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Educational Product	
Teachers & Students	Grades 9-12

Educational Brief

Subject: Planetary Science, Astronomy

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GALILEO: PROBE INTO JUPITER

Astronomer Galileo

On January 7, 1610 in Padua, Italy, Galileo Galilei aimed his newly invented telescope at Jupiter, the giant planet of the Solar System. He saw three star-like objects arranged in a line with the planet, one on the west and two on the east. A few nights of watching showed him there were four objects changing position about Jupiter. Galileo soon realized that these "stars" were small planetary bodies revolving around Jupiter like the Moon orbits Earth. He had discovered four big satellites of Jupiter. Later they were named Io, Europa, Ganymede, and Callisto, after four of Jupiter's lovers in Greek mythology. As a group they are known as the Galilean satellites of Jupiter. Astronomers and spacecraft scientists later discovered other smaller satellites of Jupiter. A retinue of 16 satellites makes the Jovian system a miniature of the Solar System.

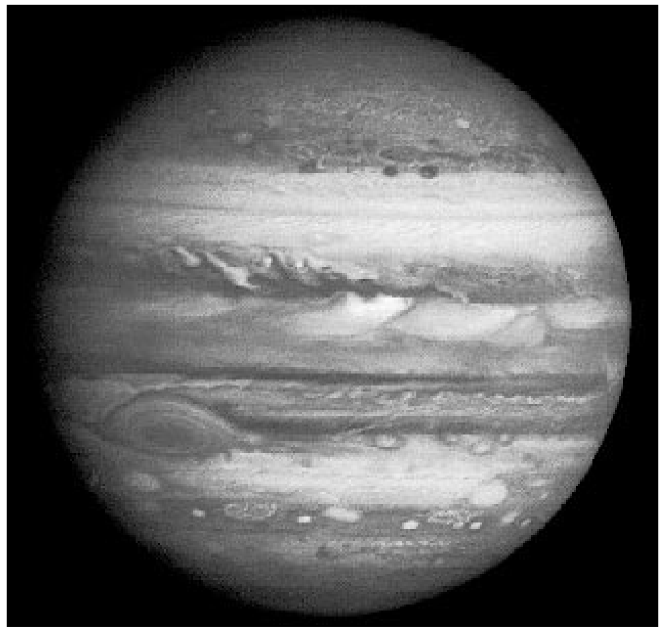
Project Galileo

It is fitting that the National Aeronautics and Space Administration's (NASA's) most ambitious Jupiter mission should be named after the Italian astronomer. Project Galileo, launched in 1989 on a six-year trip to Jupiter consists of a Jupiter Orbiter and a Jupiter Probe. The Orbiter will remain in orbit around the giant planet gathering data about the planet itself, its magnetosphere, and its satellites. The Probe will plunge into Jupiter's atmosphere at about 2:15 p.m. PST on December 7, 1995 and provide scientists with a wealth of information about that atmosphere and its cloud systems.

Ground-Based Observations

As more powerful telescopes were built, astronomers in their mountaintop observatories discovered tantalizing clues about the uniqueness of Jupiter. The planet's diameter is 11 times that of Earth. From Newton's laws of gravity and the orbits of the four large satellites, astronomers determined that Jupiter is massive but has a low density. This implies that the planet consists mainly of hydrogen. Jupiter, along with Saturn, Uranus, and Neptune, is a giant fluid planet, a gas giant. It is unlike the much smaller icy and rocky planets of which Earth is the largest. Jupiter spins much faster than Earth, so that its day lasts only 9 hours and 55 minutes compared with Earth's 24-hour day. The rapid spin and Jupiter's fluid nature give rise to a bulging equator that is quite apparent in telescopic views and photos of the giant cloud-shrouded planet. When viewing Jupiter, you only see clouds. No solid surface exists. Also, these clouds are very different from those of Earth.

When we view Earth from space, patterns of clouds are visible but a solid surface is also clearly seen. On Jupiter the cloud patterns are east-west bands consisting of dark belts of



A Voyager image of cloud-banded giant Jupiter and its Great Red Spot

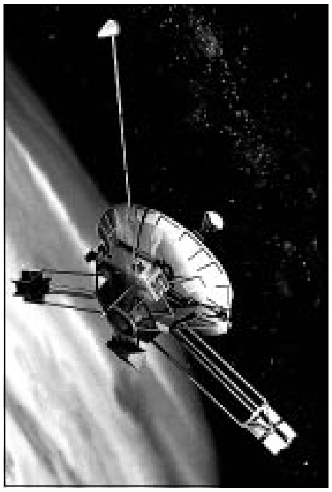
descending atmosphere and bright zones of ascending gases. Jupiter also has atmospheric spots, ovals, barges, and plumes, some of which may be like storms on Earth. The most famous and largest of these is the Great Red Spot.

Astronomers first measured the rotation of Jupiter by tracking cloud features in its atmosphere. They found a puzzling result called atmospheric superrotation; the rotation rate near the equator of this giant planet is faster than the rotation rate at high latitudes. By observing variations in radio waves emitted by electrons spiraling in Jupiter's tilted magnetic field (which is produced deep inside the planet), astronomers found the deep interior has a uniform rotation period of 9 hours and 55 minutes. Winds in the atmosphere are determined by comparisons to this period. The superrotation of the equatorial atmosphere of Jupiter is unlike Earth. Here the atmosphere at the equator lags behind the rotation of the planet so that winds blow from east to west. Scientists also found that Jupiter radiates into space about twice the amount of energy it receives from the Sun. This also is unlike Earth. The large "internal heat" may help explain the unusual winds on Jupiter.

While telescopes gave intriguing views of Jupiter major advances resulted when NASA spacecraft flew by the planet starting in the 1970s.

