GO WHERE YOU KNOW: BEGIN HUMAN EXPLORATION OF MARS AT LOW LATITUDES.

F. J. Calef III[1] B. Cohen[2], M. Seibert[3], [1]Jet Propulsion Laboratory-Caltech, fcalef@jpl.nasa.gov, [2]NASA Marshall Space Flight Center, [3]Colorado School of Mines

Introduction: Mars is the "horizon goal" for human space flight [1]. Towards that endeavor, factors influencing landing site suitability for a human-rated mission include: entry, descent, and landing (EDL) characteristics, scientific diversity, and the type, form, and accessibility of in situ resources [2]. Precursor robotic missions offer the ability to understand the operational environment at the ground level. All missions require a careful balance of reducing risks and increasing scientific return for the mission, though for the first human missions, a higher emphasis on safety is to be expected. Towards those goals, we outline why equatorial sites (below 30° latitude) offer the best opportunities for safe and scientifically rich human landing sites on Mars.

Safety First: Of primary importance for the first human mission will be the safety of the astronauts. The crew perspective on safety can be described as, to paraphrase astronaut Stan Love from the 1st Mars Human Landing Site Workshop [3], "We don't care where we go, but we want it to be safe." Equatorial sites offer several engineering advantages that bring down the risk of large systems because of their location, including:

1. moderate and stable temperature regimes: as on Earth, temperature remains stable at low latitudes with less variability in range [4]. The thermal environment can be reliably predicted and compensated for with less extremes to contend with.
2. consistent "high-angle" light: during high-latitude winter, sun angle approaches the horizon which can interfere with visibility by humans and robots (who rely on stereo images to create navigable terrain data)
3. known operational conditions: seven of the nine successful landed missions have visited equatorial locations. All three rover-only missions have operated between 6-15 years each on the martian surface recording temperature, tau (atmospheric dust content) as measured from the surface, pressure (MSL), radiation environment (MSL), terrain material types, and traverse capability over ~73 km. Both the NASA Mars 2020 and ESA Rosalind Franklin rover landing sites will visit additional equatorial locations adding to these data sets.

High latitude sites suffer from challenging temperature regimes which reduce mission performace from increased energy use and reduced mechanical "up time" (extended heating times), not to mention the reduced material lifetime from harsher heat/cooling cycles. Seasonal effects, like low lighting, can reduce operational hours for collecting science observations and be a nuisance for stereo correlation used by 'assistant' robotic spacecraft.

"Go where you know": Current and proposed "final round" robotic landing sites receive extensive analysis during landing site selection and are well characterized with high resolution (25 cm/pixel) stereo and hyperspectral (18 m/pixel) datasets. The final four MSL (Eberwalde Crater, Gale Crater, Holden Crater, Mawrth Vallis) and additional five unique Mars 2020 (Columbia Hills, Nili Fossae trough, Northeast Syrtis, Jezero Crater, Southwest Melas Chasma) landing sites have near contiguous orbital coverage sufficient to land a spacecraft within a 20x25 km ellipse. For legacy and current Mars missions with extensive lifetimes (<1 year), MER Spirit, MER Opportunity (Figure 1), and MSL Curiosity (Figure 2) offer 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 sufficiently measureable or resolvable by orbital assets. In terms of safety and science return, revisiting previously explored robotically 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. Human-rated missions will require one or more precursor missions to understand the landed surface to reduce risk. From a financial perspective, insitu data is 'priceless' for a human-rated mission, removing the need for a precursor. Mission designs can be tailored to site specific constraints down to the smallest details.

"Water, Water, Everywhere": A primary driver in the current human landing site selection process, is the desire to have insitu resource utilization (ISRU) support initial human missions. Water availability is considered a critical factor to establishing a "permanent" scientific research station/settlement for human use (drinking/oxygen generation) and perhaps electrical (fuel cell) or as rocket propellent. It is not clear if access to near surface water ice at higher latitudes, is worth the trade in operational safety/consistency when compared to equatorial sites with hydrated surface materials. Regolith at equatorial latitudes, e.g. the MSL science target “Rocknest” [5] using 2 weight% water, estimated a cubic meter of soil would produce ~32 L of water. You would need to process more material for equivalent water return, though Mars ice is very cold and closer in mechanical properties to rock; mining it may be just as difficult as processing regolith for the same effect and yield other valuable byproduct (e.g. sands for construction). Developing ISRU capability to process water from regolith would allow landing sites almost anywhere on Mars, regardless of water-ice availability.

