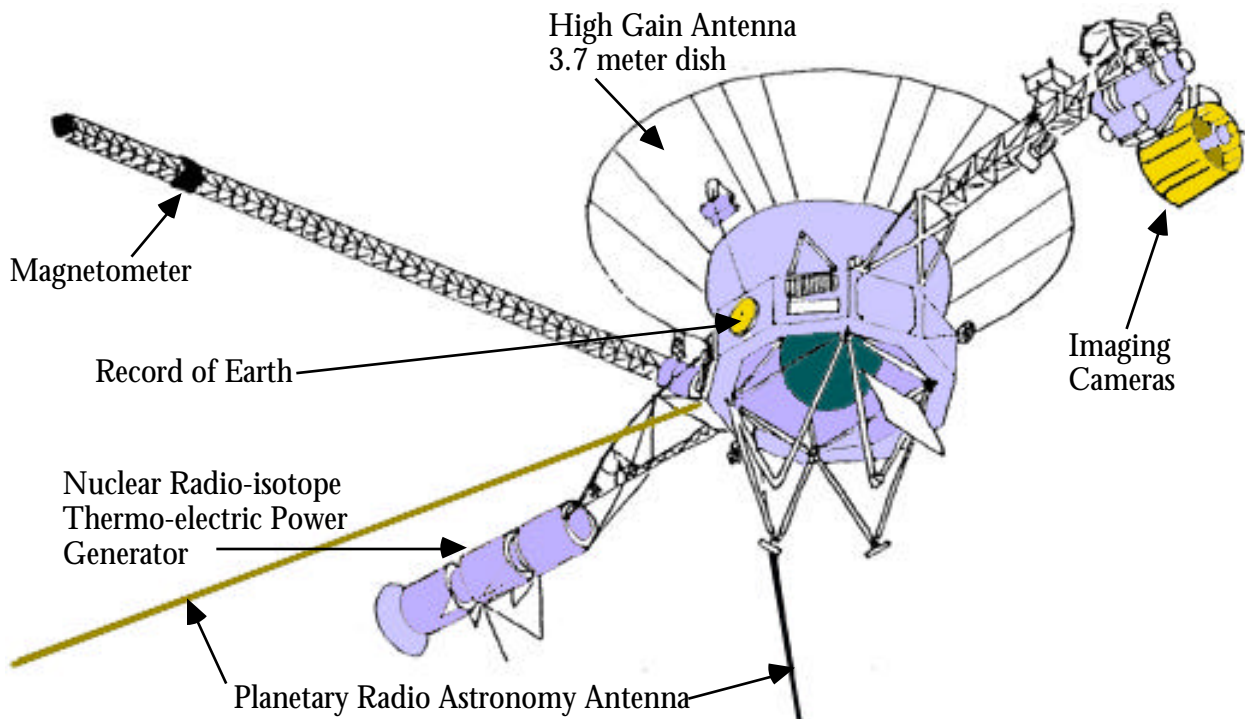
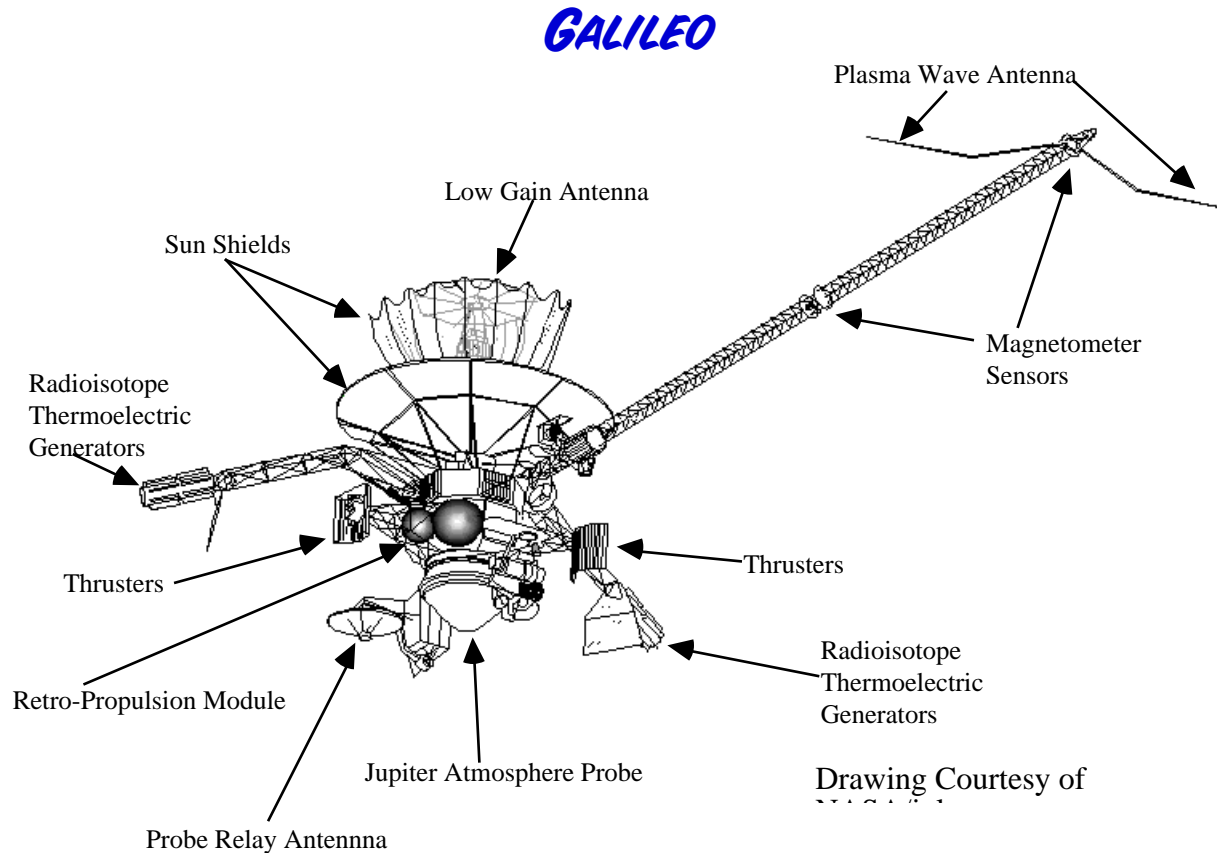


