Reports

Encounter with Venus

Abstract. *This report is an introduction to the accompanying collection of initial results from the successful Pioneer Venus orbiter and mutiprobe missions that encountered Venus on 4 December and 9 December 1978, respectively. The mission features are briefly described and furnish data accumulated over the first 30 days of the mission.*

Pioneer Venus, managed by NASA's Ames Research Center, consists of two scientifically related missions: orbiter and multiprobe. The program, spacecraft, trajectory objectives, scientific instruments, and experiments and their objectives have been described in *Space Science Reviews* (*1*), published 1 year prior to launch.

The Pioneer Venus orbiter was launched on 20 May 1978 at 1313 universal time (UT) and was inserted into a highly eccentric, near-polar orbit around Venus on 4 December 1978 at 1588 UT after a type 2 (*2*) interplanetary trajectory trip time of 198 days. The Pioneer Venus multiprobe was launched on 8 August 1978 at 0733 UT and reached Venus on 9 December 1978, just 5 days after orbiter insertion, and after a type 1 (*2*) trip time of 123 days. The orbiter trajectory and multiprobe impact locations achieved matched nearly perfectly that specified prior to launch.

Orbiter. The orbiter is spin-stabilized in the range 4.90 to 4.99 rev/min in orbit, and the positive spin-axis points in the direction of the south ecliptic pole. Nominal elliptical orbit parameters are listed in Table 1. Initial insertion produced an orbit-1 (*3*) periapsis altitude of 378 km. A thruster burn performed at the end of orbit 1 produced an orbit-2 periapsis altitude of 250 km, that is, at the top of the nominal range. This range was intended for optimum in situ sampling of the upper atmosphere and ionosphere and for operation of the surface radar mapper. A total of seven periapsis altitude correction maneuvers were performed during the first 16 orbits (days) through 20 December to reduce periapsis altitude to 150 km. These early maneuvers were to ensure low-altitude aeronomy measurements before periapsis crossed the evening terminator (see below). Periapsis altitude will gradually drift upward because of solar gravity perturbations; thus, periodic altitude corrections within the 243-day mission will be required (*4*). The planetographic (body-fixed) latitude and longitude coordinates of the periapsis location (Table 1) are defined according to the 1970 International Astronomical Union (IAU) Convention, but with a modified assumption for the Venus spin-axis direction (*5*). The orbit is fixed in inertial space, but Venus rotates in a retrograde direction (with a sidereal period of 243.0 days) beneath it. Thus the planetographic longitude of periapsis is a function of orbit number, increasing at the rate of 1.48° per day. Figure 1 includes a plot of the suborbital track appropriate to orbit 5 (9 December, multiprobe entry day). On this day periapsis occurs at 17.0° latitude, 170.2° longitude, on the dayside of Venus, on the far side of the planet as viewed from Earth, and some 22° from the evening terminator.

Table 1. Nominal Pioneer Venus orbital parameters.

Periapsis altitude (*4*)	150 to 260 km
Apoapsis altitude	66,900 km
Eccentricity	0.843
Average period (*4*)	24.03 hours
Inclination to equator	105.6°
Latitude of periapsis	17.0°
Longitude of periapsis (orbit 5)	170.2°
Primary mission duration	243 days in orbit

On orbit 1 periapsis was some 28.6° from the terminator and by orbit 18 (22 December) it had crossed the terminator. Periapsis will now remain in darkness until it crosses the morning terminator during orbit 130 on 13 April 1979 (*6*). The highly elliptical, inclined orbit makes it difficult to portray usefully the entire variation of altitude with either time or latitude. Figure 2 on a linear latitude-logarithmic altitude scale helps to compress the data; however, it severely distorts the orbit picture. Figure 3 schematically demonstrates the manner in which the orbiter penetrates the bow shock and ionopause formed by the solar wind interaction with the ionosphere.

