Report for the
3rd 2003 Mars Exploration Rovers
Landing Site Selection Workshop

Held in Pasadena/Arcadia, California
March 26th-28th, 2002

March 26th, Tuesday a.m.
Introduction

8:30 a.m.	Welcome, Overview of the Landing Site Selection Process and Workshop Goals John Grant and Matt Golombek (Co-Chairs, Landing Site Steering Committee)
8:50 a.m.	Engineering Constraints and Factors in Selecting the MER Landing Sites Mark Adler, Project Landing Site Engineer
9:50 a.m.	Entry and Descent Simulations and Ellipses Phil Knocke, JPL
10:20-10:35 a.m.	Coffee Break
10:35 a.m.	Atmospheric Modeling and Winds David Kass and Tim Schofield, JPL
11:05 p.m.	MER Wind Mitigation Measures R. Manning, JPL
11:25 p.m.	History of Ellipse Identification and Placement Matt Golombek, Co-Chair Landing Site Steering Committee
11:55-1:15 p.m.	Lunch

March 26th, Tuesday p.m.

Introduction (cont.)

1:15-2:00 p.m.	Discussion of Introductory and Overview Material

Summary of Introduction Talks and Discussion provided by Roger Phillips

1. Mark Adler: Landing site – engineering constraints
    a. Selection – EDL - failures, engineering, descent (e.g., no horizontal velocity is required – thruster system to do that), drag requirement – enough atmosphere - < -1.3 km; radar reflectivity must be adequate; slopes less than 5 deg. on 100 m scale (+/- 10 m variation; so elevation is what you think it is when you actually land given horizontal velocity); over 1 km slopes less than 2 deg. to have little roll; landing, slopes, impact velocity constraints total < 24 m/s, vertical component < 14 m/s, tangential velocity 14-21 m/s; rock size and coverage is critical; radar reflectance, wind, large rocks, deployment and egress problems, surface mission lifetime. Drivers on impact survival horizontal and vertical velocity 1st impact and subsequent; rock size and coverage. Largest rock in area is constraint.
    b. Engineering constraints – latitude and landing day, extended mission; trafficability.

c. Deployment and rover egress — slopes and rock abundance count — egress is not a factor in site selection.
d. Lifetime constraint > -97 C = latitude, thermal inertia and albedo used to estimate T.
e. This workshop prioritizes; select sites in April 2003. Use TCM1 (TCM-A1, TCM-B1) to target. Change in our plan because new environmental data raises concerns; air bag performance testing; Odyssey data; New opportunity to target after launch. Maybe select MER-A half-planet in November, 2002.
f. New data on landing sites — high winds/wind shear at present sites (- Isidis?) ; Melas has mesa problems; Hematite has thermal constraint problems – okay – no perfect landing sites - continued analyses make sites worse; need other candidate sites to guarantee 2 safe sites.
g. System – airbag capability improving – good; greater sensitivity to sustained winds — bad, s/c changes to deal with this.
h. Defer decision because of more propellant available for TCM-1; option for 3rd launch target as long as which half of planet is selected for MER-A in 11/02.
i. Summary:
    i. Winds are big concern
    ii. All sites have difficulty
    iii. Need other candidate sites
    iv. May be able to extend latitude band N and elevation up
    v. But more time is now available for making decision. 6 months to a year deferral.
j. How we can help — This meeting: comment on sites – science merits, environmental models and their application, prioritize sites; how to improve environmental analyses or make new analyses. After meeting: Find new landing sites.

2. Phil Knocke: Entry and Descent simulations and ellipses —
    a. analyses included atmospheric dispersions, density dispersions, wind dispersions, plus other effects — added up to 26 km down-track to ellipses; 10 km cross-track.
    b. Navivation update - 0.02 deg. in 3 sigma EPFA (Entry Path Flight Angle) – DSN errors may add to this — improvement
    c. Net effect is: No changes to ellipse sizes recommended for now.
3. David Kass: Atmospheric modeling and winds
    a. Mesoscale wind modeling: average wind plus turbulence/shear; models passed peer review
    b. Review results for different sites
    c. All sites have problems — Hematite site the best (fewest problems)
    d. Very large flat smooth plain is best — which is fact where dust collects — boring in general
4. Rob Manning – MER wind mitigation measures
    a. Horizontal velocity problem
    b. Max tangential velocity = 16-20 m/s , 12- 15 m/s max normal velocity =
    c. Airbags by themselves cannot solve horizontal velocity problem
    d. Added Transverse Impulse Rocket System (TIRS)
    e. Proposed Descent Imager Motions Estimation System (DIMES)
    f. Contour plots probability of failure vs. DC wind and shear factor
    g. Add "Reliable Sensor" for relative horizontal ground velocity improves (maybe significantly) probability of failure plot.
    h. Therefore, include DIMES.
5. Matt Golombek history of ellipses
    a. Hematite site – ellipse TM20B
    b. See USGS sites for this stuff
    c. Hematite, Gusev, Melas, Isidis, Athabasca, Eos
    d. Potential new landing sites: No new science sites; we already considered all possibilities and of the old ones none will be any better from engineering than of sites already considered, 2 safe sites – In central Isidis and west of Elysium but scientifically "less favorable" sites

   e. Find more favorable temperature sites in Hematite area
6. Summary
   a. Melas is out; Gusav may become acceptable with both TIRS and DIMES. Question whether or not DIMES will be used. Isidis also maybe too (simulations not done yet). Boring sites will not meet basic "Follow the Water" strategy.
   b. Two models are reasonable; perhaps good within a factor of two. May be used as a relative discriminator. Models will be a factor in site selection.
   c. Will hematite ellipse be "wiggled" to an acceptable temperature environment. THEMIS will give direct 3:30 AM temperature.
   d. Science vs. safety trade-offs. "Safe" is a sliding scale; i.e., not black and white but gray. Find sites that "acceptable" from both science and safety.

Overview of Landing Site Science Potential

2:00 p.m. Geologic Evaluation of MER Landing Sites from THEMIS Data
Phil Christensen and Jim Rice, Arizona State University

3:00-3:15 p.m. Coffee

3:15 p.m. Landing Site Compositional Assessment Using High Resolution TES Data
Steve Ruff, Vicky Hamilton, and Phil Christensen, ASU

Overview of Landing Site Science Potential Talks and Discussion, by Tim Parker

The discussion began with a number of questions about the DIMES imager. The project is using simulated DIMES images, derived from MOC images with similar lighting to DIMES, to test software being developed for the descent camera. These images are being processed to simulate blur due to SC motion and tilting, and scaling differences between subsequent DIMES images as the SC descends. Gentry Lee pointed out that DIMES may come or go, and was added to get into the "low tens" of meters/sec winds sites. None of the remaining sites have over 20m/sec. Pete Theisinger noted that the project and lab are committed to the top sites, and don't want to let a "late-comer" "ruin" mission.

There was some discussion about wind models for the top landing sites. In Gusev Crater, wind shear may be a problem. Mark Adler noted that updrafts in the Hematite region and those predicted for Gusev are of relatively minor concern.

