explorers may have (e.g., astronauts, historians, engineers, scientists.) Ask students to look at the list they made in Step 1; do the entries in the list apply to present-day explorers, as well? Make sure students understand that the reasons for past explorations are usually the same as the motivations for present explorations. Students may want to amend the list in light of thinking about exploration in general rather than just past exploration. Combine some of the reasons, if necessary, to keep the list at seven entries.

3. Divide the students into seven teams and hand out a piece of poster board and a set of markers to each team. Assign each of the teams one of the seven reasons they have come up with, as well as one letter from the word "EXPLORE." Instruct the teams to come up with an inspirational slogan to describe their reason for exploration that begins with their assigned letter. (The team assigned to "X" can make their letter the second or third letter in their slogan, as there are not many words that begin with the letter X.) Ask the students to design a poster based on their slogan. Advise the students to write their letter on top and then design the rest of the poster.

4. Tape the teams' posters on the wall, and discuss as a class the contents of the posters, the slogans and the underlying reason for exploration.

Materials

Per class:

- ▼ Roll of masking tape
- ▼ 7 sheets of poster board (1 sheet per team)
- ▼ 7 sets of markers (1 set per team)

Activity 1: Famous Explorers

Students investigate different explorers and examine the driving questions behind their explorations. Students choose an explorer that they are interested in studying, and conduct an Internet investigation on that explorer. Teachers are advised as to the best ways for students to conduct this research, and students learn how to conduct an effective Internet research project using credible sources. Students answer questions about their explorer as to why he or she wanted to explore. As a group, the students are able to add or subtract from the list of reasons for exploration that they had come up with in the warm-up section.

Materials

Per student:

- Internet access
- *Student Internet Resources*
- Student Worksheet 1

Preparation

- Make copies of Student Worksheet 1 and *Student Internet Resources* list located in the back of the lesson.

Procedures

1. Ask the students to brainstorm a list of famous explorers. Possible answers include Columbus, Magellan, Lewis and Clark, Leif Erikson, Yuri Gagarin, John Glenn, Neil Armstrong, Amelia Earhart, Sally Ride, etc.
2. Have the students choose one of the explorers on the list—or another explorer that they are interested in learning about—to research.

Teaching Tips

Make sure that the students get an opportunity to research one of their favorite explorers, since it is important to research something in which the students are interested. However, also try to make sure also that there is a variety of explorers being researched in terms of historical times, subjects of exploration, and the personal characteristics of the explorers.

3. Hand out copies of *Student Internet Resources*. Have the students complete the questions on Student Worksheet 1 by visiting the Web sites listed, or finding other appropriate Web sites. Make sure that the students cite appropriately the sources of their information.

Teaching Tips

- Take this opportunity to review with the students what to look for in a reliable Web site. Point out that basically anyone can set up a Web page where they portray their opinions as facts. Make sure the students understand that having reputable sources is essential in good Internet research. Review how to cite Internet resources properly. See the *Science Overview* for further information.

4. Have the students prepare a poster or a short presentation about their explorer and his or her reasons for exploring.

Discussion & Reflection

1. Have the students briefly present the explorer he or she researched, either in front of the whole class or in small groups.
2. Ask the students to compare the explorers and their reasons for exploring. Were there any similarities? Were there any differences?
3. Discuss how the students learned that explorers can be very different in many ways, but all share some common characteristics. Refer back to the reasons for explorations the class discussed during the Warm-Up. Discuss whether the students themselves share those characteristics and are also explorers, questioning and learning new things about their environment.

Activity 2: Exploring the Solar System

After examining a short write-up about a planet or another world in the Solar System, students come up with an explanation why humans would want to explore that world. They will create a poster or an electronic presentation (e.g., PowerPoint, Web page) and write a proposal to NASA about why we would want to build a spacecraft to explore this particular world.

Materials

Per class:

- Audiovisual materials, depending on type of presentation (e.g., LCD projector, screen; place to hang posters.)

Per group of 2 or 3:

- *Space Exploration Card* (one card per group)
- Presentation materials (if presented electronically, students will need access to computers with appropriate presentation software; if with a poster, students will need access to poster board, markers, etc.)
- Student Worksheet 2

Preparation

- Make copies of Student Worksheet 2. Make copies of the *Space Exploration Cards* located in the back of the lesson so that each team will have one card.
- Remind students (or teach them) how to use PowerPoint or a similar presentation program, or how to make a simple Web page. Be sure to get all of the audiovisual needs taken care of before class.

Procedures

1. Remind students of the Warm-Up and Activity 1 as to why people explore. Ask them how the reasons relate to space exploration.
2. Have a discussion about why people want to explore space and ways in which they can do so (e.g. human spaceflight versus robotic missions, sending spacecraft to other planets, moons, asteroids, comets, etc.) Ask the students what they know about space missions that have taken place in the past, ones that are underway right now, and missions that are planned in the future.
3. Divide the students into groups of two or three.
4. Assign each group (or have each group choose) one of the worlds described on the *Space Exploration Cards*. Give each group the card pertaining to their world.
5. Hand out Student Worksheet 2. The Worksheet will guide students through the process of investigating why their world might be worth exploring.
6. Have the groups present to the rest of the class the results of their investigation. Make sure the groups describe the kind of information they would like to discover with a mission to explore their world.

Teaching Tip

Be sure to point out that even though each *Space Exploration Card* mentions the likelihood of life existing on the different worlds, the search for life is by no means the only, or in many cases even a very important, reason to explore these worlds. There are open science questions about all worlds discussed in the *Cards*, making them well worth exploring. Challenge the students to find basic science questions about the properties of the worlds based on their description; these questions are not spelled out in detail in the *Cards* themselves so that the students can come up with their own questions.

Discussion & Reflection

After the students present their planned missions, have each group give a "closing argument" as to why NASA should fund their mission. Make sure the groups focus on *why* they want to explore this world, and why others should want to explore it, too.

Teaching Tip

Have the students vote anonymously which mission they would choose—with the restriction that they cannot vote for their own mission. You may want to give a reward for the winning team.

Lesson Adaptations

- This lesson provides Web sites that the students can use for their research. However, you may want to take some time before the lesson to do your own research to find additional Web sites that are appropriate for your students' abilities and needs.

Extensions

- Enlist a local scientist to come to your class to talk about his/her explorations. Universities, university extension services, NASA centers, federal land management agencies, and private industries are good resources for locating scientists.
- Have the students locate an explorer in their community and write a short biography about that person, highlighting why the person is an explorer and what motivates him or her.

Curriculum Connections

- *History*: Have the students examine the role of explorers in shaping human history. We often focus on how wars and politics have shaped history, but what effect have new discoveries made by explorers had? How have explorations in the past been connected to other events taking place at the same time, such as armed conflicts, or societal and political concerns?
- *Language Arts*: Have the students read a novel or a short story about exploration, either real or imaginary. Have the students write a book report, focusing on the reasons the characters in the novel or the story explored.
- *Language Arts*: Have the students write a story of explorations hundreds of years from now. Will human desire for exploration continue? Where will these explorations take us?
- *History of Science*: In discussing exploration, we tend to concentrate on success stories. However, even a failed experiment or expedition may teach us a lot about the Universe around us. Have the students investigate cases where a failure or an accident has advanced our knowledge.

Closing Discussion

1. Discuss with the students how it is human nature to explore: babies crawl, kids survey the playground, teenagers question, and adults often find themselves in a new situation where they may have to explore previously unknown courses of action. We are all explorers. Exploration can lead the students to an exciting career that greatly enriches their lives and benefits society.
2. Lead a discussion about how exploring the worlds in the Solar System can help us understand our own world better. Students will find that the reasons for exploring a familiar place are the same reasons humans want to explore unknown environments and other worlds.
3. Discuss how our current explorations build on the work of previous explorers, who charted the face of the Earth, explored the depths of the oceans, reached into the sky, and now have taken the furthest reaches of exploration into space.
4. Discuss with the students how technology helps exploration. The explorations of today have been made possible by advances in our ability to create new tools to aid our exploration of the unknown.
5. The students should understand that no matter what we explore, whether it is a new city we have moved to, a new place on the Earth never seen by humans before, or another world in

the Solar System or in the rest of the Universe, the basic reasons we explore are the same; the motivation for exploration is universal.

6. Hand out copies of the *Mission Information Sheet* located at the back of the lesson. Discuss with the students how the mission builds on the rich history of exploration.

Assessment

4 points

- Student described the reasons for exploration for the explorer of his or her choice in Student Worksheet 1.
- Student used reasoning to explain why his or her group's assigned world is worth exploring in Student Worksheet 2.
- Student participated in the presentation of his or her group's proposal to explore their assigned world and used evidence and reasoning to support their proposal.
- Student completed both Worksheets.

3 points

- Three of the four above criteria were met.

2 points

- Two of the four above criteria were met.

1 point

- One of the four above criteria was met.

0 points

- No work completed.