Exploration by Spacecraft

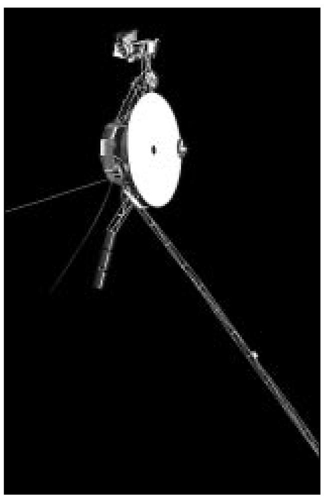
Scientists studying the giant planet entered a new era in 1972 when spacecraft began to explore the outer Solar System. Pioneer 10 was the first of four spacecraft to fly by Jupiter. Pioneers 10 and 11 were trailblazers, with Pioneer 11 swinging by Jupiter and continuing on to explore Saturn. They answered two basic questions about exploration of the outer Solar System. They showed that spacecraft could safely pass through the swarm of small planetary bodies (asteroids) in orbits between those of Mars and Jupiter.



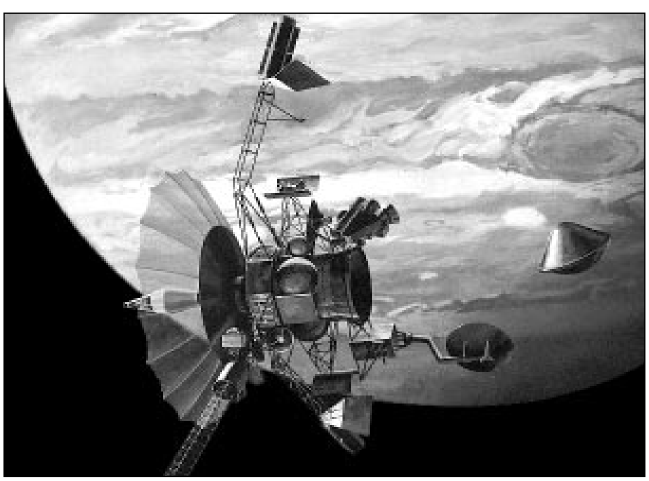
Pioneer 10

They also showed that spacecraft could pass relatively unscathed through the intense magnetic field and radiation environment of Jupiter. This showed that spacecraft could safely use a gravitational slingshot technique at Jupiter to reach more distant outer planets.

The Pioneers were followed by Voyagers 1 and 2. These NASA spacecraft made a more detailed survey of Jupiter and Saturn. Voyager 2 continued to Uranus and Neptune so that all the gas giants of the outer Solar System were explored. The Voyagers carried ad-vanced instrumentation and high resolution cameras and made many important discoveries. At Jupiter, the Voyagers sent to Earth detailed maps of the radiation environment and magnetosphere. The magnetosphere is the region around a planet where the planet's magnetic field is dominant and holds off the solar wind, the blizzard of charged particles streaming across the Solar System from the Sun. The Voyagers obtained high resolution images of the cloud systems of Jupiter, and detailed images of the planet's big satellites.



Voyager



Galileo

Volcanic plume on Io discovered by Voyager

The Hubble Space Telescope provided a follow-on from the Pioneers and the Voyagers by allowing a new era of long-term, detailed monitoring of the planet from low Earth orbit (LEO). Operating beyond Earth's atmosphere, the space telescope has major advantages over Earth-based telescopes.

Galileo is the next great step forward in Jupiter's exploration. The Probe and Orbiter carry a battery of instruments for increasing our understanding of this giant planet's atmosphere, as described in this Educational Brief. While the Probe will plunge deep into the planet's atmosphere, the Orbiter will also gather information about the atmosphere from orbit and will provide detailed observations of the Galilean satellites during close approaches to these bodies. Entering orbit in December 1995, the Orbiter will obtain detailed images of mysterious volcanic Io. Then the spacecraft's 11 science experiments will gather information about the giant planet and details of the four large satellites using slingshot gravitational techniques to navigate through the Jovian system until December 1997. That is when the nominal mission ends. In addition, it will extensively observe the strong magnetic fields and radiation belts of Jupiter's magnetosphere for those many months. The radiation belts are where electrons and protons are trapped in the planet's magnetic field. Galileo will greatly increase our understanding of the Jupiter system.

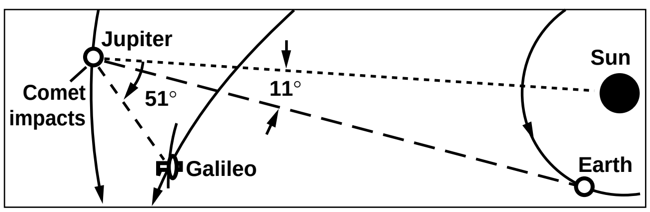
A spacecraft similar in size to Galileo, called Cassini, is due to be launched toward Saturn in October 1997 making this a most exciting era of exploration of the giants of our Solar System, their atmospheres, complex magnetospheres, and retinues of satellites.

Impact of a Comet

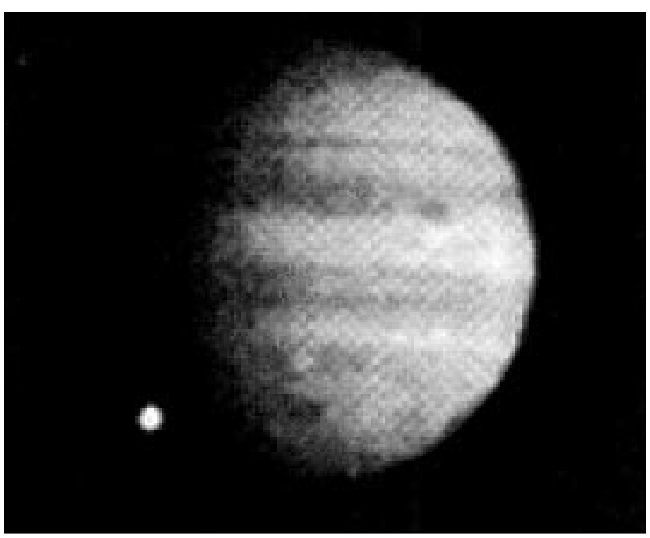
In 1994 an unusual circumstance provided scientists with an unexpected opportunity to investigate Jupiter's atmosphere and prepare for the experiments of the Galileo Probe mission. Comet Shoemaker-Levy 9, a string of cometary bodies, was headed for Jupiter. Astronomers calculated the comet's orbit and found that the comet had been captured by Jupiter. Calculations showed that Jupiter's strong gravity had broken the comet apart as it made a close approach to Jupiter, about 2000 km (1250 miles) above the giant planet's cloud tops, in 1992. Astronomers world-wide became excited about this comet when further calculations showed that the comet would crash into Jupiter at 210,000 km/hr (130,000 mph) in July 1994.

