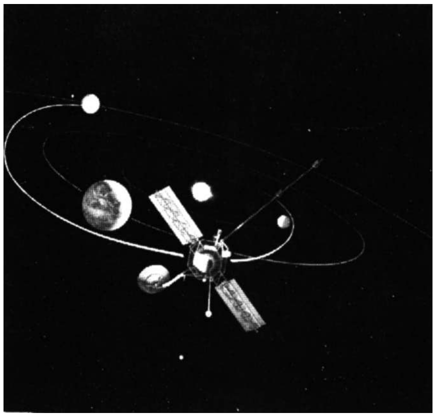

MARINER VENUS / MERCURY 1973
STATUS BULLETIN

Preliminary Science Results of Venus Encounter

VENUS MAGNETOMETER SUMMARY

Dr. James A. Dunne, Jet Propulsion Laboratory

The NASA Goddard Space Flight Center Magnetic Field instrument consists of two very sensitive magnetometers placed on a long boom. The purpose of the dual magnetometer system is to eliminate by appropriate mathematical analysis the contamination of measurement of the very weak magnetic field in space by the large and changing magnetic field of the spacecraft itself. The experiment has functioned extremely well since launch. During the Earth-Venus transit continuous and accurate measurements of the interplanetary magnetic field were performed with the highest sensitivity and most rapid sampling rates ever achieved in this region of space. While the interplanetary magnetic field ranged from 2 to 25 gammas (Earth's magnetic field at equator equals 30,000 gammas) it was usually between 5 to 10 gammas and in general agreement with earlier studies and theoretical expectations.

The trajectory of Mariner 10 is uniquely well suited for studying the inter-action of the magnetized solar wind plasma with Venus. This is because the motion of the spacecraft places it along the dark side of Venus for a period of more than 10 days moving from great distances up to closest approach.

For more than 6 days preceding the Venus encounter, the magnetic field experiment has observed distortion of the interplanetary magnetic field in which the direction is twisted so that the magnetic field appears to be pointing towards the planet Venus. This is interpreted to be associated with the interaction of the solar wind with the ionosphere of Venus and thus there is a magnetic tail trailing behind Venus much like a comet's tail. During the 5 hours immediately preceding closest approach the fluctuations of the magnetic field increased considerably and just before radio occultation the magnetic field doubled in magnitude from approximately 10 to 20 gammas. The critical questions of whether or not a detached bow shock wave was crossed or not cannot be answered until the radio occultation data are available for analysis and a comparison is made with the plasma experiment data.

However, it is certain that Venus does not possess a magnetic field like the Earth and indeed any such magnetic field must be less than one-twentieth of one percent of the Earth's magnetic field.

The physical processes involved in deflecting the solar wind plasma by the ionosphere of Venus are of a new type, quite unlike that associated with the Earth, Jupiter, Moon, or Mars. The results obtained are generally consistent with earlier U.S.A. and U.S.S.R. studies, but the significant differences will be associated with the analysis of the long interval of data preceding closest approach along the unique trajectory of Mariner 10 and the substantially higher performance of the instrument and the spacecraft telemetry system.

The magnetic field experiment is conducted by a team of investigators from the NASA Goddard Space Flight Center Drs. K. W. Behannon, R. P. Lepping, N. F. Ness, Professor Y. C. Whang, of Catholic University, Professor K. H. Schatten at Victoria University, Wellington, New Zealand.

PLASMA SCIENCE EXPERIMENT SUMMARY

Dr. Herbert S. Bridge, Massachusetts Institute of Technology

From the results of Plasma and Magnetic field experiments carried on the Mariner 5 Venus mission it is known that the solar wind flow near Venus is greatly modified by the presence of the planet. It is generally believed that the solar plasma interacts with the ionosphere of Venus so that a bowshock is formed upstream from the planet (on the sunward side) and that a transition region of modified plasma flow exists between the bow shock and the ionosphere. In the transition region, the flow velocity of the plasma is lower and the particle density is higher than the corresponding values in the undisturbed plasma stream far away from Venus.

The trajectory of Mariner 10 during the near encounter period (out to 10 Venus radii) was expected to lie completely within the transition region. It can be predicted that the plasma density should increase smoothly along the trajectory up to a maximum value at the point where Mariner 10 passed through the bow shock; just after the bow shock the density should drop sharply.

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Jet Propulsion Labratory California Institute of Technology
National Areonautics and Space Administration
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We have plotted values of the plasma density observed by Mariner 10 near Venus encounter as a function of time and find that they do increase as expected up to a maximum value at about the predicted position of the bow shock and then decrease abruptly. The position of maximum density occurs close to the time at which real time data transmission ceased and so a detailed analysis of the shock crossing must wait until the playback data has been received.

