National Aeronautics and Space Administration

The Solar System

A Tactile Representation

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www.nasa.gov

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Purpose of this Tactile:

This tactile and accompanying CD is intended for audiences of all ages and interests to explore the relative sizes and distances between the planets in our solar system. Have fun!

Information for this version was gathered from NASA missions, NASA funded scientists, and orbital and ground-based telescopes. For more information on the planets and our solar system, we encourage you to visit NASA's web sites such as:

General overview of the solar system:

solarsystem.nasa.gov
jpl.nasa.gov/solar_system

Direct link to cool information about the planets:

solarsystem.nasa.gov/planets/index.cfm
jpl.nasa.gov/solar_system/planets/planets_index.html

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To Scale by Size:

Before you begin your adventure with the planets and our star the Sun, imagine shrinking the Sun's diameter to 203 centimeters (or 80 inches), which is the height of an average size doorway. If the Sun would just fit in the doorway then the following table will give you an idea of the size of the other planets in our solar system.

Object in our Solar System	Diameter in centimeters (cm)	Comparable Object
Sun	203 cm	Height of doorway
Mercury	0.7 cm	Sweet Pea
Venus	1.8 cm	Dime
Earth	1.9 cm	Dime
Mars	1.0 cm	Round aspirin tablet
Jupiter	20.8 cm	Size 5 soccer ball
Saturn	17.5 cm	Size 3 soccer ball
Uranus	7.4 cm	Baseball
Neptune	7.1 cm	Baseball
Pluto	0.3 cm	BB

A Tour of the Tactile:

Welcome to a walkthrough of the Tactile Guide to the Solar System. Follow along with your fingers as we explore. The foldout describes a scale model of our solar system. It is often hard to show both scale to size and scale by distance because the sizes are so different and the distances are so great that it is difficult to combine the two. So we have separated them out into two tactiles. You will find comparative distances from the sun along the bottom of the foldout spanning both pages, and planet sizes on the right hand side of the foldout. Let's start with the comparative distances from the sun along the bottom of the foldout. Starting on the left is the sun. You'll notice a planet key on the left hand side above the scale line telling the abbreviations used for the planets.. We also have a scale of distances on the left hand page of the foldout. 1 centimeter equals 68 million Kilometers. If we start in the lower left corner with the dot that represents the sun, we find mercury, Venus, earth and Mars very close to each other, and very close to the sun. The sizes of the dots are the same, because we aren't comparing size here, only distance from the sun. The next bunch of dots represents the asteroid belt. After the asteroid belt, the next dot we encounter is labeled JU, which stands for Jupiter. After Jupiter comes then SA, Saturn, then UR , Uranus, way over on the right hand side of the left page, near the seam of the book. Following the line across the seam to the right hand page, we come to NE for Neptune, and finally towards the right side of the second page, we come to PL, Pluto.

To wrap up the comparative distances part of the tactile, as we ran our hands along this line at the bottom of the foldout, we found the relative distance of the planets from the

sun. The first four planets are very tightly compacted near the sun, with the other planets further from each other and from the sun.

Moving on, we'll explore the comparative sizes of the planets and sun. We find these on the right hand page of the foldout. On the left of this page we will find the sun. The rough surface of the sun is used to represent the sinuous fibers in the photosphere, the upper layer of the sun's atmosphere. We also feel an arch coming off the sun, as well as other areas where the surface has things coming off of it. The arch is a solar prominence, and the other areas are solar flares— both are bursts of energy coming from the sun. This is size of the sun in relation to the planets. We were only able to show a portion of the circle of the sun because it is so large. The inner planets in the first column are all pretty similar in size. Mercury is the smallest and the earth the largest, but they are all very close in size. As we move to the right hand set of planets, the outer planets, we'll notice how much larger Jupiter is than any of the other planets. Jupiter Saturn, Uranus and Neptune are called the giant gas planets. With Saturn, we'll notice that there is a ring around the planet. Uranus and Neptune are approximately the same size: much larger than the inner planets, but smaller than Jupiter or Saturn. Finally, we'll feel Pluto, a minor planet or dwarf planet, much smaller than the other outer planets. We have now compared the sizes of the objects in our solar system. The sun is the largest, followed by Jupiter, Saturn Uranus, Neptune, and the other planets.