INTERNET RESOURCES & REFERENCES

MESSENGER Web Site

http://messenger.jhuapl.edu/

American Association for the Advancement of Science, Project 2061, Benchmarks for Science Literacy

http://www.project2061.org/publications/bsl/online/bolintro.htm

National Science Education Standards

http://www.nap.edu/html/nses/

BBC Space Exploration Timeline

http://www.bbc.co.uk/science/space/exploration/missiontimeline/

Enchanted Learning Zoom Explorers

http://www.enchantedlearning.com/explorers/

The Explorers Club

http://www.explorers.org/

Mariana Trench

http://www.marianatrench.com/

The Mariner's Museum: Exploration through the Ages

http://ww2.mariner.org/exploration/index.php

NASA 50th Anniversary

http://www.nasa.gov/50th/home/

NASA Apollo Program

http://spaceflight1.nasa.gov/history/apollo/

NASA Cassini Mission

http://saturn.jpl.nasa.gov /

NASA Exploration: "Why We Explore"

http://www.nasa.gov/exploration/whyweexplore/why_we_explore_main.html

NASA History Division: Sputnik

http://www.hq.nasa.gov/office/pao/History/sputnik/

NASA Hubble Space Telescope

http://hubblesite.org/

NASA Mars Exploration Rovers

http://marsrovers.jpl.nasa.gov/home/

NASA National Space Science Data Center's Chronology of Lunar and Planetary Exploration

http://nssdc.gsfc.nasa.gov/planetary/chronology.html

NASA New Horizons Mission

http://pluto.jhuapl.edu/

NASA Solar System Exploration

http://solarsystem.nasa.gov/

NASA Solar System Exploration: Dwarf Planets

http://solarsystem.nasa.gov/planets/profile.cfm?Object=Dwarf

NASA Space Shuttle

http://www.nasa.gov/mission_pages/shuttle/main/

NASA Spitzer Space Telescope: Lyman Spitzer, Jr.

http://www.spitzer.caltech.edu/about/spitzer.shtml

NASA Stardust Mission

http://stardust.jpl.nasa.gov/home/

National Geographic Lewis and Clark Web Site

http://www.nationalgeographic.com/lewisandclark/

The Nine Planets Web Site

http://www.nineplanets.org/

PBS: Polynesians Voyagers

http://www.pbs.org/wayfinders/polynesian.html

Polynesian Voyaging Society

http://pvs.kcc.hawaii.edu/

Smithsonian Institution National Air and Space Museum Space Race Exhibition

http://www.nasm.si.edu/exhibitions/gal114/gal114.htm

Smithsonian Institution National Museum of Natural History Viking Exhibition

http://www.mnh.si.edu/vikings/

Technical University Eindhoven Discoverers Web

http://www.win.tue.nl/~engels/discovery/

The University of Calgary: Christopher Columbus

http://www.ucalgary.ca/applied_history/tutor/eurvoya/columbus.html

U.S. Centennial of Flight Web Site

http://www.centennialofflight.gov/

Student Internet Resources

If the explorer of your choice is listed here, you may want to use the Web sites listed below to find information on the explorer. If he or she is not listed, you can use Internet search engines to find information on the explorer on other Web sites.

Explorers in General

http://www.win.tue.nl/~engels/discovery/
http://ww2.mariner.org/exploration/index.php
http://edtech.kennesaw.edu/web/explorer.html
http://www.enchantedlearning.com/explorers/

Apollo 11 Astronauts

http://www.nasa.gov/mission_pages(apollo)/apollo11_40th.html
http://www.hq.nasa.gov/office/pao/History/ap11ann/astrobios.htm
http://starchild.gsfc.nasa.gov/docs/StarChild/space_level2/apollo11.html

Christopher Columbus

http://ww2.mariner.org/exploration/index.php?type=explorer&id=12
http://www.ibiblio.org/expo/1492.exhibit/c-Columbus/columbus.html
http://www.ucalgary.ca/applied_history/tutor/eurvoya/columbus.html

Amelia Earhart

http://www.ameliaearhart.com/
http://www.acepilots.com/earhart.html
http://www.centennialofflight.gov/essay/Explorers_Record_Setters_and_Daredevils/earhart/EX29.htm

Leif Erikson

http://ww2.mariner.org/exploration/index.php?type=explorer&id=10
http://www.enchantedlearning.com/explorers/america.shtml
http://www.bbc.co.uk/history/historic_figures/erikson_leif.shtml

Yuri Gagarin

http://www.centennialofflight.gov/essay/Dictionary/GAGARIN/DI169.htm

http://starchild.gsfc.nasa.gov/docs/StarChild/whos_who_level2/gagarin.html

http://www.astronautix.com/astros/gagarin.htm

Galileo Galilei

http://galileo.rice.edu/

http://brunelleschi.imss.fi.it/museum/esim.asp?c=300251

http://www.pbs.org/wgbh/nova/galileo/

John Glenn

http://www.jsc.nasa.gov/Bios/htmlbios/glenn-j.html

http://www.johnglennhome.org/john_glenn.shtml

http://history.nasa.gov/40thmerc7/glenn.htm

Thor Heyerdahl

http://news.bbc.co.uk/1/hi/world/europe/1938294.stm

http://www.blueworldexplorer.co.uk/explorers/heyerdahl.htm

http://www.mnsu.edu/emuseum/information/biography/fghij/heyerdahl_thor.html

Lewis and Clark Expedition

http://www.nationalgeographic.com/lewisandclark/

http://www.pbs.org/lewisandclark/

http://www.nps.gov/lecl/historyculture/index.htm

Charles Lindberg

http://www.lindberghfoundation.org/charles_a._lindbergh/ charles_a._lindbergh-biography.html

http://www.charleslindbergh.com/

http://www.uh.edu/engines/epi1062.htm

Ferdinand Magellan

http://ww2.mariner.org/exploration/index.php?type=explorer&id=8

http://www.nmm.ac.uk/magellan/

http://www.bbc.co.uk/history/historic_figures/magellan_ferdinand.shtml

Sally Ride

http://www.jsc.nasa.gov/Bios/htmlbios/ride-sk.html

http://quest.arc.nasa.gov/people/bios/women/sr.html

http://www.greatwomen.org/women.php?action=viewone&id=125

Valentina Tereshkova

http://starchild.gsfc.nasa.gov/docs/StarChild/whos_who_level2/tereshkova.html

http://www.astronautix.com/astros/terhkova.htm

http://www.enchantedlearning.com/explorers/page/t/tereshkova.shtml

Orville and Wilbur Wright

http://www.pbs.org/kcet/chasingthesun/innovators/owwright.html

http://www.centennialofflight.gov/wbh/index.htm

http://wright.nasa.gov/index.htm

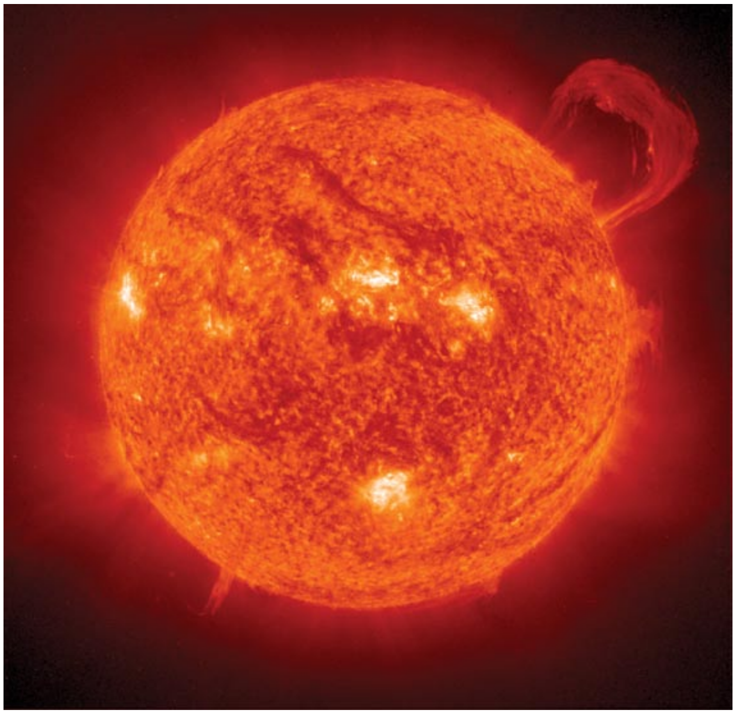
Charles E. "Chuck" Yeager

http://www.af.mil/information/bios/bio.asp?bioID=7680

http://www.aiaa.org/content.cfm?pageid=469

http://www.acepilots.com/usaaf_yeager.html

The Sun



The Sun is the star at the center of our Solar System. It is a fairly typical star, just one of over 200 billion stars in the Milky Way galaxy. It is not among the brightest or the faintest stars. Even though it is more massive than most of the stars in the Milky Way, there are still billions of stars more massive than the Sun. The reason it looks so big and bright as compared with the stars in the night sky is that it is very close to the Earth. The Sun's diameter is about 109 times the diameter of the Earth. The mass of the Sun is about 333,000 times the Earth's mass. The Sun's role as the center of the planetary system comes from its high mass; it has 99.8% of the mass in the Solar System and, therefore, guides the movement of the other objects in the Solar System via gravitational forces. The Sun is made up entirely of gas, mostly of hydrogen and helium, with heavier elements such as oxygen, carbon, neon, and nitrogen mixed in. The Sun is powered by nuclear fusion occurring at its center; in this process, hydrogen atoms are converted into helium, with energy released as a by-product. While the Sun is too bright to look into directly without damaging the eyes, special instruments can be used to observe the surface of the Sun. The surface is very active: on top of the basic granular surface appearance of the Sun, striking visible features include sunspots (relatively cool, darker regions,) prominences (cool, dense plasma extending outward from the surface,) and flares (great explosions on the Sun—the most violent eruptions in the Solar System.) The light emitted by the Sun brings energy to the rest of the Solar System and largely dictates the temperatures on the planets. Without the Sun, no life could exist on the Earth.

