11

Mars Observer: Mission Toward a Basic Understanding of Mars

A. L. Albee

The Mars Observer Mission will provide a spacecraft platform about Mars from which the entire Martian surface and atmosphere will be observed and mapped by remote sensing instruments for at least 1 Martian year. The scientific objectives for the Mission emphasize qualitative and quantitative determination of the elemental and mineralogical composition of the surface; measurement of the global surface topography, gravity field, and magnetic field; and the development of a synoptic data base of climatological conditions. The Mission will provide a basic global understanding of Mars as it exists today and will provide a framework for understanding its past.

This chapter describes the Mars Observer Mission as it stood in the late 1980s. Since that time, some changes have occurred in the mission plan. Mars Observer will be launched on a Titan III and will have a somewhat higher mapping orbit and somewhat different mapping cycle. The Visual and Infrared Mapping Spectrometer experiment will not be flown and the radar altimeter has been replaced by a laser altimeter. For an updated description see Albee, A. L. and Palluconi, D. F. (1990) EOS, vol. 71, pp. 1099, 1107.

Science Objectives and Expected Results

The formal scientific objectives of this geoscience and climatological mission are to

1. Determine the global elemental and mineralogical character of the surface material;

2. Define globally the topography and gravitational field;

3. Establish the nature of the magnetic field;

4. Determine the time and space distribution, abundance, sources, and sinks of volatile material and dust over a seasonal cycle;

5. Explore the structure and aspects of the circulation of the atmosphere.

These first-order scientific objectives can be addressed within the framework of a low-cost orbital mission. All five objectives involve global mapping. For the geoscience objectives, this mapping is time-independent and therefore two-dimensional: latitude and longitude. For many climatology objectives, the mapping is four-dimensional: latitude, longitude, vertical, and season. As a result of the Mission we should have a more systematic global characterization of Mars, as it exists today, than of Earth. This characterization will help us to understand the geologic and climatologic history of Mars and the evolution of its interior and surface.

Geoscience

The first three of these objectives are geoscience objectives—they involve measurement of quantities of geological, geochemical, and geophysical interest. The single lithospheric plate comprising the Martian surface is a little larger than the combined area of all the Earth's continental plates. Mapping of this 144×10^6 km^2 area will occur over the full Martian year—687 Earth days—planned for the Mars Observer Mission. This plate is highly complex with high-altitude, heavily cratered uplands in the southern hemisphere and lower, less-cratered plains in the northern hemisphere. Relatively young volcanic shields and cones are most abundant in the north, but annual permanent ice and associated layered deposits occur near each pole. Many units have been variously modified by crustal and surface processes to produce canyons and channels; chaotic, fretted, and hummocky terrains; and sand sheets and dunes.

The Mission will seek to understand the distribution of chemical elements and minerals on the Martian surface in relation to the age, origin, nature, and weathering of the surface rocks. Simultaneous global mapping of the gravitational field, the surface topography, and the magnetic field will improve our understanding of both the surface and the interior of Mars. Combining these distinctly different measurements in a single mission exploits their inherent synergism and allows us to realistically address such global problems as Mars' bulk composition, the degree of differentiation of the planet, the chemical and mineralogical composition of the crust and mantle, and the nature and cause of the planet-wide dichotomy into uplands and plains.

The potassium/uranium ratio, for example, provides important clues. Uranium provides an index for those elements that tend to condense from the solar nebula at high temperatures, potassium is an index for elements with lower temperatures, yet both behave similarly in magmatic processes. Thus the K/U ratio, coupled with other elemental ratios, provides a means of reconstructing the bulk composition of the planet. The absolute content of these two elements in the crustal material also gives an indication of the degree of differentiation of the planet; gives an estimate of the amount of volatiles, including water, that has outgassed from the planet; and places tight constraints on the thermal modeling of the planet.

The nature of the crust will be well defined by the elemental and mineralogical mapping, and global variations in crustal thickness will be determined from mapping the gravity field and surface topography. Major unknowns are the nature and cause of the planet-wide dichotomy into old cratered upland and sparsely cratered plains. Mars Observer may determine chemical and mineralogical differences between the two regions, how the crust and lithosphere differ beneath the two regions, and the nature of their boundary. All of these will lead to a much better understanding of the nature of the dichotomy, what caused it, and when it developed.

The volcanoes of Mars are well known, but we have almost no information on the chemistry and mineralogy of the lavas—from which we could infer the composition of the mantle, the depth of origin of the magma, and whether the magmas have undergone differentiation during their passage from the source region to the surface. Mars Observer should discover whether there are regional differences in composition that might be the result of differences in source rock or depth of origin of the magmas.