This completes a walk through the comparative distances from the sun on the bottom of the foldout, as well as the comparative sizes of the planets on the right hand side of the foldout. We hope you have enjoyed this scale model and have had a chance to explore out solar system in more detail. You will find additional text that will provide more information about the planets on this CD, as well. Thank you for exploring the solar system with us.

Fun Facts About Each Planet

Supporting data comes from the National Aeronautics and Space Administration's Solar System Exploration page at: sse.jpl.nasa.gov/planets/index.cfm.

Four important notes for the reader:
1. All radii listed are based on radius as measured from the equator or what is called equatorial radius.
2. Volume listed for the planets are all given in the power of 10^{10} km^3 for the sake of comparing one to another.
3. Mass listed for the planets are all given in the power of 10^{24} kg for the sake of comparison.
4. The "Missions" list for each respective planet is not all inclusive but is designed to highlight a few of the significant missions and is ordered according to launch date listed. More mission information can be found at sse.jpl.nasa.gov/missions/index.cfm.

Sun

Radius at equator: 695,500 km (More than 100 Earth radii)
Volume: 1.4×10^{18} km^3 (1,304,000 x Earth)
Mass: 2×10^{30} kg (333,000 x Earth and 99.86% mass of entire solar system!)

Structure and Composition: The Sun is a huge, bright sphere of mostly ionized gas and is the closest star to Earth at a distance of about 150 million km. At the core, the temperature is 16 million degrees Celsius (°C), which is sufficient to sustain thermonuclear fusion reactions. The released energy prevents the collapse of the Sun and keeps it in gaseous form. The Sun's "surface," known as the photosphere, is just the visible 500-km-thick layer from which most of the Sun's radiation and light finally escape, and it is the place where Sunspots are found. Above the photosphere lies the chromosphere (sphere of color) that may be seen briefly during total solar eclipses as a reddish rim. Above the chromosphere lies the corona (crown), extending outward from the Sun in the form of the "solar wind" to the edge of the solar system. The corona near the Sun is extremely hot - millions of degrees Celsius.

Missions: STEREO (2006), Solar-B (2006), High Energy Solar Spectroscopic Imager (2002), Genesis (2001), TRACE (1998), Advanced Composition Explorer (ACE, 1997), Solar and Heliospheric Observatory (SOHO, 1995), ULYSSES (1990).

Mercury

Average Distance from Sun: 57,908,175 km
Radius: 2440 km
Volume: 6×10^{10} km^3
Mass: 0.3×10^{24} kg
Orbit: 88 days. Mercury speeds around the Sun in a wildly elliptical (non-circular) orbit that takes it as close as 46 million km and as far as 70 million km from the Sun.

Structure and Composition: Mercury is the closest planet to the Sun. Similar to our Moon, Mercury has almost no atmosphere. Because of this, temperatures on its surface can reach a scorching 427°C during the day and can drop to a frigid –178°C at night! With very little atmosphere to protect the surface, there has been no erosion from wind or water, and meteorites do not burn up due to friction as they do in other planetary atmospheres. Mercury's surface is very similar to Earth's Moon with scars from thousands of meteorite impact craters. There are areas of smooth terrain and there are also cliffs, some soaring up to a mile high, formed by ancient impacts. Mercury has a large iron core with a radius of 1,800 km making up nearly 75 percent of the planet's diameter and nearly the size of Earth's Moon. Mercury's outer shell, comparable to Earth's outer shell (called the mantle) is only 500 to 600 km thick. Due to cooling of the iron core, the outer crust (lithosphere) was compressed and contorted, effectively ending the planet's period of geologic activity.