For several days prior to Venus encounter, the properties of the plasma observed by Mariner 10 are distinctly different from the properties of the undisturbed solar wind. The results show clearly that Venus has a long plasma wake or tail which extends roughly in the antisolar direction away from the planet. Mariner 10 is the first spacecraft to approach Venus from this direction; thus this is the first time the "plasma tail" of Venus has been observed.

ULTRAVIOLET SPECTROMETER EXPERIMENT

Dr. A. Lyle Broadfoot,
Kitt Peak National Observatory

Hydrogen is an important element of Venus' atmosphere which can potentially shed light on the origin and evolution of the planet. The Earth's atmosphere evolved slowly over geologic time, leaking out of the crustal rock in hot springs and volcanoes. The major gases emitted by Earth were H_2O, CO_2 and N_2 with relative abundances given by the approximate ratios of 40: 1: 0.03. Terrestrial H_2O is found mainly in the oceans. CO_2 is precipitated as carbonates. N_2 remains in the atmosphere .

If the gases trapped by Venus were similar to those observed on earth, we might expect that the primitive Venus should have had an exceedingly dense atmosphere, characterized by a surface pressure of about 1,000 atm, with a CO_2 abundance comparable to that observed today— a partial pressure of about 90 atmospheres. The water would have been efficiently dissociated by ultraviolet sunlight and its hydrogen could have escaped into interplanetary space, leaving oxygen to be absorbed by crustal rocks.

There are, however, other possible explanations for the present hydrogen abundance of Venus. Venus could have acquired its hydrogen in a chance impact with a large cometary nucleus—a celestial snowball. Alternatively, Venus could have built up its hydrogen inventory by steady accretion from the solar wind. Incident protons can transfer charge with constituents in the outer atmosphere of Venus, in the process becoming electrically neutral, and subsequently impacting the planet. The UVS experiment expects to clarify the relative roles of these various processes. The various sources provide characteristic records of their influence. Cometary nuclei are expected to be rich in heavy dydrogen, deuterium. If comets represent a major supply of hydrogen, Venus should be enriched in deuterium relative to hydrogen. Mariner 10, in contrast to data obtained in the earlier mission of Mariner 5, shows no evidence for deuterium on Venus. The Lyman alpha data are consistent, however, with a possible solar wind source for hydrogen. The sun consumes deuterium in nuclear reactions which occur in the solar interior. Much of the sun's original deuterium inventory has been depleted over 5 billion years and the concentration of deuterium in today's solar wind is immeasurably small.

The study of Venus' hydrogen is important for several reasons: Hydrogen, despite its low abundance, controls the chemistry of Venus' atmosphere. If Venus were to exhaust its present supply of hydrogen, we would expect atmospheric CO_2 to be rapidly converted to O_2 and CO. Hydrogen is thought to be a major element of the Venus' cloud deck, present in the droplets of sulphuric acid (H_2SO4) as well as water vapor. The ultraviolet experiment will define and refine the processes which regulate Venus' hydrogen. The profile of Lyman alpha can be analyzed to give the temperature of the outer atmosphere. Preliminary analysis suggests a temperature of about 600 degrees F. The escape rate of hydrogen from Venus is smaller, by more than a factor of 10, than escape rates measured for the Earth.

Other major achievements of the Mariner 10 UV experiment can be summarized as follows:

Helium is an important trace element of the atmosphere. Its presence is clearly registered in the airglow emission observed at 584 Å.

The upper atmosphere of Venus contains important quantities of atomic oxygen. The emission at 1304 Å is stronger by about a factor of 10 than that measured by Mariner 9 for Mars. The large concentration of oxygen in Venus' atmosphere may indicate a comparative absence of rapid vertical mixing in that planet's upper atmosphere and may shed light on the dynamical processes which influence the composition of all planetary atmospheres.

Atomic carbon is a significant trace element of Venus' atmosphere formed as a photochemical product of energetic processes involving CO_2 .

CHARGED PARTICLE TELESCOPE

Dr. James E. Lamport, University of Chicago

The Charged Particle Telescope Experiment was designed by Professor John A. Simpson and the staff of the Laboratory for Astrophysics and Space Research to measure energetic particles (electrons, protons, helium, and heavier nuclei), in interplanetary space as well as to search for fluxes of such particles which might be accelerated as a result of the interaction of Venus with the solar wind. It is designed to detect electrons with energies above 0.5 million electron volts.

The experiment has remained very stable sinch launch as evidenced in its weekly self calibration.