Multiprobe. The multiprobe during interplanetary cruise consisted of a bus transporting a large probe and three small probes named north, day, and night. The spin-stabilized bus was oriented, and the large probe was released toward its planned Venus entry location on 16 November at 0237:13 UT. About 4.5 days later, on 20 November, the three small probes were released at 1306:29 UT, at a precise spin rate (49.60 rev/min) and precise time in the bus spin cycle, toward their planned Venus entry locations. All probes were then silent for 22 minutes before entry on 9 December when they were activated by pretimed internal sequencers. The bus was given a final trim maneuver on 9 December at 1137:12 UT to put it on its own final upper atmosphere entry trajectory. Table 2 contains a list of key entry events and occurrence times for each of the probes (*7*). The times are still preliminary. The day probe transmitted from the surface for more than 67 minutes after impact. Profiles of altitude as a function of time during the probes' descents were not directly determined in real time. They can be computed after-the-fact from the atmosphere structure experiments, the dif-

Table 2. Probe entry events.

Event	Time at spacecraft, UT (HHMM:SS)			
	Large probe	North probe	Day probe	Night probe
Coast timer time-out	1824:26	1827:57	1830:27	1834:08
Telemetry initiation	1829:27	1832:55	1835:27	1839:08
Entry (200 km)	1845:32	1849:40	1852:18	1856:13
Loss of signal (blackout)	1845:53	1849:58	1852:40	1856:27
Relock signal	1846:55	1850:55	1853:46	1857:48
Jettison chute	1903:28	NA	NA	NA
Impact	1939:53	1942:40	1947:59	1952:05
Loss of signal	1939:53	1942:40	2055:34	1952:05
Descent time*	54:21	53:00	55:41	55:52
Blackout time†	:62	:57	:66	:81
Time on chute	~17:07			
Operating time on surface‡	0	0	67:37	0

*Calculated by subtracting the values for entry time from those of impact time. †Calculated by subtracting the loss of signal time from the relock signal time. ‡Calculated by subtracting the impact time from loss of signal time.

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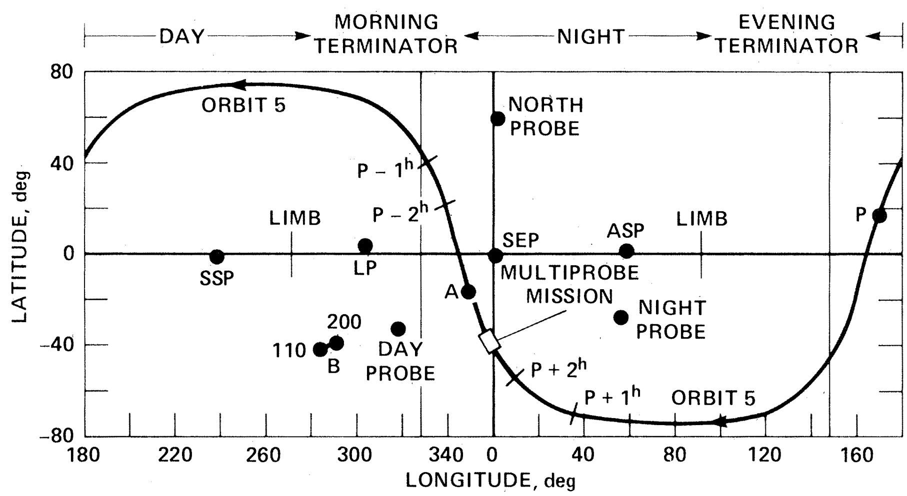
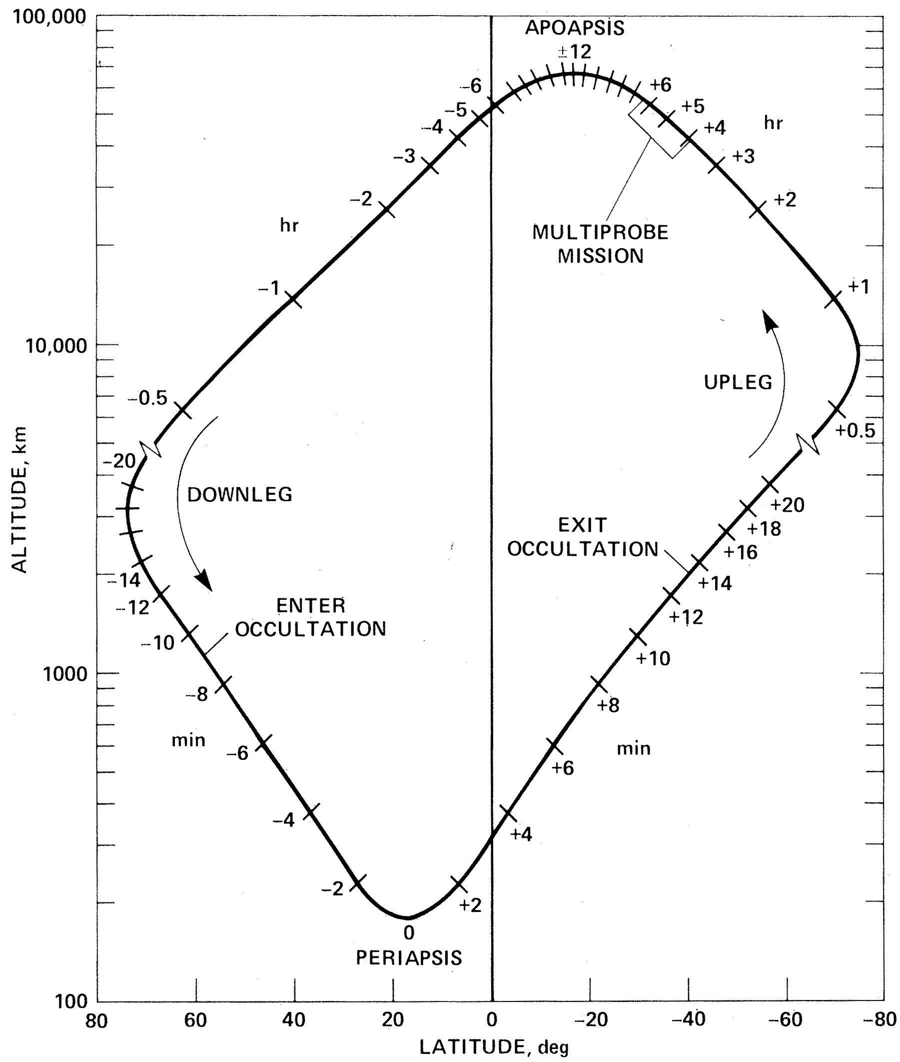
ferential long-baseline interferometry (DLBI) experiment, and other tracking data. At present, accurate profiles are not available. Thus the results from the individual experiments should be compared on a mutual time-of-occurrence basis. The bus entered (altitude 200 km) at 2021:04 UT and ceased transmitting at 2022:08 UT, thus operating for 64 seconds down to about 110 km (altitude).