Mapping of the gravitational and topographic fields will lead to better understanding of the volcanic processes and the thermal evolution of the interior. Lithospheric thickness may be determinable from the deformation of the surface by large volcanoes. Thermal conditions in the interior can be understood from the apparent viscosity of the crust and upper mantle as indicated by the degree and depth of isostatic compensation of different craters, canyons, and volcanoes. Increase in the depth of composition with the age of such features might suggest that the lithosphere has thickened with time. Magnetic measurements will indicate whether conditions in the core today can sustain a planetary dynamo and, if not, whether such conditions existed in the past.

Much of the Martian surface appears to be covered with weathering products. Tentative identifications have been made of specific absorption bands seen in telescopic observations, but we actually know very little about the chemistry and mineralogy of the surface. Mars Observer will provide these basic characterizations. We particularly want to understand the amount of water, how it is contained in the minerals, and whether these minerals are forming currently or are "fossils" from past climates. We may then infer how water is cycled during the current seasonal and obliquity cycles and whether significantly different climates in the past are required to explain the formation of the soil materials. Understanding the abundance of volatile-containing materials will lead to improved estimates of the amount of water and other volatiles outgassed from the planet and provide clues as to when the outgassed volatiles were removed from the atmosphere to become fixed in the soil.

Mars Observer provides an opportunity for mapping the planet-wide distribution of ice in the near-surface material. Ice is believed to be a major component in the polar-layered terrain, detectable by Mars Observer from both (spectral) composition and gravity information. Ice may also be present in the soils at high latitudes, its low latitude limit varying with the season. Detection of such ice will depend upon its proximity to the surface and whether seasonal changes can be discerned. Detection of liquid water is not expected, but aberrant conditions might allow seepage to the surface. Such a discovery would lead to significant reassessment of how water is circulated about Mars.

Finally, more precise determination of topography and gravity will lead to a more complete understanding of almost every geologic process that has affected the surface. Our current understandings are based largely on surface morphology and are hindered by the lack of quantitative information against which different ideas can be tested. Better information on slopes will lead to a better understanding of fluvial erosion and emplacement of lavas. Comparison of present-day slopes with past slopes as indicated by lava flow or stream directions will provide information on deformation rates. Better information on gravity patterns of craters and on crater depths, rim heights, and ejecta thickness will lead to a more complete understanding of cratering.

Acquisition of chemical, mineralogical, gravitational, and elevational data by Mars Observer will improve our understanding of almost every aspect of the planet's geology. However, the main impact will be an improved understanding of global problems rather than local geologic processes. Improved understanding of the planet's bulk composition, the composition of the crust and mantle, the thickness of the lithosphere, the thermal state of the interior, and the planet's outgassing history will inevitably follow from Mars Observer. This will be the Mission's main legacy.

Climate

The fourth and fifth objectives address volatile cycles (e.g., carbon dioxide, water), dust, the Martian atmosphere, and the atmospheric interaction with the surface. The emphasis is on the seasonal variations, hence the use of the term "climatology." An understanding of the current climate of Mars permits us to better assess how currently active processes (weathering, erosion, atmospheric transport, dust deposition) are modifying the surface. If we are able to understand the current climate, we may more confidently project this knowledge backward in time to periods when the Martian orbit, axial characteristics, and atmospheric pressure were different. In principle, determination of the daily, as well as the seasonal, behavior of the global atmosphere would be ideal. However, providing complete daily sampling is difficult from a single orbiting spacecraft and is not possible from the sun-synchronous mapping orbit selected for this Mission.

Mars Observer will provide

1. A greatly improved characterization of the atmospheric general circulation of Mars and of the factors that govern it;

2. A much more complete description of the present seasonal cycles of H_2O, CO_2, and dust, and the key parameters controlling them;

3. Important clues and constraints on the nature of past climate changes; and

4. The evolution of the Martian atmosphere.

The good synoptic coverage of the atmospheric temperature will make it possible to assess the relative importance of various circulation mechanisms in transporting heat and momentum as well as in transporting volatiles and dust. By conducting observations over a full set of Martian seasons and at times of varied dust loading and cloud cover, it should be possible to identify the feedback between the circulation, the volatiles, and the dust—how each affects the other, and how they collectively affect the climate.

These data and their analysis will provide a solid basis for comparing the general circulation of the Martian and terrestrial atmospheres. By using a variety of dynamic models to seek out their similarities and differences we will gain a more profound perspective on atmospheric dynamics and its underlying controls.