VOYAGER AND GALILEO: EXPLORATIONS OF THE OUTER PLANETS TEACHER'S GUIDE ★

"*Voyager and Galileo*" is a live planetarium show that explores the many discoveries made by the space probes: Voyager 1, Voyager 2, and Galileo. The show will follow the Voyager probes on their "*Grand Tour*" of the outer solar system. This means that our concentration will be on just four planets: Jupiter, Saturn, Uranus, and Neptune. Of course, we will take time to look at the rings and many of the moons that revolve around these four planets. It is interesting to see the difference between the Voyager images and those taken by the newer Galileo probe. The Galileo Mission ended on September 21, 2003 when Galileo plunged into Jupiter.

VOYAGER 1 & 2 (TWO IDENTICAL PROBES)





GALILEO FACTS:

Galileo was launched from the Space Shuttle on October 18, 1989. It took a long roundabout path to Jupiter which carried it past Venus, Earth, and the asteroids Gaspra and Ida. This long looping path was necessary to gain "gravitational assists" from both Venus and Earth which gave it the additional speed needed to reach Jupiter. *Galileo* arrived at Jupiter in December 1995.

On December 7, 1995 the *Galileo Atmospheric Probe* entered the atmosphere of the giant planet at a speed of 106,000 miles per hour! It's the fastest solid object created by people.

Galileo Orbiter weighs 2,223 kilograms or about 5000 pounds.

Galileo Atmospheric Probe weighs 339 kilograms or 746 pounds.

The Radioisotope Thermoelectric Generators (RTG's) that supply *Galileo's* power contain 7.8 kilograms (17.2 pounds) of Plutonium-238.

The entire probe uses about the same amount of energy as a 20 watt light bulb, like you'd find in a refrigerator.

Galileo's cameras can resolve objects as small as 12 meters or 39 feet.

