GROUND TRUTH ASSESSMENT OF THE GALE CRATER REGION USING MARS SCIENCE LABORATORY DATA FOR CHARACTERIZATION OF POTENTIAL HUMAN MISSION LANDING SITE AND IN SITU RESOURCE UTILIZATION.

S. Montaño[1], S. Johnstone[1], N. Lanza[1], and D. Delapp[1], [1]Los Alamos National Laboratory, Los Alamos, NM, sgordon@lanl.gov.

Introduction: Instruments and cameras on board the Mars Science Laboratory (MSL) rover give ground truth information on chemistry, terrain, and atmospheric characteristics of the rover's traverse to Mount Sharp in the center of Gale crater. Analysis of this unique and robust data set allows for a thought experiment to determine the ability of a future robotics-assisted human mission to survive diurnal temperature changes, navigate the terrain of the Curiosity rover's traverse, and find, access, and exploit materials for *in situ* resource utilization (ISRU). The MSL rover has been exploring Gale crater since August 2012 and has observed many different geologic regions along its traverse to Mount Sharp, including an alluvial fan, lake sediment deposits, dunes, and exposed outcrops [1]. In-depth characterization of chemistry, morphology, and environment in Gale gives this site an advantage over others, as we will be able to target resource locations on a smaller scale that would benefit a human mission. Gale crater has ground truth on the order of a 400-micron scale up to meters-long transects along the more than 10-km path of the rover. Although the rover's traverse is only 10 km long, with an analysis area spanning up to 5 m on each side of the traverse, comparison of the local-scale MSL data with orbital data from Odyssey and MRO gives a much better idea of what to expect throughout a 100 km-diameter Exploration Zone (EZ) at Gale. This crater meets the general criteria for a candidate landing site, with an elevation of less than 2 km and a near-equatorial latitude of 4° S. Specific examples of MSL results leading to candidate Regions of Interest (ROIs) and an ideal location for the Landing Site (LS) as outlined in [2] are discussed below. All locations are labeled in Figure 1.

Regions of Interest (ROIs). Gale has the advantage of hosting a current robotic mission that has confirmed past habitability [1]. The traverse of MSL, therefore, is the most obvious Science Region of Interest (ROI) to confirm and expand on the findings of the mission so far. Mount Sharp is the second most important Science ROI, as its layers hold evidence of past climate, chemical, and aqueous environmental conditions. Exploration of the MSL traverse and Mount Sharp will help answer the majority of the science objectives outlined in [2]. Examples of MSL findings that can be confirmed and expanded upon by further analysis during a human mission include confirmation of past habitability [1], methane detection [3], elemental geochemistry of surface sediments [4], and the absolute and relative ages of geologic events [5]. An extensive study of Gale crater using data from the Mars Reconnaissance Orbiter and Mars Odyssey orbital missions was completed by [6], and current MSL data agree well on a local scale with the regional analyses performed in 2010. In that study, the authors pointed out a dark-toned sheet of sand in the southwest area of the crater. This sand is a Resource ROI that can be explored (along its edges until the depth and mechanical properties are confirmed safe for astronauts and/or rovers to traverse) as a potential location of minimally-altered soils that can be used for farming.

ISRU and civil engineering objectives. ISRU-related results from the science instruments on board MSL indicate global hydrated soils [7] that could be used as a water source for astronauts. Images of unconsolidated material also showcase the availability of potential building materials and radiation shielding. A level, smooth, low thermal inertia, high albedo region has been chosen as a landing site with a site for infrastructure located less than 5 km to the northeast of the landing site. There are small craters near the infrastructure site that could be used as ready-made radiation shielding, and there is evidence of abundant, loose regolith on the crater floor that can be used for construction [8]. These soils have also been shown, along the MSL traverse, to contain about 2 wt % H_2O in soil minerals and 3 to 6 wt % H_2O in the soil's amorphous component [9]. Extrapolating this finding to the infrastructure site chosen in this study, there is more than enough hydrated soil to yield water for ISRU activities as outlined in [2]. MSL has also found evidence of cobble-sized rocks that were transported into the crater by a fluvial environment [10]. As [6] discussed, the entire crater shows evidence of fluvial environments and so it can be expected that cobble-sized rocks will also be available at the site chosen for infrastructure construction.

Mining in Gale crater may mimic terrestrial techniques to extract Si and Fe from materials. Both of these elements can be used as construction materials to build the infrastructure in the exploration zone, and both elements must be reduced from minerals using the carbon monoxide in the martian atmosphere [11]. There have been instances of extremely high silica in rocks in Gale crater [12] and the ubiquitous iron oxides give Mars its red color; therefore, Gale meets the requirement outlined in [2] for potential to mine these elements.

