P21C MCC: 134 Tuesday 0830h

Mars Exploration Rover Mission: Setting Down on the Red Planet Once Again I *(joint with B, V)*

Presiding: **J A Crisp,** Jet Propulsion Laboratory**;** **C Weitz,** NASA Headquarters

P21C-01 0830h INVITED

Overview of the Mars Exploration Rover Mission

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The Mars Exploration Rover (MER) Project is an ambitious mission to land two highly capable rovers at different sites in the equatorial region of Mars. The two vehicles are launched separately in May through July of 2003. Mars surface operations begin on January 4, 2004 with the first landing, followed by the second landing three weeks later on January 25. The useful surface lifetime of each rover will be at least 90 sols. The science objectives of exploring multiple locations within each of two widely separated and scientifically distinct landing sites will be accomplished along with the demonstration of key surface exploration technologies for future missions.

The two MER spacecraft are planned to be identical. The rovers are landed using the Mars Pathfinder approach of a heatshield and parachute to slow the vehicle relative to the atmosphere, solid rockets to slow the lander near the surface, and airbags to cushion the surface impacts. During entry, descent, and landing, the vehicles will transmit coded tones directly to Earth, and in the terminal descent phase will also transmit telemetry to the MGS orbiter to indicate progress through the critical events.

Once the lander rolls to a stop, a tetrahedral structure opens to right the lander and to reveal the folded rover, which then deploys and later by command will roll off of the lander to begin its exploration. Each six-wheeled rover carries a suite of instruments to collect contextual information about the landing site using visible and thermal infrared remote sensing, and to collect in situ information on the composition, mineralogy, and texture of selected Martian soils and rocks using an arm-mounted microscopic imager, rock abrasion tool, and spectrometers.

During their surface missions, the rovers will communicate with Earth directly through the Deep Space Network as well as indirectly through the Odyssey and MGS orbiters. The solar-powered rovers will be commanded in the morning of each Sol, with the results returned in the afternoon of that Sol guiding the plans for the following Sol. Between the command sessions, the rover will autonomously execute the requested activities, including as an example traverses of tens of meters using autonomous navigation and hazard avoidance.

P21C-02 0900h INVITED

The MER Mission's Athena Science Investigation

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The Athena Mars rover payload is a suite of scientific instruments and tools for exploration of the martian surface. Two identical copies of the Athena payload will be flown in 2003 on the two Mars Exploration Rovers.

The topography, morphology, and mineralogy of the scene around each rover will be revealed by Pancam and Mini-TES. Pancam is a stereo camera whose filters provide 14 color spectral bandpasses over the spectral region from 0.4 to 1.1 mm. Pancam's angular resolution is 0.28 mrad/pixel. Mini-TES produces high spectral resolution (10 cm^{-1}) infrared image cubes with a wavelength range of 5-29 μm and angular resolution modes of 20 and 8 mrad.

Once promising targets have been identified using Pancam and Mini-TES, they will be studied in more detail using two in-situ compositional sensors mounted on a 5-degree-of-freedom robotic arm. These are an Alpha Particle-X-Ray Spectrometer (APXS) and a Mössbauer Spectrometer. Radioactive alpha sources and two detection modes (alpha and x-ray) in the APXS provide elemental abundances of rocks and soils. The Mössbauer Spectrometer measures the resonant absorption of gamma rays produced by a ^{57}Co source to determine splitting of nuclear energy levels in Fe atoms, revealing the mineralogy and oxidation state of Fe-bearing phases.

The instrument arm also carries a Microscopic Imager that will obtain high-resolution images of the same materials for which compositional data will be obtained. Its spatial resolution is 30 mm/pixel over a 6-mm depth of field.

The Athena payload includes a Rock Abrasion Tool (RAT). When placed against a rock, it uses a mechanical grinding wheel to remove 5 mm of material over a circular area 47 mm in diameter. The resultant exposed region is large enough to be investigated in detail using all of the instruments on the payload.

