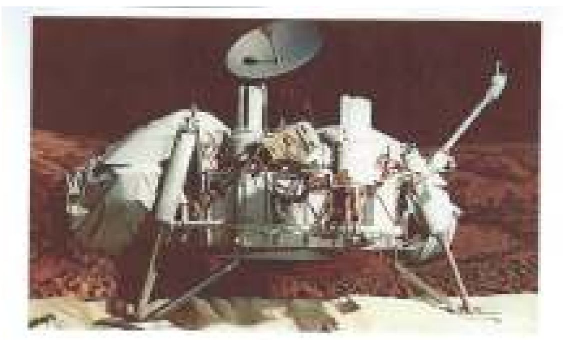
WHERE ARE WE??
By **Parker S. Stafford**

Have you ever tried to find your tent or car in the dark with only a flashlight? You wonder, where am I, where did I leave it, waving the light around and hopefully seeing it. We could have had a problem like this when we landed on Mars, July 20, 1976. The highest priority after landing was to take a picture and send it back to Earth. To accomplish this, we had to point the S-band antenna at Earth. This antenna is shown in the attached picture of the lander as the large dish at the top. The antenna had a pencil beam, only 6 degrees wide, so we had to know where Earth was within that accuracy.



If we could have landed on a perfectly flat plain, precisely where we had targeted, the pointing could have been preprogrammed into the computer;however, there were many variables that could cause the pointing to be in error, such as the slope of the landing site, the navigation errors coming out of the Mars orbit, wind drifting the parachute during the descent to the surface, and the potential of the lander spinning a little when touching down. Also, the descent trajectory would be affected by the uncertain density of the Mars atmosphere. We had to design for three atmospheric models based on the best planetary data available at the time.

Figure 1 shows the orbital motion of Mars and Earth around the Sun in 1976. Mars orbits the Sun in 687 Earth days so it moves about half as fast as the Earth. The Earth and Mars locations are shown for July 20 and on November 26, when the planets reached the opposite side of the Sun. The time required to transmit a signal to Mars and receive confirmation back on Earth can be as long as 40 minutes. This made a random point and search process with the S-band antenna impractical.

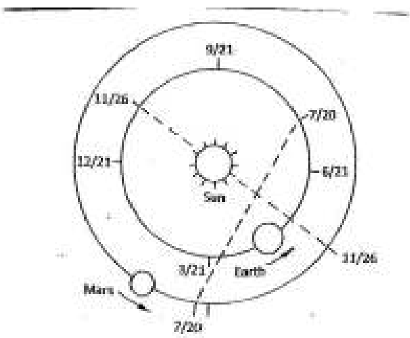


Figure 1. Earth/Mars Positions During VL 1 Mission

The solution we chose was to gyrocompass to determine where to point. Mars spins about its polar axis like Earth, but at a slightly slower rate (a Mars solar day is 38 minutes longer than an Earth day.) The gravity of Mars is 3/8 of Earth, (12.1 instead of 32.2 ft./sec.^{2}on Earth.) Refer to Fig 2. The lander gyroscopes measured the Mars spin rate in the lander frame of reference, and the lander accelerometers measured the Mars gravity in the same frame. Gyrocompassing has previously been used on ICBMs and Space Launch Vehicles on Earth to initialize guidance systems prior to launch.

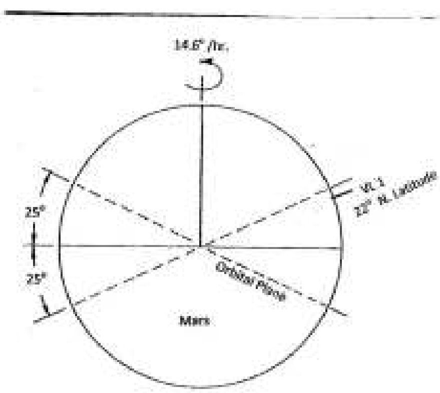


Figure 2. Mars Rotation/Gravity

(Figure 2 shows the approximate day of the year on Mars for July 20, 1976 which was mid-summer.)

The flight computer did the following computations:

1. Measure/calculate planet spin rate and gravity in three dimensions giving a vector direction in each.
2. Compute a vector cross product of the gravity and spin vectors resulting in a vector that points east.
3. Calculate a vector cross product of gravity and east that points north.

Formatted: Indent: Left: 0.13"

As a result we knew north, east, and down directions in the lander frame of reference, and this took care of latitude and tilt errors; longitude and time are equivalent. Knowing universal time from the clock on board, the computer can point the antenna at Earth given that the positions of Mars and Earth are known. This was done using algorithms stored in the lander computer. They had to take into account the rotation (time of day) and relative location of the planets. (Courtesy of Sir Issac Newton, Copernicus, and Kepler.)

The Jet Propulsion Laboratory (JPL) operates a Deep Space Network to support all planetary missions using very large antennas in Spain, Australia, and southern California. For any deep space probe at least one of these locations can receive and transmit signals at any time of day. During the Viking mission, it was supporting the two Viking landers, the two Viking orbiters, and several earlier missions like Voyager and Mariner. JPL has very sophisticated navigation computers and software to support these missions, including locations of all the planets.

On July 20, 1976 at 5:12 PDT we received the expected signal from VL 1 on Mars, showing we had landed safely and that a picture was being transmitted.

VL 1 operated in the primary science mode until about November 26 when Earth and Mars went into superior conjunction (opposite sides of the Sun) so we could not transmit for about 30 days. The major part of the Mission Operations and Science Teams went home then, and we began a lower intensity extended mission about the end of December. This mission lasted until November 11, 1982, through 3 Martian years, where it is very cold in the winter.

The first photo sent from Mars

The people who worked on this part of the project were:

- B.A. (Bonnie) Claussen: Guidance and Control, and Sequencing Computer Software chief.
- P.A.L. (Pat) DeMartine: GCSC software and architecture and operating system.
- M.A. (Mickey) Bramble: Descent Flight Software lead.
- Lloyd Gilbert: Test Manager for Antenna Pointing.
- Steve Howe: Flight Data Base.
- Parker S. Stafford: Concept Development and mathematics.

There were many others who contributed to this overall effort. Please accept my apology for this lack of memory.