A Few Basic Facts About the Sun

Average distance from the Earth	150 million kilometers
Diameter	1.4 million kilometers
Mass	333,000 Earth masses
Rotation period (around its axis)	26-36 Earth days (varies from the equator to the poles)
Composition: main components	Hydrogen, helium
Temperature at the center	15.7 million ºC (28 million ºF)
Temperature on the visible surface	5,500ºC (10,000ºF)

For more information on the Sun, visit the NASA Solar System Exploration pagehttp://solarsystem.nasa.gov/planets/profile.cfm?Object=Sun

(Picture credit: Courtesy of SOHO/Extreme Ultraviolet Imaging Telescope (EIT) consortium. SOHO is a project of international cooperation between ESA and NASA; http://solarsystem.nasa.gov/multimedia/gallery/PIA03149.jpg)

MESSENGER Mission to Mercury

Mercury

A Few Basic Facts About Mercury

Average distance from the Sun	0.387 AU[1]
Diameter	4,880 kilometers
Mass	0.055 Earth masses
Orbital period (length of one year)	88 Earth days
Rotation period (around its axis)	59 Earth days
Length of one day (sunrise to sunrise)	176 Earth days[2]
Main composition	Rock
Atmosphere	Virtually a vacuum
Average surface temperature	170ºC (330ºF)
Moons	None

[1]*Astronomical Unit (AU) is the average distance from the Earth to the Sun.*
[2]*The length of one day can be quite different from the rotation period for a slowly rotating planet like Mercury.*

Mercury is the closest planet to the Sun. Its diameter is only a little more than a third of the Earth's, and it is smaller than some of the moons of the other planets (Jupiter's Ganymede and Saturn's Titan.) It has a very tenuous atmosphere, which is only a little more substantial than a vacuum. Sunlight heats up the surface of the planet to high temperatures during the day, up to 450ºC (840ºF). At night, the surface cools off rapidly, and the temperatures can drop down to –180ºC (–300ºF). This daily temperature variation is the largest of all of the planets. Mercury orbits the Sun once every 88 Earth days. Mercury's day is much longer than the Earth's. It rotates once around its axis every 59 Earth days; the slow rotation rate, combined with the planet's fast orbital period around the Sun, makes the the length of one day on Mercury is equal to 176 Earth days; that is, the time from one sunrise to another is 176 Earth days. There is no liquid water on Mercury, although it is possible that water ice could exist in the permanently shadowed craters near Mercury's poles. Mercury is a planet with a very large iron core and a thin mantle compared with the Earth. Mercury is bombarded by intense solar radiation since its atmosphere is not sufficiently thick to provide much protection (unlike the atmosphere of the Earth), and it is so close to the Sun. It is unlikely that any life could survive on Mercury, and it would be very inhospitable for any human explorers in the future. The first spacecraft to visit Mercury was Mariner 10, which flew by the planet three times in 1974 and 1975 and took images of about half of the planet's surface. Since Mercury is too close to the Sun to be safely imaged by the Hubble Space Telescope, the planet has remained largely unknown until recently. The robotic MESSENGER spacecraft flew by Mercury three times in 2008 and 2009, taking pictures of much of the unseen parts of the planet. In 2011 the spacecraft will go into orbit around Mercury to conduct a comprehensive study of the planet.

For more information on Mercury, visit the NASA Solar System Exploration page http://solarsystem.nasa.gov/planets/profile.cfm?Object=Mercury

(Picture credit: NASA/Johns Hopkins University Applied Physics Laboratory/Carnegie Institution of Washington; http://solarsystem.nasa.gov/multimedia/gallery/messenger_new_big.jpg)

MESSENGER
Mission to Mercury

Venus

A Few Basic Facts About Venus

Average distance from the Sun	0.723 AU[1]
Diameter	12,100 kilometers
Mass	0.815 Earth masses
Orbital period (length of one year)	225 Earth days
Rotation period (around its axis)	244 Earth days[2]
Length of one day (sunrise to sunrise)	117 Earth days[3]
Main composition	Rock
Atmosphere: main component	Carbon dioxide
Average surface temperature	462ºC (864ºF)
Moons	None

[1]*Astronomical Unit (AU) is the average distance from the Earth to the Sun.*
[2]*Venus rotates around its axis clockwise as seen from the north pole of the Sun, and not counterclockwise, as most other planets do; it is said to rotate in retrograde direction.*
[3]*The length of one day can be quite different from the rotation period for a slowly rotating planet like Venus.*

Venus is the second planet from the Sun and the brightest object in the Earth's sky after the Sun and the Moon. Venus is a near twin in size to the Earth but is otherwise very different. Venus's rotates around its axis very slowly, once every 244 Earth days. The slow rotation rate, combined with the planet's orbital period around the Sun—226 Earth days—makes the length of one day on Venus equal to 117 Earth days; that is, the time from one sunrise to another is 117 Earth days. In addition, Venus rotates in a clockwise direction when viewed from above the north pole of the Sun; this is opposite to the rotation of the Earth and most other planets. Venus has a very thick carbon dioxide atmosphere that traps heat from the Sun during the day and does not let the surface cool at night. As a result, the temperatures on the surface of Venus are over 464ºC (867ºF). Similar greenhouse effect operates also on the Earth, but on Venus the process went to extremes and raised the temperature to the high value seen today. To make the planet even more inhospitable, the atmospheric ressure on the surface of Venus is about 90 times as high as the air pressure at sea level on Earth. Any water that might have existed on the surface of Venus in the past has long since evaporated, and finding life on the planet is not likely (though not entirely impossible.) We may learn a lot about Earth by learning why Venus, in so many ways similar to the Earth, turned out so differently. The first spacecraft to visit Venus was Mariner 2, which flew by the planet in 1962. The planet has been subsequently visited by many other robotic spacecraft, including Venera 7, which in 1970 became the first human-made object to return data from the surface of another planet. In the 1990s the Magellan spacecraft used radar to peer through the thick atmosphere of Venus to map 98% of the planet's surface. The high temperature and unbreathable thick atmosphere makes the planet a hostile place for any explorers.

For more information on Venus, visit the NASA Solar System Exploration page http://solarsystem.nasa.gov/planets/profile.cfm?Object=Venus

(Picture credit: NASA; http://solarsystem.nasa.gov/multimedia/gallery/Venus_Clouds.jpg)

The Moon

A Few Basic Facts About the Moon

Average distance from the Earth	384,000 kilometers
Diameter	3,475 kilometers
Mass	0.0123 Earth masses
Orbital period (once around the Earth)	27.3 Earth days
Rotation period (once around its axis)	27.3 Earth days[1]
Length of one day (sunrise to sunrise)	29.5 Earth days[2]
Main composition	Rock
Atmosphere	Virtually a vacuum
Temperature range on the surface	–233 to +123ºC (–387 to +253 ºF)

[1]Because the Moon's rotation period around its axis and orbital period around the Earth are the same, the same side of the Moon always faces the Earth.
[2]The length of one day can be different from the rotation period for a slowly rotating object like the Moon.

The Moon is Earth's celestial neighbor. It is about 384,000 km (239,000 miles) from the Earth, and its diameter is about one quarter of the Earth's. It takes the Moon 27 1/3 days to go once around the Earth. The Moon's composition is very similar to those of the Earth and the other rocky, Earth-like planets in the Solar System. In fact, its similar composition to the Earth's crust material was a crucial clue in developing an understanding of its origin. The Moon is thought to have formed when a Mars-sized object smashed into the forming Earth billions of years ago. Material was blasted into orbit around Earth by this collision and later collected together to become the Moon. The surface of the Moon is heavily cratered as a result of meteoroid bombardment in the past. There are two main types of terrain on the Moon: the old, light-colored, heavily cratered highlands, and the younger, dark, smooth areas called maria. Many robotic spacecraft have explored the Moon throughout the history of space exploration, and the Moon has the unique privilege of being the only heavenly body that humans have ever visited. Between 1969 and 1972, six Apollo spacecraft landed on the Moon. The Apollo missions brought back a total amount of 382 kg (842 lbs) of rock samples from the surface of the Moon. Studies of these samples in laboratories here on the Earth have revealed lots of information about the composition, the structure, and the history of the Moon. There are currently plans to send humans back to the Moon and even establish a permanent colony there.

