# Summary Report for the First MSL Landing Site Workshop

Held at the Pasadena Conference, Convention Center, Old Town Pasadena, CA
May 31st-June 2, 2006

**Start of Day One at 8:30 am**

Welcome/Intro

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|---|---|---|
| Michael Meyer | Welcome from HQ | 8:30 |
| Grant/Golombek | Overview of Process | 8:45 |
| Stolper/Vasavada | Overview of MSL Mission | 9:05 |
| Michael Watkins | MSL Engineering Constraints | 9:35 |

**Summary of Session (see individual presentations for more detail)**

*Michael Meyer*

- Overview of current and future missions and expected budget cutbacks
- Goals of MSL and purpose of the MSL workshop
- MSL – first to discover organics, mineralogy, surface radiation (relevant to human exploration), ground-truthing
- Comment by Jim Papike – need program continuity and collaboration between countries

*John Grant*

- Overview of process that has been established by landing site workshop and guiding principles of landing site selection process
- Participants of site selection process
- Overview of MSL engineering requirements and constraints and Planetary Protection requirements
- Series of workshops from May 2006 to October 2008 to prioritize 40 proposed sites and determine final landing site by June 2009

*Ashwin Vasavada*

- Overview of science objectives - *explore and quantitatively assess (chemical, physical, geology, mineralogy) a local region on Mars surface as a potential habitat for past or present life*
- Overview of Payload – Remote Sensing (MastCam, ChemCam), Contact (APXS, MAHLI), Analytic Laboratory (SAM, CheMin), Environmental (DAN, RAD, REMS, MARDI,SA/SPaH)

*Michael Watkins*

- Overview of engineering capabilities and constraints relevant to landing site selection
- Restrictions and contingencies for primary launch period and arrival dates for different latitude ranges
- Overview of EDL constraints (slope, altitude, rock abundance, winds, terrain specifications, etc), mobility and traverse performance
- Surface operations and science decisions

Break from 10:05 to 10:20

**General Aspects of Site Selection**

John Rummel 10:20
*Planetary Protection Constraints*

M.P. Golombek 10:40
*Mapping Engineering Constraints from orbit to the surface*

K.L. Tanaka, J.A. Skinner and T.M. Hare 11:00
*A geoscience-based digital mapping approach for MSL landing-site selection*

S.C.R. Rafkin and T.I. Michaels 11:15
*Preliminary atmospheric hazard assessment for MSL EDL*

R.L. Fergason and P.R. Christensen 11:30
*Determining surface characteristics at candidate MSL landing sites using THEMIS high-resolution orbital thermal inertia data*

S.W. Ruff 11:45
*The truth about Martian dust: Ground-truthing the TES Dust cover index and its significance to landing site selection*

J.L. Bandfield 12:00
*Landing site surface characteristics from TES EPF observations*

Lunch from 12:15 pm to 1:45 pm

**Overview of Site Science**

M.P. Golombek and J.P. Grotzinger 1:45
*Broad perspectives on preferred types of Mars Science Laboratory landing sites: Experience from characteristics of previous landing sites and developing sedimentologic facies models*

**Summary of Session (see individual presentations for more detail)**

John Rummel summarized many of the key planetary protection requirements that will impact site selection. He highlighted changes that have occurred since the MER sites were selected. The new concept of a "special region" denotes an area where microorganisms introduced from Earth could be expected to propagate. A recent MEPAG Special Regions Science Advisory Group proposed to define special regions as places where the activity of water might at least intermittently overlap partially the broadest possible range of water activities that could sustain the most desiccation-tolerant microbes known. This definition allows most present-day near-surface Martian environments to be excluded from special region status. However, recent Martian gullies indicate recent water activity and therefore would remain as examples of special regions. Unsterilized spacecraft parts cannot be exposed to a special region, therefore only a completely sterilized rover can land in or drive to a special region. Only the sterilized drill of an otherwise unsterilized lander can penetrate into a subsurface special region. The following two important scenarios will receive further study. If a nuclear power plant on future landers were to impact and penetrate ice-rich regolith, it might sustain a "special region" for an extended period. Water bound as hydrates could potentially be released and cause a region to become "special."

Matt Golombek explained how the efforts to characterize landing sites by remote sensing prior to mission launch have improved dramatically from Viking to the Mars Exploration Rovers. The efforts for Pathfinder and MER were remarkably accurate and contributed substantially to the successful outcomes of those missions. Clearly these procedures should be continued with MSL. Several more databases will be available than with MER. Planetary protection will become a more stringent criterion. As the MSL site selection process proceeds, rock abundance estimates will move from using statistical models to actual high-resolution observations of the landing ellipses by HIRISE.

Ken Tanaka summarized the new USGS Geographical Information System (GIS) for Mars site evaluation. The GIS will assimilate the diverse databases (e.g., elevation, geology, rock abundance, terrain, thermal inertia, dust index, atmospheric hazards, etc.) to support overall assessments of scientific and engineering "quality" of proposed sites.

