DOCUMENT RESUME

ED 093 662 SE 017 716

TITLE	The Now Frontier. Linking Earth and Planets. Issue No. 1-4.
INSTITUTION	Jet Propulsion Lab., Pasadena, Calif.
SPONS AGENCY	National Aeronautics and Space Administration, Washington, D.C.
PUB DATE	74
NOTE	16p.
AVAILABLE FROM	Jet Propulsion Laboratory, Public Educational Services, 4800 Oak Grove Drive, Pasadena, California 91103 (no price quoted)
EDRS PRICE	MF-$0.75 HC-$1.50 PLUS POSTAGE
DESCRIPTORS	Aerospace Technology; *Earth Science; Instruction; *Instructional Materials; *Science Activities; Science Education; Technology
IDENTIFIERS	NASA Program

ABSTRACT

This publication includes four pamphlets providing background material for understanding the NASA program of planetary flights. Each issue presents student involvement activities as well as suggested reading lists. Issue 1 describes the innermost planets of the solar system. Issue 2 gives information about the evolution of the planetary system as well as specific notes on the planets Venus and Mercury. "Mission to the Inner Planets" is the title given to Issue 3. The Mariner 10 mission is described in some detail. Issue 4, "Venus and Mercury Encounters," describes Mariner 10's encounter with Mercury and Venus. (EB)

ERIC

ED 093662

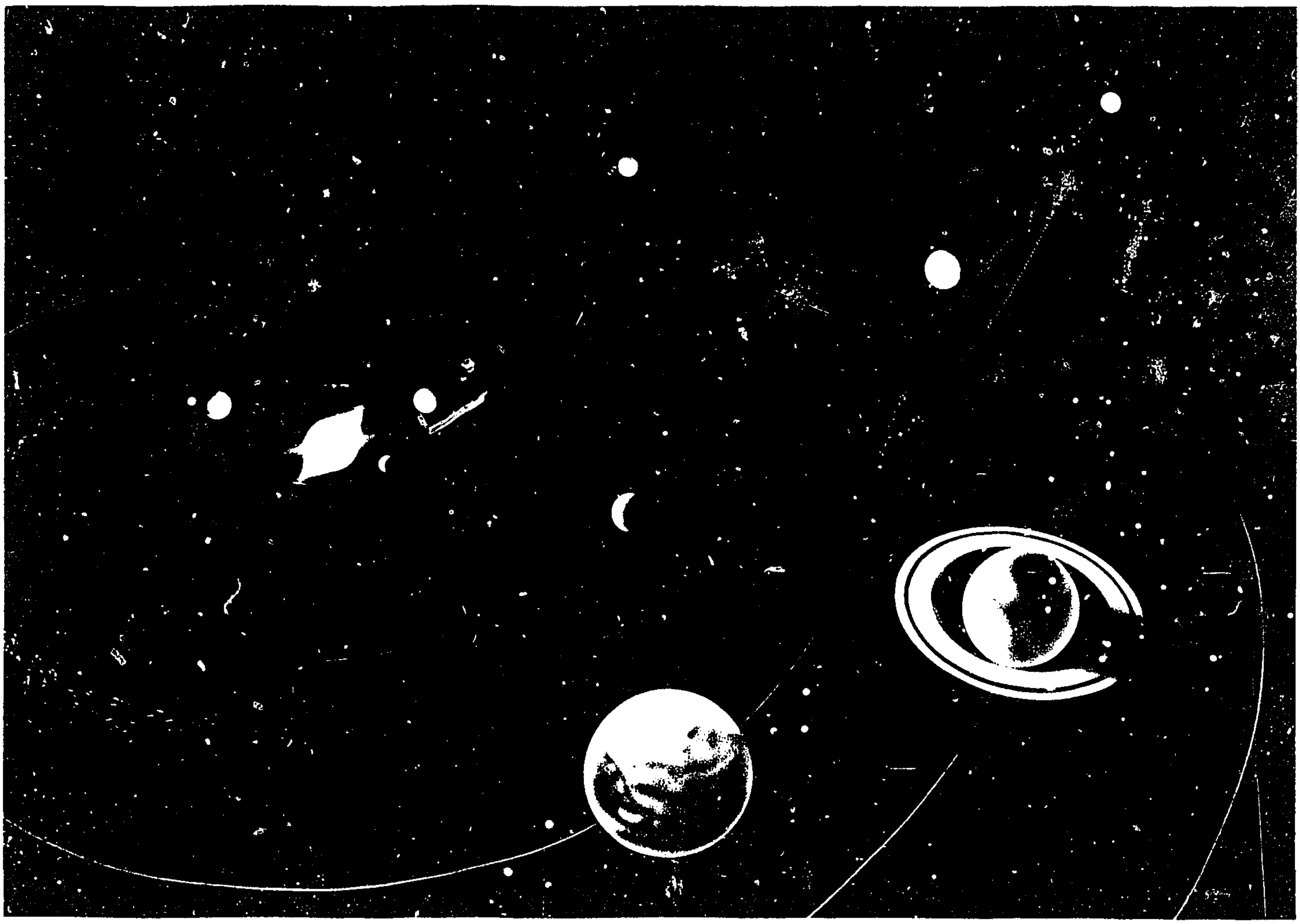
U S DEPARTMENT OF HEALTH,
EDUCATION & WELFARE
NATIONAL INSTITUTE OF
EDUCATION
THIS DOCUMENT HAS BEEN REPRO
DUCED EXACTLY AS RECEIVED FROM
THE PERSON OR ORGANIZATION ORIGIN
ATING IT POINTS OF VIEW OR OPINIONS
STATED DO NOT NECESSARILY REPRE
SENT OFFICIAL NATIONAL INSTITUTE OF
EDUCATION POSITION OR POLICY

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

THE NOW FRONTIER

LINKING EARTH AND PLANETS

Innermost Planets of the Solar System



JET PROPULSION LABORATORY
CALIFORNIA INSTITUTE OF TECHNOLOGY
PASADENA, CALIFORNIA

ISSUE NUMBER ONE

PUBLIC EDUCATIONAL SERVICES OFFICE

SE 017 716

THE INNER PLANETS

The dull-white star shone steadily across the Aegean Sea in the warm glow of dawn. The Ancient Greeks called this star Apollo. And they thought it different from another dull-white star that often lingered for a few weeks in the sunset glow across the Ionian Sea. This star they called Mercury, the messenger of the gods. But by the time of Plato, the Greeks had discovered that the two stars are one, and are not stars, but a wandering planet always moving close to the Sun like a moth around a candle flame.

Mercury is the innermost planet of the solar system. Venus orbits the Sun between the orbits of Earth and Mercury. Both planets are now targets for a Mariner 10 spacecraft launched November 1973 and scheduled to fly past Venus in February 1974, and Mercury in March 1974. Venus has been reached several times by spacecraft from the U.S. and the U.S.S.R., but Mercury has never before been reached.

Mercury averages 36 million miles from the Sun, about 40 percent of Earth's distance, while Venus, at 67 million miles, is about 75 percent of Earth's distance from the Sun.

Since the planet Mercury is so close to the Sun and moves rapidly in its orbit (1½ to 2 times faster than Earth) it flits from side to side of the Sun to be seen only just before sunrise and just after sunset. Its rapid motion and brief appearances and disappearances probably caused the ancients to associate it with the winged-foot messenger of mythology.

By contrast, Venus is closer to Earth, moves further away from the Sun in the evening and morning skies, appears placid and brilliant and is perhaps the most beautiful object in the skies—"Mistress of the Heavens" said the Babylonians. This planet was accordingly associated with the Roman goddess of beauty, Venus.

Planets of the solar system consist of two distinct types: small, dense, inner planets with solid surfaces—Mercury, Venus, Earth and its Moon, and Mars—and large, predominantly gaseous outer planets—Jupiter, Saturn, Uranus, and Neptune. Pluto, the outermost known planet, cannot be observed well enough to be accurately classified, though it is believed to be similar to the inner planets.

Also, between the orbits of Mars and Jupiter is a zone of minor planets called asteroids, the largest of which, Ceres, is only about 500 miles in diameter, while most are much smaller.

In distance outwards from the Sun, the asteroids divide the inner from the outer planets, Jupiter being the first of the outer planets, Mars the most distant of the inner planets.

ANALOGY WITH EARTH AND MOON

Venus is approximately the same size and mass as Earth, Mercury somewhat larger than Earth's Moon. While Earth and Venus both have atmospheres, the Moon, and, apparently, Mercury, are airless bodies. Venus and Mercury might have been a twin system like Earth and Moon, except that the closeness of Venus to the Sun probably prevented Mercury from being a satellite of Venus and prevented Venus from possessing a terrestrial-type atmosphere and oceans.

From the point of view of planetary dynamics, Mercury is perhaps the most important object in the solar system. Being the closest planet to the Sun, it is the most sensitive detector of departures from the laws proposed to account for planetary orbital motions. An unusual period of spin and an unusually high density make Mercury of great interest to astronomers.

A space probe flying by Mercury can provide important information about both the dynamics of Mercury and its interior. The radius, mass, and orbit can be refined.

Venus is the planet most similar to the Earth in size, density, and distance from the Sun. However, it differs significantly in having a much more massive atmosphere composed mainly of carbon dioxide, a much higher surface temperature, about 700°K, a much slower backwards rotation period of 243.1 Earth days, and no moon or oceans.

Spacecraft traveling to Venus in the past have not detected a significant magnetic field (the field being less than 1/5000 of the Earth's).

The closeness of the mean density of Venus to that of the Earth might imply that the chemical composition of the two planets is almost the same. A question often asked is whether Venus is at a stage earlier or later in evolution than the Earth, or follows an entirely different evolutionary path from Earth.

Radar inspection of Venus from Earth reveals a surface that is generally smoother than the Moon and gently undulating. There are, however, several regions that appear to be much rougher than their surroundings, and some large shallow craters.

SOLAR ORBITS AND APPEARANCE OF INNER PLANETS IN THE SKY (APPARITIONS)

It is instructive to look at Mercury and Venus from the standpoint of the early astronomers. Earthbound, they watched the motions of the planets against the background of stars and deduced that the planets, including the Earth, move around the Sun in almost circular orbits. Because Mercury and Venus orbit the Sun inside the Earth's orbit, they are termed inferior planets.

