Spaceflight Vol 47 July 2005

# Mapping the planet Mars

**by Philip Corneille**

Ancient Babylonian clay tablets depicted the Earth as a flat circular disk but both Roman, Greek and Arab empires' cartographers were more interested in producing celestial globes rather than terrestrial. The first terrestrial globe was produced by Crates of Mallos, around 150 BC, and the earliest surviving Earth globe was produced by Martin Behaim in 1492. However, it lasted until the 20th century when the first photos of Earth from space to produce the most accurate terrestrial globes. Since then mankind's attention has turned to the planets.

## Mars before the space age

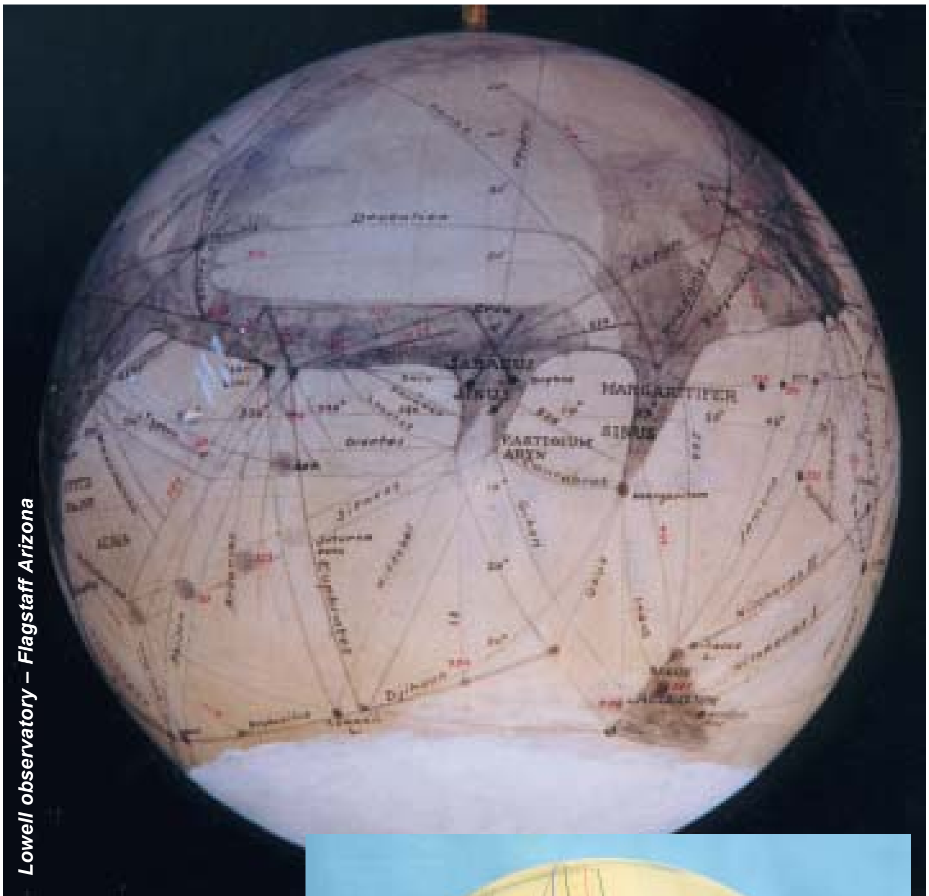
The planet Mars, named after the Roman god of war, is fourth in order of distance from the Sun and seventh in order of size and mass. The astronomical symbol for Mars, represents a shield with a spear. The so-called red planet is slightly more than half the size of Earth but the lack of oceans gives it the same landmass as Earth. Mars has no plate motion and its rotational axis is inclined to the ecliptic, like Earth's. The planet completes an elliptical orbit around the Sun in 687 days and spins on its axis with a period of 24 hours 37 minutes. This period is named a 'sol' or Martian solar day. It has two moons, Phobos (Fear) and Deimos (Terror), named after the mythical chariot horses of Mars. The inner moon, Phobos, is already within the 'Roche limit' where internal gravity alone is insufficient to hold it together. Phobos could conceivably become a ring plane around the Mars within the next 50 million years.

Galileo Galilei made the first telescopic observations of Mars in 1610. Another Italian astronomer, Francesco Fontana, produced the earliest drawings that showed markings on the disk of the planet. Unfortunately, these markings bear no resemblance to the planetary features known today, so the Dutch scientist/astronomer Christiaan Huygens was credited with the first accurate drawings with surface details of Mars (1659). In 1666, the Martian polar caps were first noted by Giovanni Cassini, who also calculated the rotation period of the red planet.

The very first map of Mars was made by German astronomers Wilhelm Beer and Johann von Mädler in 1830. It featured a system of longitude and latitude, not too different from today's coordinate system.

