Mars Observer Instrument Complement

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The Mars Observer instrument complement meets the scientific objectives derived from the National Academy of Sciences Space Science Board's Committee on Planetary and Lunar Exploration report, "Strategy for Exploration of the Inner Planets." Specifically, the complement includes the gamma-ray spectrometer, magnetometer/electron reflectometer, Mars balloon relay, Mars Observer camera, Mars Observer laser altimeter, pressure modulator infrared radiometer, thermal emission spectrometer, and ultrastable oscillator.

Introduction

THE overall Mars Observer (MO) science goals are the following: 1) to determine the global elemental and mineralogical character of the surface material; 2) to define globally the topography and gravitational field; 3) to establish the nature of the magnetic field; 4) to determine the spatial and temporal distribution abundance, sources, and sinks of volatile material and dust over a seasonal cycle; and 5) to explore the structure and aspects of the circulation of the atmosphere. These objectives will be achieved through the analysis of data provided by a complement of eight scientific instruments. These instruments and their respective principal investigators and sponsoring institutions are as follows: gamma-ray spectrometer (GRS)—Bill Boynton, University of Arizona; magnetometer/electron reflectometer (MAG/ER)—Mario Acuna, Goddard Space Flight Center; Mars balloon relay (MBR)—Jacques Blamont, Centre National d'Etudes Spatiales; Mars Observer camera (MOC)—Mike Malin, Arizona State University; Mars Observer laser altimeter (MOLA)—David Smith, Goddard Space Flight Center; pressure modulator infrared radiometer (PMIRR)—Daniel McCleese, Jet Propulsion Laboratory; thermal emission spectrometer (TES)—Phil Christensen, Arizona State University; and ultrastable oscillator (USO)—Len Tyler, Jet Propulsion Laboratory. Figure 1 illustrates the location of each externally mounted instrument on the spacecraft bus. The following text describes the higher level design and functional characteristics of the MO payload to illustrate how each instrument will obtain the data required to meet the mission objectives.

Gamma-Ray Spectrometer

The GRS will measure the elemental composition of the surface and atmosphere of Mars using a boom-mounted instrument consisting of a germanium (Ge) crystal detector surrounded by a passive V-groove radiator and four photomultiplier tubes. Elements will be identified by observing gamma rays across a spectrum of energy levels. The elements of particular interest are H, C, O, Na, Mg, Al, Si, Cl, K, Ca, Ti, Cr, Mn, Fe, Ni, Th, and U. As a bonus to the MO mission, the GRS will also detect and measure the spectra of galactic and extra-galactic bursts of gamma rays.

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Mechanical and Electrical Characteristics

The GRS will include a sensor head assembly and a central electronics assembly (CEA). The sensor head will be located at the end of a deployable 6-m boom. The CEA will be mounted onto a plate that is attached to the base of the boom canister.

The gamma-ray detector (Fig. 2) must be extremely cold to achieve the specified spectral resolution. To accomplish this, the sensor will contain a newly developed V-groove radiator that passively cools the germanium detector to slightly below 100 K and, at the same time, cools the first stage electronics to approximately 130 K. The radiator employs a set of V-shaped vanes, made of vapor-deposited gold on graphite, that are designed to radiate heat away from the detector assembly. It also includes a sunshade that permits a 180- × 139-deg deep-space field of view for the radiator assembly. In addition to this, thermal decoupling rods that contain shape-memory alloy metals will be incorporated into the design to provide support during launch and otherwise eliminate conductive heat paths to the detector. Shape-memory metal has a coefficient of thermal expansion that is dependent on whether temperature is rising or falling; the pin contracts faster when temperature is decreasing than it expands when temperature is increasing. When the pins are at room temperature, they will fully engage the crystal housing, providing the required support during exposure to the dynamics of the launch environment. As the rods cool through −55°C in the deep space environment, they will contract about 1.5% in length, eliminating thermally conductive paths to the detector housing.

The CEA will contain a computer, a neutron and gamma pulse height analyzer (PHA), neutron and gamma analog elec-

