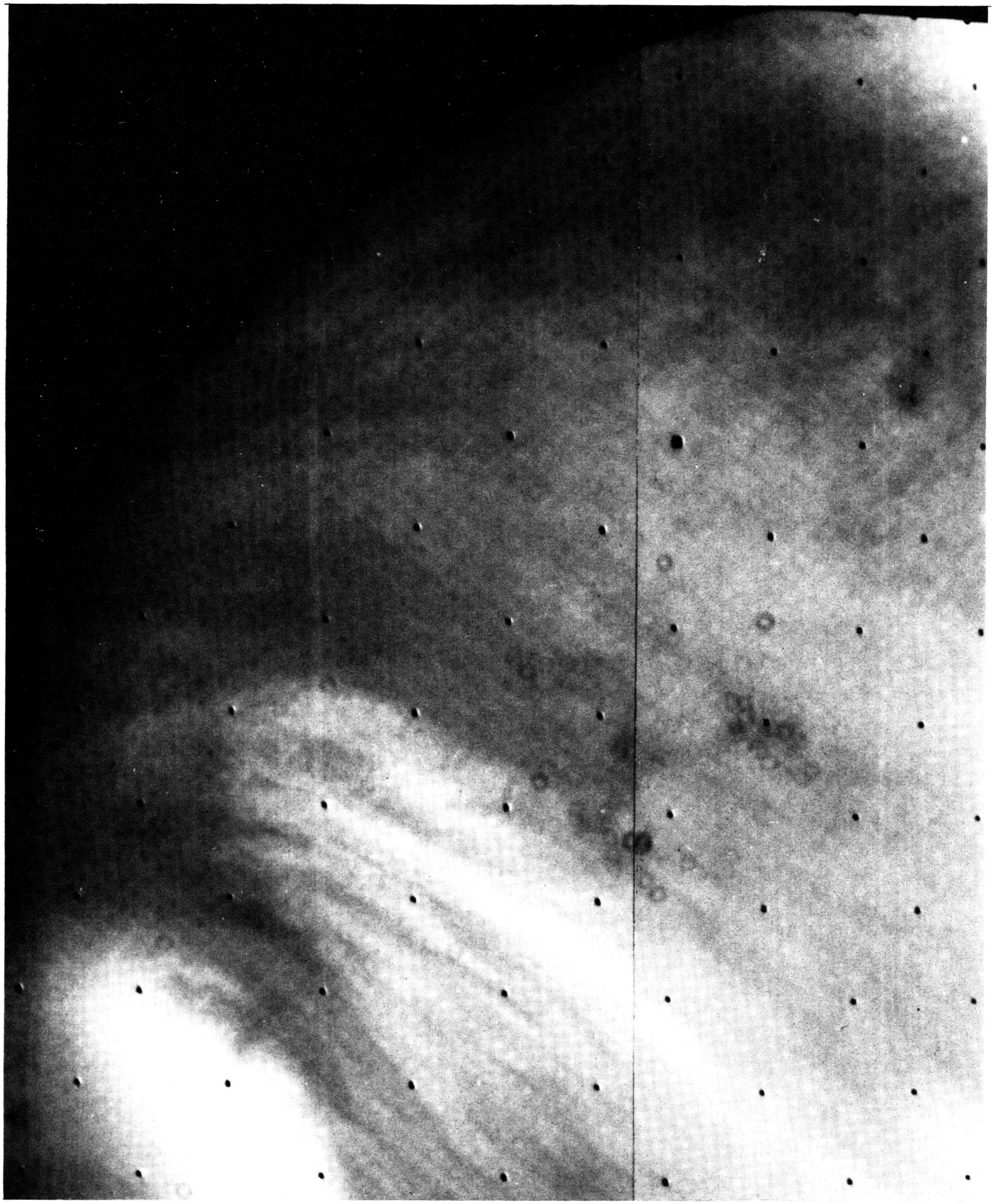
# MARINER VENUS / MERCURY 1973

## STATUS BULLETIN

## Mariner 10 Enroute to Mercury-
## Continues Query of Venus



View of Venus's Southern Hemishere Taken by Mariner 10 One Day After Closest Approach - description on following page.


Jet Propulsion Labratory  California Institute of Technology
National Areonautics and Space Administration
Pasadena, California

**6 February 1974**

**BULLETIN NO. 18**

See first page for the view of Venus' southern hemisphere described below.

This is a view of Venus' southern hemisphere taken by Mariner 10 one day after closest approach to Venus on its way to Mercury. These spiral-like markings, seen only in ultraviolet light, indicate smooth, streamline flows which originate in equatorial regions and spiral toward the pole. The picture, part of a 36-frame full planet mosaic, was taken at 10:15 a.m. PDT, 6 February, from a range of about 450,000 miles. The pattern of dots is on the face of the TV vidicon tube for calibration purposes and can be removed by computer processing.