For more information on the Moon, visit the NASA Solar System Exploration page http://solarsystem.nasa.gov/planets/profile.cfm?Object=Moon

(Picture credit: NASA; http://solarsystem.nasa.gov/multimedia/gallery/PIA00405.jpg)

Mars

A Few Basic Facts About Mars

Average distance from the Sun	1.524 AU[1]
Diameter	6,790 kilometers
Mass	0.107 Earth masses
Orbital period (length of one year)	687 Earth days
Rotation period (around its axis)	24 hours 37 min
Main composition	Rock
Atmosphere: main component	Carbon dioxide
Average surface temperature	–63ºC (–81ºF)
Moons	2

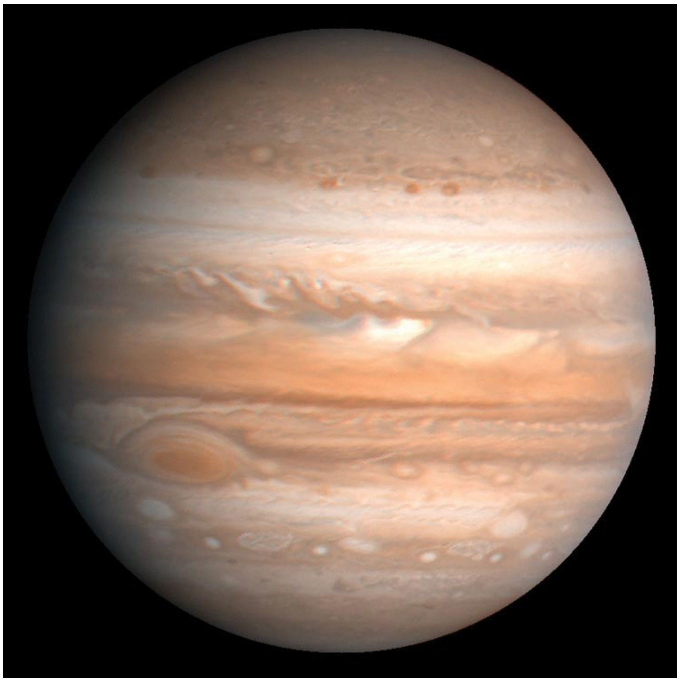
[1]*Astronomical Unit (AU) is the average distance from the Earth to the Sun.*

Mars is the fourth planet from the Sun. It is about half the size of the Earth in diameter. This makes the surface of Mars equal in area to all the land area on the Earth. The Martian day is about 43 minutes longer than the Earth day, and its year is 686 Earth days. Mars has a carbon dioxide atmosphere, but it is extremely thin, only about 1/100 as thick as the Earth's atmosphere. The thin air does not retain heat well, and surface temperatures range from a frigid –130ºC (–200ºF) on a winter night to 27ºC (80ºF) at the equator on a summer day. Mars appears red because iron contained in the rocks and the sand on its surface has combined with oxygen in the atmosphere through the same process that produces rust on the Earth. Mars occasionally has dust storms that cover the whole planet for months. Mars has polar ice caps made of carbon dioxide ice ("dry ice") and water ice. The size of the polar ice caps changes significantly during the planet's seasons. The first spacecraft to visit Mars was Mariner 4, which flew by the planet in 1965. Many robotic spacecraft have explored the planet since then. Two robotic rovers, Spirit and Opportunity, which have been roaming the surface of Mars since 2004, confirmed earlier suspicions that there used to be lots of liquid water on the surface of Mars in the past, in the form of rivers and seas. If there was plenty of water on the planet in the past, perhaps living beings could have existed there. Or, perhaps there are simple life forms still on Mars similar to bacteria on Earth that can survive in frigid conditions by creating anti-freeze chemicals that keep the water in their cells from freezing. In any case, Mars looks like the likeliest place for life to exist outside of the Earth. As a result, there are plans to send many other robotic spacecraft to Mars to explore the planet further, and even to return samples of Martian soil to Earth. Over the next few decades, Mars will probably become the second body in the Solar System after the Moon to host human visitors, and eventually to host the first colony of humans on another planet.

For more information on Mars, visit the NASA Solar System Exploration page http://solarsystem.nasa.gov/planets/profile.cfm?Object=Mars

(Picture credit: NASA; http://solarsystem.nasa.gov/multimedia/gallery/Hubble_Mars.jpg)

JUPITER



A FEW BASIC FACTS ABOUT JUPITER

Average distance from the Sun	5.204 AU[1]
Diameter	143,000 kilometers
Mass	318 Earth masses
Orbital period (length of one year)	11.9 Earth years
Rotation period (around its axis)	9 hours 56 min
Main composition	Gas
Atmosphere: main components	Hydrogen, helium
Average temperature at cloudtops	–161ºC (–258ºF)
Moons	At least 63

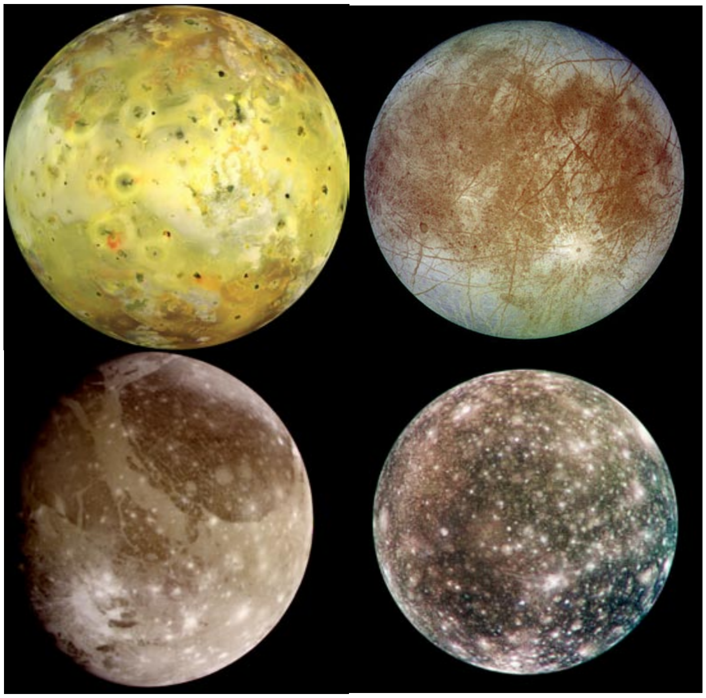
[1]*Astronomical Unit (AU) is the average distance from the Earth to the Sun.*

Jupiter is the fifth planet from the Sun and the largest planet in the Solar System. Its mass is 318 times the mass of the Earth, and over 1,300 Earths could fit inside of it. Jupiter is a gas giant mostly made of hydrogen and helium. Jupiter has no solid surface that we can see, and the apparent visible surface is just the top layers of clouds in its massive atmosphere. These upper layers of the atmosphere show complicated wind patterns. The winds blow in opposite directions in the light-colored zones and dark belts. Perhaps the most recognizable feature on Jupiter's visible surface is the Great Red Spot, a huge storm, more than twice the diameter of the Earth, which has been seen by observers on the Earth for more than 300 years. Deeper in the atmosphere, the gases become thicker until they eventually turn into a liquid. At its center, Jupiter may have a solid, rocky core a few times the size of the Earth, though based on current data, it is also possible that it does not have a solid core at all. Jupiter has at least 63 moons and a faint ring system. The ring system is much fainter than the rings of Saturn and was not discovered until the Voyager 1 and 2 spacecraft flew by the planet in 1979. Jupiter's day is about 10 hours long, and its year is about 12 Earth years. Jupiter radiates more energy into space than it receives from the Sun. This excess energy, produced by the planet being compressed under its own gravity, is thought to be ultimately responsible for the complex motions in Jupiter's atmosphere. The first spacecraft to visit Jupiter was Pioneer 10, which flew by the planet in 1973. The planet has since then been visited by several other spacecraft. It is unlikely that any life forms could live on the planet, and the lack of a solid surface on which humans could land on, as well as the high atmospheric pressure and high-energy radiation environment, make the planet a most challenging environment for any possible human visitors.

For more information on Jupiter, visit the NASA Solar System Exploration page http://solarsystem.nasa.gov/planets/profile.cfm?Object=Jupiter

(Picture credit: NASA; http://nssdc.gsfc.nasa.gov/imgcat/hires/vg2_usgs_1990.jpg)

Galilean Moons
Io, Europa, Ganymede, Callisto



The four largest moons of Jupiter (pictured in the left) are known as the Galilean moons, since they were discovered by Galileo Galilei in 1610. Jupiter's immense gravity exerts strong tidal forces on the moons. The tides bend and flex the rock of the crust and core of the moons, creating heat. The level of this tidal heating depends on the moons' distances from Jupiter, and the moons are quite different in their properties. Io (top left) is the innermost of the Galilean moons. The tidal forces from Jupiter generate enough heat to produce volcanoes and evaporate any ice and water the moon may have once had. With at least 180—and possibly as many as 400—active volcanoes, Io is the most volcanically active object in the Solar System, with a surface covered by sulfur, giving it the bright color. Europa (top right), the smallest of the Galilean moons, slightly smaller than the Earth's Moon, has a very smooth surface with few craters. The moon is covered by water ice that is probably a few kilometers thick, and underneath the ice there probably is a liquid water ocean. Ganymede (bottom left) is the largest moon in the Solar System, larger than the planet Mercury. It is the only moon known to have an internal magnetic field, possibly created the same way as the magnetic field of the Earth. Ganymede is thought to have an underground ocean, though the evidence is not quite clear as for Europa. Callisto (bottom right) is the second largest of the Galilean moons, and the third largest moon in the Solar System (after Ganymede and Saturn's Titan). Its surface is heavily cratered and ancient, and it does not appear to experience as much tidal heating as the other moons. However, it still may have a liquid water ocean under the surface. Since liquid water is thought to be one of the requirements for living beings, could life exist in the underground oceans? This question remains currently unanswered, but the Galilean moons will undoubtedly see new robotic spacecraft missions exploring this possibility in the future. The frigid temperatues at this distance from the Sun (–200°C; –390°F) and the dangerous high-energy radiation from Jupiter make the moons very uncomfortable places for any future human explorers.