For at least three days prior to and during the Venus encounter, the conditions in interplanetary space have been unusually quiet, thus providing the best possible conditions for the search for energetic particles associated with Venus.

Except for the period of spacecraft occultation for which data are not yet available, there have been no planet-associated fluxes detected in the preliminary data received, thus indirectly establishing a new upper limit for the magnetic moment of Venus which is about a factor of three (3) less than that previously reported by the Mariner Charged Particle measurements in 1967.

CELESTIAL MECHANICS AND RADIO SCIENCE EXPERIMENT

Dr. H. Taylor Howard, Stanford University

This experiment was conducted by a team of principal investigators from three institutions:

H. T. Howard—Team Leader	Stanford University
J. D. Anderson	JPL
G. Fjeldbo	JPL
A. J. Kliore	JPL
G. S. Levy	JPL
I. I. Shapiro	MIT

It was performed exactly as planned and the analysis effort is well under way.

The Mariner 10 experiment is a new one in that it transmits two frequencies from the spacecraft to Earth. It has both scientific and technological goals using both S- and X-band signals.

The prime scientific goals center around the planetary ionospheres, atmospheres, gravity fields, and masses. The technological goals are pioneering ones designed to open new communication channels for the deep space probes of the future. At this point in the mission it can be said that both goals are within our reach.

The key Celestial Mechanics questions about Venus concern the shape of the planet and the intensity and structure of the gravity field. The analysis under way at two this morning has revealed that we have close to our hands the most refined measurement of the mass of Venus and for the first time a good picture of the details of its gravity field and harmonic structure. This was regarded as a marginal experiment in our early planning but became a very strong one as the true nature of Mariner 10's radio system became apparent during the week before encounter.

The prime interest of the Radio Science experiment centers around the structure of the ionosphere and atmosphere of the planet. It is certainly an unusual atmospheric structure having a high cloud deck in the 60 km above the surface region and a lower one extending from approximately 35 to 52 km. The combination of Mariner 5, Russian, and astronomical results suggests that the upper cloud layer is thin, broken and, while rapidly moving, stable in its configuration. The lower one is dense, thick and perhaps highly absorbing to radio waves of high frequency.

Thus the radio experiments were designed to use two frequencies and clearly measure the differential absorption in these layers in an attempt to sort out the many theories of their formation and constituency. The answer perhaps holds the key to the origin and evolution of Venus.

Mariner 10 provides for the experiment particularly well in that its high gain transmitting antenna is fully articulated and driven by an onboard computer. Using our team's previous knowledge of the Venus atmosphere and the Navigation team's precise knowledge of the spacecraft position relative to the planet, JPL and Boeing engineers were able to program Mariner's computer so that the high gain antenna was directed to point throughout occultation in such a way that Venus' atmosphere would always bend the radio signal toward Earth.

This program, known as the "Teadrop" worked perfectly and will, like the X-band radio system, become an integral part of all new outer planet missions.

The attached figure shows the S-band signal as Mariner 10 approached the planet and went into occultation. The frequency scale is relative to the nominal 2295 MHz signal transmitted by the spacecraft. If the spacecraft were receding from the Earth at a uniform velocity the downward trend would be a straight line. It, however, is being accelerated by Venus gravity field and the downward trend is ever increasing causing curvature. Suddenly as the Mariner 10 radio signal hits the atmosphere the frequency reverses direction and at the same time begins to fade away. The spacecraft high gain antenna under computer control is now steering to keep the Earth in focus. Very quickly the spacecraft goes behind the planet but the signals remain locked on to by the Earth receivers. About six minutes behind the planet Mariner 10's receivers lose lock of the signal transmitted from Earth and the spacecraft switches to its backup oscillator. Since its frequency is different from what we had been seeing on Earth the ground based receivers lose lock—but they pick it up in less than a minute and track it for an additional 30 seconds.

At the same time these signals are being received by some receivers which do not lock on but instead record all the frequencies of interest. These are called the "open loop" receivers. The penalty paid for recording everything is the necessity to later computer process the data. It is slow, but very detailed and completely adaptable. There is no error induced terror, for the computer can "fly by" the planet as many times as you ask it to. We are now flying by again and it is safe to say that we can penetrate deeply into the lower cloud deck at both frequencies and will soon be able to provide accurate differential absorption profiles and temperature profiles.