Mars Observer will provide quantitative information on almost all major fluxes and reservoirs that control the seasonal cycles of CO_2, H_2O, and dust. For example, these data will help define the amount of atmospheric water gained or lost at different seasons from the principal surface water reservoirs—the seasonal polar caps, the perennial polar caps, and the mid- to low-latitude regolith. By measuring the amount of atmospheric water present, both as vapor and as ice clouds, and by concurrently obtaining data on atmospheric motions, Mars Observer will permit an evaluation of how far atmospheric water travels from its source region. Thus the relative roles played in the seasonal water cycle by the polar caps, the regolith, and atmospheric transport will be quantitatively assessed.

Mars Observer will also provide valuable insights into the factors controlling the life cycle of global dust storms. By providing good temporal and spatial coverage of the growth phase of global dust storms, by observing the atmospheric circulation, and by concurrently measuring the spatial distribution of atmospheric dust and temperature, a firm basis will be provided for understanding the processes that permit a local dust storm to grow rapidly to global proportions and then to decay soon after. Of special interest will be determination of the dust heating/wind speed relationships and understanding the influence of dust loading over the life span of a global dust storm.

It will also be possible to examine the important interactions of the various seasonal cycles. For example, the amount of dust deposited on the seasonal and perennial polar ice deposits probably plays a critical role in the stability of these deposits. The occurrence of a perennial H_2O ice cap in the north and the occasional occurrence of a perennial CO_2 ice cap in the south may be due to differing amounts of dust deposited on the two caps, thereby strongly influencing their albedos. By observing the amount of dust present in the polar atmospheres over the course of a Martian year and by measuring the heat balance of the polar regions, the experiments on Mars Observer will provide an understanding of the coupling of the dust and CO_2 cycles.

Improved understanding of atmospheric circulation and seasonal cycles may provide insight into how they may have changed in the past due to astronomical variations of orbital and axial properties. This goal will be significantly enhanced if an extended Mars Observer Mission or future mission provides observations over several Martian years. We need to characterize the interannual variation in atmospheric circulation and the H_2O/CO_2/dust cycles in order to understand their causes.

Observations of the polar layered terrain will advance our knowledge of the nature of the quasi-periodic changes on Mars. Measurements of the dust:water:ice ratio, topography, and volume of these layers will provide constraints on their formation and the nature of the episodic atmospheric transport of water and fine dust into the polar regions. Determination of the amount and size of dust and water ice particles in the present polar atmosphere will provide an estimate of the present rate of deposition.

The occurrence, abundance, and spatial distribution of hydrous and carbonate minerals in the Martian soil is important to determining when and how H_2O and CO_2 have been lost from the atmosphere by weathering processes. These provide constraints on the possible occurrence of warmer and wetter climates in Mars' past history and on the total amount of H_2O that was outgassed into the atmosphere. The nature of fluvial channels provides additional constraints on the past climate.

With all of these observations and understandings it will be possible to explore the linkages between astronomical (primarily solar) variations, climate changes, and genesis of layered terrain and fluvial channels. Finally, given such improved understanding of the coupled issue of climatic change and atmospheric evolution on Mars, it will be important to make comparisons with comparable phenomena on Earth, seeking out general patterns and controls and the factors responsible for the similarities and differences in these phenomena for the two planets.

Exobiology

Scientific evidence makes it difficult to sustain the notion that life exists on Mars today, but evidence does suggest that the climate on early Mars was quite different from that today and may have been more conducive to life. Dendritic valley systems indicate that liquid water once flowed on the Martian surface and we can infer that the Martian surface temperatures were considerably warmer and atmospheric pressures much higher than they are today. Life could have arisen on Mars during this early climate epoch. If so, some evidence might eventually be found within the large areas of the Martian surface that date back to this time.

The Mars Observer Mission is unlikely to find such evidence, but it will provide information to guide future missions to locations on the Martian surface optimal for this search. Moreover, it will help us to understand the climatic history of both Mars and Earth. The daily and seasonal weather cycles on Mars and Earth are very similar, but the Martian thin atmosphere, rapid heating and cooling of the surface, the abundance and distribution of water, the lack of oceans, the annual condensation cycle of carbon dioxide, and massive dust storms are critical differences. Since both planets show evidence of drastic climate changes in the past, common mechanisms might be responsible, which include solar luminosity changes, orbital variations, volcanic eruptions, asteroid impacts, etc. The improved understanding of climatic change, with consequent effects on biota and biologic processes, will be the most important contribution of Mars Observer to the science of exobiology.