Moons: None

Neat Facts: Mercury speeds through space at nearly 50 km per second, faster than any other planet.

Missions: MESSENGER (2008 flyby and orbit in 2011), Mariner 10 (1973-1975).

Venus

Distance from Sun: 108,208,930 km
Radius: 6,052 km
Volume: 93 x 10^{10} km^3 (0.9 x Earth)
Mass: 4.9 x 10^{24} kg (0.8 x Earth)
Orbit: 225 days

Structure and Composition: Earth and Venus are similar in size, mass, composition, and distance from the Sun; but there the similarities end. Venus has no ocean and a thick atmosphere creating a scorched greenhouse-like world with temperatures hot enough to melt lead and pressure so intense that standing on Venus would feel like the pressure felt 900 meters deep in Earth's oceans! In addition to trapping heat, these clouds reflect Sunlight, and Venus is usually the brightest planet in the sky. The atmosphere consists mainly of carbon dioxide, droplets of sulfuric acid, and virtually no water vapor - not a great place for people or plants! The thick atmosphere allows the Sun's heat in but does not allow it to escape, resulting in surface temperatures over 450°C day and night! The high density of the atmosphere results in a surface pressure 90 times that of Earth, which is why probes that have landed on Venus have only survived several hours before being crushed by the incredible pressure or destroyed by the intense heat. A Russian astronomer Lomonosov first discovered the thick atmosphere of Venus in 1761 during a transit of Venus in front of the Sun. A similar event occurred in 2004 and will again occur in 2012.

More than 1,000 volcanoes or volcanic centers larger than 20 km in diameter dot the surface of Venus. There may be close to a million volcanic centers that are over 1 km in diameter. Much of the surface is covered by vast lava flows. In the north, an elevated region named Ishtar Terra is a lava-filled basin larger than the continental United States. Volcanic flows have also produced long, sinuous channels extending for hundreds of kilometers. Venus' interior is probably very similar to that of Earth, containing an iron core about 3,000 km in radius and a molten rocky mantle covering the majority of the planet. Recent results from the Magellan spacecraft suggest that Venus' crust is stronger and thicker than had previously been thought.

Moons: None

Neat Facts: Venus sluggishly rotates on its axis once every 243 Earth days, while it orbits the Sun every 225 days - its day is longer than its year! Besides that, Venus rotates retrograde, or "backwards," spinning in the opposite direction of its orbit around the Sun. From its surface, the Sun would seem to rise in the west and set in the east. With few exceptions, features on Venus are named for accomplished women from all of Earth's cultures.

Missions: Venus is a significant planet in terms of mission history. It was the first planet to have a spacecraft land on its surface, the Venera 3 in 1966! The USSR sent 13 more spacecraft to this planet from 1967-1984. The United States sent the first interplanetary mission with Mariner 2 in 1962. The US sent 5 more spacecraft to Venus

including Magellan in 1989 which used the atmosphere of Venus to slow down, a method now referred to as aerobraking.

Earth

Distance from Sun: 149,597,890 km or about 150 million km
Radius: 6378 km
Volume: 108 x 10^{10} km^3
Mass: 6.0 x 10^{24} kg
Orbit: 365.24 days

Structure and Composition: Earth, our home planet, is the only planet in our solar system known to harbor life. Above the surface, an ocean of air that consists of 78 percent nitrogen, 21 percent oxygen, and 1 percent other ingredients envelops us. This atmosphere affects Earth's long-term climate and short-term local weather, and shields us from nearly all harmful radiation coming from the Sun. Oceans, up to 4 km deep, cover nearly 70 percent of Earth's surface.

Earth's thick mantle and thin crust are in constant motion. This causes Earth's land surfaces to also be in motion. For example, the North American continent continues to move west over the Pacific Ocean basin, roughly at a rate equal to the growth of our fingernails. Earthquakes result when plates grind past one another, ride up over one another, collide to make mountains, or split and separate. Volcanoes also dot the planet. The systematic location of most volcanoes and earthquakes; coupled with Wegener's theory of continental drift (1915) gave rise to the unifying theory of Plate Tectonics. Plate Tectonics is undoubtedly occurring on other planets and natural satellites.