Scot Rafkin summarized aspects and concerns associated with assessing atmospheric hazards such as winds, turbulence, etc. Mars is a windy planet. The southern highlands are generally windier than the northern lowlands. The high latitude southern regions are very stormy with seasonal storm tracks. High local topographic relief intensifies turbulence. Most regions are generally less windy at night, but only numerical modeling can determine wind regimes during the course of a sol with relatively high degree of certainty. Atmospheric hazard assessments of proposed sites should begin much earlier than they did with MER.

Phil Christensen provided an overview of the importance and key features of thermal inertia measurements of landing sites. The thermal inertia of a site is determined principally by conductivity of surface materials that in turn is controlled principally by grain size of the materials. Because higher thermal inertia moderates daily temperature excursions, this factor is a key site characteristic. Ground-truthing by Mini-TES on the Spirit rover confirmed that remote observations of thermal inertia by THEMIS were highly accurate. Two new THEMIS-based global maps provide estimates of daytime and night ground temperatures at 300 m/pixel resolution. Global maps offering 100 m/pixel resolution should be released within the next year or so. The THEMIS team will be able to provide maps of thermal inertia for 20 km landing site ellipses within a few weeks of a request.

Steve Ruff described the Dust Cover Index (DCI) that has been developed for characterizing Martian regions. DCI is based upon the emissivity of silicates in the 1350 to 1400 $cm^{-1}$ spectral region. DCI correlates well with albedo in very dusty, high albedo regions. Regions having very low albedos are invariably relatively dust-free. Regions having higher albedos but low DCI might harbor hydrated minerals and other key water-related minerals having great potential interest for MSL. DCI will therefore become an important tool for the evaluation of potential MSL landing sites.

Josh Bandfield described the utilization of the Emission Phase Function to interpret thermal infrared remote sensing data. Radiance can vary as a function of viewing angle with respect to the sun due both to shadowing and to the percentage of the viewed surface that is occupied by rocks. The percentage of illuminated surface decreases at higher viewing angles, leading to lower observed radiances. Higher rock abundances cause radiance to increase up to moderate viewing angles (because rocks protrude above finer-grained surfaces and occupy more of the field of view at higher angles) but then decrease at high angles (as shadowing becomes very important). Both the extent of shadowing and the rock abundance provide important perspectives about topographic roughness and other key engineering parameters.

Matt Golombek reviewed geologic characteristics of sites (e.g., sedimentary deposits) that are highly relevant to achieving MSL mission objectives to search for evidence for past habitability and life. Layered sedimentary deposits are potentially valuable targets. Sites with less dust and rock float are more desirable. Sediments deposited in low-energy environments (e.g., clay-rich mudstones or bottom-growth evaporates) are highly valuable targets of exploration. The low permeability of such deposits favors the preservation of any organic matter that might have been deposited. They propose a "go-to" site involving a pronounced mound of layered deposits within Juventae Chasma in which kieserite- overlain by gypsum-rich materials could be encountered along the stratigraphic section.

**Gale Crater**

J.F. Bell, K.S. Edgett, S. Rowland and M.C. Malin 2:00
*The Gale Crater mound: A strong candidate landing site for the 2009 Mars Science Laboratory*

N.T. Bridges 2:15
*Studies of Martian sedimentological history through in situ study of Gale and Oudemans Craters: Two landing site proposals for the Mars Science Laboratory*

Break from 2:30 to 2:45pm

**Argyre and Others**

B.A. Cohen 2:45
*Big Basins*

J.S. Kargel and J.M. Dohm 3:00
*Proposed landing site for Mars Science Laboratory: Southern Argyre Planitia*

M.A. Kreslavsky, J.L. Dickson, C.I. Fassett, J. Head, J.B. Madeleine and M.A. Ivanov 3:15
*Recent climate-related deposits in the southern hemisphere of Mars:*

*A Key class of landing site environments for the Mars Science Lander*

K.K. Williams, J.A. Grant and C.M. Fortezzo 3:30
*Fluvial Deposits in Margaritifer Basin: Potential MSL Landing Sites*

W.E. Dietrich, J. Schieber, B. Hallet, K. Edgett, and M.C. Malin 3:45
*Gully analysis by the 2009 Mars Science Laboratory*

**Summary of Session (see individual presentations for more detail)**

Gale crater is of interest to Jim Bell and colleagues, which would involve landing on the northwestern part of the crater floor on a channel fan deposit and traveling to and up a channel that cuts through a thick section of layered deposits in the center of the crater floor. The layered deposits include angular unconformities, exhumed channels, and fine layers overlain by a massive sequence that rises in elevation to above the crater rim crest. Nathan Bridges also advocates the same Gale crater site, as well as an additional one south of the central crater mound that might also access the central peak. He also points out a layered sequence in Oudemans crater, which however exceeds the 2000-m elevation constraint.

