The atmosphere of Venus is many times denser than that of earth while the atmosphere of Mars is about one per cent as dense as earth's. The surface of Venus may be hot enough to melt lead. The surface of Mars appears pockmarked by craters and looks more like the surface of the moon than that of earth.

The above and much other new information about our planetary neighbors has been acquired through the relatively close range observations made possible by NASA's Mariner spacecraft. This NASA Facts features the latest of these missions, the Mariner V survey of Venus, and presents highlights of other Mariner planetary and interplanetary experiments.

VENUS REVISITED

Although the closest planet to earth, Venus is still one of the most perplexing of heavenly objects. Because Venus appears to be constantly shrouded by clouds, its surface cannot be seen. And the composition of the clouds themselves is subject to disagreement.

A composite of photographs of the stars, of Venus, and of Mariner V has provided this conception of the spacecraft's approach to Venus.
The world’s first relatively close-up observation of Venus was made possible by Mariner II in 1962. Mariner II instruments indicated an apparent Venussian surface temperature that may be as hot as 800° F, much too hot for life as we know it.

Mariner II came within 21,645 miles of Venus to provide man with one of his most significant advances in knowledge about the planet. Mariner V was launched to Venus on June 14, 1967, to refine the results from Mariner II and from other studies and to acquire new information. Sweeping within about 2,500 miles of the planet on October 19, 1967, Mariner V provided data that enabled scientists to draw several conclusions. Among them:

- The atmosphere of Venus has critical refractivity. This means that the atmosphere is so deep and dense that it could capture light and radio waves so that they circle the planet rather than go to the surface or shoot out into space. This capture could produce bizarre optical effects for an earthly visitor to Venus.
- The major constituent of Venus’ atmosphere appears to be carbon dioxide.
- The Venus corona (its exosphere, or outermost region of its atmosphere) is made up largely of hydrogen, as is earth’s corona. The temperature of 700° F in the Venussian corona is significantly lower than the 1,300° F average temperature of earth’s corona. (The hydrogen gas atoms in this region are so far apart that no passing object would absorb appreciable heat from them.)
- No free oxygen was detected in the exosphere. It is believed that if the lower Venussian atmosphere contained water vapor, the water molecules would be broken into separate hydrogen and oxygen atoms as they rose toward the outer atmosphere.
- An ionosphere exists on both the day and night sides of the planet. A planet’s ionosphere is generated by the break-up, due to solar radiation, of neutral atmospheric molecules and atoms into electrons with negative electrical charges and ions with positive charges. It was found that the electron density of Venus’ dayside ionosphere ranged from 100 to 1,000 times that of the night side.
- Mariner V detected no magnetic field attributable to Venus nor any concentrated radiation like the Van Allen Radiation Region around earth. This confirms information previously sent by Mariner II.

And Mariner V did much more. On its multi-million mile journey to and even after it passed Venus, it regularly reported on conditions in interplanetary space during a period of rising solar activity. On January 4, 1968, it came within about 54 million miles of the sun, closer than any other man-made object has come to the solar system’s fiery center.

Tracking data gathered on how Venus’ gravity affected Mariner’s flight path have helped to refine the estimate on Venus’ mass which is now calculated at about 0.815 of that of earth. Mass is the total amount of matter in an object.

Mariner V, of course, could not provide complete answers on Venus’ surface, atmosphere, and the possibility of life. Flights carrying more elaborate instruments are required before additional conclusions can be drawn about the planet.

THE VIEW FROM VENUS

Some scientists say that the clouds of Venus are composed mostly of volcanic dust. If this is so, a visitor to Venus may find a turbulent land whose blistering surface is studded with perpetually erupting volcanos.

According to radar studies made from earth, Venus rotates completely about its axis every 243 earth days. Observations through telescopes on earth indicate that the cloudy atmosphere of Venus circles the planet about every five earth days. This is roughly fifty times as fast as the planet rotates and could mean that its surface is constantly lashed by scorching winds.

