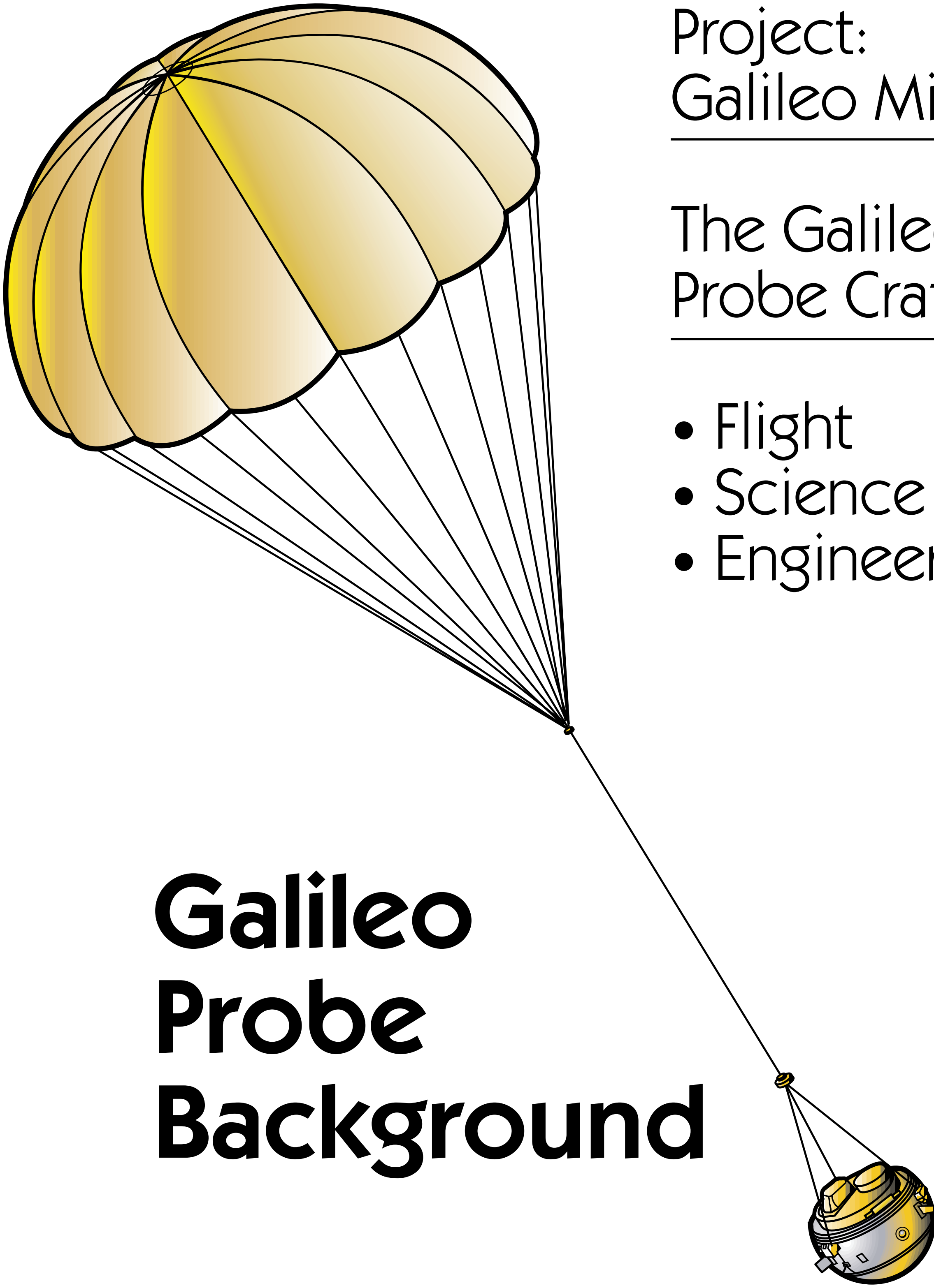
Project:
Galileo Mission

The Galileo
Probe Craft

- Flight
- Science
- Engineering



Galileo Probe Background

National Aeronautics and
Space Administration

Ames Research Center
Moffett Field, CA 94035-1000

GALILEO PROBE BACKGROUND

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GLOSSARY

bar — A unit of pressure. One bar is the normal atmospheric pressure at sea level on Earth. One bar is approximately equal to 30 inches of mercury.

dB — A comparative unit of strength used to characterize the strength of a transmitted signal or the amplification applied to a signal.

dB-Hz — A unit of signal strength over a narrow range of frequencies.

eV — Electron volt. A unit of energy. An electron volt is the energy acquired by an electron accelerated by a one volt electric field.
1 calorie = 2.6 x 1019 eV

MeV — One million electron volts.

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GALILEO PROBE TO LOOK FOR SECRETS OF JUPITER

The Galileo Probe -- like a flaming meteor -- will make history's first entry into the atmosphere of an outer planet, giant Jupiter, on Dec. 7, 1995.

The Probe craft will plunge into Jupiter's brilliantly-colored, swirling cloud tops at 106,000 mph, and then descend 400 miles through turbulence, violent winds and three major cloud layers into the hot, dense atmosphere below.

The Probe descent may provide our first true understanding of Jupiter as a planet. The Probe will make the first-ever on-the-spot measurements of Jupiter or any outer planet. It will identify the components of Jupiter's atmosphere and their proportions, and find clues to Jupiter's history and the origin of the solar system.

The Probe is a combination of complexity and rugged compactness. It has its own power supply; communications, programming, data processing and data storage systems; and six complex scientific instruments. But it is also compact and tough enough to handle by far the most difficult planet entry in the solar system, a result of Jupiter's enormous size and gravity.

During its 106,000 mph entry, the incandescent gas cap ahead of the Probe will be as bright as the Sun to an observer and twice as hot -- 15,500 degrees Celsius (C) or 28,000 degrees Fahrenheit (F) -- as the solar surface. With the exception of radiation, entry will be like flying through a nuclear fireball. Wrenching forces on the craft during its deceleration phase (from 106,000 mph to 250 mph in just four minutes) will be up to 345 times Earth gravity.

The Space Shuttle Atlantis launched the Galileo Orbiter and Probe in October 1989. The Probe separated from the Orbiter July 12, 1995, about 50 million miles from Jupiter. When it reaches Jupiter on Dec. 7, it will be half a billion miles from Earth.

The Probe project is managed by NASA's Ames Research Center, Mountain View, CA. The overall Galileo mission is managed by NASA's Jet Propulsion Laboratory, Pasadena, CA.

The Probe craft's total weight is 747 pounds. Its protective shell (the Deceleration Module) consists of the fore and aft heat shield, and weighs 469 pounds. The inner capsule the (Descent Module) carries 66 pounds. of scientific instruments.

The Probe will slam into Jupiter's atmosphere at speeds similar to those for the entry of the recent comet Shoemaker-Levy. The 106,000 mph entry speed is fast enough to fly from Washington, D.C. to San Francisco in 100 seconds.

Once it survives the hazards of its blazing entry the Probe, by comparison, will operate in a far less severe environment. Jupiter's atmosphere is primarily hydrogen and helium. For much of its descent through Jupiter's three main cloud layers, the Probe will be immersed in gases at or below room temperature. However, it may encounter hurricane winds of up to 200 mph and lightning and heavy rain at the base of the water clouds believed to exist on the planet. Eventually, the Probe will pass below these clouds, where rising pressure and temperature will cause it to lose radio contact and ultimately destroy it.

After passing through the upper atmosphere, the two protective heat shields of the Deceleration Module will be shed by first deploying a small pilot parachute and then a larger main chute, exposing the Descent Module to the hydrogen/helium atmosphere at a pressure of about one-tenth of an Earth atmosphere.

As the Probe passes through the cloud layers, its computer will receive information, process and encode it, and transmit the coded signal to the Orbiter, which will store the data for later relay to Earth. The Probe descent mission is designed to last about 60 minutes and may last 75 minutes down to a pressure of almost 30 times Earth's atmosphere before radio contact is lost.