The Athena payload will be used to investigate the geologic history of the two MER landing sites. The rovers' mobility will enable use of the payload over a substantial area around each landing site, and rover traverses will be conducted that attempt to maximize the scientific return from each site. Particular emphasis will be placed on investigation of the possible aqueous history of each site, with implications for past habitability. The remote sensing instruments (Pancam and Mini-TES) will also be used to conduct a broad range of atmospheric science investigations. The rovers themselves will be used in conjunction with the payload to investigate the physical properties of martian rocks and soils.

P21C-03 0930h

Athena Instrument Validation and Data Library Development for the Mars Exploration Rover (MER) Mission

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In May of 2001, the Athena Principle Investigator and MER Project Scientist assembled a board of scientists from the planetary community at large to review calibration procedures for the Athena science instrument payloads on the MER rovers. Separate reviews were held for the Pancam (multi-spectral camera), MI (microscopic imager), Mini-TES (thermal emission spectrometer), MB (Moessbauer spectrometer), and APXS (alpha particle x-ray spectrometer) Athena instruments. One of the recommendations of the calibration review board was for the measurement of the same well-characterized geologic samples by all Athena MER instruments. Such measurements validate (for the Athena team and the general scientific community) the primary instrument calibration and quality of measurement, aid in identification and solution of anomalies in instrument data returned from Mars, and enhance the ability of the scientific community to correlate interpretations of Mars data from one Athena instrument to another. Using flight instruments or engineering models of flight instruments, the Athena instrument teams are making measurements on 10 to 40 rock slabs that have been well characterized using laboratory instrumentation that includes the laboratory equivalents of the Athena flight instruments. A subset of these samples constitute blind test for the Athena instruments and science team. The laboratory data for the rock slabs, and for many other Martian analogue samples that are characterized in the same way as the rock slabs, form data libraries for the Athena instruments. Depending on Athena instrument, these data/spectra libraries have 200 to 2000 entries, and they extend libraries provided by individual Athena instrument teams.

P21C-04 0945h INVITED

Archiving Data From the 2003 Mars Exploration Rover Mission

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The two Mars Exploration Rovers will touch down on the red planet in January 2004 and each will operate for at least 90 sols, traversing hundreds of meters across the surface and acquiring data from the Athena Science Payload (mast-based multi-spectral, stereo-imaging data and emission spectra; arm-based *in-situ* Alpha Particle X-Ray (APXS) and Mössbauer Spectroscopy, microscopic imaging, coupled with use of a rock abrasion tool) at a number of locations. In addition, the rovers will acquire science and engineering data along traverses to characterize terrain properties and perhaps be used to dig trenches. An Analysts Notebook concept has been developed to capture, organize, archive and distribute raw and derived data sets and documentation (http://wufs.wustl.edu/rover). The Notebooks will be implemented in ways that will allow users to playback the mission, using executed commands to drive animated views of rover activities, and pop-up windows to show why particular observations were acquired, along with displays of raw and derived data products. In addition, the archive will include standard Planetary Data System files and software for processing to higher-level products. The Notebooks will exist both as an online system and as a set of distributable Digital Video Discs or other appropriate media. The Notebooks will be made available through the Planetary Data System within six months after the end of observations for the relevant rovers.

P21C-05 1030h

Selecting Landing Sites for the Mars Exploration Rovers

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Landing site selection for the 2003 Mars Exploration Rovers is based on consideration of landing safety issues and science potential as related to achieving mission objectives. Because landing safely is paramount, all mission engineering constraints must be adhered to, including relatively low latitude surfaces below the -1.3 km MOLA defined elevation with winds less than 20 m/sec. In addition, landing ellipses range from approximately 100 to 150 km in length and 20 to 15 km in width from south to north, respectively, thereby requiring that desirable targets be distributed over fairly broad areas. Mission science objectives emphasize investigation of sites favorable to the preservation of evidence of possible pre-biotic or biotic processes and those where the rovers might best define the aqueous, climatic, and geologic history. A complete list of all engineering constraints and science criteria are on the web at marsoweb.nas.nasa.gov/landingsites/mer2003 and webgis.wr.usgs.gov/mer.