Mariner 10 is completing its second full day of scientific observations of Venus in detail. Scheduled for another scientific encounter, with its primary target, Mercury, on 29 March, the 1100-lb spacecraft will continue to transmit pictures and send back other valuable scientific data regarding Venus back to Earth for the next two weeks. Over 2,000 TV frames have already been received at the Jet Propulsion Laboratory. The first TV mosaic composite pictures showing the entire planet as seen by Mariner 10 will be shown in the next bulletin. At 09:00 a.m. PDT, scientific experimenters will convene at JPL to reveal the results of their first-look at the wealth of data that has been returned by Mariner 10. The Mariner spacecraft is now 700,000 miles beyond Venus. Its speed was reduced from 82,800 mph to 72,200 mph relative to the Sun because of the retardation obtained by flying past the leading edge of Venus as explained later in the bulletin. It is now speeding toward Mercury which is 170,000,000 km (110 million miles) away.

## TRAJECTORIES FOR MULTIPLE PLANETARY MISSIONS

At Tuesday's impromptu press conference, one reporter who was impressed by Mariner 10's demonstration of the billiard carom principle for obtaining two or more planet encounters for the price of one asked for the names of the brilliant individuals who first thought of such an idea. Walker E. "Gene" Giberson replied that in October 1963, a UCLA graduate student, Michael A. Minovitch who worked summers at JPL, published a JPL Technical Report No. 32-464 which presented a detailed analysis of the feasibility for a Venus/Mercury flight in October-November 1973. Facsimile copies of tables and figures are shown on the last page. This work was performed under the guidance of Victor C. Clarke, Jr., who is the Mission Analysis and Engineering Manager for the Mariner Venus/Mercury 1973 Project.

Minovitch showed that indirect missions to Mercury that have a close encounter with Venus en route require considerably less launch energy than does a direct mission. The launch energy saving is achieved by the gravitational perturbation of Venus, which removes energy from the heliocentric trajectory.

The method by which energy is removed during the close encounter with Venus is illustrated in Fig. I. During the time the spacecraft is near Venus, the motion with respect to Venus closely approximates a hyperbola.The heliocentric velocity of the spacecraft is the vector sum of the orbital velocity of Venus, $V_{\text{♀}}$, and the velocity of the spacecraft with respect to Venus (on the hyperbola). The spacecraft arrives at Venus along an asymptote approaching from a direction opposite the Sun and with asymptotic velocity, $\bar{V}_{h_1}$. The heliocentric arrival velocity, $\bar{V}_1$, is computed from

$$\bar{V}I_1 = \bar{V}_{\text{♀}} + \bar{V}_{h_1}$$

and is shown by vectors in Fig. 1. Now the spacecraft departs Venus in a direction determined by the bending caused by the gravitational attraction of Venus' mass. The asymptotic departure speed on the hyperbola is equal to the arrival speed. For the heliocentric departure velocity,

$$\bar{V}_2 = \bar{V}_{\text{♀}} + \bar{V}_{h_2}$$

This vector sum is also shown on Fig. 1. During the relatively short time that the spacecraft is near Venus, the orbital velocity of Venus is approximately constant.

It can be seen readily from the vector sums of Fig. 1 that the deflection of the hyperbolic velocity resulting from Venus' gravity causes the helocentric velocity, and hence the heliocentric energy, to decrease. This decrease in energy lowers the perihelion and allows the spacecraft to reach the orbit of Mercury. An academic point should be made here, that the energy removed from the spacecraft is added to Venus. However, because of the extreme difference in mass, the change in the velocity of Venus is completely negligible.

Use of the above principle, while decreasing the launch energy required to achieve a close Mercury flyby, requires precise navigation to Venus or else all advantage is lost. This is due to the fact even small errors in Venus encounter require large trajectory correction maneuvers. For Mariner Venus/Mercury 1973, a 3-km miss at Venus requires approximately 1 m/second to correct at TCM-3. Since the available propellant aboard the spacecraft will allow for a maximum TCM-3 of approximately 100 m/second, the delivery accuracy to Venus must be less than approximately 300 km. This delivery accuracy placed stringent requirements on the Orbit Determination process and necessitated the use of sophisticated, techniques including for the first time on a Mariner mission, a sequential type filter. Following the Venus encounter the actual delivery error has been determined to be less than approximately 20 km. Since the actual flight path distance to Venus is about 215,000,000 km, the 20 km represents an error of less than 1 part in 100 million. Since the Project cost is 98,000,000, this is equivalent to controlling the cost of the total Mariner Venus/Mercury 1973 Project to within one dollar!—And we did it. For this error, a nominal TCM-3 will require less than 5 m/second.

