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Press Kit

Project Pioneer Venus

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NOTE TO EDITORS:

This press kit covers the launch and cruise phases of both the Pioneer Venus Orbiter and the Multiprobe spacecraft. Much of the material is also pertinent to the Venus encounter, but an updated press kit will be issued shortly before arrival at the planet in December 1978.

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PIONEER VENUS 1 LAUNCH SET FOR MAY 20

NASA is preparing to launch the first of two spacecraft toward Venus this month for a detailed scientific study of that cloud-shrouded planet.

Pioneer Venus 1 will be launched about May 20 from NASA's Kennedy Space Center, Fla., atop an Atlas Centaur rocket.

The second spacecraft, Pioneer Venus 2, will be launched toward the planet three months later, about Aug. 7.

-more-

Pioneer Venus 1, an orbiter, will reach Venus on Dec. 4, 1978, and Pioneer Venus 2, a multiprobe spacraft, will arrive five days later after splitting into a bus and four atmospheric entry probes, 13 million kilometers (8 million miles) and 20 days out from the planet.

The flights may shed new light on some of the most puzzling questions in planetary science, such as the following:

● Why do two planets with about the same mass, probably formed out of similar materials and situated at comparable distances from the Sun, have atmospheres that have evolved so differently?

● Why is the surface of Venus baked by a searing heat, while Earth luxuriates in a climate friendly to life?

The answers to both of these questions depend on an understanding of the factors that govern the evolution of a planet's atmosphere.

Information gathered by the two instrument-laden Pioneers at Venus may also help us learn more about the forces that drive the weather on our own planet.

The flights are the first ones devoted primarily to a study of the atmosphere and weather of another planet on a global scale. They will employ the largest number of vehicles ever used in such studies, and make measurements at the greatest number of locations.

The flights also will seek to learn more about the characteristics of Venus's upper atmosphere and ionosphere, as well as the lower atmosphere. They will study the interactions of these regions with the solar wind -- the continuous stream of ions and electrons flowing outward from the Sun -- and the solar magnetic and electric fields.

Circling the planet for at least eight months, the Pioneer Venus Orbiter will make the longest observations yet of Venus. It will be the first U.S. spacecraft to orbit the planet.

To reach Venus, the Orbiter will fly more than half way around the Sun on its seven-month journey, some 482.8 million km (300 million mi.), traveling outside the Earth's orbit for the first three months, and inside it for the last four months. This wide-swinging flight path will allow a slower approach to the planet, permitting a smaller orbital insertion motor and more spacecraft weight.

At Venus, the Orbiter will follow a highly-inclined (75-degree), 24-hour orbit planned so that spacecraft events are timed with those on Earth. At periapsis (orbital low point), the spacecraft will dip as low as 150 km (90 mi.) altitude, entering Venus' thin upper atmosphere. Its orbital high point or apoapsis will be 66,600 km (41,000 mi.) from the planet.

The Orbiter will make daily pictures in ultraviolet light of Venus' clouds for studies of their four-day rotation.

Experimenters will use precise orbit measurements to chart Venus' gravity field for calculation of planetary shape and density variations. The 12 Orbiter scientific instruments will make a variety of other remote-sensing and direct measurements of the planet's atmosphere and surrounding environment.

The Orbiter's primary mission of eight months in Venus orbit will cover one complete rotation of Venus on its axis -- 243 Earth days. It circles the Sun in 225 days.

The Orbiter's companion spacecraft, the Multiprobe, is made up of a transporter Bus, a Large Probe and three identical smaller probes.

These spacecraft, including the Bus, will enter at points spread over Venus' entire Earth-facing hemisphere, about 10,000 km (6,000 mi.) apart. The Bus will obtain data on the composition of the upper atmosphere before burning up. The other four probes will measure the atmosphere from top to bottom as they fly down to Venus' searing surface. The probes are not designed to survive after impact.

Scientists believe that these coordinated atmospheric missions combined with similar ones to Mars, Jupiter and other planets, will lead to a better understanding of atmospheric mechanisms in general. Studies of the interactions of temperatures, pressures, composition, clouds and atmospheric dynamics different from Earth's should provide insights into important mechanisms which are often prominent on just one planet. Such findings may help us better understand the Earth atmosphere and its complex weather machine.

Scientists think Venus may be an unusually good place to study the mechanics of atmospheres because the planet rotates slowly and there are no oceans. The atmosphere appears to be a relatively "simple" weather machine, and the important atmospheric circulation motions appear to be global. Hence, continuous measurements from orbit, combined with those of the probes from many points in the atmosphere, could provide at least a rough picture of Venusian weather processes.

The Orbiter spacecraft, like the Multiprobe bus, consists principally of a spin-stabilized, 2.4-meter (8-foot)-diameter, flat cylinder containing most spacecraft systems.

Above the cylinder, on a 1-m (10-ft.)mast aligned with the spin axis, is the despun, narrow-beam, parabolic dish antenna. The dish is used for high-speed data transmission and faces toward the Earth throughout the mission, while the spacecraft spins beneath it.

Within the cylinder is a thermally-controlled equipment compartment, which houses the 12 Orbiter scientific instruments, a million-bit data memory and the communications and data-handling systems. Other Orbiter systems are the Sun and star sensors for spacecraft orientation; thrusters to make spin-rate, orientation and course corrections; the solid-fuel orbital insertion motor; and the battery and power system. The exterior of the cylinder is coated with power-generating solar cells. A 4.6-m (15-ft.) boom extends radially outward to place two magnetometer sensors beyond spacecraft magnetic fields.

The Orbiter's launch weight is about 580 kilograms (1,280 pounds) with 45 kg (100 lb.) of scientific instruments. Weight in orbit after motor burn will be 372 kg (820 lb.).

The Orbiter's destination, Venus, is the second planet from the Sun, and the closest one to Earth. Because of its highly reflective cloud cover, Venus is the brightest object in the sky after the Sun and the Moon. Its year is 225 Earth days. Its mean distance from the Sun is 108.2 million km (67.2 million mi.). This is nearly three-quarters of Earth's distance from the Sun.

When Venus is closest to Earth, directly between Earth and Sun, the planet is only 42 million km (26 million mi.) away. While Earth and Venus are almost twins in size and mass, they are extremely different in other ways. Earth is a water-rich planet on which life thrives. Venus is a dry and desolate world, apparently without life. Scientists want to know how two similar planets can evolve so differently and if there is any chance of Earth becoming like Venus.

Available evidence suggests that Venus has a dramatically rugged surface, but it is less mountainous than Earth and Mars. Its surface temperature is hotter than the melting points of lead and zinc, about 470 degrees C (900 degrees F.), and the atmospheric pressure is about 100 times that of Earth. Surface features on Venus can never be seen because of its permanent cloud cover. The atmosphere of Venus appears to be predominantly carbon dioxide -- about 97 per cent. Only minute amounts of water vapor have been detected in it.

Venus has no significant magnetic field. So the planet's upper atmosphere interacts directly with the solar wind. Venus is one of the three planets in our solar system which has no moons, the others being Mercury and Pluto.

The mass, diameter and mean density of Earth and Venus are almost identical. Venus' high overall density suggests a dense core something like Earth's nickel-iron core.

Venus receives almost twice as much solar radiation as Earth. But without the trapping of solar heat by its atmosphere, the planet's polar regions would have habitable temperatures. This trapping is called a greenhouse effect, which means that Venus' atmosphere allows passage of incoming solar radiation, but restricts radiation of heat outward.

The temperature at the poles of Venus is only about 10 degrees C (18 degrees F.) less than that at the equator. Both its day and night hemispheres have the same temperature. Hence, Venus' massive atmosphere contains circulation mechanisms which distribute solar heat evenly over the whole planet.

In addition to carbon dioxide and water traces, Venus' atmosphere also has some carbon monoxide, hydrochloric acid and hydrogen fluoride.

Venus' permanent clouds are very tenuous, something like terrestrial smog. They are almost twice as deep as Earth's cloud layer, about 18 km (11 mi.) thick, and are believed to be composed mainly of sulfuric acid droplets.

Somewhere below the bottom of the main cloud layers, the temperature becomes great enough for the sulfuric acid droplets to evaporate into water vapor and sulfuric acid vapor. A clear atmosphere results. Enough sunlight gets through the clouds so that the surface appears as bright as on an overcast day on Earth.

From the Mariner cloud photographs in ultraviolet light, it appears that the stratosphere of Venus is in continuous high-speed motion. The clouds seem to move about 360 km/hr (220 mph), circling the planet in four Earth days. However, the Soviet Venera landers showed that wind speeds in the deep atmosphere are extremely slow. In the region between atmosphere top and bottom, an abrupt change in wind velocity appears to take place. This seems to occur at about 56 km (36 mi.) above the surface, between the base of the clouds and the clear atmosphere below them.

Some major questions relating to Earth and Venus are these:

- Like Venus, the Earth has a "greenhouse effect" which appears to be growing due to increases in carbon dioxide in our atmosphere. These increases come from large-scale burning of fossil fuels since 1850. Could the Earth's greenhouse effect become strong enough to cause serious, permanent rises in temperature?

- Since Venus presumably formed as close to Earth as it is today, we might expect Venusian oceans like our own. Yet there is almost no water on Venus. Where did the water go, if it ever existed?

One theory is that greater solar heating vaporized any oceans, and forced water vapor into the stratosphere. There it would have split into hydrogen and oxygen by solar ultra-violet radiation. The light-weight hydrogen would then have escaped to space leaving the oxygen behind. But there seems to be so little free oxygen left, that scientists wonder where it all went.

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NASA's Office of Space Science has assigned project management of the two Pioneer Venus spacecraft to Ames Research Center, Mountain View. Calif., and the spacecraft will be controlled continuously from the Mission Operations Center at Ames. The spacecraft were built by Hughes Aircraft Co., El Segundo, Calif., and the scientific instruments were supplied by NASA centers, other government organizations, universities and private industry.

The spacecraft will be tracked by NASA's Deep Space Network, operated by the Jet Propulsion Laboratory, Pasadena, Calif. NASA's Lewis Research Center, Cleveland, is responsible for the launch vehicle, which was built by General Dynamics, San Diego, Calif.

Cost of the two Pioneer Venus spacecraft, scientific instruments, mission operations and data analysis is about $175 million. This does not include cost of launch vehicles and tracking and data acquisition.

Launch period for the Orbiter flight is 22 days (May 20 through June 10, 1978), and during these days, the time of launch window opening varies between 6:08 and 9:24 a.m. EDT. The window varies in length from 15 minutes to one hour.

Launch period for the Multiprobe flight extends from Aug. 7 to Sept. 3, 1978.

(END OF GENERAL RELEASE. BACKGROUND INFORMATION FOLLOWS.)

MISSION PROFILE

The two Pioneer flights to Venus will explore the atmosphere of the planet, study its surface using radar and determine its global shape and density distribution. The first spacecraft, Pioneer Venus 1, an Orbiter, will make eight months or more of remote-sensing and direct measurement. Pioneer Venus 2, a Multiprobe, will separate into five atmospheric entry craft, eight million miles out from the planet, and measure the atmosphere from top to bottom in about two hours at points spread over the entire Earth-facing hemisphere of Venus.

The Pioneer Venus Orbiter Mission

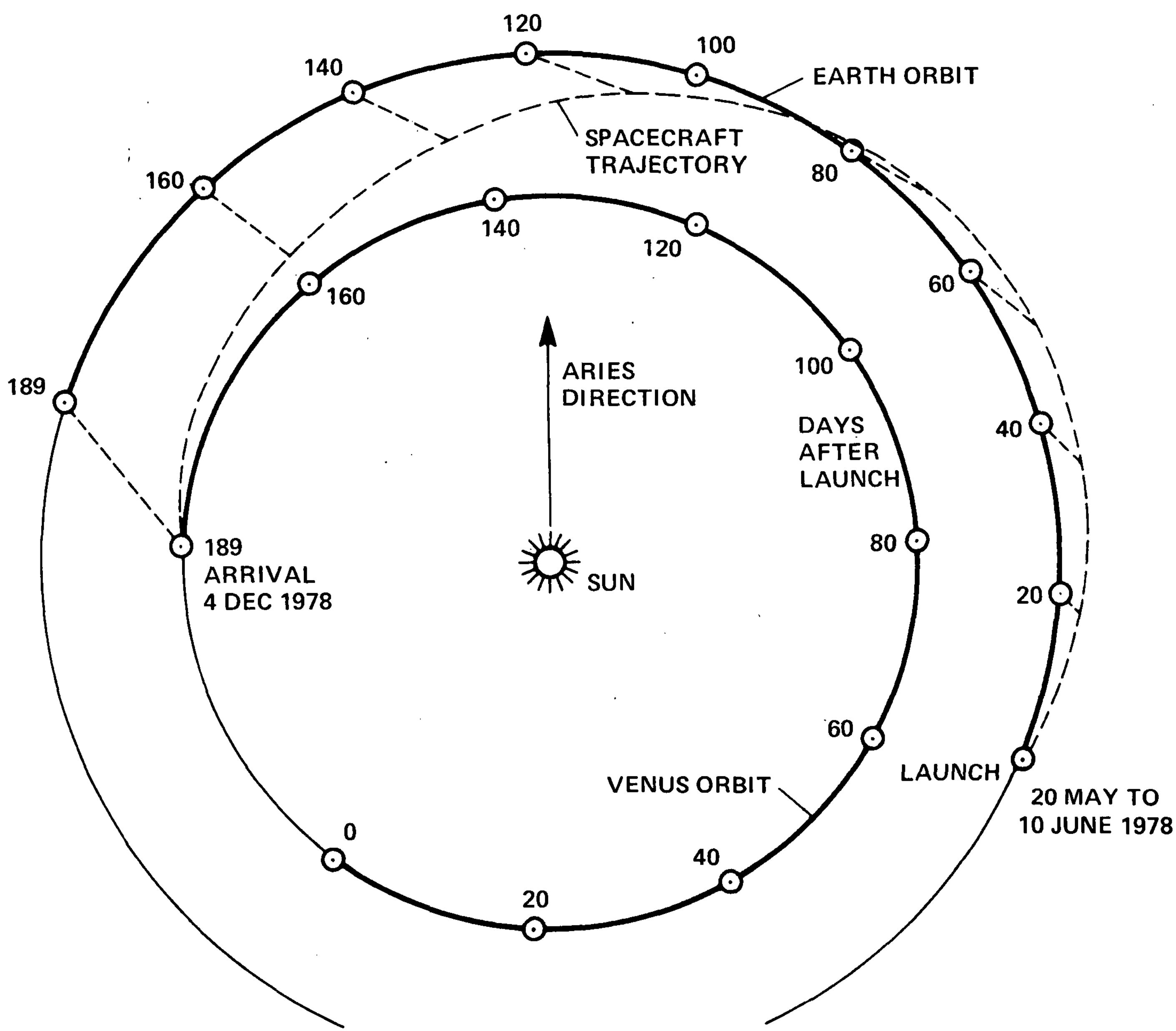
The Pioneer Venus Orbiter will be launched into a circular parking orbit ascent trajectory from Cape Canaveral, Fla., heading in a direction varying from 3 to 18 degrees south of due east during the first 15 days of the launch period. It will pass over southern Africa shortly after second stage restart and burnout. Later, the launch direction will be either 10 degrees or 30 degrees north of due east, depending on the launch date.

The seven-month flight to Venus will follow a trajectory more than half way around the Sun (through about 200 degrees), and will cover about 480 million kilometers) 300 million miles). This trajectory, three months longer than that of the Multiprobe, allows a slower arrival speed at Venus, requiring less weight for the orbit insertion motor. It also allows an orbital low point (periapsis) at a latitude of about 20 degrees north.

For the first 82 days, Pioneer Venus 1 will fly outside the Earth's orbit. In August, it will cross back inside the orbit of its home planet, and then, during the last four months of the journey, will cross the 42 million km (26 million mi.) between the orbits of the Earth and Venus on a long, curving trajectory. This flight path will be similar to that of its companion spacecraft, the Venus Multiprobe. The Multiprobe will be launched a few days after the Orbiter crosses back inside Earth's orbit.

Launch period for the Orbiter flight is 22 days (May 20 through June 10, 1978). During these days, the launch window opening times vary from 6:08 to 9:24 a.m. EDT. The window varies in length from half an hour to an hour for the first 18 launch days, but extends to two hours on the last two days of the period.

ORBITER FLIGHT PATH TO VENUS



Launch dates are timed so that the Orbiter arrives at Venus on Dec. 4, 1978, five days before the arrival of the five probes on Dec. 9. Launch dates were selected for optimum payloads for both Orbiter and Multiprobe missions.

Both Pioneer Venus spacecraft will be launched by an Atlas (SLV-3D)/Centaur (D-1AR) two-and-a-half-stage launch vehicle. Air Force Eastern Test Range personnel will conduct tracking during the near-Earth part of the mission. NASA's Deep Space Network (DSN) will be responsible for the remainder.

After liftoff, burnout of the 1,917,000-newton (431,040-pound)-thrust, one-and-one-half-stage Atlas booster will occur in about four minutes. One-half minute before this event, the 10.4-meter (34-foot)-long aerodynamic nose fairing which protects the spacecraft will split lengthwise and be jettisoned just after leaving the atmosphere. Stage separation and ignition of the 130,000-N (30,000-lb.) thrust Centaur second stage will then take place. Shortly afterward the Antigua station begins tracking. The hydrogen-fueled Centaur engine will burn for about five minutes. The Centaur engines will then shut down at 173-km (107.5-mi.) altitude, and the Orbiter and the Centaur will coast for about 12 minutes in circular parking orbit. Antigua tracking will end about 13 minutes after launch. The Ascension Island station, just below the equator in the South Atlantic, picks up the Centaur-Venus Orbiter about 10 minutes later. About 23 minutes after launch, the Centaur engine restarts and burns for about 2.5 minutes, putting the Orbiter on its Venus flight path. During the next 2.3 minutes, Centaur will orient the spacecraft with the forward (antenna) end pointing to celestial north but tilted 20 degrees toward the Sun. At this point, the Pioneer Venus Orbiter separates from the Centaur, and the spacecraft command register then begins to function.

Just after separation, about 28 minutes after launch, the command register will command storage of telemetry data and start the thruster-firing sequence for spinup to 6.5 rpm. The Orbiter's million-bit data memory can store information for 68 minutes at a bit rate of 256 bps after it is turned on.

Twenty-eight minutes after launch, and after Centaur-Orbiter separation, mission control will shift from the mission director at Cape Canaveral to the flight director at the Pioneer Mission Operations Center (PMOC) at Ames Research Center, Mountain View, Calif. Commands to spacecraft and incoming data will go via the global net of DSN tracking stations. DSN stations will receive commands from, and relay data to, the PMOC at Ames.

At launch plus about one hour, the DSN station at Canberra, Australia, will acquire the spacecraft, and 10 minutes later will have established command of the Venus bound Orbiter and verified the spacecraft's health. Flight controllers at Ames will then command the spacecraft telemetry processor into the launch-cruise format (half science, half engineering). Gaps in tracking coverage will be due to early flight altitudes between widely separated global tracking stations.

With Canberra acquisition, Ames mission directors will turn on the plasma analyzer (solar wind instrument) to make near-Earth observations. They will verify the spin period and Sun angle and check spacecraft wobble. When the wobble has subsided to an acceptable level, they will command the firing of pyrotechnics to deploy the three-section, hinged, 4.7-m (15.5-ft.) magnetometer boom. Deployment of the boom slows spacecraft spin from 6.5 to 5 rpm. Immediately afterwards, the magnetometer is turned on. With the boom deployed, controllers will be able to command spacecraft spinup to 15 rpm in ensuing weeks.

Approximately 18 hours after launch, the Orbiter will be oriented so that its spin axis is within two degrees of a right angle to the ecliptic. Mission engineers can now command operation of the high-gain antenna despin system to point the narrow-beam antenna at Earth. The antenna mast, which is aligned with the spacecraft spin axis, is commanded to stop rotating so that the antenna dish points at Earth while the spacecraft continues to spin under it. Elevation of the dish is adjusted so that it centers on Earth.

Nine and one-half hours after launch, the Orbiter picture-taking format is turned on, and one-half hour later, the electronic camera, the Cloud Photopolarimeter, using its imaging mode, begins to take pictures of Earth as Pioneer moves away.

Subsequently, mission operations will turn on the gamma ray burst detector and the electric field detector.

Midcourse Corrections and Cruise

During the first five days, trajectory specialists at NASA's Jet Propulsion Laboratory, Pasadena, Calif., will calculate the precise trajectory, establishing the precise Earth departure velocity and direction. Ames controllers will then command firing of radial and/or axial thrusters to eliminate errors in aiming at Venus. Spacecraft orientation may be changed somewhat for efficient acceleration, and then returned by further thrusts to its cruise position, perpendicular to the ecliptic.

Once the spacecraft is in a cruise mode, the six scientific instruments planned for use at Venus will be checked out periodically. Controllers will change pointing direction of the high-gain antenna dish every five days to two weeks or more, to keep it centered on Earth.

Twenty days after launch, a second course correction can be made, and 30 days before the spacecraft arrives at Venus, navigators can command a third course correction for a precise insertion into orbit around the planet. Several weeks after launch, controllers will command the spacecraft to spinup to 15 rpm, a rate which will be maintained until two days before Venus arrival. It provides solar wind measurements.

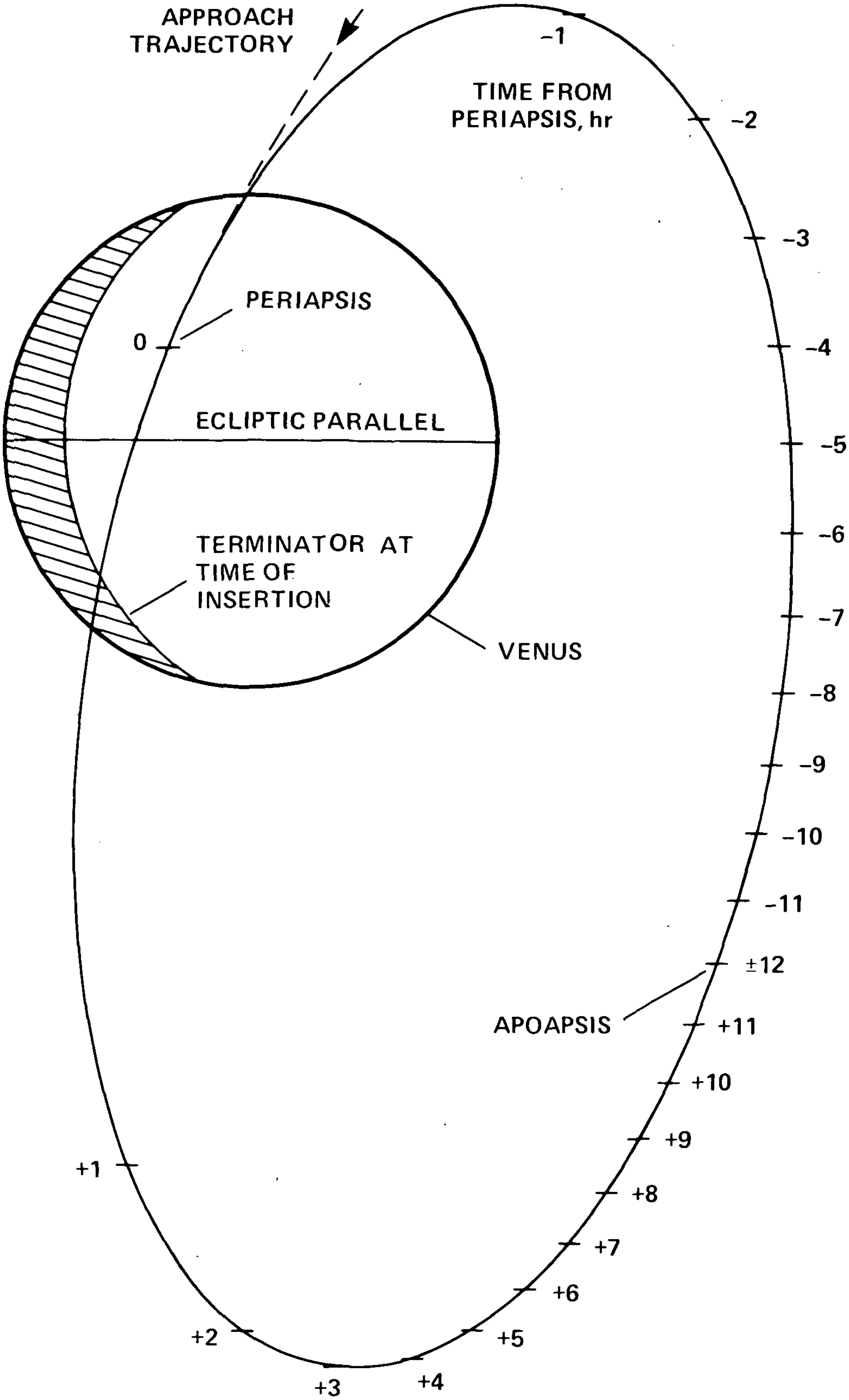
Two days before arrival at Venus, the spacecraft spin rate will be increased to 30 rpm and the Orbiter will be oriented with its 18,000-N (4,000-lb.)-thrust, solid-fueled rocket engine pointing forward, opposite the direction of travel at the point of closest approach to Venus.

On Dec. 4, 1978 (the 198th day after launch, if launch occurs on May 20), Ames Mission Control engineers will command a 28-second orbit-insertion burn. This will reduce spacecraft velocity by 3,816 km/hr (2,366 mph), placing Pioneer in a 24-hour orbit around Venus. The planned orbit will be inclined 75 degrees to Venus' equator, with its low point (periapsis) near 20 degrees north latitude. The orbit's high point (apoapsis) is expected to be at an altitude of 66,000 km (41,000 mi.), and periapsis initially will be at 300 km (180 mi.), later reduced to about 150 km (90 mi.). Planned orbital injection time is 11:00 a.m. EST.

Within hours after the orbit insertion rocket burn, members of the Orbiter navigation team will have determined any shortcomings in the orbit. After slowing the spin rate and adjusting orientation, they will command firing of thrusters to trim up the orbit to acceptable dimensions.

Attention in the Mission Operations Center will then switch to the probes scheduled to arrive five days later, but fine tuning of the orbit will continue after completion of the probe mission.

PERSPECTIVE VIEW OF PIONEER VENUS ORBIT



In-Orbit Operations

For efficient orbital operations during the 243-day primary Orbiter mission (one complete Venus rotation on its axis), the orbit will have a period very close to 24 hours. This means that most activities will occur at the same time on Earth every day. This includes the most intensive periods of data return during periapsis. Data return via the high-gain antenna will be at the two highest rates, 1,024 or 2,048 bps.

The 24-hour orbit has been divided into two periods, reflecting the kind of measurements being taken. The periapsis (orbital low point) period is about four hours long. The apoapsis (orbital high point) period is 20 hours long. Since the Orbiter dips into the upper atmosphere itself at periapsis, which may be as low as 150 km (90 mi.) to make direct measurements, the periapsis period is the time of highest data return.

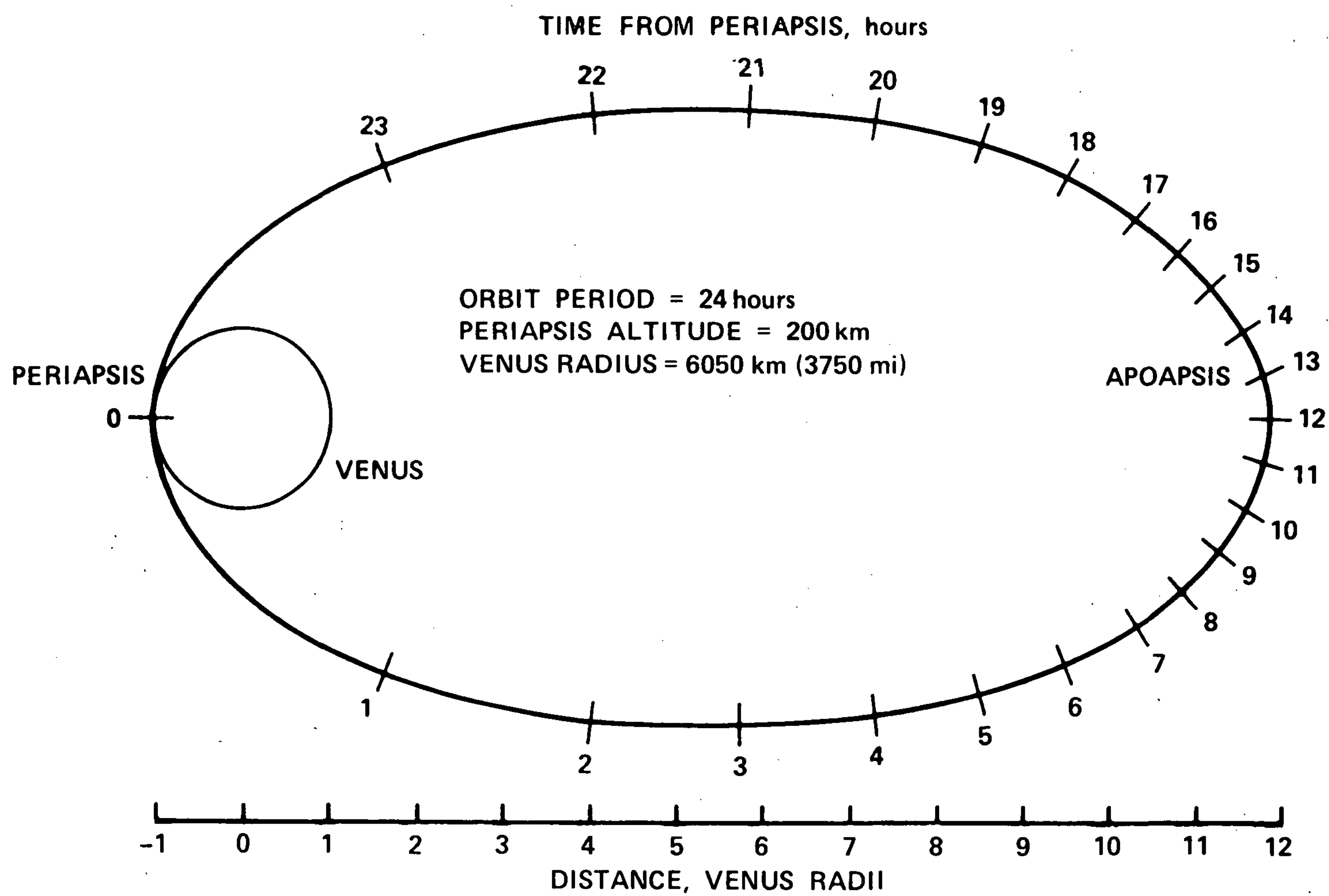
Mission operations will use five data formats during the periapsis period. These formats are designed to permit emphasis on certain instruments when desirable; for example, one provides intensive aeronomy coverage at periapsis, another stresses optical coverage.

