PLANET MARS

V. S. Venkatavaradan

Tata Institute of Fundamental Research, Bombay 400 005

INTRODUCTION :

Mars has been the subject of investigation by a number of spacecrafts and the culmination of such studies was recently achieved by two NASA missions, Viking 1 and Viking 2. No other planetary missions have attracted so much public attention as these, largely due to their capability to answer the persistent question, "Is there life on Mars?". Even though the major aim of Viking Missions to Mars is to detect extraterrestrial Martian life, it has provided valuable information regarding the planetary surface and its atmosphere.

The first close up photograph of Mars was taken by Mariner 4 of U.S.A. during its encounter with the planet on July 15, 1965. This was a flyby mission with the space craft approaching the planet to a distance of about 10,000 km and givng the first 22 close up photographs of the planet. Later, two flyby missions - Mariner 6 and Mariner 7 and an orbiter Mariner 9 as well as three Russian spacecrafts- Mars 2, Mars 3 and Mars 6 - explored the planet in great detail. However, it was Mariner 9 which clearly proved that the planet is geologically very active, more so in the past. And now we have the two missions, both of orbiter lander type which have added more information on Mars.

A large amount of information on Mars has been of course acquired much before the space era by observations made through telescopes over hundreds of years. All the basic parameters for the planet have been determined without the help of any spacecrafts. Even the existence of its two tiny satellites was known about a centrury ago. However, detailed observations of the surface of Mars could not be made with terrestrial telescopes and it was Mariner 4 in 1965 which saw the surface of Mars with some clarity showing the huge impact craters produced by giant meteorites. Subsequent missions to Mars improved the surface resolutions enormously culminating in the Viking missions which could even photograph rocks and boulders strewn on its surface and conduct chemical analysis of the soil.

MARS THROUGH A TELESCOPE :

The observation of Mars through the telescope in detail by Giovanni V. Schiaparelli in 1877 and his findings of the so called 'canals' started the great controversy regarding intelligent life on Mars and added an impetus to Martian studies. Percival Lowell became the chief advocate of the Martian canals being the engineering work of intelligent beings. He made extensive observations of the planetary surface and produced a detailed map of Mars showing a complicated grid of 'canals'.

The 'canals' theory is now proved to be wrong and it is probably due to the poor resolution of the early telescopes and a certain amount of subjectivity in the interpretation. Inspite of the subjectivity, a remarkable amount of information regarding the planet has been obtained.

The most conspicuous features, when looked through a telescope, on the Martian surface are the whitish polar caps which grow in winter and shrink in summer. Whereas on earth the thickness of polar ice deposits go to many metres, it is only a few centimeters on the Martian poles. This is derived from the rapid rate at which the caps shrink with the available sunlight which is less than half compared to earth. Similar to the case of earth when there is summer in the northern hemishpere, it is winter in southern hemisphere and vice versa. When the northern polar caps shrink during summer, the vapour gets transported to southern hemisphere by Martian winds and the south polar caps begin to grow where it is winter.

Three quarters of the Martian surface is made up of light regions called *continents* (or deserts) and the remaining dark regions are called seas or *Maria*. The light regions give the characteristic red colour to the planet. These have been assumed to be due to red oxides of iron and recently it is proved to be true.

One of the most curious phenomena on the surface of Mars concerns its dark regions. It has been observed that parallel to the shrinkage of polar regions in spring, the equatorial dark regions grew even darker. They have a dull colour in winter and the darkening during spring was considered as an evidence for the presence of some plants which grow in abundance due to the availability of excess water in spring (derived from the melting of the polar ice). This explanation again is found to be not true and the change in colour is thought to be due to storms operating during this time which deposit dark coloured soil in the equatorial regions. Telescopic observations have shown the existence of huge dust strorms.

MARS IN SPACE ERA :

The photographs transmitted by Mariner 4 and subsequent spacecrafts showed the great similarity between the lunar surface and Martian terrain particularly in the abundance of impact craters. Mariner 4 also showed that the atmospheric pressure in Mars is about 1/100th of the terrestrial atmosphere with carbon-di-oxide as the major constituent. Mariner 4 found the magnetic field of Mars to be less than 1/3000th of the earth. Mariners 6 and 7, both of fly-by type, also gave similar information but it was Mariner 9, an orbiter, which could analyse over 70% of Martian surface and gave detailed information regarding the planetary atmosphere and geology. It also photographed the two satellites of Mars - Deimos and Phoebus - revealing a good deal of information.

The results obtained through Mariner 9 mission to Mars formed the foundation for the present Viking missions. Even the proposed landing sites were selected from the observations of Mariner 9. A voluminous amount of data has been obtained through this mission which has revolutionised our idea of Mars.