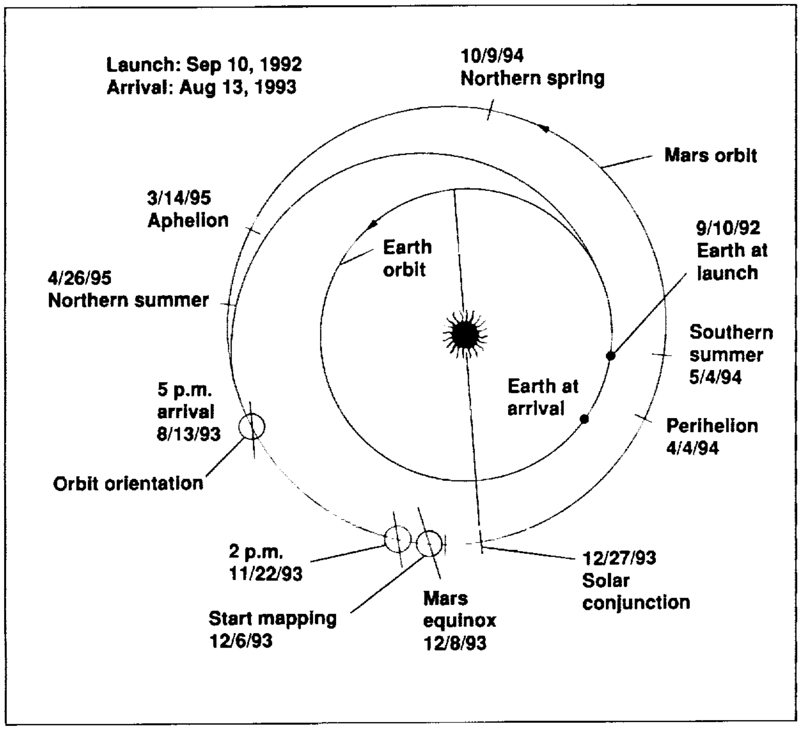


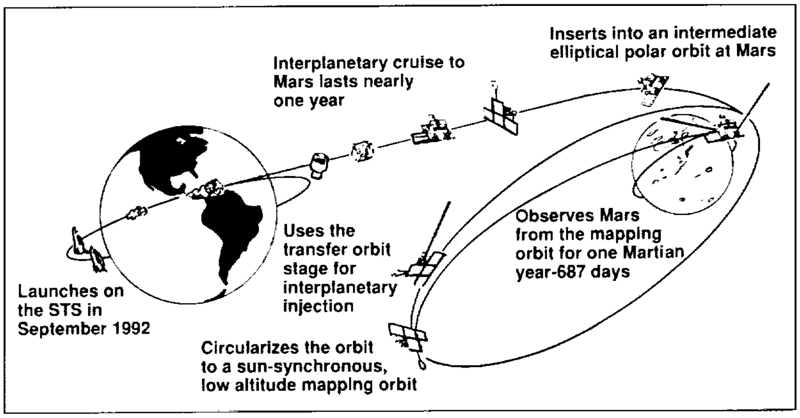
Figure 11-1. Mars Observer trajectory in heliocentric projection.

Mission Description

Mars Observer is planned for a September 1992 launch (fig. 11-1). After the 1-year transit the spacecraft is injected into an elliptical orbit about Mars with periopsis near the north pole (fig. 11-2). The orbit is then adjusted through a series of maneuvers to a near-circular, sun-synchronous (2:00 a.m./p.m.), low-altitude (360 km), near-polar orbit. During the Martian year in this mapping orbit the instruments gather data by repetitive global mapping. At the end of the Mission the spacecraft is boosted from the mapping orbit to a quarantine orbit in which it can remain indefinitely.

Figure 11-3 summarizes the mapping timeline, relative to Martian seasons and the normal dust storm period. The mapping orbit is a 2-hour orbit with a 3-day repeat cycle shifted by 30 km. As a result, the planet is repeatedly mapped in 59-day cycles with 40-km swath widths and 10-km overlaps. The Mars orbit insertion (MOI) period is shown ending just before solar conjunction and the beginning of the dust storm period. It is scientifically important to make observations, preferably for an entire 59-day cycle, before the onset of a major dust storm, and it is hoped that the fuel margin will permit a shorter MOI period. Figure 11-3 also shows that the playback data rate for an 8-hour link varies by a

Figure 11-2. Generalized Mission description. The launch may use a Titan III rather than the STS, as shown.



factor of four with Earth-Mars distance (see fig. 11-1) during the Mission. The continuous recorded data rate to the tape recorders is about one-fifth the playback rate.