The mapping format gives 44 per cent of the data stream to the radar mapper for Venus surface study, and divides the rest between the ultraviolet spectrometer and the infrared radiometer.

Normally, controllers will use only two data formats in the 20-hour apoapsis segment. The first of these will be for taking pictures of the whole planet in ultraviolet light, which will show the four-day rotation of Venus' clouds in sequence. Known as the imaging format, it allocates 67 per cent of the data stream to the imaging instrument and the cloud photopolarimeter, and divides the rest among three solar wind-planet instruments and the astronomical experiment's gamma burst detector. The other format, known as the general format, allocates data return among all Orbiter experiments except the picture-taking cloud photopolarimeter and the infrared radiometer. As much as three-quarters of the total apoapsis period will be devoted to imaging, which has very large data requirements.

Spacecraft controllers have designed a number of sequences using these formats. During the eight-month Orbiter mission, they will work with experimenters, selecting format combinations for best scientific results.

ORBIT IN SPACECRAFT ORBIT PLANE



During the first 40 days in orbit, the Orbiter will pass behind Venus (occultation) for periods of up to 23 minutes. This allows the radio science team to measure effects of Venus' atmosphere down to approximately 50 km (31 mi.) on the spacecraft radio signal as it passes through it. Since the narrow beam signal is bent by the planet's atmosphere, the antenna's dish reflector can be commanded as much as 17 degrees away from the Earth-line to extend the time of recording the signal as it is refracted around the solid planet.

Also during occultations, when communications are cut off, the Venus Orbiter will store data in its million-bit memory. Controllers will then command memory storage, and after emergence of the Orbiter, the data memory readout format for return of stored data.

During the eight months on orbit, health of the spacecraft will be monitored through the continuous flow of engineering data (see Orbiter Data Handling Section), and redundant systems for the most critical functions (such as command and data return) will be used if needed. Missions Operations engineers also will trim the orbit about every 10 days either to lower periapsis altitude which is constantly raised by solar gravity or to adjust the orbital period when it drifts from the desired value.

The primary mission ends after 243 days. Shortly afterwards, the Orbiter and Venus will be behind the Sun and communications will be garbled or cut off for several days. After emergence from the solar blackout, the opportunity will be available for extended mission operations which are not currently a part of the approved mission.

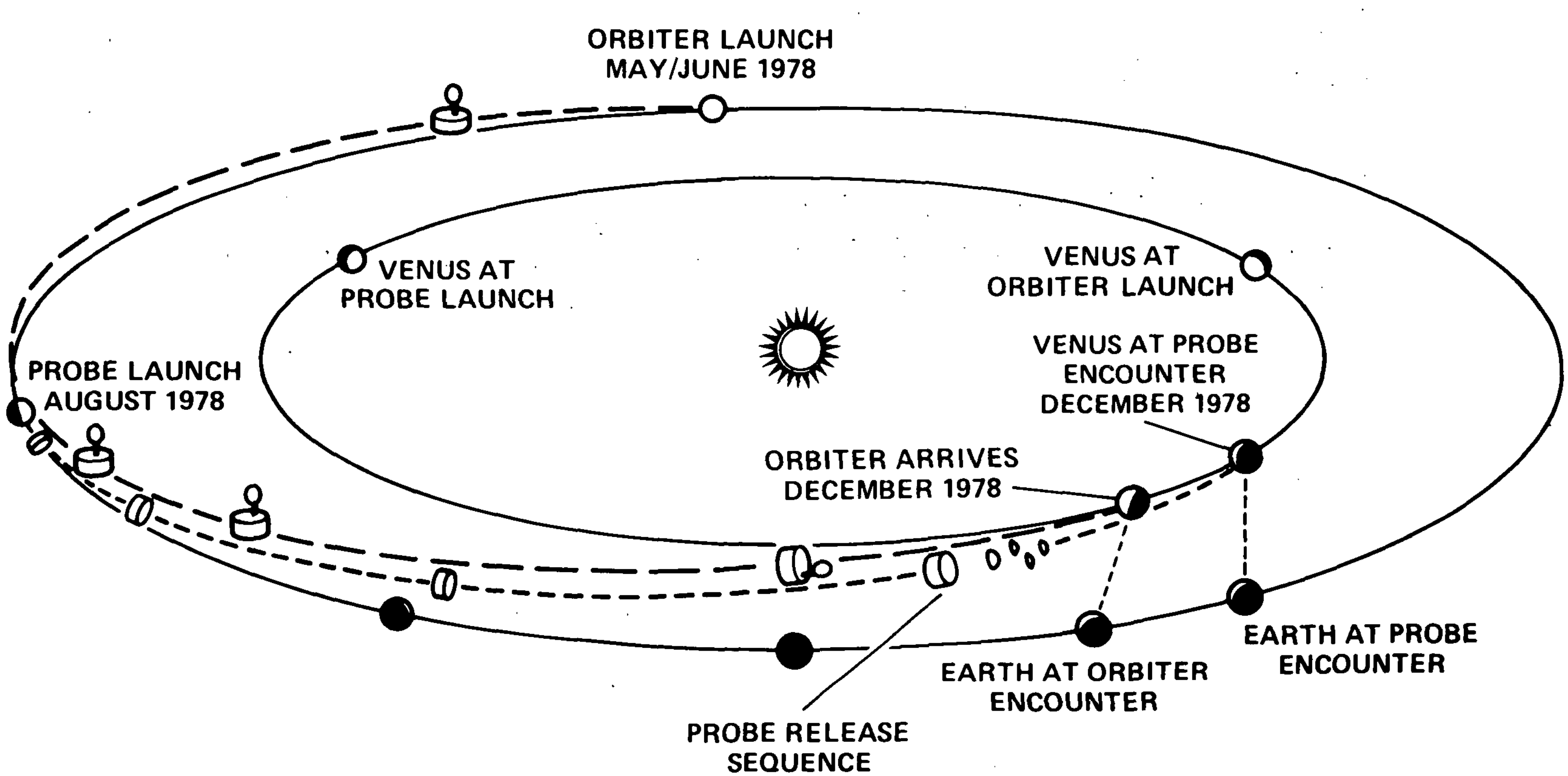
Pioneer Venus Multiprobe Mission

Pioneer Venus 2, the multiprobe spacecraft, will be launched toward Venus on a circular parking-orbit ascent trajectory from Cape Canaveral Air Force Station by NASA's Kennedy Space Center personnel. The launch vehicle will head in a direction 3 to 18 degrees south of straight east, passing over southern Africa shortly after separation of the spacecraft from the launch vehicle.

The four-month trip to Venus follows a more direct trajectory than that of the Orbiter, giving the probes approach speeds of about 19,500 km/hr (12,000 mph). This is 6,500 km/hr (4,000 mph) faster than Orbiter arrival, and is possible because the probes are slowed at atmosphere entry to a few hundred miles per hour by the braking of atmospheric friction.

PIONEER VENUS

TRAJECTORIES



The Multiprobe flight will cover about 354 million km (220 million mi.), going about two-fifths of the way around the Sun (135 degrees) in four months as it crosses the 42 million km (26 million mi.) between the orbits of Earth and Venus.

Launch period for Pioneer Venus 2 flight is 27 days, from Aug. 7 to Sept. 3, 1978. During this period, the launch window opens earlier each day from 3:36 a.m. to 12:16 a.m. EDT. This launch period will allow the probes to arrive at Venus on Dec. 9, 1978, five days after arrival of the Orbiter. The earlier Orbiter arrival will allow the Orbiter's remote and direct sensing instruments to establish corresponding data on the Venus space environment, clouds and upper atmosphere that can be correlated with the probe measurements in the atmosphere.

Pioneer Venus 2 will be launched by an Atlas (SLV-3D) Centaur (D-1AR) two-and one-half-stage launch vehicle. After liftoff, burnout of the 1,917,000-N (431,040-lb.)-thrust, stage-and-one-half Atlas booster will occur in about four minutes. Stage separation and ignition of the 130,000-N (30,000-lb.)-thrust Centaur second stage will then take place.

At six minutes after liftoff, the Antigua station begins tracking. The hydrogen-fueled Centaur engine will burn for about five minutes with the first engine cutoff at 9 minutes, 42 seconds after liftoff. This begins the 18-minute coast period in circular parking orbit at 167 km (104 mi.) altitude. At about launch plus 13 minutes, Antigua will end its tracking coverage; at about 20 minutes after launch, the Ascension station begins tracking and at launch plus 24 minutes Multiprobe-Centaur combination pass beyond Ascension range.

At 27 minutes and 30 seconds, Centaur begins its second burn and 2 minutes and 8 seconds later (launch, plus 29.6 minutes) its engine cuts off putting the Multiprobe on trajectory to Venus. About 27.6 minutes after launch an Air Force Range Instrumentation Aircraft begins five minutes of tracking coverage.

At 29.7 minutes after launch, Centaur orients the Multiprobe spin axis to within 12 degrees of perpendicular to the ecliptic (Earth's orbit plane) with its forward end pointed near the south ecliptic pole. One hundred thirty-five seconds after the second Centaur engine cutoff, also at launch plus 31.9 minutes, Pioneer separates from Centaur, and the spacecraft command register initiates the spinup sequence. Spacecraft thrusters then spin up Multiprobe to 15 rpm.

During powered flight, as with Pioneer Venus 1, launch vehicle and spacecraft will be monitored from the Pioneer Mission Control Center at Cape Canaveral via DSN and Eastern Test Range tracking stations, including Antigua and Ascension.

Thirty-two minutes after launch, after Centaur-Multiprobe separation, mission control will shift from the Ames Mission Director at Cape Canaveral to the Flight Director at the Pioneer Mission Operations Center (PMOC) at Ames Research Center in California. Commands to and data returned from the Pioneer Venus will leave and arrive at Earth via the global net of the DSN tracking stations. The stations in turn receive commands from and relay data to the PMOC at Ames.

At 50 minutes after launch, the DSN's Canberra station acquires the spacecraft and 10 minutes later command capability is established. Data rate through the spacecraft's aft omni antenna is 256 bps.

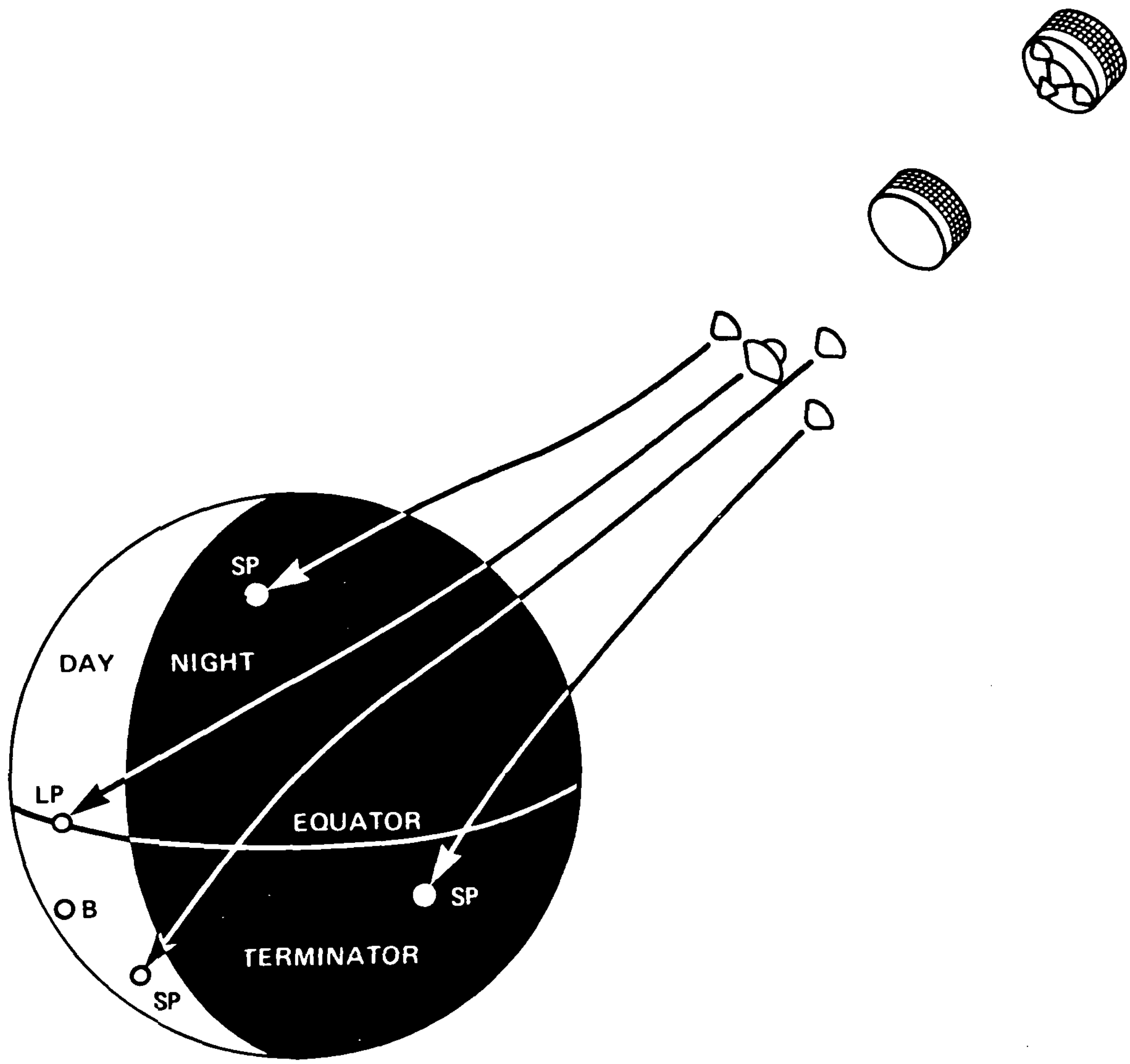
For the following two weeks communications between spacecraft and Earth will be primarily "housekeeping," since the probe and Bus instruments make no interplanetary measurements. They are designed to measure the Venus atmosphere. Data will be spacecraft health and engineering measurements.

Five days after launch, the space navigation section at the Jet Propulsion Laboratory will have calculated the Multiprobe Venus trajectory precisely, and controllers at the PMOC at Ames will command the thruster firing sequence for the first trajectory correction maneuver. About 14 days after launch, the two Bus instruments will be checked out for three hours at a data rate of 1,024 bps. Twenty days after launch, operations engineers will make a second course correction.

About 60 days after launch, the seven instruments and the systems on the Large Probe will be checked out for three hours at data rates of 256 and 128 bps. Controllers at PMOC check out the three instruments and systems on each of the Small Probes for an hour of operation each at a data rate of 64 and 16 bps. They perform similar checks on the two instruments aboard the Bus at 512 bps. The Bus communications and power system will be used for these checks.

About 94 days after launch (30 days before atmosphere entry), controllers will initiate the third trajectory correction maneuver. At about the same time, the spacecraft is oriented so that the aft-facing medium-gain horn antenna looks at Earth. This allows a higher data rate for probe separation maneuvers.

ENTRY POINTS FOR PIONEER - VENUS ATMOSPHERE PROBES



Twenty-seven days before entry, the Bus and Large Probe instruments are checked out.

Twenty-four days before atmospheric entry, and 13 million km (8 million mi.) from Venus, controllers reorient the spacecraft so that the Large Probe will enter the atmosphere with its heat shield aligned with its entry flight path. This means aligning the Bus spin axis with the planned Large Probe entry trajectory because the Large Probe is centered on the spin axis. The Large Probe is then launched by a pyrotechnic-spring mechanism toward its equatorial entry point on Venus' day side, becoming an independent spacecraft.

The next 23 days from atmospheric entry, the Bus is maneuvered for separation of the Small Probes by changing its flight path, pointing it toward the center of Venus. At 22 days before entry the three Small Probe instruments are checked out. At 20 days before entry the Bus is reoriented so that the three Small Probes can be targeted for their entry points -- one on the day side at mid-southern latitudes, the second on the night side, also at mid-southern latitudes, and the third on the night side at high northern latitudes. Mission operations then commands launch of the three Small Probes. After the transporter Bus is spun up to approximately 48 rpm, the probes are launched by releasing the clamps that hold them. Centrifugal force of the Bus spin throws the probes tangentially from the Bus into their entry trajectories. As a result of this launch process, the Small Probes retain the 48-rpm spin established while attached to the Bus.

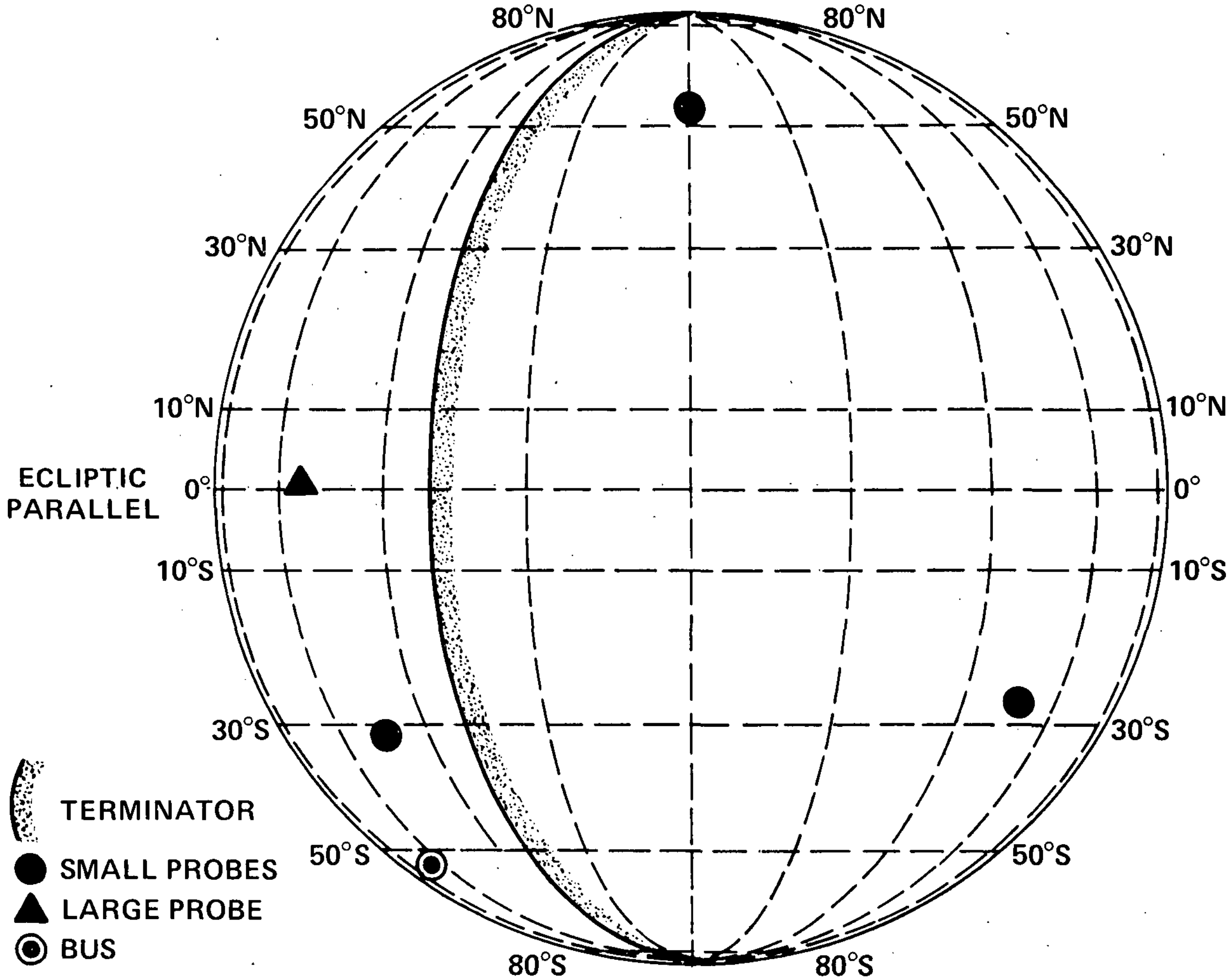
With launch of all four probes, five spacecraft -- including the Bus -- each with its own instrument and command and data system -- are headed for Venus.

Eighteen days before entry, after Small Probe separation, controllers will retarget the Bus for entry. Bus entry is delayed about 85 minutes after entry of the last Small Probe to provide a radio signal reference for precise computations of the probe descent trajectories. (Trajectory data will be used to measure winds in Venus' atmosphere.)

From this point on, the four probes will be commanded by onboard timers and other sensors and electronics, and they will not be heard from by controllers on Earth until 22 minutes before atmospheric entry.

At entry minus eight days, final adjustments will be made to the Bus' entry angle by ground command, and at entry minus two days, the Bus systems and scientific instruments will be checked.

VIEW FROM EARTH OF MULTIPROBE ENTRY LOCATIONS



Approximately two hours before Bus entry, the scientific instruments will be warmed up and commanded into the operation mode for entry.

On Dec. 9, 1978, at about 2 p.m. EST, the four probes will arrive at Venus and enter the atmosphere. The Large Probe will descend to Venus' surface in 55 minutes and the three Small Probes in about 57 minutes, depending on entry angle.

Large Probe Entry Events

At 2.5 hours before entry, the Large Probe command unit will order warmup of the battery and radio receiver. Twenty-two minutes before entry, the probe will begin transmission of radio signals to Earth. At entry minus 17 minutes, the Large Probe begins transmitting data at 256 bps. The command unit initiates warmup of the seven scientific instruments aboard, plus instrument calibration. Five minutes before the peak entry deceleration pulse of 320 G, the probe will be traveling 41,600 km/hr (26,000 mph). Entry occurs at 200 km (120 mi.) altitude, where the probe encounters the tenuous top of the atmosphere.

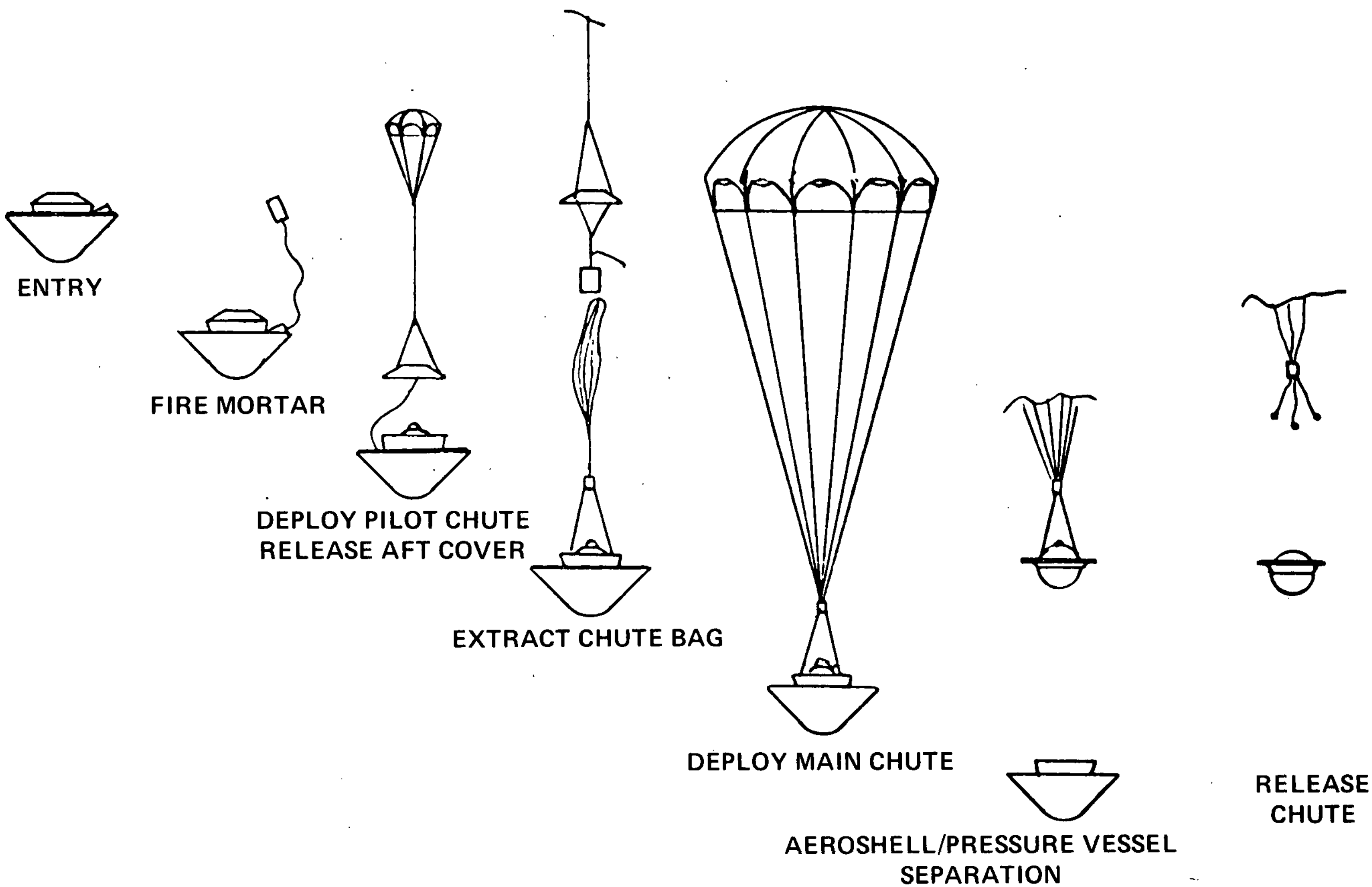
The timer will command data storage for the atmospheric structure experiment during entry communications blackout.

Thirty-eight seconds after entry, the Large Probe begins the descent phase, deploys its parachute and jettisons its forward aeroshell-heat shield. Forty-three seconds after entry, at an altitude of 66 km (40 mi.), all instruments should be operating. Seventeen minutes later, at 47 km (28 mi.) altitude, the parachute is jettisoned, and the aerodynamically stable pressure vessel descends to the surface in 39 minutes, impacting 55 minutes after entry. As the probe descends, the atmosphere gets steadily hotter and denser, until at the surface its temperature is 470 degrees C (900 degrees F.), and its pressure is nearly 100 times that at the Earth's surface. The Large Probe jettisons its parachute to speed its descent through this very dense atmosphere, so that it reaches the surface before heat destroys it.

During descent, the Large Probe's seven instruments will have obtained data to determine altitude and composition of cloud layers, atmosphere constituents, temperature, pressure, density, wind flow and variations of heat flow in the atmosphere.

The Large Probe will impact the surface at about 36 km/hr (22 mph). None of the probes is designed to survive impact.

LARGE PROBE DESCENT SEQUENCE



Small Probe Events

The three Small Probes, too, will enter the planet's atmosphere at about 41,600 km/hr (26,000 mph). However, because their entry points are spread over an entire hemisphere of Venus, and they are launched simultaneously from the Bus, the angles of their flight paths into the atmosphere vary greatly. This means that entry heating and durations of maximum deceleration pulses vary widely. Peak deceleration forces vary from 200 G to 565 G. Entry times also differ by up to 10 minutes, and descent times by one minute. As with the Large Probe, entry is defined as occurring at an altitude of 200 km (120 mi.).