Joy Crisp noted that wind modeling has not yet been run for the Isidis site. Dave Cass suggested that we should expect diurnal slope winds from the Isidis rim to the south. Mass flowing downslope may be large enough to still be blowing even at 3pm at the landing site.

John Grant asked how much weight applies to model validity for determining suitability of site? The answer is that the project doesn't trust the models to better than a factor of 2, but the models could be used to discriminate between sites by the NASA HQ review board. Joy Crisp added that 2 independent models were used at each site, giving similar results except for the timing of maximum winds at the Melas site. Larry Crumpler shared Grant's uneasiness about wind models by pointing to their inherent unpredictability, noting that although they can predict general weather trends, they may not be particularly good at predicting specific daily weather at a site.

Mike Carr expressed misgivings that safety concerns in general might make "following the water" difficult, even impossible for MER, thus losing the main theme of the mission. Horton Newsom asked whether the airbag-enclosed lander might have problems related to rolling down slopes with the wind? Mark Adler replied that there is no correlation between wind direction (aloft) and the roll direction (the roughness of the site determines which way first bounce deflects the lander, after which subsequent bounces are similarly affected by the local roughness elements).

Next topic of discussion was the distribution of thermal inertia within a landing site? (Dave DeMarais). Matt Golombek noted that we don't know the thermal inertia at the exact center of the Hematite site, for example. Eventually, the THEMIS temperature map can be used to replace or at least supplement the TES-based thermal inertia map. There was considerable discussion about finding warm lees behind obstacles to protect the rovers during the night at sites where the thermal inertia predicts cold temperatures. However, there are no temperature sensors on the rovers, so these decisions (where to park the rovers for the night) would need to be based on models.

With the new elevation limite of 0 km, sites like Eastern Meridiani (Phil Christensen and Jim Rice) become viable. Phil noted that there are varied albedo surfaces in that area, which also contains the Hematite signature from TES. The chief problem with this site, is that selecting it AND the western Hematite site places the two rovers too close together such that they compete for DSN time.

Geologic Evaluation of MER landing sites form THEMIS data: Phil Crhistensen and Jim Rice:
Phil presented THEMIS images taken with last 10 days of the 6 top landing sites. Lots of information, not much time to think about what it means! There are no showstoppers in the data as yet.
THEMIS stats:
9band IR imager – 6.5 to 15 microns
5band visible - .43=0.85 microns
100m spatial in IR
18m spatial in VIS
Global coverage in IR and 1 band VIS should be achieved during primary mission.

Most images will be one-band EMP or VIS data. One or 2 color images had been processed for landing sites for presentation. Team still working on stray light issue in IR camera, so making ratio images and PCA are difficult at this point.

Temperature images can look like VIS images if they are daytime images, due to heating effects during the day. Crater ejecta tends to be dark, because it stays cooler during the day (higher inertia). A fresh young crater, shown, has a prominent dark halo due to rocks at the surface. Surface differences in brightness show textures that don't show as obvious in visible MDIM images. During the night, rocks stay warm, and so the plateau around Valles Marineris is dark, whereas the floor is bright, indicating a rocky floor or indurated fill materials. THEMIS can distinguish sand from indurated/rocky surfaces. Also at night, craters show bright inner walls, where they are likely rockiest. Crater floors are cold. And the outer side of crater rims are darker than the wall inside the rim. Ejecta margins of fluidized craters are bright and probably suggest a rocky terminus, like a debris flow.

In daytime IR, mantled areas appear really b land. Topography, then, provides the only variation in these surfaces. THEMIS daytime IR images of mantled surfaces "look like a plaster model." "Multiple skin depths" are needed to bury rocks, implying 1-2 meters of dust at least in these areas. Low thermal inertia areas in MGS TES data are showing this kind of THEMIS image result. The previous inference that bright areas on Mars are dusty is borne out by MOC images of thick drapes and THEMIS IR images being bland.

In nighttime IR, dunes around craters with "tails" are interesting. Warm stuff (bright tails) is coarser than sand. So crater tails in this example are rock surfaces without dunes. At Nili patera, dunes are bright against a bedrock background.

Phil showed some VIS data samples of Au Qakuh Vallis, Nirgal Vallis, Ganges Chasma interior layered deposits, and White Rock. With a resolution of 18m/p, and a local time of 3:30pm, these images promise to be excellent for landing site mapping and MOC context imaging.

Preliminary THEMIS imaging of the landing sites:
*Eos Chasma (daytime image): Relatively rocky, with crater ejecta that's cooler, thus rockier. Color image: (North of Eos) The plateau is pink, floor is blue and green.
*Athabasca: (night time image): Platy flow is relatively warm, plates are cool, channel is cool. (Daytime image): platy flow is slightly brighter than surrounding plains, so warmer and dustier. VIS image data: bland. Thermal data suggests that variations will show that rocks are near surface, so MER will see rocks. Nighttime IR shows channel margins are rocky, Cerberus Rupes is cool.
*Isidis: (daytime IR of southern rim/basin floor): high inertia plains, pretty uniform. Fresh crater ejecta everywhere, looks pretty dust-free. Some evidence of thin dust, not obscuring. (Nighttime image): Crater ejecta bright, floors bright to dark, ridges are dark. Rim mountains are dark (cool), intermountain plains are bright (indurated?).

*Melas: (Daytime IR): Interior Deposits are dark (rocky or indurated). Landslide is brighter than the interior deposits. (Nighttimeimage): interior deposits are bright (cool), and landslide is almost as bright. Interior Deposits are brighter than wallrock to south.
*Meridianni (Hematite, mostly): (nighttime IR): Variability in highlands, hematite is surprisingly variable. NOT a parking lot. Thermophysical structure present. West of landing site, almost to merid highlands: THEMIS IR is very variable. (Daytime IR): Out of ellipse to east, Hematite is bright, warm, low inertia. Very sharp northern contact. (Themis VIS image of ellipse): Appears similar to MOC images with more context around it. (Daytime IR within ellipse): Hematite is relatively bright (low thermal inertia). (Color image): Hematite is greenish mostly. Crater floors and some surrounds are magenta.
*Gusev: (Daytime IR): Very patchy in center of ellipse. Themis VIS of region shows dust devil tracks very well. Etched surfaces are dark/cool during day. Cooler and rockier than cratered plains unit surrounding, but cratered plains unit is very hot when dust devils clean it off.

Landing site compositional assessment using high resolution tes data : Steve Ruff, V. Hamilton, and P. Christensen:

Composition at landing sites from TES?
*Mineral mapping: 32 mineral end members, with atmospheric end members (dust and clouds). H20 and C02 gas.

*Melas: 3 different albedo units.
1) Darkest unit = sand sheet/large dunes. Spectra: plagioclase-30%, pyroxene 25%, calcite 10%, Fe smectite 10%, SiK glass 10%, other 15%, (not much importance in 10% or less abundance values). Basaltic sand sheet.
2) Intermediate albedo unit = ripple dunes (eolian bedforms). Syrtis character, slightly brighter than sandsheet. Basaltic sand composition.
3) Bright unit = interior deposits: composition is similar to dark and intermediate surfaces, but slightly more silicic. Mounds are not some kind of carbonate or sulfate deposit, but are a more silicic material of some unknown character. Questions were asked about halite or some other evaporite contribution, but these were not detectable by TES.