Other scientists claim that their instruments on earth have detected life-sustaining water droplets or ice crystals in the Venussian clouds. And they point out that the radio emissions picked up by Mariner II, on which the assumed high Venussian temperatures are based, may be generated by atmospheric processes unrelated to heat—for example, lightning-like electrical discharges or chemical reactions.

Just a day before the Mariner V fly-by of Venus, the Soviet Union’s Venus 4 entry probe was parachuted down toward the planet. It reported temperatures as high as 518° F and atmospheric pressures as high as 22 times that of earth.

Some scientists speculate that if the surface of earth were as hot as the surface of Venus appears to be all of the carbon dioxide in earth’s oceans and earth’s carbonate rocks, such as limestone, would rise into the atmosphere. Thus, the atmosphere would be much denser, only a small proportion would be nitrogen, and oxygen would be barely traceable.

Based on data from Mariner V and atmospheric theories, scientists calculate that the Venussian atmosphere is composed of 69 to 87 percent carbon
The view from Venus compared to that from earth.

dioxide, if the other major constituent is nitrogen. Earth's atmospheric composition (excluding water) is 78 percent nitrogen, 21 percent oxygen, and 1 percent other gases, among which are argon, carbon dioxide, hydrogen, helium, krypton, and neon.

Scientists suggest that if later exploration proves that the Venusian atmosphere has more neon than nitrogen, it could mean that Venus is geologically younger than earth. Earth's primeval atmosphere is believed to have contained large amounts of neon, an extremely light gas, most of which drifted away into space long ago.

If Venus' atmosphere is as dense as current measurements indicate, it could act like a giant lens, refracting, or bending, light and radio waves in such a path that they circle the planet and may even return to where they started.

As a result, if an explorer could reach and survive on Venus, he may be subjected to wierd optical effects. Sunlight filtering through the Venusian clouds would strike an object and when reflected from it would bend around the planet. The explorer could theoretically see reflections from objects beyond the actual horizon of Venus.

If light rays actually circle the planet, the explorer will be subjected to another unbelievable sight. Theoretically, he would see the back of his own head in the distance.

The horizon itself would also appear to be above the explorer due to the bending of its reflected light by the Venusian atmosphere. The surface of Venus would seem to rise on all sides of the explorer, giving him the impression that he is on the bottom of a giant bowlshaped depression.

Sunsets on earth have been the subject of many beautiful paintings, but sunset on Venus is truly out of this world. As the sun drops below the actual Venusian horizon, its reflections are picked up so that it becomes a band across the sky. The band may be colored like a rainbow if the atmosphere produces the believed effect of a prism.

On Venus there may truly be no night as such. Because the atmosphere routes sunlight around the planet, it is possible that the night sky is aglow. Perhaps, this explains the so-called ashen light of Venus—the faint illumination of the darkened part of the planet that has puzzled astronomers viewing it through telescopes on earth.

Mariner V data also showed that Venus is surrounded by a shock wave similar but not identical to the one surrounding earth. The shock wave around earth is created by the impact of the speeding solar wind* against earth's magnetic field. Solar wind speeds have been clocked at nearly 1,700,000 miles per hour by NASA's Pioneer VI spacecraft.

The size of the shock wave around Venus is much smaller than that around earth. Scientists are not certain whether the solar wind was impinging directly on the Venusian ionosphere, a Venusian magnetic field too weak to be detected by Mariner's instruments, or both. Data from Mariner V indicate that a Venusian magnetic field, if one exists, is no greater than 1/500th of earth's.

EXPLORING SPACE WITH MARINER CRAFT

The Venus fly-by of Mariner V marked the third time that American spacecraft have made close-range observations of other planets. The world's first such observation was made by Mariner II when it flew in the vicinity of Venus on December 14, 1962.

Mariners I and III failed, but on July 14, 1965, Mariner IV swept by Mars. Its historic close-range
photographs showed a Martian surface pockmarked by craters and looking more like the moon than the earth. Among the other information it delivered was the fact that the atmosphere of Mars is only about one per cent as dense as earth's, much less than needed for most types of earthly life. Mariner IV detected no Martian magnetic field nor a radiation region such as exists around earth.