Scientific Diversity: The majority of human landing site suggested were from the equatorial regions [3]. Partially this is an artifact of robotic landing site selection, but also because the martian equator cuts through all three major age units (Noachian, Hesperian, Amazonian) and contains major geologic outcrops driving scientific inquiry. Major clay units are being explored at Gale crater and a braided stream system at Jezero crater. Meridiani Planum itself holds the record of an ancient inland sea [6].

Conclusion: Mars’ equatorial region offers an abundance of scientific diversity, benign operational environments, and nine landing sites with high-resolution orbital datasets. Three rover landings sites come with invaluable insitu measurements of ISRU resources, human and robotic operational characteristics, and cm-scale terrain details that are invaluable to any human-rated mission to the surface. If we want to go to Mars in the near future, we should aim for landing sites that fit known operational capability and scientific interest. By utilizing our existing Mars operations knowledge base and insitu datasets, we can excellerate our timeline to getting astronauts on the surface, safely.

References: [1] Pathways to Exploration, ISBN: 978-0-309-30507-5, 2014. [2] Human Exploration of Mars DRA v5.0, NASA-SP-2009-566, 2009. [3] (Bussey and Hoffman, IEEE, 2016. [4] Christensen et al., J. Geophys. Res., 106(E10), 23,823–23,871, 2001. [5] Archer et al., *JGR*, 2014, doi:10.1002/2013je004493. [(4)5] Grotzinger et al., *Science*, 2013. [6] Squyres et al., Science, 2004. [7] Cohen and Seibert, HLS2, #1030, 2014. [8] Calef et al., HLS2, #1020, 2014.

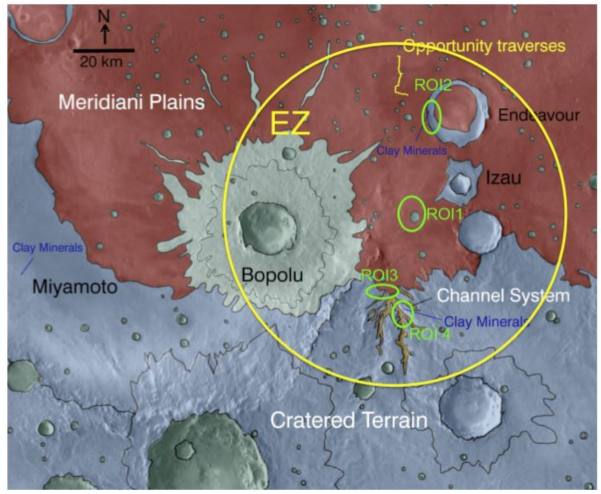

Figure 1: Meridiani Planum Exploration Zone (EZ) from Cohen and Seibert [7].

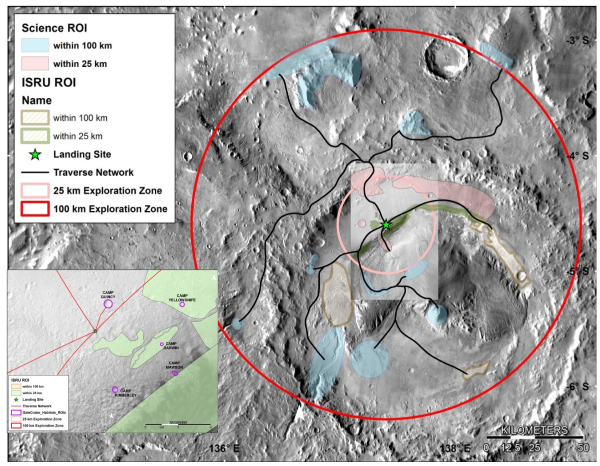

Figure 2: Gale Crater EZ from Calef et al. [8]