ASSESSING SAFE LUNAR LANDING SITE STATISTICS WITH SYNTHETHIC DEMs.

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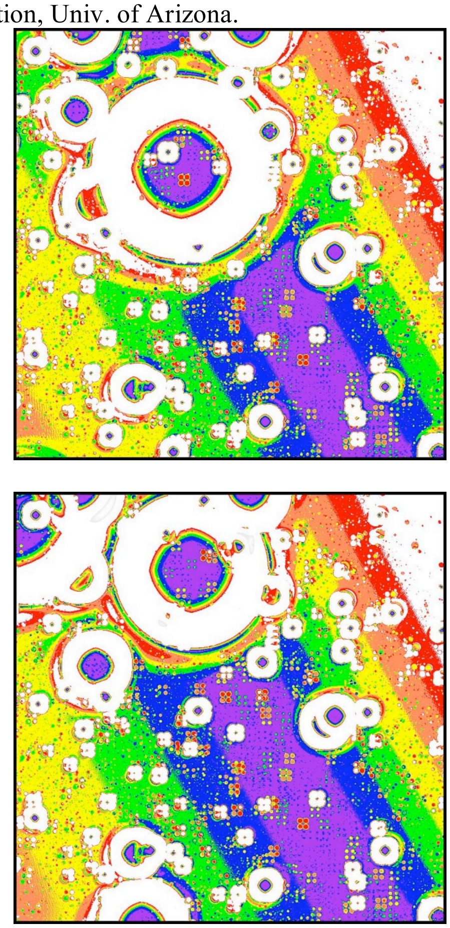
Introduction: As part of the Autonomous Landing and Hazard Avoidance Technology (ALHAT) project, the Applied Physics Lab has developed software to generate high-resolution synthetic digital elevation models (DEMs) for the Moon. The code can read in a list of crater diameters and locations for placement in the DEM, or can generate synthetic craters according to a specified size-frequency distribution [1]. We have been studying the statistics of finding a safe landing site by performing simple image processing on DEMs generated to represent surfaces of known ages in an attempt to help answer the question "Is there a safe landing site at location *X*?"

Landing Site Hazards: Any planetary lander, whether piloted or robotic, must either navigate to a site known to be free of hazards, or must be capable of assessing the hazards present at a given landing location and redirecting to a nearby safe site if necessary. "Safe" means a site that is free of steep slopes or boulders large enough to cause tipping or damage to the spacecraft. The criterion for safety is often expressed as the maximum tilt that lander can experience when it settles onto the surface. For the Apollo Lunar Excursion Modules (LEM), the tilts ranged from 2.5° at Apollo 16 to 11° at Apollo 15; 11° was considered to be near the design limit for the LEM.

Digital Elevation Models: Ideally, high-resolution imagery at the appropriate lighting geometry would be available to assess the safety of a potential landing site. Topographic maps could be generated from stereo photography or high-resolution laser altimeter mapping. This is one of the major objectives of the Lunar Reconnaissance Orbiter mission [2]. Until such data becomes available, it is desirable to have another means by which to judge the general suitability of specific sites or classes of sites. Synthetic DEMs allow exploration of the statistical topography of the surface at resolutions finer than that of the LRO data.

Safety Criterion: It is straightforward to compute the tilt that a lander of a given size would experience if it landed at any point in the DEM image. We make the following assumptions: the lander has four legs, each at the vertex of a square, with leg spacing D. The footpads are of diameter d. For the preliminary work here, we assumed $D = 15$ m, and $d = 1$ m. The lander is placed at every pixel in the image, and the maximum and minimum elevation beneath the four footpads are found. The lander tilt, τ, is computed from $\tau = \arctan[(\mathrm{elev}_{max} - \mathrm{elev}_{min})/D]$. Example tilt images for the rim of a synthetic Shackleton are shown in the figure. We can also compute parameters such as the percentage of the image with a tilt less than a specified threshold, and the minimum divert distance from any point to a safe area of a given size. By analyzing multiple synthetic DEMs with randomly placed craters, we can determine the approximate conditions to be expected at a particular landing site. Future work will include rock distributions [e.g., 3] in addition to craters.

References: [1] G. W. Patterson et al. (2008) LEAG-ICEUM-SRR meeting abstracts. [2] G. Chin et al. (2007) *Space Sci. Rev.* [3] G. D. Bart (2007) Ph.D. dissertation, Univ. of Arizona.



Color-coded tilt maps for rim of synthetic Shackleton (see [1] for location). Purple 0-2°, blue 2-4°, green 4-6°, yellow 6-8, orange 8-10°, red 10-12°, white >12°. Images each cover 1 km^2. *Top:* "average mare" crater distribution. *Bottom:* "highland" distribution. The "highland" surface has a greater number of craters >200 m in diameter; distributions on the two surfaces are the same for craters <200 m.