Three hours before atmospheric entry, the stable oscillator in the radio transmitter for one-way Doppler tracking and the battery on each Small Probe are warmed up by commands from the onboard command unit. Twenty-two minutes before entry, each Small Probe begins transmission of radio signals to Earth. Seventeen minutes before entry, the Small Probes begin transmitting data at 64 bps. The command unit initiates warmup and calibration for the three instruments on each Small Probe.

Five minutes before entry, the two cables and weights of the yo-yo despin system are deployed to reduce the spin rates of the Small Probes from 48 to 15 rpm. The high spin rates imparted by the Bus are needed to disperse the probes to entry points widely spaced over the planet. However, this wide dispersion also means that the Small Probes enter Venus' high upper atmosphere somewhat tilted to their flight paths. The "spindown" of the probes is needed to make it easier for aerodynamic forces to line up the axes of the probes with their entry flight paths. This must occur quickly before heating at the edges of the probes' conical heat shields becomes serious. Cables and weights are jettisoned immediately after spindown.

Five minutes before the peak deceleration pulse of atmospheric entry, the command unit orders the "blackout" format for storage of spacecraft data, plus heat shield temperature and accelerometer measurements for the atmospheric structure experiment. This is to assure no loss of data during the 10-to-15-second communications blackout at entry.

Within the first minute (18 to 46 seconds) after entry, the nephelometer window is opened, and the atmospheric structure and net flux radiometer housing doors are opened and instrument booms deployed.

At this time, the upper descent phase begins, with the probes in the altitude range of 72 to 65 km (43 to 39 mi.) and all instruments operating. The instrument compartment doors on each side of the Small Probe afterbodies serve to despin the probes. A small vane on the pressure sensor inlet serves to prevent the spin rate from falling to zero rpm enabling instruments to make observations over a full circle of probe rotation.

At entry plus 16.4 minutes, as the thickening atmosphere interferes with radio transmission, the data rate is reduced to 16 bps. This occurs at an altitude of 30 km (18 mi.).

From this point, the three Small Probes descend into Venus' increasingly dense lower atmosphere, impacting on the surface at 36 km/hr (22 mph) from 56 to 57 minutes after the entry time of each probe. Unlike the Large Probe, the Small Probes retain their heat shields to the surface. The density of the atmosphere is so great that the drag of these aerodynamic surfaces slows them to the desired descent speed. Like the Large Probe, the Small Probes are not designed to survive on the surface.

Bus Events

Eighty minutes after all probes have entered the Venus atmosphere, the Bus will enter on the day side of the planet at high latitudes in the southern hemisphere. Unlike the probes, the Bus has no heat shield for high-speed entry, and is expected to burn up one to two minutes after entry. The Bus carries two experiments on the composition of the atmosphere, and ion and a neutral mass spectrometer. These instruments measure constituents of the ionosphere and upper atmosphere from 200 km (120 mi.) down to 115 km (69 mi.), making the missions' only atmospheric composition measurements between 150 and 115 km . The Bus, with its more powerful transmitter, returns this data to Earth at 1,024 bps.

All data from the probe missions will be recorded simultaneously by the DSN stations at Goldstone, Calif., and Canberra, Australia, and more than 50 multiprobe experimenters will spend a year or more analyzing these data. The investigators will be especially interested in comparing results from the widely-spaced probe flight paths on the day and night sides and in both hemispheres of Venus.

Atmospheric wind velocities and directions will be calculated from measurements of the probe velocities, through triangulation measurements from four stations at once. Two STDN stations at Guam and Santiago, Chile, will record Bus and probe data along with the DSN stations.

THE PLANET VENUS

Venus is the planet most similar to Earth in size, mass and distance from the Sun. But its surface is much hotter, its atmosphere much denser, and its rotation much slower than that of Earth.

The diameter of Venus is 12,100 km (7519 mi.), compared with Earth's 12,745 km (7920 mi.). The mass of Venus is 0.81 times that of the Earth. The mean density of Venus is 5.26 grams per cubic cm compared with Earth's 5.5 grams per cubic cm.

Because Venus is closer to the Sun, it receives about twice as much energy as Earth. However, it is more reflective than Earth because of its cloudy atmosphere. As a result of these two competing factors, Venus absorbs about the same amount of solar energy as Earth. Thus Venus would be expected to have a temperature very similar to Earth's. In fact, the surface of Venus is very hot, about 480 degrees C (900 degrees F).

This theory for the high temperature of Venus assumes that the atmosphere allows the passage of the incoming solar radiation to the lower atmosphere and the surface. However, the atmosphere restricts the passage of heat radiation from the surface and the lower atmosphere back into space. The heat is trapped. Earth has a modest greenhouse effect that raises its surface temperature by about 35 degrees C (95 degrees F.),but in some parts of the infrared spectrum heat can escape by direct radiation from the Earth's surface to space. Because of its density, composition and clouds, the Venus atmosphere is very thick, and because it is mostly carbon dioxide, it is essentially opaque to outgoing heat radiation at all important wavelengths.

One of the most puzzling aspects of Venus is its lack of water. If Venus is as dry as it seems, where did the oceans of Venus go, if any ever existed? One speculation is that the water rose into the upper atmosphere and was dissociated by solar ultraviolet radiation into hydrogen and oxygen. The hydrogen escaped into space from the top of the Venus atmosphere, and the heavier oxygen diffused down to the oxidized crust. Detailed analysis shows that it might not be practical for Venus to have lost an ocean of water by such a route. Perhaps Venus formed close enough to the Sun so that the temperature prevented water from being incorporated into the solid material that formed the planet. If so, Venus would never have had enough water within its rocks to form early deep oceans like those of Earth. Direct measurements of gases within the Venus atmosphere may point toward one of two alternatives: Either that water was not incorporated into Venus as much as on Earth, or that water outgassed and was subsequently lost.

Orbit and Rotation of Venus

The rotation of Venus is very slow and in a retrograde direction, that is, opposite to the direction of the planet's revolution about the Sun and to the rotation of most other planets. Venus turns on its axis once in 243.1 Earth days.

Since Venus' rotation on its axis and revolution in orbit around the Sun are in opposite directions, the length of a solar day on Venus is 117 Earth days (58.5 Earth days of "daylight" 58.5 Earth days of night).

The orbits of Earth and Venus are tilted to each other about 3.5 degrees. Venus' axis is tilted about 6 degrees from perpendicular to the plane of the planet's orbit. This compares with Earth's axial tilt of 23.5 degrees which produces our seasons. Thus, seasonal effects on Venus are small.

Some scientists believe that Venus' period of rotation is tied to the revolution of the Earth and Venus around the Sun. Venus presents the same hemisphere toward Earth at each closest approach; that is, each time the planet passes between Sun and Earth. If the rotation of Venus is locked to the close approaches of Earth and Venus, then the internal distribution of mass within Venus should be slightly asymmetric.

Why does Venus rotate so slowly when most other planets rotate in periods of hours rather than months? One speculation is that a large body hit Venus and stopped its rotation. This large body might have been captured as a satellite into a retrograde orbit and later impacted with Venus to stop its normal rotation and rotate it slowly in an opposite direction.

It could be that Venus was formed from large fragments, and as a result of the combined impacts of these fragments never had much rotation. According to another suggestion, solar tidal effects in Venus' dense atmosphere may have slowed rotation and then "turned the planet over", accounting for its backward rotation.

Radar astronomers have mapped an area on the Earth-facing side of the planet as large as Asia and have found what appears to be a rugged surface. According to the radar results, there are huge shallow craters as well as an enormous volcano which may be as large in area, though not as high, as Olympus Mons on Mars (the solar system's largest discovered so far). Radar astronomers also detected what appears to be an enormous canyon. This chasm is 1400 km (870 mi.) long, 150 km (95 mi.) wide, and several kilometers deep.

Venus' Interior and Absence of Magnetic Field

Unlike the Earth, Venus has no significant magnetic field. The generation of Earth's field is attributed to a self-sustaining dynamo in the fluid core of the planet. Convection currents in the core give rise to electric currents that produce the external magnetic field. This theory, which also seems to apply to Jupiter, predicts that slow-spinning planets like Venus should not have magnetic fields.

Venus is a planet whose shape could be very close to a sphere according to radar measurements. They show its equator to be almost a perfect circle. Because the poles do not rotate into view as do points on the equator, circularity around the poles cannot be measured. The lack of irregularities in shape, and of a satellite makes it difficult to determine the internal density distribution of the planet. Most models of the interior are based on its similarity to Earth, consisting of a liquid core, a solid mantle and a solid crust. But the true nature of the interior of the planet is very much in doubt because scientists do not know Venus' thermal structure or the nature of the materials which make up its mass.

The Atmosphere of Venus

Carbon dioxide is the dominant gas in the Venusian atmosphere. There are also traces of water, carbon monoxide, hydrochloric acid and hydrogen fluoride. Free oxygen has never been found.

The clouds which obscure the surface of Venus consist of thick hazes of droplets believed to be made of sulfuric acid. Venus' clouds are pale yellow and very reflective, returning into space some 75 per cent of the sunlight falling on them. Space probe measurements have shown that there are distinct cloud layers much higher than terrestrial clouds. Photographs taken in ultraviolet light reveal a four-day rotation of the markings in these clouds. This rotation is like that of the planet, in a retrograde direction. Unusual dynamics of the atmosphere are required to account for this high-speed cloud motion.

The generally accepted figure for atmospheric carbon dioxide on Venus is 97 per cent. However, measurements made by early Venera spacecraft (USSR) differ from radio occulation measurements suggesting the presence of about 70 per cent carbon dioxide in the Venusian atmosphere. And, if there is much argon in the atmosphere, the amount of carbon dioxide could be as low as 25 per cent.

Adding to the uncertainty is the fact that the percentages determined by the Veneras were obtained by sampling the atmosphere in regions where there are sulfuric acid droplets. The presence of the acid may have contaminated these measurements. It is therefore possible to argue that the carbon dioxide is considerably less than 97 per cent, with the remainder being made up by some combination of nitrogen and argon.

The amount of carbon dioxide is important because it plays a major role in the interpretation of the microwave spectrum of the planet. If the atmosphere is 97 per cent carbon dioxide, the microwave observations permit the presence of as much as 0.1 per cent water below the clouds. Some instruments on the most recent Veneras 9 and 10 indicated that water vapor constituted about 0.1 per cent of the atmosphere below the main clouds. At the cloud tops it is only 0.0001 per cent, however. But, if there is another gas in the atmosphere of Venus that is not a good microwave absorber, the planet's atmosphere might contain more water than is now believed.

Carbon dioxide is also important to theories about the evolution of the atmosphere of Venus, and to the radiative properties of the present atmosphere and its dynamic characteristics.

The atmospheres of both Venus and Earth are assumed to have originated from gases that were released from the interiors of the planets which were hot when the planets first formed. In the case of Earth, most of the outgassing may have occurred soon after formation, from the heat of formation. Venus may never have had much water to outgas in the first place if it was formed from parts of the solar nebula that were poor in water. Or it may be that Venus formed with as much water as the Earth, but this water has now been lost.

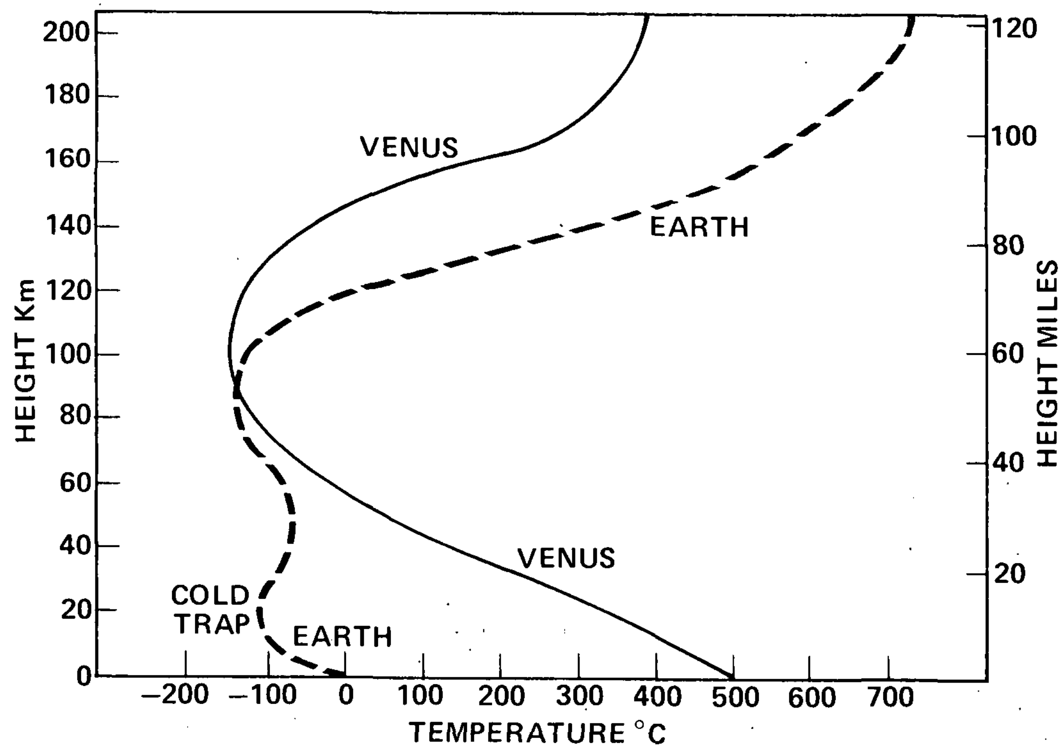
The Earth holds its water in its oceans because it is much cooler than Venus and there is a "lid" on its atmosphere. This lid is the very cold tropopause where the temperature rises with altitude. This prevents heated water vapor from rising by convection to cooler heights where it could be dissociated by solar ultraviolet radiation. But if Earth were moved to the same distance from the Sun as Venus, conditions could change drastically. The additional solar energy would be sufficient to evaporate all of Earth's oceans.

If Venus had been formed from the same mix of materials as Earth and then outgassed its volatiles, we would expect it to have an atmosphere about 350 times as massive as Earth's. Carbon dioxide would account for a surface pressure of about 100 atmospheres, and water vapor would account for about 150 atmospheres. On Earth most of the 100 atmospheres of carbon dioxide is tied up in carbonate rocks which are chemically stable at terrestrial temperatures, but unstable at Venus temperatures. Earth's oceans, if vaporized, would result in an atmospheric pressure of about 250 atmospheres. Venus does indeed have nearly 100 atmospheres of carbon dioxide, but the water is apparently absent. There are no oceans, and the atmospheric water vapor is a minor constituent. One of the major questions to be answered by Pioneer Venus is just how much water vapor is present. Water vapor would be broken down by solar ultraviolet radiation into oxygen and hydrogen. The hydrogen would escape into space leaving the oxygen behind. Effectively the oceans would be leaking into space.

This could have happened to Venus. If the primitive atmosphere of Venus consisted mostly of steam (because the planet is closer to the Sun than Earth), the resulting convective atmosphere could not have had a barrier to convection. The water vapor would have dissociated into hydrogen and oxygen. Calculations suggest that within about 30 million years perhaps 90 per cent of the water could have been lost to the planet, but all could not be lost in this way.

Furthermore, there is no easy way to explain what happened to the leftover oxygen other than that it reacted with the surface rocks. Yet without running water to continually expose fresh rocks for oxidation, the process might be insufficient to remove all the oxygen. Continental drift might be a possible mechanism to expose fresh rocks. There is a question, too, of what happens to the oxygen now released in the upper atmosphere by photodissociation of carbon dioxide to produce the carbon monoxide observed spectroscopically. The incorporation of oxygen with sulfur to form the sulfuric acid droplets does not seem to account for all the missing oxygen.

VENUS - EARTH TERMPERATURE PROFILES



On Venus, because of the high surface temperatures, reactions between rocks, minerals and the atmosphere are expected to be much faster than on Earth. However, on Earth the action of running water constantly exposes new rocks to the action of the atmosphere and aids oxidation and other reactions between the rocks and the atmosphere. This is not happening on Venus. If fresh rocks are not being exposed by some other mechanism, the atmosphere of Venus may not have achieved equilibrium with surface materials.

The Venus atmosphere can be divided into three distinct regions: a region above the visible cloud tops which includes the ionosphere and the exosphere; a region of clouds; and a region from the base of the clouds to the surface.

Upper Atmosphere

The upper atmosphere of Venus has an ionosphere which is different from that of Earth. Because Venus does not have a significant magnetic field, the solar wind interacts directly with the upper atmosphere and the ionosphere of the planet.

Among the atmospheric regions of Venus, the upper atmosphere above the cloud tops is best understood. It has been investigated from Earth and from flyby and orbiting spacecraft. Above 150 km (90 mi.) it is more rarefied than the atmosphere of Earth at the same height. Like Earth's atmosphere, it is ionized by incoming solar radiation to produce positively-charged ions and free electrons of an ionosphere, which is thinner and closer to the surface of the planet than Earth's ionosphere. Like Earth's ionosphere, the ionosphere of Venus has layers at which the number of electrons per cubic centimeter (electron density) peaks. In Earth's ionospheric layers, the peak electron density is about 100,000 to 1,000,000 electrons per cubic centimeter, and occurs at an altitude of about 250 to 300 km (150 to 180 mi.). The major ion is singly-charged carbon dioxide.

Mariner 10 found two clearly defined layers in the nighttime ionosphere: a main layer at 142 km (87 mi.) altitude and a lesser layer at 124 km (76 mi.). The peak intensity of the latter was about 78 per cent of the higher layer. On the dayside there was one main layer at 142 km (87 mi.) and several minor layers, including one at 128 km (78 mi.) and another at about 180 km (110 mi.). The Venera 9 and 10 orbiters obtained similar results, but single layers seem to be the most common.

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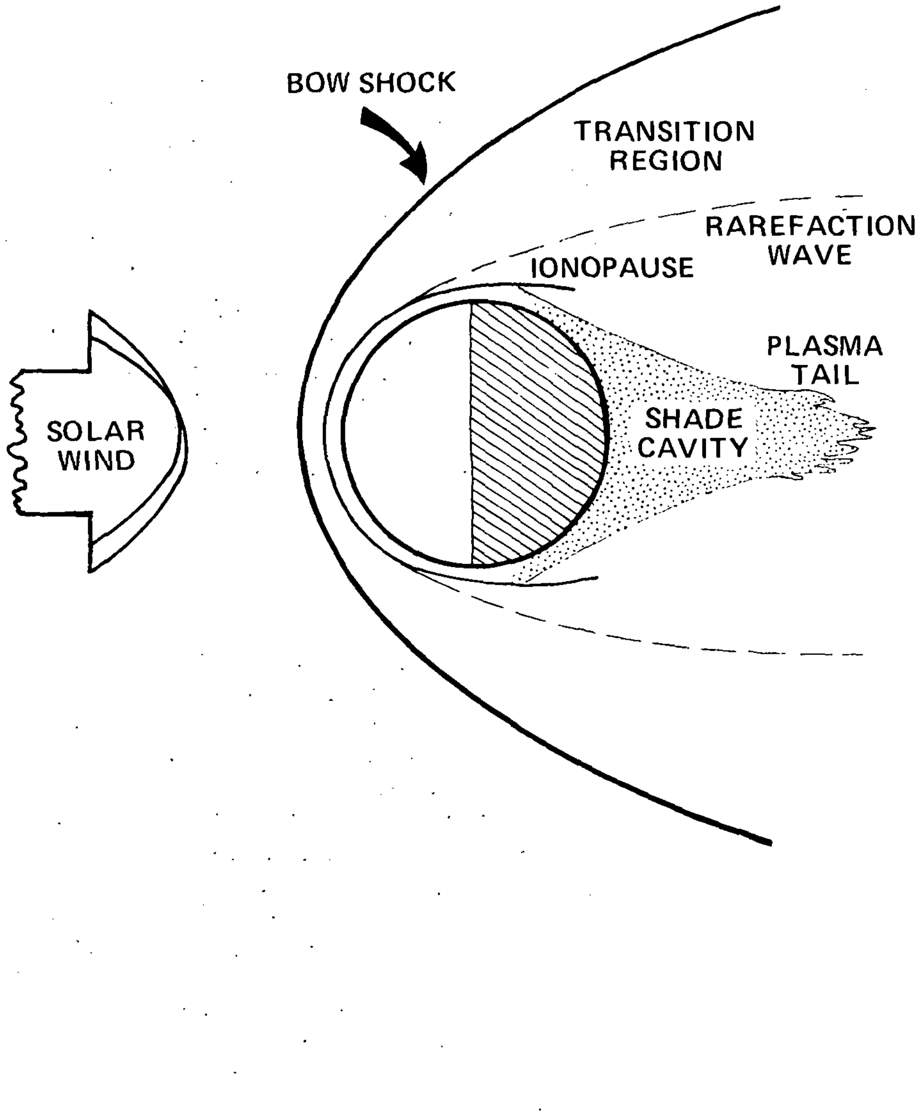
SOLAR WIND - VENUS INTERACTIONS



From a practical standpoint, Venus has no intrinsic magnetic field. The field of Venus is less than 1/10,000 of Earth's field. There is a region of rarefaction (lessened density) of the solar wind flow at Venus, and the characteristics of the plasma there indicate that Venus absorbs part of the flux of the solar wind. On the dayside of Venus, there is a sharp boundary to the ionosphere at 350 to 500 km (210 to 305 mi.). This is believed to be caused by the interaction of the solar wind with Venus' atmosphere. On the night side of the planet, the ionosphere extends high into space and probably into a plasma tail stretching away from the Sun.

Temperatures have been measured in regions above the visible cloud layers by radio occultation. The temperature of the exosphere (region where particles escape the planet) was derived from density variation with altitude found by the ultraviolet experiments of spacecraft. From observations of the ultraviolet radiation from hydrogen and helium atoms, it is calculated that the temperature of the exosphere of Venus when Mariner 10 flew past the planet was about 127 degrees C (260 degrees F). At such a temperature, the thermal escape of helium gas would be negligible. Accordingly it is thought that if helium outgassed from the rocks of Venus as it did on Earth the gas might have accumulated in the upper atmosphere of Venus. A corona of hydrogen begins at about 800 km (480 mi.) and contains up to 10,000 atoms per cubic centimeter.

Haze Layers

At least two tenuous layers of haze can be seen in high resolution pictures of the limb (edge of the disc) of Venus. They extend from equatorial regions to higher latitudes. They may be associated with temperature inversions in the high atmosphere, and may result from processes similar to those in Earth's atmosphere which produce layers of aerosols in the stratosphere. Aerosols are solid or liquid particles suspended in an atmosphere. The stratified layers of haze are in the region 80 to 90 km (50 to 56 mi.) above the surface of Venus where the atmospheric pressure is between 50 and 0.5 millibars. (Pressure at Earth's surface is 1000 millibars). These haze layers are extremely tenuous. At the topmost haze layer, if the atmosphere is mainly carbon dioxide, the temperature should be -75 degrees C. However, temperatures determined from occultations differ appreciably above 60 km (37 mi.), suggesting temperature inversions that separate the haze layers from the topmost convective cloud deck as well as the upper from the lower haze layers. In the region above 50 km (30 mi.), the daytime atmosphere is about 15 degrees C (59 degrees F) warmer than the temperature at night.

The Cloud Layers

Below the upper atmosphere is the 18-km (11-mi.)-thick region containing the clouds of Venus visible from Earth. While the clouds of Venus look extremely opaque, they are in fact very tenuous. Veneras 9 and 10 determined that visibility within the clouds is between 1 and 3 km (0.6 to 1.8 mi.). They are more like thin hazes than terrestrial clouds. The particles making up the clouds of Venus are spherical and about one to two microns in diameter. These droplets apparently consist of sulfuric acid, with concentrations varying from 50 to 500 per cubic centimeter.

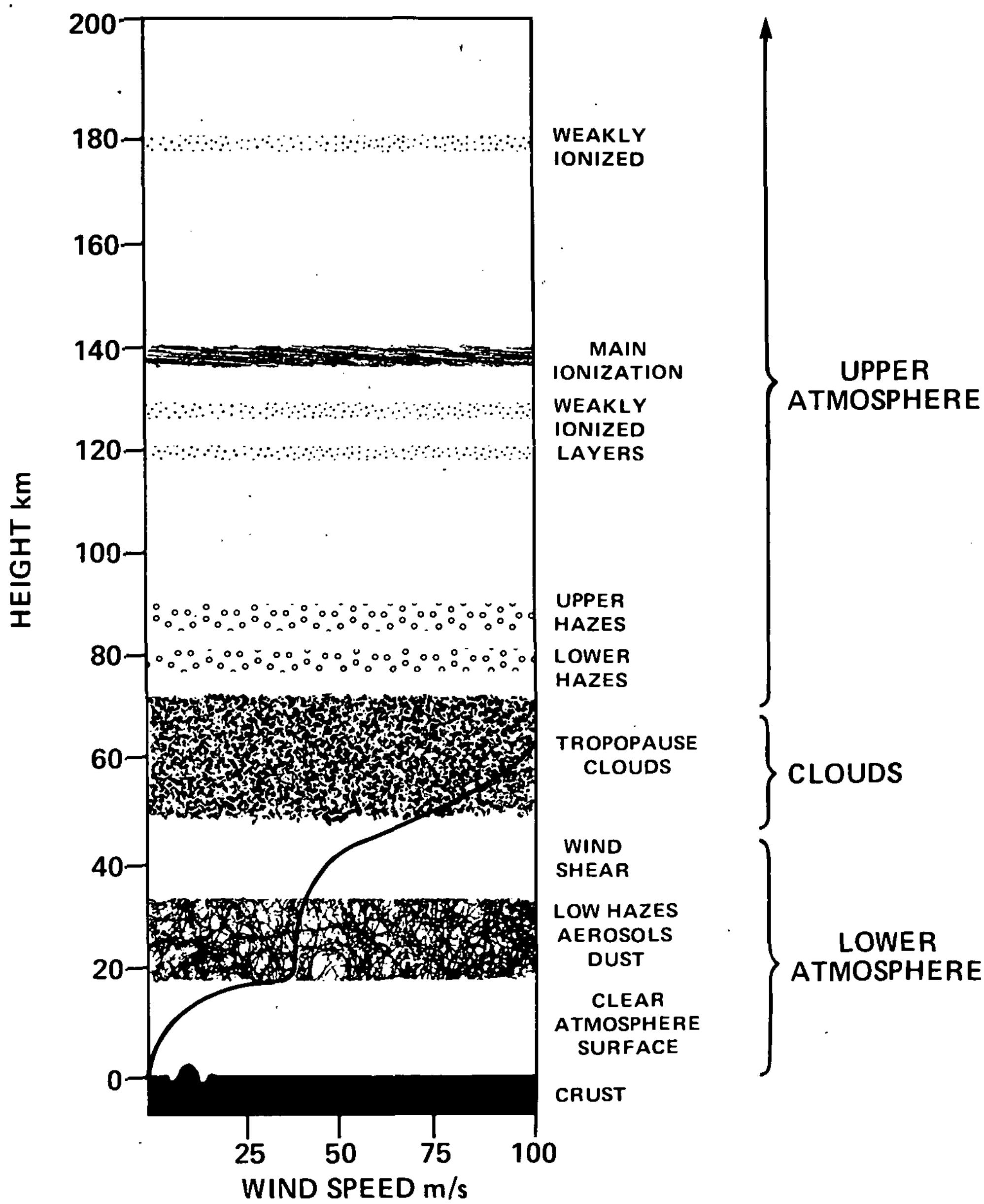
The presence of sulfuric acid clouds explain the extreme dryness of the Venus upper atmosphere. Nearly all the water has chemically bound up in the sulfuric acid droplets. The density of Venus' atmosphere at this level is about one-tenth the density of Earth's atmosphere at sea level. Sulfuric acid clouds remain as clouds over a wider range of temperature than water clouds, although high temperatures cause some of the water to evaporate from the droplets. There is evidence of the presence of fluorine in the Venus atmosphere. This element probably combines with water into the extremely stable and corrosive fluorosulfonic acid. But none of these acids can account for the absorption of ultraviolet radiation by the clouds. There must be an unknown ultraviolet absorber in the clouds which gives rise to the dark markings seen in ultraviolet pictures of Venus.

One speculation is that the dark regions seen in ultraviolet light are oxygen-depleted regions where a significant amount of ultraviolet-absorbing sulfur is being produced. There appears to be a whole series of compounds of sulfur, oxygen and halogens that enter into the chemistry of the atmosphere of Venus.

The Pioneer Venus measurements of the constituents of the atmosphere of Venus with a mass spectrometer and gas chromatograph should contribute greatly to our understanding of these chemical processes that are responsible for the Venusian clouds and their markings.

The dark markings of the clouds, seen in ultraviolet light, have characteristic forms that have been studied from Earth. There are horizontal Y-shaped features which sometimes have a tail. There are features that look like a reversed letter C. The features in the form of a reverse letter C appear more often on the evening terminator than on the morning terminator. Other features are like a reversed C with a bisecting bar. Sometimes there are two parallel equatorial bands. The patterns are also almost always symmetrical about the equator of Venus. The arms of these features are always open in the direction of their retrograde motion which varies between 180 and 470 kph (112 to 265 mph).

