# Reports

## Mariner 9 Science Experiments: Preliminary Results

Mariner 9 was launched from Cape Kennedy, Florida, at 22:23:04 G.M.T. on 30 May 1971. On 5 June, 6 days after launch of the spacecraft, a mid-course maneuver placed Mariner's aiming point closer to Mars with such accuracy that no additional mid-course maneuvers were necessary. Mariner was inserted successfully into orbit (*1*) with a 15-minute, 23-second motor burn completed on 14 November, 00: 15:29 G.M.T., becoming the first man-made object to orbit the red planet.

To form the science payload, NASA selected six experiments: television, infrared spectroscopy, infrared radiometry, ultraviolet spectrometer, S-band occultation, and celestial mechanics (*2*). A brief summary of results from these experiments, for the first 30 days after orbit insertion, is presented in the subsequent paragraphs. More detailed information is given in the individual reports that follow.

At the time of arrival of Mariner 9 at Mars, there was a planetwide obscuration, by dust, of surface features viewed by the television experiment. Obscuration caused by dust was confirmed by the infrared spectroscopy, infrared radiometry, and ultraviolet spectrometer experiments and supported by the S-band occultation experiment. Several instruments observed less dust entrained over the south polar region than over many other areas, even if allowance is made for the intrinsic contrast of polar cap features. High elevations—notably the three spots in Tharsis—were relatively clear, although surface detail also was visible in some regions of lower altitude. A slow and sporadic clearing of the dust is evident in television pictures of the south polar and other regions; such a progressive clearing is not inconsistent with results from the other science instruments. The progress of dust clearing is a complex meteorological phenomenon; to date, no one-to-one connection of clearing with latitude, longitude, elevation, or time has been found.

Confirmation by the Mariner 9 ultraviolet spectrometer (UVS) of the observations of CO and O airglow made by the UVS on Mariners 6 and 7 in 1969 and the detection of the 15-$\mu$m $CO_2$ band by the infrared interferometer spectrometer (IRIS) are consistent with a predominantly $CO_2$ atmosphere. The IRIS observation of $H_2O$ rotational lines in the lower atmosphere and UVS detection of the water vapor dissociation products, H and O, in the upper atmosphere are mutually complementary results. Above the dust, water vapor is photodissociated, while the infrared observation penetrates to a deeper level in the Martian atmosphere to observe the water vapor lines.

In agreement with theory that predicts the formation of an ionosphere from a predominantly $CO_2$ upper atmosphere, the average plasma scale height of about 38 km, as determined by means of the S-band occultation experiment, is about twice the neutral scale height of about 20 km measured by the UVS. The temperature of the upper atmosphere derived from these results is lower than that measured in 1969 and higher than in 1964, reflecting the change in solar activity between these times of measurement.

The mid-latitude temperature profiles of the Martian lower atmosphere, as determined by IRIS and the S-band occultation experiment, are more isothermal than the near-adiabatic profiles determined by the 1969 occultation measurements, which are generally expected for these latitudes and seasons (*3*). The mean temperatures at all tropospheric levels also are higher than expected. A reasonable explanation is solar energy deposition in the first one or two scale heights due to absorption by entrained dust. The reduced UVS Rayleigh scattering at normal viewing in 1971 compared with that in 1969 also implies significant dust in at least the lowest scale height. An intriguing question is whether a subadiabatic atmosphere implies the absence of convection when significant thermal exchange processes involving dust are present. Infrared results suggest significant thermal coupling among particles and gas. In the absence of convective support, particles entrained for 30 days at several scale heights will, from the Stokes-Cunningham equation, have diameters less than several micrometers (*4*). With convection, larger particles may be present in the middle troposphere. Detached limb hazes are visible in television pictures at an altitude of 60 km, but whether these are dust or condensates is indeterminate at present.

In contrast to the more isothermal atmospheric temperature profiles observed at lower latitudes, a region of strong temperature inversion exists near the south polar cap. This difference of character suggests a relation with the relative absence of atmospheric dust in this area.

The interpretation of the spectral and radiometric infrared measurements over the polar cap does not allow, at present, a decisive inference of the composition of the residual polar cap.

The margin of the remnant of the south polar cap viewed in 1971 is remarkably regular and uniform compared with the cap margin observed in 1969. This observation indicates that the underlying topography is more uniform and less cratered than the frost-covered area at the edge of the cap as viewed in 1969. The emergence of certain areas of the cap during the period of observation indicates that the frost cover is only a few centimeters thick in these areas. The thickness of the frost in other areas is still undetermined. The frost-covered curvilinear features observed in 1969 are frost free in 1971; comparison with frost-free crater rims and frost-covered crater floors indicates that the curvilinear features may be ridges.