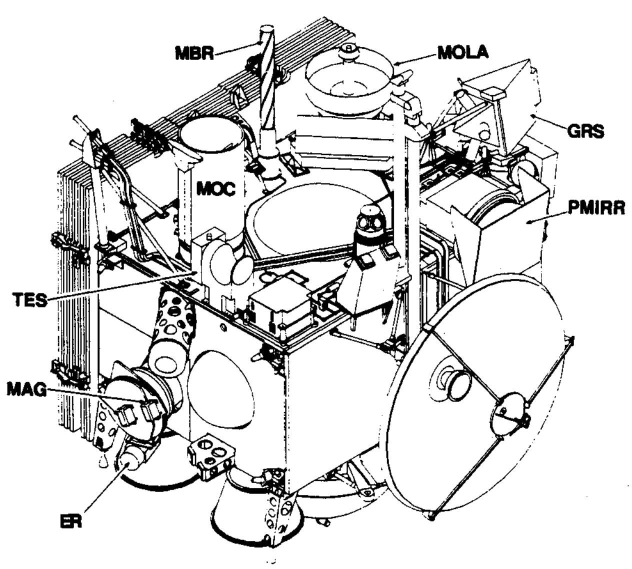

Fig. 1 Mars Observer spacecraft launch configuration.

tronics, power supplies, and heater control electronics. The computer will have 96K PROM, 64K RAM, and three 80C86, 16-bit processors. The neutron PHA will have 16 log channels, 4K PROM, 4K RAM, and 8K dual-port RAM, whereas the gamma PHA will have 10,236 channels, 4K PROM, 4K RAM, and a 2×16 ping-pong RAM. The GRS power supplies operate off of the spacecraft +28-V supply and provide high and low voltage to the instrument internal electronics. The heater control will operate the detector anneal heater and will control the door latch and drive switch heaters. After encountering a series of collisions with high-energy particles, the structure of the Ge crystal becomes fragmented, and it begins to smear spectral channels together. This can be corrected by annealing the crystal at temperatures of 380 K or higher for a period of three days.

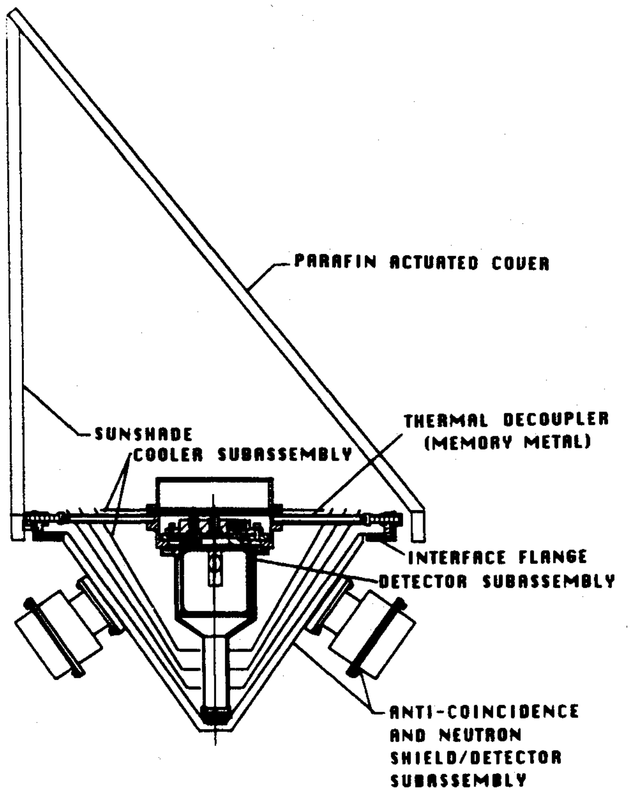

Fig. 2 Cross section of the GRS sensor (sensor size: 77.5 × 43.5 cm).

Functional Design Description

The GRS will be able to detect both gamma rays (200 keV–10 MeV) and neutrons (0–2.5 MeV) with a spectral resolution of 0.61–1.22 keV. Gamma rays will be detected by a Ge diode, which is passively cooled to about 100 K. The gamma-ray induced signals will then be amplified by first stage electronics, which are also cooled to reduce noise levels. Signals from the amplifier will be passed to pulse processing circuitry that will reside in the CEA. The gamma-ray spectra will be determined by the PHA, which measures and sorts gamma rays by signal amplitude (i.e., energy). The analog to digital converter in the PHA will facilitate high-resolution binning by providing accurate and linear measurements of the gamma-ray produced pulses.

Neutrons will be detected by photomultiplier tubes (PMTs) which detect light flashes generated when a neutron is absorbed by a boron detector. This detector is impregnated into a plastic scintillator, which will surround the Ge detector over a solid angle of at least 3π sr. The directional source of the neutrons is discriminated by identifying which PMT detected the light flash. Signals from each of the four PMTs will pass through preamplifiers and subsequently be processed in the CEA. The average data rate for the GRS is 665 bps.