Table 3. Multiprobe entry and impact locations.

Spacecraft	Flight-path angle	Entry (200 km)		Impact	
		Latitude	Longitude	Latitude	Longitude
Large probe	−31.1°	5.7°	306.0°	4.0°	304.0°
North probe	−69.5°	59.7°	5.0°	60.1°	4.4°
Day probe	−25.3°	−30.6°	320.8°	−32.4°	318.4°
Night probe	−41.5°	−26.1°	56.0°	−27.4°	56.7°
Bus (−9.4°)		−38.6°	291.8°	−41.2°*	284.1°*

*At 110 km.





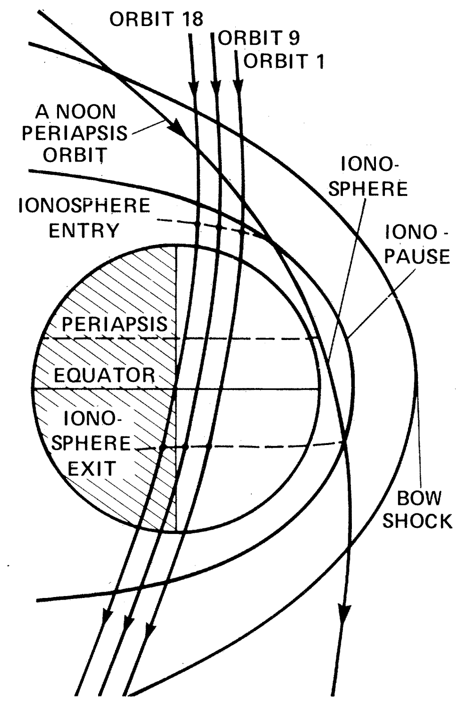


Fig. 1 (top left). Encounter geometry on 9 December 1978 of key locations as a function of latitude and longitude. The suborbital track of the orbiter is shown by the sinusoidal-like curve. Also shown is *P*, periapsis location; *A*, apoapsis location; *SSP*, subsolar point; *ASP*, antisolar point; *SEP*, subearth point; morning and evening terminator; east and west limbs as viewed from Earth; *B*, bus entry (200 km) and burnup (110 km) locations; *LP*, large probe impact location; north, day, and night probe impact locations. Periapsis occurred at $14^h48^m15^s$ UT and 179.6 km altitude on this day. Fig. 2 (bottom left). Altitude as a function of latitude for Pioneer Venus orbit 5 (periapsis altitude 179.6 km) on a semilog plot. Minutes from periapsis are shown with time ticks on the lower portion of the orbit, and the hours from periapsis are shown at the top. Note the significant variation of both altitude and latitude within 20 to 30 minutes of periapsis. The region of Earth occultation around periapsis is also marked. Fig. 3 (above). Sketches of near-periapsis portions of several orbits illustrating the geometry involved with spacecraft penetration of the bow stock, ionopause, and ionosphere. Orbits 1, 9, and 18 illustrate how periapsis initially on the dayside of the morning terminator finally crossed that region during the period covered by scientific results reported here. The noon periapsis orbit (orbit 187), where periapsis will occur at the solar meridian, more clearly illustrates these crossings as well as the simultaneous variation of both latitude and longitude along the orbit.

Table 3 lists the preliminary determinations, computed from preentry tracking data, of entry and impact locations for each of the spacecraft. Flight path angles (fpa) at entry are also shown. These impact locations are also plotted on Fig. 1 superimposed with the corresponding orbit 5. During the more than 2.5 hours of multiprobe mission duration (1824:26 to 2055:34 UT), the orbiter was about 4 to 6.5 hours postperiapsis of orbit 5. With reference to Fig. 2, this period corresponds to altitudes above 40,000 km—that is, geometrically quite close to apoapsis. From Fig. 1, it is clear that the orbiter had good "viewing" of the entry locations for the southern hemisphere probes during the multiprobe mission and good viewing of those for the northern hemisphere probes about 1 to 2 hours prior to periapsis.

Scientific experiments. There are 12 scientific experiments on the orbiter, two on the bus, seven on the large probe, and three identical experiments on each of the smaller north, day, and night probes. In addition, there are several radio-science experiments that make use of the radio systems, either separately or together, on each of the spacecraft. Preliminary results, covering approximately the first 30 days, from most of the experiments are reported in the following papers. The papers are arranged by discipline, from the top of the atmosphere to the surface: solar wind, solar wind-ionosphere interactions, ionosphere, upper atmosphere, remote sensing of the cloud tops, atmosphere structure, cloud structure, thermal balance, atmospheric composition, circulation and dynamics, and surface.