In November 1967, scientists completed a two-year study of Mariner IV Mars photographs, using new computer interpretation techniques. They found that Mars may be at least three times as densely cratered as preliminary photographs revealed.

Based on the number of craters that could be distinguished in the original photographs, scientists had projected that Mars may be pitted by more than 10,000 craters of the sizes observed (diameters 3 to 75 miles) and many smaller craters. The new crater count approaches that of earth's moon.

However, the craters of Mars are more eroded than those on the moon and are, therefore, shallower and less precipitous. The principal erosion agent on Mars may be wind-blown dust.

In addition, analyses of Mariner IV photographs through color filters show that the soil of Mars is reddish in color. This confirms observations through telescopes on earth.

An unexpected scientific bonus of Mariner IV longevity was furnished during the period August to October 1967. At one time, Mariner IV, earth, and Mariner V were located along an imaginary line extending radially from the sun. The spacecraft were about 70 million miles apart with the earth in between. This provided an opportunity to make a simultaneous three-point measurement of the motion of the solar wind and the sun's magnetic field lines that are embedded in the wind. The data increased knowledge about the properties of the solar wind.
Mariner V is tested at Cape Kennedy, Florida, prior to launch.

The solar wind, or solar plasma, is made up of atomic particles of hydrogen, helium, and other elements constantly speeding outward from the sun’s surface. It is extremely thin and can be detected only by sensitive instruments. It is considered an extension of the sun’s corona, or outer atmosphere.

The velocity and density of the wind vary not only with distance from the sun but also with solar activity during a solar cycle. The solar cycle is a period of about 11 years during which solar activity goes from a maximum to a minimum and then rises again to a maximum. Mariners IV and V acquired data during a period of increasing solar activity; Mariner II, during a period when solar activity was significantly lower.

(NASA’s Pioneer spacecraft have also contributed to investigations of the solar wind and other interplanetary phenomena.)

At another time, the three observing stations (Mariner V, earth, and Mariner IV) were in positions along an imaginary spiral line originating from the sun. Data acquired from the three stations augmented knowledge about the propagation of solar cosmic rays that spiral through space along magnetic field lines stretching from the sun.

The magnetic field lines are drawn out by the solar wind to form interplanetary magnetic fields. The combination of the solar wind’s radial (outward) movement and the sun’s rotation causes the magnetic field lines to twist like streams of water from a whirling lawn sprinkler. The sun completes a rotation every 27 days.

Cosmic rays are atomic particles as are those of the solar wind. They are made up of protons (nuclei of hydrogen atoms), alpha particles (nuclei of helium atoms), nuclei of atoms heavier than hydrogen and helium, and electrons and are generally...
produced by solar flares and other sudden solar eruptions. Cosmic rays in our solar system also originate in interstellar or intergalactic space. Cosmic rays are the most penetrating form of particle radiation that is known.

Plans call for two television-equipped Mariners to give mankind a longer and closer, and better, look at Mars in 1969. The spacecraft are expected to be half again as heavy as Mariner IV with the added weight reflected in improved instrumentation.

The planned approach to Mars is within 2,500 miles as compared to the 6,118 miles at which Mariner IV sped by Mars. The fly-by is chosen to enable experimenters to get a broad overview of the planet and prevent possible contamination of the Martian surface by microorganisms from earth.

In October 1967, experimenters on earth again turned on the picture transmission equipment and fired the rocket engine of Mariner IV. This was the first time either had been operated in roughly 2½ years. Mariner IV was about 56 million miles from earth when these operations were performed. The successful picture transmission and rocket firing after such a long period helped give engineers confidence for future missions to Jupiter and beyond.

For additional information on Mariner IV, see NASA Facts, A Report from Mariner IV, Vol. III, No. 3.