Magnetometer/Electron Reflectometer

The MAG/ER experiment will determine the nature of the magnetic field of Mars. The magnetometer will be able to measure the in situ magnetic field strength in three mutually orthogonal directions over a very wide dynamic range (± 16–$\pm 65{,}536$ nT). Given this in situ magnetic field data, the ER will remotely sense the near-surface magnetic fields by measuring the pitch angle (i.e., the angle between the electron velocity vector and the local magnetic field vector) distributions of ambient electrons over an energy range of 1 eV–20 keV. Since the path of these electrons is affected significantly by the magnetic field, their angular distribution will provide much greater (10–100 times as great) resolution of the surface magnetic field than the magnetometer alone.

Mechanical and Electrical Characteristics

The MO magnetometer and electron reflectometer, as shown in Fig. 1, will be nearly identical in design to the magne-

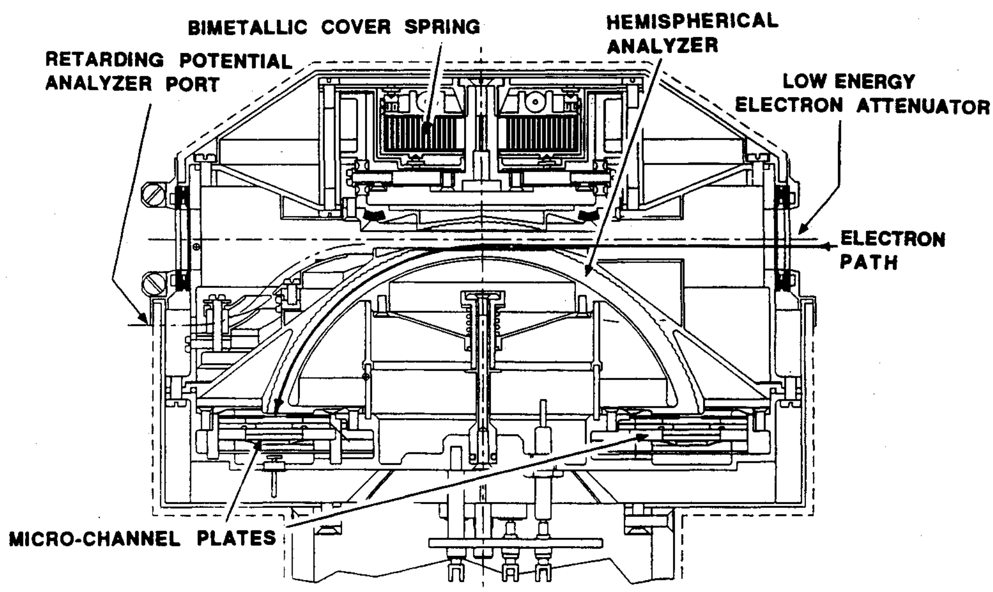

Fig. 3 ER analyzer cross section (size: 12.0-cm diam × 7.8 cm).

tometer and electron reflectometer that was flown on the GIOTTO spacecraft in 1986. The three sensors will be mounted on a 6-m deployable boom. The outboard magnetometer will be located at the end of the boom, the inboard magnetometer will be placed 1.5 m in from the outboard magnetometer, and the ER will be positioned 1.5 m in from the inboard magnetometer. The MAG/ER electronics will be located inside the spacecraft bus.

The MAG sensor will be a relatively simple design in that it will essentially contain one main element (i.e., three sense coils oriented about three mutually orthogonal axes). The ER sensor, on the other hand, will include a hemispherical electrostatic analyzer, an attenuator system to reduce sensitivities to lower energy electrons (< 500 eV), a retarding potential analyzer (RPA), which will allow measurement of low-energy electrons, and a microchannel plate (see Fig. 3). Electrically, the ER will also have a pulse position analyzer (PPA), a pitch angle mapper (PAM), a low-voltage power supply (LVPS), which will provide +5 and ±12 V, and a high-voltage power supply (HVPS), which will generate 0–4000 V for the electrostatic analyzer. The MAG/ER operates at three average data rates of 324, 648, and 1296 bps.

The major electronics elements within MAG/ER will include the analog electronics, which will control and calibrate the magnetometers, the range control electronics for the magnetometers, the data processor with 8K of RAM and ROM, and an LVPS to provide the required voltages for internal operations.

Functional Design Description

The triaxially mounted sense coils, which, effectually, are transformers, will receive a 16-kHz input drive signal from the electronics unit. In the presence of a magnetic field, the sensors will subsequently output a signal that contains the second harmonic (i.e., 32 kHz) of the drive frequency. The MAG/ER electronics will select the second harmonic of the sensor output signal and digitize the amplitude of that component using a successive approximation A/D converter. The digital data will then be sent to the computer for further processing and, finally, the data will be formatted into dual ping-pong packet buffers for transfer to the spacecraft bus.