VENUS ATMOSPHERE



In the upper atmosphere the effects of solar heating are significant, and the C-bar, C- and Y-shaped features are all associated with the sub-solar point, which is the point where the Sun shines down on the Venus atmosphere from directly overhead. However, the features move around the planet and are not fixed with respect to the sub-solar point.

A big question about Venus' atmosphere is whether the apparent motions of the ultraviolet markings are a result of actual movement or merely a wave motion. The evidence today points to an actual movement of mass; i.e., winds. But there is some evidence of wave motions, diurnal tides and parallel equatorial belts.

The division between the high wind velocities of the stratosphere, and the near calm of the dense surface atmosphere seems to come at about the 56 km (36 mi.) level. The big change in wind velocity thus appears to take place at the bottom of the clouds where there must be a shear zone. Thus, the cloud bottoms are expected to be extremely ragged.

The Soviet probes measured the amount of solar radiation down to the surface. Above 50 km (31 mi.), scattering appears to be by the cloud particles. Below about 25 km (15 mi.), the scattering is Rayleigh scattering; i.e., by much smaller air molecules. At the surface, with the Sun's position about 30 degrees from overhead, the integrated flux was measured as being about equal to that on an overcast day on the Earth at sea level in mid-latitudes.

The high velocity winds in the Venus atmosphere might arise because the planet has such a massive and deep atmosphere. Large-scale eddies containing a lot of energy could transport momentum from low to high altitudes with a high amplification. The ion wind speeds in the dense lower atmosphere produced by the heat from the Sun and the rotation of the planet are amplified into the thin upper atmosphere.

Lower Atmosphere

The penetration of Veneras 9 and 10 into the lower atmosphere produced new information about this region. At about 50 km (30 mi.) altitude, the wind velocity appears to be about 130 kph (80 mph). At the landing site of Venera 9, the local wind velocity varied from 1.2 to 2.5 kph (.9 to 1.4 mph); at the Venera 10 site, it varied from 2.9 to 4.7 kph (1.8 to 9.2 mph). The two landers thus confirmed a low wind velocity close to the surface, as well as little dust content in the low atmosphere.

There are still many unresolved questions about the atmosphere of Venus that need to be answered, such as:

- How does the Venus weather machine really work?

- It is really a greenhouse effect that makes Venus so hot compared with the Earth? Or is there a dynamic cause?

- Did Venus once have a more moderate surface temperature?

- What causes the dark markings in the Venus clouds?

- What are the constituents of the Venus atmosphere?

Thermal emission from the upper atmosphere differs very little between night and day and between low and high latitude. This indicates a dynamic activity within the atmosphere, and suggests that heat in substantial amounts is being transferred around the planet horizontally. There are dynamic activities at all levels because spacecraft have determined that the solar radiation penetrates through the clouds and, therefore, affects the atmosphere down to the surface. Direct solar heating is most important above 56 km (34 mi.); dynamic effects below that.

Over the whole of the planet there is also the effect of the atmosphere at the equator rising as it is warmed by sunlight, and sinking near the Poles, as it cools.

The Surface of Venus

Radar has revealed large-scale features that suggest tectonics and impact molding of Venus' topography. Details of the surface have been provided by the two Soviet lander spacecraft.

The radar observations reveal a large-scale granular structure, suggestive of a rock-strewn desert. Large but shallow circular features, most likely craters, are found in equatorial regions. Some areas of high radar reflectivity are interpreted as extensive lava flows and mountainous areas. A major chasm stretches 1400 km (870 mi.) north and south across the equator.

At five degrees south latitude and 320 degrees longitude is the high mountain Beta with a cratered top like the large Martian volcanoes. There are also arcuate ridges. One is at least 800 km (480 mi.) long. There are mountainous areas which may be volcanic or a result of crustal plate movements.

Photographs from one Soviet lander spacecraft confirm a dry rocky surface that has been fractured and moved about by unknown processes. The second lander produced a picture of rocks with rounded edges and pitted surfaces. The forms of these rocks may be explained by volcanic activities having taken place on the surface.

The existence of craters on Venus suggests that its surface has not been subjected to the major tectonic changes experienced on Earth, but that it has probably evolved somewhat along the same lines as Mars. Some old cratered terrain is preserved while other parts have been modified by tectonics and volcanism. Venus might, indeed, have evolved to a stage between that of Mars and that of the Earth.

Venera 9 landed at 33 degrees north latitude. Its picture shows heaps of rocks, mostly about 30 cm (12 in.) or more in size, and with rather sharp edges. The formation of these rocks is believed to be associated with tectonic processes. The lander is believed to be on the side of a hill in which there is some downward movement of the rocks. The sharp edges and lack of rounding of the rocks at this site suggest that they were formed from breakage of hard, layered rocks, possibly a lava flow.

Venera 10 landed at 15 degrees north latitude, in an area with a much smoother surface. This is believed to be a plateau or plain of greater relative age than the site of Venera 9. There are some rocky elevations which are covered with a relatively dark, fine-grained soil. This implies that the rocks have been weathered, possibly by chemical action with the atmosphere. It is unlikely that the gentle winds at the surface could have been responsible for the weathering. Generally at this site the material of the Venusian soil is dark, but there are outcrops of lighter-colored rock penetrating the soil. Some of the dark soil fills depressions of the outcrops. This surface is interpreted as being much older and more weathered than the surface seen at the Venera 9 site. The weathering process may be a chemical interaction between the hot rocks and the atmosphere, possibly by mineral acids and water vapor.

Measurements made by the spacecraft indicate that the surface rocks have a density between 2.7 and 2.9 grams per cubic centimeter, which is typical of terrestrial basaltic rocks.

Surface temperatures appear to be high enough to make portions of the surface glow a dull red. They are high enough to melt zinc, but not most common rocks. The Venus rocks at the two landing sites are about as radioactive as terrestrial lavas and granites. This suggests that Venus, like Earth, has differentiated by heating to form a dense core and a lighter crust.

Though it has dramatic major features, the surface is smoother than that of Earth and Mars. Radar-measured minimum to maximum height differences are 10 km (6 mi.) -- the height of Mt. Everest. This compares with 20 km (12.4 mi.) on the Earth, from the bottom of the Mariannas Trench to the top of Everest. It compares with 30 km (18.6 mi.) on Mars, from the floor of the Hellas basin to the peak of Olympus Mons. Craters on Venus seem to be shallower than on the other worlds of the inner solar system.

On the Moon and Mercury, and to a somewhat lesser extent on Mars, the ratio of craters diameter to depth is about 10 to 1. On Venus, according to the radar surveys, the ratio is more like 100 to 1. The craters on Venus seem to be extremely shallow; the reason is not known. It could result from plastic deformation of the hot surface or from some weathering process.

MAJOR QUESTIONS ABOUT VENUS

- Apart from carbon dioxide, of what does the lower atmosphere consist, and how are its constituents distributed?

  Venus probably has less than seven per cent of gases other than carbon dioxide in its lower atmosphere. Most likely candidates for other major gases are argon and nitrogen. There are no measurements of lower atmosphere gases other than the Soviet measurements of carbon dioxide and water vapor.

- Of what materials are Venus' clouds made?

  The visible clouds probably consist of sulphuric acid droplets, perhaps formed by sulfur compounds from the surface.

- What other cloud layers are there?

  Some kinds of cloud particles absorb solar ultraviolet radiation. This is needed to explain the ultraviolet photographs which show dark regions. These different kinds of cloud particles could be metal halides or sulfur.

- What can the lowermost atmosphere tell us about the planet's surface and interior?

  Surface constituents (possibly hydrogen fluoride and mercury and sulfur compounds) may be detectable in the bottom 20 km (12 mi.) of the hot, dense atmosphere.

- How does temperature, pressure and density vary globally about the planet?

- Why is Venus' lower atmosphere so hot?

  This is probably due to a runaway greenhouse effect in which heat from the Sun is more easily absorbed than reradiated.

- What role do vaporization-condensation cycles play in the atmosphere, and how do these processes affect Venus' weather?

- What are the composition and temperature profiles of the upper atmosphere?

- How does temperature vary in space and time in the upper atmosphere?

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- What are the roles of global circulation and local turbulence in stabilizing the upper atmosphere?

- What are the effects of the neutral particles on ionosphere composition?

- How high does super rotation (four-day rotation) of the cloud tops extend?

- Since Venus has no magnetic field, the solar wind interacts directly with the upper atmosphere. What mechanisms does this create, and do they affect the lower atmosphere?

- Where did Venus' atmosphere come from and where is it going?

  The main sources of Venus' atmosphere probably are outgassing from the interior, gases from the original solar nebula and some solar wind particles.

- Where is the water that may have once been on Venus?

  The obvious answers are that it either "leaked" to space because of high Venus heating, or it was never there. But numerous questions remain.

- Why does Venus' atmosphere differ so much from that of its "twin" planet, Earth?

- Is all Venus terrain relatively low compared to Earth and Mars or does Venus' "invisible hemisphere" contain high mountains and deep canyons comparable to those on Earth and Mars?

- Is Venus as close to a perfect sphere as the equatorial measurements suggest?

- Does Venus' interior contain large concentrations of high density material.

  The locking of Venus' rotation to Earth's orbit suggests such mass concentrations.

- What is the surface topography?

- What is the composition of the surface?

HISTORICAL DISCOVERIES ABOUT VENUS

684 BC	Ninevah tablets record observations of Venus.
1610	Using the newly-invented telescope, Galileo finds that Venus exhibits phases like those of the Moon.
1761	Mikhail V. Lomonosov (U.S.S.R) interprets optical effects observed during transit of Venus as due to an atmosphere on the planet.
1792	Johann H. Schroter (Germany) concludes Venus has an atmosphere because the cusps at the crescent phase extend beyond the geometrical crescent.
1807	Johann Wurm (Germany) determines the diameter of the visible disc of Venus as 12,293 km (7,639 mi.).
1890	Schiaparelli concludes from his observations that Venus rotates in 225 days.
1920	Edward St. John (U.S.) and Seth B. Nicholson (U.S.) suggest that Venus is a dry, dusty world because they cannot detect any water vapor in its atmosphere.
1922	Lyot measures the polarization of sunlight reflected from the clouds of Venus and introduces a new method of investigating the size and nature of particles in its clouds.
1932	Walter S. Adams (U.S.) and Theodore Dunham (U.S.) detect carbon dioxide in the atmosphere of Venus.
1942	Rupert Wildt (U.S.) shows that the high surface temperature of Venus could arise from a greenhouse effect in an atmosphere with a high proportion of carbon dioxide.
1955	Fred Hoyle (United Kingdom) suggests that the Venus clouds are a photochemical hydrocarbon smog.
1956	Radio waves at 3-cm wavelength are detected from Venus and show that the surface temperature is very high; about 330 degrees C (625 degrees F.).
1957	Charles Boyer (France) discovers a four-day rotation period of the ultraviolet markings in the clouds of Venus.

1960 Adouin Dollfus (France) determines pressure at cloud tops as 90 millibars, using polarimetry.

1960 Carl Sagan (U.S.) calculates heating in atmosphere with large amounts of carbon dioxide and water vapor, concludes surface temperature can be raised by greenhouse effect to above the boiling point of water, 100 degrees C (212 degrees F.).

1962 Low radar reflectivity of Venus rules out any possibility of there being large bodies of water on the planet's surface.

1962 Radar observation of Venus establishes rotation as retrograde in a period of approximately 240 days.

1962 Mariner 2 flyby confirms high surface pressure (at least 75 atmospheres)and temperature (about 650 degrees K) and shows no substantial magnetic field.

1967 Mariner 5 flyby uses radio occultation to measure structure of upper atmosphere and locate height of clouds above surface; discovers ionosphere and finds that carbon dioxide is major compound of atmosphere.

1967 James Pollack (U.S.) and Sagan calculate greenhouse effect for massive Venus atmosphere, showing that solar energy alone can heat surface to above 450 degrees C (845 degrees F.).

1968 Radius of Venus surface determined from radar to be 6,050 km (3,750 mi.) with uncertainty of less than 5 km (3 mi.).

1968 Surface temperatures and pressures are estimated from radio and radar data as 477 degrees C (890 degrees F.) and 90 atmospheres.

1969 U.S.S.R. probes, Venera 5 and 6, successfully land on surface, determine accurate temperature (750 degrees K) and pressure (90 atmospheres), also structure of lower atmosphere.

1971 Analysis of polarization data by James Hansen and Albert Arking (U.S.) shows that the cloud particles are spherical with a refractive index of 1.44, radius of 1.05 um and a location at a pressure level of 50 millibars.

1972 A.T. Young and G. Sill (U.S.) independently conclude that the polarization data imply that Venus clouds are composed of sulphuric acid droplets.

1972 U.S.S.R. Venera 8 lander measures radioactive content of surface rocks, concludes Venus is differentiated. Also determines that sunlight (a few per cent) penetrates to surface.

1973 Observations of carbon dioxide absorptions in Venus atmosphere show a 20 per cent fluctuation over a four-day period, interpreted as upward and downward motions of cloud deck planetwide.

1973 Radar scans of Venus reveal huge shallow craters on the planet's surface.

1973 Pollack makes observations of Venus from high-flying aircraft and concludes that clouds are deep hazes of sulfuric acid drops.

1974 Richard Goldstein (U.S.) produces high resolution radar images of small areas of the planet's surface showing many topographic features.

1974 Mariner 10 (flyby) obtains detailed ultraviolet photographs of clouds, determined circulation patterns in upper atmosphere.

1976 U.S.S.R. Venera 9 and 10 landers photograph surface at two locations, showing exposed rocks and evidence of erosion processes.

1976 Arvydas Kliore (U.S.) and colleagues conclude from radio occultation data that additional discrete cloud layers exist below the main sulfuric acid clouds.

1977 Radar images with the upgraded Arecibo radar indicate large volcanoes and craters on planet.

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EXPLORATION OF VENUS BY SPACECRAFT

Venus has been explored by 13 spacecraft of which three were American and 10 were Russian. Five of these spacecraft were flybys and eight were landers. Several of the Russian spacecraft consisted of both orbiters and landers which separated on arrival at Venus. The record is as follows:

Venera 1 (U.S.S.R.)	A flyby spacecraft; passed Venus May 1961. No science data were returned, according to reports.
Mariner 2 (U.S.)	A flyby spacecraft; passed Venus December 1962. Discovered that the temperature averages 426 degrees C (799 degrees F.) on both night and day hemispheres, and that the planet has virtually no magnetic field and no radiation belts.
Venera 2 (U.S.S.R.)	A flyby spacecraft; passed Venus February 1966. An attempt to photograph Venus apparently was not successful.
Venera 3 (U.S.S.R.)	A lander spacecraft; entered the atmosphere March 1966. No reports of any scientific data being returned.
Venera 4 (U.S.S.R.)	A lander spacecraft; entered atmosphere of Venus October 1967, and returned data during descent to a few atmospheres. Determined the atmosphere is mainly carbon dioxide.
Mariner 5 (U.S.)	A flyby spacecraft; passed October 1967. Provided temperature and pressure profiles to 527 degrees C (981 degrees F.) and 100 atmospheres at the surface. Determined the detailed structure of the ionosphere, and discovered the atomic hydrogen corona.
Venera 5 (U.S.S.R.)	A lander spacecraft; descent capsule entered the atmosphere in May 1969. Measured temperature, pressure and atmospheric composition.

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Venera 6 (U.S.S.R.)	A lander spacecraft; capsule entered the atmosphere May 1969. Determined low water vapor content; suggested presence of nitrogen. Measured carbon dioxide as 93 to 97 per cent of atmosphere, and oxygen less than 0.4 per cent; surface pressure of nearly 100 atmospheres.
Venera 7 (U.S.S.R.)	A lander spacecraft; entry capsule penetrated the atmosphere December 1971; data were transmitted for 23 minutes from the surface. Measured a surface temperature of 543 degrees C (1,009 degrees F.) and a pressure of 90 atmospheres.
Venera 8 (U.S.S.R.)	A lander spacecraft; capsule landed July 1972, and transmitted surface data for 107 minutes. Determined amounts of uranium, thorium and potassium in surface materials and showed they were similar to amounts in terrestrial rocks. Measured a surface temperature of 530 degrees C (986 degrees F.).
Mariner 10 (U.S.)	Mercury-bound spacecraft; passed Venus February 1974. Obtained first pictures from spacecraft. Revealed the structural details of the clouds in ultraviolet light. Confirmed the c-, y- and psi-shaped cloud markings, and four-day rotation of these markings. Found significant amounts of helium and confirmed the presence of hydrogen in the upper atmosphere. Photographed high-altitude haze layers.
Venera 9 (U.S.S.R.)	A lander spacecraft. Capsule reached surface October 1975 at 33 degrees N. latitude, 293 degrees longitude. Returned first picture from the surface of Venus. Measured wind speeds, pressure, temperature and solar radiation flux throughout the atmosphere to the surface. Orbiter surveyed planet.
Venera 10 (U.S.S.R.)	A lander spacecraft; capsule reached surface October 1975 at 15 degrees N. latitude, 295 degrees longitude. Returned second surface picture. Orbiter surveyed planet and looked at surface with bistatic radar. Determined surface elevations differed by only a few kilometers along orbiter track.

THE PIONEER VENUS SPACECRAFT

The Pioneer Venus mission will be accomplished by two separate spacecraft, the Orbiter and the Multiprobe. The Orbiter, carrying 12 scientific instruments, will globally survey Venus' atmosphere and surrounding environment. It will study the Venusian surface and perform one astronomical experiment.

The Multiprobe will divide into five atmosphere entry craft as it approaches Venus from Earth. These are the transporter Bus, the Large and three Small Probes. The four probes will measure Venus' atmosphere from its tenuous beginnings down to the dense superheated regions at the surface. After launching the probes, the Bus, too, will enter and measure composition of Venus' upper atmosphere.

Together the five atmospheric entry craft will carry 18 scientific instruments. The Large Probe carries seven instruments; the Small Probes, three each, and the Bus, two.

To meet the Pioneer Venus requirement for two relatively simple and low cost spacecraft, designers chose spinning vehicles. Spinning cylindrical spacecraft provide stability with minimum weight, good solar cell deployment, viewing for experiments in a full circle and spin scan for the imaging system.

The Basic Bus

The Venus Orbiter and Venus Multiprobe spacecraft share a "basic bus" design. Three quarters of the system on the basic buses are common to both spacecraft. In the Multiprobe design, the four atmosphere entry probes are mounted on the flat surface which is the top or forward end of the bus cylinder.

The common systems on the basic bus for both spacecraft include a thermally-controlled equipment and experiments compartment; solar-electric panels, batteries and power distribution system; forward and aft "omni" antennas; communications system; data-processing system; Sun and star sensors for orientation reference during cruise and maneuvers; hydrazine propellant tanks; and thrusters for orientation, course changes and spin-rate control.

Structure

The basic bus portions of both spacecraft are their main bodies, flat cylinders, 2.5 m (8.3 ft) in diameter and 1.2 m (4 ft.) high.

The buses provide a spin-stabilized platform for scientific instruments, spacecraft systems and in the case of the Multiprobe, the four probe craft. A circular equipment shelf with an area of 4.37 sq. m (50 sq. ft.) is located in the upper or foward end of the bus cylinder. The shelf is mounted on the forward end of the thrust tube, the rigid structure which connects the spacecraft to the launch vehicle. Twelve equally spaced struts support the equipment shelf perimeter from the base of the thrust tube. The cylindrical solar array is, in turn, attached to the equipment shelf with 24 brackets.

Thermal louvers (fifteen on the Orbiter and eleven on the Multiprobe) attached to the lower surface of the equipment shelf, open and close (with heat-sensitive-bimetallic springs) to control heat radiation from the equipment compartment. Large heat producers, such as radio amplifiers, are located over several of these louvers.

Maneuver System

The maneuvering system of the basic bus controls spin rates, makes course and orbit corrections, and maintains spin axis position--usually perpendicular to the ecliptic for both spacecraft.

Beneath the equipment compartment, also attached to the thrust tube, are two conical-hemispheric propellant tanks, 33 cm. (12.8 in.) in diameter. The tanks store hydrazine propellant for two axial and four radial thrusters. These can change spacecraft orientiation, spin rate or velocity.

The maneuver system has one mid-range Sun sensor, two extended-range Sun sensors, and a star sensor to sense spacecraft orientation and provide a reference for finding spin-axis angle. The star sensor is mounted on the equipment shelf and has a look angle of about 57 degrees to the spin axis. Sun sensors are all at one point on the equipment shelf perimeter. They look radially through an opening in the solar array and see the Sun on each rotation.

Redundant data processor units format the Sun and star sensor outputs for telemetry transmission to the Earth, to calculate spacecraft orientation. These data processors also provide sequenced firing commands to the thrusters to make orientation, velocity and spin rate changes.

The system's two axial thruster nozzles are aligned with the spin axis, and are located at top and bottom of the bus cylinder, diagonally opposite each other. They point in opposite directions, and to turn the bus spin axis, both fire in pulses in opposite directions. To speed up or slow down the bus along the direction of its spin axis, only one thruster is pulse fired at two points 180 degrees apart around the circle of bus rotation. Either the top or bottom thruster can be pulsed depending on desired direction of velocity change.

The Orbiter has a third axial thruster. This is located on the bottom of the bus cylinder and allows continuous firing of two bottom thrusters to make the moves in an axial direction needed for orbit changes.

The four radial thrusters are arranged in two pairs, with the pairs pointing in opposite directions. They are mounted approximately in a plane perpendicular to the spin axis, and this plane passes through the center of gravity. The radial thrusters change the velocity in a direction perpendicular to the spin axis.

These radial thrusters also have been placed at four equidistant points around the perimeter of the bus cylinder. This has the effect of pointing them at opposite acute angles to the circle of rotation. The result is that firing two of them 180 degrees apart, together, will slow down the spin rate. The other two will speed it up.

Power System

The bus solar power system provides 28-volt DC electric power to Orbiter and Multiprobe scientific instruments and spacecraft subsystems. Seven resistive shunt limiters hold the maximum voltage at 30.8 volts. When the voltage drops below 27.8 volts, the batteries start to share the load through discharge controllers. Small solar arrays recharge the batteries.

A switch protects the main power bus from current overloads or undervoltage by automatically turning off instruments, switched loads, and transmitter buses. The system's array of solar cells is slightly smaller for the Multiprobe bus than for the Orbiter bus because of the higher power demands of Orbiter's 12 experiments. The Orbiter solar array has 7.2 sq. m (77.8 sq. ft.) of 2 x 2 cm (.8 x .8 in.) cells. When at right angles to the Sun line, these provide 226 watts near Earth and 312 watts at Venus. The Multiprobe solar array has 6.9 sq. m (65.7 sq. ft.) of cells and provides 214 watts near Earth and 241 watts at Venus.

The power system's two 7.5 ampere-hour nickel-cadmium batteries provide a total of 252 watt hours of electrical energy. Power is provided to instruments from the science power bus through redundant buses in the power interface unit. On-off power switching is performed in the individual instruments for flexibility instead of centralized switching in the power interface unit. The power interface unit provides on-off switching for propulsion heaters.

Communications System

The communications system for the two buses can receive commands from Earth in any spacecraft orientation through two redundant S-band transponders, connected to two omni directional antennas. (A transponder is a radio system which receives incoming signals and tunes the outgoing transmitter to a frequency which is at a constant ratio to the incoming signal.) This means that Doppler shift in radio frequency due to spacecraft motion can be measured precisely on radio transmissions from both Earth to spacecraft and spacecraft to Earth--because frequencies, both leaving the Earth and arriving at the Earth are known precisely. This allows spacecraft velocity measurements accurate to .003 kph.

The receiver portion of each transponder is frequency-addressable (responds only to certain frequencies , and the receivers are automatically reversed by the command processor logic if no command is received for 36 hours. Hence, if one fails the other takes over. The two receiver outputs are cross-connected to redundant exciters, either of which can be selected by ground command. The transponder provides either a fixed-ratio incoming to outgoing carrier frequency, or a fixed-frequency carrier signal in case of failure of the two-way system.

The spacecraft-to-Earth radio link is provided by an S-band transmitter, which can radiate at 10 or 20 watts, with reduncant power amplifiers operating through either the fore or aft "omni" antennas. The omnis cover a hemisphere looking forward or aft. Both Orbiter and Multiprobe spacecraft have, in addition to the two Bus omnis, specialized antennas which will be described in sections on thier communications. Either omni antenna can be selected by ground command. One omni antenna is connected to one of the two redundant receivers, and the other omni (or other spacecraft antenna designated by command) is connected to the other receiver. This arrangement can be reversed by command.

Command System

The basic bus command system accepts incoming commands from the bus radio receivers. Command demodulators turn on the system, convert the signal to a usable binary bit stream, and pass it on to cross-connected command processors. Commands are either stored for later execution, or executed immediately. Spacecraft units receive commands from redundant command output modules. The command system accepts a pulse-code-modulated/frequency-shift-keyed/phase-modulated (PCM/FSK/PM) data stream at four bits per second.

Each command word consists of 48 bits including 13 bits for synchronization, which gives a one-in-a-million probability of a false command. The system has a total of 192 pulse commands and 12 magnitude commands. The command memory can store up to 128 commands (redundantly) for later execution.

Data Handling System

The telemetry processor for the bus data handling system samples scientific and engineering measurement sources in sequence. It transmits an instruction word to the Pioneer Command Module (CM) encoder which addresses a data module to read out the selected channel.

The interrogated channel can be either analog, serial digital or binary one-bit (yes-no) information. The PCM encoder ships the encoded measurement to the telemetry processor, where it is frame-formatted, convolutionally coded and used to biphase modulate a subcarrier. The subcarrier then phase modulates the outgoing carrier signal.

The telemetry processors and PCM encoders are cross-connected and fully redundant.

Critical telemetry measurements are assigned data channels on two different data modules. The data handling systems can accept up to 256 channels of data.

All Pioneer Venus telemetry data are binary (a series of ones and zeroes), and all data "words" consist of eight ones and zeroes arranged in the order determined by the information they carry. Analog data are converted to eight-bit words. Data inputs are multiplexed and formatted into frames of 64 eight-bits words. Of the 64 words, three are required for synchronization and identification, and three are subcommutated for spacecraft housekeeping data.

The output of the data system is an 8 to 2048 bit per second PCM/PSK convolutionally coded data stream, biphase modulated on a 16384 Hz subcarrier.

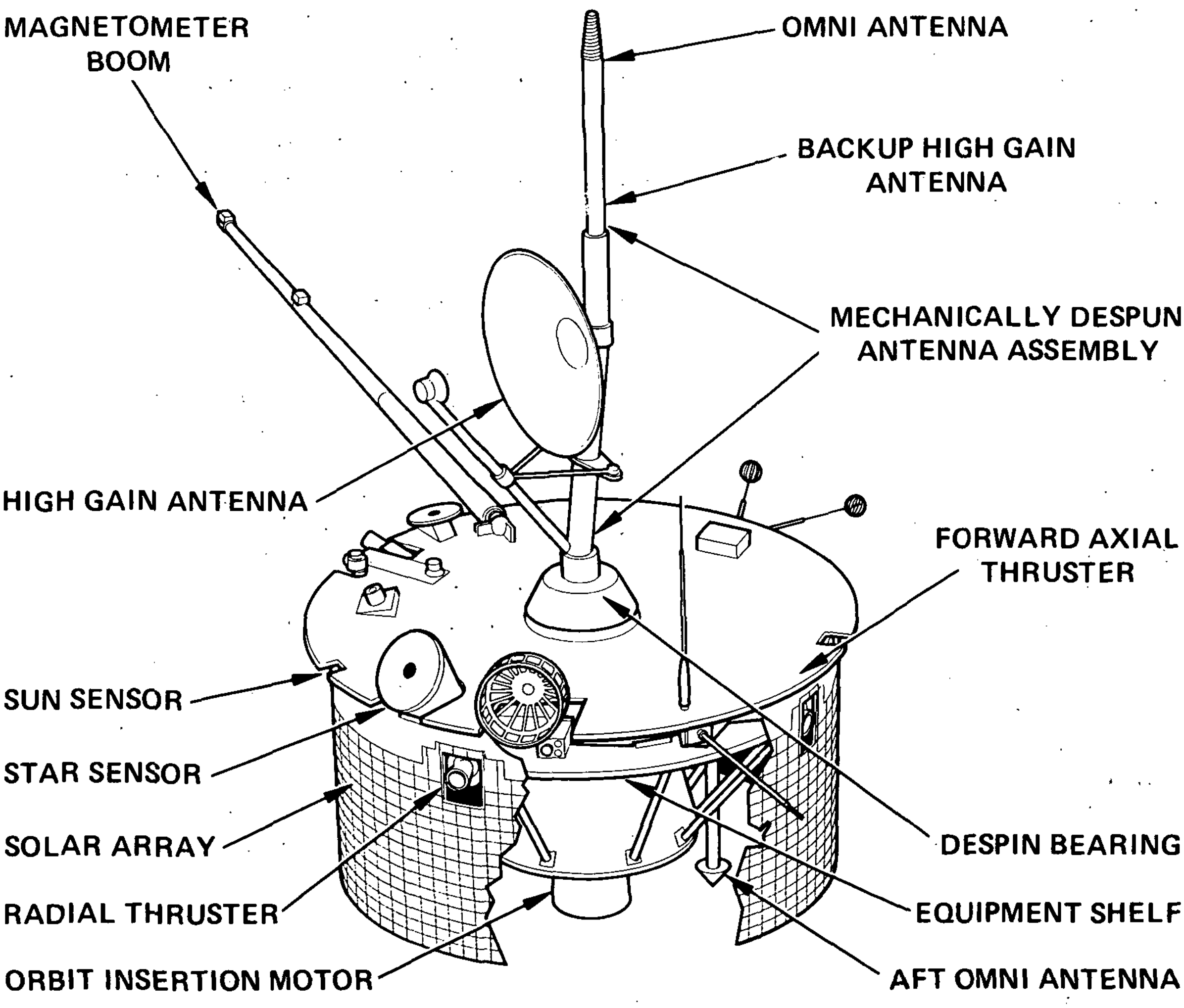
The Orbiter Spacecraft

The Venus Orbiter spacecraft incorporates the basic Pioneer Bus. It also consists of a despun, high-gain dish antenna on a 3-m (10-ft.) mast to return the large volume of Orbiter experiments and imaging data to Earth. The Orbiter carries 12 scientific instruments, a million-bit data memory to store observations (when the spacecraft is behind Venus, or they cannot be transmitted to Earth for other reasons), and a solid-fuel rocket motor for insertion into orbit at the planet.