Landing safety concerns form a template that a NASA-appointed Landing Site Steering Committee uses to focus community input regarding which sites possess the highest science potential. This has been accomplished via a series of open workshops that continue to narrow an initial list of 185 potential sites. The first workshop, in January 2001, identified 26 high priority locations with broad consensus on seven proposed landing sites. Further evaluations including analysis of Mars Global Surveyor (MGS) data were presented at a second workshop in October 2001 and resulted in shortening the list to four primary sites (the Hematite Region, Melas Chasma, Gusev Crater, and Athabasca Vallis) and two back-up sites (Isidis Basin and Eos Chasma). Additional imaging by MGS and Mars Odyssey coupled with detailed evaluation by the MER project culminated in a third workshop in March 2002 that solidified support for the Hematite Region, Gusev Crater, and Isidis Basin. Concerns about probable high winds at the time of landing and significant decimeter-scale surface roughness, however, saw elimination of Melas, Eos Chasma and Athabasca Vallis, respectively. Most recently, landing safety concerns related to occurrence of high winds has led to identification of a fourth "wind safe" site to the southwest of Elysium Mons.

Upcoming work will focus on continued engineering evaluations and development of testable hypotheses regarding evolution of the sites that can be assessed using the Athena Science Package on board the rovers. These results will be discussed at a fourth open workshop in January 2003 with the expectation that a community recommendation will emerge regarding the relative merits of the four remaining sites. Outcomes of the fourth workshop will play an important role in formulating the final site recommendations made by the Mars Exploration Rover Project and Science Team to NASA Headquarter for approval in March 2003.

P21C-06 1045h

Selection and Evaluation of Landing Sites for the Mars Exploration Rovers

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Engineering constraints developed for Mars Exploration Rover (MER) landing sites require that they be below -1.3 km MOLA elevation, appear hazard free in Viking image mosaics, and have low surface slopes. Rock abundance must be <20% and the bulk thermal inertia must >200-250 SI units, to avoid extremely low temperatures. Landing ellipses vary in size with latitude from 95 km long at 15°S to 165 km long at 15°N (around 16 km wide). About 185 ellipses satisfy these engineering constraints and about 30 were selected for further evaluation based on science. These sites were imaged using orbiter cameras and progressively downselected at a series of open workshops on the basis of science and safety during the past two years. Presently four landing sites are being considered for selection of the final two. Three prime sites (Hematite, Gusev, and Isidis) are being carried forward following a detailed evaluation at the third landing site workshop. Because of concerns over horizontal winds during landing, an additional low-wind site has been added in Elysium Planitia.

Hematite, Gusev, and Isidis show evidence for surface processes involving water and appear capable of addressing the science objectives of the MER missions, which are to determine the aqueous, climatic, and geologic history of sites on Mars where conditions may have been favorable to the preservation of evidence of possible prebiotic or biotic processes. TES results indicate coarse grained hematite distributed across a basaltic surface at the Hematite site, suggesting precipitation from liquid water or a hydrothermal deposit. Gusev has been interpreted as a crater lake with interior sediments deposited in standing water. The Isidis Planitia ellipse is located to sample ancient Noachian rocks shed off the adjacent highlands that might record an early warm and wet environment. The Elysium Planitia ellipse is located on a Hesperian-age surface transitional between the highlands and lowlands and may preserve reworked Noachian highlands. Evaluation of science criteria at the third workshop place Hematite and Gusev as the highest priority science sites.