Galileo's two gravitational assists with the earth helped the probe gain a lot of speed, but the earth in turn lost a bit of speed. How much? In 1 billion years the earth will be 5.2 inches behind in it's orbit from where it would have been if *Galileo* had not used the planet for a gravitational slingshot out to Jupiter!

PLANETARY FACTS:

JUPITER:

Jupiter was visited by Voyager 1 & Voyager 2 in 1979. Galileo reached Jupiter in December 1995. Jupiter is the largest and most massive planet in the solar system. It is larger and more massive than all the other planets, moons, and asteroids put together! The "Great Red Spot" is a hurricane that is three times larger than Earth. Atmospheric turbulence is kept in constant motion due to intense heat from Jupiter's core. It's the only planet that gives off more energy than it receives from the sun. Here are some basic statistics:



Distance from the Sun: 483.6 million miles (778.3 million kilometers)

Diameter: 88,733 miles (142,796 kilometers)

Length of year: 11.86 Earth years.

Length of day: 9 hours and 48 minutes

Mass: 317.9 Earths

Volume: 1,403 Earths

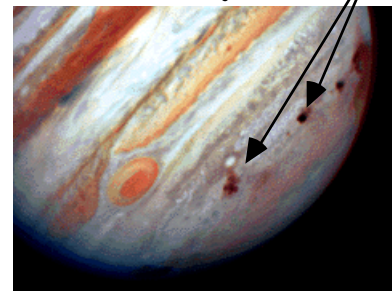
Gravity: 2.87 X Earth's gravity

Number of Known Moons: 63 + small Ring system

Temperature at the cloud tops: -243° F (-153° C)

Magnetic Field: 20,000 X stronger than Earth's.

Impact sites from Comet Shoemaker/Levy 9 7/94



In 1994 Jupiter was hit by **Comet Shoemaker/Levy 9**. When the pieces of the comet hit, they were travelling at nearly 130,000 miles per hour. Each piece exploded on impact creating huge earth-sized dark scars in the clouds.

MOONS:

---**Io** is the most volcanically active place in the solar system.

---**Ganymede** is the largest moon in the solar system, it's even larger than the planet Mercury!

---**Europa** shows evidence of a liquid ocean beneath its icy surface. Perhaps this might be the place to search for life!

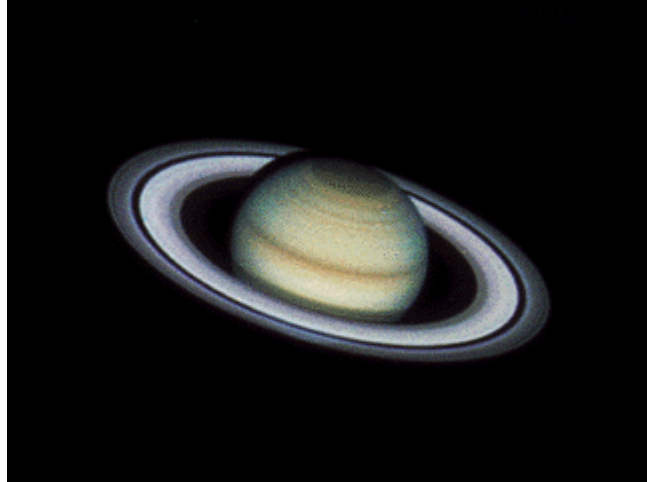
---**Callisto** has a very old surface that is as heavily cratered as any known moon.

---**Galileo Galilei** was the first person to see moons orbiting another planet when he looked at Jupiter through his telescope on January 7, 1610. What he saw were four small worlds that appeared to be orbiting Jupiter. They were Jupiter's four largest moons, Callisto, Ganymede, Europa, and Io.

PLANETARY FACTS:

SATURN:

Saturn was visited by the Voyager probes in 1980 and '81. The second largest planet in volume, Saturn is the least dense planet in the solar system. Saturn's density is so low it would float on water. Saturn has 31 known moons and more rings than any other planet. Here are some basic statistics regarding the ringed planet:



Distance from the Sun: 886.7 million miles (1,327 million kilometers)

Diameter: 74,600 miles (120,000 kilometers)

Length of year: 29.46 Earth years.