*Gusev: Dark stripes of lower albedo (equivalent to dark streaks in Viking Orbiter images). Not obscured by dust. Dust layer is mobile and thin, as it has changed a lot since Viking. Deconvolved pixels with lowest albedo. Spectra: plagioclase 30, dust 25, pyroxene 15, olivine 15, other 15. This is a significant departure from a Syrtis-type spectrum. Not andesitic.

*Eos Chasma: Dark, nor really variable in albedo. Spectra: pyroxen 30, carbonate 30, plagioclase 10, olivine 10, other 20. Intrigued by carbonate abundance of 30%, but this is unverified. Different from other dark areas on Mars.

*Athabasca: Not much albedo variation, so not much to get spectra from. All looks like surface dust.

*Isidis: Similar story as Athabasca: surface spectra characteristic of dust.

A Closer Look at the Science Potential of the Prime Sites

3:45 p.m. The Hematite Site
Ray Arvidson, Washington University St. Louis

4:15 p.m. Remote Sensing Properties of Exhumed Deposits in the Terra Meridiani Region of Mars
Seelos, F. P., Arvidson, R. E., Deal, K. S., Hynek, B. M. (Washington University St. Louis), Mellon, M. T. (University of Colorado), Garvin, J. B. (NASA Headquarters).

4:30 p.m. THEMIS Observations of Terra Meridiani and the Hematite Site
Phil Christensen, Arizona State University

4:45 p.m. The Melas Chasma Site (Gusev figure)
Tim Parker, JPL, and Cathy Weitz, NASA Headquarters

5:15 p.m. Analysis of the Melas Chasma Site Based on Multiple Data Sets
Shannon Pelkey, University of Colorado

5:30 p.m. End of Day One

Overview of Landing Site Science and a Closer Look at the Science Potential of the Prime Sites Talks and Discussion,
By Dick Morris

Steve Ruff et al., Landing Site Compositional Assessment Using High Resolution TES Data.

- Melas: Dark surface looks like Syrtis endmember; plagioclase > pyroxene, no carbonates.
- Gusev Crater: Does not look like either Syrtis or Acidalia endmember; plagioclase > pyroxene.
- EOS: Different spectral type compared to Mellas and Gusev; pyroxene > plagioclase.
- Athabaska: Only surface dust.
- Isidis: Only surface dust.

Ray Arvidson, The Hematite Site.

- Hematite-bearing material is sitting on top of bright, high thermal inertia unit, which is exposed as the “etched unit” outside the hematite unit.
- Etched region has high MOLA pulse width.
- Whole region (including hematite + etched units) has been covered and exhumed one or more times.
- Possible geologic history: formation of dissected cratered terrain, deposition of etched and hematite layers, aqueous and hydrothermal alteration, mantling with formation of duricrust, and exhumation by wind to reveal hematite unit.
- Important for landing site selection: Etched unit appears to be exposed in pockets within the hematite unit, so that both types of units are accessible at the hematite landing site.

Frank Seelos et al., Remote Sensing Properties of Exhumed deposits in the Terra Meridiani Region of Mars.

- Sequence of terrain from south to north is dissected, hematite, etched, and mantled.
- TES data indicate the mantled region is covered by dust.
- TES data indicate the hematite region is hematite plus basalt with no strong affinity for TES andesite or basalt material.

Tim Parker and Cathy Weitz, The Melas Chasma Site.

- Four major geomorphic units: Interior deposits, sand sheets, dunes , and wallrock landslides
- Interior deposits correspond to high thermal inertia areas.
- Valles Marineris could have had ~3 km of water in it at one time.
- Examples of testable hypotheses: Subaqueous versus subareal landslide material for interior deposits; volcanic versus lacustrine origin for interior deposits; possible evaporite or ferrogenous sediment as the bright deposits in depressions.
- Important for landing site selection: “The rover will be toast if it lands in the fried eggs.” – D. DesMarais.

Phil Christensen, THEMIS Observations of Terra Meridiani and the Hematite Site.

- Lots of really cool THEMIS pictures.
- THEMIS team will target existing potential landing sites and new sites that may be proposed because of landing site safety issues (e.g., strong winds).

Shannon Pelkey, analysis for the Melas Chasma Site Based on Multiple Data Sets.

- Thermally-thick for sand particles is 2-4 cm.

- Handout gave thermal inertia and albedo information for landing sites.

March 27th, Wednesday a.m.
Overview of A Closer Look at the Science Potential of the Prime Sites (cont.) Talks and Discussion

8:30 a.m.	Overview of Science and Testable Hypotheses at the Gusev Crater MER A Landing Site Nathalie Cabrol, NASA Ames, E. A. Grin, D. Fike, H. Newsom, I. Thorsos, N. G. Barlow, R. De Hon, and J. Bishop
9:00 a.m.	Identification of a large lake basin at the head of Ma'adim Vallis, Mars R. P. Irwin III, T. A. Maxwell, A. D. Howard, R. A. Craddock and D. W. Leverington, NASM Center for Earth and Planetary Studies
9:10 a.m.	Impact Hydrothermal Processes at the Gusev Crater MER A Landing Site, and the Sinus Meridiani Site. H. Newsom, UNM, C. Barber, I. Thorsos, A. Davies, N. A. Cabrol, E. A. Grin, N. G. Barlow, R. De Hon, and J. Bishop
9:20 a.m.	Gusev Crater: Assessing its Relevance as the MER-A Landing Site N. G. Barlow (U. Central FL), N. Cabrol, E. Grin, H. Newsom, R. DeHon
9:30 a.m.	Isidis Planitia MER Targets: MOC and Themis Data, Detailed Mapping, and Potential Athena Science, L. S. Crumpler, NMMNH, K. L. Tanaka, and T. M. Hare
10:15-10:30 a.m.	Coffee

Overview of A Closer Look at the Science Potential of the Prime Sites (cont'd) Talks and Discussion by Ginny Gulick

Overview of Science and Testable Hypothesis at the Gusev Crater MER A Landing Site
Nathalie Cabrol, NASA Ames, E. A. Grin, D. Fike, H. Newsom, I. Thorsos, N. G. Barlow, R. De Hon, and J. Bishop

Cabrol's overview of the science rationale for Gusev Crater focused on the dissected, mesa-like, deposits that she interprets as deltaic deposits. Cabrol argued that the presence of these deposits is the best evidence for long-term fluvial activity within Gusev. Ma'adim, which flows into Gusev, is one of the largest valley systems on the planet. Any flow from Ma'adim would presumably have ponded within Gusev. Apparent multiple terracing within Ma'adim may imply episodic fluvial activity. There are several potential water sources for Gusev including direct surface runoff, groundwater outflow, hydrothermal and glacial outflows.