Comparison of the thermophysical properties of the sites with the Viking and Pathfinder landing sites allows a first order interpretation of their surface characteristics. The Hematite site has moderate thermal inertia and fine component thermal inertia and very low albedo. This site will likely look very different from the three previous landing sites in having a darker surface, few rocks and little dust. Gusev crater and Elysium Planitia have comparable thermal inertia, fine component thermal inertia and albedo to the Viking sites and so will likely be similar to these locations (dusty), but with fewer rocks. The Isidis site has high to very high thermal inertias, moderate albedo, a high red/blue ratio and high rock abundance suggesting a rocky crusty surface with some dust. Evaluation of safety criteria such as slopes, rocks and winds at the third workshop indicate that Hematite is probably the safest, followed by Elysium, Gusev and Isidis.

URL: http://webgis.wr.usgs.gov/mer

P21C-07 1100h INVITED

Odyssey THEMIS Views of the Candidate MER Landing Sites

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The Mars Odyssey Thermal Emission Imaging System (THEMIS) has obtained infrared and visible images of seven candidate MER landing sites. Both day and night mosaics of the landing ellipse and the surrounding terrain have been produced, providing a new look at the geology, morphology, composition, and thermophysical properties of these regions. The Meridiani hematite site identified by the MGS TES instrument as having a unique mineral signature of grey crystalline hematite remains a strong scientific and engineering candidate based on the multi-spectral and thermophysical properties derived from THEMIS IR images. This area is part of a sequence of geologic units that are defined by their physical and compositional properties. This region has little dust mantle, increasing the likelihood of sampling exposed rocks at the surface. Gusev crater has been examined and found to have variations in both compositional units and thermophysical properties. This region has significant dust cover, making detailed prediction of composition from remote sensing difficult. The Isidis basin has been imaged extensively at resolutions of 100-m (IR) and 18-m (visible) that are better than obtained by Viking and with significantly greater areal coverage than obtained by the MGS MOC camera. The ancient cratered highlands south of the Isidis landing ellipse have extensive fluvial dissection. However, the THEMIS images provide evidence that the basin surface north of the highlands where the ellipse is located has embayed the major channels leading from the highlands, likely burying the deposits from these channels. Finally, several potential sites in the Elysium region have been investigated and found to have essentially the same characteristics as determined from previous imaging and spectroscopic observations. Athabasca, Eos Chasma, and Melas Chasma were initially candidate landing sites and have been extensively imaged by THEMIS. These sites, while no longer candidates for the MER Rovers, will be briefly discussed.

P21C-08 1130h

Meteorology of Candidate Mars Exploration Rover Landing Sites as Predicted by a Mesoscale Model

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The meteorology of the Mars Exploration Rover (MER) candidate landing sites is of importance because of the constraint it provides on the likely ability of the rovers to successfully land and operate. The meteorology may also be of interest insofar as the landscapes to be traversed and studied by the rovers may be influenced to a greater or lesser degree by aeolian activity. In support of the MER Program, we have conducted studies of several of the candidate landing sites using the Mars Mesoscale Model developed at Caltech and Cornell University as an adaptation of the terrestrial PSU/NCAR Mesoscale Model (MM5). The sites studied include Meridiani ("Hematite"), Gusev, and Mellas. The model results suggest that winds associated with convection and/or topography may be of concern at each of the landing sites. The relatively flat Hematite site is simulated to develop strong, deep convection. At highest resolution (few hundred meters), the convection is predicted to be cellular with significant up- and down-drafts. The local time of landing for both MER rovers is during the period of most active convection at all sites. Gusev and Mellas show varying degrees of topographic influence on winds. At Gusev, the crater walls provide strong foci for upslope-downslope circulations, while the walls and other nearby topography provide "anchor" points for the initiation (initial upwelling) of convection during the day. Mellas provides a case example of strongly channelized flow. Convection is less of a concern at Mellas, but is replaced by diurnally reversing up-canyon and down-canyon flow. The flow patterns are also strongly influenced by the effects of canyon wall heating by solar radiation. In summary, the thin Martian atmosphere responds strongly to slope heating by developing slope winds which provide a challenge to missions seeking to closely approach "interesting" terrain. Equally a problem for the MER mission, for flat landing sites, is the use of an early afternoon local time of landing, coinciding with the peak of boundary layer convection.

