LANDING SITES UNDER CONSIDERATION FOR MARS SCIENCE LABORATORY. M. Golombek[1], J. Grant[2], A. R. Vasavada[1], J. Grotzinger[3], M. Watkins[1], D. Kipp[1], E. Noe Dobrea[1], J. Griffes[3], T. Parker[1], R. Kirk[4], R. Fergason[4], R. Beyer[5], A. Huertas[1], R. Milliken[1], and Y. Sun[3], [1]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109, [2]Smithsonian Institution, Center for Earth and Planetary Sciences, Washington, D.C. 20560, [3]Division of Geological and Planetary Sciences, California Institute of Technology, Pasadena, CA 91125, [4]U. S. Geological Survey, Flagstaff, AZ 86001, [5]SETI Institute, NASA Ames, Moffet Field, CA 94035.

Introduction: A total of more than 50 landing sites/ellipses were proposed for the Mars Science Laboratory (MSL) and targeted with Mars Reconnaissance Orbiter (MRO), Mars Odyssey, Mars Express and Mars Global Surveyor observations after the First and Second Landing Site Workshops in June 2006 [1] and October 2007 [2]. Discussion of the science merits of these sites relative to MSL objectives at the first and second landing site workshops and a Project meeting in Dec. 2007 resulted in six sites being selected for further study and consideration: Nili Fossae trough, Mawrth Vallis, Holden, Eberswalde, Miyamoto and N Meridiani [2]. In July 2008, the Mars Landing Site Steering Committee and the MSL Project considered 4 potential new landing sites and added Gale crater to the list and replaced S Meridiani with N Meridiani [3]. Following the Third Landing Site Workshop in Sept. 2008 and a Project meeting in Nov. 2008, four landing sites (Holden crater (26.37°S, 325.10°E), Gale crater (4.49S, 137.42E), Mawrth Vallis (#2, 24.01°N, 341.03°E) and Eberswalde crater (23.86°S, 326.73°E) were selected from the seven considered for further study [3].

The detailed geomorphic and mineralogic interpretations enabled by the diverse and moderate (>100 m/pixel-scale) to extremely high (sub meter) spatial and spectral resolution images acquired have helped constrain past depositional environments at each of the final four candidate sites. These data have also been used to characterize the surfaces to certify that the sites are safe for landing and trafficable for the rover. This abstract describes the science targets and surface characteristics of the four landing sites being considered for MSL, and describes ongoing and future activities to select the final landing site before launch in 2011.

Science Targets: The primary scientific goal of the Mars Science Laboratory (MSL) is to assess the present and past habitability of Mars, with special emphasis on diversity, context, habitability, and preservation potential of target materials at the landing site [4]. The four landing sites being considered provide access to layered materials that can address these science objectives. Images of the interior of Holden crater reveal laterally extensive, sub-meter phyllosilicate-bearing strata near the edge of the landing ellipse that is located on a bajada. The phyllosilicate-bearing deposits are indicative of emplacement in a distal alluvial and/or lacustrine setting [5] and they have been eroded and overlain by sediments carried into the crater by water draining from Uzboi Vallis. Gale crater exposes a thick sequence of finely-bedded deposits with phyllosilicate-bearing rocks beneath sulfate-bearing rocks [6]. Deposition of the sedimentary sequence may relate to aqueous and/or eolian processes and the candidate landing ellipse is located on adjacent cratered plains. The landing ellipse west of Mawrth Vallis is on plains that display strong spectra for Mg-Fe smectites and Al-rich phyllosilicates [7] that may also be present throughout western Arabia Terra. Continuing study of the orientation and extent of these beds is being used to interpret the responsible depositional process. In Eberswalde crater, the distribution and orientation of phyllosilicate-bearing beds appears consistent with past presence of a long-lived fluvial-deltaic system [8]. The candidate landing el-

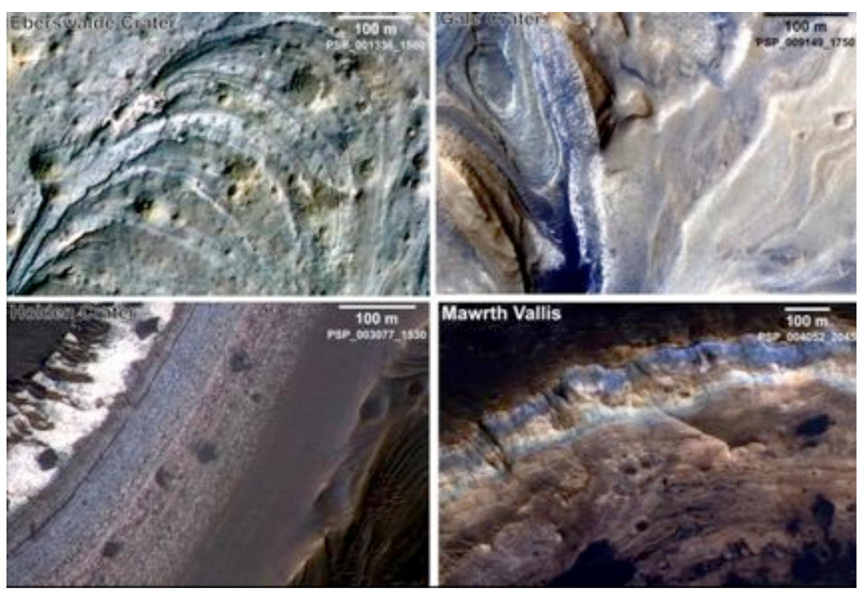

Figure 1: HiRISE color image views of the target materials at the four MSL landing sites under consideration. Upper left shows meanders in Eberswalde crater delta. Upper right shows layered material in the mound of Gale crater. Lower left shows layered materials in Holden crater. Lower right shows Al phyllosilicates overlying Fe-Mg phyllosilicates at Mawrth Vallis.

lipse is on the crater floor and would provide access to lake sediments whereas deposits are located in the western edge of the crater.