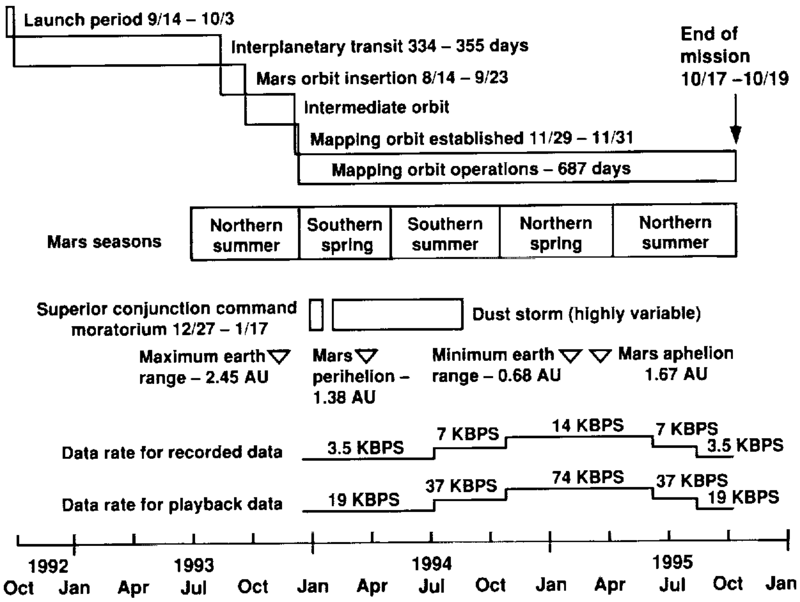


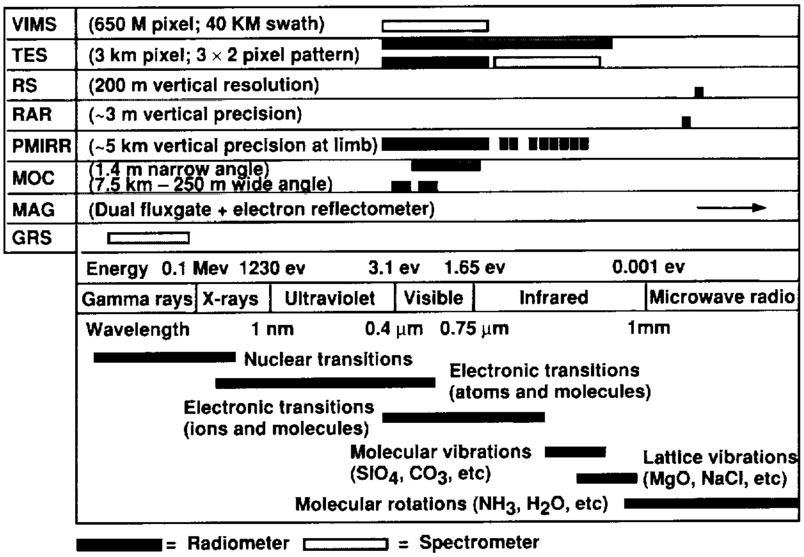
Figure 11-3. Mapping phase time line.

Science Experiments and Instruments

The remote sensing instruments for Mars Observer have been chosen with the above stated scientific objectives in mind. Collectively the instruments cover much of the electromagnetic spectrum and, as shown in figure 11-4, they sense a variety of physical processes. Each instrument produces well-defined sets of measurements and addresses specific major objectives, but nearly every data set also contributes to a much wider variety of scientific investigations. Five interdisciplinary scientists have been selected in order to exploit the strong synergism that exists between the data from the eight instruments. Moreover, participating scientists, including 10 from the former USSR, will be added in the future to further exploit the data returned from the Mission. Each of the instruments and their experimental objectives are described in the next section.

The Gamma Ray Spectrometer and Magnetometer sensor assemblies are mounted on individual

Figure 11-4. Mars Observer instrument measurement ranges and physical processes of electromagnetic radiation.



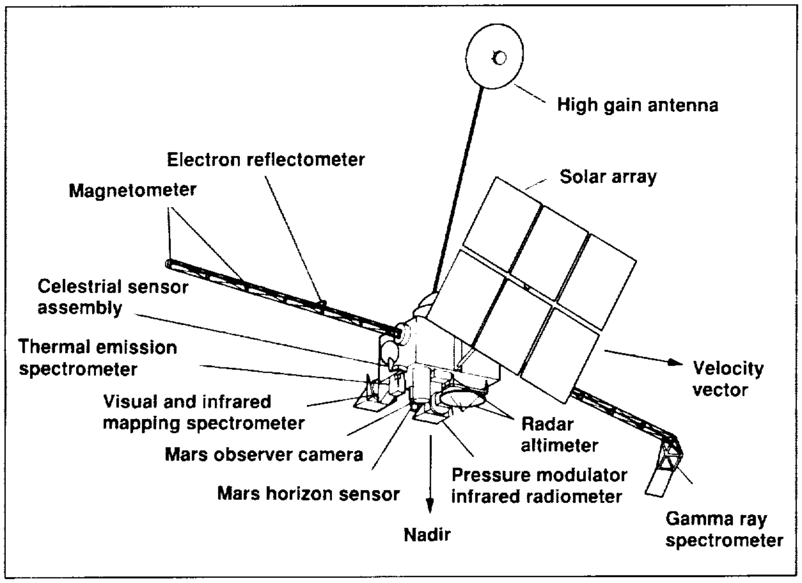


Figure 11-5. Configuration of instruments on the Mars Observer Spacecraft during the mapping orbit.

booms on the spacecraft (fig. 11-5). All other instruments are rigidly mounted to the spacecraft structure. No movable platform is provided; the spacecraft is continuously nadir-pointed, rotating at orbital rate. Thus, instruments that require scanned or multiple fields of view have internal scanning mechanisms.