Length of day: 10 hours and 39 minutes

Mass: 95.17 Earths

Volume: 833 Earths

Gravity: .93 X Earth's gravity

Number of Known Moons: 60 and an extensive ring system

Temperature at the cloud tops: -301° F (-185° C)

Magnetic Field: 540 X stronger than Earth's and is tipped less than 1° from its rotational axis. It lines up with its rotational axis better than any other planet.

The rings around Saturn can be divided into seven major bands, each made of hundreds of smaller ringlets. The main rings are about 28,000 miles wide, while all the rings including the tenuous outer "E Ring" increase that width to over 250,000 miles! Yet with all this width they are not very thick between 33 and 330 feet thick.

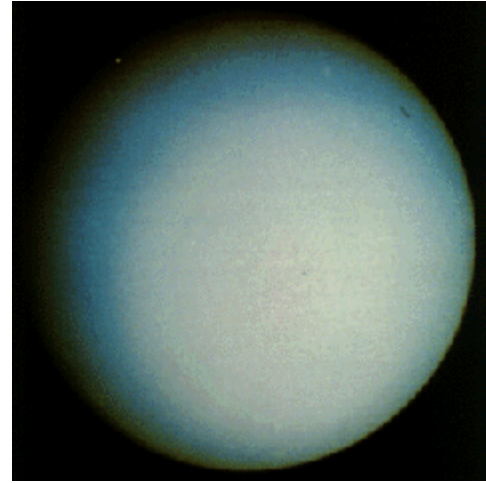
Even though Saturn is larger than Earth in volume, its density is so low that you would weigh less on Saturn than you would here on earth. A 100 pound person on Earth would only weigh 93 pounds on Saturn!

Titan, Saturn's largest moon, is the second largest in the solar system and one of two known moons to have substantial atmospheres. In fact, Titan's atmosphere is so thick with cloud cover that it is impossible to see through it to the surface.

PLANETARY FACTS:

URANUS:

Uranus is one of only two planets in the solar system that lies completely on its side as it revolves around the sun. (Pluto is the other.) It is the third largest planet and also has rings that go around the planet vertically. Uranus was the first planet to be discovered using a telescope. Its discoverer was William Herschel in 1781. Herschel originally named the planet "Georgium Sidus" after King George of England. Here are some basic statistics concerning Uranus:



A Planet named George?

Distance from the Sun: 1,782 million miles (2,869 million kilometers)

Diameter: 31,600 miles (50,800 kilometers)

Length of year: 84 Earth years.

Length of day: 16 hours and 48 minutes

Mass: 14.56 Earths

Volume: 63 Earths

Gravity: .80 X Earth's gravity

Number of Known Moons: 27 and a small vertical ring system

Temperature at the cloud tops: -350° F (-212° C)

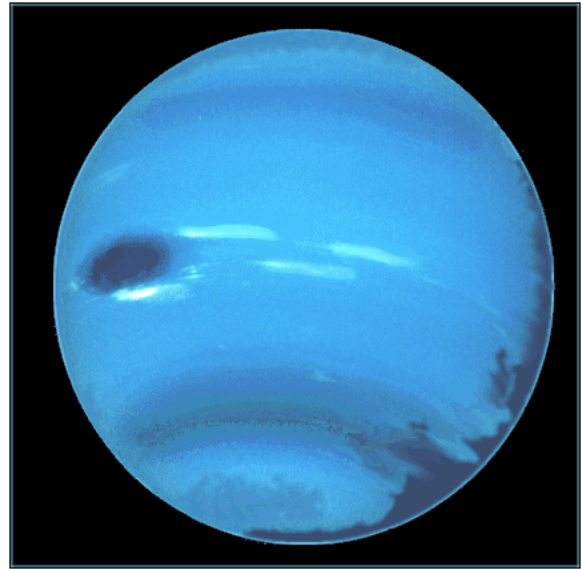
Magnetic Field: 48 X stronger than Earth's and is tipped 59° from its rotational axis

Voyager 2 is the only space probe to have reached Uranus. It arrived there in late January 1986. It was a special challenge for controllers at JPL due to the low light conditions (because of the extreme distance from the sun) and the fact that all the moon and rings orbit vertically. That meant that everything was encountered nearly at once, since Voyager 2 came in from the side. At other planets it was easier because the moons and rings were spread out sideways. This allowed the probe to encounter a moon, then another moon, a ring, the planet, rings again, and then perhaps another couple of moons. It allowed the whole encounter to be spread out over several days or even weeks. This was not the case with Uranus because the rings and moons are arranged vertically rather than horizontally. It required precision timing on the parts of the controllers. They did a remarkable job to say the least!