As seen from the Earth, inferior planets appear to move close to the ecliptic (the apparent yearly path of the Sun relative to the stars, which is the plane of the Earth's orbit projected against the stars), and to move backwards and forwards, oscillating to either side of the Sun and never far from it in the sky (Figure 1). The maximum distance to east or west of the Sun is termed elongation. At eastern elongation, Mercury and Venus are seen in the evening sky as evening stars because they appear to follow the Sun in its daily motion across Earth's sky due to the rotation of the Earth. At western elongation, they are ahead of the Sun and are seen as morning stars before sunrise.

Cover: Mercury and Venus – the innermost planets of the solar system – are shown here in their orbits around the Sun: first, Mercury (seen here as a crescent), and then Venus; the Earth is next, with our Moon close to it. Planets farther from the Sun are Mars, Jupiter (shown with some of its satellites), and Saturn, with its rings. Uranus, Neptune, and Pluto are the most distant planets.

ERIC

Table 1. Venus Picture Sequences

Date and time (PST)	Sequence
Feb. 5, 8.28 to 8.58 a.m.	Limb, cusps, and terminator scans
9.02 and 9.46 a.m.	Point directly beneath the Sun on the limb
10.13 a.m.	163 photo strips of Venus
12.18 p.m.	238 ultraviolet for mosaics
2.12 p.m. to 4.51 a.m., Feb. 6	1207 photos for various mosaics
Feb. 6, 9.35 a.m. through Feb. 22, 10.30 a.m.	408 pictures, one each hour

The infrared radiometer can also be used during the approach to sweep across the darkened planet and measure the temperatures of the clouds on the night side of Venus. Also, the magnetic field and particles instruments will observe the "tail" of Venus and the interaction of the planet and its electrically charged upper atmosphere (ionosphere) with the solar wind. The ultraviolet instrument will check on the auroras on the night side of Venus. These have been detected by earlier spacecraft and may be responsible for the ashen light of darkened Venus as seen by astronomers from Earth.

At the closest approach of Mariner to within 3100 miles of the cloud tops, the sunlit side of the planet has become visible and the cameras are busily photographing the brilliant cloud tops. Filters are changed to inspect the clouds in light of different colors and different planes of vibration (polarization). Some of the pictures are along the terminator line, the boundary between night and day on the planet. Because the Sun shines at a very low angle along the terminator it will reveal structural details of the clouds if they are present, just as an automobile's headlamps will show up small detail in the road surface to a pedestrian standing some way in front of the automobile and looking down at the road.

A few minutes after closest approach to Venus, Mariner sees the nearly fully illuminated disc of Venus. Series of pictures are taken in ultraviolet and polarized visible light of several colors to obtain information about the size of particles in the clouds, composition of the clouds, pressures in the atmosphere, and small- and large-scale cloud structure. Scientists hope to determine whether the clouds are hazy, foglike sheets or possess turbulent billowing tops like Earth's cumulus clouds. The cameras also photograph the limb edge of the planet to look at the cloud tops as they appear silhouetted against the dark background of space.

As Mariner flies around the daylight hemisphere of Venus it becomes hidden from Earth on the far side of the planet. Communications are temporarily interrupted. But Mariner 10 continues with all its scientific missions, storing the information, including photographs, in its memory. Then when it emerges again from behind the planet and radio waves again can get back to Earth, the information is transmitted.

As well as taking many photographs of Venus, Mariner 10 scans the clouds in ultraviolet and infrared for clues as to their composition.

But quickly Mariner flies on, its rendezvous with Venus over. As it heads back towards interplanetary space its instruments look at the solar wind and magnetic fields and particularly the effects of the bow shock where the planet plows into the environment of space like a supersonic airplane shocking the the Earth's atmosphere.

And for several days (17) after encounter, planet photography continues, the cameras looking back on the gradually diminishing disc of the planet. This 2-week series of pictures is very important. Scientists have observed rapid rotations of ultraviolet markings on Venus and major up-and-down pulsations of the atmosphere. So as Mariner recedes from Venus, emphasis is placed on time-lapse photographs of ultraviolet and any visible light markings to measure their period of rotation about the planet, which is believed to be about 4 days from Earth-based observations.

This task over, Mariner reverts to observations of interplanetary space until it begins to approach Mercury towards the end of March 1974 (Figure 2).

About 4 weeks elapse from the last pictures of Venus to the first pictures of Mercury. Mariner 10's prime target is Mercury, since other spacecraft have flown to Venus but none previously have gone to Mercury. The sequences of pictures of Mercury are the most important part of the mission, and as many pictures as possible will be taken (Table 2). The sequence is divided into five distinct parts: incoming far encounter, incoming near encounter, encounter, outgoing near encounter, and outgoing far encounter.

Mariner 10 approaches Mercury almost on a tangent to the planet's orbit near its furthest point from the Sun (aphelion). Each day in the final week before Mercury encounter, Mariner sends back to Earth sequences of pictures taken through several different color filters. Project scientists will inspect these to search for features of interest which can later be photographed in more detail as the encounter proceeds. Since no one has seen any real detail on Mercury from Earth, this pre-encounter series of photographs is awaited expectantly. As with most earlier planetary explorations, the photographs will probably be filled with many surprises.

Man's concepts of Mars were completely revised as a result of close looks by earlier spacecraft. And Mars shows quite extensive detail when observed by telescope from Earth. By contrast, Mercury shows little if any detail when seen through an Earth-based telescope, so it has remained very much a planet of mystery.

As Mariner bears down on Mercury, the ultraviolet instruments will search for evidence of an atmosphere and the infrared in-

ERIC

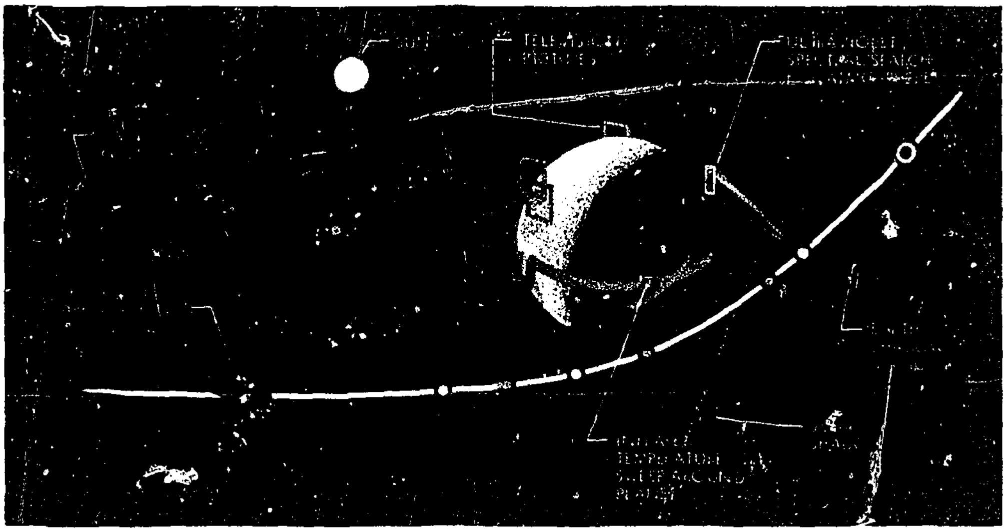


Figure 2. An artist's conception of the Mariner 10 encounter with Mercury.

strument will be checking on the temperature of the planet.

Just before encounter, the cameras will be programmed to sweep space around Mercury to see whether the planet possesses any small satellites that would be invisible from Earth.

On the day of closest approach, March 29, 1974, detailed photographic surveys are made of the surface, particularly the boundary between light and darkness where detail will be thrown into sharp relief by the low angle of sunlight shining on the planet's surface. Objects only 350 feet across are expected to be revealed on these pictures. Rapidly the illuminated shape of Mercury changes from a half-moon to a crescent as the spacecraft hurtles towards close approach. About 12.00 noon PST on March 29, Mariner flies within 600 miles of the barren surface and then starts away from the planet. But this close approach is made over the night hemisphere of the planet and the surface cannot be photographed. There are opportunities to observe and photograph the pointed ends of the crescent of Mercury, as with Venus, at the beginning and end of the night side pass. These may be inspected to check for atmosphere and for surface irregularities. Then, as Mariner moves away from the planet and over towards the daytime hemisphere, the picture taking will start again. It will continue until the image of Mercury no longer reveals any detail.

As with the Venus flyby, instruments on the spacecraft will check the interaction of the planet with the solar wind and the interplanetary medium.

Table 2. Mercury Near-Encounter Picture Sequences

Date and time (PST)	Sequence
Satellite search, March 23, 5.00 to 8.30 a.m.	45 pictures
March 27, 3.30 to 6.30 a.m.	45 pictures
Near encounter, March 28, 8.24 p.m. to 8.30 a.m. (March 29)	162 pictures (9 mosaics)
Encounter, March 29, 8.30 to 11.24 a.m.	225 pictures
11.24 to 11.37 a.m.	18 pictures
12.10 to 12.22 p.m.	17 pictures
12.22 to 4.20 p.m.	329 pictures
5.30 p.m. to 3.30 a.m. (March 30)	144 pictures

In the following months, project scientists and engineers inspect the wealth of information returned from Mercury and confer on a plan for a second encounter with this innermost planet of the solar system.

And during this period, too, while Mariner inspects the interplanetary medium, it will also look around with its cameras to see whether there are any small planets within the orbit of Mercury.

There are plans for more than 7500 pictures of Venus and Mercury during the encounters. These will provide the first photographic survey of both planets and present information impossible to obtain from Earth. Many of the pictures will be made available to national television and the newspapers within hours after being received, pictures that generations of astronomers would have given almost anything to be able to see. Thus Mariner 10 will complete much of the jigsaw puzzle of the terrestrial-type planets of the solar system and allow better understanding of how these planets were formed and evolved to their present states.

STUDENT INVOLVEMENT

Student Project One

Take the various events listed in the tables in this leaflet and make a combined listing of the sequential happening when Mariner 10 makes its encounters with its interplanetary targets. List the date, time, what happens, and leave a column for your remarks about each event. Remember that the times given here are for Pacific Standard Time (PST). (This could be an individual or a class project.)

Classroom Project

Study the results of the Mercury encounter. Discuss any unknowns that have still not been clarified by the first flyby. With the knowledge that sufficient propellant exists to make another flyby, make a plan for this next flyby: whether it should fly on the day side or the night side, what it should photograph, and why. Then later, when the next leaflet of this series is issued, check to see whether your mission plan agrees with that selected by the project scientists and compare your reasons with theirs.