The ER hemispherical analyzer shown in Fig. 3 will focus electrons onto the detector by applying preselected bias voltages across the inner and outer spherical surfaces. The entire spectrum of energy levels from 1 eV to 20 keV will be sampled every 1.5 s. The microchannel plate along with an imaging resistive anode will detect the electrons and determine their azimuthal angular distribution at a resolution of 1.4 deg. The analyzer will be capable of outputting count rates of up to approximately 10^6/s to the ER electronics module. The PPA within the electronics will accept the analog outputs of the resistive anode and determine the pulse positions, which are then mapped by the digital electronics into 256 bins that are 1.4 deg in width. This information will be sent to the data processing unit within the MAG/ER electronics where it is reduced into physically meaningful parameters (e.g., pitch angle distribution and energy spectra).

Mars Balloon Relay

The MBR interrogates the balloon-borne sensor packages via radio link and demodulates, decodes, and formats the sensor data for transmission to Earth. It is a joint venture between France, the Soviet Union, and the United States. The French and the Russians plan to launch the first two balloons from the Russian Mars 1996 spacecraft in the summer of 1997. The second balloon will follow about three weeks later since the lifetime of each balloon on the surface of Mars is expected to be about two weeks. Once in full operation, each balloon will measure lower atmospheric variables such as temperature, pressure, and humidity and will also take highly detailed images of surface features that the balloon passes over during the sunlit portion of each day.

Mechanical and Electrical Characteristics

The MBR antenna will be a quadrifilar helix design with a 65-deg conical pattern, which will have 0 decibels of gain over an isotropic antenna (dBi) in the nadir direction (i.e., a vector aligned along the antenna boresight that is normal to the local planetary surface) and 3 dBi gain at the horizon to compensate for the larger RF path loss through the atmosphere. The antenna will be rigidly mounted to the spacecraft to obviate the accommodation of stowed and swept volumes associated with a deployable, 1-m-long antenna system. The antenna will be connected to the MBR RF electronics via a flexible coax cable.

The MBR electronics will be located inside the spacecraft approximately 2 m from the antenna. The primary modules within the electronics are a UHF coherent receiver, a Viterbi decoder adapted to the 7½ bit constraint length convolutional code, a Doppler unit, and a memory module for the storage of Doppler data.

Functional Design Description

The MBR will interrogate the balloons by transmitting a continuous 437-MHz wave subcarrier-modulated signal to the surface. When this signal exceeds a specified threshold, the balloon will begin transmitting stored data to the spacecraft using one of two channels allocated, one at about 401 MHz and a second at about 405 MHz. The MBR electronics receiver will demodulate the uplink signal and also measure the Doppler shift in the signal due to the spacecraft motion. The latter capability will allow balloon tracking during each spacecraft pass. By using balloon carrier Doppler shift data and spacecraft navigation data, the position of the balloons and their migration across the Martian surface will also be tracked, providing data that can be related to surface winds.

The demodulated and decoded balloon data are sent to the MOC electronics along with the balloon Doppler data and MBR internal health and welfare telemetry, and they remain there until it is downlinked to Earth as part of the MOC data packet. The maximum data rate allocated to the MBR during balloon operations is 9120 bps.

Mars Observer Camera

The MOC will acquire images of the surface and atmosphere of Mars for qualitative and quantitative photographic interpretation. The data will be acquired at a variety of spatial resolutions and over a range of time in order to address questions concerning Martian meteorology, climatology, and geoscience. Global monitoring will result from the use of the low-resolution capability of the camera (~7.5 km). Regional targeting observations will be acquired by the wide-angle optics system, which will provide a resolution of 250 m/pixel at nadir and 2 km/pixel at the limb. High-resolution sampling will be accomplished using the narrow-angle optics of the camera, which will produce images having 1.4 m/pixel resolution.

Mechanical and Electrical Characteristics

The MOC will be mounted as a single assembly onto the nadir facing panel of the spacecraft bus (Fig. 1). The three major subassemblies of the camera, as indicated in Fig. 4, are the narrow-angle telescope, the wide-angle lens, and the electronics. The telescope will be housed in a graphite epoxy cylindrical canister, which is 70 cm in height and 40 cm in diameter. The wide-angle lens (5 × 23 × 5.8 cm) will be attached to the exterior of the canister, and the electronics will be located within the conically shaped structure below the canister.

The telescope subassembly will contain an f/10 Ritchey Critien reflector with a hyperbolic primary, an aspheric secondary, and a field flattener. The focal length of the system will be 3.5 m. The narrow-angle focal plane will have two 2048 element, 13-μm pixel charged couple device (CCD) line arrays. The line arrays are mounted perpendicular to the spacecraft velocity vector; a two-dimensional image is formed as the detectors are swept forward by the motion of the spacecraft.