Our planet's rapid spin and molten nickel-iron core give rise to a magnetic field, which the solar wind distorts into a teardrop shape. The solar wind is a stream of charged particles continuously ejected from the Sun. When charged particles from the solar wind become trapped in Earth's magnetic field, they collide with air molecules above our planet's magnetic poles. These air molecules then begin to glow and are known as aurora, or the Northern and Southern Lights.

Moons: One

Neat Facts: The four seasons are a result of Earth's axis of rotation being tilted 23.5 degrees and NOT the Earth's proximity to the Sun in its elliptical revolution around the Sun. Ironically, during summer in the northern hemisphere, the Earth is farther from the Sun than it is during the winter.

Earth's Moon

Average distance from EARTH: 384,400 km
Radius: 1737 km
Volume: 2×10^{10} km^3 (0.02 x Earth)
Mass: 0.07×10^{24} kg (0.01 x Earth)
Orbit about EARTH: Revolution with respect to stars is 27.3 days**,** Rotation - 27.3 days

Notice that the rotation period is the same as the revolution period. This is called a synchronous orbit; therefore viewers from Earth always see the same side of the Moon all the time! Even though viewers always see the same side or "face" of the Moon, the Moon is constantly changing its "phase." The changing phases are dependent upon where the Moon is in its orbit around the Earth with respect to the Sun. If it is found opposite the Sun, we see the entire illuminated portion and call it a Full Moon. Other times we see only a portion of the sun lit side and it appears as a gibbous, quarter or crescent Moon. Sometimes the Moon cannot be seen at all when it is located between the Earth and the Sun. This phase is called a New Moon.

Structure and Composition: How did the Moon form? The leading theory is that a Mars-sized body once hit Earth and the resulting debris (from both Earth and the impacting body) accumulated to form the Moon. Scientists believe that the Moon was formed approximately 4.5 billion years ago (the age of the oldest collected lunar rocks). Patterns of dark and light features on the nearside have given rise to the fanciful "Man in the Moon" and other descriptions. The light areas are lunar highlands, or small 'mountains'. The dark features, called Maria, are impact basins that were filled with dark lava between 4 and 2.5 billion years ago. The Moon's surface is charcoal gray and sandy with a powdery blanket of soil called the lunar regolith. Unlike Earth, the Moon does not have moving crustal plates or active volcanoes, nor does it have a magnetic field.

In 1998, the Lunar Prospector spacecraft team reported finding water ice at both poles. Comet impacts deposited water on the Moon. Some of it migrated to very dark, very cold areas, called traps, at the poles. Much remains to be learned about our Moon. Researchers continue to study the samples and data returned by Apollo and other missions, as well as lunar meteorites.

Neat Facts: More than 70 spacecraft have been sent to the Moon; 12 astronauts have walked upon its surface and brought back 382 kg (842 pounds) of lunar rock and soil to Earth.

Missions: India's first mission to the moon is Chandrayaan-1 and includes NASA's Moon Mineralogy Mapper (2008), Lunar Reconnaissance Orbiter (2008), Lunar Prospector (1998 – 1999), Clementine (1994), Hiten (1990 - 1993), Luna Program (1959 -1976), Apollo (1963 – 1972), Explorer -Moon(1966), Surveyor (1966 - 1967), Lunar Orbiter (1966 - 1967), Ranger (1964), Pioneer (1958-1959), Luna 2 – first craft to impact lunar surface (1959 – USSR)

Mars

Distance from Sun: 227,936,640 km
Radius: 3,397 km
Volume: 16 x 10^{10} km^3
Mass: 0.6 x 10^{24} kg
Orbit: 687 days