READING LIST

Watch TV newscasts and special programs
Listen to radio newscasts.
Read your local newspaper or news-magazines.

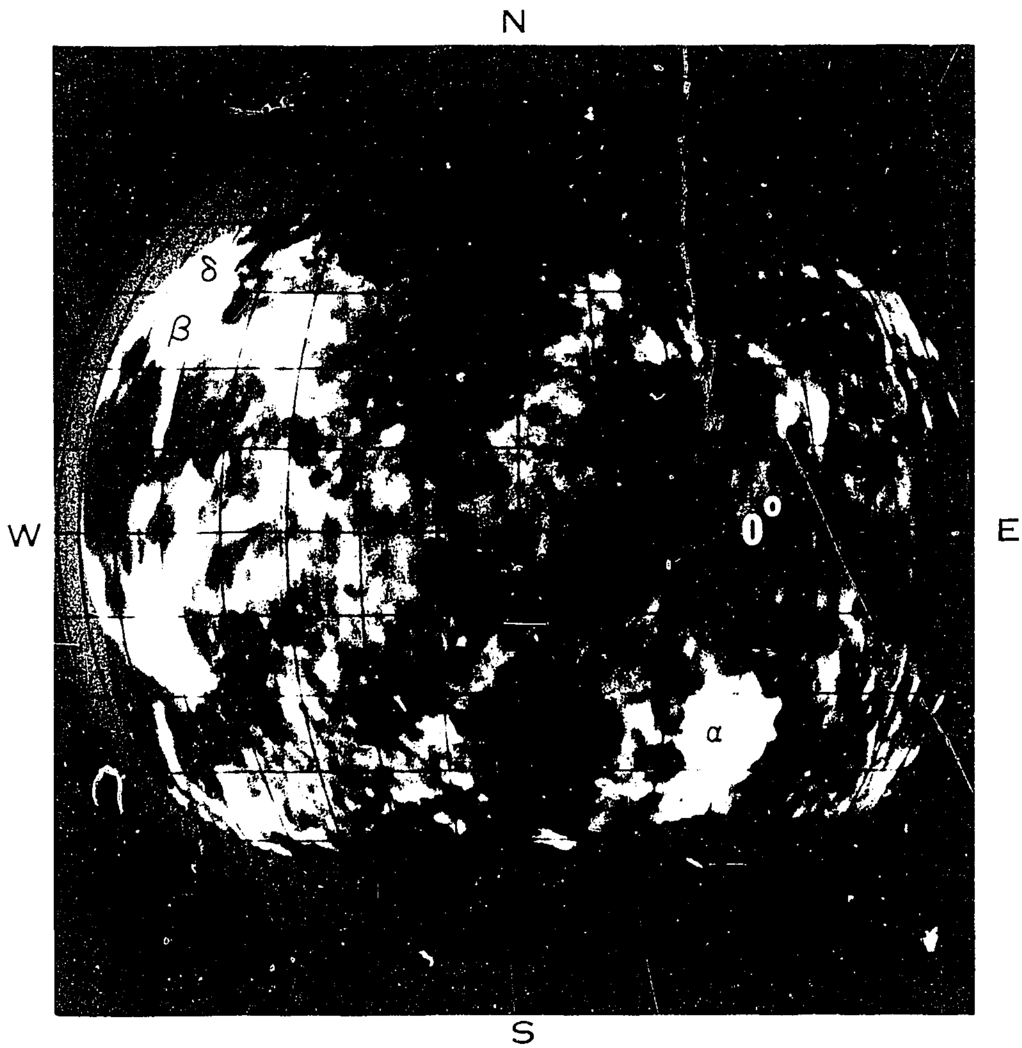
P73-219 JPL 654 4.5M 1-74 PRINTED

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

THE NOW FRONTIER

LINKING EARTH AND PLANETS

Venus and Mercury as Planets



JET PROPULSION LABORATORY
CALIFORNIA INSTITUTE OF TECHNOLOGY
PASADENA, CALIFORNIA

ISSUE NUMBER TWO
PUBLIC EDUCATIONAL SERVICES OFFICE

SE 017 716

EVOLUTION OF THE PLANETARY SYSTEM

Planets of the solar system probably formed four to five billion years ago when hosts of small rocky particles and clouds of gases collected together by their own gravity. Gravity appears to be a universal property of matter, as a result of which every particle, no matter how small, attracts every other. Thus, left to themselves in space, individual particles (and a gas consists of particles: molecules) tend to collect together into large masses.

So after the Sun condensed from the primeval nebula, planets of different sizes and probably different composition originated from concentrations of matter present at various distances from the Sun. And electric and magnetic fields in the gas forced these condensing planets into orbits around the central Sun and spun them on their own axes like tops.

The larger craters on Mars, the Moon, and Venus are thought to be gouged by falling bodies during the final stages of planetary accretion, as the process of falling together is termed. Smaller ones represent a continuing but much lower rate of bombardment by solar system debris.

While Mariner 10, now on its way to Venus, is not designed to find out anything directly about life on Venus, the scientific information about conditions on Venus may be important to biologists seeking understanding of why Earth spawned life and Venus did not. It was life in the primitive atmosphere of Earth which helped to produce the oxygen-rich atmosphere that in turn keeps a lid on the oceans and stops them leaking off into space. Oxygen, converted to ozone at high altitude by the Sun's rays, prevents solar ultraviolet from penetrating low enough into Earth's atmosphere to break water vapor into oxygen and hydrogen. This is important because the hydrogen would bubble off into space like steam from a saucepan and gradually Earth would have lost its oceans in this way.

A photographic mosaic of the Earth, taken by Mariner 10, is shown in Figure 1.

Cover: The planet Venus as it has been observed from Earth through the technique of radar mapping, in which a radar signal is bounced off the surface of the planet. The three light areas marked with Greek letters (α, β, and δ) are rough sections that may be mountains, but could also be craters or boulder fields. The mapping was done by the Jet Propulsion Laboratory (JPL), using the NASA/JPL deep space antennas at Goldstone, California.

THE CHARACTERISTICS OF VENUS

Venus is very similar to Earth in size and mass; its diameter is 7,520 miles compared with Earth's 7,920, its mass and density are slightly less than those of Earth. Physically the two planets are almost twins, but they seem to have grown up quite differently.

Venus, too, is Earth's nearest neighbor in space after the Moon. Its closest approach is 26 million miles compared with 34 million miles for Mars.

But a telescope reveals virtually no details on the bright disc of the planet. Some observers have recorded faint and elusive markings, visible in the near ultraviolet, ill-defined dark shadows and bright patches seemingly behaving very much as cloud systems might behave.

The absence of surface features or persistent cloud features made it difficult to determine the period of rotation of Venus on its axis. Wildly varying estimates were made, ranging from a 24-hour day like that of Earth to a day equal to the Venusian year. The question was not answered until recently when radio waves penetrated the thick clouds of the brilliant planet. Surprisingly, it was found that Venus rotates in 243 days in the opposite direction to that of the Earth. This is slightly longer than the Venus year—the time the planet takes to revolve around the Sun, which is 225 Earth days. Because of the rotation and revolution in opposite directions, the day on Venus is only 127 Earth days. But these figures pose the question of how Venus might have slowed down from rotating as the other planets do and started to rotate in the opposite direction. One of several theories is that Venus captured a large Moon-like body moving in the opposite direction to Venus' spin and that this body crashed onto the surface of Venus. The impact would have stopped Venus from rotating and would also have released tremendous quantities of heat that might have been the cause of extensive volcanism to generate the dense atmosphere of Venus.

Figure 1. A mosaic view of the Earth taken by Mariner 10 on its way to Venus and Mercury. Such pictures were used by the engineers and scientists to test the spacecraft's cameras in space. These pictures were taken when Mariner 10 was 120,000 miles from Earth.

Venus has been the target for several earlier space missions: two successful flybys were made by earlier Mariners, and Soviet Venera spacecraft flew by, orbited, and landed capsules on the surface. These probes confirmed a high surface temperature of around 475°C and a pressure at the base of Venus' atmosphere about equal to that at a depth of 400 fathoms in Earth's oceans. Generally Venus is a hot dry planet with only slight traces of water vapor in its atmosphere of 95 percent carbon dioxide. There are also traces of oxygen, nitrogen, and inert gases, it is believed.

The clouds of Venus, which, according to recent spectroscopic observations, may have a topmost layer of concentrated sulfuric acid droplets, are about 18 to 25 miles thick, and their tops may be about 90 miles above the surface, compared with Earth's highest clouds of six miles or so. Below the Venus clouds is a clear atmosphere, while the clouds themselves probably consist of stacked layers of different composition; for example, carbon dioxide ice at some levels and water ice at others.

Cloud features seen in ultraviolet light appear to move around the planet in only four days. There are also some large scale up-and-down pulsations of the cloud layers.

An interesting theoretical aspect of the dense but clear atmosphere below the clouds of Venus is that if a student could stand on the surface and look around, he would appear to be standing in the bottom of a vast bowl. Looking into the distance in each direction, he would see a blurred, ruddy red landscape curving upwards towards the cloud layers as though he were inside a hollow planet: the atmosphere, acting like a giant lens, would bend the light rays upwards in an effect similar to a mirage appearing on a hot road surface in summer.

This strong bending of light might turn night into a dull day on the night side of the planet, and this could explain the ashen light of Venus. Astronomers have claimed that they see this faint glow on the dark side of the planet when it is turned towards Earth. But this ashen light, first seen in 1643, is nowadays believed to be an auroral glow, like the northern and southern lights over Earth's polar region. Since Venus does not have a strong magnetic field, its auroras can occur all over the planet, whereas on Earth the strong magnetic field causes the aurora-producing particles from the Sun to stream towards the polar regions. One of the spacecraft did observe the glow over the night side of Venus, and the existence of an electrically excited upper atmosphere, the ionosphere, has also been confirmed by spacecraft.

Study of the atmosphere of Venus is important because the whole balance between heat coming in and heat going out from the planet is bound up with atmospheric structure and composition. This heat budget of energy income and spending could explain why Venus is today such a vastly different planet from Earth despite the similarities in size. The great mystery about Venus is how a planet about the same size as Earth, which might have supported oceans in the past as Earth does today, developed so differently during its evolution. Why did the planet lose all its water? Why did the surface temperature rise so high? How did the atmosphere build up such high pressures? How could bodies plunge through this dense atmosphere to produce craters detected by radar?