Powerful telescopes, including the Hubble Space Telescope, were aimed at Jupiter, but the comet fragments impacted Jupiter on its nightside where the impact could not be seen directly from Earth although some of the effects were observed. The atmospheric scars of each impact were seen later when Jupiter's rotation brought the impact sites into view. These scars were large enough to be seen by observers with relatively small telescopes.

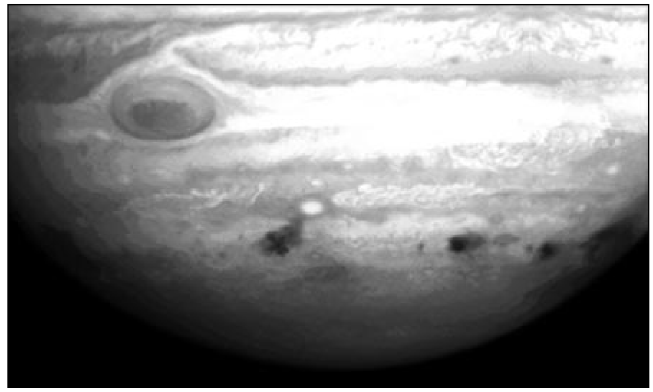
Fortunately, the Galileo spacecraft, speeding through interplanetary space toward Jupiter, could see the actual impacts from its vantage point in space. Images returned to NASA from the spacecraft showed the effects of the impacts as fireballs on the dark hemisphere of Jupiter. Observers on Earth also saw the spectacular effects of the impacts when hot gases surged into space over the visible edge of Jupiter. The series of impact events started when astronomers witnessed a dull infrared glow as a swarm of small debris plunged into Jupiter's atmosphere. Soon afterward the first large fragment of the comet plunged into Jupiter. Scientists calculated that it penetrated about 100 km (about 60 miles) into Jupiter's atmosphere before exploding into a large fireball. The enormous amount of released energy shot an incandescent plume of superheated gases some 3000 km (1850 miles) above the cloud tops. This cosmic explosion repeated as each of the 21 cometary nuclei hurtled into Jupiter. Some fireballs were so bright they momentarily outshone the planet itself. The scars from the impacts spotted the Jovian clouds with extensive dark areas surrounded by concentric circles.



Viewpoint of Galileo spacecraft for the Comet Shoemaker-Levy 9 impacts



Brilliant flash of an impacting comet fragment imaged by Galileo spacecraft



Dark spots produced by comet's impact

Coupled with the many ground-based observations, data gathered by the Galileo spacecraft gave scientists key information about the impacts. Scientists calculated the duration, size, and temperature of the fireballs. They analyzed the light coming from the fireballs and plumes and found evidence of many substances such as methane, sulfur, hydrogen sulfide, and carbon monoxide, and other molecules never before detected on Jupiter. Whether these substances came from Jupiter or from the comet cannot be settled yet. Galileo's Probe is expected to supply answers. One hope of astronomers was that by stirring up and disturbing Jupiter's deep atmosphere, the comet impacts could tell us more about the mysterious region below the visible cloud tops. A preliminary analysis of the dark concentric blemishes as they moved away from the impact sites suggests they are waves like ripples from a rock thrown into a pond. The speed and structure of these waves suggest that the deep atmosphere of Jupiter has a very high abundance of water. Again, the Galileo Probe should help resolve this question.

Mysteries of Jupiter

Astronomers have gathered sufficient information to conclude that Jupiter's composition is similar to that of the Sun. This supports theories about planets accreting from a solar nebula—the vast cloud of gas and dust which billions of years ago condensed to form the Sun and planets. However, scienthe Sun, By accurately comparing the composition of Jupiter's atmosphere to the Sun's, we can learn about how planets formed and the origin of the Solar System.

Images of Jupiter show that the planet is veiled by clouds. But these clouds could not be penetrated even with the high resolution instruments on board the Voyager spacecraft. Scientists think that Jupiter's visible clouds consist of ammonia, but this composition is not entirely certain. A problem with ammonia is that it is white whereas the Jovian clouds are colorful. These colors are a mystery also. Scientists think that the colors are due to sulfur compounds or organic materials in the atmosphere. Solar abundances of elements would suggest that beneath the clouds there are probably various cloud decks of different compositions. But this would depend on abundances of materials in the original solar nebula at Jupiter's distance from the Sun. Scientists also speculate that Jupiter might have water clouds like Earth.

Researchers discovered that Jupiter has multiple east-west jet streams traveling at up to 400 km/hr (250 mph) that are related to the cloud bands on the planet. Several years of observations with the Voyager spacecraft and the Hubble Space Telescope have shown that the jet streams have maintained the same strength and location for at least ten years. In contrast with Earth's jet streams the Jovian streams are very stable. We do not yet know why. Also, we want to know how far into Jupiter these winds extend.

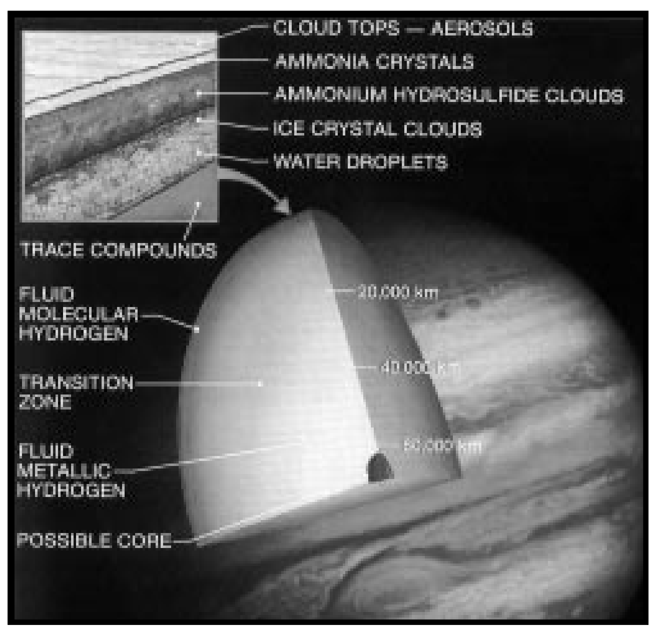
A major question is the power source driving the winds of Jupiter. On Earth, energy from sunlight heats the atmosphere more at the equator than at the poles. Resulting temperature and pressure differences combined with the Earth's rotation produce the major wind patterns on our planet. At Jupiter, sunlight is much weaker and is probably not sufficient to drive the Jovian wind systems. For Jupiter a source other than or in addition to sunlight is necessary to power the winds. Most likely the internal heat makes major contributions. Also there may be energy derived from the latent heat of water — rising water vapor, cooling to where water condenses into droplets, releases heat — or from latent heat of other substances. This could contribute to the driving energy of Jupiter's wind systems. By the Probe's measurements of where sunlight is deposited in the cloudy atmosphere, and the depth of the winds, important clues about the origin of Jupiter's winds can be had.