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References and Notes

1. For the required background material, see "Venus exploration," *Space Science Reviews* **20**, 248 (May 1977); *ibid.*, pp. 356–525 (June 1977).
2. For a type 2 trajectory, the spacecraft travels more than 180° around the sun; for a type 1 trajectory this angle is less than 180°.
3. Orbit numbers increase by one each time the spacecraft passes through apoapsis. Orbit 0 began at orbit insertion and ended with the first apoapsis, whereupon orbit 1 commenced. The inbound leg of each orbit passes over the northern hemisphere of Venus.
4. Adjustments may also be made at times to periapsis altitudes below 150 km, should atmospheric drag limitations and other considerations permit. In fact, periapsis altitude was reduced to 148 km on orbit 30 (3 January 1979). Current operations provide for weekly corrections to maintain periapsis altitude between 180 and 150 km, at least for the first 100 orbits, a smaller range than the nominal shown in Table 1. Also, infrequent, small orbital period adjustments from the nominal value shown in Table 1 will be made by thruster burns near periapsis to maintain suitable ground tracking station visibility.
5. Definition of 1970 IAU coordinate system for Venus: "For Venus, the origin of planetographic longitudes is defined such that the central meridian of Venus as observed from the center of the Earth is 320.0° at 0^h on 20 June 1964 (Julian Date, 2438566.5). The rotational axis shall be provisionally defined as having a north pole direction of right ascension (α) 273.0° and declination (δ) + 66.0° (1950.0). For the purposes of obtaining longitudes at earlier or later time, a provisional value for the sidereal rotational period of 243.0 days is adopted (from the proceedings of the Fourteenth General Assembly, Brighton 1970, Transactions of the International Astronomical Union, Vol. 14B, Reidel Publishing Co., Holland, 1971)." Based on more recent data, the Pioneer Venus Science Steering Group adopted the IAU convention with a modified north pole direction α = 273.3°, δ = 67.3° (1950.0); see I. I. Shapiro, W. De Campli, D. B. Campbell, *Astrophys. J. Lett.*, in press. A mean value of 6052 km is assumed for the radius of Venus, also.
6. Periapsis occurs within Earth occultation for the first 80 orbits with durations of up to 23 minutes. An apoapsis occultation season occurs between orbits 154 and 164, with longer durations up to 3.5 hours. An occultation radius of 6139.5 km (87.5 km altitude) has been assumed. There are two solar eclipse seasons, orbits 24 to 124 with durations up to 24 minutes and orbits 181 to 188 with duration up to 3.5 hours. An eclipse radius of 6130 km (78 km altitude) has been assumed.
7. Times are at the spacecraft. Ground-received times are larger by one-way light time, 3^m12^s, on this day.
8. I would like to thank the entire Pioneer Venus team, not only C. F. Hall, project manager, and his staff and others at the Ames Research Center, but also other individuals at other NASA centers and industry who helped produce and execute these exceptional and extraordinarily complex missions. In particular, S. Dorfman and his team at the Hughes Aircraft Company, builders of the spacecraft, should be congratulated for providing superb spacecraft performance. Also, R. B. Miller and the staff at the DSN stations should be singled out for their real-time tracking of the multiprobe mission on 9 December 1978. I thank also C. F. Hall, J. W. Dyer, and J. R. Cowley, Jr., for review of this manuscript.