P21C-09 1145h

Remote Robotic Geology: Learning from the MER-FIDO Field Test Site

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Understanding the geology of a region from a robotic platform can be a challenging and difficult task. In order to prepare the team of investigators and engineers for the upcoming 2003 Mars Exploration Rover (MER) Mission, a blind rover field test was performed August 10 19, 2002, using the Field Integrated Design and Operations (FIDO) Rover. The field site, which is located near Gray Mountain Arizona (approximately 40 miles north of Flagstaff), was chosen because it: (1) maximizes science return and permits rover trafficability, (2) is easily accessed via a well-maintained mining road, (3) occurs north of Flagstaff, Arizona, where seasonal temperatures are adequate for rover operations and climate records show minimal rainfall, (4) lacks vegetation (a very difficult variable for Earth), and (5) contains diverse geological terrains similar to what might be encountered on Mars, including claystones, siltsones, mudstones, and sandstones of the Shinarump Member of the Chinle Formation. that crop out among fluvially carved drainages, fluvial and eolian deposits that partly blanket the drainage floors, and cobbles and boulders of diverse petrology and geochemistry (e.g., basalt, chert, sandstone, limestone, metamorphic).

The goal of the FIDO test was to teach the MER Science Team the techniques involved in conducting a geologic investigation with a remote rover. Inherent disadvantages associated with remote robotic exploration include a limited time-associated visibility to the site. This disadvantage is somewhat offset by the availability of instruments on the rover that might ordinarily be available to a geologist only in a laboratory setting. This talk will further explore the coupling of a remote robotic platform with what is known about the field site to provide insight into future robotic exploration of planetary locales.

P22A MCC: Hall D Tuesday 1330h

Mars Exploration Rover Mission: Setting Down on the Red Planet Once Again II Posters *(joint with B, V)*

Presiding: **A F Haldemann,** Jet Propulsion Laboratory**; W M Calvin,** University of Nevada, Reno

P22A-0382 1330h POSTER

Spectral Properties at Terra Meridiani, Prelude to MER.

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Spectral information from both the Mariner 6 and 7 Infrared Spectrometers (IRS) and the French Phobos Imaging Spectrometer for Mars (ISM) suggest that there is strong heterogeneity in the strength, and quantity, of surface hydration, based upon the characteristic absorption feature at 3-μm. Studies by Calvin (1997, 1998) and Murchie et al (2000) have noted that anomalously high hydration features appear in moderate to low albedo regions. The discovery of bulk, gray hematite by the Thermal Emission Spectrometer (TES) in the Sinus Meridiani region (Christensen et al. 2000) further supports this model of aqueous processes leaving remnant signatures in medium to low albedo regions.

The Terra Meridiani hematite area is among the final candidates for the Mars Exploration Rover landing sites. We have recently noted the precise correlation between the TES hematite locations and IRS spectra suggesting increased water of hydration. As this oxide mineral does not include hydration features it suggests the presence of other, associated hydrated minerals at the site. Analogs for this type of low-temperature, low-oxygen alteration include both terrestrial Archean iron formations and carbonaceous chondrites. Strong similarities are noted between the types of alteration minerals found in both these environments. In these models, the most likely carrier of the water is hydrated ferrous silicates. Calvin (1998) has previously presented the compatibility of these phyllosilicates with short wavelength observations and we extend this analysis to the spectral range covered by mini-TES. In particular, focus on the 6-μm water feature as indicative of water content is explored.

In these natural analogs, mineral components are often mixed on microscopic (0.1 to 2 μm) and macroscopic (mm to cm) scales. The Mars Exploration Rover we will be able to identify finely laminated structures using the microscopic imager and PanCam and resolve associated mineralogies using mini-TES. While atmospheric interference degrades spectral quality at the shortest wavelengths in TES, we expect improved signal-to-noise with surface measurements from mini-TES and can use the 6-μm band to examine local variability in water content at the rover site.

P22A-0383 1330h POSTER

Mantled and Exhumed Terrains in Terra Meridiani, Mars

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