PLANETARY FACTS:

NEPTUNE:

Neptune is slightly smaller in volume than Uranus, but it is more massive. That means that Neptune is *heavier* than Uranus even though it is smaller. When Voyager 2 visited Neptune in August 1989 and took the picture to the right there were several distinct features visible. Most noticeable were the dark cloud bands, bright white high altitude cirrus clouds, and the "Great Dark Spot" which appeared to be an Earth sized storm, similar to the red spot on Jupiter. In 1995 the Hubble Space Telescope imaged Neptune and the Great Dark Spot and most of the white cirrus clouds had disappeared. This is obviously a very dynamic planet. Here are some basic statistics for Neptune:



Distance from the Sun: 2,794 million miles (4,497 million kilometers)

Diameter: 30,200 miles (48,600 kilometers)

Length of year: 168 Earth years.

Length of day: 16 hours and 3 minutes

Mass: 17.24 Earths

Volume: 55.3 Earths

Gravity: 1.23 X Earth's gravity

Number of Known Moons: 13 and a small ring system

Temperature at the cloud tops: -373° F (-225° C)

Magnetic Field: 25 X stronger than Earth's and is tipped 47° from its rotational axis.

Triton is Neptune's largest moon and is composed of rock and ice. It has a nitrogen atmosphere. It was discovered to have "ice volcanoes" by Voyager 2. It also revolves around Neptune in a clockwise direction when viewed from above the north, this is unusual, most moons revolve counter-clockwise.

Neptune also periodically crosses orbital paths with Pluto. In 1979 Pluto crossed inside Neptune's orbit, making Neptune the most distant planet for nearly 20 years. The date for Pluto to go back outside Neptune's orbit is February 17, 1999. Pluto will not venture inside Neptune's realm for another 228 years.

20 QUESTIONS TO CONSIDER:

1. What is the "Grand Tour"?
2. What is the "Great Red Spot"?
3. Why was a "recording of sounds and greetings from Earth" and pictures of people, animals, and places put on board each of the two Voyager Space Probes?
4. Why wasn't a similar "Record of Earth" put aboard the Galileo Probe?
5. Most space probes in the past have been solar powered. Why weren't either the Voyager probes or Galileo solar powered?
6. How do pictures taken by space probes get back to us on Earth?
- 7 & 8. The Voyager probes are moving at over 40,000 m.p.h.. Their small engines are only used for minor maneuvers, not general propulsion. How did the probes get going so fast? Why don't they slow down?
9. Jupiter has no solid surface to land a space craft on, yet it is impossible to fly through. Why?
10. Why didn't they design the Voyager or Galileo probes to return to Earth?
11. Why did they decide to name a probe, designed to orbit and study Jupiter, Galileo?
12. Who was Galileo Galilei?
13. Why is it significant that the Galileo Space Probe has found evidence of an ocean of water beneath the ices of Jupiter's moon Europa?
14. Io is the closest of the four large Galilean moons to Jupiter. It has many active volcanoes. Jupiter's gravity makes Io's solid surface have a tidal rise and fall of 330 feet. How do these two phenomena relate to each other?
15. On Galileo's journey to Jupiter it received two "gravitation assists" from Earth and one from Venus. These assists made Galileo increase speed. Did they have any effect on the planet?
16. What is telemetry?
17. Uranus and Neptune are often referred to as "twins", but Uranus is larger in volume than Neptune, yet Neptune is more massive than Uranus. Why should the more massive (heavier) planet be smaller?
18. Saturn is more than 800 times larger than Earth and more than 90 times more massive, yet if you visited the planet you would weigh less there than on Earth. Why?
19. What is a magnetic field?
20. Jupiter's magnetic field is 20,000 times stronger than the Earth's. It is so strong it strips a ton of material off Io each second! What would it do to an astronaut? How are probes protected?