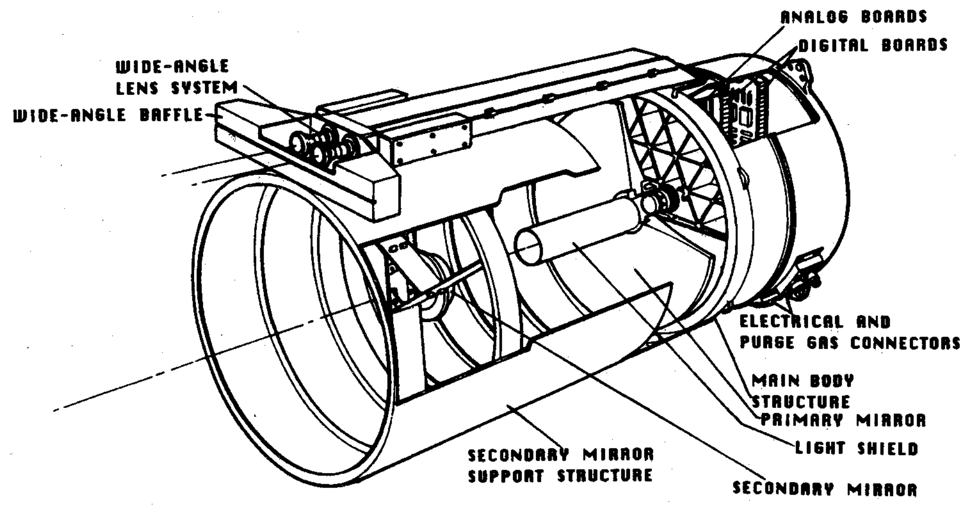

Fig. 4 MOC configuration (size: 40.0-cm diam × 86 cm).

Mounted over the arrays will be a broad bandpass filter in the 500–900 nm spectral region.

The wide-angle assembly will consist of two lenses and one focal plane subassembly. One lens will have a 400–500 nm bandpass (blue) and the other will have a 500–700 nm bandpass (red). Each lens will be a $f/6 \pm 2$ fisheye with a 9.7 ± 0.5 mm focal length. The focal plane will have two 3456 element, 7-μm pixel CCD line arrays, analog preamplifiers to amplify the CCD output, and clock drivers to drive them.

The MOC electronics will contain analog processing circuitry, analog to digital converters (ADC), a 12-Mbyte data buffer for sequence and data storage, a 32-bit microprocessor to accommodate sophisticated acquisition, processing, and compression software, and a LVPS, which converts the 28-V dc spacecraft power to the required internal voltages.

Functional Design Description

Once the CCD converts the captured light into electrical charges, the CCDs will be clocked out by the controlled gate arrays using clock drivers. The resulting signals will then be filtered by the analog electronics. The ADC will convert the analog output into 8-bit digital signals at a maximum rate of 5×10^6 samples/s. The data compression hardware will then compress the data at a selectable ratio of 2:1 (no informational loss) to 10:1 (some amount of informational loss). The images will be stored in the data buffer where they can be accessed at the appropriate time, packetized, and downlinked to Earth. The MOC operates at several data rates ranging from 700 bps to 40 kbps, depending on the available spacecraft downlink rate.

Mars Observer Laser Altimeter

The main objective of the MOLA is to determine the global topography of Mars at a resolution that allows study in the areas of geology, geophysics, and dynamic meteorology. Very accurate measurement of regional and global topographic gradients will lead to better understanding of the internal structure and the global tectonics of Mars, the stress fields within the outermost layers of the planet, surface processes (e.g., erosion), volcanic flow volumes and gradients, impact cratering, and the effects of the topography on atmospheric circulation. MOLA return signal waveform analysis will contribute to the understanding of local topography and surface roughness. The MOLA will also contribute to the characterization of the surface composition by measuring the way the surface backscatters the transmitted 1.06-μm signal.

Mechanical and Electrical Characteristics

The MOLA will be integrated onto the spacecraft bus as a single assembly (Fig. 1). The main MOLA subassemblies will be a receiver telescope, a diode-pumped neodymium:yttrium aluminum garnet (Nd:YAG) laser, a detector package, and an electronics box (see Fig. 5). With the exception of the telescope, which will be mounted on the laser package, all other subassemblies will be mounted on a common support panel.