In the MOC data of Gusev, Cabrol has identified layers of variable thickness and albedo, and evidence for possible playas, evaporates, shorelines and lacustrine terraces within the landing ellipse. Using both MOC and MOLA data, she deduced a maximum lake depth of approximately 410 m with a depth of lasting ponding of at least 35 m. The landing site is located within the deepest point of the potential paleolake, which she feels would be the best location for evaporite deposits because water would have ponded in the deepest location for the longest period of time.

Questions: Ray Arvidson asked what observations could be made to test that the putative delta deposits are indeed depositional in origin? John Grant: the Pancam could be used to search an exposed face or trench excavated by rover wheels to look for low angle truncations in stratigraphy that is deagnostic of berm deposition. Jim Rice asked what evidence there was for glaciers in this region. He also commented that the "delta" is approximately 500m in relief; that would mean that you had at least 500m of water! Tim Parker commented that a rover would likely only see one unit and would not in fact be able to go anywhere near the shorelines. Phil Christensen asked what alternate hypotheses had been considered for the "delta deposits" and offered the alternative hypothesis that they are in fact loess deposits.

Identification of a Large Lake Basin At The head of Ma'adim Vallis, Mars

R. P. Irwin III, T. A. Maxwell, A. D. Howard, R. A. Craddock and D. W. Leverington

Irwin outlined the evidence for a large lake at the head of Ma'adim Valles, the valley system that flows into Gusev Crater. His criteria for the existence of a past lake are a closed basin, single or multiple inflowing valleys, a single outflowing valley traversing one or more drainage divides, interior depositional terracing, deltas or erosional benches, and interior plains deposits. He presented evidence that the putative lake at the head of Ma'adim fits this description and argued that the kilometer-relief deposits within the basin rule out a possible origin as Mare type volcanic deposits. Mesa clusters have been eroded out in place and are not areas of collapse. He estimates the volume of surface water available for direct runoff is 97,000 km^3. The regional ground water table within the basin area is approximately 1,100 m with the water table declining toward the highlands/lowlands dichotomy. The group also calculated the crater densities within the source basin and Gusev crater and concluded that both date to near the Noachian/Hesperian boundary. He estimated that the volume eroded from Ma'adim Valles is approximately 14,000 km^3, which is comparable to an independent estimate of the fill in Gusev crater. They concluded that multiple outflows within Ma'adim would have been required to remove sediment delivered by the tributaries.

Impact Hydrothermal Processes at the Gusev Crater MER A Landing Site, and the Sinus Meridiani Site

H. Newsom, UNM, C. Barber, I. Thorsos, A. Davies, N. A. Cabrol, E. A. Grin, N. G. Barlow, R. De Hon, and J. Bishop

Newsom summarized the potential to locate hydrothermal and fluvial deposits inside Gusev and assessed the ejecta contribution of superimposed craters within the landing site ellipse. Gusev, a 158 km diameter impact crater, may have generated as much as 10,000 km^3 of impact melt. An equal amount of heat is delivered by uplift of the central peak. Newsom estimated that the formation of Gusev Crater generated approximately 50 times the amount of energy that Yellowstone has put out in 15,000 years. The superimposed 21 km in diameter impact crater Thyra is contained within the landing ellipse and may have generated as much as 140 km^3 of impact melt.

The landing site ellipse may contain Gusev rim material delivered by emplacement of ejecta from younger impact craters around the rim, although any such material is probably buried. Fluvial processes probably also transported Gusev rim material to within the ellipse. Newsom suggested that hydrothermal deposits may still be exposed on the rim of Thyra crater. Thyra's rim lies only 21 km from the center of the ellipse. Materials from Thyra's rim may thus have been transported down slope to the landing site.

Newsom also briefly discussed impact processes at other sites. Ejecta material may be present inside the Hematite site. The 140 km diameter impact crater H4 could have formed an impact melt as large as 7,000 km^3, releasing a heat equivalent to approximately 40 times Yellowstone's over 15,000 years. The Hematite site may contain impact melt and possible lake deposits from H4 and transport of H4 rim material to the landing site ellipse. The Isidis landing site likewise has several smaller impact craters located on the highlands boundary adjacent to the landing site. The largest of these, the 60 km diameter crater IS1, may have produced as much as 500 km^3 of impact melt which is equivalent to the heat from three Yellowstone events. He concludes that lacustrine deposits may be present in both the Gusev and the Hematite sites, while it is unlikely to be present at the Isidis site. Hydrothermal deposits are most likely in the ejecta of the H4 crater in the Hematite site, on the rim of Thyra and in fluvial deposits in Gusev and in the fluvial deposits of Isidis.

Questions: Ken Tanaka asked if any such deposits would be covered by sediments? Horton responded that that might be true, but the rim of Thyra might still preserve hydrothermal deposits.

Gusev Crater: Assessing its Relevance as the MER-A Landing Site

N. G. Barlow, N. Cabrol, E. Grin, H. Newsom, R. DeHon

Barlow compared the science goals and safety constraints at Gusev with the other landing site candidates. She argued that while Gusev is not smooth, the other candidate sites aren't either. She compared the RMS surface slopes, the 1.2 km slopes, the IRTM mean rock abundance, the TES Bulk mean TI and the fine component TI and stated that Gusev met all the safety constraints. She said that Gusev and Isidis both show evidence for past water activity, but Gusev shows additional potential evidence for ponding of water. She stated that both Gusev and Terra Meridiani are probably the best sites for preservation of possible prebiotic or biotic material and that impacts could have re-exposed such materials at the surface. Potential geologic materials that may be available at Gusev include paleolake sediments, highland material and hydrothermal material from the Thyra impact crater located within Gusev.

Questions: Horton Newsom asked about the likelihood that there was an impact crater lake before ponding of water. Nadine felt that the probability was pretty good. Nathalie agreed, adding that "There is impact gardening, but the layering around impacts in MOC image data is beautiful." Steve Squyres asked, in relation to the issue of impacts exposing subsurface rocks versus obscuring lake deposits, "Is it a good thing or bad thing if subsequent impacts occur? I am interested in getting the collective wisdom on this issue."

Isidis Planitia MER Targets: MOC and Themis Data, Detailed Mapping, and Potential Athena Science
L. S. Crumpler, K. L. Tanaka, and T. M. Hare

Larry summarized the science rational for going to Isidis as it is a location that we could potentially sample the oldest rocks "from the bottom of the stratigraphic column". These units form sediment fans at the termini of several valley networks emanating from the highlands. This region has a long fluvial history accumulating fluvial and paleolake sediments. The sediment fans provide traps for the collection of weathered materials and for preservation of the most ancient Noachian materials from the geologic record. These fans would have provided deposition in a low energy environment as opposed to a high energy catastrophic flood environment. The site should contain both fines and rocks with re-worked sediments from previous deposition and paleolakes, highland rocks and fines, deep substrate mafic rocks, and weathered highland materials. Crumpler's interpretation of the site is that it is a long-lived fluvial system representing multiple dry and wet periods carrying sediments from early paleolakes, highland massifs, and local volcanic rocks. The fluvial system was active from earliest Martian geologic history through late Hesperian. He predicted that the surface materials would contain rocky debris mixed with fine-grained material, containing layered deposits. The mineralogy would be diverse and would likely include water-altered (weathered) materials.