Barbara Cohen advocates big impact basins for landing sites, because they would access ancient materials, including those of the lower crust that likely have been altered by hydrothermal activity. Such materials may have had histories similar to that of Martian meteorite ALH84001, including potentially habitable conditions. Cohen cited Argyre basin and Terby crater as potential landing sites. Jeff Kargel and James Dohm chose primary sites in southern Argyre Planitia, where sinuous ridges occur in plains of low relief adjacent to the high-relief Charitum Montes, which are marked by a suite of landforms analogous to glacial features on Earth. However, $CO_2$ frost and near-surface ice raises landing safety and planetary protection concerns. John Mustard spoke for Mikhail Kreslavsky and colleagues on recent climate-related deposits and structures, including viscous-flow features, gullies, patterned ground, and dissected mantles. A potential site is offered where a tall mesa of layered material occurs within an unnamed crater; the mesa and surrounding crater floor includes recently mantled slopes, gullies, light-colored outcrops, and dark dunes.

Kevin Williams and John Grant propose two sites in Margaritifer Terra in which Noachian to Amazonian fluvial activity has been evident. The preferred site is within Amazonian plains material, whereas the secondary site occurs on a channel floor. Ken Edgett presented an analysis of Dietrich and others regarding potential “go-to” sites that could explore recent gullies. Four crater floors large enough to contain landing-site ellipses are identified. However, planetary protection issues appear to preclude a gully site.

**Discussion from 4:00 to 5:00pm**

**Summary of Discussion**

*Major issues discussed were engineering constraints of winds and clarification of planetary protection issues associated with high latitude sites or sites with geomorphic evidence of ice-related features.*

**General comments:**
- Mike Watkins – entry guidance performance – 20 km diameter landing circle can be elongated but will not change dramatically
- Ken Edgett – if you aren't here on Friday is there a way to vote anyway?

**Gale Crater:**
- Brian Hynek – asked about access to LD in Gale Crater. Bell – said LD were accessible by traversing over sandy deposits
- Alan Howard – concerned about traversing and trafficability of sandy material to access LD in Gale. Matt – mentioned that want traverse path to be mapped out for any site well before landing.
- Matt Golombek – Regarding trafficability concerns, Matt said that in general, granular slopes are more difficult to traverse than competent bedrock slopes.

**Winds Issue:**
- Jeff Moore – expressed concerns about altitude winds and limitations of landing sites. Response from engineer: lateral component might be less sensitive than vertical component
- Phil Christensen– is a nighttime landing precluded?
- Scott Rafkin– engineering team is not well connected…variability has not been fully investigated and MSL appears to be less sensitive than MER.
- Diana Blaney– people need to find out where the break points are and the comfort level in the system, preliminary results indicate that there are many places in the southern hemisphere that might not pass engineering constraints.
- Adam Steltzner – some engineering constraints are "harder" than others – the 10 m/s vertical is better constrained than the horizontal. In the end, more detailed analysis of individual sites is necessary.
- Scott Rafkin– need to firm up wind issue by quantitatively working in topography
- Adam Steltzner – hard to define what a "killer" wind is until you see it and detailed investigation is necessary
- Tim Parker in response to Jeff Moore – want to hedge bets as best we can given the expense of the mission and the sooner we can narrow the number of sites, the better we can guarantee large amounts of data for the top sites.

**High latitude sites, evidence for ice and planetary protection:**
- Dawn Sumner– some higher latitude sites have geomorphic evidence of ice. What are the approaches that we should take to evaluate those sites to access sites in terms of planetary protection?
- Jeff Kargel - How much freedom do we have to change landing ellipse?

- Matt Golombek - Geomorphic evidence of ice is not ideal for landing ellipse, but driving to those sites does not violate planetary protection
- Ashwin Vasavada – high latitude sites in the southern hemisphere are covered by seasonal $CO_2$
- Dave DesMarais– primary scientific objective of MSL is to assess past or present (or both) habitability of Mars. MSL payload may be more suited to assess past habitability rather than present.
- Dave DesMarais – even ancient habitable environments are still habitable
- Jack Mustard – seasonal deposit is not only $CO_2$, but water as well, which can go up to 23° or so. This fact might be a consideration that we might need to think about for the southern hemisphere because it might violate planetary protection.
- Jim Bell – latitude constraint puts severe requirements on their system, but we might be able to provide some science basis to pull in latitude constraints to relieve other stresses on the parameter of the system.
- Jeff Kargel – is there an example of a habitable site on Mars that could be visited?? Is there a fundamental conflict between the goals and the landing?
- John Rummel – don't know of a site that is definitively habitable…suggested gullies as a potential are not feasible to visit with MSL. Crashing into ground ice is bad!
- Golombek - it's okay to drive to a site with ice.
- Alan Howard – patterned ground is not necessarily indicative of ground ice
- Horton– if you can say that the nearest ice is a good distance away from the landing ellipse, a landing site can be certified.