Answers to these and other questions about Venus will help us understand how planets evolve and why there is an Eden-like Earth while nearby planets are so inhospitable. Understanding how the atmosphere of Venus became, or stayed, inimical to life may help us prevent our own atmosphere from going wrong too, either from natural or man-made causes. An important question today is whether pollution might trigger drastic changes in Earth's atmosphere which could change our planet into another Venus.

At the distance of Venus from the Sun its temperature would be expected to be about $60^{o}C$ on the average if it were an airless body. Why then is it so much hotter, especially when its clouds reflect a large part of the solar radiation falling upon them? The answer seems to lie in the atmosphere of carbon dioxide. This gas acts, with water vapor, as a one-way transmitter of incoming heat energy from the Sun. It opens a door to let the energy in and slams it shut when the energy tries to go out again. The planet heats up like the inside of an automobile in sunshine with its windows closed.

By contrast, the atmosphere of Earth has only 0.03 percent of carbon dioxide. On Venus, carbon dioxide has remained free in the atmosphere, whereas on Earth in the presence of much water it has reacted with minerals to form large deposits of carbonates. Photosynthesis in plants has also extracted carbon from the atmosphere.

Another mystery about Venus is why it does not have much water. One suggestion is that the water is still entrapped in molten rock beneath a plastic surface which resists fractures. In the formation of Venus, high temperatures drove off carbon dioxide but allowed water to remain in solution in the rocks. As the planet cooled, a plastic crust formed of sufficient thickness to prevent fractures and the consequent escape of water to form oceans.

However, the fact that the planet has not outgassed suggests little differentiation or, at the least, an inactive mantle. If the planet were to outgas, the crust would not be likely to keep the lid on this outgassing.

One theory suggests that water is trapped in voluminous polar caps of Venus; another, that all the water was lost because water vapor could rise in the atmosphere of Venus and be broken down by sunlight into oxygen and hydrogen. The hydrogen boiled off into space. But what happened to the oxygen? It does not appear to be left in the atmosphere.

On the other hand, the major differences among the terrestrial planets may have arisen because these planets formed at different distances from the Sun and thus consisted of different materials in the first instance. For example, Mercury might have formed from materials rich in iron, whereas Venus formed from silicate-rich materials. And Earth may have accreted in a region in which there were water-containing substances while Venus did not. Calculations have shown that the primeval nebula might have separated in this way at various distances from the Sun.

THE CHARACTERISTICS OF MERCURY

Mercury, 3000 miles in diameter, is probably the smallest planet in the solar system (Figure 2). The outermost planet, Pluto, might possibly be smaller. Mercury is halfway between the Moon and Mars in size. Even two satellites of the planet Jupiter are as large as Mercury, though much less dense.

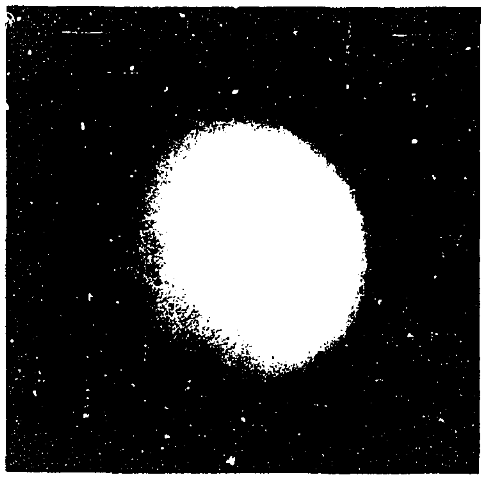


Figure 2. A photograph of Mercury taken at the Pic du Midi observatory in France. This is the best type of picture that can be taken from Earth, but Mariner 10 should send back Mercury photographs as good as the picture of Earth in Figure 1.

At one time it was thought that the closeness of the planet to the Sun caused it to turn one hemisphere eternally sunwards, just as the Moon turns one hemisphere towards Earth. However, radio astronomers discovered very recently (1965) that Mercury rotates on its axis in 58 days. Coupled with the planet's 88-day period of revolution around the Sun, this gives Mercury a solar day of 176 Earth days. So one day of Mercury occupies two years of Mercury time. And because the planet follows an elliptical path around the Sun with its speed in orbit changing as a consequence, the path of the Sun through Mercury's sky is quite erratic. Some parts of Mercury experience a double dawn, for example, in which the Sun rises, then slips back below the horizon, to rise again later.

Through a large telescope the planet presents a yellowish color broken by some grayish patches. Mercury is believed to be cratered and much like Earth's Moon. The grayish areas may be the same as the lunar maria, the great gray plains of the Moon. Mercury, like the Moon, does not appear to have an appreciable atmosphere, and it is a poor reflector of light. But its density is believed to be much more than that of the Moon, possibly a little greater than the Earth's. This is unexplained. It leads to the anomaly that Mercury's surface gravity is greater than that of the bigger planet Mars. A 100-pound student would weigh 40 pounds on Mercury, compared with 38 pounds on Mars and 17 pounds on the Moon. On Venus the same student would weigh 91 pounds.

It is unlikely that Mercury can possess an atmosphere, though some astronomers say they have seen veilings of surface detail at times, in the form of a whitish haze. Despite Mercury's greater surface gravity over that of the Moon, Mercury is closer to the Sun and therefore much hotter than the Moon: molecules can be heated to move at greater velocities and thereby reach escape velocity. Thus, gases that may have come from the rocks as a result of volcanic activity will, over millions of years, have escaped from the planet's gravitational grasp and rocketed as molecules into space.

Mercury does, however, collect plasma from the Sun, the steady stream of particles flung out by the Sun into interplanetary space and referred to as the solar wind. Some of this plasma might indeed form an atmosphere of a kind, as it is temporarily held by Mercury before streaming off again into space.

The surface temperature of Mercury is thought to range from about 325°C at local noon to -125°C at local midnight, but these temperatures vary considerably with the position of Mercury on its orbit as the planet moves in and out from the Sun.

Mercury's surface is exposed to the fierce erosion of the solar wind as well as to solar heat and light. As with Earth's Moon, the solar wind probably changes the composition of the outer surfaces of rocks and surface soils. Solar radiation can vary between five and ten times that received by Earth between aphelion and perihelion of Mercury (most distant and closest parts of its orbit to the Sun). Imagine a day in Earth's desert with ten suns shining at once in the noon sky. That approaches what it may be like on Mercury when the planet is at perihelion.

Key questions about this tiny planet concern its rotation, density, and surface molding. Why does Mercury rotate three times while making two revolutions around the Sun? Might this have produced some unusual surface features? One theory suggests that the heat from the Sun at perihelion may have produced two opposing bulges on the planet which now keep Mercury locked into this peculiar rhythm of rotation and revolution.

Why does Mercury have the highest density among the planets and their satellites? Does it have a central core of iron? And what processes have shaped the surface of the innermost planet?

Mariner 10 is expected to provide much valuable information bearing upon these questions.

STUDENT INVOLVEMENT

Student Project One

From reading astronomical textbooks make four lists as follows:

(1) Those things about Venus that are similar to those on Earth.
(2) Those things that are different.
(3) Those things about Mercury that are similar to those on the Moon.
(4) Those things that are different.

Make a drawing or painting of your impression of the surface of Mercury.

Student Project Two

From the textbooks now make a list of the unknowns about Mercury and Venus, their surface features, their atmosphere, their physical characteristics, their origin, their evolution. Check with a later pamphlet in this series as to what instruments are carried by Mariner 10 and what they might reveal. Identify those present unknowns that might be solved by Mariner 10. Later check the actual results from the flybys and see which of the problems are solved.

Student Project Three

For individual student or as a classroom project. Using the map of the orbits of Earth, Venus, and Mercury prepared as a project in connection with the first pamphlet of this series, mark a position for Earth with a circle on its orbit. Then on the orbits of Venus and Mercury draw circles, approximately to scale (that is, the circle representing Venus should be about the same size as that for Earth and about 2½ times the diameter of Mercury) at the correct positions for eastern and western elongation, superior conjunction (far side of the Sun) and inferior conjunction (between Earth and Sun) and half way between each of these positions, that is, eight positions for each orbit.

Now draw a set of circles showing the relative sizes of each planet as seen from Earth for each of the eight positions. On each of these comparative circles draw the phase of the planet, that is, the part that is in darkness as seen from Earth and the part illuminated; for example, fully illuminated like the full Moon, half illuminated like a quarter Moon, gibbous, and crescent shaped. You will have to calculate the size of the planet at each of these phases from the rule that if the planet is twice as far from the Earth it will appear half as large (in diameter) and so on.

Note how much smaller Mercury always appears to an observer on Earth even when close to the Earth, and how both planets turn their dark hemispheres towards us when they are at the very closest.

Thus you understand why we know so little about these planets and why a spacecraft flying by them can add greatly to man's knowledge of these neighboring worlds.