So far, understanding of this huge gas planet is limited to a two-dimensional view (pictures of the planet's cloud tops) of a three-dimensional process (Jupiter's weather). But to explain the incredible coloring, swirling shapes and high-speed motion of its cloud tops, scientists must explore far below the visible surface. They must know the structure and composition of the atmosphere, nature and location (altitude) of the deeper cloud layers, and forces that drive the winds.

The Galileo Probe will be:

- the first spacecraft to enter the atmosphere of any of the four outer gas giant planets beyond Mars;
- the first spacecraft to directly measure Jupiter's atmosphere;
- The first complex spacecraft built to survive violent extremes such as Jupiter entry and return sophisticated scientific data.

The Orbiter provided communications and power to the Probe during its six-year cruise to Jupiter and will serve as a data relay station during the Probe’s descent mission.

Jupiter entry conditions cannot be simulated in conventional wind tunnels. To test heat shield materials, scientists at NASA's Ames Research Center built special arcjet and laser facilities.

The Probe's six scientific instruments will measure the radiation field near Jupiter, as well as the temperature, pressure, density and composition of the planet's primarily hydrogen and helium atmosphere from faint outer traces to the hot, cloud-free regions believed to begin 100 miles below the cloud tops. Instruments will gather data before and during atmosphere entry and during the

Probe's 400-mile descent. Probe data will be radioed to the Galileo Orbiter 130,000 miles overhead, then relayed a half billion miles to Deep Space Network stations on Earth.

The Probe relay radio aboard the Galileo Orbiter craft must acquire the Probe signal from 130,000 miles below within 50 seconds, with a success probability of 99.5 percent. It must reacquire the signal immediately should it become lost.

The Probe will pass through the white cirrus clouds of ammonia crystals in the highest cloud deck. Beneath this ammonia layer probably lie reddish-brown clouds of ammonium hydrosulfides. Once past this layer, the Probe is expected to reach heavier water clouds. This lowest cloud layer may act as a buffer between what some scientists believe will be uniformly mixed regions below the clouds and the turbulent swirl of gases above.

Probe instruments will measure the temperature and pressure of the atmosphere, its constituents (such as hydrogen, helium, ammonia, methane and water) and the ratio of hydrogen to helium. Jupiter is thought to have a bulk composition similar to that of the primitive solar nebula from which it was formed.

The instruments will also find the location and structure of Jupiter's clouds, the nature of its lightning, and its heat budget. They will measure Jupiter's immense radio emissions and high-energy particles trapped in its innermost magnetic field. These particles can severely damage spacecraft electronics. Such measurements will be made within 5,000 miles of Jupiter's cloud tops, far closer than the previous closest approach by Ames' Pioneer 11 spacecraft. Scientists will find vertical wind shears from Probe motions by tracking the frequency of the Probe transmitter from the Orbiter.

Jupiter radiates about twice as much energy as it receives from the Sun. The resulting convection currents from Jupiter's internal heat source toward its cooler polar regions could explain some of the planet's unusual weather patterns.

Jupiter is over 10 times the diameter of Earth and spins about two and one-half times faster -- a jovian day whizzes by in 10 hours. A point on the equator of Jupiter's visible surface races along at 28,000 mph. This rapid spin may account for much of its bizarre circulation.

To the eye, Jupiter's surface appears as ribbons of wispy belts and cloudy zones, flowing in alternate directions. It is textured with dots, spots and twisters, which are given such names as white ovals, brown barges and white plumes.

The Great Red Spot, a 16,000-mile-wide enigma observed for over 300 years, seems to be a gigantic eddy of swirling gases that continuously sucks in smaller whirlpools, somehow creating a permanent feature in Jupiter's atmosphere.

Last July 12, the Orbiter spun up to 10 rpm and aimed the Probe at the Jupiter entry point. Sharp cable cutters sliced through wires connecting the Probe to the Orbiter and the craft began its solo flight to Jupiter.

Six hours before entry, at speeds of 40,000 mph, the command unit will signal "wake up" and instruments begin collecting data on lightning, radio emissions and energetic particles.

The Probe will strike the atmosphere at an angle of only eight degrees to the horizon -- deep enough so it won't skip out again, shallow enough to survive the heat and jolting deceleration of entry.

The Probe will enter the equatorial zone traveling the same direction as the planet's rotation. Once the Probe has decelerated and the parachute deployed, an observer on the craft would see the Probe as simply descending through the atmosphere. However, like the surrounding atmosphere, it will have the 28,000 mph rotation speed of the planet. Hence it will swiftly approach Jupiter's night side and pass through a "jovian sunset."

Direct measurement of the atmosphere will be made from the six instruments aboard the parachute-borne inner capsule. These instruments are:

- Atmosphere Structure Instrument -- provides information about temperature, density, pressure and molecular weight.
- Neutral Mass Spectrometer -- analyzes the composition of gases by measuring their molecular weight.
- Nephelometer -- locates cloud layers in the atmosphere and measures some of the characteristics of the particles making up the clouds.
- Lightning and Radio Emissions Detector -- searches and records radio bursts and optical flashes generated by lightning flashes on Jupiter.
- Helium Abundance Detector -- determines the important ratio of hydrogen to helium in Jupiter's atmosphere.
- Net Flux Radiometer -- senses the differences between the energy flux (light and heat) being radiated downward and upward at each level in the atmosphere.

The Probe’s radio transmitter and special receivers on the Orbiter act as a scientific experiment as well. The radio signal variations show Jupiter’s winds and atmospheric adsorption.

Before entry, the Energetic Particle Instrument, built as part of the Lightning and Radio Emissions Detector, will measure electrons, protons, alpha particles and heavy ions as the Probe passes through the innermost regions of Jupiter's magnetosphere.

Probe communications are provided by two L-band transmitters. These provide two channels for return of data.

The Probe is powered by high-discharge-rate 39-volt lithium batteries, which remained dormant for more than six years during the journey to Jupiter.

The command and data system provides commands, telemetry, data storage and timing. It generates two nearly redundant data strings, each with its own processor. The Probe relay radio aboard the Orbiter has two redundant receivers that process the incoming data streams, and generate radio science data for transmission to the Orbiter communications system. Minimum received signal strength is 31 dB-Hz at initial acquisition. Throughout the expected 75-minute mission, the communications link should remain above the minimum tracking threshold of 26 dB-Hz.

The Galileo Probe Project is managed by NASA's Ames Research Center, Mountain View, CA. Hughes Aircraft Company, El Segundo, CA, built the inner capsule and supports Probe operations. The protective deceleration vehicle, including the Probe heat shields, was developed by General Electric Company (now Lockheed-Martin), Philadelphia, PA.

The Probe project manager is Ames' Marcie Smith. Probe project scientist is Dr. Richard E. Young of Ames.

(END OF GENERAL RELEASE. BACKGROUND INFORMATION FOLLOWS.)

JUPITER BACKGROUND

In orbit half a billion miles from the Sun is the enormous, rapidly spinning planet Jupiter, largest of the solar system planets. Named for the chief of the Roman gods, Jupiter contains more mass than all the other planets combined. It is more than 300 times the mass of Earth.

With a thin skin of turbulent winds and brilliant, swift-moving clouds, the huge sphere of Jupiter is a vast sea of hydrogen and helium. Jupiter's composition (about 88 percent hydrogen and 11 percent helium with small amounts of methane, ammonia and water) is thought to resemble the makeup of the solar nebula, the cloud of gas and dust from which the Sun and planets formed. Scientists believe Jupiter holds important clues to conditions in the early solar system and the process of planet formation.