Structure and Composition: Mars is a small dynamic rocky body that has been changed by volcanism, impacts, movements of its crust, and atmospheric effects. It has polar ice caps that grow and recede with the change of seasons. Areas of layered soils near the Martian poles suggest that the planet's climate has changed more than once, perhaps caused by a regular change in the planet's orbit. Martian tectonics - the formation and change of a planet's crust - differs from Earth's. Where Earth tectonics involve sliding plates that grind against each other or spread apart in the seafloors, Martian tectonics seem to be vertical, with hot lava pushing upwards through the crust to the surface. Periodically, great dust storms engulf the entire planet. The effects of these storms are dramatic, including giant dunes, wind streaks, and wind-carved features.

Mars has some remarkable geological characteristics, including the largest volcanic mountain in the solar system, Olympus Mons (27 km high and 600 km across); volcanoes in the northern Tharsis region that are so huge they deform the planet's roundness; and a gigantic equatorial rift valley, the Valles Marineris. This canyon system stretches a distance equivalent to the distance from New York to Los Angeles and Arizona's Grand Canyon could easily fit into one of the side canyons of this great chasm.

Moons: Mars has two small carbon-rich moons, Phobos and Deimos. No one knows exactly how they formed, perhaps they were once asteroids captured by Mars' gravity.

Neat Facts: Unraveling the story of water on Mars is important to unlocking its past climate history, which will help us understand the evolution of all planets, including our own. Water is also believed to be a central ingredient for the early stages of life. The evidence of past or present water on Mars is expected to hold clues about past or present life on Mars, as well as the potential for life elsewhere in the universe. Before humans can safely go to Mars, we need to know much more about the planet's environment, including the availability of resources such as water. In 2002 the Mars Odyssey spacecraft detected large quantities of water ice close to the surface - enough to fill Lake Michigan twice over. The ice is mixed into the soil only a meter (about 3 feet) below the surface of a wide area near the Martian south pole.

Missions: US – Phoenix Mars Mission (2008), Mars Exploration Rovers, Spirit and Opportunity (2003), Mars Odyssey (2001), Mars Global Surveyor (1996), Mars Pathfinder (1997-1998), Viking (1976-1984), Mariner (1964-1971).
Soviet – Mars 2 crashed on Mars (1971), Mars 3 soft landing (1971).
European Space Agency (ESA) – Mars Express (2003-2004).

Asteroid Belt

Discovered: 1801 by Guiseppe Piazzi. In 1802, the astronomer William Herschel first used the word "asteroid," which means "starlike" in Greek, to describe these celestial bodies.

Distance from Sun: broad band mainly between Mars and Jupiter
Radius: varies from <1 km to more than 450 km
Mass: varies… The mass of the largest asteroid, Ceres, is 0.0009 x 10^{24} kg. That is less than 0.0002 times the mass of Earth and yet it is about a third of the total mass of asteroid belt objects combined.
Orbit: varies from about 1 to 50 years

Structure and Composition: Asteroids are rocky fragments left over from the formation of the solar system. Most of these fragments of ancient space rubble - sometimes referred to by scientists as minor planets - can be found orbiting the Sun in a belt between Mars and Jupiter. This region in our solar system, called the Asteroid Belt, probably contains millions of asteroids ranging widely in size from the minor planet Ceres, which at 913 km in diameter is about one-quarter the diameter of our Moon, to bodies that are less than 1 km across. There are more than 20,000 numbered asteroids. About three-quarters of asteroids are extremely dark and are similar to carbon-rich meteorites called carbonaceous chondrites. About one-sixth of asteroids are reddish, stony-iron bodies. The asteroids should be distinguished from Kuiper Belt Objects (KBOs) found beyond the orbit of Neptune. In general, KBOs are larger and contain more ice than asteroids. Many large KBOs are yet to be discovered and will probably rival the dwarf planet Quaoar with a diameter of 1250 km, Orcus with a diameter of 1600 km, and even Eris with a diameter of 2400 km.