Gamma Ray Spectrometer and Neutron Spectrometer

The team leader for the Gamma Ray Spectrometer experiment is W. Boynton of the University of Arizona. The instrument has a high spectral-resolution germanium detector cooled below 100 K by a passive radiator. It will measure the intensities of characteristic gamma-ray lines that emerge from the Martian surface within the energy range 0.20 to 10 MeV. Neutrons will be detected with a plastic scintillator to determine the abundance of H_2O and CO_2.

The specific objectives of this investigation are to

1. Determine the elemental composition of the surface of Mars with a spatial resolution of a few hundred kilometers through measurements of excited gamma-rays and albedo neutrons (H, O, Mg, Al, Si, S, Cl, K, Ca, Fe, Th, and U);

2. Determine hydrogen depth dependence in the top tens of centimeters of the surface;

3. Determine the atmospheric column density; and

4. Determine the arrival time and spectra of gamma-ray bursts.

Mars Observer Camera

The principal investigator of the Mars Observer Camera is M. Malin of Arizona State University. The instrument is a line scan camera which incorporates both wide-angle and narrow-angle optics for producing global coverage (7.5 km/pixel), selective moderate resolution images (480 m/pixel), and very selective high-resolution (1.4 m/pixel) images.

The specific objectives of this investigation are to

1. Obtain global synoptic views of the Martian atmosphere and surface to study meteorological, climatological, and related surface changes;

2. Monitor surface and atmospheric features at moderate resolution for changes at time scales of hours, days, weeks, months, and a year; and

3. Systematically examine local areas at extremely high spatial resolution in order to quantify surface/atmosphere interactions and geological processes.

Visual and Infrared Mapping Spectrometer

This instrument was selected for the Mission, but the necessity to reduce anticipated costs to meet the budget led to its deletion in August 1988.

The team leader for the Visual and Infrared Mapping Spectrometer was L. Soderblom of the U.S. Geological Survey. The instrument was a whisk broom, 320-channel mapping spectrometer operating in the 0.35 to 5.2 micrometer spectral region. It utilized a line array cooled to 80 K by a passive radiator, grating dispersion, and had a 1.8 mrad instantaneous field-of-view and a full field-of-view of 6.6°. The high spectral resolution and broad spectral coverage (11 nanometers from 0.35 to 2.4 micrometers and 22 nanometers from 2.4 to 5.2 micrometers) would have permitted direct identification of many minerals on Mars.

The specific objectives of this investigation were to

1. Produce km-resolution mosaics of the Martian surface in 320 spectral channels for the purpose of identifying mineralogical and chemical units, studying the distribution of surface volatiles, and understanding the physical structure of the regolith; and

2. Produce a global map of the Martian surface at 10 km resolution in 10 selected wavelengths to extend the local interpretation to a global scale.

Thermal Emission Spectrometer

The principal investigator of the Thermal Emission Spectrometer is P. Christensen of Arizona State University. The instrument is a Michelson interferometer which covers the spectral range 6.25 to 50 micrometers with 10 cm^{-1} spectral resolution. Separate solar reflectance (0.3 to 3.9 micrometers) and broad band radiance (0.3 to 100 micrometers) channels are included. It has six 8.3 mrad fields of view, each with 3 km spatial resolution at nadir.

The specific objectives of this investigation are to

1. Determine and map the composition of surface minerals, rocks, and ices;

2. Study the composition, particle size, and spatial and temporal distribution of atmospheric dust;

3. Locate water-ice and carbon dioxide condensation clouds and determine their temperature, height, and condensate abundance;

4. Study the growth, retreat, and total energy balance of the polar cap deposits;

5. Measure the thermophysical properties of the Martian surface (thermal inertia, albedo) that can be used to derive surface particle size and rock abundance; and

6. Determine atmospheric temperature, pressure, water vapor, and ozone profiles, and seasonal pressure variations.

Pressure Modulator Infrared Radiometer

The principal investigator of the Pressure Modulator Infrared Radiometer is D. McCleese of the Jet Propulsion Laboratory. The instrument is a limb, off-nadir, and nadir scanning radiometer. Measurements are made in nine spectral bands with five filter channels and two pressure modulator cells (one containing carbon dioxide, the other, water vapor). The detectors are cooled to 88 K by a passive radiator.