**End Day 1 at 5:00**

**Start of Day 2 at 8:30**

**Holden Crater**

M.C. Malin and K.S. Edgett 8:45
*Testing a lacustrine hypothesis: An MSL Lading site candidate in south Holden Crater*

R.P. Irwin and J.A. Grant 9:00
*Aqueous sedimentary deposits in Holden Crater: Landing site for the Mars Science Laboratory*

J.W. Rice 9:15
*Leading MSL to water: Paleolacustrine landing sites redux*

**Eberswalde Crater**

J. Schieber, K. Edgett and M. Minitti 9:30
*The Eberswalde deltaic complex as a high science-return target for the 2009 Mars Science Laboratory*

J.L. Dickson, C.I. Fassett, J.W. Head, M.A. Kreslavsky, J.B. Madeleine, and M.A. Ivanov — 9:45
*Deltas and related ponded sedimentary deposits: A key class of landing sites for the Mars Science Laboratory mission*

**Terby Crater**

E. Z. Noe Dobrea — 10:00
*Terby Crater as a proposed landing site: MOC and OMEGA views of the geology and spectral variability in and around Terby Crater*

S.A. Wilson, A.D. Howard and J.M. Moore — 10:15
*Terby Crater as a potential landing site for the Mars Science Laboratory*

**Summary of Session (see individual presentations for more detail)**

Holden crater fan (26.4°S, 325.3°E, -2.3 km landing site elevations, 154-km diameter) offers the opportunity to sample relatively nearby ("go-to") probable lacustrine deposits and the alluvial fan of the landing site itself. The putative lacustrine deposits are in the form of layering, which is light- and dark-toned, and displays differential erosion (stair steps, which could be traversed), suggesting a multiple lithologies. The layered deposits are too rough for a landing site, but placing the landing site on the nearby alluvial fan may be acceptable within the engineering constraints. The fan itself may be a good science target in that it may contain a variety of fluvially-deposited rock types that can be sampled. Vertical sampling in the fan is provided by a 2.5 km crater. Neither phyllosilicate nor sulfate mineralogy has been observed in Holden crater.

Eberswalde crater (24.0°S, 326.3°E, -0.8 and -0.4 km landing site elevations, 65-km diameter) contains a well-exposed deltaic complex developed from ponding of valley network outflow onto the crater floor. The complex exposes ~200 m of layers on the northwestern portion of the crater floor. Aeolian erosion has uncovered (and occasionally inverted) meandering channels, channel belts, distributary channel systems, and multiple delta lobes. All of these features are consistent with deltaic development on the floor of the crater. Landing in Eberswalde crater near the deltaic complex appears to be challenging. The deltaic complex itself is too rugged. Possible safe landing sites exist and require at least a 30-km traverse from the ellipse center, but the "go-to" capability may allow exploration of the edges of the complex. Hydration and clay signatures have been observed by OMEGA in the watershed, but not on the floor of the crater.

Terby Crater (28°S, 73°E, -5 km landing site elevation, 164-km diameter) is a Noachian-aged feature located on the northern rim of Hellas. Sedimentary layered sequences up to 2-km thick are observed within the crater and are proposed to be lacustrine in origin. The south-dipping layered deposits are exposed in large ridges that trend roughly north-south within a moat-like depression surrounding the ridges. The proposed landing site is in this smooth-floored moat, and the access to the layering uses the "go-to" capability. The layers themselves may be difficult to traverse. OMEGA data indicate the presence of hydrated minerals (clays, sulfates, or possibly iron hydroxides) in the layered sequence. Terby crater also hosts a variety of geomorphic features indicative of glacial activity, suggesting a rich, long-lived geologic history. It should be noted that the site is in fog about a quarter of the year and is near the $CO_2$ frost line in southern winter.

Break from 10:30 to 10:45am

**Valles Marineris/Chaos**

N. Mangold, J-P. Bibring, A. Gendrin, C. Quantin, J. F. Mustard, F. Poulet, and S. Pelkey — 10:45
*Sulfate rich deposits in Candor Chasma, Valles Marineris*

C. Quantin, C. Weitz, R. Williams, G. Dromart, and N. Mangold — 11:00
*Paleo-lake in Melas Chasma (Valles Marineris) as a potential landing site for MSL*

M. Chojnacki and B. Hynek — 11:15
*East Melas Chasms landing site rationale*

V. Hamilton — 11:30
*Astrobiology-Relevant Hypotheses for the Origin of Quartz- bearing materials in Eos Chasma: Tests for the 2009 Mars Science Laboratory*

N.A. Cabrol and E.A. Grin — 11:45
*Mars Science Laboratory landing Site: Linking the past and the present with Aram Basin*

T.D. Glotch — 12:00
*Iani Chaos as a landing site for the Mars Science Laboratory*

**Summary of Session (see individual presentations for more detail)**

Most of the sites proposed in this session are proposed based on a combination of sulfate mineral identification from OMEGA, geomorphology, and landing safety. The arguments for landing in these particular areas generally focus on the opportunity to combine investigation of layered deposits with addressing long-standing science questions about the origin of some of the most striking geomorphic features on Mars.

Vicky Hamilton proposes a site where THEMIS data suggest the presence of quartz in distinct mounds. The origin and detailed form of the quartz is not yet constrained, and high resolution imaging might help distinguish whether it is in mounds or beds.