| DATE | RANGE VS EARTH | | RANGE VS VENUS | | VELOC. VS SUN | | VELOC. VS VENUS | |
|---|---|---|---|---|---|---|---|---|
| | km | miles | km | miles | km/s | mph | km/s | mph |
| Feb. 3, 8 GMT | 41,390,080 | 25,718,600 | 1,699,805 | 1,056,210 | 36,390 | 81,402 | 8,225 | 18,399 |
| Feb. 4, 8 GMT | 42,496,813 | 26,406,300 | 989,721 | 614,984 | 36,608 | 81,890 | 8,218 | 18,383 |
| Feb. 5, 8 GMT | 43,639,963 | 27,116,600 | 277,921 | 172,692 | 36,851 | 82,433 | 8,309 | 18,587 |
| 12 GMT | 43,835,156 | 27,237,900 | 157,990 | 98,170 | 36,912 | 82,570 | 8,414 | 18,822 |
| 16 GMT | 44,034,496 | 27,361,800 | 36,180 | 22,481 | *37,008 | 82,785* | 9,200 | 20,580 |
| P 17:02 GMT | 44,087,966 | 27,395,000 | 11,853 | 7,365 | *34,841 | 77,937* | 11,023 | 24,658 |
| 20 GMT | 44,207,052 | 27,469,000 | 96,268 | 96,268 | *32,283 | 72,215* | 8,569 | 19,168 |
| Feb. 6, 8 GMT | 44,660,587 | 27,750,800 | 455,401 | 282,973 | 32,436 | 72,557 | 8,255 | 18,466 |
| Feb. 7, 8 GMT | 45,590,305 | 28,328,500 | 1,165,801 | 724,395 | 32,665 | 73,070 | 8,211 | 18,367 |
| Feb. 8, 8 GMT | 46,556,668 | 28,929,000 | 1,875,272 | 1,165,240 | 32,891 | 73,575 | 8,216 | 18,379 |

*Note Mariner 10's abrupt 10,000-mph speed reduction in its orbit motion relative to the Sun.

## Scheduled Venus Encounter Sequence of Events

**Day 38—Thursday, February 7, 1974**

Continue cyclic 2 TV. Resolution decreases from 24 kilometers to about 40 kilometers. Thirteen playback sequences (playback rate is one picture every 3/34 minutes) begin at 5 minutes before midnight, 1:45 a.m., 3:25, 5:10, 8:35,10:25 a.m., 12:10 p.m. 2:00, 3:350, 5:25, 7:10, 9:00 and 10:50 p.m. Total frames: 234.

07:35 PDT Transfer tracking Madrid to Goldstone.

10:01 PDT Venus encounter plus two days. Venus range: 890,000 miles.

10:30 PDT UVS airglow far encounter scans.

14:15 PDT Transfer tracking Goldstone to Canberra.

23:35 PDT Transfer tracking Canberra to Madrid.

**Table 10. Some important properties of Earth–Venus–Mercury trajectories, 1973**

| Launch date | $HEV_1$ km/sec | $T_{12}$ days | $\theta_{12}$ deg | $\hat{B}\cdot\hat{T}$ km | $\hat{B}\cdot\hat{R}$ km | $HEV_2$ km/sec | TISI days | DOCA km | VACA km/sec | DA deg | $T_{23}$ days | $\theta_{23}$ deg | $HEV_3$ km/sec | TFT days |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Oct. 21 | 4.39 | 106.56 | 115.30 | 12,558. | −5,758. | 7.86 | 1.75 | 3,423. | 11.40 | 41.68 | 58.00 | 136.29 | 10.86 | 164.56 |
| 23 | 4.36 | 104.73 | 113.58 | 12,706. | −5,800. | 7.89 | 1.75 | 3,596. | 11.37 | 40.92 | 57.59 | 135.32 | 10.81 | 162.32 |
| 25 | 4.33 | 102.91 | 111.88 | 12,342. | −6,008. | 7.93 | 1.74 | 3,400. | 11.46 | 41.26 | 57.87 | 136.35 | 10.90 | 160.78 |
| 27 | 4.30 | 101.09 | 110.19 | 12,078. | −6,160. | 7.96 | 1.73 | 3,271. | 11.52 | 41.40 | 58.00 | 136.94 | 10.97 | 159.09 |
| 29 | 4.28 | 99.26 | 108.47 | 11,997. | −6,259. | 8.00 | 1.72 | 3,275. | 11.54 | 41.14 | 57.88 | 136.83 | 10.99 | 157.15 |
| 31 | 4.26 | 97.44 | 106.76 | 11,733. | −6,383. | 8.03 | 1.72 | 3,139. | 11.61 | 41.31 | 58.00 | 137.38 | 11.06 | 155.44 |
| Nov. 2 | 4.25 | 95.61 | 105.04 | 11,610. | −6,474. | 8.07 | 1.71 | 3,107. | 11.65 | 41.17 | 57.93 | 137.39 | 11.08 | 153.54 |
| 4 | 4.25 | 93.79 | 103.34 | 11,370. | −6,567. | 8.10 | 1.70 | 2,983. | 11.71 | 41.31 | 58.00 | 137.83 | 11.14 | 151.79 |
| 6 | 4.25 | 91.97 | 101.61 | 11,228. | −6,643. | 8.13 | 1.70 | 2,931. | 11.75 | 41.23 | 57.94 | 137.88 | 11.17 | 149.91 |
| 8 | 4.25 | 90.14 | 99.89 | 10,992. | −6,712. | 8.17 | 1.69 | 2,802. | 11.82 | 41.40 | 58.00 | 138.27 | 11.23 | 148.14 |
| 10 | 4.27 | 88.31 | 98.16 | 10,933. | −6,770. | 8.20 | 1.68 | 2,810. | 11.84 | 41.13 | 57.82 | 137.98 | 11.23 | 146.14 |
| 12 | 4.29 | 86.49 | 96.45 | 10,601. | −6,814. | 8.24 | 1.68 | 2,594. | 11.94 | 41.59 | 58.00 | 138.72 | 11.33 | 144.49 |
| 14 | 4.33 | 84.66 | 94.71 | 10,450. | −6,852. | 8.27 | 1.67 | 2,521. | 11.99 | 41.59 | 57.94 | 138.76 | 11.36 | 142.60 |
| 16 | 4.37 | 82.83 | 92.98 | 10,365. | −6,887. | 8.31 | 1.66 | 2,499. | 12.02 | 41.42 | 57.78 | 138.52 | 11.36 | 140.61 |