A Few Basic Facts About the Galilean Moons

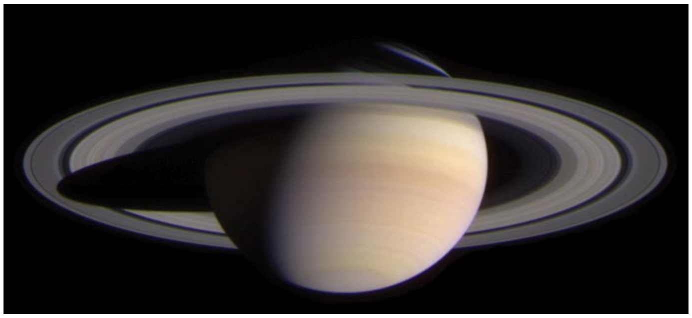
	Io	Europa	Ganymede	Callisto
Average distance from Jupiter	421,600 kilometers	670,900 kilometers	1,070,400 kilometers	1,882,700 kilometers
Diameter	3,640 kilometers	3,120 kilometers	5,260 kilometers	4,820 kilometers
Mass	0.015 Earth masses	0.008 Earth masses	0.025 Earth masses	0.018 Earth masses
Orbital period (around Jupiter)[1]	1.8 Earth days	3.6 Earth days	7.2 Earth days	16.7 Earth days

[1]Because the rotation period around the axis and the orbital period around Jupiter are the same for these moons, their same side always faces Jupiter.

For more information on the Galilean moons, visit the NASA Solar System Exploration page http://solarsystem.nasa.gov/planets/profile.cfm?Display=Moons&Object=Jupiter

(Picture credits: Io: NASA/JPL/University of Arizona, http://photojournal.jpl.nasa.gov/catalog/PIA02308; Europa: NASA, http://nssdc.gsfc.nasa.gov/imgcat/hires/gal_p48040.jpg; Ganymede: NASA/JPL, http://photojournal.jpl.nasa.gov/catalog/PIA00716; Callisto: NASA/JPL/DLR, http://photojournal.jpl.nasa.gov/catalog/PIA03456)

Saturn



A Few Basic Facts About Saturn

Average distance from the Sun	9.582 AU[1]
Diameter	120,500 kilometers
Mass	95.2 Earth masses
Orbital period (length of one year)	29.5 Earth years
Rotation period (around its axis)	10 hours 39 min
Main composition	Gas
Atmosphere: main components	Hydrogen, helium
Average temperature at cloudtops	–189ºC (–308ºF)
Moons	At least 61

[1]*Astronomical Unit (AU) is the average distance from the Earth to the Sun.*

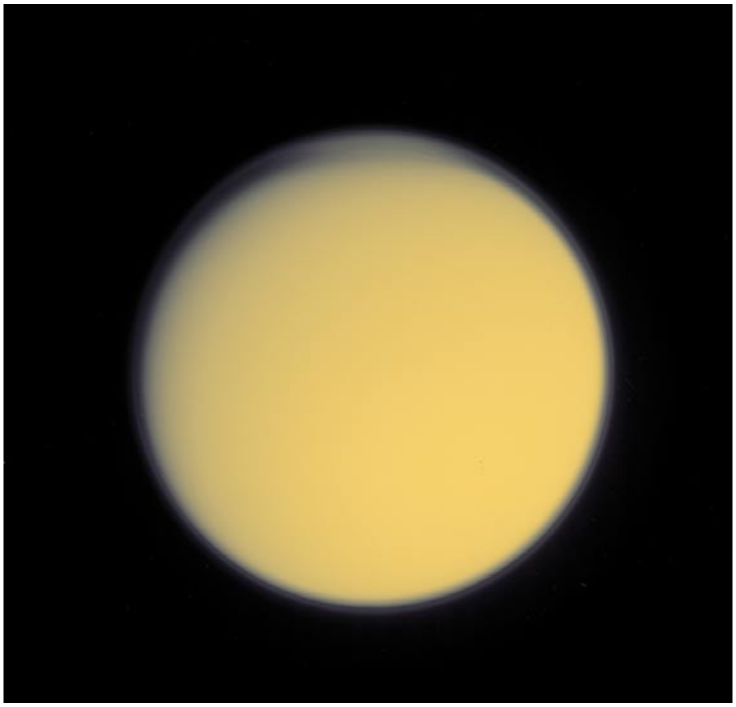
Saturn is the sixth planet from the Sun and the second largest planet in the Solar System after Jupiter. Its diameter is about 85% of Jupiter's but it is a lot lighter: its mass is about a third of Jupiter's. This means that it has a very low density. In fact, its density is the lowest of all the planets and less than the density of water. This leads to the popular description that in a planet-size bathtub filled with water, Saturn would float. Still, in composition and internal structure, the planet is thought to be fairly similar to its larger sibling, Jupiter. Like Jupiter, Saturn is a gas giant mostly made of hydrogen and helium gas. Saturn has no solid surface we can see, and the apparent visible surface is just the top layers of clouds in its atmosphere. These outer layers of the atmosphere have light-colored zones and dark belts, where the winds blow in opposite directions, but the bands are not as prominent as on Jupiter. Deeper in the atmosphere, the gases get thicker, until finally they turn into a liquid. At its center Saturn may have a solid core a few times the size of Earth, though based on current data, it is also possible that it does not have a solid core at all. Saturn's day is about 10.5 hours long, and its year is about 29.5 Earth years. Saturn has at least 61 moons, and perhaps many more that are yet to be discovered. Saturn's most striking property may be its exquisite ring system. All giant planets in the Solar System are surrounded by a complex ring system, but Saturn's ring system is, by far, the most extensive. The rings are surprisingly thin: they are 250,000 km (155,000 miles) in diameter, but their thickness is typically less than 10 meters (30 feet), though this varies somewhat within the ring system depending on the location and the size of the ring particles. Even though the rings look solid when viewed from the Earth, they are actually composed of millions of small icy particles varying in size from a centimeter (less than an inch) to a few meters (yards), and perhaps even to a size of a kilometer (half a mile). Scientists are still trying to determine the origin of the ring particles; the most commonly accepted suggestions are that they are particles blown off the planets' moons by asteroid or meteoroid impacts, or leftovers from the breakup of larger moons. Saturn radiates more energy into space than it receives from the Sun. Some of the excess energy comes from the planet being compressed under its own gravity, but some may come from other sources, such as helium gas condensing in Saturn's atmosphere into droplets and raining down deeper into the planet. The first spacecraft to visit Saturn was Pioneer 11, which flew by the planet in 1979. It has since then been visited by a handful of other spacecraft, most recently by the Cassini-Huygens spacecraft, which arrived at Saturn in 2004. It is unlikely that any life forms could live on Saturn, and the lack of solid surface on which humans could land on and the high atmospheric pressure make the planet an unlikely destination for human visitors.

For more information on Saturn, visit the NASA Solar System Exploration page http://solarsystem.nasa.gov/planets/profile.cfm?Object=Saturn

(Picture credit: NASA/JPL/Space Science Institute; http://solarsystem.nasa.gov/multimedia/gallery/Saturn_Approach.jpg)

MESSENGER
Mission to Mercury

Titan



Titan is one of the 61 known moons of Saturn, and the second largest moon in the Solar System (after Jupiter's Ganymede.) It is 1.5 as large in diameter as the Earth's Moon, and even larger in diameter than the planet Mercury. Titan's most interesting feature is that it is the only moon in to Solar System to have a significant atmosphere. At Titan's surface, the atmospheric pressure is 1.5 times that of the Earth's at sea level. The atmosphere is composed primarily of molecular nitrogen with a little argon and methane mixed in. In many ways, Titan's atmosphere is similar to the conditions on the Earth early in its history when life first emerged on our planet. But it is this thick hazy atmosphere that makes it so hard to see Titan's surface. Titan has been recently studied in detail by the robotic Cassini-Huygens spacecraft, which has been studying the Saturn system since 2004, and by the Huygens probe, which in 2005 flew through the moon's thick atmosphere and landed on the surface. The images taken by the spacecraft revealed an active surface with flowing liquids (composed of methane, rather than water) and many meteorological and geologic processes in action. Titan could have been a possible host for life, if it were not so cold—the temperature on the surface of Titan is frigid –180ºC (–290ºF)—that no living beings that we know of could survive on its surface. As a result, it is unlikely any living beings could have ever survived on the surface of Titan, and the moon would not be a comfortable environment for human visitors to explore.