Starlike in composition, Jupiter is too small to generate temperatures high enough to ignite nuclear fusion, the process that powers the stars. Some scientists believe the Sun and Jupiter began as unequal partners in a binary star system. (If a double star system had developed, it is unlikely life could have arisen in the solar system.) While in a sense a "failed star," Jupiter is almost as large as a planet can be. If it contained more mass, it would not have grown larger, but would shrink from compression by its own gravity. If it were 100 times more massive, thermonuclear reactions would ignite and Jupiter would "turn on" as a star.

For a brief period after its formation, Jupiter was much hotter, more luminous and about 10 times larger than it is now, scientists believe. Soon after accretion (condensation of a gas and dust cloud into a planet), its brightness dropped from about 1 percent of the Sun's to about one-billionth.

In its present state Jupiter emits about twice as much heat as it receives from the Sun. The loss of this heat -- residual energy left over from the compressive heat of accretion -- means that Jupiter is steadily cooling and losing energy. Temperatures in Jupiter's core, which were about 50,000 degrees C (90,000 degrees F) in the planet's hot, early phase, are now about 30,000 degrees C (54,000 degrees F) -- 100 times hotter than any terrestrial surface, but 500 times cooler than the temperature at the center of the Sun. Temperatures on Jupiter are now thought to range from 30,000 degrees C (54,000 degrees F) at the core to minus 120 degrees C (minus 184 degrees F) at the top of the cloud banks.

Believed to be mainly uniform in composition, Jupiter's structure is thought to be determined by gradations in temperature and pressure. Deep in Jupiter's interior there is thought to be a small, rocky core, comprising about 4 percent of the planet's mass. This "small" core (about the size of 10 Earths) is surrounded by a 25,000-mile-thick layer of liquid metallic hydrogen. (Metallic hydrogen is liquid, but sufficiently compressed to behave as metal.) Motions of this liquid "metal" are the source of the planet's enormous magnetic field. This field is created by the same dynamo effect found in the metallic cores of Earth and other planets. At the outer limit of the metallic hydrogen layer, pressures equal 3 million times that of Earth's atmosphere and the temperature has cooled to about 10,000 degrees C (18,000 degrees F).

Surrounding the central metallic hydrogen region is an outer shell of "fluid" molecular hydrogen. Jupiter's atmosphere extends deep into the planet, but only in the top 50 miles are found the brilliant bands of clouds for which Jupiter is known. The tops of these bands are colored yellow, red and orange from traces of compounds not yet identified. Five or six of these bands, counterflowing east and west, encircle the planet in each hemisphere. At one point near Jupiter's equator, eastward winds of 220 mph blow right next to westward winds of 110 mph. At boundaries of these bands, rapid changes in wind speed and direction create large areas of turbulence and shear. Turbulent regions create chaotic, swirling winds and may be responsible for spiral features such as white ovals.

The brightest cloud banks, known as zones, are believed to be higher, cooler areas where gases are ascending. The darker bands, called belts, are thought to be warmer, drier regions of descent.

The top cloud layer consists of white cirrus clouds of ammonia ice crystals, at a pressure six-tenths that of Earth's atmosphere at sea level (.6 bar). Beneath this layer, at a pressure of about two Earth atmospheres (two bars) and a temperature of about minus 70 degrees C (minus 94 degrees F), a reddish-brown cloud of ammonium hydrosulfide is predicted.

At a pressure of about six bars, there are believed to be clouds of water and ice. Currently, estimates of water on Jupiter range from twice as much as expected from a solar composition to 10 times the solar amount. In this case, there will be dense water clouds at the six-bar level.

However, Jupiter's cloud structure, except for the highest layer of ammonia crystals, remains uncertain. The altitude of the lower clouds rests mainly on theory -- clouds are predicted to lie at the temperature levels where their assumed constituents are expected to condense. The Galileo Probe will make the first direct observations of Jupiter's lower atmosphere and clouds, providing a crucial third dimension.

The forces driving Jupiter's fast-moving winds and interior circulation are not yet well understood. The most likely explanation is that strong currents are created by convection of heat from Jupiter's hot interior, and the east-west banded wind system results from the interaction of Jupiter's rapid rotation with the convective motions.

Jupiter's rapid rotation rate has effects on wind patterns and produces some of Jupiter's bizarre circulation phenomena, including many spiral features. These rotational effects result from the Coriolis force, the force that deflects motions in a rotating system.

Coriolis force is what determines the spin direction of weather systems. This means that on the surface of a sphere (a planet), a parcel of gas farther from the poles has a higher rotational velocity around the planet than a parcel closer to the poles. As gases then move north or south, interacting parcels with different velocities produce vortices (whirlpools). This may account for some of Jupiter's circular surface features.

Jupiter spins faster than any planet in the solar system. Though 10 times Earth's diameter, Jupiter spins more than twice as fast (once in 10 hours), giving gases on the surface extremely high rates of travel --- 28,000 mph at the equator, compared with 1,000 mph for air at Earth's equator. Jupiter's rapid spin also causes this gas and liquid planet to flatten markedly at the poles and bulge at the equator.

Visible at the top of Jupiter's atmosphere are eye-catching features such as the famous Great Red Spot (GRS) and exotic white ovals, brown barges and white plumes. The Great Red Spot, which is 16,000 miles wide and large enough to swallow two Earths, is an enormous oval eddy of swirling gases. It is bounded by two counter-flowing jet streams, which pass, one on each side of it, moving in opposite directions, each with speeds of 100 mph to 200 mph.

The Great Red Spot was first discovered in 1664 by the British scientist Roger Hook, using Galileo's telescope. In the three centuries since, the huge vortex has remained constant in latitude in Jupiter's South Tropical Zone. Because of its stable position, astronomers once thought it might be a volcano -- though it would have had to be a huge volcano, on a planet now known to have no solid surface.

Another past theory compared the Great Red Spot to a gigantic hurricane. However, the GRS rotates anti-cyclonically, while hurricanes are cyclonic features (counterclockwise in the northern hemisphere, clockwise in the southern) -- and the dynamics of the Great Red Spot appear unrelated to moisture. The Great Red Spot resembles an enormous tornado, a huge vortex that sucks in smaller vortices. The Coriolis effect created by Jupiter's fast spin appears to be the key to the dynamics that drive the spot.

The Great Red Spot's color remains a mystery. It has been suggested that phosphorus may be responsible, but this remains uncertain. The GRS may be the largest in a whole array of spiral phenomena with similar dynamics. About a dozen white ovals, with circulation patterns resembling the GRS, exist in the southern latitudes of Jupiter, and appear to be driven by the same forces. (Scientists do not know why these ovals are white.)

Scientists believe the brown barges, which appear like dark patches on the planet, are holes in the upper clouds, and we see deeper into the atmosphere there. The equatorial plumes, or white plumes, are now believed to be thunderheads or anvil clouds in a region of strong convection, similar to Earth’s cumulus clouds.

PROBE MISSION TIME LINE

LAUNCH (L) Oct. 18, 1989	Galileo Orbiter/Probe spacecraft carried to Earth orbit by Space Shuttle Atlantis
L+2 hours	Orbiter/Probe craft ejected by astronauts from Atlantis' payload bay
L+3 hours	After two orbits (3 hours), Inertial Upper Stage (IUS) rocket launches Galileo to Jupiter
L+8 hours	First Probe status check
	Cruise phase begins and continues for 5 years, 9 months. Probe remains mated to Orbiter • Periodic commands from Orbiter to Probe • Telemetry from Probe to Orbiter relay receiver
L+13 months	Second Probe status check. Check of all Probe subsystems and instruments. Data relayed to Earth by Orbiter radio
L+38 months	Third Probe status check.
L+65 months March 16, 1995	Abbreviated System Function Test (ASFT). Probe found healthy for separation and entry

ENTRY (E)

E-155 days	Coast timer clock set to give signals for coast and entry events
E-153 days	Probe switches to internal power
E-149 days	Cable cutters cut the Orbiter/Probe umbilical
E-147 days	Orbiter/Probe spacecraft spins up to 10 rpm July 12, 1995 Spin axis is lined up precisely with Probe trajectory