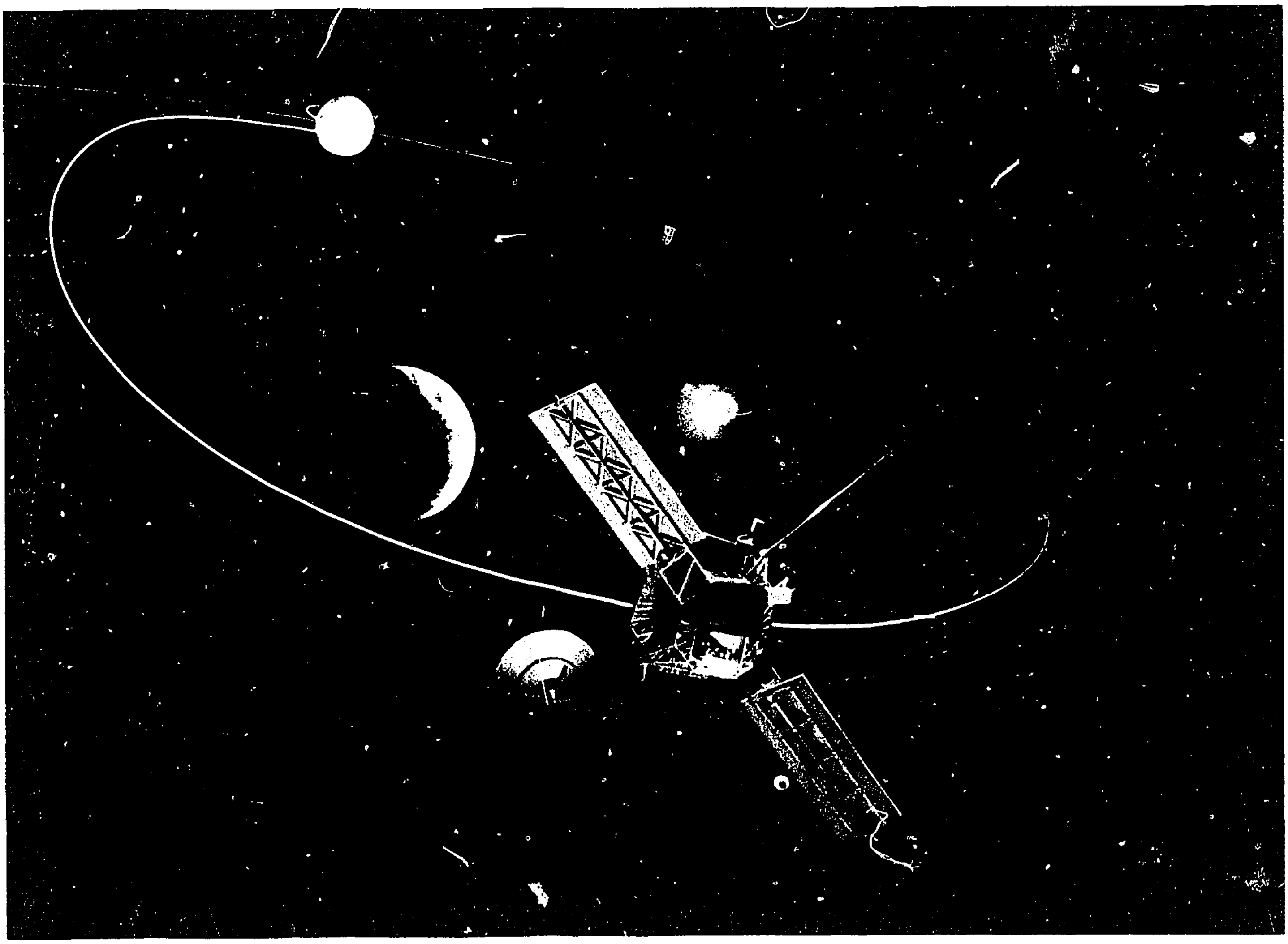
P73-219 JPL 654 4.5M 1-74 PRINTED IN U.S.A.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

THE NOW FRONTIER

LINKING EARTH AND PLANETS

Mission to the Inner Planets



JET PROPULSION LABORATORY
CALIFORNIA INSTITUTE OF TECHNOLOGY
PASADENA, CALIFORNIA

ISSUE NUMBER THREE

PUBLIC EDUCATIONAL SERVICES OFFICE

ERIC
Full Text Provided by ERIC

THE MARINER 10 MISSION

Mariner 10 arrives at Venus on February 5, 1974, after a 3-month, 150 million mile trip halfway around the Sun. The gravity of Venus changes the speed of the spacecraft to plunge it deeper into the gravitational field of the Sun to reach the orbit of Mercury and rendezvous with this innermost planet on March 29, 1974.

Mariner 10 sped from Cape Canaveral, Florida, November 2, 1973, atop an Atlas/Centaur multistage rocket launch vehicle. And, in contrast with earlier planetary spacecraft, it tried out its instruments on the Earth and Moon as it sped at 25,255 miles per hour on its way to Venus. The day following launch, scientists directed Mariner's two television cameras to produce four mosaics of 88 pictures each of Earth and Moon. Since Earth is cloud-covered like Venus, and the Moon airless and optically similar to Mercury, these picture series gave valuable early information on how the cameras might return information about the two target planets. Thus the instruments were calibrated. Other instruments too were tested on the Earth and Moon.

Experimenters were delighted at the clarity of the returned pictures. The Earth photographs revealed clear details of clouds; some provided three-dimensional views. And the pictures of the Moon showed north polar regions not seen by astronauts, photographs that recorded objects only 2 miles across.

Later the cameras photographed star fields and further confirmed the high quality of the images being returned over the radio link to Earth.

THE SPACECRAFT AND ITS PATH

Mariner 10 is the first complex spacecraft to be designed to travel into the inner reaches of the solar system as close to the Sun as 43 million miles. Developed from earlier spacecraft in the Mariner series that flew by Venus and Mars and orbited Mars, Mariner 10 faces new challenges of the interplanetary environment.

Cover: Mariner 10 on its path from Earth (in the upper left part of the picture, with the Moon close by). The spacecraft has just passed Venus and is on its way to Mercury.

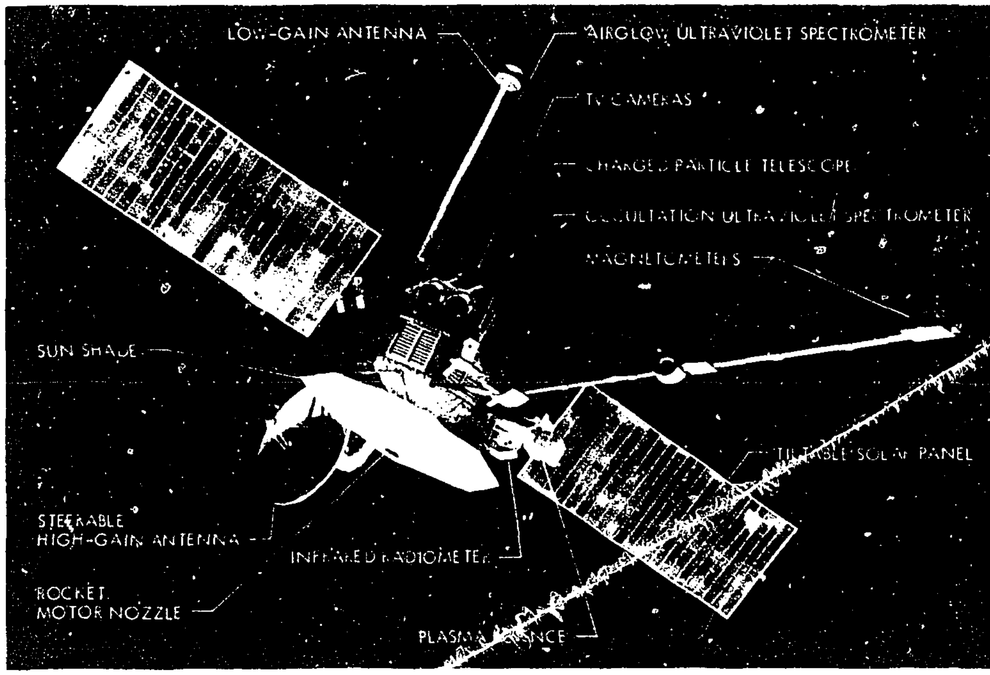


Figure 1. The Mariner 10 spacecraft.

For example, at Mariner's closest approach to the Sun, it receives five times as much light and heat as it does on leaving Earth. This requires that the solar radiation must be screened from the spacecraft and its scientific instruments to prevent them from overheating. A sunshade of beta cloth—the material used for astronauts' suits—is extended as the spacecraft leaves Earth.

The solar panels, too, which extend into sunlight to collect and convert solar radiation into electrical energy for the spacecraft's instruments and controls, are designed to be tilted more and more from the sunlight as Mariner 10 approaches closer and closer to the Sun.

Figure 1 shows the main features of the Mariner spacecraft. There is a basic eight-sided framework which encloses eight bays of electronics. This structure is 54½ inches across and 18 inches deep. Its center cavity is almost filled by a spherical tank of rocket propellant and a rocket motor used to maneuver the spacecraft. The nozzle of this rocket projects through the base of the structure, which is on the sunwards side during the flight. Below this structure is the heat shade, through a hole in which the rocket nozzle projects.

Two solar panels extend on either side of the basic structure for almost 9 feet. There are also two antennas for communicating with Earth. A low-gain antenna projects almost 10 feet from the top of the basic structure. A high-gain parabolic antenna, 54 inches across, extends to one side and is motor-driven to point towards Earth.

There are also sensors to track the star Canopus and the Sun, and a battery of scientific instruments. Two identical television cameras peer like twin eyes from the top of the structure. Together with an ultraviolet spectrometer, they can be pointed by Earth command. Other instruments are affixed directly to the basic structure and are fixed relative to the spacecraft. Also, booms extend from the basic structure, carrying instruments to measure magnetic fields and the interplanetary plasma of charged particles.

Mariner 10 carries reliable communication radio systems to accept commands from Earth and return scientific and engineering information. The spacecraft also carries a computer so that commands can be accepted by Mariner that will trigger a whole sequence of events, as well as direct commands to perform specific tasks, such as switching on a piece of apparatus.

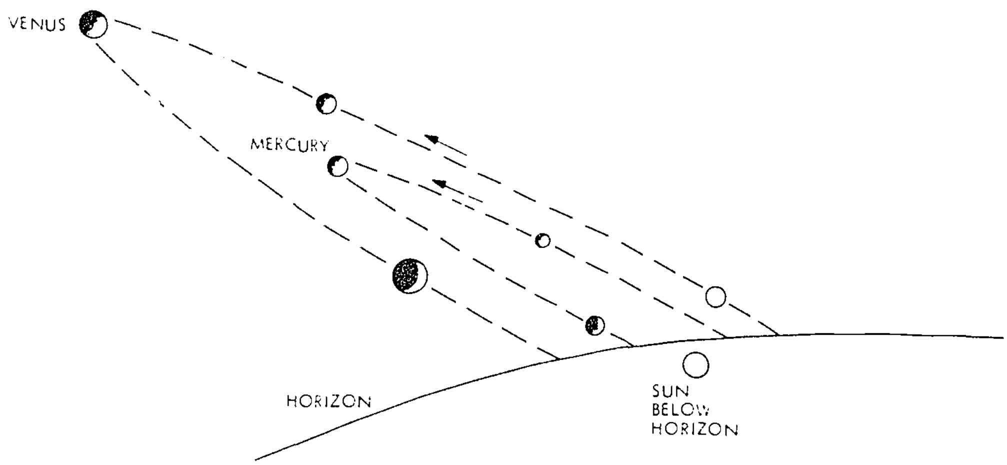


Figure 1. The appearance of Mercury and Venus as evening stars as they travel around the Sun, inside the orbit of Earth.