A prominent feature of Jupiter's cloud system is a Great Red Spot that has been observed for almost 400 years. The spot is an extensive vortex storm, somewhat like a hurricane on Earth. Its diameter is about twice Earth's diameter. The intensity and size of the spot has, however, varied over the many years that it has been observed. Big questions awaiting answers are why is it red and why is it so permanent? Earth's storms last for days or weeks only. Also, why is there only one red spot? Increased knowledge about Jupiter's atmosphere is expected to solve these mysteries.

Twice as much heat leaves Jupiter as that arriving from solar radiation. This heat could be escaping from the interior of Jupiter by large scale convection like a boiling pot of water, or by narrow plumes like those in thunderstorms. Rising columns of air produce thunderstorm-like features. Spacecraft have recorded brilliant lightning flashes in Jupiter's atmosphere. These are far brighter than typical lightning occurring on Earth. On Jupiter, lightning seems to occur in a few favored locations on the planet, unlike Earth where it is distributed fairly randomly over land and sea. The mystery is why? Another question that may be answered by Galileo is whether or not these lightning bolts originate in water clouds as lightning does on Earth.

Scientists think that the internal heat of Jupiter comes from the gravitational contraction of this huge fluid world together with heat left over from the formation of the planet. Soon after its formation Jupiter was most likely much hotter than it is now, almost approaching a second star in our Solar System. The Galilean satellites were heated and atmospheres driven from them. However, Jupiter did not possess sufficient mass for nuclear reactions to start converting hydrogen into helium, the power source that makes stars shine.

The interior of Jupiter is very different from those of the Solar System's terrestrial planets. These inner planets — Mercury, Venus, Earth, and Mars — are rocky bodies possessing thin atmospheric shells. By contrast Jupiter is unlikely to have a solid surface. Studies of the density, size, shape, rotation, and gravitational field of Jupiter allowed scientists to approximate what the interior of Jupiter is like. There is a deep atmospheric shell of mainly gaseous hydrogen and helium below which pressure and temperature are high enough for a liquid hydrogen shell. Deeper still the hydrogen is converted into a shell of metallic hydrogen in which currents give rise to Jupiter's intense magnetic field — the strongest of all planets of the Solar System. At the center of the metallic hydrogen region there may be a small rocky core consisting of rocks that because of the extremely high temperature and pressure must be unlike any rocks we know on Earth.



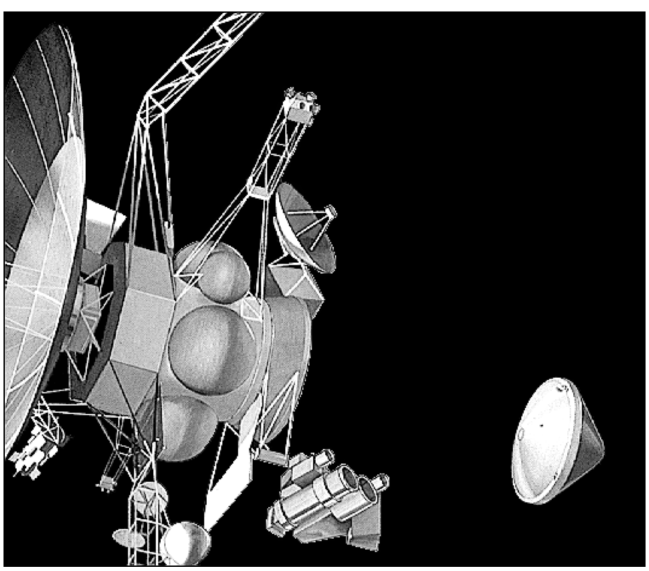
Structure of Jupiter based on data gathered prior to Project Galileo

Searching for Answers: Galileo Entry Probe and Orbiter

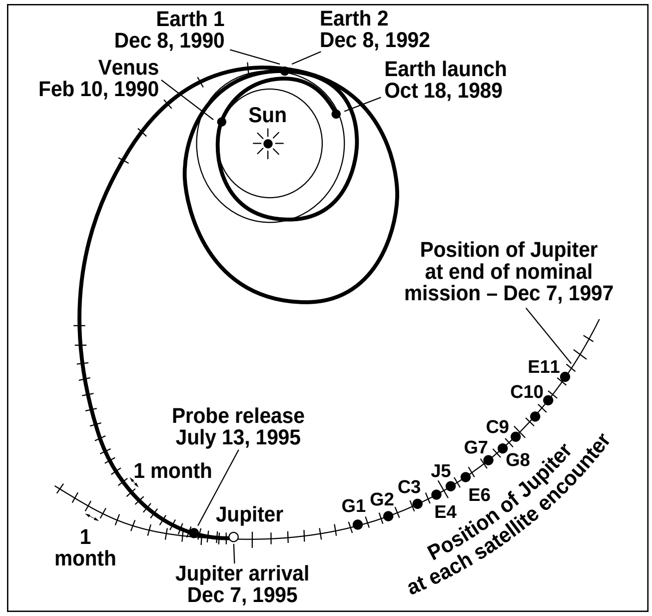
Project Galileo will orbit a spacecraft around Jupiter and send a probe deep into Jupiter's atmosphere to solve many of the puzzles about the giant planet. Galileo is a project sponsored by the National Aeronautics and Space Administration. The Jet Propulsion Laboratory has overall project management and responsibility for the Orbiter, mission design, and mission operations. NASA's Ames Research Center is responsible for the Atmospheric Entry Probe built by Hughes Space and Communications Group. Scientists expect that Galileo will provide not only information about Jupiter, but also important evidence about the origin and evolution of the Solar System. In addition it will provide new insights into phenomena that directly relate to our understanding of all the planets including Earth.