A Closer Look at the Science Potential of the Backup Sites

10:30 a.m.	Eos Chasma David Nelson, ASU
10:50 am	Detection of Martian meteorite-like (ALH84001) spectral signatures near the Eos Chasma landing site and Geomorphology of Eos Chasma, Vicky Hamilton and Jim Rice, ASU
11:10 a.m.	Recent Eruption of Deep Groundwater into Athabasca Vallis Devon Burr, Alfred McEwen, Laszlo Keszthelyi, Jennifer Grier, University of Arizona
11:25 am	Estimating cm-scale Morphology of Volcanic Terrains using MOC Images and Lower Resolution Data Sets, Laszlo Keszthelyi and Alfred McEwen, U of A
11:40 a.m.	Exploration of Athabasca Vallis: Does Athena Have the Right Stuff? Alfred McEwen, Devon Burr, Laszlo Keszthelyi, Ross Beyer, and Peter Lanagan, U of A
11:55-1:30 p.m.	Lunch
1:30-2:30 p.m.	Discussion of Science Potential of the Sites

Summary of Session on Science Potential of Backup Sites by M. K. Shepard

<u>Eos Chasma (Nelson).</u>

Outlined the case for landing in backup site Eos Chasma and included the following topics.
Overview of geology and engineering constraints. Essentially dust free, rocky(?). Low slopes over large scales and appears smooth. Chaos terrain in eastern 5% of ellipse is rough.

Science rationale. Fluvial site, evidence of terracing and multiple episodes of erosion. Late Hesperian to Early Amazonian in age. Fewer craters than Pathfinder site. Possibility of hydrothermal source for groundwater release through the area.

Things to look for on surface.

1. Surface materials including (a) fluvial deposits (b) groundwater evidence (c) windblown sediments.
2. Bedrock including (a) basement rock (b) brecciated rock
3. Cliff wall materials, debris flows, direct imaging of cliff faces
4. Evaporite deposits
5. Signs/conditions favorable for astrobiology.

<u>Detection of Martian meteorite-like (ALH84001) spectral signatures near Eos Chasma (Hamilton and Rice)</u>.

Outlined the spectral search for ALH84001 analogs on Mars using TES data. Noted that the two basic Martian surface types are basaltic and andesitic and are not like Martian meteorites. ALH84001 is an orthopyroxenite, possibly plutonic. Search of the entire planet using TES spectra finds a single location near Eos Chasma with signature of ALH84001, independent of atmospheric conditions, time of day, and verified on multiple orbits. The carbonates associated with the meteorite are consistent with the evidence for water in this area. Possibility that this material may be visible in wall rock at Eos and detectable with Pancam/MiniTES.

<u>Recent eruption of deep groundwater into Athabasca Vallis (Burr et al.)</u>

Evidence of flooding in Athabasca Vallis. Origin of floods appears to be Cerberus Fossae. Diagnosis of flood terrain (1) streamline mesas (2) longitudinal grooves/features (3) megaripples. Deep source of groundwater is inferred from lack of local subsidence. Modeling suggests source depth of a kilometer or more. Age estimates are 2-8 Ma for the last flooding event.

Estimating cm-scale morphology of volcanic terrains using MOC images (Keszthelyi and McEwen)

Outlined a method of estimating cm-scale surface roughness based on the appearance of flows in imagery. Examples shown of terrestrial ponded, pahoehoe, a'a, and platy-ridged flows. Noted that platy-ridged flows appear to be significant in current Athabasca ellipse and recommended moving it to the East.

Exploration of Athabasca Vallis (McEwen et al)

Outlined the testable questions/hypotheses at Athabasca Vallis including:

(1) deep source of groundwater
(2) presence of fine layers of aqueous origin
(3) origin of giant ripples
(4) evidence of multiple flooding episodes
(5) potential for hydrothermal systems

Noted that this is the youngest place on Mars for large scale fluvial activity. How young is an important question to address.

Brief discussion on radar properties and noted that this area appears (visually) smoother than any other site except Sinus Meridiani, down to scales of a few meters. Radar, however, suggests cm-scale roughness to be extreme.

General Discussion of Science Potential of the Sites by M.K. Shepard

Cabrol: We need more time to assimilate data.
Parker: There won't be much to assimilate for any new sites we choose on safety grounds.
Golombek: Hematite site is even stronger now. There are two to three definitive materials to sample and it appears to be safe.
Hamilton: Would like to see more specific hypothesis testing to help choose sites.
Parker: This is difficult given the data we have is primarily orbital and larger scale.
Golombek: Athena payload is better for rock than soil.
Morris: Why is that?
General discussion: Soils are well studied with Mossbauer, micro-imager.
Farmer: Follows up, reemphasizes Hamilton's comments on hypothesis testing.

Parker: Agrees, but notes we're also exploring and are likely to find things we weren't prepared for.
Squyres: Gives general overview of science rationale for Headquarters to approve; notes we must be very specific.
Christensen: Hematite has been extensively looked at in this manner; other sites less so. As an example, what if we go to Gusev and do not find (expected) evaporates? Notes we must be prepared for all scenarios like this.
Arvidson: Hypotheses should be framed so as to be testable with the Athena payload.
Nelson: Regions should have diversity.
Gilmore: Put 1-km diameter circles on MOC images to estimate diversity at any given site.
Grant: Re-iterates Arvidson's comment to look at how rover package answers hypotheses.
Morris: One example is to look at whether mineral phases are water soluble.
Carr: Notes that at Isidis, Gusev, and Hematite, water's roll has been depositional. Athabasca, however, is volcanic and water scoured. Argues depositional environment is more important for this mission.
Squyres: Science must be traceable to mission objectives. Best fit is a depositional environment where chemical signatures can be seen.
Christensen: Time scale is important. Deposition over days is not as interesting as deposition over years to millions of years.
Rice: At Athabasca, the subsurface residence time may be very long.
Cabrol: Disagrees – suggests mud may be seen but not altered minerals.
Lane: Agrees with Cabrol and reiterates the case.
General discussion: How do you determine where alteration products come from?
Gulick: There are depositional environments in Athabasca.
Squyres: Gusev is old depositional environment and has been altered. Athabasca is young and probably is probably better preserved. Asks for a discussion of benefits of youth versus age for a site.
Parker: Young surface removes confusion factor of overlapping events.
Hamilton: Wants to see TES data used to look for chemical signatures of interest, and in general suggests MGS and Odyssey be used to aid rover operations.
Golombek: The thing that makes a site interesting is how much we know before we get there.
Lane: Athabasca is compelling because of it's youth.
Tanaka: The simpler the site, the more likely you'll solve the geologic question.
Dave (?): The important geologic questions are global, not local.