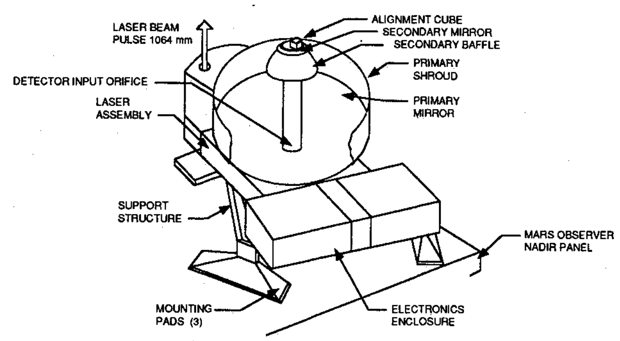

Fig. 5 MOLA configuration (electronics size: 58.4 × 20.6 × 11.4 cm).

The primary mirror within the telescope will be a 50-cm-diam Cassegrain. The focal length of the telescope will be 74 cm. The Nd:YAG laser will operate at 1.06 μm with a pulse energy of 45 mJ and a pulse width of 10 ns at half maximum. The repetition rate will be 10 pulses/s. The vertical resolution will be 1.5 m, which is driven by the complementary metal oxide semiconductor/tristate transistor logic (CMOS/TTL) limitation on the internal clock frequency of 100 MHz. This package will also contain the laser power supply equipment such as batteries and associated controllers. The detector will be a silicon avalanche photodiode (SiAPD) with a 1-nW sensitivity. The optical filter will have a 2-nm bandpass.

Functional Design Description

The MOLA will transmit laser pulses at a rate of 10 pulses/s. The ranging and waveform electronics (RWE) will sense the transmitted pulse at the laser output and start a time interval measurement. A receive pulse from the SiAPD detector stops the time interval measurement via one of four pulse duration filters. Each filter is associated with a pulse duration band, centered at 20, 60, 180, and 540 ns, which indicates the surface roughness. The eight bits of interval measurement, combined with four bits of filter data, are sent to the microprocessor. The processor will control the RWE, monitor critical instrument temperature and voltages, and process/format and transmit the digital data that are output from the RWE. The MOLA has an average data rate of 618 bps.

Pressure Modulator Infrared Radiometer

The PMIRR will be a nine-channel infrared radiometer employing pressure modulation and filter radiometry. It will determine the temporal and spatial distribution, abundance, sources, and sinks of volatile materials (e.g., H_2O and CO_2), and dust over a seasonal cycle. In addition, global measurements of vertical temperature and pressure profiles will allow an exploration of the structure and general circulation characteristics of the Martian atmosphere.

Mechanical and Electrical Characteristics

The PMIRR will consist of two assemblies: a nadir mounted electronics (NME) and a sensor assembly (see Fig. 6). The sensor assembly includes a passive radiator cooler (PRC), an optics bench, an optics mounted electronics (OME), and a scan mirror.

The optics bench will contain a 6-cm aperture, f/11.9 Gregorian telescope with two secondary mirrors and nine radiometric IR detectors. Incoming radiation from Mars will be alternately directed between two optical paths by a reflective chopper that is positioned at the primary focus of the telescope. Doublet condenser lenses will be used by all channels except 6 and 9, which employ Schwarzchild objectives. The PRC is also attached to the optics bench so that four of the detectors may be cooled to 80 K. The primary reason for positioning the sensor assembly on the anti-Sun side of the spacecraft is to provide the PRC with a clear view to cold space (see Fig. 1). It will be very similar to the PRC used on the LANDSAT enhanced thematic mapper (ETM).

The scan arm will include the scan mirror, which will have elevation and azimuth drive actuators mounted orthogonally in a yoke arrangement. The system will provide elevation and azimuth steps of 0.045 deg (1/2 detector field of view) and slew rates of 31.25 deg/s. The OME will contain first stage signal processing electronics such as the wideband/sideband signal processors and the voltage to frequency converters. The NME will include the main power converter, thermal control electronics, and a 16-bit microprocessor with 64K of RAM and 16K of PROM. The PMIRR operates at a single average data rate of 156 bps.

Functional Design Description

All nine channels will receive inputs via the scan mirror and also view Mars and space alternately at a chop rate of 800 Hz by means of a rotating double-sided mirror chopper. Individual channels will be defined by spatial beam splitters, dichroics, spatial bandpass filters, and by spectral response of the detectors.