Originally scheduled for launch in January 1982, Galileo was delayed several times by development and scheduling problems in the Space Shuttle and rockets it could carry to boost interplanetary missions out of Earth's orbit. Resulting from the tragic Challenger accident in 1986, a less powerful rocket (a solid propellant Inertial Upper Stage, IUS) had to be used to propel Galileo from Earth's orbit. The spacecraft and the IUS were finally launched into low Earth orbit by the Space Shuttle Atlantis on October 18, 1989. Within hours the IUS propelled the Galileo spacecraft out of Earth's orbit.

Because the lower thrust IUS had to be used, reaching Jupiter required a gravity-assist trajectory. The gravity and orbital energy of Venus and Earth boosted the energy of the Galileo spacecraft by close flybys of these two planets (called the Venus-Earth-Earth-Gravity-Assist or VEEGA trajectory). This resulted in a six-year circuitous journey of almost 2.4 billion miles from Earth to Jupiter. The spacecraft used a close flyby of Venus (February 1990) and two close flybys of Earth (December 1990 and December 1992) as gravity slingshots. Without these flybys Galileo would have required twelve times as much propellant at launch to carry the desired payload of scientific instruments to Jupiter. Navigation engineers lined-up each maneuver and slingshot encounter so that Galileo arrived precisely on target for the separation of the Probe from the Orbiter on July 13, 1995. The probe continues on a ballistic path heading straight toward Jupiter for a meteoric plunge into the atmosphere on December 7, 1995. The Orbiter was maneuvered into a separate trajectory that will allow it to enter an orbit around Jupiter on the same date.



Probe release, July 13, 1995



Gravity slingshots to Jupiter

The Probe will speed toward Jupiter's swirling cloudtops at 170,000 km/hr (106,000 mph)—a speed equivalent to flying from San Francisco to Washington D.C. in 100 seconds. The Probe is aimed to strike the atmosphere at an angle of 8.5 degrees to the horizontal. A 1.5 degree shallower angle would cause the Probe to skip off back into space; a 1.5 degree steeper angle would overheat the spacecraft and destroy it. With a successful entry, the Probe will descend through turbulence, violent winds, and three (?) major cloud layers into the hot, dense atmosphere below. It is designed to survive until at least 200 km (125 miles) below the visible cloud tops where the atmospheric pressure is about 25 times that at Earth's sea level As hinted by the question mark above, what the Probe will find during its descent is, to a large extent, a mystery.

On the day the Probe enters the atmosphere, the Orbiter will be busy. It will make a very close flyby of Io (Jupiter's exotic volcanic moon), then record the radio signal from the Probe descending into the atmosphere. Next the Orbiter will fire its rocket engine to become the first spacecraft to enter orbit about Jupiter. This will start the Orbiter's 22 months of high resolution observation of Jupiter's system. The flyby of Io will be the closest flyby of the mission—a unique opportunity for high resolution study of this enigmatic satellite. Jupiter's radiation belts are particularly strong near the orbit of Io. Consequently the Orbiter's time near Io will be limited to avoid damage to the spacecraft. The Orbiter will listen to the signals from the Probe for up to 75 minutes only before the bulk of Jupiter obscures the entry site from the Orbiter. How much longer the Probe will continue to radio its findings into space, and what its ultimate fate might be, will be unknown.

The Probe Spacecraft: First Entry Into a Giant Planet's Atmosphere

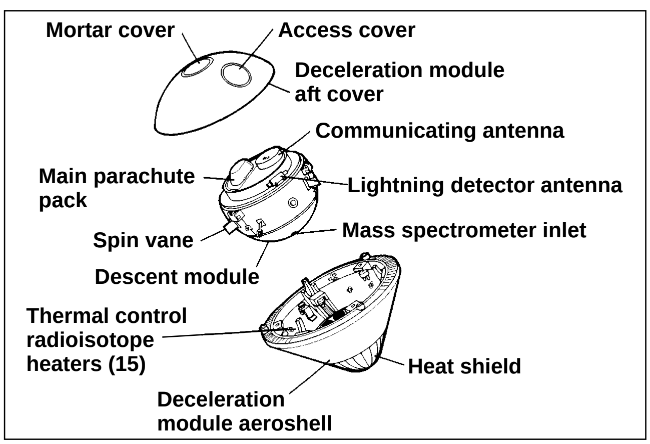
The 340 kilogram (747 lb) Probe spacecraft has its own power supply, communications, command, programming, data processing, data storage systems, and science payload. The Probe will be the first spacecraft to enter the atmosphere of any of the four gas giant planets beyond the orbit of Mars. It will be the first to measure directly Jupiter's atmosphere. The Probe's protective shell is rugged enough to withstand the extreme heat generated by the high-speed plunge into this atmosphere. As the Probe is pulled in by massive Jupiter's strong gravity, an enormous release of energy occurs as the spacecraft is slowed from 170,000 km/hr (106,000 mph) to 160 km/hr (100 mph) in four minutes. The 15,500 deg. C (28,000 deg. F), incandescent plasma envelope generated ahead of the Probe will briefly be brighter than the Sun's surface.

The spacecraft consists of a descent module carrying 30 kilograms (66 lb) of seven scientific instruments (see box). A protective shell consists of fore and aft covers to shield the capsule from the heat of entry. When the spacecraft has slowed to 160 km/hr (100 mph), these covers are discarded and the descent module descends on a large parachute, with speeds ranging from 750 m/sec (2500 ft/sec) at high levels of the atmosphere to 27 m/sec (88 ft/sec) deep in the atmosphere. The sequence of events and estimated conditions during the descent are shown in the diagram on the opposite page.

The Probe's nine science experiments will greatly enhance our understanding of Jupiter as a planet. Even before entering the atmosphere, one of the instruments carried by the Probe will measure Jupiter's intense radiation belts within 8050 km (5000 miles) of the cloud tops, far closer than was possible with earlier flyby spacecraft.

