ASSESSING GALE CRATER AS A LANDING SITE FOR THE FIRST HUMAN MISSION TO MARS. A. F. J. Calef III[1] D. Archer[2], B. Clark[3], M. Day[4], W. Goetz[5], J. Lasue[6], J. Martin-Torres[7], and M. Zorzano Mier, [1]Jet Propulsion Laboratory-Caltech, fcalef@jpl.nasa.gov, [2]Jacobs Technology, Inc., doug.archer@nasa.gov, [3]Space Science Institute, bclark@spacescience.org, [4]University of Texas-Austin, mdday@utexas.edu, [5]Max Planck Institute for Solar System Research, Goetz@mps.mpg.de, [6]L'Irap Soutient Sciences En Marche, jlasue@irap.omp.eu, [7]Instituto Anda-luz de Ciencias de la Tierra (CSIC-UGR), javiermt@iact.ugr-csic.es, [8]Centro de Astrobiología (INTA-CSIC), zorza-nomm@cab.inta-csic.es.

Introduction: Mars is the "horizon goal" for human space flight [1]. Towards that endeavor, one must consider several factors in regards to choosing a landing site suitable for a human-rated mission including: entry, descent, and landing (EDL) characteristics, scientific diversity, and possible insitu resources [2]. Selecting any one place is a careful balance of reducing risks and increasing scientific return for the mission.

"Go where you know": Proposed future landing sites such as Eberswalde delta or Mawrth Vallis received extensive analysis during the MSL landing site selection workshop and are well characterized. More candidates sites are being evaluated for the Mars2020 rover, e.g. Jezero Crater, and contain almost equal orbital data coverage [3]. For legacy and current Mars missions, three are landers, and one lander/rover, all with limited areal extent: Viking 1 Viking 2, Phoenix, and Pathfinder/Sojourner. The remaining rover missions, MER Spirit, MER Opportunity, and MSL Curiosity offer the most ground truth over several to tens of kilometers both in and outside their nominal landing ellipses. While the HiRISE instrument provides unprecedented detail of Mars' surface for current and future missions, the insitu observations of rock density, soil mechanics, temperature fluctuations, dust opacity, radiation (via Curiosity), traversability, not to mention insitu science, are not readily measureable or resolvable by orbital assets. While we can make well-educated and higher-order assessments of landing sites, revisiting anywhere we've gone before can only reduce risk by removing uncertainty or shrinking errors bars in science and engineering landing site analysis. Insitu data decreases risk compared to other potential landing sites that have never been visited because of this ability to remove the unknown at the surface. However, a human-rated mission will likely require reducing risk by an order of magnitude, thereby requiring an order of magnitude better data than we currently have; only insitu data provides this level of certainty. From a financial perspective, insitu data is 'priceless' for a human-rated mission, not replicable for many sites.

Why Gale crater: The following is a breakdown of reasons Gale crater makes an excellent landing site for the first human mission to Mars.

EDL: Gale crater is one of the lowest elevation landing sites at ~4.5 km MOLA elevation. This increased atmospheric density will decrease requirements for landing from increased velocity reduction with parachutes or other methods like low-density supersonic deceleration. Dynamic entry data and a well-understood atmospheric profile, including additional seasonal data (temperature, pressure, wind speed) from the Rover Environmental Monitoring Station [REMS] package onboard Curiosity for at least a Martian year, adds to reducing uncertainty during any landing. This landing site easily meets the latitude, slope, and dust constraints.

Exploration Zone: Our proposed landing site is located at the center of the final MSL landing ellipse at 137.4019° longitude and -4.5965° latitude (Figure 1). Besides the nominal 100 km radius Exploration Zone (EZ, in red), we've also identified a smaller 25 km radius EZ (pink) to emphasize the scientific and ISRU ROIs closer to the landing site. Several 'camps' were also identified within small ~100 m diameter craters with a 2-5 m high crater walls that could serve as infrastructure points within a few kilometers of the landing site (purple, Figure 1 inset).

S***cientific Diversity:*** At Gale crater, the Peace Vallis delta deposits [4], confirmed habitable environments [5], evidence of a lake [5], insitu methane observations [6], and existence of indigenous Martian carbon both ancient and active [7], not to mention the yet fully explored 5 km sedimentary stack of Mt. Sharp (Aeolis Mons) are a scientific cornucopia for an human mission to expand upon and explore, meeting many of the nominal science requirements for a human mission. Gale crater offers access to both northern plains and southern highland material within a relatively short distance (Figure 1, inset A).

Water Resources: There is little chance of near-surface water-ice for resource utilization in Gale, but water bound in minerals and adsorbed to loose grains could serve as a water source [8]. Some 'easy' water is found extracting adsorbed atmospheric water in ripple and dune sediments [9]. [10] estimates 3-6 weight% water in amorphous sediments at Rocknest. Calculations from [11] using 2 weight% estimated a cubic meter of Rocknest soil would contain ~32 L of water. A back-of-the-envelope estimate for total sand volume in dunes, sand sheets, and transverse aeolian ridges (TARs) is 6.51 km^3. Assuming a 30% porosity gives a material volume of 4.56 km^3. Conservatively assuming an average density of 2500 kg/m^3, yields a total sand mass of ~10^{13} kg. Using 3 wt% water result from Rocknest [10], yields a total of ~10^{11} kg of water, or 10^8 metric tons. Such water sources may be renewable as REMS measurement indicate new adsorbtion of atmospheric water as humidity increases during the night[8]. Rocks at Yellowknife bay [12] and the Kimberley drill sites [Planetary Data System release] yielded ~2 wt% water, so additional water may be recoverable from mining efforts. Sand water ISRU ROIs have been delineated based (Figure 1).

Feedstock Resources: Using geochemical results from the CHEMCAM instrument on MSL, we've identified an ROIs for Al, Fe, and Si (Figure 1). Rocks that occur in and around Yellowknife bay and in rocks associated with 'highly cratered surfaces' around the lower reach of the Gale mound have on average higher wt% Fe at 15-24%. Higher wt% Al (>10%) and Si (>50%) occur in the Bradbury Rise area. An additional ISRU resource for growing plants is nitrogen in the form of nitrates discovered at Rocknest (~45 ppm) and rock samples (20-250 ppm) [13] making Gale crater soils potentially suitable for growing plants insitu. Together, these ISRU ROIs are starting points for assessing mining and processing of these resources.

Conclusion: Gale crater is a scientifically fascinating site on Mars with abundant orbital and ground data for assessing a human mission. The MSL science team has already shown Gale crater to harbor ancient habitable environments and abundant liquid water in the past. ISRU resources for H_2O, Fe, Al, and Si have been identified and quantified. A human mission to this location comes with the assurance to what we'd find on arrival and the strong potential for future discoveries.

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