	Separation is commanded from the Orbiter and explosive nuts accomplish separation. Three springs push the spinning Probe away.
	Probe separates (July 12, 1995, 11:07 p.m. PDT) and begins 150-day flight to Jupiter entry. No radio transmission from Probe until entry at Jupiter.
	Orbiter then does burn to avoid impacting Jupiter, to reach position for receiving Probe signals at entry, and for entering orbit around Jupiter
E-150 to E-0 days	Probe coast phase. Minimal operation on internal power (lithium battery modules). No radio transmission.
E-6 hours	Coast timer initiates Probe operation. (Deceleration switches are backup for timer malfunction.) Internal commands: 1) Battery activation, 2) Energetic Particle Instrument (EPI) biased for operation, 3) Stable oscillator warmed up.
E-6 hours to E- 3 hours	Flight from 8 to 5 Jupiter radii -- Continuing warm-up activities
E-3 hours to E-.5 hours	Flight from 5 to 2 Jupiter radii -- Passage of jovian magnetosphere. Turn on: 1) Lightning and Radio Emissions Detector, 2) Energetic Particle Instrument.
E-.5 hours	Altitude 27,000 miles.* 1) Atmosphere Structure Instrument and Nephelometer calibrations. 2) Data and command processor final self-test At 500 miles, Probe encounters sensible atmosphere.

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* Altitude zero-point located at atmosphere pressure point of 1 bar (normal Earth surface pressure).

E=0 Dec. 7, 1995 22:04:04 GMT	Probe entry, region of intense heat and deceleration begins at altitude of 280 miles. Entry trajectory angle minus 8.6 degrees Entry point 6.5 degrees north of Jupiter equator Heat shield loses about 190 pounds of mass during entry heating. Seen from nearby would be as bright as the Sun. Incandescent shock layer around Probe is 15,500 degrees C (28,000 degrees F) Spacecraft slows from 106,000 mph to 200 mph. G forces on Probe approximately 230 G Atmosphere Structure Instrument data-taking continues, taking deceleration data from which upper atmosphere density may be found.
E+35 seconds	Altitude 135 miles. Atmosphere pressure 0.0001 bar, atmosphere temperature minus 101 degrees C (minus 150 degrees F) Begin main heat pulse, heat shield ablation Heat shield burnoff sensors begin measurements, mass loss of heat shield
E+55 seconds	Peak G forces (nominal 230 G, maximum 345 G) Pressure 0.006 bar, temperature minus 118 degrees C (minus 180 degrees F)
E+80 seconds	End main heat pulse and heat shield ablation
E+113 seconds	Speed Mach 1, fire mortar for pilot chute deployment
E+114 seconds	Aft heat shield separates, pulls out main chute
E+115 seconds	Main chute deploys. Altitude 30 miles
E+118 seconds	Start Neutral Mass Spectrometer sequence.

E+123 seconds — With firing of three separation bolts, forward heat shield separates, falls away as main chute slows Descent Module to speed of 400 mph. Speed continues to drop through the rest of the mission.

E+124 seconds — Deploy Nephelometer sensor (measures cloud particles). Descent science operational.

Pressure 0.1 bar; temperature minus 162 degrees C (minus 260 degrees F); altitude 27 miles

E+2 to E+75 minutes — Descent science. Six instruments take data, direct atmosphere measurements.

Begin real-time radio transmission of Probe data to overflying Orbiter, which serves as link to Earth. Data from three instruments and engineering subsystems stored on board the Probe prior to entry are interleaved with new data.

Relay radio receivers and antenna located on Orbiter are part of Probe system, frequencies 1387.0 MHz and 1387.1 MHz. Relay receivers acquire Probe signal in 50 seconds maximum, reacquire signal immediately if lost.

Instruments on:

1) Neutral Mass Spectrometer,
2) Helium Abundance Detector,
3) Atmosphere Structure Instrument,
4) Nephelometer,
5) Net Flux Radiometer,
6) Lightning and Radio Emissions Detector.

E +75 minutes — Maximum time to end of Probe mission (end of communications with Orbiter, due to preparation for Jupiter orbit insertion)

UNKNOWNS BEGIN (Estimated times and events)

E+3 minutes — Altitude 20 miles Pressure .2 bar

Enter ammonia clouds,** a haze of white crystals.
jovian winds at various altitudes may be up to 210 mph.

E+8 minutes	Altitude 0 miles. Pressure 1 bar (Earth surface pressure). Temperature minus 112 degrees C (minus 170 degrees F).
E+9 minutes to E+18 minutes	Enter top of water clouds (highest layer ice crystals). This may be a very heavy cloud, denser than Earth's water clouds. The lower part, 2.5 to 3 miles deep, may have heavy rain. This region also probably has intense lightning. With high-velocity jovian winds, clouds may move and change very rapidly.
E+32 minutes	Bottom of cloud deck. Enter clear, hot atmosphere. Altitude minus 47 miles
E+38 minutes	Pressure 10 bar. Temperature 63 degrees C (145 degrees F).
E+42 minutes	Spacecraft crosses the terminator to the night side of the planet. Night is preceded by a period of twilight and sunset. Passage of lower water clouds in darkness, probably heavy rain.
E+60 minutes	End of reference mission Pressure 20 bar. Temperature 140 degrees C (285 degrees F).

** Exact altitude of cloud layers not well known

E+75 minutes	End of Probe data reception. Orbiter must reconfigure from relay radio orientation for orbital insertion burn. Combination of pressure and temperature on Probe systems, limited battery capacity plus difficulty of radio signal transmission through dense atmosphere and clouds will likely lead to degraded Probe operation in any case. Pressure 28 bar. Temperature 182 degrees C (360 degrees F). Altitude minus 99 miles

THE PROBE SPACECRAFT

Jupiter's gravitational pull is so immense that the Galileo Probe's speed on entry will be around 106,000 mph. As the spacecraft strikes the atmosphere, it will experience a force up to 345 times Earth's gravity and searing temperatures in the shock wave in front of it as high as 15,500 degrees C (28,000 degrees F). To survive entry, the Probe must be strong enough to withstand these severe temperatures and pressures, as well as the mechanical erosion of its surface caused by the incandescent shock layer ahead of it.

Never before has a spacecraft experienced such intense conditions, and to simulate the entry environment and the response of the Probe, scientists at NASA's Ames Research Center had to build special high-speed arcjet and laser facilities. In addition, a complex computer code was developed by Ames, NASA's Langley Research Center and contractors to determine the response of the Probe to severe entry temperatures. What resulted was a spacecraft comprised of two sections: a virtually impenetrable outer shell (Deceleration Module) for protection during entry and an inner capsule (Descent Module) containing the delicate electronics and scientific instruments.

The outer shell, which will surround the capsule through entry and then drop away, includes thick heat shields and their supporting structure, the thermal control hardware for mission phases up through entry, and a pilot parachute. Nested inside of this shell is the inner capsule, which carries the payload and which alone will descend through Jupiter's atmosphere. This section carries the main parachute and the science instruments, plus the systems that support the experiments and transmit their data back to the overflying Orbiter for relay to Earth.

Due to delays in the Galileo launch and lengthening of the mission to 6 years, several Probe components were replaced or rebuilt. These are the parachute, the mortar cartridge for chute deployment and the lithium-sulfur dioxide batteries. The Net Flux Radiometer instrument also was rebuilt for improved performance. In addition, in the years before launch, all scientific instruments and subsystems aboard the Probe underwent detailed performance tests.

THE OUTER SHELL (Deceleration Module)

CONFIGURATION: The Probe is about 2.8 feet high with a rounded top (aft cover) above a conical base (forebody), which angles down to a blunted tip. At its widest, the Probe has a diameter of about 4 feet.

HEAT SHIELDS: The extreme velocity at which the Probe will enter Jupiter's atmosphere has required a new approach to heat shield design. The

Probe has two heat shields: a carbon phenolic heat shield on its forebody and phenolic nylon heat shield on the aft cover.