As the Probe descends through the atmosphere, its electronic computer will receive information from the science payload, process and encode it, and immediately transmit the coded signal to the Orbiter overhead. There the information will be stored for later transmission to Earth. The Orbiter will be able to receive data from the Probe for up to 75 minutes

The Probe hurtles into Jupiter's atmosphere



The components of the Galileo Probe

SCIENCE INSTRUMENTS

Atmospheric Structure Instrument

Provides information about temperature, density, pressure, and molecular weight of atmospheric gases.

Neutral Mass Spectrometer

Analyzes the composition of gases by measuring their molecular weights.

Nephelometer

Locates cloud layers in the atmosphere and measures some of the characteristics of the cloud particles.

Lightning and Radio Emission Instrument.

Searches and records radio bursts and optical flashes generated by lightning in Jupiter's atmosphere.

Helium Abundance Detector

Determines the important ratio of hydrogen to helium in Jupiter's atmosphere.

Net Flux Radiometer

Senses the differences between the flux of light and heat radiated downward and upward at various levels in Jupiter's atmosphere.

Energetic Particles

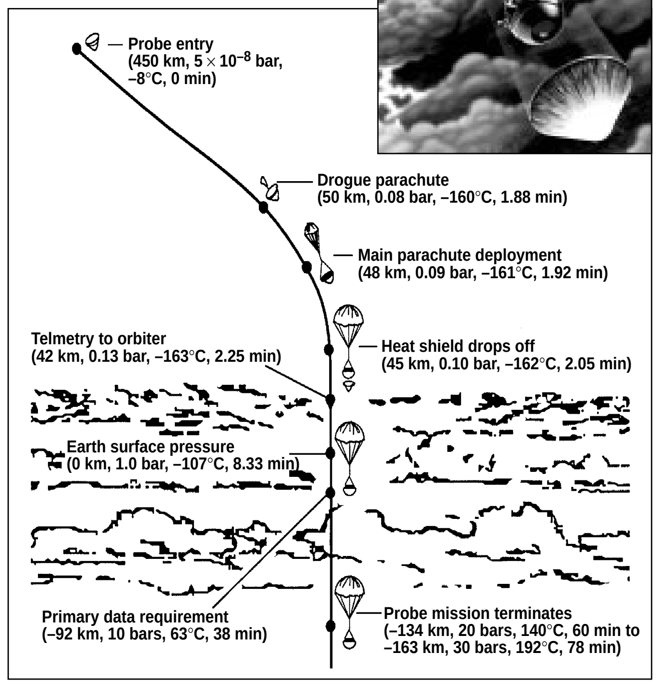
Used before entry to measure fluxes of electrons, protons, alpha particles, and heavy ions as the Probe passes through the inner regions of Jupiter's ionosphere.

Also, variations in the Probe's radio signals to the Orbiter will be used to determine wind speeds and atmospheric absorptions.

Data from the seven instruments and two radio experiments will be the first on-the-spot measurements in the atmosphere of a gas giant planet. By accurately determining the abundances of gaseous atmospheric constituents, such as hydrogen, helium, ammonia, methane and water, experimenters can compare the composition of Jupiter's atmosphere with the composition of the Sun to obtain information about planetary formation. Jupiter's strong gravity has prevented any of the ingredients which formed it 4.5 billion years ago from escaping. As the Probe descends it will search for droplets and solid particles which would indicate the occurrence of clouds in the atmosphere. By combining the measured gaseous composition with measurements of barometric pressure and temperature, scientists can use chemistry and physics to estimate the composition of the cloud layers. Three cloud layers should exist; the top layer of ammonia liquid droplets and ice crystals (believed to be the cloud tops we see), an ammonium hydrosulfide cloud layer, and a deeper water cloud layer. But there are large uncertainties.

Two experiments will help us understand the mysterious multiple jet streams and atmospheric superrotation. Variations in the frequency of the Probe's radio signal received by the Orbiter will reveal the variation of winds with altitude. Measurement of amounts of sunlight and of interior heat at each atmospheric level will give information about power sources driving the winds. Searches for lightning flashes and radio waves emitted from them will provide clues on how internal heat escapes from the planet's interior.

Artist's concept of Probe approaching clouds



Path of Probe through Jupiter's atmosphere

The Orbiter Spacecraft: Monitoring the Atmosphere from Orbit

Data from the Probe will apply to only one latitude, longitude, and time. Observations by the Orbiter will provide a context for the Probe results by intensely studying the entry site from orbit, comparing it with other parts of the planet, and watching its variations over time.

The Orbiter (see picture on page 2 and diagram alongside) has a unique design allowing the main body of the spacecraft (electronic bays, propulsion systems, power source, main antenna, and experiments to measure radiation belts and magnetic field) to spin at about three RPM. This stabilizes the spacecraft. Immediately aft of the main body a despun section, driven by an electric motor, counters the main body's rotation. This provides a scan platform with scientific instruments and the radio antenna to receive signals from the Probe.

Four instruments on the scan platform provide most of the Orbiter's observations of the atmosphere. These instruments (imaging, near infrared mapping spectrometer, photopolarimeter, and ultraviolet spectrometer) can view Jupiter from many angles at high spatial resolution with broad spectral coverage. They can also view the planet's nightside. The data obtained from the Orbiter will be less than planned because its main antenna did not fully open. The antenna problem does not affect the return of all data gathered by the Probe. Communication with Earth will rely on one smaller antenna. Galileo scientists will, nevertheless, maximize scientific returns over the mission by selecting observations that use the uniqueness of the Orbiter.