The Orbiter, including antenna mast, is nearly 4.5 m (15 ft.) high. The basic bus cylinder making up its main body is about 2.5 m (8.3 ft.) in diameter, and 1.2 m (4 ft.) high. Launch weight of the Orbiter is about 582 kg (1280 lbs.) with 45 kg (100 lbs.) of scientific instruments. Weight after orbital insertion is 368 kg (810 lbs.).

Three instruments (the magnetometer electron temperature probe and electric field detector) have sensor elements mounted on booms. The magnetometer sensors are mounted on the three-section, deployable 4.7 m (15.5 ft.) boom. A single sensor is mounted about two-thirds of the way out from the bus cylinder, and a perpendicular pair are mounted at the boom's end. The boom is deployed after launch by firing pyrotechnic devices, and extends radially from the upper rim of the cylinder. The boom positions the sensors at a point of minimum magnetic interference from the spacecraft.

ORBITER SPACECRAFT



The ball-like sensors (antennas) for the electric field detector spring out 0.6 m (26 in.) after jettison of the launch fairing. The electron temperature probe uses two sensor elements mounted at right angles to one another. The axial sensor is mounted parallel to the spin axis and extends through the thermal top cover. The radial sensor is on a 1.0 m (40 in.) boom, deployed after orbit insertion.

The gamma ray burst detector uses two detectors mounted on the equipment shelf about 180 degrees apart. This allows complete coverage of the celestial sphere for all positions of spacecraft rotation.

Orbiter Scientific Instruments

All 12 scientific instruments are mounted directly on the top side of the equipment shelf. Eight of the instruments view the planet through either the side or top of the bus cylinder. Of the eight, two (the cloud Photo-polarimeter and the radar mapper) employ scanning sensors which move through a range of 140 degrees in a plane perpendicular to the bus experiment shelf.

Orbiter Antenna Systems

A basic part of the Orbiter system, not part of the basic bus, is the despun, high-gain parabolic-reflector antenna, which focuses a 7.6 degree-wide radio beam on the Earth throughout the mission. The antenna dish is 109 cm (43 in.) in diameter, and amplifies the Orbiter radio signal 316 times. Venus and the Orbiter will be 203 million km (126 million mi.) farther from Earth at the end of the 243-day Orbiter primary mission than at planet-arrival. The antenna is needed to return data at high rates over these distances. The high-gain antenna dish, a sleeve dipole antenna, and the forward "omni" antenna are all mounted on the despun 2.9-m (9.8-ft.) mast projecting up along the spin-axis from the top of the Orbiter cylinder. The sleeve dipole antenna broadcasts a radio beam which forms a pancake-like pattern around the spacecraft, perpendicular to its spin axis. This provides a backup for the narrow-beam dish antenna in case of failure of the despin system. The bus aft omni antenna provides the fourth Orbiter antenna. The omnis broadcast in a hemispheric pattern, forward or aft.

Since the Orbiter dish antenna does not spin, as does the spacecraft below it, it constantly faces Earth, both on cruise and orbit. The despun condition of the antenna and its mast is maintained by bearing, electric motor, and slip-ring arrangement.

A quadripod structure, mounted on the upper end of the bus thrust tube, supports the Bearing and Power Transfer Assembly (BAPTA) which mechanically despins the antennas. The mast is attached to the despun flange of the bearing assembly. The three antennas on the mast are connected to transmitters and receivers by a series of transfer switches through the dual frequency rotary joint. Pulse commands from Earth to these switches are provided through the BAPTA slip rings and brushes.

The control system provides redundant despin control electronics to drive one of two redundant BAPTA motors to despin and point the high-gain antenna toward the Earth. The despin control system functions as a closed loop, autonomously operating the system to maintain antenna pointing.

Motor torque commands are generated by the despin control electronics based upon Sun or star sensor and BAPTA master index pulses. An elevation drive maintains antenna pointing during occultations.

For the occultation experiments, the Orbiter carries an extra 750 milliwatt X-band transmitter, whose signal frequency is always maintained at a ratio of 11.3 to that of the main S-band transmitter. Both S and X-Band signals are transmitted by the dish antenna, which can be moved 15 degrees from the Earth line as the Orbiter passes behind Venus. This permits keeping the radio beam to be aimed at Venus' upper atmosphere for a longer time. Refraction by the atmosphere bends the narrow-beam signal around the planet so it reaches Earth despite these pointing angles.

The X-band signal cannot be modulated, and is only for study of atmosphere effects on radio signals at two wavelengths. The X-band beam width is 2.2 degrees compared with the S-band 7.6 degrees.

Ground commands control the antenna pointing angle. The elevation drive for the antenna dish consists of a motor-driven jackscrew. Electronics convert commands into discrete pulses to control the motor.

Orbiter Data Storage

For periods when the spacecraft is behind Venus and radio communication is cut off, the data memory can store up to a million data bits. Occultations last up to 26 minutes, and a million-bit memory allows data to be taken at a minimum rate of about 700 bits per second in this time. The data storage capacity can also help when Deep Space Network (DSN) stations are not listening to the Orbiter for various reasons. Stored data are played back at a minimum rate of 170 bps, and the Orbiter can play back data while taking and transmitting new data.

Orbiter Data-Handling System

The Orbiter spacecraft data-handling system uses the bus data system components, plus its million-bit memory. It accepts information from spacecraft systems and the 12 scientific instruments in serial digital, analog and one-bit binary (yes-no) form. It converts analog and yes-no information to serial digital form, and arranges all information in formats for transmission. This consists of a continuous sequence of major telemetry frames, each composed of 64 minor frames. Each minor frame contains 64 eight-bit words (512 bits per minor frame). The words in a minor frame are arranged into one of 13 preprogrammed formats, selectable by command. Each minor frame contains within it:

- High-rate science or engineering data (in one of the 13 formats);
- Sub-commutated data formats;
- Spacecraft data; and
- Frame synchronization data.

The three sub-commutated data formats in each minor frame carry data which can be reported at low rates. One is for low-rate science and science housekeeping data, and the two others are for low-rate spacecraft engineering data.

The Orbiter's 13 high-rate data formats include seven science formats for use on orbit. The other high-rate formats are Data memory playback (containing some real-time science), Data memory readout (stored data only), Launch-cruise, Engineering-only format, Attitude control system format (for maneuvers), and Command memory readout format.

The data system operates in real-time for telemetry storage mode. Its memory stores both science and engineering data. Twelve telemetry storage playback and real-time data rates between 8 and 2048 bps are available. A rate of 1024 bps is used during interplanetary cruise.

Of the seven science formats used on orbit, five are for the close-in periapsis section of the orbit. Two are for the far-out apoapsis portion of the orbit.

Of the five close-in formats, two emphasize acquisition of aeronomy data. A third general format allows data taking by virtually all experiments.

The fourth close-in format, the Optical, is for just two instruments. It allocates 73 per cent of the data stream to the infrared radiometer, the rest of the photopolarimeter. The last format, the Mapping format, gives 44 per cent of the data stream to the radar mapper, and the rest is divided among four other "mapping" type instruments.

Of the two science formats for the far-out apoapsis orbital segment, the Imaging format provides 67 per cent of the data stream for cloud photopolarimeter pictures of Venus' clouds, and the rest for four space environment instruments. The General format for apoapsis carries data for all instruments except the infrafed and imaging instruments, but makes big allocations to the space environment measurements of the magnetometer, solar wind instrument and the gamma ray burst detector.

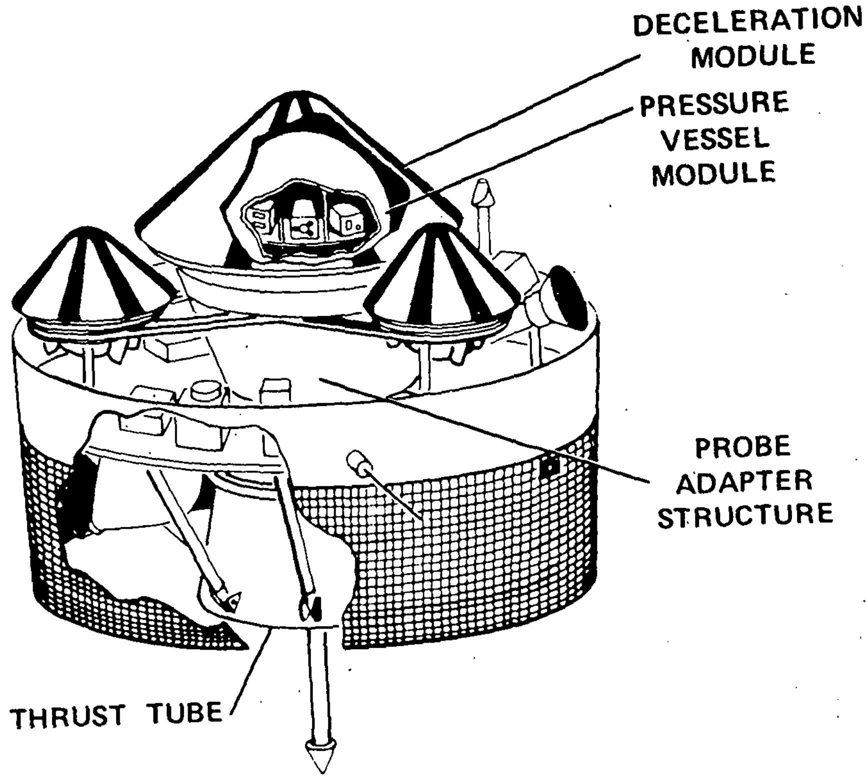
Orbital Insertion Rocket

The orbital insertion motor reduces Orbiter velocity by 3,816 kph (2,366 mph) for orbital capture by Venus. It is a solid propellant engine, attached to the bus thrust tube below the equipment compartment. The engine has 18,000 Newtons (4000 lbs.) of thrust, and the insertion rocket burn reduces Orbiter weight by 181 kg (398 lb.).

The Multiprobe Spacecraft

The first simultaneous multiple-entry craft measurements of the atmosphere of another planet will be accomplished by the Venus Multiprobe.

MULTIPROBE SPACECRAFT



The four probes will be launched from the Multiprobe Bus 13 million km (7.8 million mi.) from the planet and will then fly to their entry points, two on the day side and two on the night side of Venus.

The Multiprobe spacecraft weighs 904 kg (1,990 lb.) and carries 51 kg (112 lbs.) of scientific instruments. The spacecraft consists of the Pioneer Venus basic bus modified to carry the four atmosphere probes. Its diameter is that of the Bus, 2.5 m (8.3 ft.). From the bottom of the Bus to the tip of the main probe, it is 2.9 m (9.5 ft.) high.

During the flight to Venus, the four probes are carried on the Bus by a large inverted cone structure and three equally-spaced circular clamps surrounding the cone. These attachment structures are bolted to the Bus thrust tube, the structural link to the launch vehicle. The Large Probe is centered on the Bus spin axis, and is launched toward Venus by a pyrotechnic-spring separation system. The ring support clamps attaching the Small Probes are hinged. For launch of the Samll Probes, the clamps open by the firing of explosive nuts. When open, they allow the probes to spin off the Bus in a tangential direction due to Bus rotation. Controllers increase Bus spin from 15 to 48 rpm for Small Probe launch.

The Multiprobe's forward omni antenna extends above the top of the Bus cylinder, and an aft omni extends down below it. Both omni antennas have hemispheric radiation patterns. Attached to the equipment shelf is an aft-pointing, medium-gain horn antenna, for use during critical maneuvers when the aft end of the spacecraft is pointed toward the Earth, as it is when the probes are launched toward Venus.

The remaining systems on the Multiprobe spacecraft are those carried on both Orbiter and Multiprobe buses. These common bus systems are: The instrument-equipment compartment and basic bus structure; the solar array, batteries and power distribution system; the Sun and star sensors, propellant storage tanks and thrusters of the bus maneuvering and stabilizing system. Other Bus systems are the transmitters, receivers and processors of the bus communications, command and data handling system.

These systems allow the Bus to provide for the Multiprobe spacecraft, as it does for the Orbiter, a stable, rotating platform and a protective, temperature-controlled environment for the scientific instruments and spacecraft systems.

They also provide electric power, make maneuvers, receive commands, process experiment data, and transmit data to Earth.

Multiprobe Data System

The data system for the Multiprobe spacecraft uses the standard bus components. However, data formats are organized to meet requirements of the Multiprobe mission. The Multiprobe data system handles data from both Bus and probes before probe launch. After probe launch, it handles Bus data only. The probes have their own data systems. (See sections describing these.)

The Multiprobe data system accepts engineering and mission operations information from the four probes aboard the spacecraft, until probe launch, as well as from the Multiprobe bus itself. It also handles data from the two experiments carried on the Multiprobe bus. As on the Orbiter, the system accepts data in serial digital, analog and one-bit binary status (yes-no) form. It converts the analog data to serial digital binary from and arranges all information for transmission to Earth in the standard Pioneer Venus series of major telemetry frames, each composed of 64 minor frames.

Each minor frame is composed of a series of 64 eight-bit words. The words in a minor frame are arranged in several formats. Each minor frame contains high-rate science or engineering data, plus sub-commutated formats, spacecraft data, and frame synchronization data. One sub-commutated format carries low-rate science and science housekeeping data; two are for low-rate spacecraft information. Twelve real-time (no data storage on the Multiprobe) data transmission rates between 8 and 2048 bps can be used. Like the Orbiter, the Multiprobe also has high-data-rate formats for Attitude control (used during maneuvers), for Engineering data only, and for command memory readout. A single format for atmosphere entry transmits high-rate science data. Assuming the expected data rate of 1024 bps at entry, data rate for the two Multiprobe Bus experiments will be 256 bps for the neutral mass spectrometer, and 112 bps for the ion mass spectrometer.

Multiprobe Bus Experiments

After launch of its four probes 20 days out from Venus, the Multiprobe Bus becomes a probe itself, providing the mission's only high upper atmosphere composition measurements. These operate as the Bus enters but before it starts to burn up at 115 km (71 mi.) altitude.

These two mass spectometer instruments are attached to the equipment shelf with their inlets projecting above the flat top of the Bus cylinder.

- more -

VENUS ATMOSPHERIC PROBES

Because of its high pressures (nearly 100 times Earth's), high temperatures and corrosive constituents, Venus' atmosphere presents a difficult problem for flight designers. The high entry speeds of about 41,600 kph (26,000 mph) add to the problem.

The Large and Small Probes are geometrically similar. The main component of each is a spherical pressure vessel, which houses the scientific instruments and the following spacecraft systems: communications, data, command and power. The Large Probe weighs about 316 kg (698 lbs.); the Small Probes, 93 kg (206 lbs.) each.

Conical aeroshells provide stable flight paths and heat protection for all four probes during atmospheric entry. The heat shield-carrying aeroshells are 45-degree cones with spherically blunted tips, whose radii are equal to half the base radii of the cones.

All instruments within the pressure vessels of all four probes require either observing or direct sampling access to the hostile Venusian atmosphere. This access is one of the hardest problems of the mission. The Large Probe has 14 sealed penetrations of several types. Each Small Probe has seven. Pressure vessel penetrations for all probes include 15 sapphire and one diamond window.

The Large Probe

The Large Probe weighs about 316 kg (695 lbs.) and is about 1.5 meters (5 feet) in diameter. It returns data at 256 bps. Its seven scientific instruments weigh 28 kg (62 lbs.). These include two instruments to identify atmosphere components. The other five instruments will measure the clouds, atmospheric structure, energy distribution and circulation. The probe enters at the equator on the day side of the planet.

Large Probe Structure

The Large Probe consists of the forward aeroshell-heat shield, the pressure vessel and the aft cover. Both aeroshell and aft cover are jettisoned at main chute deployment.

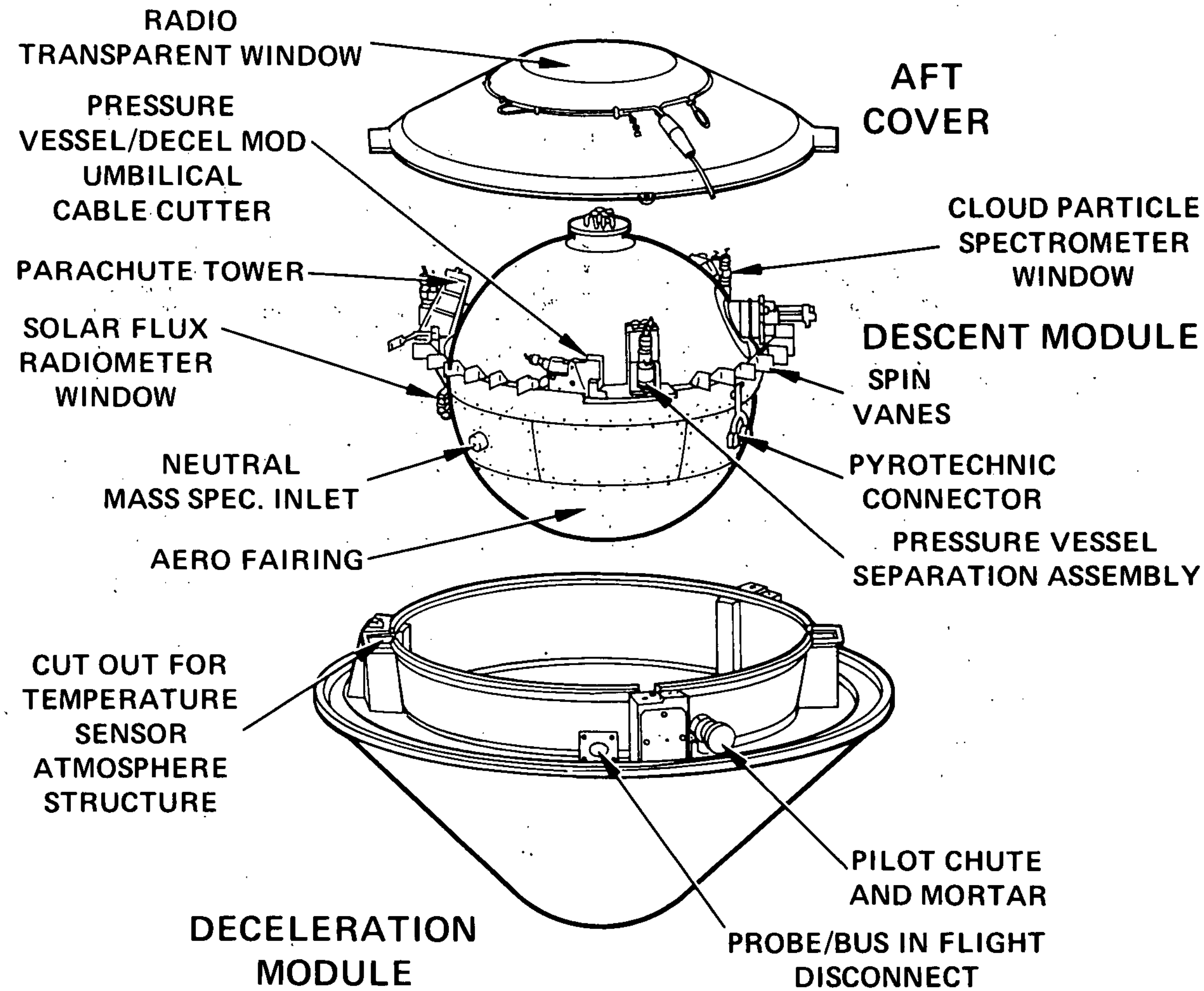
The spherical pressure vessel is 73.2 cm (28.8 in.) in diameter, and is made of titanium for light weight and high strength at high temperatures. Because it is jettisoned at relatively cool, high altitudes, the aeroshell can be made of less heat-resistant aluminum.

The weight limits on interplanetary spacecraft and the 14 hull penetrations required that the pressure vessel be designed with great care and machined with precision for both lightness and strength. The flight vessel has been tested successfully under Venus-like conditions of 100 Earth atmospheres of pressure and 470 degrees C (900 degrees F) temperatures. Test vessels have withstood higher pressures.

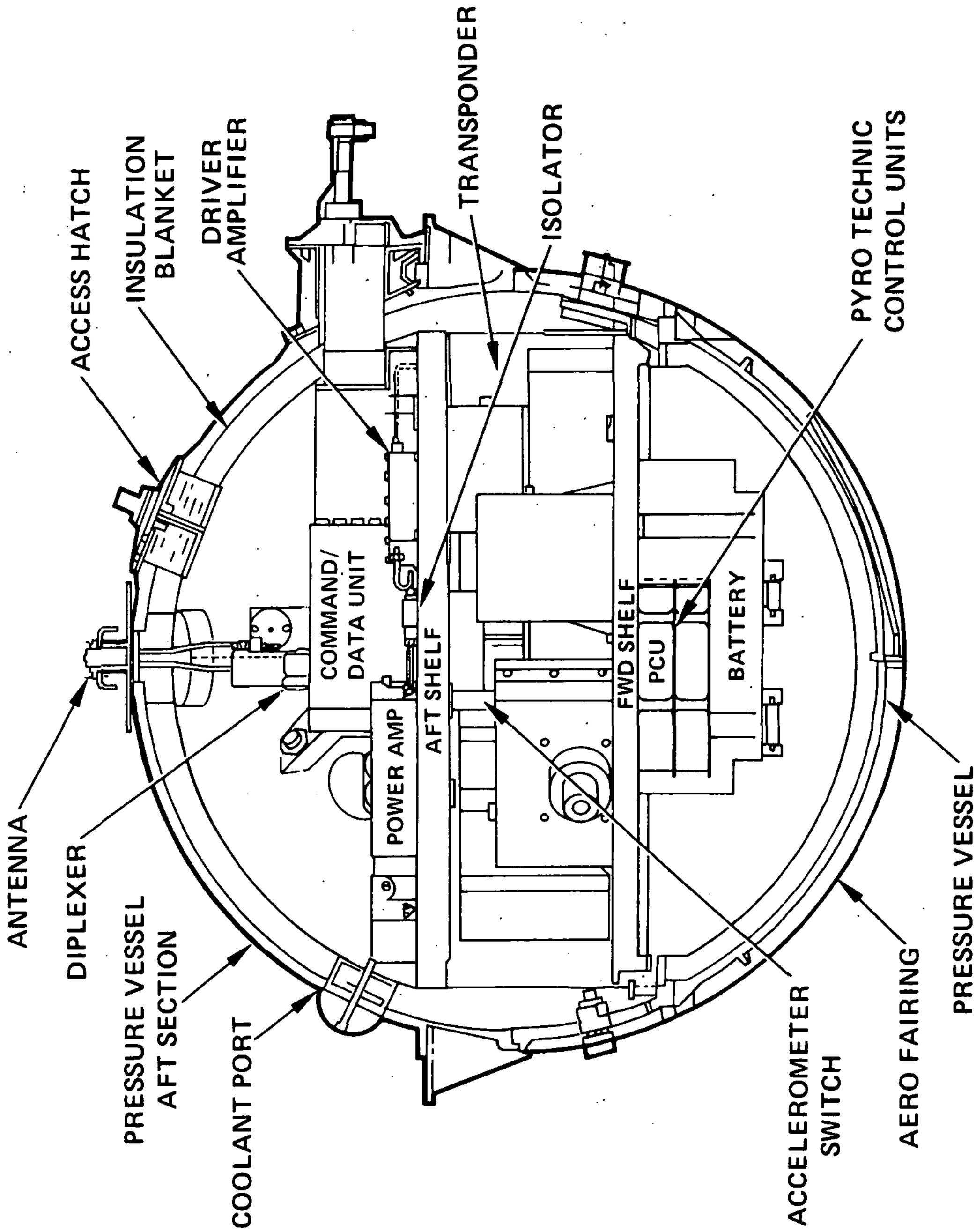
The vessel is made in three pieces, joined by flanges, seals and bolts. Sections are the aft hemisphere, a forward cap and a flat ring section between the two. The vessel has 14 sealed penetrations (one for the antenna, four for electrical cabling, two for access hatches and seven for scientific instruments). Four instruments use nine observation windows through four of the hull penetrations. Eight windows are of sapphire, and one of diamond. These materials admit light or heat at the wavelengths being measured, while withstanding Venusian heat and pressure. The solar flux radiometer has five windows through one hull penetration; the nephelometer, two windows and the infrared and cloud particle instruments, one window each.

Three vessel penetrations are inlets for direct atmosphere sampling by three instruments--mass spectrometer, gas chromatograph and atmosphere structure experiment. At its aft pole the spherical vessel has a hemisphere pattern antenna for communication with Earth. Two four-inch arms on one side hold the reflecting prism for the cloud particle instrument. A single arm on the other side has a temperature sensor at its tip. Three parachute-shroud towers are mounted above aerodynamic drag plates, spaced equally around the equator of the sphere. The vessel has an electronics access port for system checkout, and a cooling port used in ground tests.

LARGE PROBE


RADIO TRANSPARENT WINDOW
AFT COVER
PRESSURE VESSEL/DECEL MOD UMBILICAL CABLE CUTTER
CLOUD PARTICLE SPECTROMETER WINDOW
PARACHUTE TOWER
SOLAR FLUX RADIOMETER WINDOW
DESCENT MODULE
SPIN VANES
NEUTRAL MASS SPEC. INLET
PYROTECHNIC CONNECTOR
AERO FAIRING
PRESSURE VESSEL SEPARATION ASSEMBLY
CUT OUT FOR TEMPERATURE SENSOR ATMOSPHERE STRUCTURE
PILOT CHUTE AND MORTAR
DECELERATION MODULE
PROBE/BUS IN FLIGHT DISCONNECT

LARGE PROBE PRESSURE VESSEL



Flight Sequence

About 20 minutes before atmospheric entry, with the probe traveling at speeds of about 41,600 kph (26,000 mph), timer commands turn on and warm up the Large Probe instruments and systems. The craft establishes its radio link with Earth. At an altitude of about 120 km (75 mi.), significant atmospheric braking has begun, and three-axis accelerations and heat shield temperature data are being stored for later playback (providing spacecraft flight data for use by the atmospheric structure experiment). Entry occurs with peak deceleration of 320 G at about 78 km (49 mi.). As deceleration forces slack off, a G-switch starts a timer, ending data storage and starting a timing sequence for aeroshell and heat shield jettison.

Just below 68 km (42 mi.), when the Large Probe has slowed to about 680 kph (420 mph), the pilot chute is mortar-fired from a small compartment in the side of the aeroshell. This small parachute is attached by lines to the aft cover which is separated by an explosive nut and pulled free. The cover, in turn, is attached to the main parachute. The pilot chute then extracts the main chute from its compartment within the conical aeroshell. The main chute then opens. After vehicle stabilization, mechanical and electrical ties to the aeroshell are severed by explosive nuts, or by cable cutters, and the main chute pulls the spherical pressure vessel out of its surrounding aeroshell. The aeroshell falls away.

Once the pressure vessel is freed of the aeroshell and aft cover, the scientific instruments have full access to Venus' atmosphere, and the parachute has slowed its descent rate to 270 kph (165 mph). Seventeen minutes later, at 47 km (28 mi.) altitude, the main chute is jettisoned, and the aerodynamically stable pressure vessel descends to the surface in 39 minutes.

Flight Systems

Thermal protection during atmosphere entry is provided by the carbon phenolic heat shield covering the forward facing conical aeroshell, and by coating all other surfaces of the aeroshell and aft cover with a low density elastomeric material. The conical aeroshell is a one-piece aluminum structure with integrally-machined stiffening rings. The ablative carbon phenolic heat shield is bonded to this structure. The aeroshell cone has a base diameter of 142 cm (4.7 ft.).