Although these materials have been used extensively for Earth reentry vehicles, on the Galileo mission they will be subjected to environments never before experienced. A major effort was devoted to calculating the severity of entry heating in the incandescent shock layer ahead of the craft (expected to be around 15,500 degrees C or 28,000 degrees F).

The shield on the forebody will have to withstand not only this enormous amount of radiated heat but also sheer mechanical erosion as the spacecraft slams into the atmosphere. By comparing test results to the calculations and allowing a 30 percent to 44 percent safety margin at various places along the Probe's body, scientists are confident that the shield is thick enough (about 6 inches at the nose) to withstand these severe entry conditions. The total weight of the forebody heat shield is 335 pounds, of which 193 pounds are expected to be vaporized during entry. What remains of this heat shield after entry will separate from the Descent Module when the main body of the outer shell drops away.

The shield on the aft cover will experience severe, but less intense, conditions since it is not in immediate contact with the shock layer. The aft cover with its heat shield weighs about 37 pounds. It will be pulled away from the craft by the pilot chute.

THERMAL CONTROL: Thermal control of the Probe prior to entry into Jupiter's atmosphere is provided by a passive system of layered Mylar blankets, plus 36 one-watt radioisotope heaters. During descent, temperatures in the Descent Module must be kept between minus 20 degrees C and 50 degrees C (minus 4 degrees F and 122 degrees F) to ensure proper functioning of the batteries, electronics and instruments.

To minimize electrical charging during passage through the charged particles of Jupiter's radiation belts, all surfaces in the Probe are either made of conducting material or are coated with conducting film and grounded to the Probe structure.

STRUCTURE: The heat shields and deceleration module equipment are mounted to an aluminum frame covered by an aluminum skin. A radio window is cut into the skin of the aft cover for the lightning and radio emission experiment. The aft cover is an aluminum dome held in place by three explosive nuts and bolts spaced equally apart. Total weight for the deceleration module is 469 pounds, with the heat shields accounting for the bulk of the weight.

PARACHUTES: When the heat shield has slowed the Probe to a speed of 1,800 mph, the pilot chute is deployed. The chute is fired into the wake by a mortar at 1,700 mph. After this, the explosive nuts fire to release the aft cover, which in turn pulls out the bag of the main parachute. All this occurs in less than two seconds.

The canopy and shroud lines of the main parachute are made of Dacron; the riser is made of Kevlar. The parachute is 8.2 feet in diameter.

THE INNER CAPSULE (Descent Module)

STRUCTURE: The roughly spherical Descent Module is divided into two sections by a shelf that carries most of the equipment. The equipment shelf is an aluminum honeycomb, with other structural components made of aluminum, titanium or fiberglass.

The scientific instruments are on the aft side of this shelf, with batteries and programmers on the forward side. Communications and control for all the Probe's pyrotechnic, or explosive, devices are mounted in the compartment aft of the equipment shelf. (See drawing.) On top of this compartment are the main parachute, the Probe's transmitting antenna, the antenna for the Lightning and Radio Emissions Detector, and the sensor for the Energetic Particle Instrument. Unlike the Pioneer Venus Probe, which used a sealed pressure vessel to withstand Venus's 100-bar pressure environment, the Galileo capsule, which is designed to operate to a required pressure 10 times that of the Earth's atmospheric pressure at sea level (10 bars), saves weight by being vented to Jupiter's atmosphere, with individual units sealed in housings as needed. (The capsule may well survive down to a pressure of 25 bars.)

The scientific instruments are laid out roughly around the Descent Modules' circular interior with their sensors extending through its titanium sheet walls. Instruments are located according to whether they require a particular view of the atmosphere or whether they have any sensors that must be kept free from atmospheric turbulence. Each instrument uses one digital line for primary data transfer.

In addition, there are six analog and eight bi-level channels, plus nine frame rate and seven clock signals. The total weight of the instruments is 66 pounds.

THERMAL CONTROL: Before entry, thermal control is provided by hardware in the outer shell. After entry, layered Kapton blankets slow down the rate of temperature changes in the Probe capsule, protecting the interior from rapid heating or cooling.

COMMUNICATIONS: The communications subsystem transmits two parallel and simultaneous data streams. These are two L-band channels, one at 1387.0 MHz and one at 1387.1 MHz. Each channel consists of an exciter, a 23-watt power amplifier, and either an ultrastable oscillator or a standard, thermally controlled oscillator. The channel with the ultrastable oscillator will be used for Doppler measurement of Jupiter's winds. The transmitter also measures its own power output. This measurement, along with a measurement of the received signal strength at the Orbiter relay receiver, is used to find the atmospheric absorption of radio signals. The system has an antenna with a 56-degree, 3 dB beam and a peak gain of 9.8 dB.

POWER: The power subsystem consists of two electronics units, lithium/sulfur dioxide batteries and a set of thermal batteries. The subsystem power interface unit routes power from either Probe batteries or the Orbiter power supply directly to the Probe's subsystems and to the scientific instruments through the instrument power interface unit.

Voltage of the lithium batteries is 39 volts, when not under load. Total capacity at the time of manufacture is 21 ampere hours, of which one ampere hour will be consumed in storage loss. Probe mission require-ments, to operate for an hour after entry, are about 16.5 ampere hours, leaving a margin of 3.5 ampere hours. This is enough power to last for at least 75 minutes after entry.

Four thermal batteries provide energy for pyrotechnic events. These explosive events include the mortar fire for deploying the pilot parachute, the release of the aft cover and forebody from the craft, deployment of the Nephelometer (cloud sensor) arm, and the activation of sharp cable cutters that will sever wires connecting the Probe's outer protective shell to its inner capsule.

COMMAND AND DATA SYSTEM: This system includes the data and command processor, the pyrotechnic control unit and four acceleration switches. The data and command processor controls all system command, telemetry, data storage and timing functions. It uses two redundant data strings, each controlled by its own microprocessor. Virtually all post-entry functions are the same on both strings. Preentry functions are divided between the two strings and are not redundant. The system's self-test function is activated once, about 27 minutes before entry. If a fault is found on one data string that might affect the data on the other string, the faulty string will be turned off and remain off.

During the coast phase when the Probe has separated from the Orbiter, only the coast timer operates. Its purpose is to "wake up" the Probe about six hours before entry. During the next six hours or so, just one string gathers data on lightning and radio emissions and energetic particles. Starting 27 minutes before entry, both strings operate through the end of the mission. The entire operations sequence from separation to the end of mission is contained in permanent memory.

Because researchers are not certain exactly where Jupiter's atmosphere begins, acceleration switches will sense the atmosphere to determine when the pilot parachute should be deployed and the main body of the Probe's shell released. These switches will "wake up" the Probe should the coast timer fail.

RELAY RADIO HARDWARE: The relay radios aboard the Orbiter receive data from the Probe both during checkout before the Probe separates from the Orbiter and as it descends into Jupiter's atmosphere. The system consists of two receivers, ultrastable oscillators and an antenna.

Each receiver acquires, tracks and processes the Probe data along with radio science and engineering data. The receivers also format data for transmission to the Orbiter command and data system.

The unit is designed to meet the following requirements: It will acquire the Probe signal within 50 seconds, with an acquisition probability of 99.5 percent and a probability of reading a false signal of only 0.01 percent. Minimum signal strength at acquisition is 31 dB-Hz. The system is required to track a signal strength as low as 26 dB-Hz. If loss of lock occurs during Probe descent, software is built into the system to allow the signal to be reacquired within 30 seconds. The unit also measures Probe signal strength and Doppler rates for radio science use (wind and atmosphere absorption measurements).

To meet these requirements, scientists must allow for uncertainties in the Probe signal frequency and spin rate; for violent motion of the craft due to winds and turbulence; and for signal distortion from both the background noise of the high energy, charged particles in Jupiter's radiation belts and from absorption of radio signals by the atmosphere.