The S-band occultation experiment revealed overall elevation differences of about 12 km, with an associated variation in atmospheric surface pressure of about 3 to 8 mb. The floor of Hellas is a low area, lying about 6 km below its western rim (4 km below the mean radius) and gradually sloping up toward the east. This finding is in good agreement with the pressure mapping results from the ultraviolet and infrared spectrometers on Mariner 7. The area at 33° to 40°S latitude between Mare Sirenum and Solis Lacus is elevated by 5 to 8 km, in good agreement with planetary ranging results at more northerly latitudes. Radius measurements from the S-band occultation experiment are consistent with a mean equatorial radius of 3394 km.

Dynamical measurements give broad-scale elevation contours that are compatible with radar and occultation elevations. The variations are much greater than would be expected by scaling from Earth and the moon, implying large crustal stresses. Equatorial variations in the dynamical measurements have a high of 3 km in the area of Tharsis, where the radar profile peaks at 8 km above the mean radius. These values suggest that less dense rocks underlie the Tharsis ridge. The picture of the possible volcanic vents along this ridge is consistent with this suggestion.

From the IRIS data, it is suggested that the composition of the Martian dust corresponds approximately to that of rocks of intermediate $SiO_2$ content (55 to 65 percent by weight). The form of the possible volcanic vents at Nix Olympica and the three spots along the Tharsis ridge is consistent with this intermediate igneous rock composition and therefore imply planetary differentiation.

The large dynamical pole flattening obtained from satellite observations has been confirmed by the Mariner 9 data. The effect of this flattening on the spacecraft's orbit has been used to improve our knowledge of the polar axis direction; television picture measurements confirm these results. Television pictures also have been used metrically to improve the ephemerides of the orbits of the Martian satellites, Phobos and Deimos.

Closeup observations of Phobos and Deimos, obtained for the first time, show irregular, cratered surfaces of low visual albedo. Data from the UVS indicate an ultraviolet albedo lower than, but a reddish color similar to, that of Mars.

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**References and Notes**

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## Mariner 9 Television Reconnaissance of Mars and Its Satellites: Preliminary Results

Abstract. *At orbit insertion on 14 November 1971 the Martian surface was largely obscured by a dust haze with an extinction optical depth that ranged from near unity in the south polar region to probably greater than 2 over most of the planet. The only features clearly visible were the south polar cap, one dark spot in Nix Olympica, and three dark spots in the Tharsis region. During the third week the atmosphere began to clear and surface visibility improved, but contrasts remained a fraction of their normal value. Each of the dark spots that apparently protrude through most of the dust-filled atmosphere has a crater or crater complex in its center. The craters are rimless and have featureless floors that, in the crater complexes, are at different levels. The largest crater within the southernmost spot is approximately 100 kilometers wide. The craters apparently were formed by subsidence and resemble terrestrial calderas. The south polar cap has a regular margin, suggsting very flat topography. Two craters outside the cap have frost on their floors; an apparent crater rim within the cap is frost free, indicating preferential loss of frost from elevated ground. If this is so then the curvilinear streaks, which were frost covered in 1969 and are now clear of frost, may be low-relief ridges. Closeup pictures of Phobos and Deimos show that Phobos is about 25 ± 5 by 21 ± 1 kilometers and Deimos is about 13.5 ± 2 by 12.0 ± 0.5 kilometers. Both have irregular shapes and are highly cratered, with some craters showing raised rims. The satellites are dark objects with geometric albedos of 0.05.*

The Mariner 9 spacecraft arrived at Mars on 14 November 1971 during a planetwide dust storm of unusual intensity. While forcing the postponement of most geologic and cartographic objectives, the storm has provided an unparalleled opportunity to examine at close range a phenomenon connected with Martian meteorology, topography, depositional and erosional processes, and variable features.

On 22 September Earth-based observers (*1*) recorded that a bright yellow cloud had developed over Noachis, in the midsouthern latitudes of Mars. It spread rapidly over the rest of the planet, and in a little more than 2 weeks the entire visible globe was covered by dust; even the south polar cap had disappeared from view of telescopes. By the fifth week the dust storm had reached its peak, exceeding all previously observed Martian storms in obscuration, areal extent, and duration. Over the next several weeks the atmosphere of Mars showed a gradual clearing, and the south polar cap reappeared. Upon is arrival Mariner 9 found the obscuration still severe.

As Mars rotated in the view of the approaching spacecraft, three preorbital science (POS) sequences of photographs were taken, giving total global coverage of the dust-shrouded planet. Only five distinct features could be seen—the south polar cap and four dark spots (Fig. 1). One of these has been identified as Nix Olympica, and the other three (provisionally labeled North, Middle, and South Spots) have been identified with a group of features that

Table 1. Camera filters. The effective wavelength is for sunlight.

| Camera | Filter type | Effective wavelength (μm) |
|---|---|---|
| Wide angle | Orange | 0.610 |
| Wide angle | Green | 0.545 |
| Wide angle | Blue | 0.477 |
| Wide angle | Violet | 0.414 |
| Wide angle | Polarization* | 0.565 |
| Wide angle | Yellow (minus blue) | 0.560 |
| Narrow angle | Yellow (minus blue) | 0.558 |

* Three filters with axes spaced in 120° steps.