**SPACECRAFT DESCRIPTION**

Mariner V is a windmill-shaped craft consisting of an octagonal structure to which are attached solar panels and radio antennas. The octagonal framework is 4 feet 2 inches across. With solar panels extended, the vehicle spans 18 feet. It weighed 540 pounds at launch.

The octagonal framework has eight compartments, or bays. Seven are occupied by instruments; and one, by a rocket system designed to achieve small changes in the spacecraft’s trajectory, or flight path, by increasing or decreasing its speed. The velocity change may be as fine as ¼-th mph or as much as 188 mph. The engine provides 51 pounds of thrust.

Mariner V began life as a back-up for the brilliantly successful Mariner IV spacecraft. Major changes were made to prepare Mariner V for a flight toward rather than away from the sun and to meet other Venus mission requirements. Relative to this, a secondary objective of the Mariner V project was to acquire engineering experience in converting a spacecraft designed for flight to Mars into one that could explore Venus.

Among the changes made in Mariner V was a reduction in the size of the solar panels. The four panels, looking like the blades of a windmill, are covered with photovoltaic cells that convert sunlight to electricity for spacecraft power. The amount of electricity they generate depends for the most part on the intensity of the light striking them. Since sunlight near Venus is brighter than near Mars, fewer photovoltaic cells could provide the same watt hours of electricity.

The Canopus sensor on Mariner V is a photomultiplier tube. In a photomultiplier tube, light striking a grid knocks off electrons that in turn knock off electrons in succeeding grids. The resulting stream of electrons becomes a measurable electric current. Ground personnel know how much current the light from the star Canopus can eventually generate and thus can ascertain when Mariner is locked onto this reference point.

Because Mariner V was to head closer to the sun than any other spacecraft, its sensitive instruments had to be carefully insulated. The sun’s heat was
reflected by a deployable sunshade which works like an awning, and by paint patterns and polished metal surfaces. In addition, thermal blankets made up of several layers of aluminized Teflon and Mylar surrounded instruments. These also served to retard loss of heat through the cold dark side of the craft. In airless space, the part of a spacecraft facing the sun may be intensely hot while the other side is in subzero cold. A certain amount of internal warmth, derived largely from working instruments, is needed to keep a craft operating.

Other modifications included relocation, removal, or addition of instruments as needed. However, equipment for steering, stabilizing, and communicating with the craft was basically similar to that of Mariner IV.
ACQUISITION OF SCIENTIFIC INFORMATION

The instruments employed by Mariner V for acquisition of scientific information included an ultraviolet photometer, radio receivers and transmitters, a magnetometer, a plasma (solar wind) detector, and a trapped radiation detector. The photometer measured the brightness, or intensity, of ultraviolet light in selected wavelength ranges that signified the presence of hydrogen and oxygen.

Early in Mariner's flight, as the craft sped from earth, its photometer measured the hydrogen and oxygen in earth’s corona to a greater distance outward than ever before accomplished. During its four-month flight between the planets, the photometer measured ultraviolet emanations far and near in our galaxy. Since hydrogen is the most abundant element of stars and of the clouds of dust and gas in interstellar space, these measurements added significantly to scientific knowledge about the Milky Way. The information about background galactic radiation also contributed to the accuracy of measurements taken of the Venusian corona.

Mariner found that the ultraviolet band for hydrogen in Venus' corona was about as bright as that for earth, indicating comparable hydrogen content. There was no indication of oxygen around Venus.

The two radio experiments conducted near Venus are called the occultation experiments. Occultation has been defined as the disappearance of one body behind another of larger apparent size. A solar eclipse, for example, is the occultation of the sun by the moon.

The atmosphere of Venus and Venus itself came between earth and Mariner V in the occultation experiments. Radio waves were transmitted into the Venusian atmosphere. From analyses of how these waves were refracted, attenuated, or blocked were derived conclusions on atmospheric density, temperature, and composition.

In one occultation experiment, the 210-foot diameter tracking antenna of NASA’s Deep Space Network station at Goldstone, California, picked up Mariner’s tracking signals before and after Mariner was occulted by the planet. Even before Mariner was occulted by the solid body of the planet, the spacecraft’s signals to earth were cut off.