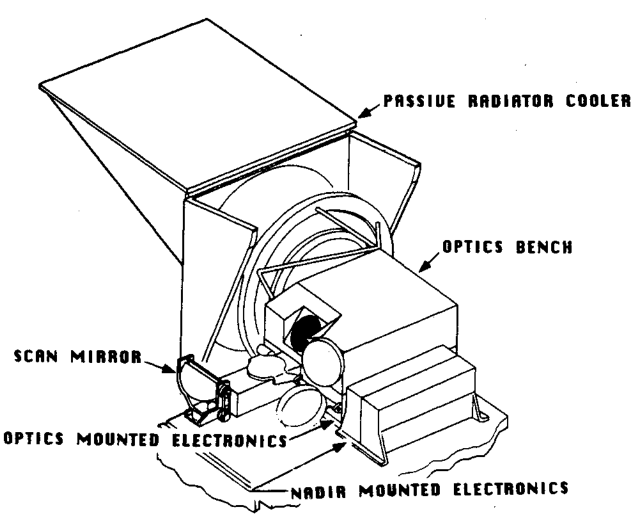

Fig. 6 PMIRR configuration (bench size: 39.3 × 29.7 × 17.8 cm).

Channels 1–4

Channels 1 (7.5 μm), 2 (13.6 μm), 3 (14.6 μm), and 4 (6.8 μm) will employ a pressure modulator radiometer (PMR) and HgCdTe photovoltaic photon detectors, which are cooled by the passive radiator to 80 K. The gas used in the pressure modulator cells for channels 1–3 will be CO_2, whereas the gas for channel 4 will be H_2O. The PMR modulates the pressure in these cells at a frequency of 50 Hz. Since the CO_2/H_2O absorption lines broaden with increasing pressure and sharpen with decreasing pressure, energy transmission through the cells will vary at the modulation frequency. Selective processing of this signal will allow accurate correlation between atmospheric emissions in and near the CO_2/H_2O absorption lines in the cell and the emissions lines of the same gases in the atmosphere. Atmospheric temperatures and pressures will be obtained from the CO_2 channels, channels 1–3, whereas channel 4 will measure water vapor content.

Along with the modulated signals just described, there will be an unmodulated component. All incoming radiation will be mechanically chopped at 800 Hz to allow electronic processing of the unmodulated signal. This wideband signal will provide a measure of the uncorrelated background radiation.

Channels 5–9

Channels 5 (11.8 μm), 6 (20.6 μm), 7 (31.7 μm), 8 (46.5 μm), and 9 (0.3–3.0 μm) will all be wideband channels that are to be chopped at 800 Hz. Their operation, using filters and broadband detectors, is much simpler than channels 1–4. Channel 5 will use a HgCdTe photoconductive detector cooled to 80 K, whereas channels 6–9 will employ deuterated tri-glycine sulfate (DTGS) pyroelectric detectors that will be at 300 K. These channels will measure dust, condensates, and planetary albedo.

Radiometric Calibration

Radiometric accuracy will be enhanced by a two-point, on-orbit calibration cycle. First, the scan mirror will move to permit all channels to view cold space and then a blackbody target at 300 K ($\pm$0.1 K) will be introduced into the optical path.

An additional calibration source will be required for the broadband albedo channel 9. This is provided by a diffusely scattering target mounted on the front of the optics bench. The target will be viewed via the scan mirror at a time in the Mars orbit when the target is directly illuminated by the Sun (i.e., near polar terminator).

Thermal Emission Spectrometer

The TES will provide infrared spectral measurements of the surfaces and atmosphere of Mars in the 6.25–50 μm region and radiometric measurements in the 3.9–100 μm and in the 0.3–3.0 μm bands. Specifically, the objectives of the TES experiment are the following: 1) to determine and map the composition of surface minerals, rocks, and ices; 2) to study the composition, particle size, and distribution of atmospheric dust; 3) to locate clouds and determine their height, temperature, and condensate abundance; 4) to study the condensate properties, processes, and total energy balance of the polar cap deposits; and 5) to measure the thermophysical properties of the martian surface material.

Mechanical and Electrical Characteristics

The TES will be packaged as a single unit (Fig. 7) that consists of the pointing mirror, telescope, interferometer, calibration, and electronic processing subassemblies. Two telescopes will share the common pointing mirror system. The main telescope will be a 15.2-cm-diam Cassegrain afocal design, and the small telescope will be a 1.5-cm-diam off-axis paraboloid design. Both telescopes will use an array of DTGS pyroelectric detectors, similar to the PMIRR.