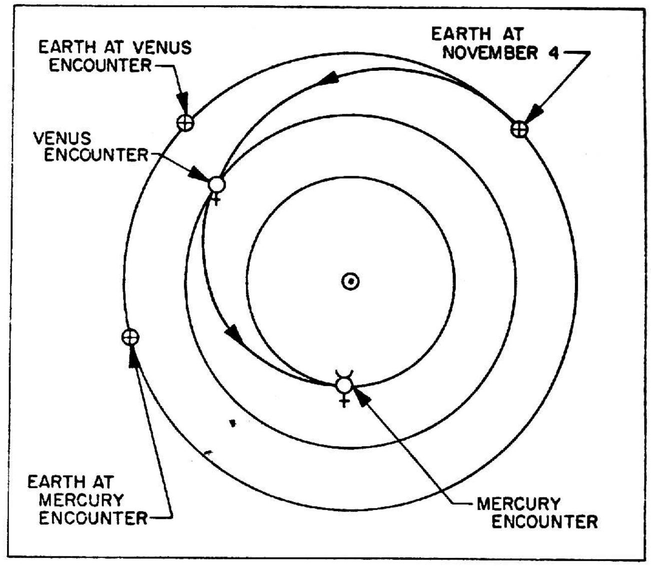



**Fig. 22. Planetary configuration for Earth–Venus–Mercury, 1973 (November 4 trajectory)**

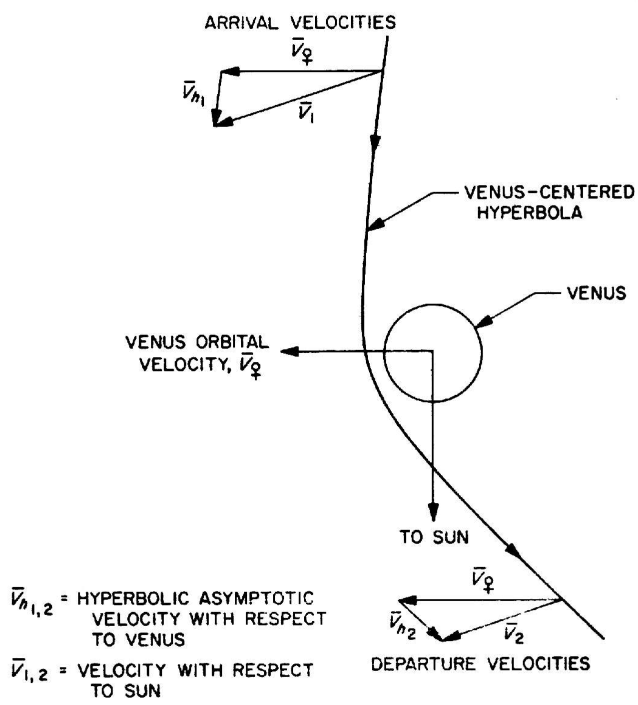



**Fig. 1 Spacecraft velocity changes obtained during Venus flyby**

FACSIMILE COPY OF TABLE AND FIGURES CONTAINED IN
JPL TECHNICAL REPORTS 32-464 and 32-1062