Engineering constraints. The landing site criteria outlined in [2] are met in the location labeled in Figure 1. This landing site is relatively level, smooth, and free from hazards. The infrastructure construction site is located far enough from the landing site that an acceptable "lander blast zone" will not be obstructed by building materials or ISRU facilities. With regard to traversing across the crater to get to the ROIs outlined above, the best small-scale data lie with the wheel wear seen at Gale with MSL. Orbital images give good indications of which terrain is navigable within a landing site but in situ experimentation has shown the limits of a large rover with aluminum wheels driving through sand, over rocks, and up inclines [13]. In particular, ventifacted rocks have been encountered at Gale that have damaged the rover's wheels much more quickly than expected. With this knowledge of the environment at Gale, proper precautions can be taken to reinforce any wheeled vehicles and avoid similar damage during a long-term human expedition.

References: [1] Grotzinger, J. et al. (2014) *Science, 343,* DOI: 10.1126/science.1242777. [2] Workshop Supplemental Background Information, http://www.hou.usra.edu/meetings/explorationzone2015/supplemental_background_information.pdf. [3] Webster, C. R. et al. (2014) *Science, 347*, 415-417. [4] McLennan, S. et al. (2014) [5] Grant, J. A. et al. (2014) *JGR,* DOI: 10.1002/2013GL058909 [6] Anderson, R. B. and Bell III, J. F. (2010) *Mars, 5,* 76-128. [7] Meslin, P.-Y. et al. (2013) *Science, 341,* DOI: 10.1126/science.1238670. [8] Anderson, R. C. et al (2015) *Icarus, 256*, 66-77. [9] Leshin, L. A. et al. (2013) *Science, 341*, DOI: 10.1126/science.1238937. [10] Williams, R. M. E. et al. (2013) *Science, 340*, 1068-1072. [11] Badescu, V. (Ed.) (2009), *Mars: Prospective Energy and Material Resources*, Springer. [12] Frydenvang, J. (2015) *AGU*, submitted. [13] White, C. et al. (2014) *Aerospace Conference, 2014 IEEE*, DOI: 10.1109/AERO.2014.6836407.

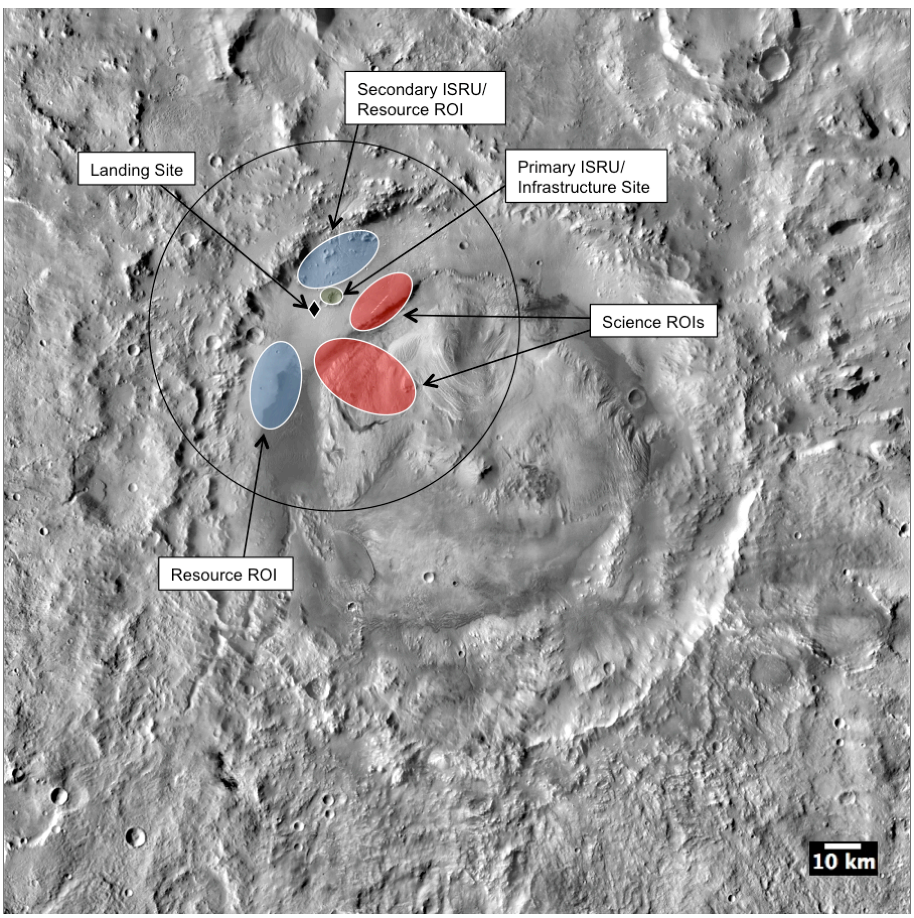

Figure 1. Gale crater Exploration Zone. Red Ovals= Science Regions of Interest (ROIs), Blue Ovals= Resource ROIs, Green Oval= Infrastructure Site, Black Diamond = Landing Site. MSL Traverse as of August 2015 shown as white line in upper Science ROI.