March 27th, Wednesday p.m.
Safety Considerations I: Radar and Slopes

2:30 p.m.	MER Engineering Constraints: Impact Velocity, Slopes, and Rocks Wayne Lee, JPL
3:30-3:45 p.m.	Coffee
3:45 p.m.	Radar Properties of the Landing Sites Albert Haldemann, JPL
4:15 p.m.	MOLA Slopes at 1.2 km Scale and Roughness at 150 m Scale for the Ellipses M. Golombek, S. Anderson, N. Bridges, M. Kennedy, J. Garvin
4:45 p.m.	MOLA 100 m Allan variation and hectometer Hurst exponent analysis of the MER landing sites, Albert Haldemann and Scott Anderson, JPL
5:15 p.m.	MOLA Pulse Spread Data and Landing Site Selection Jim Garvin, NASA Mars Exploration Program Scientist
5:45 p.m.	The Roughness of the Martian Surface at Decimeter to Meter Scales: What we know. Mike Shepard, Bloomsburg University, F. P. Seelos IV, R. E. Arvidson, A. Haldemann

6:15 p.m. End of Day Two

Summary of Safety Considerations I: Radar and Slopes by Frank Seelos

Wayne Lee
MER Engineering Constraints: Impact Velocity, Slopes, and Rocks

- Monte Carlo simulation of EDL with varying wind and terrain configurations
- Wind modeling limited to steady state winds and shear winds
- Terrain characterized by
    - % rocks (area)
    - 10 m RMS slope
    - 10 m 99% slope
    - 100 m scale slope

- Not generating quantitative results; providing site-to-site comparison
- Simulation based on terminal decent physics
- State of the system at bridal cut → Ballistic propagation → Survive (YES/NO)?

- Big problem: Ricochet effect
    - Bounce N+1 > bounce N
    - Results from unfortunate combination of horizontal velocity (wind induced) and slopes

- Degradation of survival rate with respect to Hematite (aggressive conditions)

	Hematite	Melas	Gusev	Isidis
Baseline	0	-37	-14	-8
Winds	-6	-60	-39	N/A
Rocks	-5	-44	-19	-15
Slopes	-2	-50	-19	-10

- Survival rate is most sensitive to winds
- Rock and slope effects are secondary

Albert Haldemann
Radar Properties of the Landing Sites

- 12.6 cm (Arecibo) and 3.5 cm (Goldstone)
- If data not available over the ellipse, then data was used from the corresponding geomorphic unit as a proxy

- Specular echo: Required for radar altimeter system (RAS) to function properly
    - All of the sites would provide sufficient echo for the RAS to detect the surface
- Diffuse echo: Relates to roughness at scales of interest to rover trafficability.
    - Rougher sites: Gusev, Melas, Eos (similar to VL1, MPF in this measure)
    - Smoother sites: Hematite, Isidis, Athabasca
- Athabasca depolarization ratio ~1
    - Implies dominance of multiple scattering
    - Four hypotheses
        - Chaotic texture
        - Blocky texture ← preferred model, based on corroborating analyses
        - Enhanced dielectric constant
        - Volume scattering

Matt Golombek

MOLA Slopes at 1.2 km Scales and Roughness at 150 m Scales for the Ellipses

- 1.0 km scale from MOLA inter-shot
- 100 m scale from MOLA pulse-width

Site	B1.2	A1.2	B1.2 sd	A1.2 sd	Av PW	sd PW
TM10A2	0.15	0.21	0.18	0.45	0.75	0.24
TM20B2	0.16	0.22	0.20	0.47	0.75	0.24
VM53A2	1.22	1.13	1.35	0.65	1.18	0.73
VM53B2	1.29	1.15	1.49	0.68	1.24	0.75
IP84A2	0.19	0.14	0.24	0.10	1.10	0.35
IP96B2	0.18	0.14	0.24	0.10	1.08	0.33
EP55A2	0.20	0.16	0.44	0.20	1.42	0.44
VM41A2	1.22	0.94	1.87	0.98	1.06	1.14
EP49B2	0.20	0.18	0.35	0.23	1.18	0.35
VL1	0.27	0.32	1.02	1.01		
VL2	0.28	0.27	0.28	0.19		
MPF	0.30	0.25	1.07	0.68		

B = bidirectional; A = adirectional

- All Sites Meet 1.2 km Slope Criterion <2°
  - Hematite, Isidis, Gusev, Athabasca Very Smooth
    - Average ~0.2°: Comparable to VL1, VL2 & MPF
  - Melas & Eos Higher, Average ≥1°
- All Sites Meet 100 m Slope Criterion <5°
  - Hematite, Isidis, Melas, Athabasca, Eos PW
    - Average <1.2 m
  - Gusev Slightly Higher, Average ~1.4 m
- To Come: Sites Rough at 100 m are Rough at 10 m
  - Rough-to-Smooth:
    - Melas, Eos, Gusev, Isidis, Athabasca, Hematite

Albert Haldemann

MOLA 100 m Allan Variation and Hectometer Hurst Exponent Analysis…

- Assume topography on Mars is self-affine
- Use MOLA profiles to calculate the Hurst exponent for baselines ranging from 300 to 1200 m and extrapolate to smaller scales (100 m)

Site	H	?(100 m) /m	S_{RMS} (100 m) /deg	?(1 m) /m	S_{RMS} (1 m) /deg
Hematite	0.53	3.4	1.9	0.30	16.7
Melas	0.81	9.9	5.7	0.24	13.5
Gusev	0.56	5.8	3.3	0.44	23.8
Isidis	0.51	2.6	1.5	0.25	14.0
Athabasca	0.76	4.3	2.5	0.13	7.4
Eos	n/a	n/a	n/a	n/a	n/a
MPF +/- 0.2º	0.37	5.0	2.9	0.92	42.6

MPF 0.5º radius	0.77	5.0	2.9	0.15	8.5
VL1 +/- 0.2º	0.53	1.8	1.0	0.15	8.5

Mike Shepard
The Roughness of the Martian Surface at Decimeter Scales…

- Characterize known landing sites at all possible spatial scales
- Calibrate other remote sensing techniques for estimating surface roughness
- Data Sources:
    - Pathfinder
        - USGS DEM
        - Rover Wheel Slopes
        - MOLA Point-to-Point (PtP) Slopes
    - Viking Lander 1
        - New Stereo DEM
        - MOLA PtP Slopes
    - Viking Lander 2
        - Some New Stereo DEM
        - MOLA PtP Slopes
- Analyses:
    - Pathfinder
        - Hurst exponent 0.54 - 0.61
        - RMS slope @100m 1.7°± 0.9°
@ 10m 2.5°± 1.0°
@ 1m 5.4°± 1.0°
    - Viking Lander 1
        - 83 new profiles from stereo
        - Hurst exponent 0.5 - 0.8
        - RMS slopes @100m 1.2°± 0.3°
@ 10m 3.0°± 1.0°
@ 1m 4.8°± 1.0°
    - Viking Lander 2
        - Only 1 usable new profile *so far* (6m long)
        - Hurst exponent ~0.8
        - RMS slopes @100m 1.4° ± 0.4°
@ 10m 3.8° ± 2.0°
@ 1m 8.8° ± 3.0°

- All sites have comparable roughness at 10m-50m scales.