MATCH THE PLANET TO THE MOON!

TITAN

MIMAS

GANYMEDE

MIRANDA

IO

PANDORA

TRITON

DIONE

NERIED

EUROPA

UMBRIEL

CALLISTO

AMALTHEA

IAPETUS

PROMETHEUS

JUPITER

SATURN

URANUS

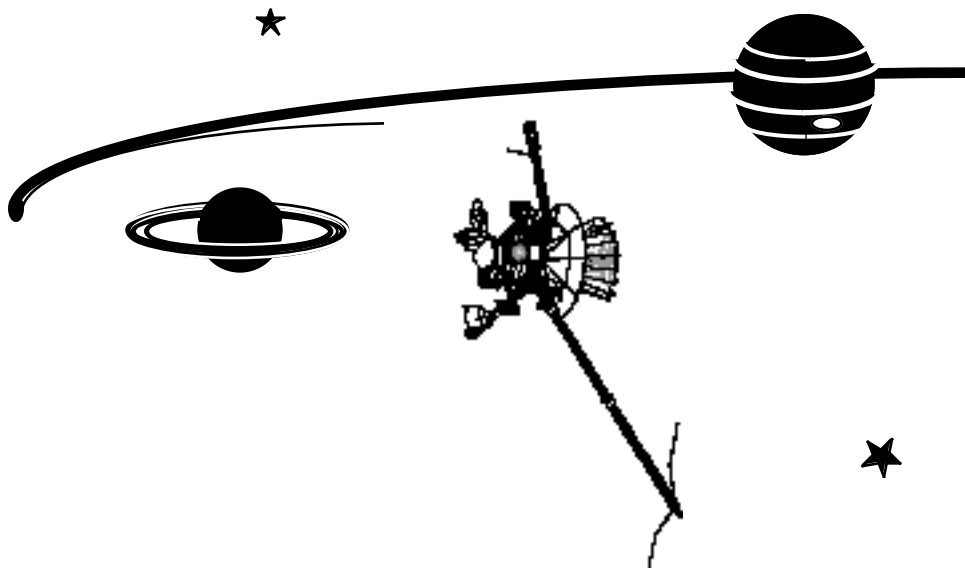
NEPTUNE

OUTER PLANETS WORD SEARCH

The following words are lost in the telemetry somewhere:

Jupiter Saturn Uranus Neptune Planets Red Spot Sun Clouds
Rings Titan Miranda Callisto Triton Mimas Io Europa Moons
Radio Waves Voyager The Grand Tour Rocket Camera Record
Antenna Probe Telemetry Kennedy Space Center

R E H N V J T E L E M E T R Y V I M D R
A W T I T A N G D L Z K I M I M A S P E
D H G H W O W E K C X B T I G N J P E D
I R M V E U R O P A L E F R E C O R D S
O V O Y A G E R A T V O C A I V P O J P
W U L C L L R M R Q U M U N C T R O U O
A H K A K D L A I U M N X D B E O R P T
V N G M G E L O N Z I O E A S H B N I A
E X W E V H T C G D R H O W H G E H T T
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K E N N E D Y S P A C E C E N T E R O V
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WEB SITES:

Nine Planets: <http://seds.lpl.arizona.edu/nineplanets/nineplanets/nineplanets.html>

Galileo Home Page: <http://www.jpl.nasa.gov/galileo/>

Galileo Site especially for kids: <http://eis.jpl.nasa.gov/~skientz/galileo/>

What's New with the Hubble Space Telescope: <http://oposite.stsci.edu/pubinfo/whats-new.html>

See Galileo Galilei's actual finger (ewwww, gross!) <http://www.jpl.nasa.gov/galileo/finger.html>

Build a scale model of the Galileo Space Probe: <http://www.jpl.nasa.gov/galileo/model.html>

Voyager 1 & 2 : <http://ringmaster.arc.nasa.gov/voyager/mission/mission.html>

Voyager Project Home Page: <http://vraptor.jpl.nasa.gov/voyager/voyager.html>

Shoemaker/Levy 9 Hits Jupiter: <http://pdcmoon.jpl.nasa.gov/~meyertr/Stardust/comets/sl9.html>