Because the orbits of these inferior planets are completely contained within the Earth's orbit, both Mercury and Venus pass between Earth and Sun. This is termed inferior conjunction. When the planets are on the far side of the Sun from Earth, they pass through superior conjunction. And because the orbits of the Earth and the two planets are not exactly in the same plane, that is, they are tilted slightly with respect to each other like crossed hoops, Mercury and Venus normally pass through conjunction above or below the Sun. Infrequently the orbits line up so that the planets pass across the face of the Sun in a transit or behind the Sun in occultation. Occultations are not observable because of the brilliance of the Sun, but transits are. (It was Captain Cook's voyage to observe a transit of Venus where it was visible in the South Pacific that lead to his discovering Tahiti.)

Transits of Venus occur very rarely: the most recent occurred in 1882, the next are not due until the beginning of the next century—June 7, 2004, and June 5, 2012 (they occur in close pairs). Transits of Mercury occur much more frequently. One was visible from the East Coast of the United States on November 11, 1973. The next transit will take place on November 12, 1986.

Mercury revolves around the Sun in a period of 88 days, Venus in a period of 225 days. But their visibility in Earth's skies must also take account of Earth's movement around the Sun. So Venus repeats its apparitions (elongations and conjunctions) approximately every 584 days. Mercury repeats approximately every 116 days. But since Mercury's orbit varies much more from a true circle than does that of Venus, the repetition of Mercury's positions relative to the Sun in Earth's skies varies too.

The distance of Mercury from the Sun in the sky at elongation also varies, from only 18 degrees to as much as 27 degrees, and thus affects its visibility. Mercury is a relatively dull object. Like the Moon, it does not reflect much of the sunlight falling on it, so it does not appear very bright in the sky. Moreover, Mercury can rise before the Sun or set after the Sun by only 2¼ hours, so it is rarely seen in a dark sky, but usually only in the twilight glow, low down near the horizon, competing with the sunset. And the planet cannot be seen for much longer than two weeks close to the time of its elongation. There is an average interval of 44 days between Mercury's appearance as an evening and a morning star.

By contrast, Venus can move as much as 47 degrees from the Sun and can be seen in the late evening or early morning skies as the brightest object after the Moon. Venus reflects a large proportion of the Sun's light falling upon it and it appears very bright in the skies of Earth. Venus is brightest about one month before and after inferior conjunction, when a telescope shows it as a fat crescent shape. It can then become so bright as to cast distinct shadows. The planet can be observed for many months and has even been observed through binoculars as it passes above or below the Sun at closest approach. It is also clearly visible in daylight if an observer knows where to look; for example, when the planet appears close to the Moon in the sky. Venus passes from greatest elongation as an evening star to greatest western elongation as a morning star in about 140 days, and from a morning star back to an evening star in about 430 days.

SIGHTINGS AND MOTIONS IN THE SKY

During December 1973, Venus was a brilliant evening star close to the planet Jupiter. Venus passed between Earth and Sun on January 24, appearing above the Sun as seen from Earth's northern hemisphere. Then Venus becomes a brightening morning star through February and March, gradually rising earlier and earlier before sunrise (Figure 2).

Mercury is an evening star observable from the beginning of February through about the third week of that month, then passes above the Sun early in March and becomes a morning star with good elongation from the Sun towards the end of March. Unfortunately, Mercury as a morning star in the spring is not well suited to observation since it is very close to the horizon south of the point of sunrise (Figure 3). It will be in the constellation Aquarius, where there are not many bright stars to help identify the planet.

Venus, too, will be in Aquarius at this time but will be unmistakable because of its brightness, even though it is also close to the horizon.

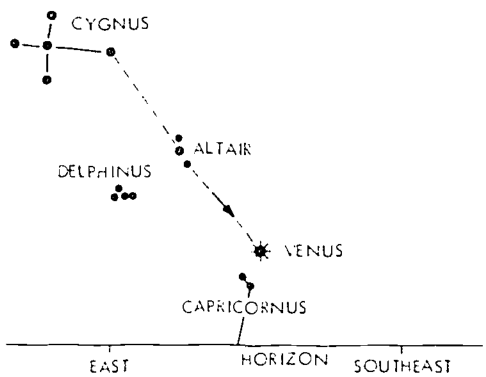


Figure 2. Venus at the day of Mariner 10 flyby (February 5, about 6:30 a.m., Pacific Standard Time).

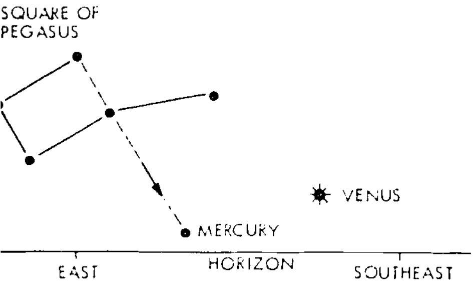


Figure 3. Mercury at the day of Mariner 10 flyby (March 29, about 6:00 a.m., Pacific Standard Time).

fhe comet Kohoutek, visible in late Decem- ɔer and early January close to Venus and lupiter in the evening sky, will still be a faint ɔbject in the evening sky when Venus and Vlercury have become morning stars during -ebruary.

'HASES OF THE INNER PLANETS

\s the inferior planets move around the Sun hey display phases, as seen from Earth, com- ıarable to those of the Moon. When Mercury nd Venus are on the far side of the Sun hey appear fully illuminated like a full Moon, but because of their great distances hey are then unfavorably placed for obser- ation and show only very small discs. At astern and western elongations, Mercury nd Venus appear half illuminated, like half- noons. Then as they swing between Earth nd Sun, the planets display a narrowing rescent phase to Earth until, if they cross he disc of the Sun, they appear as black pots upon it. Most times they pass either lightly above or below the Sun as seen from :arth and thus, in a telescope, can be ob- erved as a fine crescent all the way through nferior conjunction.

;TUDENT INVOLVEMENT

:lassroom Project

lave one student stand in the center of the lassroom (which is preferably semi- arkened) to represent the Sun. Have another tudent stand at the front of the class to re- resent the observer on Earth. Position two ther students to represent Mercury and 'enus, the first almost half way between un and Earth, the second three quarters of the way. Have these two students hold a white styrofoam ball, big enough for other students to see (about 4 inches in diameter for a medium-sized class).

The student representing the Sun shines a flashlight on the globe representing Mercury, and the Earth observer, standing close to a blackboard, draws what he sees, a dark globe. The student Mercury then moves part way round to the side of the class as though orbiting the Sun. Again the flashlight is shone on the globe from the Sun, and the Earth student now draws the half-lit planet he sees.

The Venus student demonstrates likewise, then the class is asked to draw the visible illuminated shapes of Venus and Mercury as these planets move around the Sun as seen from Earth, at closest approach to Earth, at greatest elongations, and when most distant from Earth.

Student Project One

Early in January, look at the evening sky when it starts to become dark after sunset. The Sun sets in the southwest. Look left from the sunset point, and close to the horizon there will be a fairly bright star, which is the planet Venus. If you have access to a small telescope or very good field glasses you will be able to see that it is shaped like a tiny, very fine crescent Moon. If Comet Kohoutek is still a bright object, Venus will be between the head of the comet and the point on the horizon where the Sun set. In the following days, observe how Venus moves deeper and deeper into the sunset glow until it finally disappears.

About the first week in February, get up before sunrise and look for Venus in the morning skies before the Sun comes up and while the sky is still fairly dark. Try to see Venus on February 5, since this will be the day when the Mariner spacecraft flies past the planet.

Continue to observe Venus in the following weeks and watch how it moves further from the sunset glare and becomes brighter day by day. If you have access to a telescope observe, too, that it is now a crescent facing opposite to the way it faced when it was an evening star.

Around mid-March, start looking for Mercury, a very faint star-like object in the morning sky between Venus and the point of the sky where the Sun will rise. Try to see Mercury on March 29, the date Mariner flies past Mercury, and you will be able to compare what you see in the sky, a faint star-like object, with the close-ups of a possibly Moon-like cratered world seen on the television newscasts that evening.

On this date, Mercury will be about one-third of the way between Venus and the Sun but below the direct line between Venus and Sun. Of course you will not be able to see either when the Sun is in the sky unless you observe with a precisely pointed astronomical telescope, so you will have to estimate where the Sun is below the horizon.

Student Project Two

This can also be a classroom project on the blackboard. Refer to an astronomical textbook and draw a plan map of the solar system showing the orbits of Mercury, Venus, and Earth. Try to draw them to scale, and note that Mercury's orbit seems offset to one side of the Sun. Then try to work out where the Earth and the two planets must be to be seen in the sky as they are. Remember, as seen from above (north), Earth rotates on its axis and all the planets revolve around the Sun in a counterclockwise direction. Remember, too, that Venus moves between Earth and Sun on January 24 and Mercury between Earth and Sun around February 25. Plot points on the orbits every ten days working backwards and forwards from the times of conjunction. Save your solar system plan map for a later exercise.

READING LIST

G. O. Abell, *Exploration of the Universe*, Holt, Rinehart and Winston, New York, 1964, pp. 23-26 (orbits).

J. H. Wilson, *Mariner Venus Mercury 1973*, Technical Memorandum 33-657, Jet Propulsion Laboratory, Pasadena, California, October 15, 1973.