When Mariner 9 was approaching the planet a dust storm prevented observation. Even though it was disadvantageous from the point of view of surface photography, it could be used advantageously for studying the surface features at each stage as the dust storm settled. In the case of Earth, the storms are activated by the energy derived from the condensation of water vapour and the consequent release of latent heat. Mars with no liquid surface would provide a laboratory model of how a large storm disperses in the absence of water.

Mariner 9 has studied the atmosphere of Mars in great detail. The temperature of the upper atomsphere was found to be about 350°K with a 10-20% range of temperature variation in the region of 100-250 Km altitude. Atomic hydrogen and atomic oxygen have been detected in the upper atmosphere. Whereas the hydrogen content is similar to earth's upper atmosphere, substantially less amount of oxygen was observed. These gases are presumably produced by the photo-dissociation of water vapour by ultraviolet rays. Ozone is also detected in the atmosphere. There seems to be an anticorrelation between the amount of water vapour and ozone in the atmosphere. In regions where Mariner 9 measured (using infrared interferometer) precipitable water of 10-20 μm, the ultraviolet spectrometer determined the amount of ozone to be less thn 3μm-atm. In polar regions, where water vapour is much less, ozone content varies between 10-60μm-atm. This is because the photochemistry of the atmosphere inhibits the formation of ozone in the presence of water.

Water is present in trace quantities particularly on the top of volcanic mountains like Nix Olympica. The presence of water in this region could mean that this volcano is still active releasing water vapour and other gases similar to terrestrial volcanoes. It is believed that the polar ice is mainly made up of carbon dioxide with some water. Lower atmospheric regions showed a constant temperature profile whereas a variation 3°C/Km was expected. This has been attributed to the dust storm which acts as a blanket equalising the temperature. The mean atmospheric pressure is found to be 5.5 millibar as against the terrestrial atmospheric pressure of 1013 millibar. The Martian ionosphere was found to exist at about 145-150 kilometers altitude. Thermal escape of hydrogen and nonthermal escape of oxygen, carbon and nitrogen also takes place from the Martian ionosphere. The dissociative recombination reaction which lead to such escape due to excess energy available are :

$$O_2^+ + e \rightarrow O + O + \text{excess energy}$$

$$CO^+ + e \rightarrow C + O + \text{excess energy}$$

$$N_2^+ + e \rightarrow N + N + \text{excess energy.}$$

The Martian surface is pitted with a large number of craters both meteoritic and volcanic in origin. Fissures, cracks and rilles have been seen. The rilles seen in Mars are accompanied by tributaries pointing to the fact that liquid water was present during earlier geological periods. Parallel rilles whose length exceeds more than 1500 Km and sinuous rilles showing remarkable similarity to the terrestrial stream erosion patterns are seen with many branching tributaries. The surface has been shaped by many processes operating over a long time. Some of the important processes are meteoritic bombardments, volcanic activity, tectonic movements, running water(?) and dust storms. Enormous canyons also occur pointing to the intense geological activity of the planet in the past.

Infrared interferometric studies have shown that the surface has a wide range of materials mainly silicates with some regions comprising pure quartz. Mariner 9 has found the gravitational field of Mars to be uneven and has detected mass concentrations (or *mascons*) similar to those found on the lunar surface. The mascons are expected to be huge meteorites buried below the surface. An equatorial bulge of about 1 to 2 Km is found at about 110° in longitude. This bulge is repeated at about 180° on the other side of the planet. This observation is unexpected and needs an explanation.

The two Martian satellites, Phobos and Deimos, were also observed by Mariner 9 and found to be pitted with a large number of impact craters. The large number of craters indicate their long age as well as their high strength. Phobos has a height of 21 Km and width of 25 Km. Deimos is estimated to be 12 Km high and 13.5 Km wide. Their uneven sizes point to the possibility that they were once captured from the asteroidal belt. However, neither of them is in the kind of orbit around Mars as would be expected of a captured asteroid. The satellites may be the residuary of a shattered bigger satellite due to asteroidal impact.

The findings of Mariner 9 have shown the planet to be geologically and meteorologically well alive. The question whether it is biologically alive is left to be answered by the Viking missions.

VIKING MISSIONS TO MARS :

The Viking mission to Mars with the major aim of detecting 'life on Mars' also has innumerable experiments to conduct various physical, chemical, geological and meteorological survey of the planet. There are two missions - identical to each other - which will explore the planet in detail at two different sites of landing. Each of the Viking missions has two spacecrafts, an orbiter and lander.

Both Vikings 1 and 2 have successfully landed on the chosen sites and have transmitted data from various experiments. There are certain ambiguities regarding preliminary results from the life detection experiments in Viking 1. Detailed analysis of the soil sample and control experiments will be able to give a positive answer. The results so far give encouraging support to the presence of some form of micro-organisms. The Viking 2 site has more water vapour compared to the Viking 1 site which increases the chance of finding life.