Scientists theorize that the signals were bent and contained within the Venusian atmosphere. For an atmosphere to do this, they say, it would have to be at least seven to eight times as dense as that at earth’s surface. Signal cut-off occurred at a radial distance (distance from Venus' center) of about 3,785 miles. Because of Venus’ thick cloud cover, scientists are not certain about the actual size of its solid body. But recent radar measurements indicate a Venus radius of roughly 3,765 miles.

On these bases, it appears that Venusian atmospheric pressure at a 20-mile altitude is at least seven to eight times that at earth’s surface. Even greater pressures are expected at lower altitudes and at the Venusian surface. Using the data from the tracking signals, scientists were also able, by a complex process, to derive temperature ranges and major constituents of the Venusian atmosphere.

In the other occultation experiment, called dual-frequency, the 150-foot-diameter antenna of the Stanford Center for Radar Astronomy at Palo Alto, California, transmitted radio signals to Mariner at two different frequencies. Comparison of the differences on how the two signals were affected in transit to Mariner’s receiver gave information about the Venusian ionosphere and about charged atomic particles in interplanetary space.

A planet’s ionosphere results when solar radiation causes neutral atmospheric molecules and atoms to give up electrons. The remaining parts of the atoms or molecules are called ions, and the

Stanford University radio antenna at Palo Alto, California.
process by which neutral atoms and molecules are stripped of one or more electrons is called ionization. The part of a planet's atmosphere where ionization takes place is usually referred to as the ionosphere.

One property of the ionosphere is that it refracts and reflects radio waves. This ability depends on the density of its electrons and the frequency of the radio signals. As frequencies rise, increasing electron density is required.

The magnetometer, plasma detector, and trapped radiation detector of Mariner V were designed to report on the environments of Venus and of interplanetary space. The absence of a region of higher radiation around Venus appears consistent with the apparent lack of a Venusian magnetic field. Scientists believe that a radiation belt like the Van Allen Radiation Region around earth is a creation of a planet's magnetic field which captures charged atomic particles as they speed near the planet.

Mariner V was also equipped with a newly designed data automation system to facilitate preparation of scientific information it acquires for transmission to earth. To get this information to earth, its high-gain antenna focused its radio energy into a narrow beam to direct maximum radio signal strength to receivers on earth. Mariner V also has a low gain omni-antenna. The omni-antenna radiates a broader beam than the high-gain antenna. Although the signal received from the omni-antenna is weaker, it enables trackers on earth to maintain contact with the spacecraft during periods when the high-gain antenna is not pointing toward earth; for example, during a mid-course maneuver.
TRACKING AND DATA ACQUISITION

From launch until spacecraft separation from the launch vehicle (see "Journey to Venus," below), Mariner V was tracked by the facilities of the Air Force Eastern Test Range and stations of NASA’s Manned Space Flight Network and Deep Space Network (DSN). Afterwards, contact with the spacecraft was maintained by NASA’s DSN stations in California, Spain, Australia, and the Republic of South Africa.

The DSN is a network facility of the NASA Office of Tracking and Data Acquisition under the systems management and technical direction of the Jet Propulsion Laboratory. The DSN supports NASA unmanned lunar, interplanetary, and planetary missions. Among such missions, in addition to Mariner, have been Pioneers, which are exploring interplanetary space, and the Ranger, Lunar Orbiter, and

Atlas-Agena stands ready to launch Mariner V.
Surveyor spacecraft, which have revolutionized mankind's knowledge of the moon.

**JOURNEY TO VENUS**

Mariner V began its lonely and magnificent journey to Venus aboard a two-stage Atlas-Agena launch vehicle rocketed from Cape Kennedy, Florida, on June 14, 1967. After the Atlas had ceased firing, the shroud, which protected Mariner from the buffeting of the atmosphere at lower altitudes, separated, followed seconds later by falling away of the first-stage Atlas. The Agena then propelled itself and Mariner into an orbit about 115 miles above earth and shut off its engine.