Neat Facts: Scientists believe that stray asteroids and KBOs have slammed into Earth in the past, playing a major role both in altering the geological history of our planet and in the evolution of life on it. The extinction of the dinosaurs 65 million years ago has been linked to a devastating impact near the Yucatan peninsula in Mexico. Scientists define near-Earth asteroids as those whose orbits come close to or cross Earth's orbit (see Near-Earth Asteroid Tracking or NEAR for more information). Scientists also examine meteorites - the remains of comets or asteroids that can be found on Earth - for clues to the origin of these bodies.

Missions: NASA's Galileo spacecraft was the first to observe an asteroid close-up, flying by asteroids Gaspra in 1991 and Ida in 1993. Gaspra and Ida proved to be irregularly shaped objects, looking rather like potatoes, riddled with craters and fractures, about 19 km and 57 km long respectively. Galileo also discovered that Ida has its own moon, Dactyl, a tiny body in orbit around the asteroid that may be a fragment from past collisions.

NASA's Near-Earth Asteroid Rendezvous (NEAR) mission was the first dedicated scientific mission to an asteroid. The NEAR Shoemaker spacecraft caught up with asteroid Eros in February 2000 and orbited the small body for a year, studying its

surface, orbit, mass, composition, and magnetic field. In February 2001, mission controllers guided the spacecraft to the first-ever landing on an asteroid.

Jupiter

Distance from Sun: 778,412,020 km
Radius: 71,4932 km
Volume: 142,550 x 10^{10} km^3
Mass: 1,898.7 x 10^{24} kg (318 x Earth)
Orbit: 11.86 years

Structure and Composition: A small dense core with a huge, thick atmosphere. At first glance, Jupiter appears striped. These stripes are dark belts and light zones created by strong east-west winds in Jupiter's upper atmosphere. Large turbulent “storms” form between these zones like the southern hemisphere's Great Red Spot which has existed for at least 300 years, and perhaps longer, as Galileo reported seeing a similar feature nearly 400 years ago. Three Earths could fit across the Great Red Spot. Jupiter's core is probably not solid but a dense, hot liquid with a consistency like thick soup. The pressure inside Jupiter may be 30 million times greater than the pressure at Earth's surface.

Moons: On January 7, 1610, Italian astronomer, Galileo Galilei discovered Jupiter's four largest moons: Io, Europa, Ganymede, and Callisto. Collectively, these four moons are known today as the Galilean satellites. Io is the most volcanically active body in our solar system. Ganymede is the largest planetary moon and has its own magnetic field. A liquid ocean may lie beneath the frozen crust of Europa. An icy ocean may also lie beneath the crust of Callisto. Jupiter has at least 63 moons. Most, if not all, of the outer moons are probably asteroids captured by the giant planet's gravity.

Rings: Discovered in 1979 by NASA's Voyager 1 spacecraft, Jupiter's rings were a surprise. The inner ring is cloud-like and the main ring is flattened. A third ring extends outward from the main ring.

Neat Facts: With its numerous moons and several rings, the Jupiter system is a "mini-solar system." Jupiter is the most massive planet in our solar system, and in composition it resembles a small star. In fact, if Jupiter had been at least fifty times more massive, it may have become a star rather than a planet. As Jupiter rotates, a giant magnetic field is generated in its electrically conducting liquid interior creating the most deadly radiation environment of any of the planets, both for humans and for electronic equipment. The "tail" of Jupiter's magnetic field - that portion stretched behind the planet as the solar wind rushes past - has been detected as far as Saturn's orbit.

Missions: In December 1995, NASA's Galileo spacecraft dropped a probe into Jupiter's atmosphere. Carrying six scientific instruments, the probe survived the crushing pressure and searing heat for nearly an hour, collecting the first direct measurements of Jupiter's atmosphere. Cassini - Huygens (2000-2001), Galileo (1995-2003), Voyager 1 & 2 (1979), Pioneer 10 & 11 (1973, 1974).