In 1877, the American astronomer Asaph Hall discovered Mars' two tiny moons and the Italian astronomer Giovanni Schiaparelli produced the first modern map of Mars, which contained Latin nomenclature in terms of the ancient geography of the Mediterranean area in biblical times. The map showed indications of grooves or channels on the bright areas and Schiaparelli is usually credited with their first description.

However, the idea of 'canals' might have originated in the work of the Italian astronomer Angelo Secchi of the Vatican observatory (1868). When Schiaparelli had to abandon his observations, a wealthy Boston aristocrat, Percival Lowell, decided to continue the work and set up an observatory atop 'Mars hill', Flagstaff, Arizona in 1894. The dedicated amateur astronomer was convinced that the 'canals' on Mars were



Lowell observatory – Flagstaff Arizona

*Mars globe (top) made by Percival Lowell in 1911, based on his observations. It shows the 'canals' in the area of Elysium planitia and Utopia planitia and (above) Mars photo-frames show the areas covered by the 1969 fly-bys of Mariner 6 and 7.*
*NASA/JPL*

built by an intelligent civilization on the red planet.

Lowell made maps and Mars-globes based on his 15 year long observations and published his views in three books: 'Mars' (1895), 'Mars and its canals' (1906) and 'Mars as the abode of Life' (1908). Although controversial, Lowell's maps were widely used until the 1950s when photographic advances were hoped to resolve some differences but even photographs were subject to interpretation. It lasted until 1958 for the International Astronomical Union (IAU) to adopt a formal list of place-names on Mars related to a Mars-map by Glauco de Mottoni, which was based on a large number of photographs taken by the French astronomer Henri Camichel at the Pic du Midi observatory.

Confidence in visual observation remained strong until telescopic views of Mars were replaced by high-resolution space probe images. Finally in July 1965, the Mariner 4 fly-by ended an era of Mars studies limited to Earth-based observations.

## Mars-mapping from spacecraft

NASA's Jet Propulsion Laboratory (JPL) Mariner Mars project started the initial exploration of Mars when the Mariner 4 fly-by provided the first views of the Martian surface (see page 270). The Mariner 4 television experiment showed cratered terrains and proved to be historic and scientific significant but the pictures could not contribute to a clear understanding of transient features.

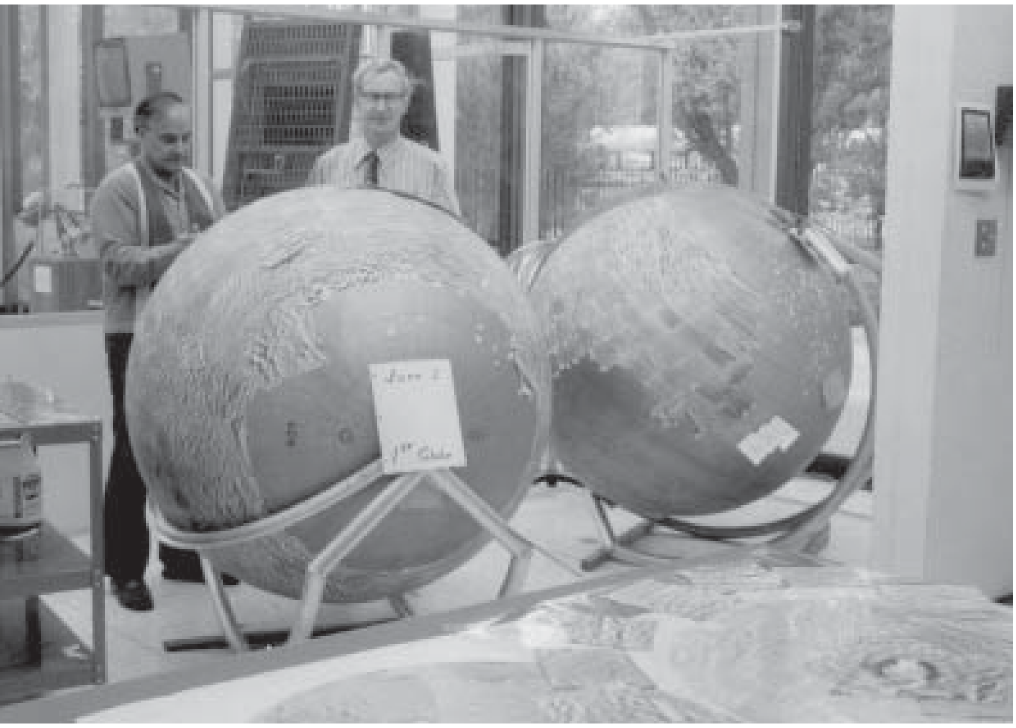
The 1969 fly-bys of Mariner 6 and 7 returned about 200 times the picture data of Mariner 4 and these probes also provided low-resolution coverage of the entire planet by acquiring full disc views of Mars using the high-resolution camera before close-encounter. However, these remarkable far-encounter global photographs were insufficient to create an accurate complete globe of the red planet.