Surface Characteristics: The four 25 km by 20 km landing ellipses have been placed in relatively smooth and flat locations at all of the sites [3]. Data and references for surface characteristics are contained in [9] and engineering constraints are described in [10] and. None of the landing sites have thermal inertias, albedos, or radar reflectivity that indicate any concerns regarding load bearing surfaces, surface density, extremely dusty or unusually rough surfaces.

All of the landing sites have slopes <20° over baseline lengths of 2-10 km, to avoid spoofing the radar. Relief must be ≤43 m over baselines of 0.2-1 km for control authority during powered descent. MOLA point-to-point slopes were evaluated at baselines of 0.3, 0.6, and 0.9 km and most areas in all of the ellipses satisfy the relief constraint at ≤0.6 km length scales. Mawrth and Holden are also smooth at the 0.9 km length scale, however, the edges of Gale and several hills in the Eberswalde ellipses have relief that exceeds the constraint (up to ~100 m at 0.9 km scale). Evaluation of MOLA pulse spread, which is a measure of the relief within the 75 m laser spot, shows that Holden is the smoothest site, whereas Mawrth, Gale and Eberswalde are comparable to the Mars Pathfinder landing site.

An important slope constraint at the 2-5 m length scale of the rover is that the surface must be ≤15° for landing stability and rover trafficability in cohesionless material. Slopes at these length scales have been evaluated using digital elevation models derived from stereogrammetry [11] and photoclinometry [12] of HiRISE images (~25 cm/pixel). At these scales, Holden is the smoothest site followed by Mawrth, Gale and Eberswalde. Rocks are a concern for landing and can impede mobility. The engineering constraint is to have a <0.5% probability of impacting a 0.55 m high rock by the rover belly during touchdown, which translates to surfaces with low to moderate rock abundance. Rocks measured in HiRISE images using the same technique used to correctly predict rocks at the Phoenix landing site [13], show that the Holden ellipse is relatively rock free, followed by Mawrth, Gale and Eberswalde.

Considering all the surface data with special reference to 2-5 m slopes and rocks (the most important criteria) shows that the Holden landing site is the smoothest and least rocky site, followed by Mawrth, Gale and Eberswalde. All are comparable to surfaces of previously visited landing sites. Eberswalde has areas within the ellipse that are both rocky and have high 2-5 m scale slopes, which pose additional concerns. Additional data analysis and landing simulations using these data will be used to determine the relative safety of the landing sites, which along with the science potential will be used to select the final MSL landing site.

Ongoing and Future Events: With the launch of MSL having slipped to Oct. 2011, landing site selection will take place around June 2011. All of the candidate landing sites remain accessible in the 2011 opportunity. Atmospheric models run for each of the sites show that early afternoon conditions at L_s 150-170 are within the acceptable range for entry, descent, and landing. Ongoing work is addressing the frequency of local dust storms and their influence on entry, descent and landing.

Because of the additional time before site selection and the rapid increase in new information from MRO and other orbiters, an opportunity was made available to the science community to propose new landing sites for MSL. Any site proposed requires both mineralogic and morphologic evidence demonstrating a compelling argument that it is at least as promising scientifically and as safe as the sites currently being evaluated.

A call was issued for new MSL sites in Aug. 2009 with sites proposed using an abstract template required by the end of Oct. 2009. Five sites were proposed that met these guidelines and as of this writing are being evaluated. A subset will be targeted for imaging by MRO and other spacecraft. In May 2010, this subset will be evaluated with new data to decide if any should be added to the four sites presently under consideration. If a site is added at that time, it will be studied along with the other sites for inclusion at the Fourth Landing Site Workshop in Sept. 2010, which will include a complete discussion of the science potential, surface and atmosphere characteristics important for landing, and trafficability. A Fifth Landing Site Workshop will be held in April 2011 to fully discuss and evaluate the prospective sites before the MSL Project recommends a site in May 2011. Following a series of reviews of the site selected and the process used, NASA Headquarters will select the MSL landing site in June 2011, before launch in Oct. 2011.

References: [1] Golombek M. et al. (2007) *LPS XXXVIII*, Abs. #1392. [2] Golombek M. et al. (2008) *LPS XXXIX*, Abstract #2181. [3] Golombek M. et al. (2009) *40th LPS*, Abs. #1409. [4] Grotzinger J. http://marsoweb.nas.nasa.gov/landingsites/msl2009/workshops/3rd_workshop/program.html [5] Grant, Irwin, ibid. [6] Edgett, Milliken, Thompson, ibid. [7] Bibring, Mangold, Bishop, Wray, Dobrea, ibid. [8] Rice, Schieber, Lewis, ibid. [9] Golombek et al. ibid. [10] MSL Engineering Constraints http://marsoweb.nas.nasa.gov/landingsites/ [11] Kirk et al., ibid. [12] Beyer, ibid. [13] Golombek M. et al. (2008) *JGR 113*, E00A09, doi:10.1029/2007JE003065