Saturn

Distance from Sun: 1,426,725,400 km
Radius: 60,268 km
Volume: 82,713 x 10^{10} km^3
Mass: 596 x 10^{24} kg
Orbit: 29.46 years

Structure and Composition: Saturn is made mostly of hydrogen and helium with a tiny icy core.

Moons: Saturn has 60 known satellites (moons). The largest, Titan, is a bit bigger than the planet Mercury and second only to Jupiter's Ganymede among planetary satellites. Titan is shrouded in a thick nitrogen-rich atmosphere that might be similar to what Earth's was like long ago. In addition to Titan, Saturn has many smaller "icy" satellites. From Enceladus, which shows evidence of surface changes, to Iapetus, with one hemisphere darker than asphalt and the other as bright as snow, each of Saturn's satellites is unique.

Rings: In 1659, Dutch astronomer Christiaan Huygens first recognized that Saturn's "handles," as described by Galileo in 1610, were actually a ring encircling the planet. In 1675, Italian-born astronomer Jean Dominique Cassini discovered a gap between what are now called the A and B rings. In the early 1980s, NASA's two Voyager spacecraft revealed that Saturn's rings are far more complex than scientists expected; and they found "braided" rings, ringlets, and "spokes" with varying rotation rates. Saturn's ring system is the most extensive and complex in our solar system; it extends hundreds of thousands of kilometers from the planet. In fact, Saturn and its main rings would just fit in the distance between Earth and the Moon! Some of the small moons orbit within the ring system as well. Material in the rings ranges in size from a few micrometers to several tens of meters.

Neat Facts: Winds in the upper atmosphere reach 500 meters per second in the equatorial region. (In contrast, the strongest hurricane-force winds on Earth top out at about 110 meters per second.) Saturn has the lowest density of any of the other planets. In fact, it is less than that of water and would float if put into water!

Missions: The Cassini- Huygens spacecraft arrived July 1, 2004. Riding on Cassini's back, the Huygens probe landed on Saturn's moon, Titan. Cassini orbited Saturn more than 70 times during its four-year study of the planet, its moons, rings, and magnetosphere. Voyager 1 & 2 (1980, 1981), Pioneer 11 (1979).

Uranus (pronounced Yer uh nus)

Discovered: 1781 by astronomer William Herschel

Distance from Sun: 2,870,972,200 km
Radius: 25,559 km
Volume: 5914.2×10^{10} km^3
Mass: 86.8×10^{24} kg
Orbit: 84 years; Uranus currently moves around the Sun with its rotation axis on its side, nearly in the orbital plane. This unusual orientation may be the result of a collision with a planet-sized body early in the planet's history.

Structure and Composition: Uranus has no solid surface. The atmosphere of Uranus is hydrogen and helium, with a small amount of methane and traces of water and ammonia. The bulk (80 percent or more) of the mass of Uranus is contained in an extended liquid core consisting primarily of "icy" materials (water, methane, and ammonia), with higher-density material at depth.

Moons: Uranus has over 27 moons, named mostly for characters from the works of Shakespeare and Alexander Pope. Miranda is one of the strangest. The high cliffs and winding valleys of the moon may indicate partial melting of the interior, with icy material occasionally drifting to the surface.

Rings: First discovered in 1977, Uranus has 11 rings which are in the planet's equatorial plane, perpendicular to the plane of its orbit about the Sun. The 10 outer rings are dark, thin, and narrow, while the 11th ring is inside the other ten and is broad and diffuse. The rings of Uranus are very different from those surrounding Jupiter and Saturn. When viewed with the Sun behind the rings, fine dust can be seen scattered throughout all of the ring system.

Neat Facts: Uranus gets its blue-green color from methane gas above the deeper cloud layers (methane absorbs red light and reflects blue light). Uranus is so far from the Sun that, even though tipped on its side and experiencing seasons that last over twenty years, the temperature differences on the summer and winter sides of the planet do not differ that greatly, hovering around -215°C near the cloud tops. The absence of seasonal temperature changes is true of all the giant planets and is more a function of their atmospheres rather than any tilt of the rotational axis.