Altogether, the Mariner 4, 6 and 7 fly-bys only photographed 10 percent of the surface of Mars. A complete mapping of the red planet was performed by the Mariner 9 spacecraft, which went in orbit around the planet in November 1971. The spacecraft's mission was to map 70 percent of the surface of Mars during 90 days in orbit but Mariner 9 remained operational for 349 days and mapped the complete surface of Mars. It also photographed the Martian moons Phobos and Deimos.

After nearly one year of operation, Mariner 9 returned 7300 photos, which

*Three large four foot diameter photomosaic globes are completed with Mariner 9 pictures. Each picture underwent many stages of computer processing and photographic printing.* NASA/JPL

*The Mariner 9 photomosaic Mars globe showing the consistency of the tone and contrast of the photographs. A specially designed protractor that swivelled around the poles was used to locate each picture.* NASA/JPL



*The two large four foot diameter globes being produced based on the 1971 Mariner 9 mapping pictures. Mariner 9 circled Mars 698 times and returned 7300 photographs.* NASA/JPL

revealed a planet beyond speculation. The images showed astonishing geological features such as giant volcanoes, plateaus and the largest canyon in the solar system, named "Valles Marineris" in honour of its discoverer.

More surprisingly, after computer processing of the digital TV images, subtle details such as the relics of ancient riverbeds and gullies were revealed in the landscape of this seemingly dry and dusty planet. These enhanced high resolution photographs enabled JPL to produce the first photo-mosaic globes of a planetary body.

The task of planning and supervising the mosaicing of the four-foot globes was assigned to Elmer Christensen, who designed the protractor to precisely locate the images on the sphere. Each Mariner 9 mapping picture was produced in one of three projections: 'Mercator' for the equatorial latitudes, 'Polar stereographic' for the polar regions and 'Lambert' for the intermediate regions. The JPL team carefully positioned 1500 photographs on the globe.

Known variations in the Mariner 9 camera response were removed, along with geometric distortions and reference marks. Surface detail enhancement allowed ridges and craters to be seen with equal clarity in the dark regions and on the bright polar caps. The completed four foot globe was sprayed with a clear coating to protect the surface. The original globe was re-photographed in 452 roughly rectangular segments, which allowed the construction of a 6-foot diameter globe for the von Karman auditorium of the JPL campus in Pasadena, California. Completed in September 1973, these globes showed large-scale geologic features with a perspective that scientists couldn't obtain on flat projections.

The next generations of spacecraft sent to Mars had cameras (vidicons) with vastly improved capabilities. The 1976 Viking orbiters photographed 95 percent of the surface at a resolution of 200 metres. The 1997 Mars Global Surveyor orbiter cameras made wide-angle images of the Martian surface and data from the spacecraft's laser altimeter have given scientists their first 3-D views of Mars' north polar ice cap. The 2001 Mars Odyssey's camera system obtained the most detailed complete global maps of Mars ever, with daytime and night time infrared images at a resolution of 100 metres.

The 2004 Mars Express high-resolution stereo camera is capable of 10 metre per pixel resolution and the reconnaissance task is to observe half of the surface at this resolution and 1 percent of the surface at 2 metre per pixel resolution.

After 40 years of reconnaissance, exploration and intensive study it certainly seems that mankind is ready to make the dream of a human mission to Mars come true.

*The author thanks Lowell observatory in Flagstaff – Arizona for the Lowell globe picture and Russell Castonguay of Anteon for providing the NASA-JPL Mariner 9 globe photographs.*

# Mariner 4 –

**During the November 1964 launch window to Mars, both Russia and America sent unmanned spacecraft to the red planet. After the Russians lost contact with their Zond-2 in April 1965, it was the American Mariner 4 which, in July 1965, became the first interplanetary spacecraft to successfully flyby Mars and send back photos.**

## Mariner 4 spacecraft

NASA approved the Mariner-Mars project in November 1962 and the Jet Propulsion Laboratory (JPL) started to build the twin Mariner 3 and 4 spacecraft. These were based on Mariner 2 but with four solar panels.

The 261 kg Mariner 4 carried seven scientific instruments, most of which were mounted on the outside of the frame, a Helium magnetometer, a solar-plasma probe, a trapped radiation detector, a cosmic ray telescope, a micrometeorite detector, an ionisation chamber and Geiger-Muller tube to measure radiation.