A Few Basic Facts About Titan

Average distance from Saturn	1,221,800 kilometers
Diameter	5,150 kilometers
Mass	0.0225 Earth masses
Orbital period (once around Saturn)	15.9 Earth days
Rotation period (around its axis)	15.9 Earth days[1]
Atmosphere: main components	Nitrogen, methane
Average temperature at surface	–180ºC (–290ºF)

[1] Because Titan's rotation period around its axis and orbital period around Saturn are the same, the same side of Titan always faces Saturn.

For more information on Saturn, visit the NASA Solar System Exploration page http://solarsystem.nasa.gov/planets/profile.cfm?Object=Saturn&Display=Moons

(Picture credit: NASA/JPL/Space Science Institute; http://photojournal.jpl.nasa.gov/tiff/PIA06122.tif)

Uranus

A Few Basic Facts About Uranus

Average distance from the Sun	19.201 AU[1]
Diameter	51,100 kilometers
Mass	14.4 Earth masses
Orbital period (length of one year)	84.0 Earth years
Rotation period (around its axis)	17 hours 14 min[2]
Main composition	Gas, icy and rocky materials
Atmosphere: main components	Hydrogen, helium, methane
Average temperature at cloudtops	–220ºC (–364ºF)
Moons	At least 27

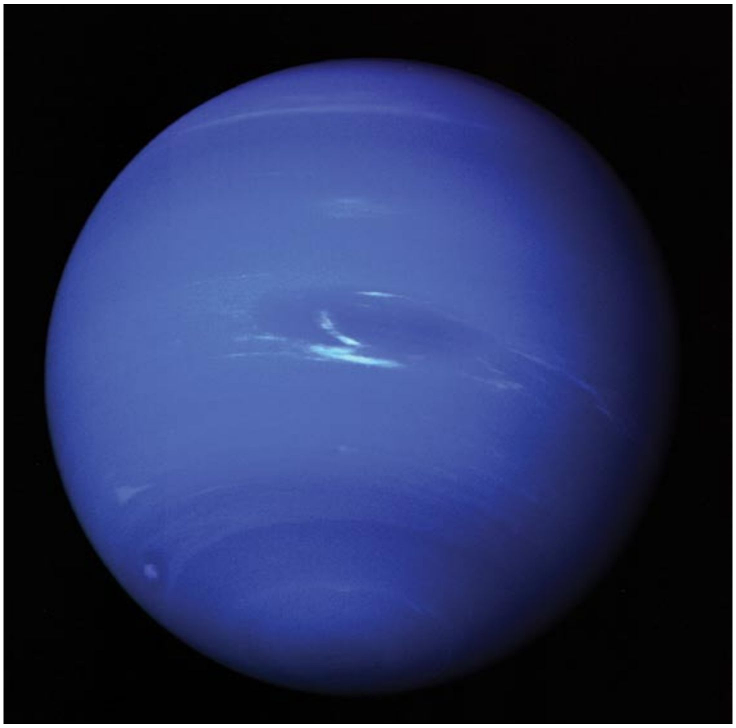
[1]*Astronomical Unit (AU) is the average distance from the Earth to the Sun.*
[2]*Uranus rotates around its axis clockwise as seen from the Sun's north pole, and not counterclockwise, as most other planets do; it is said to rotate in retrograde direction*

Uranus is the seventh planet from the Sun. It is smaller than Jupiter and Saturn, but similar to Neptune in size. Uranus's composition is a little different from Jupiter and Saturn in the sense that it seems to be made of mostly of a mixture of rocky and icy materials, and even though it has an extensive atmosphere by the Earth's standards, it is not as large a component of the planet as it is on Jupiter and Saturn. As a result, Uranus (as well as Neptune) is sometimes called an "ice giant" instead of a gas giant. Uranus has no solid surface that we can see, and the apparent visible surface is just the top layers of clouds in its atmosphere. These outer layers of the atmosphere have light and dark bands where the winds blow in opposite directions, but they are very faint and not visible in images taken of the planet without extensive image enhancements. However, it may be that the visibility of the bands changes according to the planet's seasons. Underneath Uranus's atmosphere, the mixture of icy and rocky materials is probably distributed uniformly, and the planet may not have a solid core at all. Uranus's day is about 17 hours long, and its year is about 84 Earth years. Uranus has at least 27 moons (and perhaps many more yet to be discovered.) Like the other giant planets, Uranus has a ring system, though it is much fainter than the rings of Saturn. Uranus's unique feature is that it appears to have been knocked over sometime in the past. Most planets orbit around the Sun spinning upright; that is, their rotational axes are almost perpendicular with respect to their orbit (with small deviations, like the Earth's 23.5º tilt). Uranus's rotation axis is almost lying within its orbital plane. The cause of this unique feature is not certain, but it may have been caused by an impact of a large object, such as an asteroid or a moon. Giant impacts like this were common during the early history of the Solar System; a similar impact is thought to have created the Earth's Moon. Unlike the other giant planets, Uranus does not appear to have an internal heat source. Why this is the case is not certain. The only spacecraft to have visited Uranus is Voyager 2, which flew by the planet in 1986. It is unlikely that any life forms could live on Uranus, and the lack of solid surface on which humans could land on, as well as the high atmospheric pressure make the planet a very difficult environment for humans to explore.

For more information on Uranus, visit the NASA Solar System Exploration page http://solarsystem.nasa.gov/planets/profile.cfm?Object=Uranus

(Picture credit: NASA and Heidi Hammel / Massachusetts Institute of Technology; http://photojournal.jpl.nasa.gov/tiff/PIA00032.tif)

Neptune



Neptune is the eighth planet from the Sun. It is smaller than Jupiter and Saturn, but similar to Uranus in size. Neptune's composition is a little different from Jupiter and Saturn in the sense that it seems to be made of mostly of a mixture of rocky and icy materials, and even though it has an extensive atmosphere by the Earth's standards, it is not as large a component of the planet as it is on Jupiter and Saturn. As a result, Neptune (as well as Uranus) is sometimes called an "ice giant" as opposed to a gas giant. We cannot see Neptune's solid surface, and the apparent visible surface is just the top layers of clouds in its atmosphere. Giant storm centers can be seen on its visible surface, similar to those on the other giant planets. Also, like on the other giant planets, the atmosphere has great wind patterns creating bands on the atmosphere where winds blow in different directions. In fact, the winds on Neptune are the fastest in the Solar System, reaching speeds of 2,000 km/hour (or 1,200 miles/hour) relative to the planet's interior rotation rate. Underneath the atmosphere, the mixture of icy and rocky materials making up the bulk of the planet is probably uniformly mixed, though there may be a solid core about the mass of the Earth at the planet's center. Neptune's day is about 17 hours long, and its year is about 165 Earth years. It has at least 13 moons; probably many more are yet to be discovered. Like the other giant planets, Neptune has a ring system, though it is much fainter than the rings of Saturn. The only spacecraft to have visited Neptune is Voyager 2, which flew by the planet in 1989. It is unlikely that any life forms could live on Neptune, and the high atmospheric pressure would make the planet quite inhospitable for human visitors.

A Few Basic Facts About Neptune

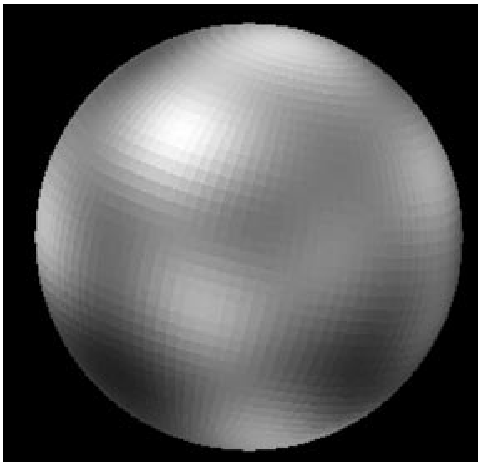
Average distance from the Sun	30.047 AU[1]
Diameter	49,500 kilometers
Mass	17.1 Earth masses
Orbital period (length of one year)	165 Earth years
Rotation period (around its axis)	16 hours 7 min
Main composition	Gas and icy materials
Atmosphere: main components	Hydrogen, helium, methane
Average temperature at cloudtops	–218ºC (–360ºF)
Moons	At least 13

[1] *Astronomical Unit (AU) is the average distance from the Earth to the Sun.*

For more information on Neptune, visit the NASA Solar System Exploration page http://solarsystem.nasa.gov/planets/profile.cfm?Object=Neptune

(Picture credit: NASA; http://solarsystem.nasa.gov/multimedia/gallery/Neptune_Full.jpg)

Pluto



A Few Basic Facts About Pluto

Average distance from the Sun	39.482 AU[1]
Diameter	2,390 kilometers
Mass	0.0021 Earth masses
Orbital period (length of one year)	248 Earth years
Rotation period (around its axis)	6.4 Earth days[2]
Moons	3
Main composition	Ice and rock
Atmosphere: main components	Methane, nitrogen
Average surface temperature	–223ºC (–369ºF)