The orbiter has equipments to take photographs of the surface and analyse the thermal and chemical properties of the upper atmosphere; lander is provided with instruments to study the composition of lower atmosphere and the surface soil. Two cameras have scanned the Marscape providing images in colour as well as black and white and in stereo. The atmosphere and the soil around the lander have been analysed. Information on minerology, magnetic properties, physical and chemical properties of the soil such as porosity, hardness, etc., have been obtained. There are three different types of life detection experiments in the 15 kilograms automated biological laboratory.

Orbiter :- The Orbiter carries three instruments packages on a common scan platform to scan the same area of the planet simultaneously. They consist of (i) a pair of high resolution cameras (ii) infrared atmospheric water mapper and (iii) infrared radiometer for thermally mapping the surface. When the lander is on the ground the orbiter will scan the lander region to get the parameters on a macro scale. Seasonal and secular changes can be studied well by this combined macro and micro approach.

The *visual imaging* is carried out by two vidicon cameras. At 1500 km altitude, the pictures taken by each camera will have an area of 40×40 Km with a resolution of 25 metres.

The *infrared spectrometer* for water mapping operating in the 14 micron region has a sensitivity of 1/1000 mm of precipitable water. The water mapper has played a vital role in selecting the landing site The chosen landing site should have a high concentration of water vapour to increase the chance of detecting life if any.

The *thermal mapper* uses a radiometer with a fixed array of infrared detectors to cover the region above 6 microns. The principal aim is to search for areas of discontinuity that might suggest thermal lag of some planetary activity and relate this to data obtained by the cameras.

Lander :- The lander has a number of experiments to investigate the surface constituents and the atmosphere at ground level. There are equipments to photograph surface, analyse its chemical composition and other physical and biological properties. There is also a miniature meteorological laboratory to study the Martian weather.

Two cameras mounted on extensions above the upper surface of the lander are used to photograph 360° panoramic view of the landing site. Surface samples selection for biological and chemical analysis is made using the visual imaging system. Seasonal changes in the surface samples will be also monitored by the cameras.

The meteorological package will measure temperature, pressure, humidity and wind velocity at regular intervals of time.

A small seismometer is mounted in each of the landers and coupled to the ground through the landing leg. These instruments operating at 0.4-4 Hz will detect seismic disturbances which will be usefull in understanding the thermal history of the planet and its differentiation. However the seismometer is the only equipment which failed to function in the Viking 1 mission. It is hoped that the instrument in Viking 2 will perform well. There are also experiments to determine the magnetic and other physical properties of the soil.

Among all the experiments there is nothing to surpass the complexity of the biological laboratory which will determine whether microscopic life exists on Mars. There are three different experiments to test for biological activity of the soil. One of the experiments will determine whether carbon is fixed by the organism through photosynthesis using radioactive carbon as tracer. A second experiment tests for metabolic activity using C-14 labelled nutrients. The third one detects the release of typical gases of life process. Mass spectormetric and chromotographic analysis will also be carried out to detect organic compounds in the soil as well as in the atmosphere. The soil will be scooped by the long arm of Viking lander and will be transported to these three experiments among others. The results so far indicate the possibility of the existence of microorganisms on Mars. But this is to be confirmed (see later)

The first thing the lander confirmed on landing is that the soil is indeed red- a deep rusty red- and this red colour is due to the oxides of iron as suggested earlier. Martian sky has a pink colour due to the presence of the dust in the atmosphere which abosorbs the blue and scatters red light. The colour pictures are taken as three black and white pictures through seperate filters later to be reconstructed.

Igneous rocks of different textures have been seen on the Martian suface. Rough textures of igneous rocks probably due to slow cooling of the magma and fine textured rocks due to rapid cooling of the lava lie in abundance in various shapes and sizes. The nearby rocks were about 15 centimetres in diameter but boulders of several metres also could be seen a few kilometers away. Very smooth light coloured rocks also occur which are probably transported from a distance. On the whole the site resembles a terrestrial desert.

The foot pad of the lander penetrated only 1.4″ into the soil denoting the high strength of the Martian regolith. The surface features as photographed by the Orbiter show the terrain to be pitted with craters. Rivers and tributaries are also seen. The observation of the rilles and their tributaries clearly point to the presence of water sometime in the past.

The mass spectrometer in Viking1 lander has given the composition of the lower atmosphere with remarkaable accuracy. As expected, the major component is CO_2 which makes up about 95% of the atmosphere. Nitrogen is the next in the list with 2 to 3% whereas argon-

40 (which is the decay product of K-40) occurs with 1-2% and oxygen about 0.3%. Atmospheric pressure at the landing site was 7.7 millibar (this pressure occurs on earth at an altitude of about 38 kilometers above sea level).