PROBE SCIENTIFIC OBJECTIVES

CHEMICAL COMPOSITION OF THE ATMOSPHERE (Neutral Mass Spectrometer, Helium Abundance Detector) -- Determine the composition of Jupiter's atmosphere by measuring the abundance and isotope ratios of major constituents (hydrogen and helium) and trace constituents as a function of altitude. Jupiter is presumed to have a bulk composition similar to that of the gas and dust cloud of the primitive solar nebula from which the planets and the Sun were formed.

Clues to the origin of a planet come from isotopic ratios, which are only slightly affected by a planet's subsequent chemical evolution. On Jupiter, two ratios have been measured from Earth: carbon 13 to carbon 12 and deuterium (heavy hydrogen) to hydrogen, but these measurements are somewhat uncertain.

For hydrogen, helium and other elements such as oxygen, carbon and nitrogen, Jupiter's composition is thought to be close to that of the Sun. If measurements of Jupiter's atmosphere differ greatly from current calculations, scientists may have to revise ideas of planet formation.

Another objective is to precisely determine the ratio of hydrogen to helium in Jupiter's atmosphere. This ratio should give insights into planetary evolution. For example, the helium to hydrogen ratio found for Saturn is quite a bit smaller than for Jupiter, and planet evolution processes are probably responsible.

PHYSICAL STRUCTURE OF THE ATMOSPHERE (Atmosphere Structure Instrument) - - Measure the density, pressure and temperature structure of Jupiter's atmosphere beginning high in the ionosphere and upper atmosphere and continuing to a depth where pressure is at least 10 times as great as Earth's atmospheric pressure at sea level (10 bars). This altitude is believed to be below the water clouds. From these measurement sand others, scientists will be able to define the temperature and pressure levels at which clouds form, the internal structure of the clouds (whether they are liquid, vapor or solid), and the altitudes at which clouds form distinct layers.

Because of its great distance from the Sun, solar heating of Jupiter is only 3 percent as great as that of the Earth. Energy from Jupiter's interior appears to rise and heat the planet's surface, a result of convective overturning of the fluid interior. Studying the convective upwelling could enable researchers to better understand the circulation and internal dynamics of Jupiter's atmosphere, and may improve understanding of what causes the wispy belts and cloudy zones, and why they flow in opposite directions.

CLOUD LOCATION AND COMPOSITION (Nephelometer) -- Determine the nature of cloud particles, such as their number density, size, physical structure (solid or liquid) and distribution, by measuring their light-scattering ability. Researchers believe Jupiter has three distinct cloud layers: a topmost layer of white ammonia crystals, followed by reddish-brown clouds of ammonium hydrosulfide, and finally a layer of water clouds and ice crystals. Ground and spacecraft observations had previously indicated that Jupiter had much less water than expected for a Sun-like composition. However, recent astronomical observations and reinterpretation of spacecraft data indicate the presence of abundant water in the atmosphere. Part of the Probe's mission is to descend through the atmosphere and measure the water content. If there were to be few or no water clouds, scientists would have to rethink their theory of Jupiter's formation.

Finally, by confirming the composition and location of Jupiter's clouds, researchers will be able to calculate how much radiative energy the clouds absorb. This information will indicate the effects of energy flowing from Jupiter's internal heat source compared with that coming from the Sun and will lead to a greater understanding of the unusual circulation patterns observed in the planet's cloud tops.

The Probe will penetrate the cloud layers and provide continuous sampling of their properties during the descent phase from an altitude where pressure is one-tenth that of the Earth at sea level (0.1 bar) to the end of the mission -- which may be as deep as the 25-bar pressure level.

RADIATIVE ENERGY BALANCE (Net Flux Radiometer) -- Investigate the circulation and dynamics of the atmosphere at different levels by measuring the radiative energy (heat) emitted by Jupiter at the measurement altitude and the heat and light penetrating to the same altitude from the Sun. The distribution of radiative energy in the atmosphere helps shape the atmospheric circulation of Jupiter as well as of Earth. Such information will help explain the driving motions behind the circulation patterns seen on Jupiter's visible surface. An understanding of this distribution on Jupiter should provide better understanding of basic weather mechanisms on all planets. Determining where radiative energy is absorbed in Jupiter's atmosphere will also help scientists understand the opacity of the cloud layers, and thus their composition.

ELECTRICAL DISCHARGES (Lightning and Radio Emissions Detector) -- Verify the existence of lightning in Jupiter's atmosphere and provide data on the spectrum of radio frequency noises and light from these flashes. On Earth, lightning is produced by collisions of water droplets and ice particles in clouds, causing some particles to become charged positively and some to become charged negatively. When lightning strikes the ground, it transfers charge from the bottom of the cloud to the Earth's surface. If scientists find that lightning is frequent on Jupiter, the next question to answer will be, “How does charge separation occur?” For instance, convective currents, by carrying cloud particles from place to place, could create this separation.

Also, lightning is a process that can spark chemical changes -- life on Earth may have begun with chemical reactions induced by high temperatures and lightning. Such reactions form complex organic molecules.

The existence of lightning on Jupiter would increase the probability that complex organic molecules may be found in its atmosphere. Jupiter's mainly hydrogen atmosphere is hostile to any known life form, unless protected enclaves of more favorable gases exist, perhaps in its permanent circulation features.

THE INNERMOST MAGNETOSPHERE (Lightning and Radio Emissions Detector and Energetic Particle Instrument) -- Measure fluxes of protons, electrons, alpha particles and heavy ions in the innermost regions of Jupiter's magnetosphere -- within four radii of the planet -- and into the upper atmosphere. The Orbiter's instruments, designed to study Jupiter's magnetosphere, will not be able to take measurements at this altitude. So the Probe's data are critical to a complete study of Jupiter's huge magnetic field and radiation belts.

Information about Jupiter's innermost magnetosphere will help researchers understand the nature of plasmas -- the hot clouds of high- velocity, electrically-charged particles in which most highly energetic reactions occur. Jupiter's surface magnetic field is 10 times larger than that of the Earth and contains radiation belts 100 times more intense than Earth's Van Allen belts. Understanding this magnetosphere is fundamentally important to understanding the planet's interior. The belts' high concentrations of energetic particles can damage electronic component instruments, severely reducing the lifetimes of future spacecraft.

WINDS (Relay Radio System) -- Measure wind speeds and their variance at different altitudes. This information will help scientists understand what drives Jupiter's winds. A range of models has been developed to explain these counter-flowing jet streams. One theory proposes that there is more sunlight at the equator than at the poles and that the difference in heating creates turbulent currents, which cause the winds.

Another theory claims that Jupiter's internal heat source, which radiates energy upwards into the atmosphere, and the energy radiating downward from the Sun create turbulence in the atmosphere, which in turn causes the winds. Yet another explanation depends on the existence of a significant amount of water in Jupiter's atmosphere: If a great deal of water exists, the heat released as the water condenses to form clouds may create the winds.

By tracking the Probe from the Orbiter and finding how deep in the atmosphere the winds occur, it should be possible to eliminate some explanations of how the winds are driven.

THE PROBE INSTRUMENTS

NEUTRAL MASS SPECTROMETER (Organization: Goddard Space Flight Center): This instrument will determine the chemical constituents of Jupiter's atmosphere and their distribution at various altitudes. As the Galileo Probe descends, the spectrometer will measure the proportions of methane, helium, ammonia, water vapor, the isotopes of neon (from Ne20 to Ne22) and other atoms and molecules as they begin to appear in each distinct layer. Readings begin at the altitude where atmospheric pressure is approximately one-tenth that of the Earth at sea level (100 millibar (mb)) and continue until it is approximately 25 times as great as the Earth's atmospheric pressure at sea level (25 bars).

At 100 mb, ceramic break-off caps rupture and open up the instrument's two inlet tubes, allowing samples of the jovian atmosphere to enter the instrument. A beam of energetic (70eV) electrons splits the atmospheric gas molecules into ions. As the ions stream through electric time-varying fields, they are filtered according to mass. The ion masses, characteristic of their parent molecules, are counted as they strike an electrical detector. The spectrometer measures and records ions ranging from one to 150 Atomic Mass Units.