[1]*Astronomical Unit (AU) is the average distance from the Earth to the Sun.*
[2]*Pluto rotates around its axis clockwise as seen from the north pole of the Sun, and not counterclockwise, as most major planets do; it is said to rotate in retrograde direction.*

Pluto used to be known as the ninth planet, but it always seemed a bit odd when compared with the other eight planets. Like the terrestrial planets (Mercury, Venus, the Earth, and Mars), it is small, but, because it is a mixture of rock and ice, its density is low, and it is not located in the same part of the Solar System as the terrestrial planets. Instead, it is located in the outer part of the planetary realm of the Solar System, where the giant planets reside, but it certainly is not a gas or an ice giant, either. Instead, Pluto appears to be more closely related to the hundreds of objects astronomers have discovered beyond Neptune's orbit in recent years. When one of these so-called Kuiper Belt Objects was discovered to be larger than Pluto, the International Astronomical Union decided in 2006 that Pluto cannot be considered a major planet any more, and instead belongs to a new class of objects called dwarf planets. As a result, there are now only eight major planets in the Solar System, and Pluto is an example of the new group of objects called dwarf planets. There are probably many more dwarf planets in the outer regions of the Solar System yet to be discovered. Pluto has three moons, but this is not unusual for smaller Solar System objects: many dwarf planets, Kuiper Belt Objects, and asteroids have moons. Pluto's day is about 6.4 Earth days long, and its year is about 248 Earth years. Pluto was discovered in 1930 by a fortunate accident. When scientists in the 19th and 20th centuries observed the orbits of Uranus and Neptune around the Sun, they noticed that the planets did not quite follow the predicted path in the sky. They deduced that there must be another planet-size object further out in the Solar System disturbing the orbits of these planets. Scientists started scanning the skies for planets in the places where the calculations suggested the planet (sometimes called "Planet X") would be, and in 1930 Pluto was discovered. However, it later turned out that Pluto's mass is much too small to cause the effects seen in the orbits of Uranus and Neptune. Eventually it was found out that the apparent problem with these observed orbits was not caused by a yet-to-be-discovered planet but by the fact that Neptune's mass was not known well at the time of the orbital calculations. We now know that no massive planet further out in the Solar System is needed to explain the orbits of Uranus and Neptune. Instead, Pluto's discovery turned out to be just fortunate happenstance. No spacecraft has ever visited Pluto. This will change soon, when the robotic spacecraft New Horizons, launched in 2006, will arrive at Pluto in 2015. The frigidly cold temperatures—the temperature on the surface of Pluto is thought to be –223ºC (–369ºF)—make it unlikely for any living beings to live on the dwarf planet, and they certainly make Pluto very inhospitable for any possible future human explorers.

For more information on Pluto, visit the NASA Solar System Exploration page http://solarsystem.nasa.gov/planets/profile.cfm?Object=Pluto

(Picture credit: NASA; http://solarsystem.nasa.gov/multimedia/gallery/nssdc_hst_pr96_09a.jpg)

MESSENGER
Mission to Mercury

Asteroids

A Few Basic Facts About Asteroids

Range of average distances from the Sun	Most between 1.1-3.0 AU[1], some up to 14 AU
Diameters	1-960 kilometers
Masses	Up to 0.0002 Earth masses
Orbital periods (around the Sun)	Most between 1.1 and 5.2, some up to 51 Earth years
Rotation periods (around their axis)	2.3 to 418 hours
Main composition	Rock
Moons	Some asteroids have moons

[1]*Astronomical Unit (AU) is the average distance from the Earth to the Sun.*

Asteroids are small rocky objects that can be found in different regions of the Solar System. They orbit the Sun like planets, but they are a lot smaller. Ceres used to be known as the largest asteroid; it is about 950 km (590 miles) in diameter. However, Ceres is now classified as a "dwarf planet", a new category of objects in the Solar System defined by the International Astronomical Union in 2006 to include objects like Ceres and Pluto, which are too small to be considered major planets, but resemble them in many other ways. Ceres is still associated with asteroids, since it is located in the same part of the Solar System as the vast majority of asteroids—the Asteroid Belt, a region between the orbits of Mars and Jupiter. The largest asteroids are Pallas, Vesta and Hygiea, which are between 400 km (249 miles) and 525 km (326 miles) in diameter. There are hundreds of thousands of known asteroids. Astronomers probably have seen almost all of the asteroids larger than 100 km, and about half of those with diameters in the 10-100 km range. But there are probably millions of asteroids with sizes in the 1 km range that have never been seen. Some of the moons of planets, such as the two moons of Mars and the outer moons of Jupiter and Saturn, are similar to asteroids, and they may be captured asteroids rather than having formed in the same way around the planet as other moons. Asteroids are thought to be remnants of the formation of the Solar System that did not accrete into the planets. There have been about a half-dozen spacecraft that have flown by asteroids, sometimes on their way to other destinations. The first spacecraft to take close-up pictures of an asteroid was Galileo, which flew by the asteroids Gaspra (in 1991), and Ida, as well as its moon Dactyl (in 1993), before heading to study Jupiter. The first spacecraft specifically designed to explore an asteroid was the Near-Earth Asteroid Rendezvous – Shoemaker spacecraft, which explored the asteroids Mathilde and Eros, and eventually landed on the surface of Eros in 2001. The spacecraft Dawn, launched in 2007, is planned to fly by Ceres and Vesta in 2011-2015. Because asteroids are small, they are unlikely to host living beings. However, they might be good sources of raw materials for future space explorers.

For more information on asteroids, visit the NASA Solar System Exploration page http://solarsystem.nasa.gov/planets/profile.cfm?Object=Asteroids

(Pictured above: Asteroid Gaspra; picture credit: NASA/JPL; http://photojournal.jpl.nasa.gov/tiff/PIA00118.tif)

Comets

A Few Basic Facts About Comets

Range of average distances from the Sun	2.2 – 1,170 AU[1]; perhaps up to 50,000 AU
Diameters	A few to up to 20 kilometers
Masses	1-10 trillionth of Earth mass
Orbital periods (around the Sun)	3.3 –40,000 Earth years; even more for more distant comets
Rotation periods (around their axes)	3 – 70 hours
Main composition	Ice and rock

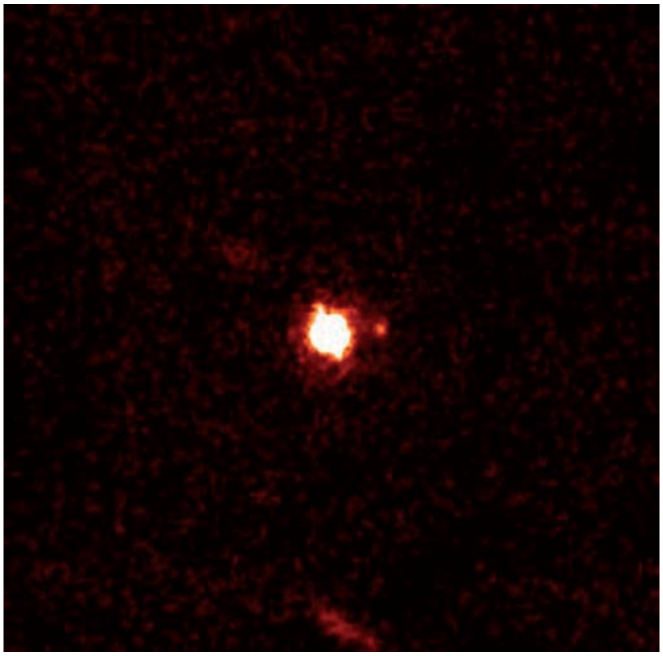
[1]*Astronomical Unit (AU) is the average distance from the Earth to the Sun.*

Comets reside in the outer regions of the Solar System. They are basically dirty ice balls composed of ices (water ice, as well as other kinds of ices, such as carbon dioxide, ammonia, and methane ices), rock, and dust. They are thought to be remnants of or the actual building blocks of (at least the outer) planets, and, therefore, are a subject of great interest for researchers interested in understanding the early history of the Solar System. Comets spend most of their time in the outer reaches of the Solar System and are not visible to observers on the Earth. There, the comet consists of only its solid body, the nucleus, which is only a few kilometers across and darker than charcoal. It is only when a comet's orbit takes it to the inner parts of the Solar System that a comet becomes observable. The Sun heats the frozen body of the comet, and causes ices on the comet's surface to sublimate—change directly from solid to gas. The gases blown off the nucleus, as well as specks of dust caught in the outflow, form a large cloud of gas and dust particles around the nucleus, called the coma, which can be over 1.6 million km (1 million miles) in size. Sunlight pushes against the dust particles in the coma, while the solar wind—fast outflow of electrically charged particles from the Sun—interacts with the gas. As a result, gas in the coma is pushed away from the nucleus, forming a very long tail stretching away from the comet pointed away from the Sun. It is not unusual for the tails of comets to extend tens of millions of kilometers. The dust that is forced off the coma forms a second tail that is curved away from the comet's direction of motion. If comets venture close to the Earth, they can be some of the most striking objects in the sky. There have been about a dozen robotic spacecraft that have explored comets, sometimes on the way to (or after flying by and exploring) other objects in the Solar System. The most famous comet-exploring spacecraft are perhaps Deep Impact, which released a probe that smashed into the comet Tempel 1 in 2005, and Stardust, which collected material from the coma of comet Wild 2 in 2004 and returned the captured samples to the Earth in 2006. Because comets are small, because they are located in the far reaches of the Solar System during much of their orbit and because they have very unstable surfaces when they get close to the Sun, they are unlikely to host living beings. However, they might be good sources of raw materials for future space explorers.