L. Rudaux and G. De Vaucouleurs, *Larousse Encyclopedia of Astronomy*, Prometheus Press, New York, 1959.

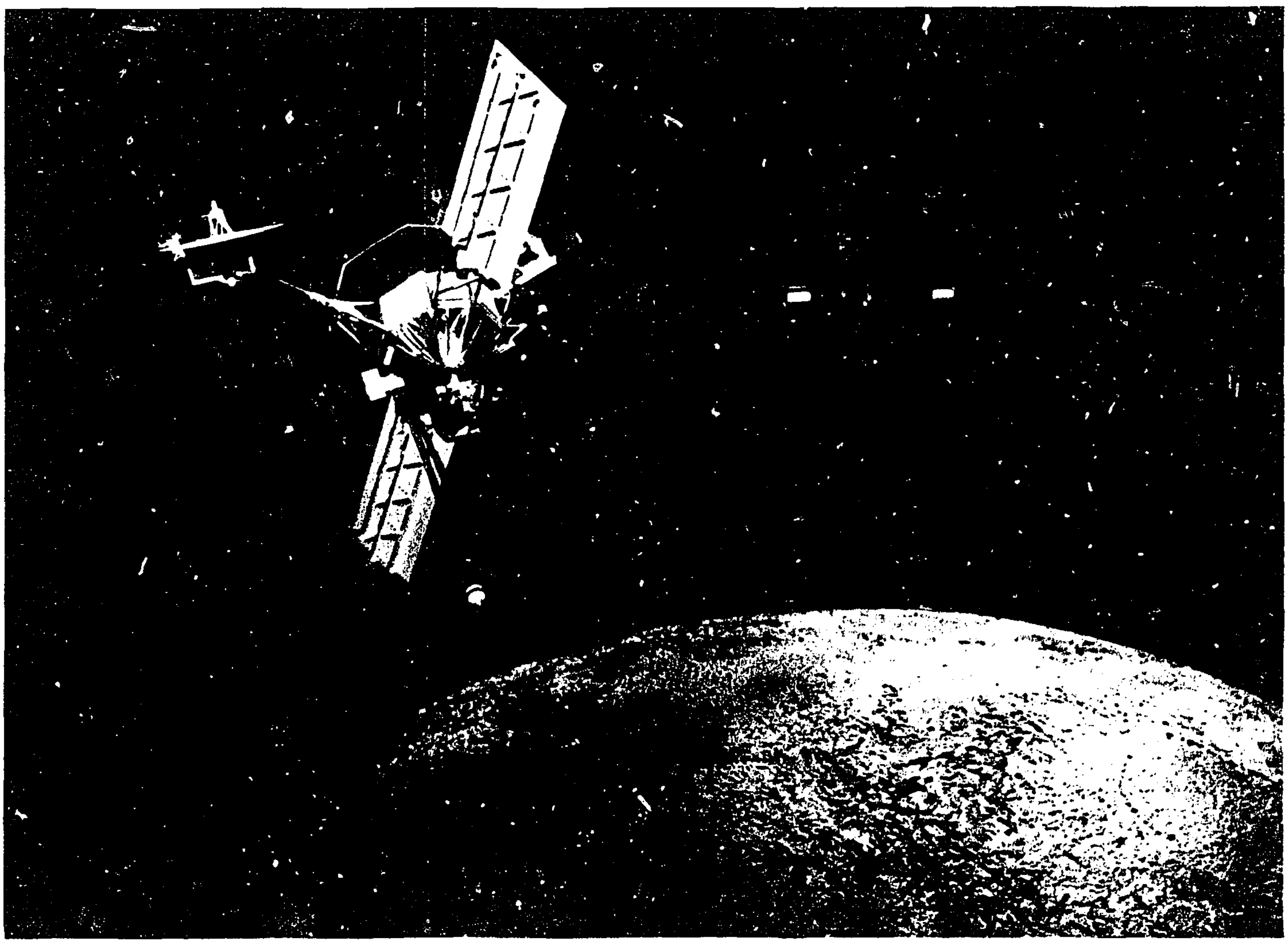
P73-219 JPL 654 4.5M 1-74 PRINTED IN U.S.A.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

THE NOW FRONTIER

LINKING EARTH AND PLANETS

Venus and Mercury Encounters



JET PROPULSION LABORATORY
CALIFORNIA INSTITUTE OF TECHNOLOGY
PASADENA, CALIFORNIA

ISSUE NUMBER FOUR
PUBLIC EDUCATIONAL SERVICES OFFICE

ERIC

ENCOUNTERING THE PLANETS

At 8.57 a.m. PST on February 5, 1974, Mariner 10 will speed past Venus only 3000 miles above the brilliant cloud tops and six minutes later disappear behind Venus. Communication with the spacecraft will then be lost for 21 minutes until Mariner emerges on the other side of the planet.

For several weeks around that date, teams of spacecraft controllers, engineers, analysts, and scientists will be running a 24-hour-a-day, three-shift operation, inspecting engineering and scientific information pouring in from the spacecraft and commanding and controlling its actions. The solar panels are tilted at increasing angles from the Sun to protect them from the greater intensity of the sunlight, and the necessary corrections are made in the trajectory.

Mission Operations System activities are centered in the Mission Control and Computing Center at the Jet Propulsion Laboratory and make use of a widespread ground data system consisting of facilities spread around the world as a part of the tracking and data system network.

Information from the spacecraft is presented to flight controllers as quickly as it is received and processed by the computers; this is almost as the events happen. The only real delay is the time—several minutes—taken for the radio waves to travel from Venus and Mercury to Earth. Television pictures of the planets are displayed on monitors similar to home television sets so that the scientists can quickly see the quality of the information coming from the spacecraft.

Computers back up the men and women at the Mission Control and Computing Center. Many computer programs are available for quick instructions to the spacecraft. For example, suppose a scientist sees something interesting on a picture returned from Mercury, an unusual crater or a volcanic cinder cone or a sinuous valley, he can call for a computer program that will generate instructions to the spacecraft camera pointing system to photograph this area again despite the rapid movement of the spacecraft and the rotation of the planet.

About 120 persons are involved in operating the spacecraft to ensure the success of the mission by keeping the spacecraft performing as it should and directing it to make the experiments required by the project scientists.

The men and women of the project have to be on the alert every second of the encounter, ready to issue correcting commands to right any problems that might arise in the spacecraft and around the worldwide data gathering net. Communications are maintained with the spacecraft at all times, 24 hours each day. As the spacecraft sets over the tracking station at Goldstone in California's Mojave Desert, it is rising for the station at Canberra, Australia. And as it sets at that station it comes into view at the next station, near Madrid, Spain. Then it is handed back to Goldstone. Antennas the size of football fields gather the incoming signals and pass the information to the control center at the Jet Propulsion Laboratory in Pasadena, California.

ENCOUNTER SEQUENCES

The first encounter is with a comet, but this is not a close encounter, since Comet Kohoutek has swung around the Sun away from Mariner. Nevertheless Mariner has the opportunity of inspecting the comet from space, photographing its head and probing it with the ultraviolet instrument. And because Mariner 10 looks at the comet at a different angle from observers on Earth, photographs can be obtained simultaneously from Earth and Mariner that provide two views of the comet, a stereo pair. These two photographs, when looked at together—one with the right eye and the other with the left in a special viewer—will let scientists see an unprecedented three-dimensional view of the comet.

Comet Kohoutek will be observed from Mariner during the period January 17 through 25, 1974. The ultraviolet airglow instrument of Mariner 10 inspects the coma (the hazy head of the comet) and the comet's long tail about January 17. Picture mosaics of Kohoutek will be obtained on January 19, 22, and 25. Four television pictures will be taken every hour for 9 hours on each of these days.

The second encounter is with Venus (Figure 1). Mariner approaches Venus from the night side of the planet. Viewing is thus unfavorable for photographs, since the cloud tops are shrouded in darkness. Moreover, since the spacecraft is in an attitude to screen its instruments from the intense radiation from the Sun, its sunshade obstructs a view of Venus. The cameras on the spacecraft do not get a glimpse of Venus until about 28 minutes before closest approach to the planet (Table 1). This opportunity may be taken to obtain photographs of the pointed ends of the crescent shape seen from Mariner, the cusps of Venus. These ends are important because the atmosphere causes them to be illuminated into the dark hemisphere, and from the observations scientists can obtain more information about the composition and structure of the Venusian atmosphere.

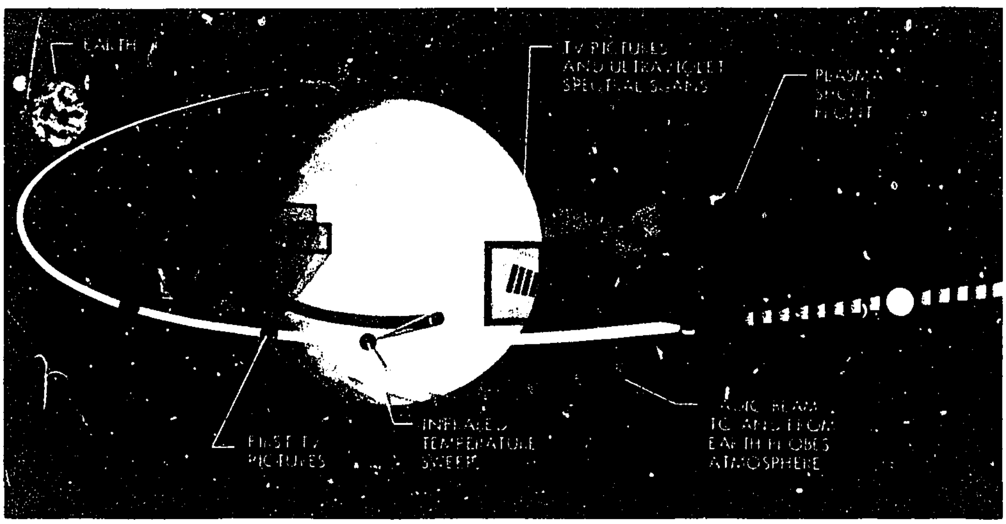


Figure 1. An artist's conception of the Mariner 10 encounter with Venus. The antennas on the Earth, of course, are not drawn to scale.

Cover: An artist's conception of Mariner 10 as it approaches the planet Mercury.

Some information collected by the spacecraft can be stored on magnetic tape within it and transmitted later. This permits the spacecraft to collect data when it is hidden from Earth behind a planet and later to send this data when it emerges.

The Mariner 10 spacecraft weighed 1042 pounds at launch, including 64 pounds of rocket fuel and nitrogen gas.

A requirement for this new spacecraft is to transmit much more information back to Earth than earlier flyby spacecraft during the brief periods of encounter with the two target planets. So the rate at which information is transmitted over the radio links has been increased. This is like talking faster on the telephone if you want to describe as much as possible about an event as it actually happens.

This higher data rate, as it is termed, permits Mariner to send back more live pictures of the planets as it flies past them.

Another requirement for the mission was to ensure very accurate flight. Because the spacecraft uses the gravity of Venus to swing it on a path to Mercury, small errors in its approach to Venus would be magnified a thousand times at Mercury unless corrected by the rocket engine of the spacecraft. But since project scientists want to conserve as much fuel as possible so that they can command the spacecraft into other maneuvers after it passes Mercury, the spacecraft has to be aimed as accurately as possible in the early stages of flight. Even so, four corrective thrust periods are planned: the first just after leaving Earth and Moon, the second just before arrival at Venus, the third after flying by Venus, and the fourth before arrival at Mercury.