The discussion initially centered on precision of terminology for quartz versus chert, as well as the implications of having olivine and quartz in neighboring areas within Vicky's site. A hematite spectral signature has not been identified at any of the Valles Marineris sites (except possibly one; I didn't catch which one), but is present in Iani Chaos layered rocks.

Lunch at 12:15 to 1:15 pm

**Meridiani/Arabia**

K.S. Edgett and M.C. Malin 1:15
*Northern Sinus Meridiani landing sites for the 2009 Mars Science Laboratory*

A.D. Howard 1:30
*Traverse across lower strata of Meridiani Planum layered deposits*

L.V. Posiolova, K.S. Edgett and M.C. Malin 1:45
*MSL Investigation of possible crater lake sediments in northern Sinus Meridiani*

B.M. Hynek 2:00
*East of Eden: A return to the Meridiani region*

H.E. Newsom 2:15
*MSL Landing site in Eastern Meridiani Planum – Ancient cratered crust, sediments, sulfates, and hematite*

Break 2:30 to 2:45 pm

E. Heydari, L.C. Kah, M.C. Malin and P.C. Thomas 2:45
*Rhythmic sedimentary rock outcrops in a crater in west Arabia, for the 2009Mars Science Laboratory*

C.C. Allen, D.Z. Oehler1, and E.M. Venechuk 3:00
*Sedimentary rocks and methane – southwest Arabia Terra*

J.C. Bridges and M.R. Balme 3:15
*MSL Landing sties in ancient layered terrain: Becquerel Crater*

**Summary of Session (see individual presentations for more detail)**

K. Edgett: NW Sinus Meridiani.
Picking sites should be based on (with respect to science and mission objectives) at least one of the following 4 beacons (1) hypothesis beacon (e.g., Gusev), (2) mineralogical beacon (e.g., Meridiani Planum), (3) geomorphic beacon (e.g., VL1 and VL2), (4) variety of materials beacon (e.g., MPF). Speaker advocates a site with diversity - to yield results on habitability. To that end, NW Sinus Meridiani has low albedo, is NE of MER-B, and has dust-free outcrop that permits access to stratigraphy not accessible by MER-B.

The site is characterized by diversity, bedding, water involved, OMEGA sulfate region and will enable a look at material lower in the stratigraphic section than MER-B. There are many places to put ellipses, but not in the outcrop, as it appears too rugged. Nevertheless, the speaker suggested 5 sites that qualify as a GO TO mission site and are described in more detail in the presentation.

A. Howard: Meridiani Planum (MP).
Speaker noted that MER-B explored only top of 800 m section.Proposes a site that would enable the MSL mission to sample deposits under MP and would include sampling a scarp, buttes, and mesa. Three sites were suggested, but the speaker also felt that the sites proposed by Edgett were OK. Proposed sites qualify as GO TO.

L. Posiolova: N Sinus Meridiani.
Proposed a site in fine layered deposits in N Sinus Meridiani that are stratigraphically lower than those exposed at the MER-B landing site. The site is centered on a small crater that once may have held a small lake. The source rock for the sediments within the crater may potentially occur on the crater rim. Speaker suggested that the fine layering exposed in the crater requires a persistent aqueous setting for deposition that relates to habitability. The layers do not have a stair-step character and appear good for trafficability. Two landing ellipses were proposed, one N and one S of crater that would then require a drive into the crater. Both proposed ellipses qualify as GOTO.

B. Hynek: Eastern Meridiani.
The speaker proposed a landing site located approximately 600 km ENE of the MER-B landing site in Meridiani. The proposed site has a sulfate signature and large water-related features beyond ellipse and the Landing ellipse is within etched terrain. The site is the highest thermal inertia and albedo site proposed. There are no obvious aeolian features present and it is likely that the site is characterized by a diverse and navigable surface. Although many ellipses are possible, the speaker focused on one that does not require any go to mission capability.

H. Newsome: Far W Meridiani.
The speaker focused on a site with diversity that includes hematite, sediment, crater floor deposit layered terrain. There is also an exposed crater rim with possible access to highland material. The ellipse is located on western edge of TES defined hematite region, but the sediments are likely different from what is observed at MER-B, and there is no apparent sulfate signature. The proposed ellipse does not require any go to mission capability.

L. Kay: W Arabia Terrae
Advocates focusing on layered terrain as strata records geologic history.
Speaker promotes a small crater (22 km diameter) with GO TO landing ellipses N and S of crater. It was suggested that the ellipse to the S affords easier access to the crater. There are distinct albedo units in crater and the crater floor is exposed with a incised region in the crater center. There are some high albedo areas that may equate to wind-blown materials.

C. Allen: SW Arabia Terra
The speaker advocates searching sediments for biomarkers of past life and proposed that MSL be sent to a 55 km diameter crater (750 m deep) that is embedded in and partially exhumed from sedimentary rock. Advocates use of SAM to search for CH4, which can have both inorganic and organic sources. Proposed 2 landing ellipses that are both GO TO and would involve roving into the exhumed portion of the crater in SW Arabia Terra.