The atmosphere is very cold with -86°C temperature just above the surface during dawn to reach a maximum of -30°C after 3-4 hours afternoon. There are light winds with a maximum speed of about 30 Kmph. However turbulent weather prevails around the giant volcanoes of Mars with clouds 600 kilometres across and wind speeds at 200 Kmph.

It has been found that the ionospheric charged particle concentration reaches a peak value of about 2×10^5 /cc at 135 Km altitude (the E-region of terrestrial ionosphere for example has some 2×10^5 electrons/cc). The temperature at this altitude is 135°K and increases to 270°K at 250 Km . At the peak layer of ionosphre O_2^+ and C_2^+ occur with equal frequency. Atomic oxygen also occurs with an abundance of 1-2% in this region. As mentioned earlier the atomic oxygen escapes from Mars at a rate equivalent to 60,000 gallons of water being lost per day. The recombination of oxygen and nitrogen ions with electrons result in fast oxygen and nitrogen atoms (5.5 Km/s and 6.3 Km/s respectively) exceeding the velocity of escape from Mars (5 Km/s).

The results from all the biology experiments are puzzling. Each of the biology experiments is designed to go through sequences lasting upto 20 days. And some of them may be repeated a few times. The preliminary results from all the biological experiments have given positive signals. Whether the signals are due to biological processes or merely due to some inorganic chemistry is yet to be confirmed.

The Martian soil was chemically very active. Moistened soil incubated at an earthlike temperature released a surprisingly large volume of oxygen. In the radiocarbon labelled nutrient experiment, release of radioactive carbon dioxide from the soil expected to last for about 10 days if micro organisms were present. A chemical reaction would give an instantaneous release and would terminate immediately. In the Viking tests the gas was released for about 3 days somewhat intermediate between pure chemistry and biology.

Eventhough the two experiments-'gas exchange' and 'labelled release' could be explained by some form of chemical reactions the third results from the 'pyrolytic release' is difficult to be explained by non-biological processes. It is however, certain that no soil on earth behaves the same way as Martian soil does. Before arriving at a final conclusion many other possibilities have to be excluded. The controls are also expected to give more information which will be useful in interpreting the unique results. Also Viking 2 lander which has landed in an area that contains about 5 times more water vapour than Viking 1 site could give some conclusive results regarding life on Mars.

The observations of Mars by space crafts have given some new insights regarding the planet, some of which are summarised below :

The surface of Mars bears witness to an active geological history in the form of impact craters, volcanic mountains, sand dunes and river-like channels formed probably due to the flow of water. The planet is also meteorologically alive with huge cloud formations, high winds and occasional dust storms.

The dust storms play an important role in shaping the Martian landscape. The pattern of light and dark markings may be due to windblown dust by prevailing winds. Even the Martian sky looks pinkish due to the large abundance of dust particles in the atmosphere.

The major constituent of the atmoshpere is CO_2 with nitrogen coming second with a mean atmospheric pressure of about 6 millibars in a range of about 3 to 11 millibars depending on the topography.

The polar ice caps are mostly due to soild CO_2 with some water. The permanent polar deposits may contain a relatively large amount of water.

The Martian soil is rusty red due to oxides of iron which also indicate the presence of water in the past. Mars may have had a denser atmosphere and flowing water in its earlier history. The pressure could have been of the order of present day earth's atmosphere. The biological activity of Martian soil is yet to be confirmed but it behaves uniquely when subjected to biological tests. No soil on earth behaves like this.

Recent observations by Viking 2 has also given results similar to those of Viking 1 for life detection experiments. However both Viking 1 and Viking 2 failed to detect organic compounds on Martian soil. It is believed that the high dose of ultraviolet radiation on Martian surface will break any organic matter. Experiments are under way to test for organic compounds in deeper layers where some organic compounds might be detected. Detailed analysis of life detection experiments and their controls will probably be able to give some tentative answers to the question of life on Mars (see Nuclear India, Vol. 15, No. 2, October 1976 for details on Life on Mars).

In summary we may say that the Viking Missions to Mars have clearly proved the planet to be both geologically and meteorologically well alive. Whether it is also biologically alive is not yet known with certainty. An answer to this persistent question is surely near at hand.

References :

1. Hartman, W.K. and Raper, O., 1974, 'The New Mars' The Discoveries of Mariner 9 NASA SP-337, Washington, D. C.

2. Whitten, R.C. and Colin, L., 1974, "The Ionospheres of Mars and Venus" Rev. Geophys. & Space Phys. **12,** 155-192.

3. Soffen, G.A. and Young, A.T., 1972, "The Viking Mission to Mars" Icarus **16,** 1-16 (and other papers in this ussue).

4. Venkatavaradan, V.S., 1976, 'Life on Mars', Nuclear India, Vol. 15, No. 2, pp. 4-8.

5. Sagan, C. (Editor), ICARUS, special Pre-Viking issue, 1976 Vol. 28, No. 2 (June 1976).