There are several preliminary results of interest. First we have seen the dayside ionosphere of Venus confirming the Mariner 5 results. Second we know that the "closed loop" quick look S-band signal penetrated to an altitude of 45 km above the surface of Venus while the X-band signal suffered an entirely different fate: At an altitude of 52 to 53 km it disappeared. This is the top of the lower cloud layer and the suggestion is that the layer is highly absorbing to our signal at 8415 MHz. Analysis of this differential absorption is proceeding at the fastest possible rate. The analysis requires large computational power and time.

The mass derived from the Mariner 10 data is slightly less than that gleaned from Mariner 5. The data quality is so high that our knowledge of Venus' mass will improve by a factor of 2 to 5—thus increasing the accuracy to equal that of the Earth's mass determination. Further it is now apparent that Venus is distinctly circular as compared to the Earth—about 100 times less oblate.

The final results are going to be basically new inputs to our understanding of Venus—her body and her clothing. Her body? Why does she always present the same face to us at closest approach? Her clothes?—anybody with that much on must have a lot to hide.

INFRARED RADIOMETER EXPERIMENT SUMMARY

Dr. Ellis D. Miner, Jet Propulsion Laboratory

The Mariner 10 Infrared Radiometer (IRR) has obtained a thermal profile across Venus at a resolution at least a factor of three greater than any observable from Earth. This measurement should be of interest for the determination of the structure of the Venus atmosphere near the cloud tops. However, we emphasize that this IRR experiment was designed primarily to measure the thermal radiation from the surface of Mercury, and it was not therefore optimized for the study of Venus.

The IRR measures temperatures in two broad infrared wavelength bands, centered near 11 and 45 micrometers. The shortwave (11 micrometer) channel is specifically designed to measure temperatures up to 700°K (about 800°F), the maximum temperature expected for the surface of Mercury, and it is quite insensitive at temperatures below 300°K (80°F). Since the temperature at the cloud tops of Venus is in the vicinity of 240°K (-30°F), this shortwave channel is not useful for study of this planet, and only high-quality temperature measurements were obtained with the longwave (45 micrometer) channel of the IRR.

The IRR obtained one temperature profile across Venus in the 20 minutes before closest approach, scanning from the night side of the planet into the illuminated hemisphere. As expected, there was not detectable difference in temperature between the day and night sides at the level in the atmosphere measured by the IRR. The measured brightness temperature at 45 micrometers extrapolates to 250°K (-12°F) for vertical viewing angles, where one expects to see radiation that originates at relatively deep levels of the atmosphere. At oblique viewing angles, the IRR sees less deeply into the clouds, and we sample radiation that arises in higher and cooler layers of the atmosphere. The temperature measured at a viewing angle of 75° from the vertical (very near the apparent edge of the planet) is approximately 220°K (-64°F).

The rate at which the emitted energy declines (thermal limb darkening) as we observe at larger viewing angles is substantially less than that measured with ground-based telescopes at shorter wavelengths in the infrared, primarily near 10 micrometers. Both the higher resolution of these new observations and the fact that they are obtained at a wavelength where the opacity of the Earth's atmosphere makes ground-based observations impossible, contribute to their usefulness for further investigation of the nature of the atmosphere of Venus in and above the clouds.

In view of the excellent performance of the IRR instrument in the Venus flyby, we look forward to the observations of our primary target, Mercury, in seven weeks.

SCHEDULED VENUS ENCOUNTER SEQUENCE OF EVENTS

Day 39—Friday, 8 February 1974

Continue cyclic 2 TV. Average resolution: 58 kilometers. Thirteen 18-frame taped TV mosaics. Playbacks, at rate of one picture every 3 3/4 minutes, start at 24:25 PDT, 02:10, 04:00, 05:35, 07:25, 09:10, 11 :50, 13:40, 15:25, 17: 10, 18:55, 20:40, and 22:20. Total frames: 234.

Tracking coverage is approximately the same as 7 February.

07:30 PDT — UVS airglow far encounter scans.

Day 40—Saturday, 9 February 1974

Continue cyclic 2 TV. Fourteen 18-frame taped TV mosaics. Playbacks start at 24:10 PDT, 01:50, 03:35, 05:25, 07:05, 08:35, 10:25, 12:10, 14:00, 15:40, 17:25, 19:10, 21:00, and 22:40. Total trames: 252.

07:30 PDT — UVS airglow far encounter scans.

Day 41—Sunday, 10 February 1974

Continue cyclic 2 TV.

16:00 PDT — Update spacecraft computer to load and enable 3rd trajectory correction maneuver (TCM-3).

Day 42—Monday, 11 February 1974

02:38 PDT — Tilt +x axis solar panel to 45 degrees.

03:38 PDT — Tilt -x axis solar panel to 45 degrees.

11:05 PDT — Execute 3rd trajectory correction maneuver.