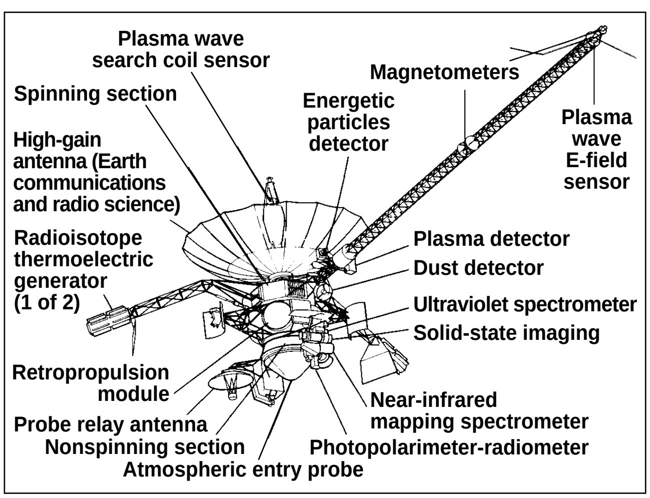


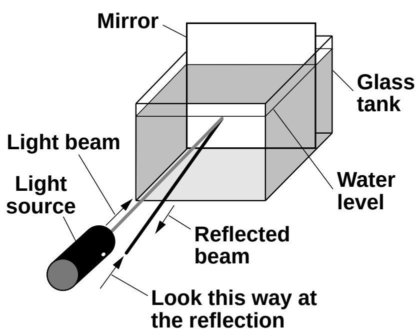
Diagram of the Galileo Orbiter

Exercises for Students

1. Exploring the Clouds:

The Nephelometer carried by the Galileo Probe into Jupiter's atmosphere is designed to search for clouds and determine their properties. The instrument measures the scattering of light from the atmosphere near the Probe. You can simulate the basic idea of this experiment very easily in the classroom.

You need an aquarium tank or similar rectangular glass enclosure (a deep square or rectangular glass dish will do). Also you need a thin beam of light from a small flashlight or a slide projector with an opaque card that has a small central hole. The experiment works best in a darkened room.



Fill the glass tank with water and shine the beam of light into the tank. If you place a mirror near the center of the tank you should see a reflection of the light (see sketch). View the tank from several angles. What do you observe? When you look at the tank perpendicular to the beam of light, do you see much scattered light? What is its color? What about reflected light? The angle between the light beam and your line of sight is the phase angle. The perpendicular view is a phase angle of 90 degrees. Changes in intensity and color of scattered light with phase angle gives information about the particles scattering the light.

Drop a small quantity of milk into the water in the light path. Observe the reflection from the mirror. Also, view the tank from different phase angles. Compare the scattered light with the no-milk conditions. What is the color of the reflected light from the mirror? Does it change color as you change the distance between the mirror and the light source? What further changes occur as the milk dissipates into the water? If necessary add more milk to see the effects.

The particles of milk in water act similarly to the particles of clouds in the Jovian atmosphere. The Nephelometer passes a beam of light through the Jovian atmosphere to a mirror suspended on an arm extended outside the Probe. The reflected light is analyzed to determine the characteristics of the particles. Also light scattered from the cloud particles back to the instrument is analyzed. This is analogous to your seeing the whiteness of the milk/water mixture without seeing a direct reflection of the light through the mirror. Observe that the back-scattered light become whiter as more milk is added, while the reflected light changes color more and becomes fainter.

Recall the color of the reflected light beam and compare it to the faint color in the light scattered 90 degrees to the light source. If you think of the light source in this experiment as being the sun, does the experiment and the resulting colors remind you of colors you see in the sky during the day and around sunset?

2. Exploring an Atmosphere:

If you were going to the atmosphere of a planet for the first time what would you want to know about it to decide if your stay on the planet would be pleasant or if a robotic probe could survive there? An example; consider what you want to know about weather before going on a trip. Check the newspaper weather section and the TV news weather reports. Make a list of the reported atmospheric characteristics. What do these tell you about atmospheric conditions on Earth? Compare with experiments on the Probe. Are there other experiments you'd like to do at Jupiter?

Contrast the strength and variation with latitude of winds on Jupiter and Earth. Until the Galileo Probe enters the atmosphere, we have to estimate winds on Jupiter by tracking cloud features. Even after the entry of the Probe, cloud tracking will provide the only way to study the variation of the winds with latitude, longitude, and time. You can estimate winds in Jupiter's atmosphere using the cylindrical projection mosaics of Voyager 2 images included on the insert to this Educational Brief. The top mosaic on each side shows the appearance of the planet between +45 and -45 degrees latitude on May 27, 1979; one half of Jupiter (180 degrees of longitude) is on one side of the insert and the other half is on the other side. The bottom mosaic on each side shows the appearance of the same region of Jupiter 30 hours later. Locate cloud features you can identify on both images. The bright repeating features near 5° N latitude are called "plumes". Are there any plumes near 5° S latitude? The dark spots near 15° N are called "barges". Locate the Great Red Spot. Make a table of latitude and longitude for several cloud features in each mosaic and calculate the change in position for each feature. Is movement mainly in latitude or longitude?

Convert the change in position to a distance in kilometers using 1246 kilometers per degree of latitude or longitude. Divide the distance traveled by each cloud feature by the time interval between the mosaics to find the velocity of the cloud features. How strong are the winds and where do the strongest winds occur? Does the strength and/or direction vary with latitude? Are the motions mainly north-south or east-west? What is the speed of the Great Red Spot? How much change do you see in the cloud features? The Galileo Probe is plunging through Jupiter's atmosphere at about 7°N latitude. What types of cloud features and wind speeds will the Probe encounter?

Compare your findings for Jupiter with Earth. Determine the strength, direction, and pattern of Earth's winds from weather maps in a newspaper. Locate a book on Earth's weather to see the wind patterns over our entire planet. Visit your local TV weather department or weather bureau.

For progress reports and results from the Galileo mission, go to these World Wide Web sites.