J. Bridges and J. Balme (presented by J. Grant): Becquerel Crater
The speaker proposed landing in ancient layered terrain to evaluate the depositional history recorded in the deposits. Becquerel is a 167 km diameter crater with layered terrain in the southern portion of the crater. The deposits appear light toned and dust free and landing ellipses were proposed on the E and W sides of layered deposit. The region is characterized by very low thermal inertia and both of the proposed ellipses require GO TO capabilities.

**<u>Volcanoes and/or Water</u>**

L.S. Crumpler 3:30
*Sites of potential long term sub-surface water, mineral-rich environments, and deposition in South Elysium Planitia, Hellas-Dao Vallis, Isidis Basin, and Xanthe-Hypanis Vallis: Candidate Mars Science Laboratory Landing Sites*

J.M. Dohm, R.C. Anderson, V. Baker, T.M. Hare, and S.J. Wheelock 3:45
*Northwestern slope valleys (NSVS) region: Prime candidate site for MSL Exploration of Mars*

D.M. Burr, A.J. Brown, R.A. Beyer, A.S. McEwen, K.L. Tanaka, L.P. Keszthelyi, J.P. Emery, and P.D. Lanagan 4:00
*Athabasca Valles as a candidate MSL landing site*

M.R. Fisk and M.C. Storrie-Lombardi 4:15
*Searching for silicate bioweathering on Earth and Mars*

R.P. Harvey 4:30
*Visit NE Syrtis Major! Win valuable Martian geological history!*

**<u>Clays and Sulfates</u>**

J-P. Bibring 4:45
*Mineralogical context for landing site selection: the OMEGA/MEx potential contribution*

J. F. Mustard, F. Poulet, N. Mangold, J-P. Bibring, R. E. Milliken and S. Pelkey 5:00

*Aqueous alteration and evidence of habitability in Nili Fossae*

**Summary of Session (see individual presentations for more detail)**

*L. C. Crumpler*
Four regions were proposed as landing sites possibilities. The habitability goals of MSL were supported by the presence of fluvial/sedimentary morphology, and/or thermal and chemical distinctiveness. The sites are in a) Isidis at the escarpment with the Syrtis Major lava flows, b) Elysium where a distinctive region show a distinctive high Fe chemistry and evidence of thermal processing, c) Hellas where 6 landing ellipses were presented all with evidence of possible warm springs (e.g. Dao Valles), and d) Xanthe region in Hypanis Valles at the terminus of a fluvial channel. Based on a series of criteria, the Hypanis were considered the top priority.

*James Dohm*
In this region west of Tharsis near major outflow channels, it is proposed to be a site to be rich in rocks derived up stream in habitable environments characterized by hydrothermal systems. Essentially a grab-bag draining the ancient Tharsis region, but it does have very low thermal inertia.

*D.M. Burr et al.*
This region sites in the deposits formed during the activity associated with the Cerberus Fossae and plains lavas. The apparently fluvial channels emanate from volcanic fissures and thus the fluids were present in a volcanically active region. The habitability goals would relate to outflow of this groundwater in recent times. It is a large region requiring go-to capability

*M.R. Fisk and M.C. Storrie-Lombardi*
The key elements of this concept are that lavas erupted into oceans on Earth are rich in biomarkers and thus make excellent targets for MSL. No specific sites were advocated, though the criteria for selection include ancient igneous rocks sites with evidence of volcanism and hydrologic systems.

*R. P. Harvey*
The region of NE Syrtis Major marks the stratigraphic boundary between the Noachian and Hesperian and is also the boundary between the phyllosilicate rich period (Noachian) and sulfate rich Hesperian. A landing site in this region would be able to sample the Noachian crust and the Syrtis Major lavas and help to constrain the volcanic and igneous crustal evolution of Mars.

Jean-Pirre. Bibring et al.
The OMEGA results indicate that phyllosilicates occur largely in Noachian terrains, sulfate in Hesperian terrain and largely anhydrous oxides in Amazonian terrains. The Mawrth Valles region on the north-west edge of Arabia has excellent phyllosilicate exposures in Noachian-aged rocks and would be the key region to explore for MSL.

*J.F. Mustard, et al.*
In the vicinity of Nili Fossae are a) Noachian-aged rocks rich in phyllosilicate, b) lavas from Syrtis Major, and c) ejecta rich in phyllosilicate from a 60 km diameter impact. This would allow the investigation of ancient habilability as well as sampling an important time-stratigraphic marker (Syrtis Major) and explore ejecta from a large impact.

**<u>Discussion 5:15 to 6:00 pm</u>**

**<u>Summary of Discussion</u>**

**Day 2 Discussion 5:15-6pm**

*Major issue discussed was looking for evidence of microbial life in basalt rocks.*

**General comments:**

- Why is there discrepancy between the GRS and OMEGA?
- Jack Mustard – dust cover – get hydration signature when there are windows through the dust cover. The penetration depth of OMEGA is hundreds of microns.