The specific objectives of this investigation are to

1. Map the three-dimensional and time-varying thermal structure of the atmosphere from the surface to 80 km altitude;

2. Map the atmospheric dust loading and its global, vertical, and temporal variation;

3. Map the seasonal and spatial variation of the vertical distribution of atmospheric water vapor to an altitude of at least 35 km;

4. Distinguish between atmospheric condensates and map their spatial and temporal variation;

5. Map the seasonal and spatial variability of atmospheric pressure; and

6. Monitor the polar radiation balance.

Radar Altimeter and Radiometer

This instrument was initially selected for the Mission. However, the necessity to reduce anticipated costs to meet the budget led to plans to substitute this instrument with a reduced capability and less costly laser altimeter in August 1988.

The principal investigator of the Radar Altimeter and Radiometer is D. Smith of the Goddard Space Flight Center. The instrument is a Ku-band (13.6 GHz) radar altimeter/radiometer with an adaptive resolution tracking system; it will return amplitude, shape, and time delay of echo along with brightness temperature using a 1-meter nadir-pointed antenna.

The specific objectives of this investigation are to

1. Provide topographic height measurements with a vertical resolution better than 0.5% of the elevation differences within the footprint;

2. Provide slope information, averaged over the footprint;

3. Provide surface brightness temperatures at 13.6 GHz with a precision of better than 2.5 K; and

4. Provide well-sampled, radar-return waveforms for precise range corrections and the characterization of the Martian surface.

Radio Science

The team leader for the Radio Science investigation is G. L. Tyler of Stanford University. The instrument is the spacecraft radio subsystem, x-band up- and down-link, supplemented with an ultrastable oscillator to maximize the science during occultation.

The specific objectives of this investigation are

Atmosphere–

1. Determine profiles of refractive index, number density, temperature, and pressure at about 200 m resolution for the lowest few scale heights at high latitudes in both hemispheres on a daily basis;

2. Monitor both short-term and seasonal variation in atmospheric stratification;

3. Characterize the thermal response of the atmosphere to dust loading;

4. Explore the thermal structure of the boundary layer at about 10 m resolution;

5. Determine the height and peak plasma density of the daytime ionosphere; and

6. Characterize the small-scale structure of the atmosphere and ionosphere.

Gravity–

1. Develop a global, high-resolution model of the gravitational field;

2. Determine both local and broad-scale density structure and stress state of the Martian crust and upper mantle;

3. Detect and measure temporal changes in low degree harmonics of the gravitational field; and

4. Provide planetary radius measurements.

Magnetometer and Electron Reflectometer

The principal investigator of the Magnetometer is M. Acuna of the Goddard Space Flight Center. The instrument has two triaxial fluxgate magnetometers and an electron-reflectometer, mounted on a 6-meter spacecraft boom. Two to sixteen vector samples per second will be acquired.

The specific objectives of this investigation are to

1. Establish the nature of the magnetic field of Mars;

2. Develop models for its representation which take into account the internal sources of magnetism and the effects of the interaction with the solar wind;

3. Map the Martian crustal remnant field using the fluxgate sensors and extend these *in situ* measurements with the remote capability of the electron-reflectometer sensor;

4. Characterize the solar wind/Mars plasma interaction; and

5. Remotely sense the Martian ionosphere.

Interdisciplinary Scientists

R. Arvidson of Washington University—Geoscience.

The objectives of this investigation are to gain an understanding of the mechanisms of weathering, their temporal variations, and the cycling of volatiles through the sedimentary system. He has additional responsibilities for science data management and archiving.

M. Carr of U.S. Geological Survey—Geoscience.

The objectives of this investigation are to gain a better understanding of the role of water in the evolution of the Martian surface, to characterize the planet's volcanic history, and to determine the nature and cause of the uplands/plains dichotomy.

A. Ingersoll of the California Institute of Technology—Polar Atmospheric Science.

The objectives of this investigation are to define atmospheric circulation during all seasons to specify polarward transport of carbon dioxide, water, dust, and energy as well as the radiative and surface fluxes in the polar regions.

B. Jakosky of the University of Colorado—Surface-Atmospheric Science.

The objectives of this investigation are to determine the nature of the interaction between the surface and atmosphere in order to better understand the processes involved in the formation and evolution of the Martian surface and atmosphere.

J. Pollack of Ames Research Center—Climatology.

The objectives of this investigation are to assess the influence of dust on atmospheric circulation, the factors which control the life cycle of dust storms, the role of dynamics in the seasonal water cycle, the transport of dust, the constraints on an early dense carbon dioxide atmosphere, and the modulations of atmospheric circulation due to astronomical variations.