Last but not least, Mariner 4 was equipped with a television camera capable of taking 22 black-and-white photographs through a small Cassegrain telescope mounted on a scan platform at the bottom centre of the spacecraft.

## Eight month journey

After two years of preparation, Mariner 3 was launched on 5 November 1964 by an Atlas-Agena. However, about 50 minutes into flight, the spacecraft unsuccessfully attempted to deploy its solar panels and eight hours later the spacecraft battery ran out of power. A later investigation indicated that the cylindrical fibreglass-honeycomb nose fairing, designed to protect the spacecraft during launch and ascent, failed to be jettisoned, a problem solved before the end of the Mars launch window. The Atlas-Agena launch vehicle had been fitted with a complete new magnesium fairing, constructed in record time by the JPL engineers, and Mariner 4 was launched on 28 November 1964.

This time the launch procedure was successful and the restartable Agena

# the first flyby of Mars

stage put the spacecraft on course to the red planet. A single midcourse correction was made on 5 December 1964 to ensure that the probe would pass within 10,000 km of the planet's surface. The 1964 Mariner Mars spacecraft was the first space mission to use a star (canopus) as a navigational reference object as, during its flight, Earth would transit across the face of the Sun.

April 1965 was a period of records – Mariner 4 broke both the record of continuous operation (129 days previously set by Mariner 2 to Venus) and the record for long-distance radio communications (62 million miles previously set by Zond-1 to Venus). En route to Mars, the unmanned spacecraft detected the effects of solar flares and measured cosmic radiation.

By 7 July, Mariner 4 had entered the gravitational field of Mars and four days later it was only one million miles away. On 14 July 1965 the signal was sent to aim the cameras at the Martian surface and Mariner 4 began photography when the spacecraft was 9000 km above Mars' surface.

The television subsystem worked correctly, filled its magnetic tape with 22 pictures, shut itself off and ordered the telemetry system into cruise mode in order to activate the science instruments.

One of the great achievements of the Mariner 4 mission was the modification of mission plans while the spacecraft was in transit in order to accommodate certain science experiments. The mission had been designed to occult Mariner 4 behind the planet so that the effects of the Martian ionosphere and atmosphere on the spacecraft's radio signals could be observed. Not only did the experiment indicate surface pressures of 4.1 to 7.0 mbar but it also confirmed the benefits of maintaining some flexibility in mission plans even after a spacecraft is launched. The close flyby of the Mariner 4 spacecraft past Mars, combined with the accurate tracking of the spacecraft on its trajectory, allowed improvements in the calculation of the planet's mass. Mariner 4's magnetometer discovered no magnetic field and the spacecraft continued sampling the space environment just outside the orbit of Mars for nine hours. Then the CC&S turned off the cruise science and began the playback mode, in which engineering telemetry would alternate with playback of the TV pictures data.

On 15 July, JPL received the first signals. The 22 photographs stored on magnetic tape were transmitted to Earth at a speed of eight bits per second. Each image had a size of 250000 bits, so it took nine days before the full set arrived at the Pasadena centre.

Mariner 4's pictures comprised of 200 TV lines with 200 picture elements per line, each represented by 64 shades of grey from white (0) to black (63). Afterwards the photographs were computer-enhanced by stretching the intensity values in order to make feature identification easier.

The first, historical image showed 350 km of the 15,000 km far Martian limb at about 40° North latitude.

The most significant finding from the 22 close-up Mariner 4 photos was the fact that Mars appeared much more Moon-like than Earth-like as the surface was heavily cratered. More than 70 craters appeared in the Mariner 4 pictures.

Although the spacecraft couldn't give any definite data on the possibility of extra-terrestrial life forms on Mars, from the data returned by the spacecraft's instruments scientists concluded that no form of life existed.

Mariner 4 was not expected to survive much longer than the eight months after its flyby, but actually lasted about three years in solar orbit, continuing long-term studies of the solar wind environment and making coordinated measurements with Mariner 5, a sister ship launched to Venus in 1967.

The 1965 flyby of Mars emphasised the exploratory potential of space photography. Although only one percent of the Martian surface was pictured, and the photos returned by Mariner 4 dashed the hope of finding life forms on Mars, scientists convinced NASA to conduct a more thorough exploration with orbiting missions. The greatly improved images of Mariner 9 (1971) led to the revitalisation of interest in Mars as a place where life might have harboured at some time, if not in the present.

*Radio-tests on the Mariner IV spacecraft. Compare the size of the craft against the JPL-engineers. Photos: NASA/JPL*

*Side-view of Mariner IV clearly showing the TV camera underneath the octagonal structure. The 'Venetian blinds' on the sides were used for internal temperature control.*

*Mariner IV is being readied for its historical mission to Mars in 1964.*