**DOWNSELECTION OF LANDING SITES FOR THE MARS EXPLORATION ROVERS.** M. Golombek[1], J. Grant[2], T. Parker[1], T. Schofield[1], D. Kass[1], P. Knocke[1], R. Roncoli[1], N. Bridges[1], S. Anderson[1], J. Crisp[1], A. Haldemann[1], M. Adler[1], W. Lee[1], S. Squyres[3], R. Arvidson[4], M. Carr[5] and C. Weitz[6], [1]Jet Propulsion Laboratory, Caltech, Pasadena, CA 91109, [2]Smithsonian Institution, Washington, D.C. 20560, [3]Cornell University, Ithaca, NY 14853, [4]Washington University, St. Louis, MO 63130, [5]U. S. Geological Survey, Menlo Park, CA 94025, [6]NASA Headquarters, Washington, DC 20546.

**Downselection Process:** Following the *First Landing Site Workshop for the 2003 Mars Exploration Rovers*, January 24-25, 2001, at NASA Ames Research Center, Mountain View, CA, roughly 25 sites from a possible ~185 were selected on the basis of their science potential [1, 2] and targeted for MOC (Mars Orbiter Camera) imaging. The basic characteristics of these sites were then investigated in more detail and the engineering constraints on the landing sites were better defined.

Engineering constraints developed for Mars Exploration Rover (MER) landing sites indicate they must be below –1.3 km MOLA (Mars Orbiter Laser Altimeter) elevation [1]. This elevation is derived from spacecraft entry, descent and landing simulations using atmospheric density profiles. Surface pressures used to derive the atmospheric density profiles are scaled hydrostatically from elevation differences with Viking lander 1. Temperature versus altitude profiles are derived from Thermal Emission Spectrometer (TES) results [e.g., 3], one-dimensional dynamical models of the lower few kilometers of the atmosphere, and Global Circulation Model (GCM) results [4] for the landing site location, season, and time of arrival.

Landing ellipses, which vary in size with latitude between 15°S and 10°N, must ultimately be separated by a minimum central angle of approximately 37° to avoid telecommunications contention with orbiters [1]. They must appear hazard free in Viking image mosaics, with low surface slopes (<2° over 1 km; <5° over 100 m, and <15° over 5 m). Rock abundance must be <20% and the bulk thermal inertia must be >250 and >200 SI units ($J\ m^{-2}\ s^{-0.5}\ K^{-1}$) with albedos <0.26 and <0.18, respectively. This requirement stems from extremely low temperatures likely at low thermal inertia, high albedo sites. This requirement removed two sites (3/01) in Elysium Planitia, one site at Apollinaris and another in Durius Vallis from consideration.

Of the remaining sites, one site in Ganges Chasma and two sites in Candor Chasma were later eliminated (6/01) on the basis of high topographic relief, steep scarps, and hummocky topography. This left about 17 sites in which ellipses were located and thermophysical properties gathered. These sites were: Hematite in Terra Meridiani, Melas Chasma, Isidis Planitia, Gusev crater, Gale crater, Eos Chasma, NE and central Vallis Marineris, Meridiani crater, Boedickker crater, an unnamed crater (9°S, 209°W) and Meridiani highlands. Ellipses for these sites varied in length with latitude from 340 to ~80 km long by 30 km wide and were based on ranging and 2-way Doppler tracking of the spacecraft with 5 trajectory correction maneuvers, the last of which would be 12 hours before entry.

In the summer of 2001, the MER project evaluated the possibility of using DeltaDOR tracking of the spacecraft (simultaneous tracking by two Deep Space Network stations). Preliminary results suggested ellipse sizes would be up to a factor of 2 smaller (without margin). Because landing sites of this size had never been evaluated for MER, new landing sites with ellipses that varied in length between 100 km at 10°N to about 40 km at 15°S were considered. All landing sites proposed for the ’01 lander and all areas that had significant MOC coverage within the latitude and elevation bounds for MER that were at least as scientifically compelling as existing sites were considered. Nine new locations met these criteria: Margaritifer Valles, Crommelin crater, 2 Athabasca Vallis sites in Elysium Planitia, Ares Vallis tributary, Sinus Meridiani, Highlands (8N, 12W), and additional sites in Melas (SE) and Isidis.

In September 2001, the MER project completed a full analysis of landing ellipse sizes that included DeltaDOR tracking, a 5$^{th}$ trajectory correction maneuver 2 days before atmospheric entry, a new arrival date for MER B, and a full assessment of navigation errors. Ellipse lengths were 150 to 95 km, depending on latitude, with widths of 16-20 km. Three of these new sites (Margaritifer Valles, Crommelin crater, and SE Melas) were removed based on these longer ellipses.

The remaining 24 sites were discussed at the *Second Landing Site Workshop*, October 17-18, 2001, in Pasadena, CA [2]. This workshop focused on evaluation of the science that can be accomplished at each site. Each site had a science spokesperson who discussed the science potential, the testable hypotheses, and specific measurements and investigations possible by the Athena science instruments at that site. In addition, safety considerations for the sites were discussed (ellipses did not fit within Gale, Boedickker, and the un-named craters, or central and NE Valles Marineris). Consensus was reached on 4 prime sites and 2 backups. Ellipse locations were moved slightly after the workshop to improve their science potential or safety (Table 1).