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Initial Pioneer Venus Magnetic Field Results: Dayside Observations

Abstract. *Initial observations by the Pioneer Venus magnetometer in the sunlit ionosphere reveal a dynamic ionosphere, very responsive to external solar wind conditions. The locations of the bow shock and ionosphere are variable. The strength of the magnetic field just outside the ionopause is in approximate pressure balance with the thermal plasma of the ionosphere and changes markedly from day to day in response to changes in solar wind pressure. The field strength in the ionosphere is also variable from day to day. The field is often weak, at most a few gammas, but reaching many tens of gammas for periods of the order of seconds. These field enchantments are interpreted as due to the passage of spacecraft through flux ropes consisting of bundles of twisted field lines surrounded by the ionospheric plasma. The helicity of the flux varies through the flux tube, with low pitch angles on the inside and very large angles in the low-field outer edges of the ropes. These ropes may have external or internal sources. Consistent with previous results, the average position of the bow shock is much closer to the planet than would be expected if the solar wind were completely deflected by the planet. In total, these observations indicate that the solar wind plays a significant role in the physics of the Venus ionosphere.*

This report is a summary of the results obtained by the UCLA fluxgate magnetometer on the first 24 orbits of the Pioneer Venus orbiter. The solar zenith angle of periapsis ranged from an initial 63° to 99° on orbit 24. At the altitude of the spacecraft the ionosphere was sunlit throughout each pass. During these 24 orbits, which included the major part of a solar rotation, there was a wide range of solar wind conditions, resulting in a wide range of ionospheric conditions. The observations reported here were prepared from preliminary digital data relayed daily over telephone lines from Ames Research Center. These records have more data gaps than there will be in the final processed tapes and cover only the region near periapsis. Further, they do not include inertial reference information for the time when the spacecraft is nearest the planet. Thus we have no information at present on the orientation of the magnetic field in the spin plane of the satellite in the ionosphere, and only plots of the magnetic field magnitude will be presented.

Venus has been visited by numerous spacecraft carrying magnetometers. Mariners 2, 5, and 10 flew by at distances ranging from 6.6 to 1.7 Venus radii (R_V). The Venera 4 mother, or bus, spacecraft penetrated the nighttime ionosphere, returning data from altitudes as low as 200 km. Veneras 9 and 10 orbited Venus with 48-hour orbits and 1500-km periapsis altitudes. These earlier missions revealed that Venus has a well-developed bow shock, which deflects and heats the solar wind around the planetary obstacle in much the same way as Earth's bow shock (*1*). The Venus bow shock has much smaller dimensions, however. Verigin *et al.* (*2*) place the nose of the shock at 1.5 R_V; average nose distance of Earth's bow shock is 14 earth radii. Other analyses suggest that the nose position of the shock may be as close to the planet as 1.2R_V, which has been interpreted as implying significant absorption of the