Missions: Voyager 2, 1986

Neptune

Discovered: 1846 by Galle and d'Arrest as predicted by two mathematicians, LeVerrier and Adams

Distance from Sun: 4,498,252,900 km
Radius: 24,764 km
Volume: 6253 x 10^{10} km^3
Mass: 102.4 x 10^{24} kg
Orbit: Once every 165 years, thus Neptune has made only one full orbit as of 2011 since it was discovered!

Structure and Composition: Neptune has the smallest diameter of our solar system's giant gas planets (including Jupiter, Saturn, and Uranus), so called because they have no solid surfaces. Neptune's volume could hold nearly 60 Earths. Neptune's atmosphere extends to great depths, gradually merging into water and other "melted ices" over a heavier, approximately Earth-sized liquid core. Neptune's seasons last an incredible 41 years. During the northern summer, the north pole is in constant Sunlight for about 41 years. Even with the extended seasons, the temperature on Neptune hovers around –212°C and the wind can blow over 1900 km/h! Neptune's atmosphere is made up of hydrogen, helium, and methane. Methane gives the planet its blue color (because methane absorbs red light).

Moons: Neptune has more than 13 moons, six of which were discovered by Voyager 2. The largest, Triton, orbits Neptune in a direction opposite to the planet's rotation direction, and is gradually getting closer until it will collide with the planet in about 50 million years, probably forming vast rings around Neptune that will rival or exceed Saturn's extensive ring system. Triton is the coldest body yet visited in our solar system; temperatures on its surface are about -235°C. Despite the extreme cold temperatures, Voyager 2 discovered great geysers of gaseous nitrogen on Triton.

Rings: The planet has several rings of varying widths, confirmed by Voyager 2's observations in 1989. Neptune's rings are believed to be relatively young and relatively short-lived.

Neat Facts: Neptune's winds are three times stronger than Jupiter's and nine times stronger than Earth's. In 1989, Voyager 2 tracked a large oval dark storm in Neptune's southern hemisphere. This hurricane-like "Great Dark Spot" was large enough to contain the entire Earth and moved westward at almost 1,200 km per hour. Recent images from the Hubble Space Telescope show no sign of the "Great Dark Spot."

Missions: Voyager 2, 1989

Pluto

Discovered: 1930 by Clyde Tombaugh, an American Astronomer

Distance from Sun: 5,906,376,200 km
Radius: 1,151 km
Volume: 0.64 x 10^{10} km^3 (0.006 x Earth)
Mass: 0.013 x 10^{24} kg (0.002 x Earth)
Orbit: 248 years in a highly elliptical orbit. The most recent closest approach to Earth was in 1989

Structure and Composition: The dwarf planet Pluto is the coldest known planet with a temperature estimated at -234ºC. Pluto is about two-thirds the diameter of Earth's Moon and may have a rocky core surrounded by a mantle of water ice. Due to its lower density, Pluto's mass is about one-sixth that of the Moon. Telescopic data show Pluto to have a bright layer of frozen methane, nitrogen, and carbon monoxide on its surface. Most scientists now classify Pluto as a dwarf planet or minor planet in the same vein as Ceres which is found in the asteroid belt. Other classifications refer to Pluto as a Kuiper Belt Object (see section on asteroids), since it is so similar to other KBOs. With respect to its position in the solar system, it is sometimes referred to as a Trans-Neptunian Object which is part of the Kuiper Belt.

Moon: Pluto has 3 known moons. Charon (pronounced SHAHR-en), was discovered in 1978. Charon's surface is covered with dirty water ice and doesn't reflect as much light as Pluto's surface. Charon is almost half the size of Pluto. Nix and Hydra were discovered in 2005 and make Pluto the only known KBO with more than one satellite.

Missions: New Horizons will explore both Pluto and the Kuiper Belt region beyond. New Horizon launched in 2006 and will reach Pluto in 2015.