**Basalt rocks:**

- Dawn Sumner – Looking for microbial alteration of basalts is not ideal for MSL because spatial resolution is not fine enough to observe etched pits in rocks (only seen in thin section/microscopy), we currently don't know where to look on Mars, and even the terrestrial origin (abiotic/biogenic) is ambiguous.
- Only looking for habitable zones on Mars, not life on Mars
- Dave Des Marais– Noachian is the best target to look for life on Mars
- Co-author of Fiske talk - Rover payload is not prepared to look in igneous rocks for life.

**<u>End Day 2</u>**

**<u>Start Day 3 at 8:30 am</u>**

**<u>What's Next?</u>**

E. Hauber, G. Neukum, R. Jaumann, K. Gwinner, F. Scholten, H. Hoffmann, S. van Gasselt and T. Duxbury — 8:30
*The High Resolution Stereo Camera (HRSC): A tool for landing site selection*

Sue Smrekar
*The role of MRO in MSL landing site selection activities* — 8:45

John Grant — 9:00
*The HiRISE Camera on MRO*

John Mustard — 9:10
*An Overview of CRISM on MRO*

T.J. Parker 9:20
*Mapping the proposed MSL landing sites*

**Summary of Session (see individual presentations for more detail)**

*E. Hauber - Overview of HRSC and data products*

- HRSC is a “bridge” to landing sites and can be used in combination (especially as a base map) with any other spatial datasets
- Scientists can request specially processed high-resolution DTMs, map-projected photometric and color data, anaglyphs of landing sties. (Contact: Ernst.Hauber@dlr.de, gneukum@zedat.fu-berlin.de)

*Sue Smrekar*

- MRO Instrument Specifications, Data and ROIs for landing site

*John Grant – HiRISE imaging of MSL landing sites*

- Stereo images of landing sites will not be obtained before the second workshop
- Context image is 30x30 km
- CRISM and HiRISE are co-located

*John Mustard – Overview of CRISM on MRO*

- Resolution is 20x greater spatial resolution and 2x greater spectral resolution compared to OMEGA
- Spectral library will be released to the public

*Ken Edgett*

- You can request MOC to target your landing site via a public website

*Tim Parker- Process and progress in landing site map compilation for MSL*

**Discussion 9:35 to 10:00 am**

**Summary of Discussion**

**Defining ROIs and the availability and format of CRISM, HRSC and OMEGA data:**

- Matt Golombek - There will be one managed list for MSL that will provide to MRO that includes definition of targets in ROIs that includes area of interest and the ellipse. Inside ROI, you will get co-located HiRISE and CRISM data, all centered on the location of the HiRISE footprint. This will also be provided in the same format to all appropriate spacecraft. First pass before 2nd workshop is intended to be one per site. New sites can be proposed at the second workshop based on MRO observations.
- Jim Bell– Are there specifications about what “raw” data means? Golombek – we have a general agreement and understanding from the science teams that the data will be usable (image, calibration file, etc) and once the data is processed, the website will be updated. Jim – will the team share the tools that they have developed to use the data? Golombek – not necessarily, the teams are committed to taking the data and making them available. Jim – so, we have to provide our

own tools or you have to get "friendly" with the team members. Mustard – we have a pipeline process that takes the product through radiance. ENVI is the next step but the parameter maps are successful in the face of atmospheric calibration, etc., Shannon Pelky's paper (in preparation) will detail this process and show where the "interesting" areas are. Jim – same questions for HRSC people. Hauber - Raw HRSC is available on the PDS and we do not provide DEMs. Jim – what is the timescale for the data to become useable for someone not on the HRSC team? Hauber – on the order of weeks, maybe faster. Need to wait for updated spice kernels.

- Steve Ruff - Omega and CRISM data – is there going to be a way to know where OMEGA has covered at a reasonable resolution and what the plan is for CRISM survey mode? JP-Bebring – OMEGA will produce mineral maps for specific sites, but this is not a standard data product. Producing mineral maps is a process. Jack Mustard– the survey products take time, data will be analyzed as they come in.
- Phil Christensen– ASU will produce and provide thermophysical maps for all sites and they will be posted on the THEMIS website. Look for MSL landing site link on website.
- Describe process by which new datasets will be correlated and incorporated into the MSL process. Grant – people who recommended the sites have to look at the data and determine positive and negative aspects of the sites. It's best to have as many people as possible looking at the data.
- John Grant – There will be a lag for CRISM data due to the complicated nature of the dataset.
- Ken Tanaka– USGS PIGWAD has datasets that are already released and registered spatially for download and overlay.
- Matt Golombek – other resources include Marsoweb, JMars, other websites already have registered data.

Break 10:00 to 10:15 am

**Discussion and Prioritization**   **10:15 am to 12:00 pm**

**Summary of Discussion**

**More on ROIs:**

- Golombek – need ROI (defined by polygon) that includes the 20 km diameter landing circle. Polygon can be as large as required to sample the landing site and drive-to-site sample, but this has to be done within a reasonable amount of time. In addition to the ROI and circle, if you have a different place that you want a HiRISE data, you need to indicate that. Lay down HiRISE to get best CRISM coverage. You get a N/S swath. If you have Ls constraints or mission angle specifications, add those details. List will be provided to MGS, Mars Express and Odyssey.
- Ross Beyer wanted to know if the ROIs would be put on the webpage

- Grant – Reminder that PowerPoint presentations from this workshop will be posted online. These sites get priority for MRO targeting.