The 4.9 meter (16.2 ft.)-diameter dacron main parachute is of the conical ribbon type. Located in a curved compartment on one side of the aeroshell, the mortar-deployed dacron pilot chute is 76 cm (2.5 feet) in diameter. After separation of the aeroshell, aft cover and main chute have occurred, the pressure vessel descends to the surface. The motion is stabilized by locating the center of gravity of the pressure vessel well forward and by an airflow separation ring around the sphere's equator. Drag plates on the flow separation ring slow the descent rate, and vanes attached to the airflow ring maintain spin for continuous viewing in a full circle by the experiments during descent. A fairing covers the forward hemisphere of the pressure vessel, providing a smooth aerodynamic surface during descent.

Heat Protection

The Large Probe pressure vessel is made of titanium for heat resistance. Within the spherical vessel, instruments and systems are mounted on two parallel shelves made of beryllium to serve as heat sinks. Equipment inside the vessel is further protected from heat by a 2.5 cm (1 in.)-thick kapton blanket, which completely lines the interior.

Scientific Instruments

The seven scientific instruments on the Large Probe include the gas chromatograph and mass spectrometer, which measure the composition of Venus' atmosphere directly. The other five instruments either "look out" windows or sense vehicle motions and/ or temperature with accelerometers and a wire-connected heat sensor, respectively.

The infrared radiometer requires a diamond window because diamond is the only material transparent to the appropriate wavelengths and able to withstand the high temperatures and pressures of the atmosphere. This window is about three-quarters of an inch in diameter and an eighth of an inch thick (about the size of a quarter). It weighs 13.5 carats and was shaped by diamond cutters in The Netherlands from a 205-carat industrial grade rough diamond. The nephelometer (cloud-sensor) uses two sapphire windows. The cloud particle instrument directs a laser beam through a sapphire window to an outside reflecting prism and back to its sensor. The solar flux radiometer has five sapphire windows.

Communications System

Scientific instrument and spacecraft systems data are returned by the communications system. Spacecraft data include internal temperature and pressure measurements, electrical current flow and voltage and on-or-off status of systems and instruments.

The probe's solid state transmitter and hemispherical coverage antenna return a 256-bps data stream to Earth. The system uses four 10-watt solid state amplifiers providing a transmitter power of 40 watts.

A transponder receives an S-band carrier wave at 2.1 GHz, and sets the probe transmitter to send at 2.3 GHz. The transponder receiver is used only for two-way Doppler tracking. The incoming signal carries no information, and the probe does not receive commands.

Command System

Once the Large Probe has separated from the Bus, onboard electronics provide all probe commands. The command system consists of a command unit, a pyrotechnic control unit and the sensors to service the command unit.

The system can provide 64 separate commands for spacecraft systems and scientific instruments. It contains the cruise timer (the only operating unit during the 24-day period between Bus separation and entry), an entry sequence programmer and a command decoder. Commands are initiated by a clock generator or a G-switch to sense deceleration forces. A temperature switch provides backup for the timer at parachute jettison.

The pyrotechnic control unit is made up of 12 squib drivers which provide current to fire explosive nuts for separation of the aeroshell, the aft cover and main chute; and actuators for the cable cutter, pilot chute mortar and mass spectrometer inlet cover.

Data Handling System

The Large Probe data handling unit can accept 36 analog, 12 serial digital, and 24 one-bit (yes-no) status channels from scientific instruments and probe systems. The unit converts the analog and yes-no data to serial digital form and arranges all data in major telemetry frames composed of 16 minor frames for time-multiplexed transmission to Earth. Each minor frame is composed of a series of 64 eight-bit words (512 data bits per minor frame).

The data handling system provides for two data formats: blackout and descent. A storage capacity of 3072 bits is provided by a data memory, for use during entry blackout. Following the blackout period, the stored data will be read out of the memory and telemetered in the descent format. Data are stored at 128 bps. In the descent format, transmission will be at 256 bps. Allocation of this bit rate among the seven Large Probe experiments will range from 16 to 44 bps per experiment. Only the atmospheric structure and nephelometer experiments will use the entry blackout storage format at 72 bps and 4 bps, respectively. Two subcommutated formats for lowrate phenomena also provide housekeeping data, and additional data for the atmospheric structure, nephelometer, cloud particle spectrometer and solar flux radiometer experiments.

Power System

The power system uses a silver-zinc battery, providing 40 ampere hours of energy at 28 volts. The system consists of a battery, a power interface unit and a current sensor. The power interface unit controls power and contains fuses and power switching relays for vehicle systems. Power for probe checkout and heating is provided by the Bus prior to probe to probe separation. During this time, the batteries are open-circuited by switches in the power interface unit.

The Small Probes

Atmosphere entry points for the Small Probes are spread over the face of Venus--two on the night side at high northern and mid-southern latitudes, and the third at mid-southern latitudes on the day side.

Like the Large Probe, each of the Small Probes consists of a forward heat shield, a pressure vessel and an afterbody. The three small probes are identical. Each is 0.8 m (30 in.) in diameter and weighs 90 kg (200 lb.). Each carries three scientific instruments, weighing 3.5 kg (7.7 lb.). The three Small Probe instruments return less detailed information than the seven on the Large Probe. But except for the atmospheric composition measurements, made only by two Large Probe instruments, Small Probe atmosphere measurements are in many respects comparable to Large Probe data. The Small Probes transmit data at 64 bps during flight down to 30 km (18 mi.) altitude and 16 bps from there to the surface.

Neither forward aeroshell nor afterbody of the Small Probes ever separates from the pressure vessel, nor is a parachute used for deceleration as with the Large Probe. The Small Probes are slowed entirely by aerodynamic braking, and instruments gain access to the atmosphere through doors in the integral afterbody. Both aeroshell and pressure vessel are made of titanium for light weight and strength at high temperatures. The afterbody is made of aluminum.

Small Probe Structures

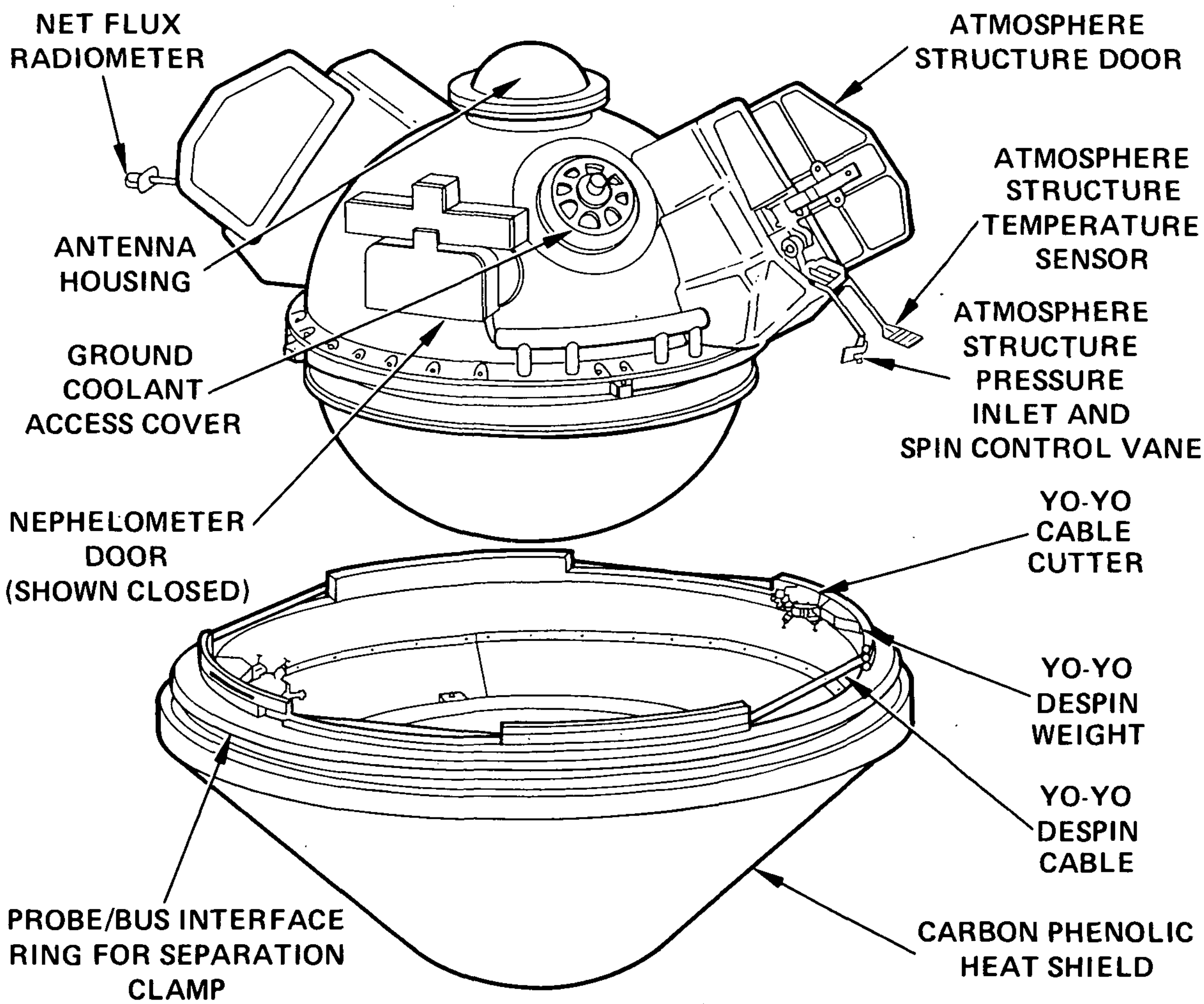
The pressure vessel nests into the aeroshell and is permanently attached to it. The afterbody also is permanently attached to the pressure vessel, and its shape closely follows the contours of the vessel's aft hemisphere, protecting it from atmosphere heat. As in the case of the Large Probe, the pressure vessels for the three small probes had to be very carefully designed and machined because of weight limitations, the seven hull penetrations required and the strength requirements at high Venusian pressures and temperatures.

The pressure vessels are fabricated in two hemispheres and joined with flanges, bolts and seals. The flight vessels were tested at Venus surface temperatures and pressures, and the test vessels tested even under more severe conditions.

Three doors in the afterbody open after entry heating at about 70 km altitude (44 mi.), providing access by the three instruments to the atmosphere. Two of these doors open out from each of two protective housings--one for the atmospheric structure and the other for the net flux radiometer instrument. These housings project like ears from each side of the pressure vessel sphere. The temperature sensor and atmospheric pressure inlet for the atmospheric structure instrument extend 10 cm (4 in.) from the door of one housing, and the nex flux radiometer sensor extends similarly on the opposite side.

When the doors to these two housings open after atmospheric entry at 70 km (44 mi.) altitude, they are retained, rather than jettisoned, and serve to slow spacecraft spin rate. A vane, less than one square inch, is attached to the pressure sensor inlet to assure that the vehicle will spin throughout the descent, so that instruments can see in a full circle as the probe rotates. The cloud sensor (nephelometer) cover opens and folds down. As with the Large Probe, a hemispherical-pattern antenna is mounted at the aft pole of the pressure vessel sphere.

SMALL PROBE



DECELERATION MODULE

Each Small Probe pressure vessel has a total of seven sealed penetrations: one for the antenna, one for the two sapphire nephelometer windows, one for the atmospheric pressure inlet and a hatch for ground test cooling and systems checkout. The other three vessel penetrations are feed-throughs for electrical cables. Each external radiometer sensor on each small probe has two diamond windows.

Flight Sequence

For the three Small Probes, atmospheric entry speeds are about 42,000 kph (26,000 mph), and peak decelerations vary in entry flight path angles.

Twenty minutes before entry, all systems and instruments are activated and communications with Earth are established. Just before entry, spin rates are cut about three times from 48 to 14 rpm The 48-rpm spin rate imparted by spin-off launch from the Bus disperses the probes over the planet to desired entry points. But it also means that the probes enter the upper atmosphere somewhat tilted to their entry flight paths. With the slower 15-rpm rotation, aerodynamic forces quickly line up the axes of the probes with their entry heating damage could occur on the edges of the probes conical heat shields.

A yo-yo system spins down the probes. Two weights are cut loose by a pyrotechnic cable cutter, and probe spin swings the weights out on 2.4 m (8-ft.) cables. With this weight moved radially outward, rotation rate must slow to maintain the same rotational momentum. Weights and cables are then jettisoned.

In order to save weight and also because a longer stay-time at upper altitudes is not needed, the small probes do not use parachutes. On the large probe, more time is needed for measurements of atmosphere and cloud composition. The small probes do not carry atmospheric composition instruments.

As with the Large Probe, heat shield temperature and probe acceleration data are stored for the atmospheric structure experiment during the entry communications blackout. A G-switch ends data storage after blackout.

Flight Systems

Thermal protection during entry is provided by ablative carbon phenolic heat shields, which are 45-degree cones with the same geometry as the Large Probe heat shield. For further heat protection, the entire afterbody is coated with a low-density elastomeric material. The heat shield material is bonded to the Small Probe titanium aeroshell. Base diameter of the aeroshell heat shield cone is 76 cm (30 in.).

The conical aeroshell provides aerodynamic braking and flight stability, as does location of the probe center of gravity well forward in the vehicle. Designers chose the aeroshell cone structure primarily for flight through the searing heat and extreme deceleration of atmosphere entry. However, the cone also provides stable flight and substantially slows descent rate in Venus' thick lower atmosphere.

Heat Protection

As with the Large Probe, heat protection for the small probes is provided by a kapton blanket completely lining the interior of an 45 cm (18-in.) diameter spherical titanium pressure vessel. It, too, has two shelves which carry all equipment and scientific instruments, and are made of beryllium to serve as heat sinks. Since the aeroshell descends to the surface with the pressure vessel, it, too, is made of light-weight, heat-resistant titanium.

Scientific Instruments

The three scientific instruments on the small probes measure atmospheric structure (pressure, temperature and acceleration from which altitude and density are determined), cloud particles and layers and heat distribution in the atmosphere. These measurements, and claculations based on them, will allow characterization of Venus' atmosphere.

For the atmospheric structure experiment, the outside inlet for the pressure sensor, and the arm carrying the harp-like temperature sensor both extend from the experiment housing. The pressure sensor itself and temperature-sensor electronics internal, as are the accelerometers used for density calculations.

The cloud sensor instrument (nephelometer) is entirely inside the pressure vessel, and looks out through two sapphire windows. For the net flux radiometer (heat deposition instrument) sensors are completely external, mounted on a small boom extending from the experiment housing. The radiometer sensor with its two diamond windows turns constantly in a half circle, first looking up and then down. Instrument electronics are internal.

Communications

Communications systems for the Small Probes consist of solid state transmitters and hemispherical coverage antennas, identical with those for the Large Probe. Each transmitter has one 10-Watt, solid state amplifier. This compares with 40 watts for the Large Probe. This system can transmit data to the DSN's 64-m (210-foot) antennas at a rate of 64 bps above 30 km (19 mi.) altitude and 16 bps below that to impact. The Small Probes do not carry a receiver for two-way Doppler tracking as does the Large Probe, and Doppler tracking is done using an oscillator (stable to approximately one part in a billion) on the probes as a reference frequency for ground tracking computations.

Data returned include scientific and engineering information. This includes internal temperature and pressure measurements, electrical current flow and voltages, and on-off status of instruments and probe systems.

Command System

The command system on the Small Probes is identical to that on the Large Probe. It provides 64 commands, all originated on board the probes by timers, programmers, G-switches and other logics and devices.

Data Handling System

Components of the data handling system on the Small Probes are identical to those for the Large Probe. The data-handling unit can accept 36 analog, 12 digital and 24 one-bit channels from instruments and systems. Logic of data formats also is identical.

The system for each Small Probe provides for three high-rate data formats: upper descent, lower descent and entry blackout. As with the Large Probe, a storage capacity of 3072 bits is provided by the data memory. Following the entry communications blackout, stored data will be played back and telemetered in the upper descent format at 64 bps. Real time transmission will occur initially at 64 bps in the upper descent format, changing to 16 bps at 30 km (19 mi.) altitude (lower descent format). Data rate allocation among the three Small Probe instruments ranges from 6 to 20 bps in the upper format and 1.5 to 7.25 bps in the lower format.

Power Systems

Small Probe power systems are silver-zinc batteries which provide 11 ampere-hours of energy at a normal 28 volts. The system includes a battery, power interface unit and current sensor. Other components are identical to those for the Large Probe.

SCIENTIFIC INVESTIGATIONS

Orbiter

Cloud Photopolarimeter -- This instrument measures the vertical distribution of cloud and haze particles and observes ultraviolet atmospheric markings and cloud circulations. Ultraviolet images provide the visual reference for data from other Orbiter experiments and for this instrument's polarization readings.

A 3.7-cm (1.5-in.) telescope with a rotating filter wheel observes the planet at fixed angles, using the Orbiter rotation for scans across the planet and motion along the spacecraft trajectory around Venus for complete planetary mapping. The angle of the telescope may be varied by ground command for select observations from any point in orbit.

The instrument uses an ultraviolet (UV) filter (for maximum contrast) to track the puzzling fast-moving UV absorbing markings. Five planetary images can be made in each spacecraft orbit. The field of view is about one-half milliradian, corresponding to a resolution of about 30 km (19 mi.) directly below the Orbiter.

The instrument measures scattered sunlight polarization based on cloud and haze particle size, shape and density. Vertical distribution of cloud and haze particles in relation to atmospheric pressure is extracted from this data.

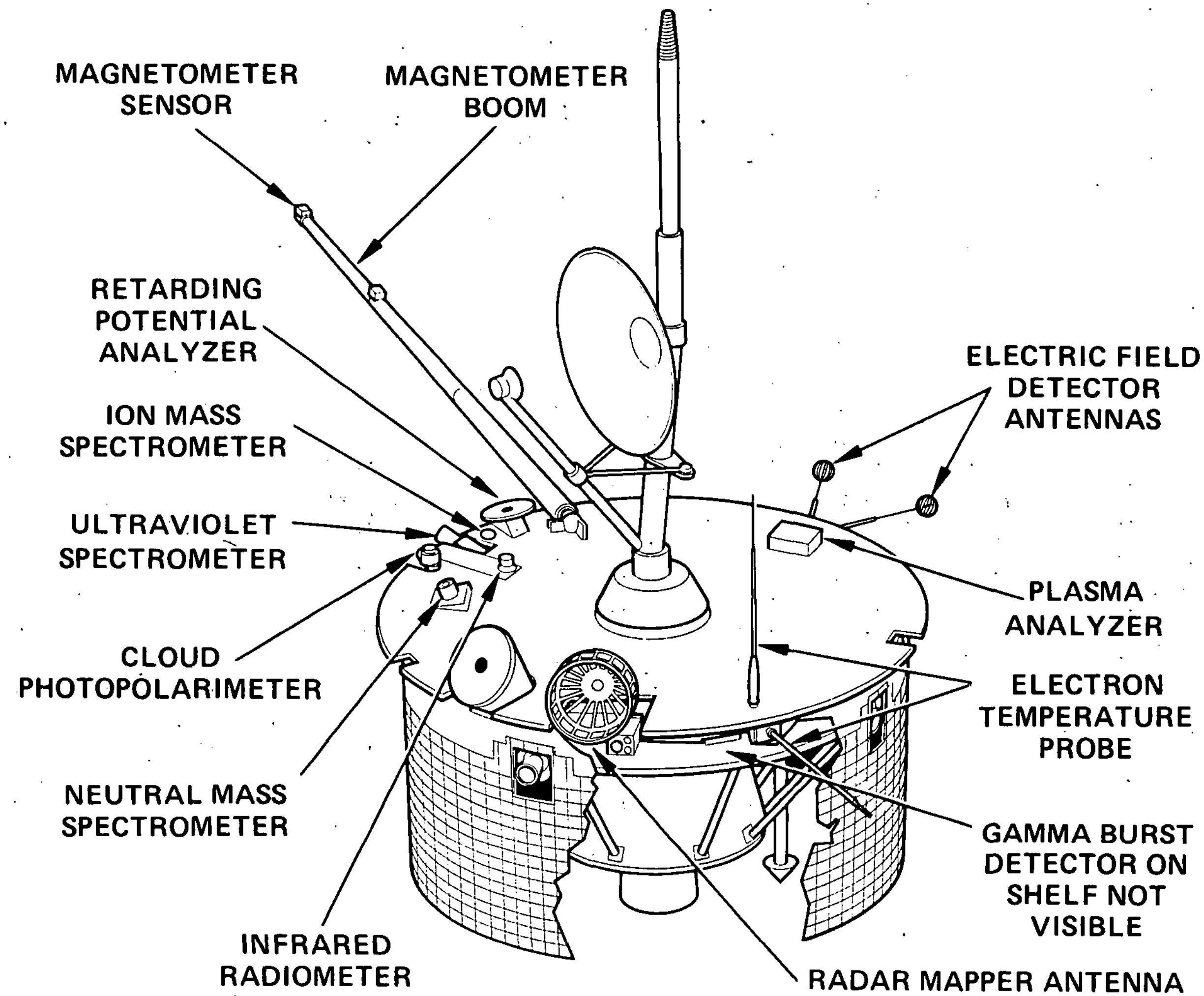
While the Orbiter is at periapsis the instrument observes in visible light the high-haze layers of the atmosphere. These "limb scans" have a resolution as small as .5 km (.3 mi.).

The instrument weighs 5 kg (11 lb.) and uses 5.4 watts.

Surface Radar Mapper -- The radar mapping experiment makes for the first time studies of large portions of the planet's hemisphere not visible from Earth. This experiment will provide the only direct observations of the surface to be obtained from the Orbiter. From observing the echo of several radio frequencies, experimenters derive surface heights along the orbital trajectory to an accuracy of 100 m (300 ft.) or better, giving a good estimate of global topography and shape. Surface electrical conductivity can also be derived from the radar data.

A low power (20 watts peak pulse power) S-band (1.757 GHz)radar system observes the surface for one out of every 12 seconds of spacecraft rotation.

ORBITER EXPERIMENTS



Measurements are made whenever the Orbiter is below 3,000 km (1,860 mi.), subject to constraints set by the revolving radar antenna and by competition with other experiments for the limited telemetry capacity. The instrument automatically compensates for Doppler shift caused by the radial motion of the Orbiter.

Team scientists subtract the observed distance between the Orbiter and the surface from the spacecraft's orbital radius (obtained from DSN tracking) to find absolute topographical measurements. Surface resolution is best at a periapsis altitude of 200 km (174 mi.): 20 km (12 mi.) long and 16 km (9.6 mi.) across the suborbital track. Data gathered by the instrument and telemetered to Earth will be computer-assembled into radar maps of the planet.

Resolution is comparable to the Earth-based radar studies; enough to discern major surface features.

The instrument weighs 9.7 kg (21.3 lb.) and uses 18 watts.

<u>Infrared Radiometer</u> -- This instrument measures the "heat" (infrared radiation) emitted by the atmosphere at various altitudes from 60 km (36 mi.) at the top of the dense cloud layers out to 150 km (90 mi.). In addition, the instrument searches for water vapor above the cloud layers, measures the size of heat trapping cloud layers and measures the planetary solar reflectance (albedo). The radiometer's data yields a vertical temperature profile of the upper atmosphere as well as a horizontal temperature profile along the suborbital track. Such information is important in uncovering the extent and driving forces of the seeming four-day circulation of the upper atmosphere.

The instrument features eight detectors, each sensitive to a different fraction of the infrared spectrum. Five detectors measure the infrared emissions at five selected wavelengths of the µm (micrometers), absorption band of carbon dioxide. Each wavelength samples a specific depth in the atmosphere, depending on heat absorbing characteristics of the CO_2 molecule and the variation of temperature with altitude. One detector exclusively detects and maps the distribution of water vapor (if it exists) in the upper atmosphere. Another detector measures the size and shape of cloud layers, and the last detector measures the total solar reflectance.

A 48-mm-aperture telescope mirror feeds all eight channels. The telescope is set at 45 degrees to the Orbiter spin axis so that scans are made by spacecraft rotation. When looking at one planet's limb the narrow field of view gives vertical resolution of 5 km (3 mi.) at periapsis. When the Orbiter is in best position for limb scanning of the planet's atmospheric "edge," the instrument obtains additional data on cloud layers and the vertical distribution of water vapor.

The instrument weighs 5.9 kg (13 lb.) and uses 5.2 watts.

Airglow Ultraviolet Spectrometer -- The ultraviolet spectrometer observes the numerous atmospheric markings which can be seen only through ultraviolet (UV) filters. The instrument tracks the UV absorbing masses which rotate in four days, measures the escape rate of atomic hydrogen from the outer atmosphere and measures the ultraviolet scattering properties of the cloud tops and hazes at about 80 km (50 mi.) altitude.

Absorption of UV radiation in the upper atmosphere produces optical UV emissions known as the "airglow". Various airglow emissions are caused by different physical processes (e.g., split-up of molecules into electronically excited atoms). By viewing day and night airglow at wavelengths between 1,100 Angstroms and 3,400 Angstroms, the spectrometer can thus identify the mechanism which excites the gases of the upper atmosphere. The temperatures of the upper atmosphere at various altitudes can also be inferred from data from limb scans at the atmosphere's edge, at selected wavelengths.

The instrument measures the Lyman Alpha corona to find hydrogen escaping from the farthest reaches of Venus' atmosphere. These data are important because escaping atomic hydrogen is the last step when a planet is losing water.

The spectrometer features a 125-mm telescope and monochromator to restrict (upon ground command) the viewing spectrum to any UV wavelength. Photomultiplier tubes convert the impinging UV radiation to electrical impulses, which are then telemetered to Earth for construction into ultraviolet planetary maps.

The instrument weighs 3.1 kg (6.9 lb.) and uses 1.7 watts.

Neutral Mass Spectrometer -- This instrument measures the densities of neutral ionized atoms and molecules in Venus' upper atmosphere between 150 km (90 mi.) at periapsis and 200 km (120 mi.). Finding the vertical and horizontal variations in the neutral gas molecules will help define the chemical state of the upper atmosphere. Variations of hydrogen and helium concentrations will tell the extent of gas escape from the atmosphere. Researchers will find the height of the homopause (above which atmosphere mixing stops) by comparing the densities of inert gases at the Orbiter altitudes with measurements made by the Large Probe and Bus neutral mass spectrometers below 150 km (93 mi.).

Noble gases, other non-reactive gases and chemically active gases up to 46 atomic mass units are identified and measured. Gas molecules are first ionized and then deflected by a magnetic field according to their mass. The average vertical spacing of sample points is approximately 400 m (240 ft.) at 500 km (300 mi.) altitude while the horizontal spacing for sampling along the Orbiter path is about 2 km (1.2 mi.).

The instrument weighs 4.5 kg (9.8 lb.) and uses 15 watts.

Ion Mass Spectrometer -- The ion mass spectrometer measures the distribution and concentration of positively charged ions in the Venusian upper atmosphere from 150 km (90 mi.) to the ionosphere. The instrument directly measures ions in a mass range from hydrogen ion (proton) to ions of iron, corresponding to from 1 to 56 atomic mass units. Such data are important in understanding the basic nature of the ionosphere and its relation with the solar wind.

The instrument makes first an exploratory sweep of 1.5 seconds, during which a search is made for up to 16 different ions. It then makes a series of sweeps, repeating the sampling of the eight most prominent ions identified during the exploratory sweep. (The Bus instrument is identical to the Orbiter version except that these operating sequences cannot be modified by ground command as they can on the Orbiter.)

In flight, a sensor is exposed to a stream of atmospheric ions, which flow into an aluminum cylinder enclosing a series of parallel wire grids. Each ion species is accelerated by a specific voltage applied to the grids so that the ions impinge on a collector at the rear of the sensor cylinder. The ion stream's accelerating voltage will yield its identity and its amplitude will reveal its concentration.

The instrument weighs 3 kg (6.6 lb.) and uses 1.5 watts.

Solar Wind Plasma Analyzer -- This instrument measures properties of the solar wind and its interactions with Venus' ionosphere and upper atmosphere. The instrument measures velocity, flow direction and temperature of the solar wind. Such findings should help explain how the ionosphere reacts with the solar wind and possibly the role the solar wind plays in Venus' weather patterns.

The region around Venus, the cavity "shadowed" by the solar wind, is determined to the extent allowed by the spacecraft orbit. The instrument searches for streams of solar particles in this region.

The plasma analyzer is an electrostatic/energy-per-unit charge spectrometer. The solar wind flux (rate of flow of the solar wind) is measured by the deflection of in-rushing particles by an electrostatic field between two metal plates. If the particles are within the energy range determined by the plates' voltage differences, they exit between the plates, hitting one of five detectors. Which target the particles hit determines the solar wind direction. By varying the voltage between the plates, the instrument yields a complete particle spectrum of the solar wind.

The instrument weighs 3.9 kg (8.6 lb.) and uses 5.2 watts.