Galileo Probe Homepage at NASA-Ames:
http://ccf.arc.nasa.gov/galileo_probe/

The Galileo Homepage at JPL:
http://www.jpl.nasa.gov:80/galileo/

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National Aeronautics and
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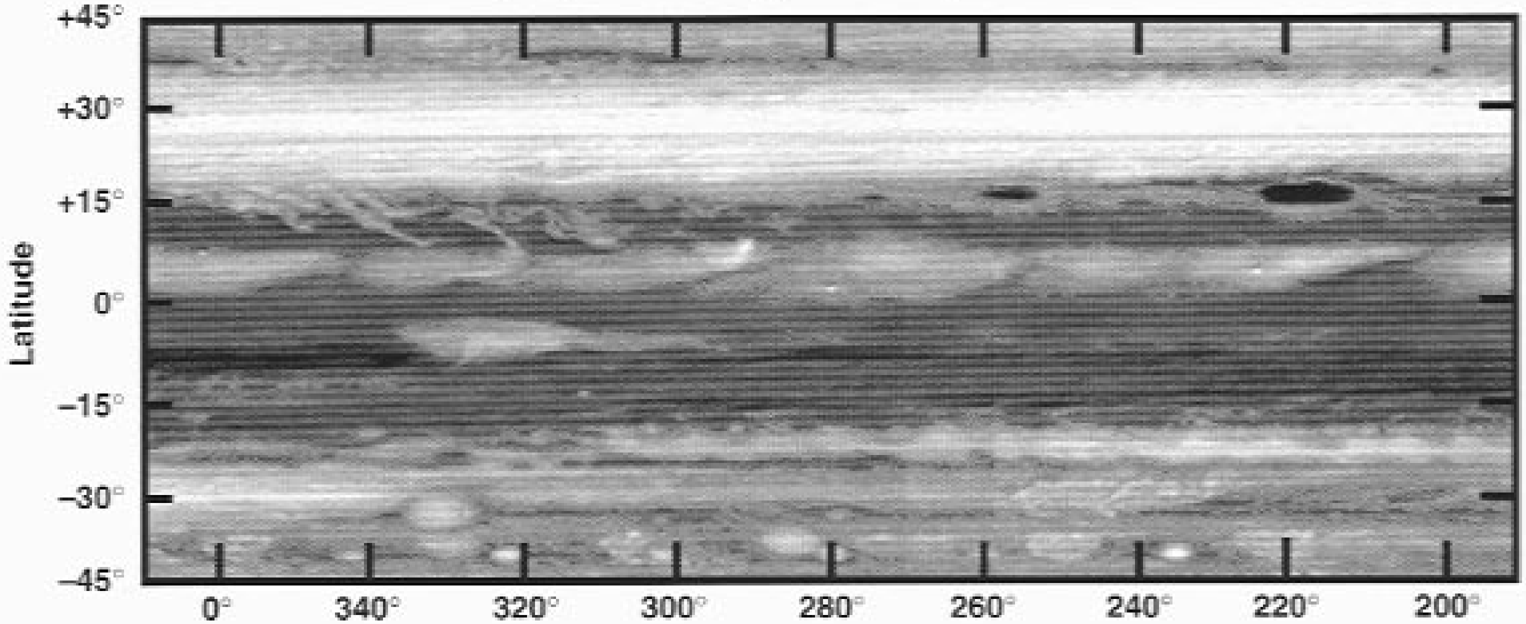
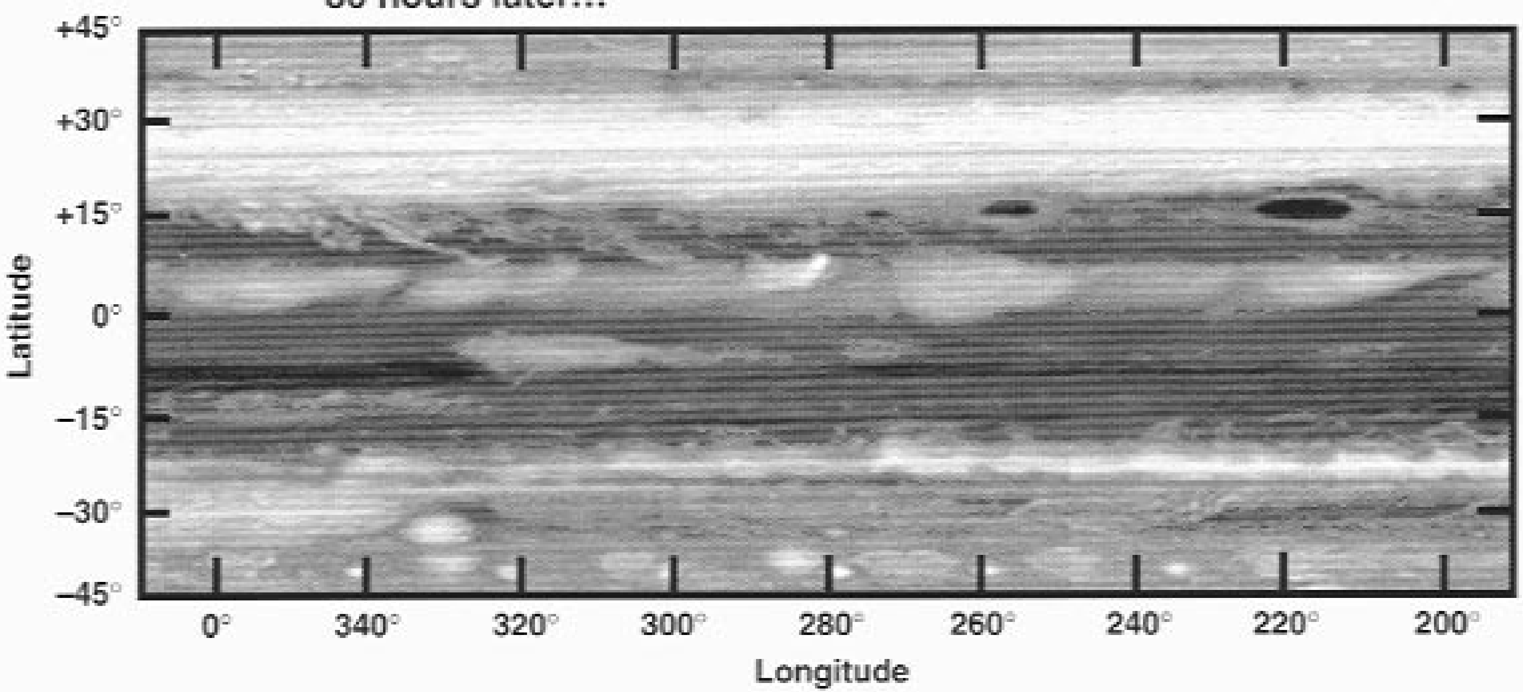
Ames Research Center
Space Science Division and
Educational Programs Office

The Changing Face of Jupiter: Longitudes 190°–10° West



30 hours later...



The Changing Face of Jupiter: Longitudes 10°–190° West