**General Comments:**

- Jeff Kargel – thought it would be good feedback if scores were plotted against thermal inertia and latitude. Golombek – basic properties of each site will be gathered and posted online.
- Mike – if there are sites that were not proposed because of the changes in the altitude capabilities, send these sites to Mike, Matt of John. Jeff Moore asked about latitude band and those limitations.

**<u>Summary of Prioritization</u>**

| LANDING SITES PRIORITIZED AT FIRST MSL WORKSHOP | | | | |
|---|---|---|---|---|
| **NAME** | **LOCATION** | **ELEVATION** | **TARGET** | **PROPOSER** |
| Nili Fossae Trough | ~22ºN, ~75ºE | -0.6 km | Phyllosilicates | J. Mustard |
| Holden Crater Fan | 26.4ºS, 325.3ºE | -2.3 km | Layered Materials | R. Irwin, J. Grant, Malin, Edgett, Rice |
| Terby Crater | 28°S, 73°E | -5 km | Layered Material | S. Wilson, Cohen, Dobrea |
| Marwth Vallis | 22.3ºN, 343.5ºE | ~-2 km | Phyllosilicates | J-P Bibring |
| Eberswalde Crater | 24.0°S, 326.3°E | -0.8 and -0.4 km | Delta | J. Schieber, J. Dickson, Rice |
| Gale Crater | 4.6°S, 137.2°E | -4.5 km | Interior Layered Deposits | J. Bell, N. Bridges |
| W Candor East | Various | -4 km | Sulfate Deposits | N. Mangold |
| N Meridiani | 2.7°N, 358.8°E | -1.5 | Sedimentary Layers | Edgett/Malin |
| Juventae Chasma | 5°S, 297°E | -2 km | Layered Sulfates | J. Grotzinger |
| Nilo Syrtis | ~23°N, ~76°E | <-2.0 km | Phyllosilicates | Mustard |
| Melas Chasma | 9.8°S, 283.6°E | -1.9 km | Paleolake | C. Quantin |
| | | | | |
| E. Meridiani | 0°, 3.7°E | ~-1.3 km | Sedimentary Layers | B. Hynek |
| Athabasca Vallis | 10N, ?ºE | -2.4 km | Cerberus Rupes Deposits | D. Burr |
| Iani Chaos | 2°S , ~342°E | Below -2 km | Hematite, Sulfate | T. Glotch |
| Nili Fossae Crater | 18.4ºN, 77.68ºE | -2.6 km | Valley Networks, layers | J. Rice |
| Eos Chasma | ~11°N, ~320°E | ~-4 km | Chert | Hamilton |
| Meridiani Crater Lake | 5.6°N, 358°E | ~-1.5 km | Crater lake sediments | L. Posiolova |
| NE Syrtis Major | ~10ºN, ~70ºE | ~1 km | Volcanics | R. Harvey |
| Margaritifer basin | 12.77ºS, 338.1ºE | -2.12 km | Fluvial Deposits | K. Williams |
| E. Melas Chasma | 11.62°S, 290.45°E | Below-2 km | Interior Layered Deposits | M. Chojnacki |
| Hellas/Dao Vallis | 40ºS, 85ºE | Below -2 km | A major valley | L. Crumpler |
| Xanthe/Hypanis | 11ºN, 314ºE | Below -2 km | Delta | L. Crumpler |

| | | | | |
|---|---|---|---|---|
| Vallis | | | | |
| Becquerel Crater | 21.8°N, 351°E | -2.6 to -3.8 km | Layered Sedimentary Rocks | J. C. Bridges |
| | | | | |
| SW Arabia Terra | 2-12°N, 355-348°E | -1 km | Sed. Rocks, Methane | C. Allen |
| Gullies/Hale Crater | 35.7°S, 323.4°E | –2.4 km | Gullies | W. E. Dietrich |
| W. Arabia | 8.9°N, 358.8°E | -1.2 km | Sedimentary Rocks | E. Heydari |
| Argyre | 56.8ºS, 317.7ºE | -1.5 km | Glacial Features | J. Kargel |
| NW Slope Valleys | ~0, 145°E | ~-2 km | Flood Features | J. Dohm |
| W. Meridiani | 1.8°S, 7.6°E | ~-1.0 to -1.5 km | Sediments, Hematite | H. Newsom |
| Elysium/Avernus Colles | 1.0ºS, 169.5ºE | Below -2 km | High iron abundance | L. Crumpler |
| Meridiani Bench | 7.5ºN, 354ºE | ~-1 to –1.5 km | Layered Sediments | A. Howard |
| SML CratersS | 49°S, 14°E | Above -0.5 km | Recent Climate Deposits | M. Kreslavsky |
| Isidis Basin Escarp | 5-15ºN, 80-95ºE | Below -2 km | Volatile sink | L. Crumpler |

**End of Landing Site Workshop at 12:00 pm**