Magnetometer -- The magnetometer studies Venus' magnetic field and the interaction of the solar wind with the planet. It "searches" for surface-correlated magnetic features, such as regions of crust magnetized in the past perhaps when Venus had much stronger magnetic properties. The measurements of the magnetic field of Earth's sister planet may shed light on what internal fluid motions produce planetary magnetic fields. (It is still not known what motions are responsible for Earth's magnetic fields.)

It appears Venus has a very weak magnetic field; yet, it may play an important role in the ionosphere-solar wind interaction. The magnetometer should find whether it is the weak intrinsic magnetic field, an induced magnetic field or the ionosphere itself which deflects the solar wind.

The instrument consists of three sensors on 4.7-m (15.5-ft.) booms, long enough to isolate them from much of the spacecraft's own magnetic field. The inboard sensor, tilted 45 degrees to the spin axis exclusively measures the Orbiter's magnetic field, which will be subtracted from the outboard sensors' readings.

Each sensor consists of a ring around which is wrapped a ribbon of permeable metal. Any external magnetic field causes the core to produce an electrical signal. A feed-back signal then cancels the external field so that the magnetometer always operates in a zero field condition. The strength of the feedback signal is a measure of the external magnetic field.

The instrument weighs 2 kg (4.4 lb.) and uses 2.2 watts power.

Electric Field Detector=-- This instrument will help answer questions concerning the characteristics of the inter-actions between Venus and the solar wind, the million-mile-an-hour ionized gas that continually streams outward from the Sun to the solar system.

The detector will determine the kinds of interactions between the plasma (the mass of ions and electrons) of Venus' ionosphere and the solar wind, the extent to which the solar wind is deflected around Venus, the extent to which the solar wind heats the ionosphere, the extent of ionization caused by exosphere-solar wind interaction and solar wind turbulence. The instrument also searches for "whistlers" -- electromagnetic disturbances which travel along a planet's magnetic field lines.

The instrument measures electric components of plasma waves and radio emissions in the frequency region from 100 to 100,000 Hertz which induce a current in the instru-ment's V-type electric dipole antenna. The current is amplified and the information processed and relayed back to Earth. Four 30 per cent bandwidth channels are employed; each is useful at different points along the Orbiter tra-jectory, as it passes through varying densities of the solar wind. The 0.6-m (26-in.)-long antenna is designed to lean on the Orbiter shroud and deploy automatically when the shroud is ejected.

The instrument weighs 0.8 kg (1.74 lb.) and uses 0.7 watts of power.

Electron Temperature Probes -- The probes measure the thermal characteristics of Venus' ionosphere: electron temperature and concentration and ion plasma mass and con-centration, as well as the spacecraft's own electrical potential. Such measurements will help scientists under-stand the heating mechanisms of Venus' ionosphere, currently believed to include heating at higher altitudes by the solar wind and at lower altitudes by solar ultraviolet radiation.

Two cylindrical probes 7 cm (3 in.) by 0.25 cm (0.5 in.) are used. One probe is mounted parallel to the spacecraft spin axis on a 0.4-m (16-in.) boom, and the other probe is mounted perpendicular to the spin axis on a 1-m (40-in.) boom. (The booms are long enough to place the sensors beyond much of the photoelectron cloud and ion sheath surrounding the spacecraft which might distort readings.) The longer boom allows measurement of electron content and temperature for conditions of very low electron concentrations.

Each probe has its own power generator while sharing inflight data analysis circuitry. A sawtooth voltage sweeps each probe twice per second and is electronically adapted to match the existing electron density and temperature being measured.

The instrument weighs 2.2 kg (4.76 lb.) and uses 4.8 watts of power.

Charged Particle Retarding Potential Analyzer -- This instrument measures the temperature, concentration and velocity of the most abundant ions in the ionosphere (presumably carbon dioxide and oxygen ions.) It also measures the concentration, temperature and energy of surrounding photoelectrons in the ionosphere.

The instrument is designed specifically for detecting the low energy plasma particles in Venus' ionosphere, as opposed to the much more highly energized solar wind particles. However, the analyzer should provide data concerning the solar wind-ionosphere interaction at an altitude of 400 to 500 km (240 to 300 mi.) at the point where the solar wind streams into the ionosphere.

By varying electrical potentials, collector grids of 6 cm (2.5 in.) diameter selectively allow various ionospheric particles to strike a detector. Current induced in the detector is amplified by an electrometer.

Measurements are taken at intervals along a 120-km (72-mi.) orbit segment through the ionospheric plasma region. Onboard analysis selects the optimum point in the spacecraft rotation at which to sample the ionospheric plasma, so that each scan is completed in a small fraction of a spin period. The instrument achieves a 20-km (12-mi.) resolution for total ion concentration.

The instrument weighs 2.8 kg (6.3 lb.) and uses 2.4 watts of power.

Gamma Ray Burst Detector -- The gamma ray burst detector observes the intense short duration (one-tenth second to a few tenths of seconds) "bursts" of high energy protons from outer space. This phenomenon wasn't discovered until 1973, and the nature and origin of the sources are still unknown. The gamma ray bursts occur randomly in time (roughly 10 per year) and appear to originate from random points in the universe. The gamma ray burst detector is the only experiment on Pioneer Venus which is not involved in the direct study of Venus and its environs.

The Venus Orbiter, separated from Earth by roughly one astronomical unit (149 million km or 93 million mi.) provides a means to obtain a "fix" on the strange bursts, by correlating its observations with those made by orbiting Earth satellites. Measurements of the gamma ray sources will be made with an accuracy of less than one arc minute, precise enough for an attempt at optical identification of the sources.

Two sodium iodide photomultiplier detector units sensitive to photons in the 0.2 to 2.0 million electron volts (Mev) energy range provide a continuous time history for those bursts intense enough to be detected and give a coarse profile of the gamma burst energy range. A memory unit of 20,000 "bits" for storing data for later readout is required to accommodate the very high data rates that occur during a brief burst.

The instrument weighs 2.8 kg (6.35 lb.) and uses 1.3 watts of power.

Orbiter Radio Science

Internal Density Distribution Experiment -- This experiment determines Venus's internal mass distribution, the processes which have produced that distribution, the planet's global shape and the relationship between Venus' surface features and their corresponding internal densities. Researchers hope to construct a model of the physical processes which governed Venus' planetary evolution with the help of this experiment's data.

Scientists use the two-way Doppler tracking of the Orbiter, which is also used for navigation, to find very small changes in its orbit. They use these orbit changes to chart Venus' gravity field. This gravity information can then be used to calculate variations in planet density.

An S-band signal of 2.2 GHz is transmitted from a DSN antenna, received by the Orbiter spacecraft and retransmitted back to the DSN antenna. Doppler shifts in frequency of these signals mean changes in spacecraft velocity. Most of the velocity changes are due to the relative orbital motions of Earth, Venus and the Pioneer Venus Orbiter. However, local anomalies in the internal mass distribution of Venus induce additional velocity changes. Analysis of the velocity changes therefore provides information on the internal mass distribution of Venus.

Comparison of this data with the radar mapping data may support the existence of basic on-going physical processes, such as Earth-like plate tectonics (the movement of massive crustal plates slowly past one another). The data also will infer the likely composition and temperature of Venus' interior.

Celestial Mechanics Experiment -- The celestial mechanics experiment studies Venus' gravity field, leading to calculations of its global shape and inferences about the dynamics of the planet's upper atmosphere and ionosphere. The experiment also measures the direction of Venus' spin axis, rotation of the planet's poles, density of the upper atmosphere, relativistic effects of solar gravity on the Orbiter tracking signal and improves our knowledge of the exact planetary trajectories of Venus and Earth.

Scientists use Doppler tracking to chart the planet's gravity field. A DSN antenna on Earth transmits a radio signal of 2.2 GHz to the Orbiter, which retransmits that signal, multiplied by 240/221 (to discriminate outgoing from incoming signals). Unexpected frequency shifts in these signals mean changes in spacecraft position. These changes are caused by the mass and gravitational field of Venus, gravity field of the Sun and Venus' own atmosphere, which exerts a drag on the Orbiter. More detailed studies of the atmosphere are possible just before and after the occultations of the Orbiter by Venus, when the radio signal must pass quite close to the planet surface on its way to Earth. Distortions (scintillations) of the Orbiter signal during these periods reveal variations in upper atmosphere density.

Simultaneous radio tracking of the Orbiter with extragalactic radio sources will allow very precise determination of the orbits of Earth and Venus with respect to these extragalactic objects.

Dual Frequency Radio Occultation Experiment -- This experiment studies the atmosphere of Venus by observing how Orbiter X- and S-band radio signals penetrate Venus' atmosphere on the way to receivers on Earth. The 40 occultations with Venus which the Orbiter trajectory encounters over its mission lifetime will produce 80 profiles of the signal distorting properties of the planet's lower and upper atmosphere and ionosphere.

By analyzing the scintillations in radio signals caused by various atmospheric layers, investigators can infer the refraction, temperature, pressure and densities of the atmosphere from 34 km (20 mi.) altitude up through the ionosphere. As the radio signals pierce the ionosphere, investigators can measure signal distortion due to varying electron densities in this barely-known region. Since most of these measurements are made on Venus' night side, data is provided on the reportedly variable Venusian nighttime ionosphere.

The Orbiter high-gain antenna is specially aimed during occultations so that the refracted radio signal is optimally aimed at Earth. DSN stations on Earth are equipped with special receivers to track the incoming signals as their phase and frequencies are modified during transmission through Venus's atmosphere.

Atmospheric and Solar Wind Turbulence Experiment -- The experiment observes the small scale turbulence (less than 10 km or 6 mi.) in the Venusian atmosphere above 35 km (22 mi.) altitude. It will reveal the variation of atmospheric turbulence with latitude, longitude and altitude changes during the 40 occultations when Orbiter spacecraft signals must pass through Venus' atmosphere on their way to Earth tracking stations. Because the signals travel through the ionosphere as well, fluctuations in electron density can also be inferred from the data.

Following conclusion of the normal mission lifetime (around August 1979), the Orbiter will provide density and velocity measurements of the solar wind near the Sun. Venus will then approach superior conjunction (Earth and Venus will be on opposite sides of the Sun). This is an ideal time to investigate the solar wind, the stream of ionized particles constantly swirling off the Sun. Because the solar wind is so changeable, repeated Orbiter observations of the solar wind near to and far from the Sun will provide needed information about solar wind density, turbulence and velocity uniformity. Two DSN stations will analyze the fluctuations (scintillations) in the Orbiter S- and X-band signals as they pass the solar wind on their way to Earth.

Atmospheric Drag Experiment -- This investigation takes drag measurement for the first time of another planet's atmosphere, as the atmosphere "friction" of Venus slows the Orbiter. Experimenters will use drag measurements throughout the Orbiter mission to search for any variations in atmospheric density that correlate with solar wind activity changes in solar ultraviolet radiation and differences in density on the planet's night side. In addition, project scientists are looking for evidence that the seeming four-day rotation of the lower atmosphere extends into the upper atmosphere.

DSN stations analyze the Doppler effect on the spacecraft's X- and S-band radio signal, caused by atmospheric drag-induced change in the Orbiter's direction and speed.

The entire spacecraft, essentially the shape of a cylinder, acts as the test instrument. Atmospheric density is determined best in the vicinity of periapsis (between 150 and 250 km or 93 and 155 mi.), where the drag effect is much greater than elsewhere along the Orbiter trajectory. As the periapsis altitude changes, variations of atmospheric density with altitude can be plotted.

Knowledge of atmospheric density aids interpretation of mass spectrometer findings, infers the composition and temperature of the upper atmosphere and aids in constructing a model of Venus' upper atmosphere.

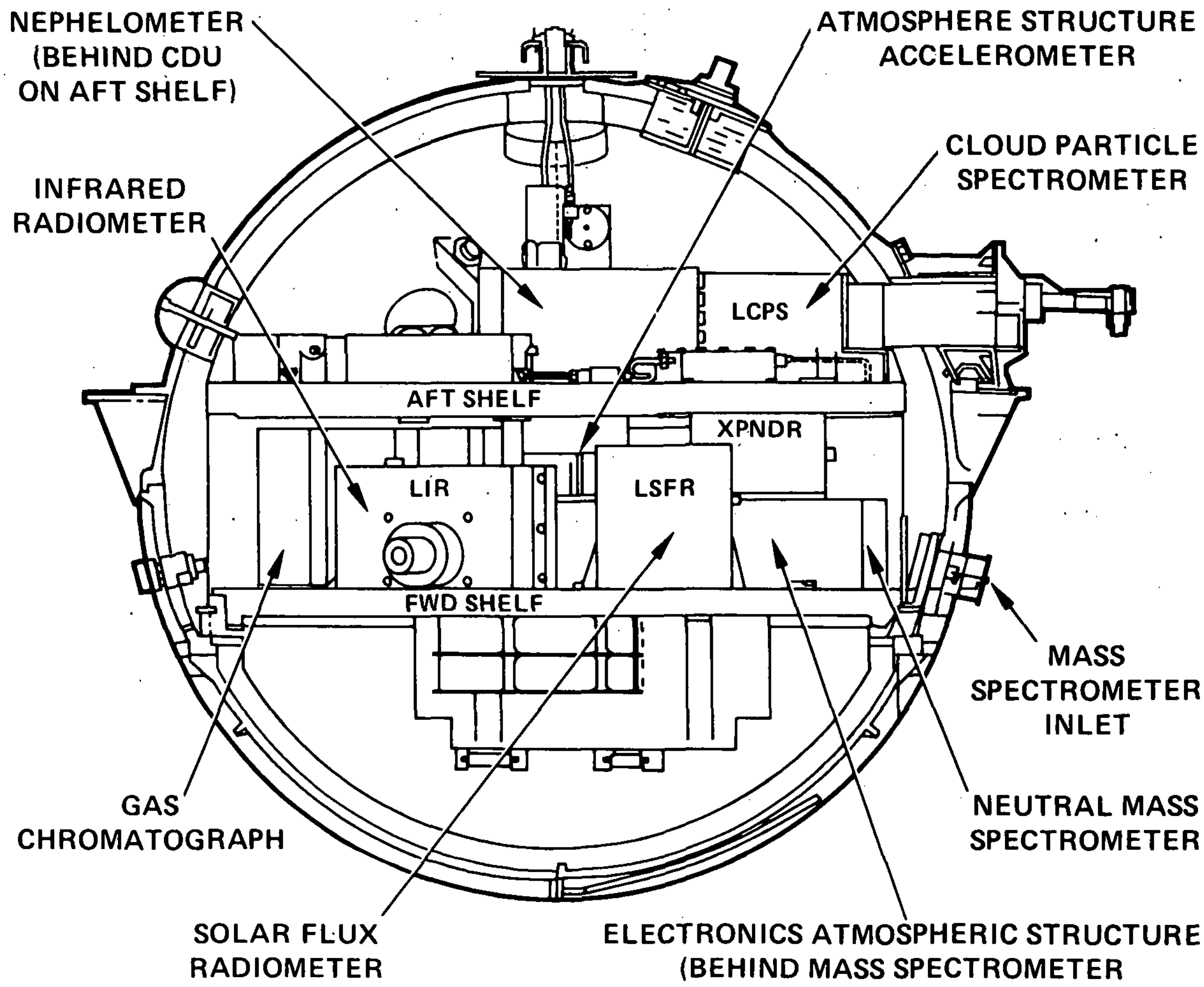
Large Probe Experiments

Neutral Mass Spectrometer -- The neutral mass spectrometer measures the atmospheric composition of the lower 60 km (36 mi.) of Venus' atmosphere(largely the atmosphere below the massive cloud layers) as the Large Probe descends by parachute. Knowledge of the relative abundances of gases will help answer questions about the evolution, structure and heat balance of Venus.

The instrument determines the vertical distribution and concentration of non-reactive gases, chemically active gases and ratios of inert gas isotopes. Water vapor (if it exists) is also measured.

The instrument is mounted inside the Large Probe pressure vessel. It receives a continuous flow of atmospheric gas through two unique ceramic inlet tubes that protrude through the pressure vessel wall. The inlet tubes are called Ceramic Micro Leaks (CMLs) and are made to greatly limit the amount of gas entering the instrument, without chemically altering it.

LARGE PROBE EXPERIMENTS



The CMLs are passive devices and the amount of gas flowing through them increases with increasing atmospheric pressure. To prevent "flooding" of the instrument, one CML is sealed when the atmospheric pressure is about 1.5 bars. After entering the instrument, the atmospheric gas is first ionized and the separated ions sorted out for mass and quantity of each constituent by their different deflections in passing through magnetic fields.

The spectrometer can identify gases with masses up to 208 atomic mass units, believed to be a large enough mass range for all molecules likely to be encountered in the lower atmosphere. Sensitivity is one part per million. Sixty atmospheric samplings are planned, with a mass spectrum taking 64 seconds. An onboard microprocessor controls the instrument and accumulates data for telemetry to Earth.

The instrument weighs 10.9 kg (24 lb.) and uses 14 watts.

Gas Chromatograph -- The gas chromatograph measures the gaseous composition of Venus' lower atmosphere. By finding the major sources of infrared opacity (those gases that trap heat), scientists should better understand why Venus has 480-degree C (900-degree F.) surface temperatures. From the measurement of gases produced by radioactive decay, scientists can infer the degree of differentiation within Venus' interior. Experimenters will also be able to deduce the similarity of the composition of the solid parts of Venus and Earth by the identification of various sulfuric gases.

The instrument samples the lower atmosphere three times during the Large Probe's descent. The atmosphere flows into a tube penetrating the exterior of the Large Probe and into a helium gas stream, which sweeps the sample into two chromatograph columns. Atmospheric gases are identified by the time it takes them to flow through the columns. As a calibration check, two samples of freon (a gas not likely to be encountered in the atmosphere) are added to the third sample, and their resolution noted.

The instrument weighs 6.3 kg (13.8 lb.) and uses 42 watts, the most of any Pioneer Venus instrument.

Solar Flux Radiometer --This instrument measures where solar energy is deposited in the lower Venusian atmosphere, giving a vertical profile of sunlight input. It reveals how much sunlight is absorbed by the clouds and how much sunlight reaches the surface, important information for resolving whether Venus has a greenhouse weather machine and explaining why its surface is so hot.

The instrument continually measures the difference in sunlight intensity directly above and below the Large Probe horizon as the probe drifts to the planet surface. Five quartz lenses of 3 mm (1/8 in.) diameter inside five flat sapphire windows collect the light and transmit it by quartz rods to an electronic light detector. Sunlight intensity is detected in the spectral range of 0.4 to 1.8 μm (micrometers), the wavelength range for most solar energy. Vertical resolution is 700 to 1,000 m (2,300 to 3,300 ft.). Lenses are positioned both up and down to find the amount of solar energy absorbed in layers of the atmosphere. To avoid having the probe or its parachute in the field of view, the radiometer samples sunlight in narrow 5-degree fields of view.

The instrument weighs 1.6 kg (3.5 lb.) and uses 4 watts.

Infrared Radiometer -- The infrared radiometer measures the vertical distribution of infrared radiation in the atmosphere from Large Probe parachute deployment at 67 km (40 mi.) down to the surface. It also detects cloud layers and water vapor, both of which may well be trapping enormous amounts of heat and preventing their reradiation back into space. Finding major heat sources (and traps) is essential to proving Venus has a greenhouse heating mechanism.

Six pyroelectric infrared detectors were chosen because they do not need special cooling equipment for their use in the extreme atmospheric heat. Each detector views the atmosphere via rotating light pipes through a different infrared filter between 3 and 50 microns. The views of the detectors is directed at 45 degrees above and below the probe horizon through a diamond window heated to prevent particle contamination during passage through clouds. The difference in infrared radiation, cloud opacity and water vapor between the two viewing angles is telemetered to Earth every 6 seconds, giving a vertical infrared spatial resolution of 250 m (825 ft.) or better.

Two of the six detectors monitor the temperature and optical uniformity of the diamond viewing window, two detectors detect and measure water vapor, one detector measures cloud opacity and the remaining detector measures the infrared intensities of the atmospheric layers the Large Probe passes through.

The instrument weighs 2.6 kg (5.8 lb.) and uses 5.5 watts.

Cloud Particle Size Spectrometer -- This instrument measures the particle size and shape and density of Venus' clouds in the lower atmosphere from 67 km (40 mi.) down to the surface.

Through measurements of particle size and mass, the investigation provides a vertical profile of particulate concentration for 34 different size classifications, ranging from 1 to 500 microns in diameter (a micron is one millionth of a meter or roughly two ten-thousandths of an inch). Such measurements will give clues to basic cloud formation processes and cloud-sunlight interactions on Venus. The spectrometer also differentiates ice crystals -- if any are present -- from other crystalline particulates by determining the ice's characteristic "aspect ratio" -- the ratio of particle thickness to size.

The instrument directs a laser beam onto an external mirror supported 15 cm (6 in.) from the pressure vessel's outer surface. The mirror directs the beam back into a backscatter detector. As a particle enters the instrument's field of view, its shadow is imaged onto a photodiode array detector, where its shadow size is measured and recorded.

The instrument weighs 4.4 kg (9.6 lb.) and uses 20 watts.

Large and Small Probe Instruments

Atmospheric Structure Experiments -- These investigations determine Venus' atmospheric structure from 200 km (120 mi.) to impact at four entry sites well separated from one another. Temperature, pressure and acceleration sensors on all four probes yield data on the location and intensities of atmospheric turbulence, the variation of temperatures with pressure and altitude, the average atmospheric molecular weight and the radial distance to the center of Venus. If the Probes survive impact (a remote possibility), they will reveal any seismic activity in the crust of the planet.

The temperature sensors are dual resistance thermometers. Each has one free wire element protruding into the atmosphere for maximum sensitivity and one element bonded to the support frame for maximum survivability. Its extreme temperature range permits it to record temperatures from below freezing to 470 degrees C (900 degrees F.).

Pressure sensors are multiple range, miniature silicon diaphragm sensors. The wide range needed from 30 millibars to 100 bars pressure is achieved by 12 sensors of overlapping sensitivity. This also provides redundancy in case of a sensor malfunction.

Acceleration sensors (four on the larger probe, one on each of the small probes) have a pendulous mass, maintained in null (zero) position by the interaction of a current in a coil inside the mass with a magnetic field. The nulling current is the measure of acceleration.

An electronics package distributes power to all sensors, samples their output, changes their ranges and stores data.

The instruments on the Large Probe weigh 2.3 kg (5.1 lb.) and use 4.9 watts. On each of the Small Probes the instruments weigh 1.2 kg (2.7 lb.) and use 3.5 watts.

Nephelometer -- The nephelometer searches for cloud particles (solid or liquid) in the lower atmosphere from 67 km (40 mi.) to the surface. By providing all four probes with nephelometers, investigators can determine whether cloud layers vary from location to location or are uniformly distributed across the planet.

A light emitting diode (LED) of 9,000 Angstroms together with a plastic Fresnel lens for focusing the light illuminate the atmosphere through a window mounted in the probe pressure vessel. The transmitted light beam is projected a distance beyond the turbulent atmosphere surrounding the probes as they descend. Through a second window, a receiver measures the intensity of light backscattered (about 175 degrees) by atmospheric particles. Both windows are protected from the searing temperatures of the Venusian atmosphere and from stray light.

Investigators will use the backward light scattering property of clouds and hazes to construct a vertical profile of particle distribution in the lower atmosphere. In addition, the two small probes descending in the sunlit side will be measuring the vertical distribution of solar scattered light at 3,500 Angstroms and 5,300 Angstroms.

The instrument weighs 1.1 kg (2.4 lb.) and uses 2.4 watts.

Small Probe Experiments

Net Flux Radiometer -- This instrument maps the planetary positions of sources and absorbers of radiative energy and their vertical distribution. The distribution of radiative energy (heat and sunlight) powers the atmospheric circulation on Venus as well as Earth. The instrument data will be related to the observed atmospheric motions, temperature structure and cloud characteristics from other Pioneer Venus experiments to gain a more accurate picture of Venus' weather machine.

The instruments on each of the three Small Probes are identical and can operate equally in either day or night hemispheres. Following descent into the lower atmosphere below 72 km (45 mi.) the instrument's sensor is deployed from a protective enclosure to a position locating it beyond the turbulence near the base of the heat shield. Data collection continues until impact.

The instrument's flux plate is oriented parallel to the planet's surface. A difference between upward and downward radiant energy falling on the two sides of the plate produces a temperature gradient through it, which induces an electrical current. The plate is flipped 180 degrees every second to assure even data collection.

The instrument weighs 1.1 kg (2.4 lb.) and uses 3.8 watts.

Multiprobe Bus Experiments

Neutral Mass Spectrometer -- The neutral mass spectrometer measures the various components (atoms and molecules) of the atmospheres and their vertical distribution from about 1,000 km (600 mi.) to 130 km (80 mi.), emphasizing the altitude range 150 to 120 km (90 to 75 mi.) which neither the Orbiter nor the four probes reach. (The Bus is expected to burn up at an altitude of about 120 km (75 mi.).

From the instrument data, investigators can derive the height of the turbopause (the region above which atmospheric gases do not mix), find the ratios of atmospheric isotopes and derive eddy diffusion coefficients (mathematical expressions describing how rapidly the atmosphere is mixed). The composition of the ionosphere's maximum density can also be determined, as well as the temperature of the exosphere, the outermost fringe of Venus' atmosphere.

The instrument ionizes atmospheric components up to 46 atomic mass (hydrogen to iron) by electron bombardment. It then separates them according to their masses by how far they are deflected by a magnetic field. The instrument features a fast data sampling and telemetering capacity to cope with the 3 km-per-second (110 mph) Bus descent speed. One day before Venus encounter, a known amount of gas is released into the instrument for identification and measurement, to be used as a reference for the spectrometer's sensitivity.

The instrument weighs 6.8 kg (15 lb.) and uses 5 watts.

Ion Mass Spectrometer -- The ion mass spectrometer measures the distribution and concentration of positively charged ions in the upper Venus atmosphere from 120 km (75 mi.) up through the ionosphere.

(See Orbiter Ion Mass Spectrometer for instrument description.)

Multiprobe Radio Science Experiments

Differential Long Baseline Interferometry -- This instrument measures the velocity and direction of Venus' winds as the four probes descend through the atmosphere. By comparing the descent paths of the probes with simultaneous measurements of atmospheric temperature and pressure from probe sensors, investigators can assemble a better model of Venus' atmospheric circulation, particularly in regard to wind speeds.

While the four probes descend to the surface, the Bus follows a ballistic trajectory in the upper atmosphere. This trajectory serves as a reference. Probe velocities can be reconstructed and measured very accurately relative the bus, and absolute probe velocities can be reconstructed from the known bus velocity. Investigators assume deviations of the probe trajectories from an atmosphereless mathematical model are caused by atmospheric winds.

Two widely separated DSN stations simultaneously tracking all spacecraft determine that part of the velocity vector along the Earth-Venus line of sight. Differential long-based interferometry uses three DSN stations to find the other two components of the velocity vector to triangulate or get a "fix" in three dimensions on the constantly changing paths of the falling probes.

Atmospheric Propagation Experiment -- This investigation attempts to glean information about Venus' surface and atmosphere by the effects of the atmosphere on the probes' radio signals. As the probes descend, Pioneer scientists search for evidence of a very weak signal that travels downward, reflects off the surface of Venus and then bounces to Earth. Such a distorted signal is Doppler shifted away from the probe signal of 2,300 MHz (million Hertz) by less than Hz and is almost undetectable. If this signal is discovered, it should reveal information about the Venusian surface -- hence, aid in the interpretation of the radar mapping data.

The descending probes also reveal information about the atmosphere. Probe radio signals weaken with decreasing altitude due to CO_2 absorption, atmosphere refraction and additional absorption from cloud layers or some other absorber. The strength of the probe signals should reveal the unknown absorber; if it is a cloud layer, investigators can measure the height and thickness of the layer.

Atmospheric Turbulence Experiments -- This investigation studies the turbulence in the Venusian atmosphere, thus aiding in the understanding of the dynamics of Venus' atmosphere circulation. As all four probes descend to the surface, their transmitting signals will likely be distorted by small regions of turbulence caused by temperature, pressure and velocity fluctuations. DSN receiving stations on Earth will analyze the signals for distortion caused by atmospheric turbulence. The probe data complements atmospheric turbulence data above 35 km (21 mi.) taken by the Orbiter.

PRINCIPAL INVESTIGATORS AND SCIENTIFIC INSTRUMENTS

Orbiter Spacecraft

Dr. James Hansen Goddard Institute of Space Studies	Cloud Polarimeter, Imaging Experiment
Dr. Gordon Pettengill (Team Leader), Massachusetts Institute of Technology	Radar Mapper
Dr. Fredric Taylor Jet Propulsion Laboratory	Temperature Sounding Infrared Radiometer
Dr. Ian Stewart University of Colorado	Ultraviolet Spectrometer
Dr. Hasso Niemann Goddard Space Flight Center	Neutral Mass Spectrometer
Harry Taylor Goddard Space Flight Center	Ion Mass Spectrometer
Dr. John Wolfe Ames Research Center	Solar Wind/Plasma Analyzer
Dr. Christopher Russell University of California, Los Angeles	Magnetometer
Dr. Frederick Scarf TRW, Inc.	Electric Field Detector
Larry Brace Goddard Space Flight Center	Electron Temperature Probe
Dr. William Knudsen Lockheed Missiles and Space Co.	Retarding Potential Analyzer
Dr. W. D. Evans Los Alamos Scientific Laboratory	Gamma Ray Burst Detector

Orbiter Radio Science

Radio science experiments measure interaction of spacecraft radio signals with Venus and its atmosphere, using the Orbiter and five probe craft as instruments. Dr. Gordon Pettengill, Massachusetts Institute of Technology, is team leader.