To facilitate the detection of minor elements in Jupiter's atmosphere, each inlet tube has a sample enrichment cell that boosts the ratio of minor to major components of the sample gas. One of the inlet channels also contains a noble gas purification cell, to aid in the detection of chemically inert gases.

The instrument is mounted to the equipment shelf. It weighs 29.1 pounds, consumes 25 watts of power and operates at a data rate of 32 bits per second.

HELIUM ABUNDANCE DETECTOR (Organization: Bonn University): The Helium Abundance Detector will precisely determine the ratio of helium to hydrogen in Jupiter's atmosphere. The instrument consists of an electronics unit and an optical sensor called the Jamin-Mascart two-arm interferometer.

One arm of the interferometer is vented to Jupiter's atmosphere; the other arm connects to a supply of a reference gas. To determine the relative abundance of helium, the interferometer compares the refractive index of ambient atmosphere samples with that of the reference gas, whose index of refraction is known. (A medium's index of refraction is the speed at which waves move through the medium divided into their speed through a vacuum.)

When the descending Galileo Probe reaches an altitude where atmospheric pressure equals two-and-a half times that of the Earth at sea level (2.5 bars), a diaphragm bursts and the ambient atmosphere and reference gases enter separate arms of the interferometer. A light-emitting diode beams infrared radiation through both chambers. Where the beams merge, a specific interference pattern of light and dark bands is created, a result of the design of the interferometer. The pattern will not change if both chambers are filled with identical gas mixtures, but if the sample gas and the reference gas are different, the pattern will shift. An array of nine light-sensitive diodes detects this shift. If the pattern shifts to the right, the sample has a higher refractive index than the reference gas. If it shifts to the left, the opposite is true.

Jupiter's atmosphere is approximately 89 percent hydrogen and 11 percent helium, and the refractive indices of both these gases are known. If we know the refractive index of ambient atmosphere, we can derive the relative abundance of helium.

The interferometer will determine, with 99.9 percent accuracy, the relative abundance of helium in Jupiter's atmosphere. The instrument will operate until it runs out of reference gas, at an altitude where the atmospheric pressure is between 10 and 12 bars.

The instrument weighs 3.3 pounds, consumes 1.1 watts of power and produces 4 bits of data per second.

ATMOSPHERE STRUCTURE INSTRUMENT (Organization: San Jose State University Foundation): This instrument will measure directly the temperature and pressure of the lower atmosphere, and indirectly the density of Jupiter's upper atmosphere.

The instrument consists of four parts: an electronics unit, an accelerometer to measure deceleration (from which density can be derived), and sensors for both temperature and pressure. The temperature and pressure sensors are exposed to the atmosphere. The accelerometer and electronics unit are mounted on the Probe equipment shelf.

During entry the accelerometer will record and store data in the Probe's limited memory until parachute descent, when the data can be read out of memory and transmitted to the Orbiter. At an altitude where atmospheric pressure is approximately one-tenth that of the Earth at sea level (100 millibars), the Probe jettisons its heat shield, uncovering the temperature sensor and pressure sensor inlet. The instrument then enters descent mode, in which temperature and pressure sensors take readings every two seconds and the acceleromete will record every eight seconds. The temperature sensor's range of zero to 540 degrees Kelvin (K) permits measurements to continue, if the Probe exceeds the planned mission depth of 10 bars pressure. (Zero degrees Kelvin equals minus 273 degrees C or minus 460 degrees F). It may survive down as deep as 28 bars pressure. There, temperature is estimated to be near 450 degrees K. Three pressure sensors will cover the range from 0.1 bar to 28 bars.

The instrument weighs 9.1 pounds, uses 6.3 watts of power and operates at a data rate of 18 bits per second.

NEPHELOMETER (Cloud Particle Sensor) -- (Organization: San Jose State University Foundation): This instrument will determine the location of cloud layers in Jupiter's atmosphere as well as characteristics of cloud particles, such as their number per unit volume, physical structure (solid or liquid) and mean sizes.

The instrument consists of an electronics unit and an optics unit with one back-scatter and four forward-scatter channels. Both units are attached to the Probe equipment shelf.

The forward-scatter unit consists of a laser light transmitter, mirror and receiving assemblies. The mirror assembly is rigidly mounted on a deployable arm, which extends outside the Probe's skin. The transmitter consists of a pulsed solid-state laser diode source and driving electronics, a lens for collecting and focusing the light, a long collimating tube and a monitor of the source output. The mirror assembly collects light scattered by particles in the forward direction at the four preselected angles from sampled volumes of atmosphere. It reflects this light back to the receiver assembly. Light hitting the receivers is focused onto detectors through sunlight-blocking, narrow-bandpass filters, and the electrical signals generated are processed in the receiver electronics for transmission to the Probe data system.

The backward-scatter unit is conceptually similar to that of the forward-scatter unit except that the unit does not require a collecting mirror, because in the backward direction, particles scatter light directly back to the receiver.

The Nephelometer will make many measurements, looking in five directions, of the light scattered from particle matter in the atmosphere of Jupiter as the Probe descends.

By comparing the measured data with models of particle distribution, the experiment can determine the best fits for proposed particle characteristics. These results will include mean particle size, information about whether the particles are spherical or non-spherical (liquid or solid), visual ranges in the atmosphere, and mass of various cloud areas. The instrument can see as few as 3 particles/cc, in size ranges between 0.2 and 20 microns. Together with the results of other experiments, they can provide hints as to the composition and optical properties of the particles.

The instrument will begin sending out its flashes of laser light after the Probe's parachute has been deployed (at an altitude corresponding to pressure of about 0.1 bar) and continue to the end of the Probe mission (at pressures greater than 10 bars).

The instrument weighs 10.6 pounds, consumes 11.2 watts of power and operates at a data rate of 10 bits per second.

NET FLUX RADIOMETER (Organization: University of Wisconsin): The Net Flux Radiometer measures energy (heat and light) radiated by Jupiter and the Sun at different levels in Jupiter's atmosphere.

The instrument is designed as a single unit with an optical head attached to an electronics compartment, which is mounted on the Probe's equipment shaft. Radiation from Jupiter's atmosphere enters the instrument through a diamond window and is reflected through a Fabry optical system.

The technique used to measure the net flux in a planet's atmosphere is to view the upward and downward hemispheres and to determine the difference in energy emitted by the Planet's internal heat source and that absorbed from the Sun. If the downward-going radiation from the Sun and the upward-going radiation from the planet are both increasing or both decreasing, the net flux will be smooth. If a planet's atmosphere has cloud layers, turbulence in an otherwise smooth net flux profile will result. The magnitude of the turbulence in various spectral regions gives information about the opacity of the cloud layers and how much their particles contribute to the radiation in that region. When correlated with temperature and pressure levels (from the atmospheric structure experiment), such information can point to the cause of the disturbance -- condensation clouds, for example. The experiment will also yield information about the effectiveness of cloud layers in preventing solar radiation from penetrating Jupiter's atmosphere.

The instrument weighs 7.5 pounds, consumes 13 watts of power and operates at a data rate of 16 bits per second.

LIGHTNING AND RADIO EMISSIONS DETECTOR (Organization: Bell Labs and the Max Planck Institute): This instrument measures electromagnetic waves being generated by lightning flashes in Jupiter's atmosphere and detects the light and radio transmissions from those flashes. From this information, scientists can determine the number and location of lightning cells and the size of the cloud turbulence. The instrument will also make radio frequency measurements at distances of four, three, two and one planetary radii above the cloud tops as the Probe approaches Jupiter.

The instrument consists of three sensors (one radio frequency sensor and two optical sensors) connected to an electronics box, which is shared with the energetic particles instrument.