F. Scott Anderson
Characterization of MER Landing Sites Using MOC and MOLA

- Extract MOLA topography, slope, and PW for each MOC image in landing ellipse
- Read MOC image and determine sclk start/stop of image, and orbit number
- Search specific MOLA orbit for matching sclk times

	Relief (m)	Mean Slope (degrees)	Mean PW (ns)
Hematite	29.5	1.7	14.7
Melas	268.5	8.0	43.2
Athabasca	71.0	2.7	20.4
Gusev	70.0	6.3	49.6
Isidis	43.1	1.3	20.5

Randy Kirk
DTMs Derived from MOC Stereo Images
- Photoclinometry and stereoanalysis applied to landing ellipse MOC images
- Slope analysis based on DEMs produced

Site	Set	Sub Area	DEM from	Baseline (m)	RMS Bidir Slope (°)	RMS Adir Slope (°)	99% Adir Slope (°)	Correction to 5 m Base	99% Adir Slope @ 5 m	P(Adir =15°) @ 5 m (%)
Athabasca	1	a	PC	5.87	1.26	1.72	5.02	1.020	5.12	0.001
		b	PC	5.87	0.94	1.48	3.77	1.057	3.97	0.001
		c	PC	5.87	1.25	1.86	4.85	1.019	4.99	0.001
Athabasca	2	n	ST	10	3.39	4.72	15.67	1.125	17.64	0.019
Athabasca	3	a	ST	20	2.48	3.45	10.20	1.409	11.64	0.004
		c	PC	5.87	3.99	5.35	13.79	1.007	13.88	0.006
		d	PC	5.87	2.66	3.48	8.50	1.010	8.58	0.001
Eos	1	nc	ST	10	6.27	9.22	34.39	1.092	37.56	0.072
		nd	PC	3	5.82	7.07	23.50	0.927	22.95	0.029
Eos	2	a	ST	10	6.05	7.97	25.26	1.189	30.03	0.087
		c	PC	2.87	8.10	9.61	28.20	1.005	28.33	0.082
		d	PC	2.87	10.58	13.82	35.40	1.005	35.57	0.239
Gusev	1	a	ST	10	2.80	4.93	16.29	1.076	17.53	0.015
		c	ST	10	5.63	8.20	24.95	1.066	26.61	0.078
		d	PC	3	4.20	5.23	15.31	0.982	15.03	0.010
		e	PC	3	9.35	11.67	22.30	0.990	31.97	0.163
Gusev	2	a	ST	10	8.32	11.37	37.58	1.048	37.38	0.157
		b	ST	10	12.75	16.52	48.17	1.049	50.52	0.340
		c	PC	3	9.00	11.65	30.80	0.989	30.45	0.166
		d	PC	3	12.23	15.92	42.99	0.985	52.36	0.299
Hematite	2	a	PC	2.9	4.89	9.45	24.38	0.791	19.29	0.037
		b	PC	2.9	1.25	1.82	4.94	0.946	4.68	0.001
		c	PC	2.9	2.21	3.38	9.46	0.933	8.83	0.001
Isidis	1	nb	ST	10	4.66	6.39	25.60	1.202	30.78	0.037
		nc	PC	3	5.70	7.45	22.32	0.983	21.93	0.027
		sa	ST	10	4.12	5.80	20.08	1.058	21.24	0.027
		sb	PC	3	8.49	10.78	31.18	0.987	30.78	0.121
Melas	1	a	ST	10	2.72	4.86	14.34	1.000	14.34	0.008
		b	ST	10	1.56	2.66	7.74	1.000	7.74	0.001
		c	ST	10	2.43	4.11	12.61	1.000	12.61	0.004
		e	PC	3	13.19	15.85	41.37	0.923	38.17	0.289
Melas	2	a	ST	10	9.96	12.89	43.42	1.187	51.52	0.233
Melas	3	a	ST	10	11.37	14.37	53.80	1.273	68.49	0.274

- http://marsoweb.nas.nasa.gov/landingsites/mer2003/doc/pasadena_02/talks/kirk/ for complete analysis and results or for results and downloads http://webgis.wr.usgs.gov/mer

Anton Ivanov
DTMs from MOC Stereo Images
- Analysis similar to R. Kirk

- Results consistent with other photoclinometric efforts

Ross Beyer
Evaluation of Small-Scale Roughness via Photoclinometry

- Pixel-by-pixel photoclinometric analysis
- Results in a down-sun slope magnitude map, not a DEM
- Assumptions:
    - No overall tilt to the terrain
    - Image shading is due to slopes, not albedo variations

- Lunar-Lambert photometric function
- Estimated errors on the order of 1 degree
- Two processing modes:
    - No haze removal: underestimates slope magnitude
    - 1st order haze removal: overestimates slope magnitude

- Results:
    - Eos: Rough but acceptable
    - Gusev: Rough but acceptable
    - Hematite: Albedo contributing to slope calculations; slopes are likely much lower than those reported
    - Isidis: Low roughness (suffers from under sampling)
    - Athabasca: Low roughness

- http://pirlwww.lpl.arizona.edu/~rbeyer/MER_3lsws/ for summary plots

March 28th, Thursday a.m.
Safety Considerations I: Radar and Slopes (cont'd)

8:30 a.m.	Characterization of MER landing sites using MOC and MOLA. F. Scott Anderson and Tim Parker, JPL
9:00 a.m.	DTM's Derived from MOC Stereo Images Randy Kirk, USGS
9:30 a.m.	DTMs from MOC Stereo Images A. Ivanov, JPL
10:00 a.m.	Evaluation of Small-Scale Roughness via Photoclinometry Ross Beyer and Alfred McEwen, University of Arizona
10:30-10:45 a.m.	Coffee

Safety Considerations II: Thermal Inertia, Albedo, and Rocks

10:45 a.m.	Surface Lifetime Jake Matijevic, JPL
11:15 a.m.	TES Thermal Inertia and Albedo Data and Implications for Minimum Near-Surface Temperatures, Nathan Bridges and Terry Martin, JPL
11:45 a.m.	Rock Abundance derived from TES data Scott Nowicki and Phil Christensen, ASU

12:15 p.m. Rock Statistics Calculations for the Landing Sites
Matt Golombek

12:45-1:30 p.m. Lunch

Summary of Safety Considerations II: Thermal Inertia, Albedo, and Rocks by P. Christensen

Randy Kirk. DTM's Derived from MOC Stereo Images. A set of 12 MOC stereo and photoclinometric images have been analyzed for each of the six primary and backup landing sites. The details of the methodologies and uncertainties were presented for these methods and for the MOC images. The MOC dataset has limits that were discussed. The stereo and photoclinometric data for Gusev and highly consistent; Melas currently lacks stereo; the photoclinometry in Isidis, Hematite, and Eos are effected by albedo or sampling; and Athabasca is "complicated", Based on a criteria of have only a 1-2% chance of a slope >15° at MOC pixel scales. In ranked order from best to worst the sites are; Hematite, Athabasca, Isidis, Eos, Gusev (smooth terrain is better), and Melas. Only Hematite and Athabasca fall with a formal "safe zone".