For more information on comets, visit the NASA Solar System Exploration page http://solarsystem.nasa.gov/planets/profile.cfm?Object=Comets

(Pictured above: Comet C/2001 Q4 – NEAT; picture credit: T. Rector (University of Alaska Anchorage), Z. Levay and L. Frattare (Space Telescope Science Institute) and National Optical Astronomy Observatory/Association of Universities for Research in Astronomy/National Science Foundation; http://solarsystem.nasa.gov/multimedia/gallery/Comet_NEAT.jpg)

Kuiper Belt Objects



Since 1992, astronomers have found hundreds of objects similar to Pluto beyond Neptune's orbit. These objects are all small icy worlds most commonly called Kuiper Belt Objects (KBO), after the astronomer Gerard Kuiper, though they are sometimes also called trans-Neptunian objects, because they reside in space beyond the orbit of Neptune. The Kuiper Belt region, located at a distance of 30 to 50 times as far from the Sun as the Earth, may have 35,000 objects with diameters larger than 100 km (60 miles). These objects are similar to Pluto: small objects made of a mixture of rock and ice. Most of the Kuiper Belt Objects discovered to date are smaller than Pluto, but detailed observations of an object named Eris, first discovered in 2003, revealed that it is larger than Pluto. This led the International Astronomical Union to decide in 2006 that Pluto (as well as Eris) belongs to a new class of objects called dwarf planets. There probably are more dwarf planets, in addition to smaller KBOs, yet to be discovered in the Kuiper Belt. Because the objects there are so far away from the Sun and are so small, they are hard to discover without powerful telescopes and advanced observation techniques. No spacecraft has ever visited any Kuiper Belt Object, though this may change in a few years, since the robotic spacecraft New Horizons, launched in 2006, is scheduled to fly by one or more Kuiper Belt Objects after flying by Pluto in 2015. The frigidly cold temperatures in the Kuiper Belt—the temperatures on the surfaces of KBOs are not thought to reach much above –230ºC (–450ºF)—make it unlikely for any living beings to live there, and these harsh conditions certainly make the objects very inhospitable destinations for human explorers.

A Few Basic Facts About Kuiper Belt Objects

Range of average distances from the Sun	30 – 50 AU[1]; maybe up to 135 AU
Diameters	37 – 200, maybe up to 2,400 kilometers
Masses	Varies, up to slightly more than 0.00021 Earth masses
Orbital periods (around the Sun)	200 – 300, maybe up to 770 Earth years
Rotation periods (around their axis)	3 hours to a few Earth days
Main composition	Ice and rock
Moons	Some Kuiper Belt Objects have moons

[1] *Astronomical Unit (AU) is the average distance from the Earth to the Sun.*

For more information on Kuiper Belt Objects, visit the NASA Solar System Exploration page http://solarsystem.nasa.gov/planets/profile.cfm?Object=KBOs

(Pictured above: Dwarf planet Eris; picture credit: Courtesy W. M. Keck Observatory; https://www.keckobservatory.org/images/gallery_pictures/4_73.jpg)

Famous Explorers

Name: ______________________________ **Date:** ______________________

Directions: Choose an explorer to research. Using the Internet, answer the questions below. If the explorer of your choice is included in *Student Internet Resources*, you may want to use the Web sites given there. If not, you can use Internet search engines or Web sites provided by your teacher to find information. After answering the questions, create a way to present your explorer to the class, either by making a poster or a short presentation.

Name of the Explorer: ______________________________

1. What was he or she exploring?

2. What experiences did the explorer have in his or her life that led to a passion to explore this area?

3. What questions do you think the explorer had when he or she began the exploration? Explain.

4. Did the explorer answer his or her questions, or are these ongoing explorations? Describe the results of the exploration.

5. What was the fundamental reason why he or she explored?

6. List the sources of information for your research.

Exploring the Solar System

Your team: ______________________________

____

____

Date: ______________________________

Directions: Read the *Space Exploration Card* describing the world you are going to investigate, and answer the questions below. After answering the questions, prepare a presentation on your world and why you would want to explore it. When preparing your presentation, follow the instructions given by your teacher.

The name of the world you are going to investigate: ______________________________

1. Why would you want to explore this world?

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2. What do you hope to learn about the world in your exploration?

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3. How would you want to explore this world? Would you like to send humans to do the exploration? Would you like to send a robotic spacecraft? Explain.

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4. How do you think your exploration builds on what previous explorations of this world have discovered already?

5. Do you think exploring this world will help us understand other worlds in the Solar System better? Explain.

6. Does your exploration need any special technology? Pay special attention to the environment in which the exploration will take place (For example: Is it hot? Cold? Will the exploration be done by humans or robotic equipment needing special protection from the environment?)

Based on your answers, write a proposal to NASA explaining in detail why you think NASA should fund a mission to explore your world. Use the following page for your proposal.

Proposal

World to be explored: ______________________________

Proposal Team/Principal Investigators: ______________________________

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Organization/School: ______________________________

Proposal to investigate the target world:

Answer Key

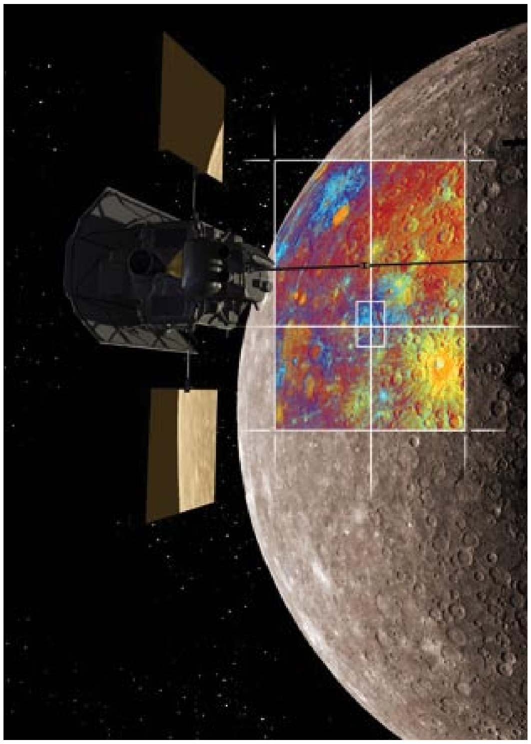
Student Worksheet 1

Answers will vary. Be sure the answers include careful thought into what motivated the explorer to undertake their exploration. You may also want to make sure the answers include topics discussed during the Warm-Up.

Student Worksheet 2

Answers will vary. Make sure the students explain the reasons for exploring their world, as well as how the exploration of their world connects with exploration in general.

MESSENGER Mission Information Sheet



MESSENGER is an unmanned NASA spacecraft that was launched in 2004 to study the planet Mercury. After three flybys of its target planet in 2008 and 2009, the spacecraft will go into orbit around Mercury in 2011. It will not land but will make detailed observations from orbit. MESSENGER will never return to the Earth, but will stay in orbit around Mercury to gather data until at least 2012.

MESSENGER is an acronym that stands for “MErcury Surface Space ENvironment, GEochemistry and Ranging,” but it is also a reference to the name of the ancient Roman messenger of the gods: Mercury, who, it was said, wore winged sandals and was somewhat of a trickster.

MESSENGER will be the second spacecraft ever to study Mercury; in 1974 and 1975 Mariner 10 flew by the planet three times and took pictures of about half the planet’s surface. MESSENGER will stay in orbit around Mercury for about one Earth year, during which time it will make close-up and long-term observations, allowing us to see the whole planet in detail for the first time.

During its mission, MESSENGER will attempt to answer several questions about Mercury. How was the planet formed and how has it changed? Mercury is the only rocky planet besides the Earth to have a global magnetic field; what are its properties and origin? What is the nature and origin of Mercury’s very tenuous atmosphere? Does ice really exist in the permanently shadowed craters near the planet’s poles? Mercury is an important subject of study because it is the extreme of the terrestrial planets (Mercury, Venus, Earth, Mars): it is the smallest, one of the densest, it has one of the oldest surfaces and the largest daily variations in surface temperature—but is the least explored. Understanding this “end member” of the terrestrial planets holds unique clues to the questions of the formation of the Solar System, evolution of the planets, magnetic field generation, and magnetospheric physics. Exploring Mercury will help us understand how our own Earth was formed, how it has evolved, and how it interacts with the Sun.

For more information about the MESSENGER mission to Mercury, visit: http://messenger.jhuapl.edu/

MESSENGER