The primary elements within the electronics will include the following: detector channel postamplifiers, an analog mul-

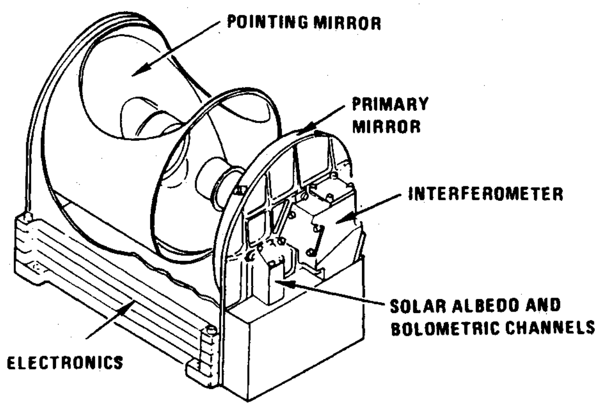

Fig. 7 TES configuration (size: 34.2 × 21.1 × 39.4 cm).

tiplexer, an A/D converter, a controller for the optical mechanisms, a power converter, and a 16-bit microprocessor with a total of 128K of PROM and 384K of RAM.

Functional Design Description

The TES (Fig. 7) contains a single-axis rotating mirror, which can be pointed from the nadir position to the fore and aft limbs of Mars for science data collection and to space for calibration. This pointing mirror will also provide image compensation while viewing nadir by adjusting the stepping rate to conform to the orbital rate of the spacecraft.

The pointing mirror will direct the incoming IR energy into the main, Dall-Kirkham (folded), telescope. The telescope will recollimate the energy and produce a 1.5-cm-diam output beam that feeds a two-port Michelson interferometer, which in turn directs the energy onto a 2×3 array of DTGS detectors behind condensing optics. The pointing mirror will also direct the incoming radiation into the small telescope aperture, obscuring <2% of the main telescope aperture area. This telescope contains a chopper mirror beamsplitter driven by a resonant fork, which will split the solar reflectance channels (0.3–3.0 μm) from the thermal bolometric channels (3.9–100 μm).

The TES electronics postamplifier will amplify and process the low-level analog detector signals from each of the six interferometers and the two sets of six bolometric channels. The electronics will then perform an A/D conversion of all analog signals. The microprocessor will perform digital signal processing including filtering, phase correction, fast Fourier transform (FFT) processing, data compression coding, and command processing. FFT and data compression are performed to provide more efficient use of the TES data rate by performing data reduction onboard the instrument. However, this instrument also has the capability of downlinking unprocessed data.

The TES operates at average data rates of 688, 1664, and 4992 bps. The microprocessor-based controller will control and monitor all mode functions and housekeeping measurements (e.g., external temperatures and voltages) and will transfer the data packets to the spacecraft bus.

Ultrastable Oscillator

Mars Observer radio science has two primary objectives. The first is to provide data on seasonal (and shorter) variations of the total gas content and vertical structure of the atmosphere, including the periods of extensive dust storm activity. These radio occultation measurements will provide vertical profiles of refractive index, number density, temperature, and pressure at a resolution as high as 200 m. Second, radio Doppler tracking of the Mars Observer spacecraft will provide improved information on the structure of the Mars gravitational field. These data will permit parameter estimation of Mars' internal structure and inferences of the planet's evolution. The instrument in this case includes the entire spacecraft combined with the Jet Propulsion Laboratory Deep Space Network (DSN). The DSN will detect frequency shift, phase variation, and amplitude variations as the spacecraft enters and leaves planetary occultation, during the periods when the X-band carrier radiates through the Martian atmosphere. The USO provides a highly stable local oscillator for the spacecraft telecommunications subsystem, facilitating radio science objectives by minimizing disturbances to the unmodulated, X-band carrier. The USO is a high-quality, low-noise, 19.143519-MHz oscillator with a 24-h frequency variation limit of $<2.0 \times 10^{-10}$ Hz and a long-term frequency variation limit of 1.0×10^{-10} Hz. Therefore, it must be placed inside the spacecraft bus at a location that provides the most stable thermal environment, preferably with variations of no more than 3°C/h. The USO unit will include a crystal oven, signal processing electronics, and power supply electronics subassembly. The signal processing electronics contains a signal multiplier and a power divider.

Summary

The Mars Observer science payload will be a collection of sophisticated instruments with some, such as the GRS, employing state-of-the-art technologies. Vicariously, through Mars Observer, we will observe Mars through a full Martian year, monitoring seasonal cycles in the atmosphere and at the polar ice caps and obtaining repetitive observations of magnetic and gravitational phenomena. A Mars Observer interdisciplinary science investigation team will attempt to determine the nature of the interaction between the surface and the atmosphere of Mars. This requires information on the regolith structure, subsurface H_2O, H_2O residual caps, CO_2 seasonal cycle, and airborne dust. Data from each of the MO instruments described in this paper are needed to perform such a comprehensive study. The MO instrument complement was selected not only to study specific Martian phenomena but to also permit a synergistic exchange of experimental data.