Anton Ivanov. Analysis of MOC Stereo DTM;s. Four MOC stereo pairs were analyzed for each of Gusev, Eos, Hematite, and Melas. The method does automatic tie pointing for approximate one million points in the image pairs. The primary errors are spacecraft pointing, which can be improved, and jitter which cannot. The results show that at 10 m scale the four sites rank from best to worst are Hematite/Gusev/Melas/Eos. The mean slope varied from 4.1 (Hematite) to 9.2 (Melas).

Ross Beyer and Alfred McEwen. Evaluation of Small-scale Roughness via Photoclinometry. A 1-D photoclinometry model was applied to approximately 100 MOC images. The method assumed a Lunar-Lambert photometric function. The uncertainly is estimated to be ~1°. The results are sensitive to albedo and atmospheric haze; albedo variations produce overestimates in slopes; haze produces an underestimate in slope. For comparison the Viking and Pathfinder sites were found to have 3-4° slopes at 6m/pixel scale. Melas could not be analyzed due to albedo variations. Gusev has acceptable slopes; hematite is acceptable, with the slopes likely lower due to the effect of albedo; Isidis has low roughness; Eos and Gusev are rough but acceptable. Athabasca is very smooth at > 6 m length scales, with no evidence for an increase in roughness at 1.5-m scales. These results are not consistent with the radar roughness results and need to be explored further.

Jake Matijevic. Surface Lifetime. The talk presented an overview of mission lifetime issues. Based on realistic mission scenarios the sites were estimated to lifetimes of: Hematite 100-112 days; Gusev 92 (MER A only); Melas 84-100; and Isidis 124-136. A major question has arisen regarding the nighttime temperature of the sites, with hematite being the problematic. Thermal inertia and albedo were used in a 1-D GCM model to provide a 3-sigma estimate of potential surface temperatures. The nighttime temperatures are modeled to be 7 °C cooler at the end of the mission, with a potential reduction in mission life to 82-90 sols. Other constraints: energy 10-20% more planning energy for A than B; 25-15% less efficient data return for B than A. Examples of mission scenarios give a total 4.7 Gb data return for MER A at Gusev and 4.4 Gb for MER B at Isidis. Trafficability was estimated to be Hematite and Gusev – easy; Melas – variable; Isidis – 60% increase in travel time; Eos 4x increase in travel time; and Athabasca – 40% increase.

Nathan Bridges and Terry Martin. TES Thermal Inertia and Albedo Data and Implications for Minimum Near-Surface Temperature.
TES data were used to estimate surface and near-surface atmospheric temperatures. The hematite site was found to have regions in which the nighttime temperature is at or below the lander survivability limit.

Scott Nowicki and Phil Christensen. Rock Abundance Derived From TES Data. The rock abundance model methodology and uncertainties were briefly described. A rock abundance map has been produced at 8 pixels/degree for the region from 15S to 15 N. The rock abundance results for the six landing sites are:

Melas (ave; 15-20%; maximum 25-30%); Isidis (20-25%; 25-30%); Eos (10-15%; 25-30%); Gusev (5-10%; 10-15%); Athabasca (5-10%; 10-15%); and Hematite (5-10%; 10-15%).

Matt Golombek. Rock Statistics Calculations for the Landing Sites. The methodology and uncertainties for determining the rock size distribution from the total areal abundance derived from IRTM and TES was presented. The IRTM model gives close (within 20%) values for the three past landing sites. An exponential rock size distribution works well to fit terrestrial surfaces. Based on this model the following conclusions can be stated. First, if rocks are not visible in MOC images, then the surface likely has less than 20% abundance. Second, the probability of impacting a 1-m diameter rock can be estimated versus the number of bounces. Assuming four bounces the probability of hitting a rock is 2.4% for Hematite, 18% for Melas, 6% for Gusev, 30% for Isidis, 18% for Athabasca, and 60% for Eos. Airbag test have shown the 40% coverage by 1-m diameter rocks.

March 28th, Thursday p.m.
Summary of Safety Considerations

1:30 p.m. MER Project Hazard Analysis
Mark Adler, JPL

2:15-2:45 p.m. Discussion of Safety Issues

2:45 p.m. Athena Payload Capabilities and the MER Landing Sites
Steve Squyres, Athena PI, Cornell U.

Summary of Session on Safety Considerations by M.H. Carr.

Safety issues were summarized by Mark Adler (JPL). Winds are now more of a concern then previously. There is no perfect site, all have some problems. Of the four prime sites, Hematite is the safest for landing, Melas is the least safe, for landing (combination of slopes and horizontal winds). Gusev is fine except for wind shear. We have no information on winds at Isidis. Eos is likely to be unacceptable because of the combination of rocks and high winds. Egress of the rover from the lander is unlikely to be a problem at any site. With respect to the surface mission, low temperatures may cause a lifetime problem at Hematite. Trafficability is a concern at Eos and Athabasca, and may be a concern at Melas and Isidis. Much more work needs to be done to resolve the safety issues. The project has limited resources and must focus them on a few sites. Considering the safety issues, Adler recommended retaining Hematite, Gusev and Isidis as prime sites, dropping Melas and Eos from further consideration, and retaining Athabasca as a back-up. The ellipse in Athabasca would be moved to avoid the platey lava that may be causing the anomalous radar returns. Because of remaining concerns about winds at Gusev and Isidis, Adler also recommended relaxing the elevation constraints, and possibly latitude and hematite exclusion zone constraints to look for additional sites with hematite-like levels of safety. The new sites should be chosen on the basis of characteristics that would minimize winds, as defined by atmospheric scientists. All these recommendations should be implemented soon and transmitted to the THEMIS and MOC teams so that acquisition of data on the sites can start ASAP.

Summary Discussion of Landing Sites

3:15-4:30 p.m. Summary Discussion of All Sites

The final discussion portion of the workshop focused on establishing community consensus of the releative merits of the Sites (primary and back-up) with respect to mission science, safety, and public engagement objectives. Sites were treated discussed individually beginning with the Hematite site, then moving on toi consider Melas, Eos, Athatbasca, Gusev, and Isidis. Based on the outcome of these discussions, the attached summary chart was produced indicating a good (green), mediocre (yellow), or poor (red) rating for the various criteria. This summary chart then became the basis for additional recommendations regarding the sites that included dropping both Eos and Melas Chasma from further consideration and retaining the Athabasca site (after optimizing the position of the landing ellipse) as a back-up site. Based on additional concerns related to the sites and new concerns introduced by the results of wind modeling, the high importance of identifying multiple "safe" landing sites (e.g., towards the center of Isidis Basin) was also agreed upon.

See Attached Summary Landing Site Evaluations Compiled at End of Workshop

4:30-5:30 p.m. Community Input to Project and Athena Science Team

5:30 p.m. End of Workshop