This interim trajectory of Mariner V is known as a parking orbit. The combined craft was continued in this orbit until reaching the best point for a launch toward Venus. Then, the Agena ignited again and accelerated the combined vehicle from earth-orbital speed of about 17,500 mph to more than 25,000 mph. The craft was so aimed that it would travel along a solar orbit that would enable it and Venus to be near each other on October 19.

Mariner V and the Agena were then separated, and Agena maneuvered so that it would neither hit Venus nor interfere with Mariner. Mariner unfolded its solar panels and oriented itself toward the sun. About 17 hours later, it also locked on Canopus, brightest star over earth's southern hemisphere. This orientation permitted the pointing of the high gain antenna toward earth.

Mariner V was originally launched on a flight path well away from Venus to insure that impact would not occur. Review of tracking data indicated that if Mariner continued on this trajectory, it would miss Venus by about 42,000 miles. On June 19, the Space Flight Operations Center ordered a mid-course maneuver which included precise positioning and firing of the craft's rocket motor to bring the craft within approximately 2,500 miles of Venus. (This was but one of 62 commands that Mariner V obeyed during its 217-million mile curving journey to Venus. In this period of about four months, it also returned to earth data on interplanetary weather during a period of rising solar activity.)

Mariner V was now a planetoid in solar orbit. Because it was launched backward with respect to earth, its speed relative to the sun was about 60,000 mph as compared to the earth's speed of 66,000 mph and Venus' 78,000 mph.

The path of Mariner V from earth to Venus, 1967.
Mariner's speed was too slow to stay in the same orbit as earth, and it began to fall toward the sun. The combination of the sun's inward pull and Mariner's kinetic energy that would keep it moving straight ahead produced an orbit that intersected the orbit of Venus. As Mariner curved toward the sun, it accelerated, overtook and passed earth, and gradually caught up with Venus.

By October 11, Mariner V was 1.4 million miles from Venus and approaching the planet at a speed of 6,900 mph. Pulled by the gravity of Venus, Mariner V continued to accelerate. On October 19, 1967, Mariner swept by Venus at a speed of 19,157 mph relative to the planet.

Mariner's radio signals were occulted—or blacked out—for a period of 20 minutes 51 seconds as Mariner V went behind the planet relative to earth. The pull of Venus caused the spacecraft's orbit to curve even more toward the sun, bringing it, on January 4, 1968, as near as about 54 million miles.

Long before its closest approach to the sun, Mariner had been ordered to return its information on Venus. It had spent two hours in Venus' vicinity and recorded a million bits of information. These it returned to earth at a rate of 8½ bits per second over a period of 34 hours. The Space Flight Operations Facility completed the first playback of data on October 21, 1967. Although quality of data was excellent, with only four errors in the million bits transmitted, the recording was played a second time on October 23, 1967 as insurance. In November 1967, a combination of distance and antenna-pointing direction caused termination of communication with Mariner V.

**MANAGEMENT**

The Mariner program is managed by the NASA Headquarters Office of Space Science and Applications. Project management as well as responsibility for the spacecraft, mission operations, and tracking and data acquisition is handled by the Jet Propulsion Laboratory, Pasadena, California. The laboratory is managed for NASA under contract by the California Institute of Technology.

On December 20, 1967, more than three years after launch, the Mariner IV experiment program was officially closed. The 575-pound spacecraft, launched November 28, 1964, which took the world's first close-range photographs of Mars on July 15, 1965, is the longest working interplanetary spacecraft. During its operating lifetime, the craft covered over 1½ billion miles of space.

Mariner IV literally ran out of gas—the nitrogen gas used to keep its solar panels pointed to the sun for power and its antenna pointed to earth for communication. When its gas tanks were empty, it was spin stabilized in the hope of extending its usefulness. However, it was not sufficiently stable to keep adequate sun orientation and its radio signal became too weak for reception on earth.