Mission Operations and Data Analysis

The Mars Observer Mission will be conducted in a mission support area at the Jet Propulsion Laboratory and will be supported by the Deep Space Network and the Space Flight Operations Center. The science investigation teams will be remotely located at the home institutions of the principal investigators, team leaders, and other key science personnel. Workstations and electronic communication links will connect the mission planning and data analysis activities of these scientists, engineers, and mission managers. Via the workstations, the science teams will receive data and planning products, plan investigation activities, prepare inputs to the sequence generation process, provide analyses of instrument health and performance, and return reduced or processed investigation data for use by other project participants.

The Mars Observer project will use data standards for packet telemetry and telemetry channel coding and will use a standard formatted data unit for data transfer among ground systems. Mission data will be stored in a project data base. Analysis data will consist of a record of each instrument's packet telemetry data provided as an experiment data record; spacecraft position and pointing information data available as a supplementary experiment data record; and related data such as spacecraft status, commands, data availability, and ancillary data. Planning products available will be the up-to-date mission sequence plan, schedules and commanding opportunities, and orbit/viewing forecasts. Investigators and analysts will access the data base to participate in the planning process and provide analysis products, including spacecraft and instrument performance and status, and higher-order data products, such as intermediate and final science products.

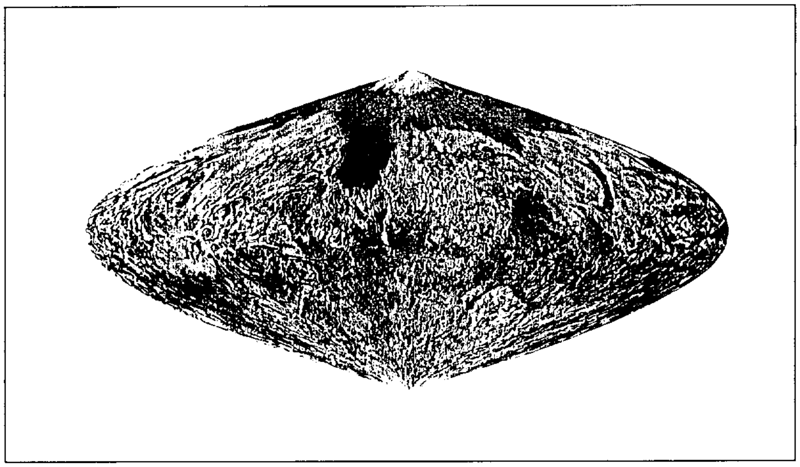


Figure 11-6. Sinusoidal equal-area projection of Mars made from a digitized airbrush map with 3.7 km pixels.

All of the instruments are "mapping" instruments in some sense. Efficient comparison of such data requires global digital data bases that are each accessible to end users and that can be manipulated without the assistance of technological experts. A sinusoidal equal-area projection will be used as a base. In this projection each parallel of latitude is an image line with its length compressed by the cosine of its latitude (fig. 11-6). A global digital image mosaic is being constructed from selected Viking images, which will be radiometrically, photometrically, and geometrically transformed. Each pixel represents 1/256° (about 230 m) and the scale can be readily changed by negative powers of two. Such a base and system is designed to allow efficient computer storage and management, user access, coregistration of data bases, rapid manipulation of data bases for effective analysis and interpretation, and inexpensive preparation of image maps on desired projections. The data bases will be widely distributed, probably on digital-optical (CD-ROM) disks.

Summary

The Mars Observer Mission will extend the exploration and characterization of Mars by providing new and systematic measurements of the surface and atmosphere of the planet. These measurements will be made from a low-altitude polar orbiter over a period of 1 Martian year, permitting repetitive observations of the surface and of the seasonal variations of the atmosphere. The Mission is being designed and will be conducted in a manner that will provide new and valuable scientific data at a significant reduction in cost and operational complexity.

Additional Reading

Batson, R. M.: Digital Cartography of the Planets: New Methods, Its Status and Future. Photogrammetric Engineering and Remote Sensing, vol. 53, 1987, pp. 1211-1218.

Edwards, K.: Geometric Processing of Digital Images of the Planets. Photogrammetric Engineering and Remote Sensing, vol. 53, 1987, pp. 1219-1222.

McCleese, D. J.; Schofield, J. T.; Zurek, R. W.; Martonchik, J. V.; Haskins, R. D.; Paige, D. A.; West, R. A.; Diner, D. J.; Locke, J. R.; Chrisp, M. P.; Willis, W.; Leovy, C. B.; and Taylor, F. W.: Remote Sensing of the Atmosphere of Mars Using Infrared Pressure Modulation and Filter Radiometry. Applied Optics, vol. 25, 1986, pp. 4232-4245.