**Top Landing Sites:** Presentations at the workshop [2] indicate all of the sites 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 pre-biotic or biotic processes. TES spectra indicate coarse-grained hematite distributed across a basaltic surface at the Hematite site, suggesting precipitation from liquid water or a hydrothermal deposit [5]. MOC images of the center of the Melas ellipse show what appear to be layered sediments likely deposited in standing water [6]. Gusev has been interpreted as a crater lake with interior sediments deposited in standing water [7]. The ellipse in southernmost Isidis Planitia is located to sample ancient Noachian rocks shed off the highlands [8] that might record an early warm and wet environment as suggested by the abundant valley networks. Athabasca Vallis is an extremely young outflow channel with young volcanics that might contain hydrothermal deposits [9]. Eos Chasma is located to sample a variety of materials draining a lake in Vallis Marineris [R. Kuzmin et al., 2].

Table 1. MER Landing sites; A and B ellipses refer to first and second MER, respectively. Center of ellipses in MDIM2 (aerographic), west (W) longitude and MOLA (aerocentric), east (E) longitude reference systems. Ellipse (El.) Length (Ln), width (Wd) and azimuth (Az) of major axis, measured clockwise, shown for launch at the beginning of the launch period.

| Landing Site, Ellipse # | MDIM2 Lat. Long. W | MOLA Lat. Long. E | El. Ln km | El. Wd km | El. Az deg |
|---|---|---|---|---|---|
| Hematite, TM20B2<br>TM10A2 | 2.07S<br>6.08 | 2.06S<br>353.77 | 117<br>119 | 18<br>17 | 86<br>84 |
| Melas, VM53A2<br>B2 | 8.88S<br>77.48 | 8.75S<br>282.36 | 103<br>105 | 18<br>20 | 80<br>82 |
| Gusev,<br>EP55A2 | 14.82S<br>184.85 | 14.64S<br>175.06 | 96 | 19 | 76 |
| Isidis, IP84A2<br>IP96B2 | 4.31N<br>271.97 | 4.22N<br>87.91 | 132<br>135 | 16<br>16 | 88<br>91 |
| Eos,<br>VM41A2 | 13.34S<br>41.39 | 13.20S<br>318.46 | 98 | 19 | 78 |
| Athabasca,<br>EP49B2 | 8.92N<br>205.21 | 8.83N<br>154.67 | 152 | 16 | 95 |

Comparison of the thermophysical properties of the sites with the Viking (VL) and Pathfinder (MPF) landing sites (Table 2) allows an 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. Melas Chasma has moderate thermal inertia and fine component thermal inertia and low albedo. This site will likely be moderately rocky but with less dust than the MPF and VL landing sites. Gusev crater has comparable thermal inertia, fine component thermal inertia and albedo to the VL sites and so will likely be similar to these locations, but with fewer rocks. The Athabasca Vallis site has high albedo and moderate thermal inertia, suggesting a moderately rocky and dusty site. The Isidis and Eos sites have high to very high thermal inertias suggesting a crusty surface. The Isidis site has moderate albedo and a high red/blue ratio, suggesting a rocky weathered crusty surface without too much dust. Eos has low albedo, suggesting a rocky and crusty surface with little dust.

Table 2: Average thermophysical properties of MER landing sites [10]. Thermal inertia (I) and fine component (FC) thermal inertia in SI units or J $m^{-2}$ $s^{-0.5}$ $K^{-1}$. Rock abundance (Rock) in percent of surface covered by rocks. Note inconsistency between TES I and IRTM (InfraRed Thermal Mapper) fine component I.

| Landing Site | TES I | TES Albedo | IRTM FC I | IRTM Rock |
|---|---|---|---|---|
| Hematite | 258 | 0.153 | 307 | 5 |
| Melas | 308 | 0.168 | 253 | 12 |
| Gusev | 302 | 0.230 | 247 | 6 |
| Isidis | 487 | 0.227 | 392 | 15 |
| Eos | 397 | 0.138 | 298 | 15 |
| Athabasca | 195 | 0.275 | 207 | 10 |
| VL1 | 320 | 0.255 | 250 | 15 |
| VL2 | 240 | 0.235 | 175 | 17 |
| MPF | 425 | 0.218 | 344 | 18 |

**Plans:** Another open landing site workshop is scheduled in March 2002 that will focus in detail on these sites. MOC and 20 m/pixel THEMIS (Thermal Emission Imaging System) visible images will be targeted. These sites will receive detailed scrutiny (MOLA slopes over 0.3-2 km lengths and pulse spread, image photoclinometry and stereogrammetry, thermophysical properties, and radar data) in terms of their safety and science and two will be selected in May 2002. These locations are boxes 10° in latitude by 15° in longitude, which will continue to be evaluated until May 2003, with final targeting of the specific landing ellipses within the boxes at the first trajectory correction maneuver (6/03 and 7/03).

**References:** [1] Golombek M. et al. (2001) *LPS XXXII,* Abs. #1234. [2] http://webgis.wr.usgs.gov/mer and http://marsoweb.nas.nasa.gov/landingsites/mer2003. [3] Conrath B. et al. (2000) *JGR 105*, 9509-9519. Smith M. et al. (2000) *JGR 106*, 23,929-23,945. [4] Pollack et al. (1990) *JGR 95*, 1447-1473. Joshi M. et al. (2000) *JGR 105*, 17,601-17,615. Haberle R. et al. (1993) *JGR 98*, 3093-3123; (1999) *JGR 104*, 8957-8974. [5] Christensen P. et al. (2000) *JGR 105*, 9623-9642. [6] Weitz C. et al. (2001) *LPS XXXII,* Abs. #1629. [7] Grin E. & Cabrol N. (1997) *Icarus 130,* 461-474. [8] Crumpler L. et al. (2001) *LPS XXXII,* Abs. #1977. [9] Burr et al. (2001) *GRL in press*. [10] Christensen P. (1986) *Icarus, 68,* 217-238; (1982) *JGR 87,* 9985-9998; (1986) *JGR 91*, 3533-3545. Mellon M. et al. (2000) *Icarus 148,* 437-455.