Dr. Roger Phillips Jet Propulsion Laboratory	Venus Internal Density Distribution
Dr. I. I. Shapiro Massachusetts Institute of Technology	Celestial Mechanics
Dr. Arvydas Kliore Jet Propulsion Laboratory	Radio Occultation
Dr. Thomas Croft Stanford Research Institute	Radio Occultation
Dr. Richard Woo Jet Propulsion Laboratory	Atmospheric and Solar Corona
Dr. Gerald Keating Langley Research Center	Atmospheric Drag

Multiprobe Spacecraft (Large Probe)

Dr. John Hoffman University of Texas, Dallas	Mass Spectrometer
Vance Oyama Ames Research Center	Gas Chromatograph
Alvin Seiff Ames Research Center	Atmosphere Structure
Dr. Martin Tomasko University of Arizona	Solar Flux Radiometer
Robert Boese Ames Research Center	Infrared Radiometer
Dr. Robert Knollenberg Particle Measuring Systems, Inc.	Cloud Particle Size Spectrometer
Dr. Boris Ragent Ames Research Center	Nephelometer (cloud sensor)
Dr. Jacques Blamont University of Paris	Nephelometer

Multiprobe Spacecraft (Three Small Probes)

Alvin Seiff Ames Research Center	Atmosphere Structure
Dr. Boris Ragent Ames Research Center	Nephelometer
Dr. Jacques Blamont University of Paris	Nephelometer
Dr. Verner Suomi University of Wisconsin	Net Flux Radiometer

Multiprobe Spacecraft (Bus)

Dr. Ulf von Zahn University of Bonn, West Germany	Mass Spectrometer
Harry Taylor Goddard Space Flight Center	Ion Mass Spectrometer

Multiprobe Radio Science (All Probes)

Dr. Charles C. Counselman Massachusetts Institute of Technology	Differential Long-Baseline Inteferometry
Dr. Thomas Croft Stanford Research Institute	Atmospheric Attenuation
Dr. Richard Woo Jet Propulsion Laboratory	Atmospheric Turbulence

Interdisciplinary Scientists

Interdisciplinary scientists have been selected for both the Multiprobe and Orbiter Missions to provide assistance in analyses of the Venusian atmosphere. They are:

Dr. Siegfried Bauer
Goddard Space Flight Center

Dr. Thomas Donahue
University of Michigan

Dr. Richard Goody
Harvard University

Dr. Donald Hunten
University of Arizona

Dr. James Pollack
Ames Research Center

Nelson Spencer
Goddard Space Flight Center

Harold Masursky
U.S. Geological Survey

Dr. George McGill
University of Massachusetts

Dr. Andrew Nagy
University of Michigan

Dr. Gerald Schubert
University of California, Los Angeles

-more-

LAUNCH VEHICLE

The Atlas Centaur is NASA's standard launch vehicle for intermediate weight payloads. It is used for the launch of lunar, Earth orbital, Earth synchronous and planetary missions.

Developed and launched under the direction of NASA's Lewis Reaearch Center, Cleveland, Ohio, Centaur was the nation's first high-energy, liquid hydrogen-liquid oxygen propelled launch vehicle. It became operational in 1966 with the launch of Surveyor 1, the first U.S. spacecraft to soft land on the Moon's surface.

Since that time, both the Atlas booster and Centaur second stage have undergone many improvements. At present, the vehicle combination can place 4,536 kg (10,000 lb.) in low Earth orbit, 1,882 kg (4,150 lb.) in a synchronous transfer orbit and 907 kg (2,000 lb.) on an interplanetary trajectory.

The Atlas Centaur, standing approximately 40 m (131 ft.) high, consists of an Atlas SLV-3D booster and Centaur D-1A second stage. The Atlas booster develops 1,913 kilinewtons (430,000 lb.) of thrust at liftoff, using two 822,920 newton (185,000 lb.) thrust booster engines, one 266,890 N (60,000 lb.) thrust sustainer engine and two vernier engines developing 2,976 N (669 lb.) thrust each. The two RL-10 engines on Centaur produce a total of 131,222 N (29,500 lb.) thrust. Both the Atlas and the Centaur are 3 m (10 ft.) in diameter.

Centaur carries insulation panels which are jettisoned just before the vehicle leaves the Earth's atmosphere. The insulation panels, weighing about 553 kilograms (1,220 lb.) surround the second stage propellant tanks to prevent heat or air friction from causing boil-off of liquid hydrogen during flight through the atmosphere.

The spacecraft will be enclosed in an 8.8-m (29-ft.) long, 3-m (10-ft.)-diameter fiberglass nose-fairing which is jettisoned after leaving the atmosphere.

Until early 1974, Centaur was used exclusively in combination with the Atlas booster. It was subsequently used with a Titan III booster to launch heavier payloads onto interplanetary trajectories.

The Centaur D-1A has an integrated electronic system which handles navigation and guidance tasks, controls pressurization and venting, propellant management, telemetry formats and transmission and initiates vehicle events. Most operational needs can be met by changing the computer software.

LAUNCH FLIGHT SEQUENCE

Atlas Phase

After liftoff, AC-50 will rise vertically for about 15 seconds before beginning its pitch program. Starting at two seconds after liftoff and continuing to T plus 15 seconds, the vehicle will roll to the desired flight azimuth.

After 139 seconds of flight, the booster engines are shut down (Booster Engine Cutoff, BECO) and jettisoned. BECO occurs when an acceleration of 5.7 G's is sensed by accelerometer on the Centaur and the signal is issued by the Centaur guidance system. (The booster package is jettisoned 3.1 seconds after BECO.) The Atlas sustainer engine continues to burn for approximately 79 seconds after BECO propelling the vehicle to an altitude of about 146 km (91 mi.), attaining a speed of 13,659 km/hr (8,487 mph).

Prior to sustainer engine cutoff, Centaur insulation panels and the nosefairing are jettisoned.

The Atlas and Centaur stages are then separated. An explosive charge slices through the interstage adapter. Retrorockets mounted on the Atlas slow the spent stage.

Centaur Phase

At 4 minutes 26 seconds into the flight, the Centaur's two RL-10 engines ignite for a planned 5 minute 10 second burn. The Centaur engines then shut down and Orbiter and Centaur will coast for 9 to 10 minutes, depending on the data of launch, in a circular parking orbit. At the end of the coast period, the Centaur engines restart and burn for 2 minutes and 17 seconds, putting the Orbiter on its Venus flight path.

At the end of the second Centaur burn the Centaur will orient the spin axis of the spacecraft such that it is within nine degrees of perpenducular to the Earth's orbit plane, and the Pioneer Venus Orbiter will separate from Centaur.

LAUNCH VEHICLE CHARACTERISTICS

*Liftoff weight including spacecraft:	146,972 kilograms (324,018 lbs.)
Liftoff height:	40.3 m (132 ft.)
launch complex:	36A
Launch azimuth sector:	93-108 degrees

	SLV-3D Booster	Centaur Stage
Weight:	130,390 kg (287,509 lbs.)	17,678 kg (38,981 lbs.)
Height:	22.9 m (75 ft.) (including interstage adapter)	14.6 m (48 ft.) (with payload fairing)
Thrust:	1,917,174 Newtons (431,000 lbs.) sea level	131,200 Newtons (29,500 lbs.) vacuum
Propellants:	Liquid oxygen and RP-1	Liquid hydrogen and liquid oxygen
Propulsion:	MA-5 system two 822,920-newton (185,000-lbs.)-thrust engines, one 266,893-newton (60,000-lb.)-sustainer engine and two 2,976-newton (669-lb.)-thrust vernier engines)	Two 65,611-newton (14,750-lb.)-thrust RL-10 engines. Twelve small hydrogen peroxide thrusters 26.7 newton (6 lb.) thrust each
Velocity:	9,122 km/hr (5,668-mph) at BECO; 13,659 km/hr. (8487 mph) at SECO	26,580 km/hr (16,516) at MECO-1 41,127 km/hr (25,555 mph) at MECO-2
Guidance:	Pre-programmed pitch rates through BECO. Switch to Centaur inertial guidance for sustainer phase.	Inertial guidance

* Measured at 5.08 centimeters (two inches) of rise.

ATLAS/CENTAUR FLIGHT SEQUENCE (AC-50)

	Seconds Time Seconds	Altitude Kilometers	Altitude Statute Miles	Surface Range Kilometers	Surface Range Statute Miles	Relative Velocity Kilometers/Hour	Relative Velocity Miles/Hour
Liftoff	0	0	0	0	0	0	0
Booster Engine Cutoff	139.1	57.6	35.8	81.8	50.83	9122	5668
Jettison Booster	142.2	60.7	37.7	88.9	55.27	9215	5726
Jettison Insulation Panel	184.1	98.2	61.0	194.4	120.77	10,409	6468
Jettison Nose Fairing	224.1	127.0	78.92	312.4	194.40	12,035	7478
Sustainer/Vernier Cutoff	254.2	145.4	90.37	416.5	258.81	13,659	8487
Atlas/Centaur Separation	256.1	146.5	91.00	422.9	262.80	13,657	8486
Centaur Ignition 1	265.7	151.5	94.13	457.7	284.40	13,609	8456
Centaur Main Engine Cutoff 1	575.7	170.5	105.96	2051.0	1274.4	26,580	16,516
Centaur Ignition 2	MES2*	165.6	103.53	*	*	26,628	16,546
Centaur Main Engine Cutoff 2	MES2 + 137	192.0	119.30	*	*	41,127	25,555
Spacecraft Separation	MECO-2 + 135	400.9	249.12	*	*	40,789	25,332

*Depends on Parking Orbit Coast Time

LAUNCH OPERATIONS

A NASA-contractor team under the direction of Kennedy Space Center's Expendable Vehicles Directorate is responsible for the preparation and launch of unmanned space vehicles from Cape Canaveral Air Force Station.

The Atlas Centaur rockets to be used for the two Pioneer Venus Flights -- AC-50 and AC-51 -- will both be launched from Pad A, northernmost of the two pads at Launch Complex 36.

AC-50 was erected on Pad A on February 21-23. The Pioneer Venus Orbiter was delivered to the Cape on March 15 and underwent initial processing in Hangar AO. The Orbiter was moved to Spacecraft Assembly and Encapsulation Facility-2 (SAEF-2) in the KSC Industrial Area on April 25, where it was mated with its orbital insertion motor on April 26. The Orbiter was scheduled to be encapsulated within its payload shroud the first week of May and taken to the pad for mating with AC-50 on May 8. A series of electrical and functional tests are designed to clear the space vehicle for launch about May 20.

The Atlas and Centaur which will comprise AC-51 will be erected on Pad A in early June, or approximately two weeks after the launch of AC-50 with the Venus Orbiter.

The Pioneer Venus Multiprobe is to be delivered to the Cape during the first week of June. Like its predecessor, it will undergo initial processing in Hangar AO prior to being moved to SAEF-2 in early July. The Multiprobe will be encapsulated within its payload shroud during the third week of July and moved to Pad A for mating with AC-51 on July 26. A series of electrical and functional tests will be conducted to clear the space vehicle for launch about August 7.

MISSION OPERATIONS

For Pioneer Venus, mission controllers will be operating simultaneously two different spacecraft on two different missions. The Orbiter and Multiprobe are launched within three months of each other and arrive at the planet less than a week apart.

During the Venus encounter period, launch of the four probes from the transporter Bus to their atmospheric entry points will be accomplished; the Bus will be retargeted for its entry; the Orbiter will be placed on its 24-hour, high-inclination, highly elliptical orbit. Five days after Orbiter encounter, probe entry will be monitored, and the critical probe data received and stored for later analysis.

With completion of the Multiprobe mission-- after im-- pact of the probes on the surface and burn-up of the Bus controllers will continue to operate the Orbiter for the eight months of its primary mission. Controllers may make significant changes in the orbit during this extended mission period.

Since all Pioneers are relatively unautomated spacecraft, mission operations often require 24-hour-a-day control and careful analysis and planning in short time spans. Ground-controlled spacecraft provide flexibility for changing plans and objectives. They also offer economies in spacecraft design and construction.

Pioneer Venus control and spacecraft operations will be at the Pioneer Mission Operations Center (PMOC), Ames Research Center, Mountain View, Calif., from the time both spacecraft separate from their launch vehicles through the end of the Orbiter mission.

Pioneer Venus operations will be made somewhat more complex by the continued operation at the PMOC of the previously launched Pioneer spacecraft. Pioneers 6 to 9 continue to circle the Sun and return interplanetary data. Pioneer 10 continues to enter previously unexplored space on its way out of the solar system (it is now appraching Uranus' orbit). Pioneer 11 is descending back toward the ecliptic and man's first encounter with Saturn in September 1979.

The PMOC is the central mission control center. It is under operational direction of the Flight Director. This area will originate all command information and receive and display telemetry data required for mission control. Although all commands are originated in the PMOC, emergency procedures include backup command generation at the DSN stations, if necessary.

The PMOC has computing capability both for commanding the two spacecraft and for interpreting the data stream as it is received from the DSN stations for use by flight controllers monitoring spacecraft performance.

Several groups of specialists direct and support launch interplanetary, orbital and atmospheric entry operations.

The Pioneer Mission Operations team consists of personnel from government and contractor organizations, and operates under control of the Project Manager and Mission Operations System Manager.

Because Pioneer Venus includes two missions, two flight operations groups have been named for each--an Orbiter group and a Multiprobe group. Both groups have the same elements. The Science Analysis Team in each group is composed of science operations people from the project and the principal investigators (or their representatives) for each experiment on board the Orbiter and Multiprobe. They determine the status of each scientific instrument, and formulate command sequences for the instruments.

Both groups also have Spacecraft Performance Analysis teams, made up of engineering specialists on spacecraft systems such as: communications, thermal control and power. These teams analyze and evaluate spacecraft performance and predict spacecraft responses to commands.

A third organization serves both spacecraft. This is the Navigation and Maneuvers group, which handles spacecraft navigation and orientation in space; orbital injection, trim, and changes and probe-targeting and launch. This group is made up of engineering specialists in spacecraft orientation geometry, trajectories, and maneuvers. The Jet Propulsion Laboratory, under contract to Ames, does computer analysis of DSN tracking information to determine spacecraft trajectories.

The Mission Operations Team also includes a launch specialist, a hardware expert and a computer systems development and operations group.

Support groups at Ames and other NASA facilities assist the mission operations team to perform computer software development, mission control and off-line data processing.

DATA RETURN, COMMAND AND TRACKING

NASA's Deep Space Network (DSN) will track and receive data directly from all six Pioneer Venus spacecraft (the Orbiter, the Bus and the four probes). Commands are transmitted to spacecraft from the Pioneer Mission Operations Control Center through the DSN stations.

Tracking will be by the DSN's global network of 26-m (85-ft.) and highly sensitive 64-m (210-ft.) antennas. The 64s will be used during critical phases of the mission such as reorientation, velocity corrections, orbit insertion, and entry of the four probes into Venus' atmosphere -- as well as for special science events such as occultation. At the end of the Orbiter primary mission, Venus will be 203 million km (126 million mi.) farther from Earth than at Orbiter arrival.

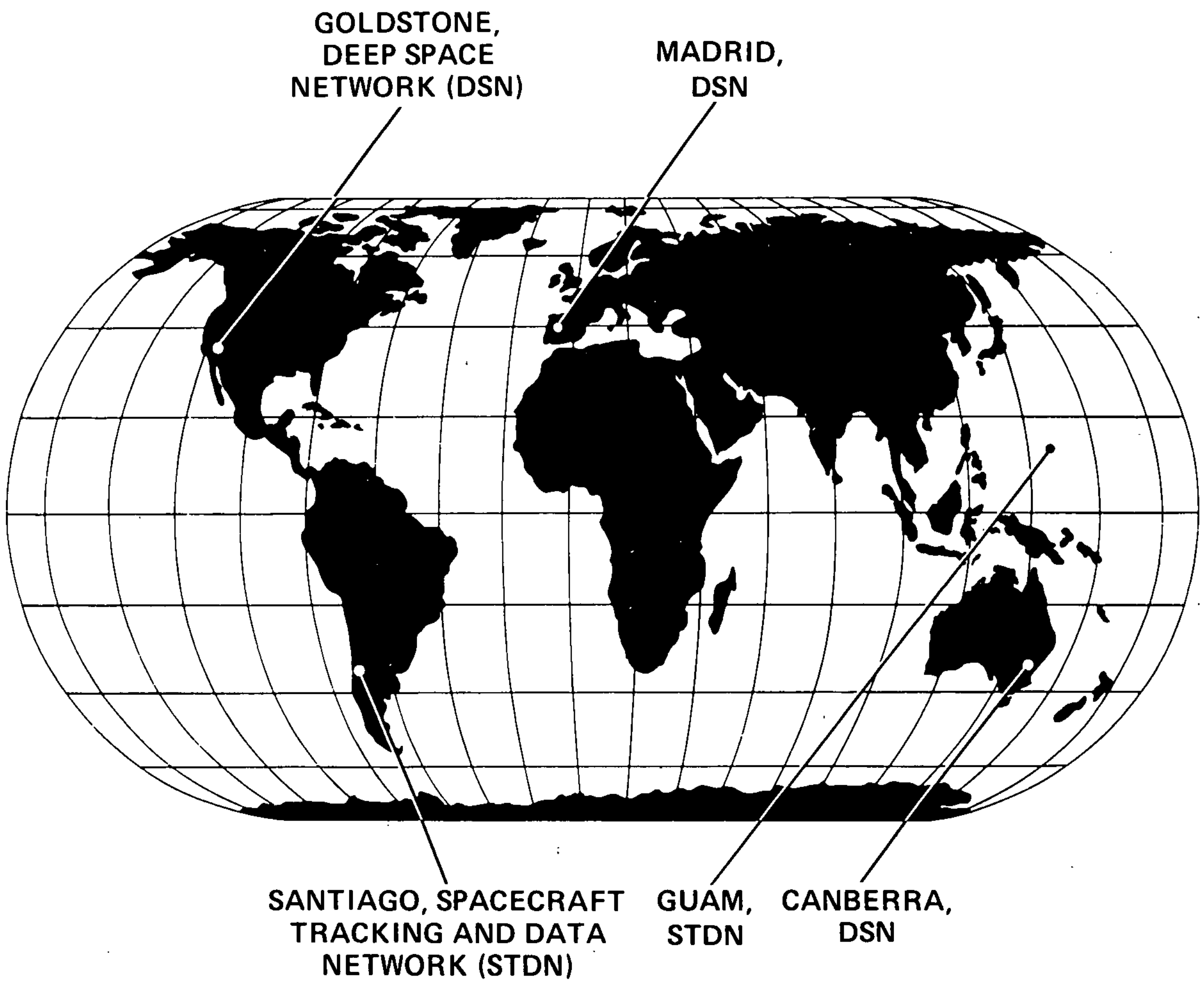
During the critical two-hour period of atmospheric entry by the Bus and flights down to the surface by the four probes, both the 64-m (210-ft.) antennas at Goldstone, Calif., and at Canberra, Australia, will be used to receive and record Venus atmosphere data, coming in simultaneously from all five probe craft.

The Deep Space Network with facilities located at approximately 120-degree intervals around the Earth, will support the Pioneer Venus spacecraft. The primary mission of the Orbiter is 15 months: six months in transit and eight months in orbit. As the Orbiter and Multiprobe "set" at one station due to the Earth's rotation, they will rise at the next one.

The DSN, operated by the Jet Propulsion Laboratory (JPL), Pasadena, Calif., has six 26-m (85-ft.) parabolic-reflector dish antennas, two at Goldstone, in California's Mojave Desert; two at Madrid, Spain and two at Canberra. There are also three 64-m (210-ft.) antennas, one each at Goldstone, Madrid and Canberra.

Radio science experimenters will estimate wind speeds and directions in the Venus atmosphere by computing the the exact flight paths of the four probes using DSN data. In addition to the Goldstone and Canberra stations, two NASA STDN stations at Guam and Santiago, Chile, will support this effort. Radio interferometry in a triangulation process will be used in this computation. (See Multiprobe Experiments - Radio Science.)

PIONEER VENUS COMMUNICATIONS NETWORK



During launch, tracking will be carried out by the DSN with the aid of other facilities. These are tracking antennas of the Air Force Eastern Test Range and elements of NASA's Spacecraft Tracking Data Network (STDN) together with support by four instrumented aircraft, the Apollo Range Instrumented Aircraft (ARIA). The aircraft are operated by Wright Patterson Air Force Base.

At all times, incoming telemetry data from the spacecraft is formatted at DSN stations for high-speed transmission to Ames computers. These computers will check for unexpected or critical changes in data and provide information for analysis by specialists in the spacecraft, experiments and ground system. Their analyses will be used for spacecraft control. Outgoing commands are verified by Ames computers and sent to DSN stations where they are reverified by computer and then transmitted. Navigation data and trajectory computations for the Pioneer spacecraft is furnished by JPL's Navigation System Section under contract to Ames. They do computer analysis of DSN Doppler and range tracking information to provide spacecraft trajectories for calculation of Venus orbit and planetary targeting.

For Poineer Venus, the DSN has made a number of special modifications. Added receivers are needed to handle the five different data streams at once of the four probes and Bus. Special wideband recorders are required to cope with the large frequency shifts which will happen with the changes in velocity at entry--and atmospheric effects on signal propagation as the probes descend to Venus' surface. To save all of the one-change-only data, due to variances outside the predicted range of frequency changes, the DSN has provided special equipment to automatically tune the receivers to the signal transmitted by each probe.

Incoming telemetry is formatted at DSN stations for transmission via NASA Communications System (NASCOM) high-speed circuits to the Pioneer Mission Computing Center (PMCC). There it is processed to supply various types of real time display information on spacecraft and instruments status.

In addition to use of telemetry for providing mission operations and quick-look data, all telemetry will be processed at the PMCC to provide data records for the individual experimenters in the form of Experimenter Data Records. Provided to Principal Investigators, it becomes the raw material for use by them in producing mission findings.

For all of NASA's unmanned missions in deep space, the DSN provides tracking information on course and direction of the flight, velocity and range from the Earth. Its global stations also receive engineering and science telemetry and sends commands. All communications links are in S-band frequency (though Venus Orbiter occultation experiments are X-band carrier only. No telemetry data are sent.

DSN stations relay spacecraft Doppler tracking to JPL. High speed data links allow real time transmission of all data from spacecraft directly to the PMOC at Ames. Throughout the mission, scientific data recorded on magnetic tape will be sent from DSN stations to Ames for processing.

NASA's networks are directed by the Office of Tracking and Data Acquisition, NASA Headquarters, Washington, D.C.

JPL manages the DSN for NASA, while STDN and NASCOM are managed by NASA's Goddard Space Flight Center, Greenbelt, Md.

The Goldstone DSN stations are operated by JPL, assisted by the Bendix Field Engineering Corporation. The Canberra station is operated by the Australian Department of Supply. The Madrid station is operated by the Spanish government's Instituto Nacional de Tecnica Aerospacial (INTA).

PIONEER VENUS TEAM

NASA Headquarters

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Dr. Geoffrey A. Briggs	Deputy Director, Planetary Programs
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F. Robert Schmidt	Manager, Atlas Centaur
Dr. William C. Schneider	Associate Administrator for Space Tracking and Data Systems
Arnold C. Belcher	Network Operations
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Henry Asch	Reliability and Quality Assurance
Ernest J. Iufer	Magnetics

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Barry Olton	KSC Project Engineer for Pioneer Venus

Hughes Aircraft Co.

S. D. Dorfman	Pioneer Venus Project Manager for Hughes

CONTRACTORS

Hughes Aircraft Co. Space and Communications Group El Segundo, Calif.	(Prime contractor) Spacecraft and Radar Mapper
Hughes Aircraft Co. Data Systems Division Culver City, Calif.	Data Storage Unit
General Electric Co. Philadelphia, Pa.	Deceleration Modules
Motorola, Inc. Phoenix, Ariz.	Transponders
Thiokol Chemical Co. Elkton, Md.	Orbit Insertion Motor
Ball Brothers Research Corp. Boulder, Colo.	Star Sensors

Northrop Corp. Los Angeles, Calif.	Thermal Louvers
Frequency Electronics, Inc. New Hyde Park, N.Y.	Stable Oscillators
General Electric Co. Gainesville, Fla.	Nickel-Cadmium Battery Cells
Eagle-Picher Industries, Inc. Joplin, Mo.	Silver-Zinc Battery Cells
Spectrolab, Inc. Sylmar, Calif.	Solar Cells and Covers
Arcturns Manufacturing Co. Oxnard, Calif.	Pressure Vessel Forgings
Newbrook Machine Corp. Silver Creek, N.Y.	Pressure Vessel Machining
Southwest Research Institute San Antonio, Texas	Pressure Vessel Testing
Siliconix, Inc. Santa Clara, Calif.	Input Buffers
University of Texas at Dallas	Large Probe Neutral Mass Spectrometer
Western Aerospace Laboratories Gardena, Calif.	Large and Small Probe Atmosphere Structure Instruments, Orbiter Plasma Analyzer
Systron-Donner Concord, Calif.	Large and Small Probe Accelerometers
University of Arizona Tucson, Ariz.	Large Probe Solar Flux Radiometer Sensor
Martin Marietta Corp. Denver, Colo.	Large Probe Solar Flux Radiometer Electronics
Ball Brothers Research Corp. Boulder, Colo.	Large Probe Infrared Radiometer and Cloud Particle Size Spectrometer
TRW Systems Group TRW, Inc. Redondo Beach, Calif.	Large Probe Gas Chromatograph, Large and Small Probe Nephelometers, Orbiter Electric Field Detector

University of Wisconsin Madison, Wis.	Small Probe Net Flux Radiometer
Aiken Industries, Inc. College Park, Md.	Multiprobe Bus and Orbiter Ion Mass Spectrometers
Lockheed Missiles and Space Co. Sunnyvale, Calif.	Orbiter Retarding Potential Analyzer
IPW Freiburg, West Germany	Orbiter Retarding Potential Analyzer Sensor
University of Colorado Boulder, Colo.	Orbiter Ultraviolet Spectrometer
University of California at Los Angeles	Orbiter Magnetometer
Westinghouse, Inc. Baltimore, Md.	Orbiter Magnetometer
Jet Propulsion Laboratory Pasadena, Calif.	Orbiter Infrared Radiometer
Massachusetts Institute of Technology Cambridge, Mass.	Multiprobe and Orbiter Ground Based Radio Science Experiments
Particle Measuring Systems, Inc. Boulder, Colo.	Large Probe Cloud Particle Size Spectrometer
DCA Reliability Laboratory Mountain View, Calif.	Electronic Parts Procurement and Screening
Bendix Field Engineering Corp. Sunnyvale, Calif.	Missions Operations and Software Development
General Dynamics Convair Division San Diego, Calif.	Launch Vehicles
Los Alamos Scientific Laboratory Los Alamos, N.M.	Orbiter Gamma Ray Burst Detector
Sandia Laboratories Albuquerque, N.M.	Orbiter Gamma Ray Burst Detector

Santa Barbara Research Center Santa Barbara, Calif.	Orbiter Cloud Photopolarimeter
University of Minnesota Minneapolis, Minn.	Multiprobe Bus Neutral Mass Spectrometer
University of Bonn Bonn, Germany	Multiprobe Bus Neutral Mass Spectrometer
Jet Propulsion Laboratory Pasadena, Calif.	Multiprobe and Orbiter Ground Based Radio Science Experiments
SRI International Menlo Park, Calif.	Multiprobe and Orbiter Ground Based Radio Science Experiments

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VENUS STATISTICS

Orbital

Mean distance from Sun:	.723 astronomical units 108.2 million km 67.2 million mi.
Inclination of orbit to plane of ecliptic:	3.3 degrees
Sidereal period (relative to stars):	225 Earth days
Mean orbital velocity:	126,180 km/hr 78,408 mph
Closest approach to Earth:	42 million km 26 million mi.

Planetary

Diameter (solid surface):	12,100 km 7,519 mi.
Diameter (top of clouds):	12,240 km 7,606 mi.
Mass:	0.815 Earth masses
Density:	5.26 gm/cm^3
Axial rotation period (retrograde)	243.1 Earth days
Rotation period, cloud tops: (retrograde)	4.0 Earth days (approx.)
Length of solar day:	116.8 Earth days
Inclination of rotation axis:	6.0 degrees
Surface atmospheric pressure:	95 atmospheres 9,616 kPa 1,396 psi
Surface temperature:	480 degrees C (approx.) 900 degrees F. (approx.)

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