The radio frequency sensor is a ferrite-core antenna, mounted in a plane perpendicular to the spin axis of the Probe. The antenna system responds to the magnetic field in the frequency range from about 100 Hz to 100 kHz.

The optical sensors are two sensitive photodiodes that detect lighting flashes. Each is mounted behind a fisheye lens whose optical axis is perpendicular to the spin axis. The sensors, mounted 180 degrees apart, cover a complete spherical field of view. Rapidly varying optical signals give a positive indication of lightning. Steady optical signals provide information about the brightness and opacity of the cloud systems.

The instrument weighs 5.4 pounds, uses 2.3 watts of power and operates at a rate of 8 bits per second.

ENERGETIC PARTICLE INSTRUMENT (Organization: University of Kiel): This instrument is part of the Lightning and Radio Emissions Detector and measures fluxes of protons, electrons, alpha particles and heavy ions that orbit in Jupiter's magnetosphere at up to tens of thousands of miles per second. The instrument also measures the energy and angular distribution of these particles.

The instrument is a quarter-inch-long, telescope-like device. It has two silicon disk detectors instead of lenses with a particle absorber, made of brass, inserted between them. The detectors are wired to charge-sensitive amplifiers and a high-voltage power converter. The entire assembly is contained in a cylindrical tungsten shield that opens in the front to allow particles to enter in the same way that light enters an optical telescope. Very high-energy particles, however, can penetrate both the tungsten shield and the brass particle absorber. That is how energy levels are determined.

For example, an electron that strikes the first, or A detector only, must be within the 2.6 to 7 MeV energy range. If it strikes detector A, passes through the brass absorber, and strikes detector B, it is in the 7 to 20 MeV range. An electron that strikes detector B without hitting A must have penetrated the tungsten shield. To do so, it must have more than 20 MeV energy.

The instrument is mounted under the aft heat shield of the Probe. Only particles with enough energy to penetrate this shield are counted by the detectors.

As the Probe descends toward Jupiter, the instrument will record data samples at five, four, three and two jovian radii. Between two jovian radii and Probe entry, the instrument will sample continuously. Measurements cease at Probe entry. In all, the instrument will generate 7,532 bits of data. The instrument weighs about 1 pound and consumes 1 watt of power.

RELAY RADIO HARDWARE (Organization: Stanford University): The Radio Science Experiment consists of two parts: Doppler wind determination and atmospheric absorption.

WINDS: As the Probe descends through Jupiter's atmosphere, its position and velocity will depend in large part on the planet's gravitational pull and 28,000-mph rotational speed. However, its velocity will also be affected by the planet's winds. A transmitter and antenna on the Probe will operate in conjunction with the Probe Relay Radio Hardware mounted on the Orbiter. Measurements of the Probe's transmitted frequency will be made during the entire period of the Probe's descent. Scientists will reconstruct the trajectories of the Probe and Orbiter during the radio relay link period. They will monitor the Doppler shift of the radio signals (the shift in frequency due to a change in velocity, similar to the change in pitch of a train whistle as a train rushes past). From this information, they can get a profile of Jupiter's east-west winds as they affect the Probe, and come closer to an understanding of the forces behind the planet's circulation patterns. The wind profile will also serve as a confirmation or "ground truth" for the wind speeds as determined by the Orbiter imaging team. The Doppler wind method for determining wind speeds will help researchers in the future to understand the dynamics and energy balance of Titan, Saturn, Uranus and Neptune.

ATMOSPHERIC ABSORPTION: As the radio signal from the Probe to the Orbiter passes through Jupiter's neutral atmosphere, it is affected by varying density structures in the atmosphere. In the ionosphere, electron density affects the radio signal. Atmospheric absorption of the signal is measured by comparing the transmitter output at the Probe with received signal strength at the Orbiter. Variation of the atmosphere absorption with changing Probe-Orbiter positions gives information about atmosphere structure, as well as about ionosphere electron density.

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Energetic Particles Instrument

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RADIO RELAY EXPERIMENT

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Jovian Atmospheric Dynamics
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Andrew P. Ingersoll, California Institute of Technology
Gerald Schubert, University of California

Structure and Aeronomy of the Atmospheres of Jupiter and its Satellites
Donald Hunten, University of Arizona

Ground-Truth Analysis of Radiative Transfer in the Atmosphere of Jupiter
Glen S. Orton, Jet Propulsion Laboratory

Composition of the Jovian Atmosphere
Tobias Owen, University of Hawaii
Michael McElroy, Harvard University

Organic Chemistry of the Jovian Atmosphere
Carl Sagan, Cornell University

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Patrick Melia	Chief, Probe engineering team
Mike Izadi	Instrument engineer

HUGHES SPACE AND COMMUNICATIONS COMPANY

Bernie Dagarin	Galileo Probe Manager
Daniel Carlock	System engineer
Frederick Linkchorst	System engineer
Richard Sakal	System engineer

GALILEO PROBE CONTRACTORS

COMPANY--LOCATION--SUBSYSTEM
DESCENT MODULE

Hughes Space & Communications Co., El Segundo, CA.
Prime Probe System Contractor

Fadal Engineering, North Hollywood, CA
Probe Structure

Rah Industries, Northridge, CA.
Aero Fairing

Motorola, Scottsdale, AZ
Exciter

Sandia Labs, Albuquerque, NM
Radiation Hardened Parts
Frequency Electronics, Long Island, NY
Stable Oscillator

Inertia Switch Company, New York, NY
Acceleration Switches

Southwest Research Institute, San Antonio, TX
Pressure Temperature Simulation

Lockheed-Martin Corp., Orlando, FL
Hi-g Test Facility

Digital Equipment, Maynard, MA
Ground Support Equipment Computers

DECELERATION MODULE

Lockheed-Martin Corp., Philadelphia, PA
Deceleration Module

Havig Incorporated, Santa Fe Springs, CA
Carbon Phenolic Manufacturing
Dow Corning, Midland, MI
Heatshield Bonding

Fansteel, Los Angeles, CA
Aerostructure Skin

General Electric, Valley Forge, PA
Thermal blanket

Pioneer Parachute, Manchester, CT
Parachute

Quantec, Fremont, CA
Mortar Cartridge

Hi-Shear, Torrance, CA
Separation Nut

Space Ordnance, Saugus, CA
Cable Cutter

Eagle-Picher, Joplin, MO
Thermal Battery

SCIENCE/INSTRUMENTS

Lockheed-Martin Corp., Denver, CO
ASI, NFR, NEP -- Instrument Design and Hardware Fabrication

Bell Aero, Textron, Buffalo, NY
ASI Accelerometers

Travis, Inc., Mariposa, CA
ASI Pressure Sensors

Rosemount, Minneapolis, MN
ASI Temperature Sensors

Ball Aerospace, Boulder, CO
NFR Electronic Parts

Barnes Engineering, Stamford, CT
NFR Detectors

Optical Coating Labs, Inc., Santa Rosa, CA
NFR Optical Filters

Frank Cook Optical, North Brookfield, MA
NFR Condenser Cone

NASA Goddard Space Flight Center, Greenbelt, MD
NMS -- System Design and Fabrication

ERG, Inc., Oakland, CA
NMS Valves

General Electric, Valley Forge, PA
NMS Hybrids

University of Michigan, Ann Arbor, MI
NMS Electrical Design

National Bureau of Standards, Boulder, CO
NMS Housings

Bell Labs, Murray Hill, NJ
LRD -- Science Support

University of Kiel, Kiel, Germany
EPI System Design

University of Braunschweig, Braunschweig, Germany
LRD Fabrication

Max Planck Aeronomy Institute (MPAE), Lindau, Germany
LRD System Design

University of Florida, Gainesville, FL
LRD Science Support

University of Bonn, Bonn, Germany
HAD System Design

Messerschmidt Bolcow, Blohm (MBB), Munich, Germany
HAD Flight Hardware

Carl Zeiss Company, Munich, Germany
HAD Optic Design

Dornier, Freidrichshafen, Germany
LRD and EPI Flight Hardware