Three further maneuvers are needed to bring the spacecraft back to Mercury again (September 1974) 6 months after the first pass. And if there is propellant left, a third pass by Mercury could be attempted 6 months later (March 1975).

The success of all these maneuvers relies upon controllers having accurate knowledge about the speed of the spacecraft and its position along its path, as well as the direction of its path. Such information is obtained by tracking the spacecraft from ground stations at Goldstone, in the Mojave Desert, California; in Spain; and in Australia. The three tracking stations pass information to a control center at the Jet Propulsion Laboratory in California where navigation specialists, aided by powerful computers, determine the exact position and speed of the spacecraft. Computers predict where the spacecraft is headed. Navigators decide on changes, and mission controllers send commands to the spacecraft to make the necessary changes in its path.

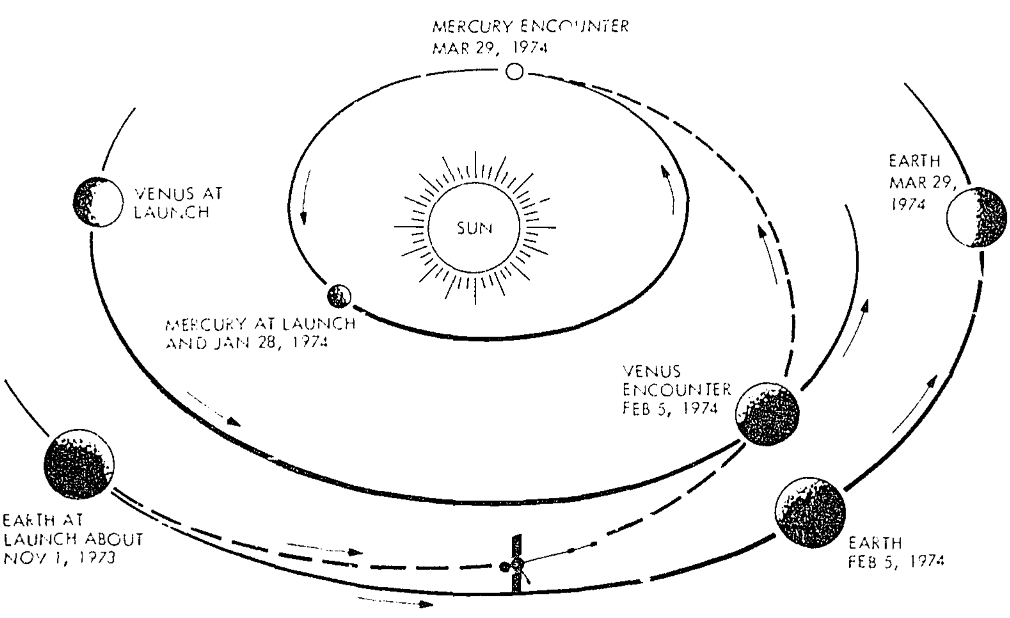


Figure 2. The Mariner 10 flight path to Venus and Mercury.

Arrival times and distances have to be arranged precisely so that instruments can not only photograph the target planets at required angles and covering specified areas, but also look at the planets at infrared and ultraviolet wavelengths and make other experiments.

For all these tasks, timing is extremely critical because of the short time that the spacecraft is near the planet.

Mariner 10 follows a curved path to Venus (Figure 2), going about one-quarter of the way around the Sun before it meets with the planet. When this path is bent by the gravity of Venus, it curves more steeply towards the Sun. The spacecraft then follows the new path for about another quarter of the way around the Sun until it meets with Mercury.

If the spacecraft were not slowed by the gravity of Venus—by the way in which it is directed to fly past that planet—its speed would be too high to allow the gravitational field of the Sun to pull Mariner to the orbit of Mercury. Without the aid from the gravity of Venus, the path of Mariner would dip only slightly inside the orbit of Venus, and to reach Mercury by a direct launch without a gravity assist from Venus would require a larger, more expensive launch vehicle or a lighter payload that could include only a few scientific experiments.

After encounter with Mercury, Mariner 10 zooms outwards again and crosses the orbit of Venus, but Venus is far away on its orbit. Later, Mariner 10 moves back to Mercury's orbit and now it is lucky. Mercury has made two circuits of the Sun while the spacecraft made one. Mariner meets Mercury for the second time. And if sufficient propellant remains in the spacecraft, a third rendezvous can be made with Mercury the next time around the spacecraft's orbit.

WHAT THE SPACECRAFT DOES

Mariner 10 is designed to investigate Mercury and Venus in several ways:

(1) Measure particles, fields, and radiation from the planets and their environs.

(2) Televise pictures of the planets with great detail to show cloud structure on Venus and the surface structure of Mercury (Figure 3).

(3) By ground-based observations of the path of the spacecraft, measure the gravity field of Venus and Mercury, their sizes, and their masses.

(4) By observations of the radio signals coming from the spacecraft as it goes behind Venus and Mercury as seen from Earth, determine the structure of the Venus atmosphere and check whether Mercury has a tenuous atmosphere of any kind.

In addition, the spacecraft also provides information on the interplanetary space from Earth's to Mercury's orbit, and on how the planets interact with this interplanetary environment.

To perform these tasks, Mariner 10 uses a battery of scientific instruments. A magnetometer measures magnetic fields, a plasma analyzer measures the ions and electrons flowing through space from the Sun (the solar wind), cosmic ray telescopes study solar and galactic cosmic rays. The main objective of all of these instruments is to learn about the planets by studying their effects on the interplanetary environment, such as magnetic tails and bow shocks connected with them.

An infrared radiometer (heat measurer) measures temperatures of the clouds of Venus and the surface of Mercury. Two independent ultraviolet instruments (measuring light beyond the violet of the spectrum) analyze the planetary atmospheres. One instrument is fixed to the body of the spacecraft and is used at Mercury to search for traces of atmosphere along the edge of the planet's disc. A scanning instrument can be pointed on command. This is used to scan the entire discs of the planets, searching for evidence of hydrogen, helium, argon, neon, oxygen, and carbon. Close to Earth, this same instrument measured the hydrogen corona of the Earth and the reflective properties of the Moon. At Venus both instruments search for specific gases, and during the cruise phase they look for sources of radiation coming from hot stars and nebula (or gas clouds) in the galaxy.

A complex of two television cameras with eight filters, capable of taking both narrow and wide angle pictures, photographs Earth and Moon (for comparison purposes) and Venus and Mercury. Mounted on a platform, the complex is directed by command from Earth. As well as taking pictures in different colors of light, these cameras also reveal how the light is vibrating (its polarization). Such observations reveal information on the composition of the clouds of Venus and the surface of Mercury.

A radio experiment uses the signals transmitted from the spacecraft to Earth. By tracking the spacecraft's signals, experimenters determine how the spacecraft is affected by the gravitational fields of the planets. From this information they may determine the shape of each planet and determine whether there are any concentrations of mass that distort the gravitational field, like the mascons (mass concentrations) discovered beneath the maria of the Moon. By analysis of what happens to the radio signals as they pass close to the edge of the planet when the spacecraft goes behind the planet as seen from Earth, experimenters probe the atmosphere of Venus to determine its characteristics and constituents and to check for any tenuous atmosphere of Mercury. If one is detected, its characteristics will also be determined.

To take full advantage of the Venus occultation, which will bend the radio signals appreciably, an antenna on the spacecraft is steered so as to partially compensate for the bending. In this manner, information can be obtained to much deeper levels of the Venusian atmosphere.

A project of NASA's Office of Space Science, the Mariner 10 project is managed by the Jet Propulsion Laboratory of the California Institute of Technology, Pasadena, California. The spacecraft was built by The Boeing Company, Seattle, Washington. Tracking is by NASA's Deep Space Network, operated by the Jet Propulsion Laboratory. The scientific instruments are supplied by NASA centers, universities, and private industry.

STUDENT INVOLVEMENT

Student Project One

On the map of the solar system, made as a project for leaflet No. 1 of this series, draw the path of Mariner 10. Work backwards from the encounter with Mercury and Venus on March 29 and February 5 respectively, using Figure 2 as a guide to find the position of the Earth at launch. Remember Earth goes around the Sun in 365¼ days, Venus in 225 days, and Mercury in 88 days. Mark positions on all orbits at 10-day intervals. Allow for the fact that Mercury moves slightly faster when on the parts of its orbit closer to the Sun than when most distant from the Sun. The most distant part of Mercury's orbit is approximately where Mariner encounters the planet. Venus' speed is almost constant, and so is the Earth's, since both move on almost circular orbits.

Student Project Two

In an earlier pamphlet it was stated that an observer on Venus would appear to be standing in a huge bowl as though in a hollow planet with clouds in the center. Use your imagination and produce an illustration, a drawing or painting, of what it would be like if you could stand on Venus in some kind of space suit that would protect you from the enormous pressure at the bottom of the carbon dioxide atmosphere. Radar indicates that the surface is gently undulating in parts with some rough surface and some large shallow craters.

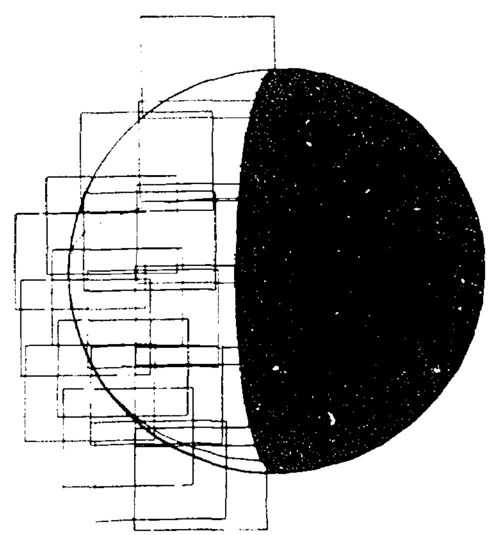


Figure 3. A photographic mosaic of Mercury is expected to be obtained from overlapping photographs of the planet.

READING LIST

J. H. Wilson, *Mariner Venus Mercury 1973*, Technical Memorandum 33-657, Jet Propulsion Laboratory, Pasadena, California, October 15, 1973.

P73-219 JPL 654 4.5M 1-74 PRINTED IN U.S.A.