AMES Stereo Pipeline Derived DEM Accuracy Experiment using LROC-NAC Stereopairs and Weighted Spatial Dependence Simulation for Lunar Site Selection J. R. Laura[1], D. Miller, [1], M. V. Paul [2] [1]The Pennsylvania State University,(jzl5325@psu.edu) [2]Team Leader, The Penn State Lunar Lion – A Google Lunar X PRIZE Team,(lunarlion.psu.edu)

Introduction: Site selection analysis for planetary missions requires cartographic data products with high spatial resolution, high precision and quantifiable accuracy. This information allows stakeholders to make informed decisions regarding the usability of datasets, the benefits which could be realized by re-imaging a region, and the degree of unknown in surface features. Digital Elevation Models (DEMs) provide gridded elevation data which is utilized to both orthorectify imagery, and derive additional datasets (slope, aspect, hill shade, etc.). Vertical DEM inaccuracy correlates directly to exaggerated errors in derived datasets [1,2]. An assessment of DEM accuracy is therefore essential in the use of these data products in mission planning.

Traditional digital elevation model accuracy assessments utilize in situ GPS collected elevation data from a random sampling of points within a DEM to assess the data product accuracy [1]. Alternatively, DEM accuracy can be assessed by using elevation products of even higher vertical accuracy. In either case the root mean square error (RMSE) of a random sampling of points serves to quantitatively describe the accuracy of the DEM in its entirety. Neither of these assessment techniques are available for DEMs derived from Lunar Reconnaissance Oribter (LRO) Narrow Angle Camera (NAC) stereopairs. In situ observation is simply impossible and no suitable higher resolution datasets are available.

Application: Announced on September 13, 2007, the Google Lunar X-Prize is a competition to foster private, non-government, investment in placing a robot on the moon. Google's X-Prize, with a total of $30 million in prizes, requires that a privately funded team (90% or greater) land on the surface, transmit both still and video imagery, and traverse at least 500 meters. Fulfilling these goals prior to a government placing a robot on the moon garners a $20 million prize. Additional prizes for traversing at least five kilometers, surviving the lunar night, obtaining imagery of previous Apollo missions, or verifying the existence of water on the lunar surface are also available.

One of twenty-six teams competing in the Lunar X-Prize competition, the Penn State LunarLion is a multidisciplinary team of aerospace, electrical, and mechanical engineers, as well as physicists, geologists, GIS analysts, and a former astronaut. Team members have previous experience with craft design, Martian rover operation, mission system development, and flight trajectory planning. Currently, the PSU LunarLion team is aiming to place a hopper somewhere within the vicinity of the historic Apollo 11 landing site.

Analogous to the Mars Science Laboratory (MSL) mission, high resolution elevation and surface hazard data is essential to ensure both safe landing and successful traversal of the surface[3]. Ideally these datasets offer sub-meter pixel resolution, vertical accuracy, and horizontal accuracy. The DEMs derived using these data sets should provide a high precision. Finally, it is important to note that DEMs are representations of the surface and even the most accurate data products will contain error [1].

By applying this most recent, high resolution image archive to the problem of landing site selection, the Lunar Lion team will be able to avoid the use of complex hazard-avoidance systems. Though privately funded, this low-cost mission to the moon's surface will be able to follow the mantra of NASA's Planetary Science Division of "Flyby, Orbit, Land, Rove, Return." NASA's excellent orbital imagery will enable this moon lander, the first in over 35 years."

Data Availability: Three primary lunar elevation sources exists to support the site selection process. The Lunar Oribter Laser Altimeter (LOLA) provides global coverage, but does not possess sufficient pixel resolution or horizontal accuracy. The recently released LRO Wide Angle Camera (WAC) derived digital terrain model (DTM) provides pixel resolution usable for small scale selection of potential landing ellipses, but is not suitable for larger scale site selection or hazard detection.

Stereoscopically derived DEMs, created using Socet Set (® BAE Systems) and LRO-NAC stereopairs, provide the highest available resolution datasets suitable for site selection. LRO-NAC consists of a pair of pushbroom sensors with a spatial resolution of ~0.5m [4].

These derived, high resolution, data products were not available to teams prior to the announcement that DEM data generated for the Constellation mission would be made available through LMMP. As of January 2012, seven high resolution (0.5m / pixel – 2.0m / pixel) DEMs have been uploaded. While the publication of these DEMs facilitates the site selection process for many teams and offers science targets which have undergone rigorous scrutiny during Constellation mission planning[5], they cover an extremely limited portion of the lunar surface.

Our Ames Stereo Pipeline Data Derivation Process: For teams with targets beyond those sites which have been identified, processed, and made available through LMMP, it is necessary that automated methods for digital elevation model creation be employed. The PSU LunarLion team is using a derivation process which closely follows previous work using HiRISE images[6]. Our methodology differs as we substitute the Ames Stereo Pipeline [7] for SocetSet.

Briefly, this process requires:

- Sourcing of overlapping stereopairs through a GIS housing a derived shapefile of LRO-NAC left and right footprints.
- Download EDR Images from the Planetary Data System (PDS)
- Calibrate and embed the image spice kernel using the USGS's ISIS3
- Bundle adjust, and triangulate each pair of overlapping images into a point cloud (Left_A / Left_B; Right_A / Right_B; Left_A / Right_B; Left_B / Right_A)
- Derive DEMs from point cloud
- Mosaic and geoblend four derived DEMs using the Geospatial Data Abstraction Library (GDAL) and custom python scripts

While this process is computationally expensive, it does not require extensive human-computer time beyond sourcing the input images. Future testing will include the use of ground control points to improve the actual vertical accuracy of these relative surface.

Sample DEM Production using ASP: Two overlapping stereopairs (Figure 1), covering the Apollo 11 landing site, were selected and processed as above to generate the DEM shown in Figure 1. The LRO-NAC input images were M102000149 and M102014464. The DEM is a relative surface, processed without Ground Control Points (GCP) and is originally produced with a ~2000m offset to the LOLA surface. This offset is removed in post processing and is anticipated to be removed entirely with the use of GCP in ASP.

Proposed ASP DEM Accuracy and Precision Assessment: Utilizing the weighted spatial dependence random field method, developed by [1], Socket Set DEM of Tranquilitas Mare, processed by the USGS will be used as control surface to assess the vertical accuracy of a ASP derived DEM. To perform this analysis, Monte Carlo simulation will be performed to generate *n* additional realizations of the control surface with values within 1σ of the USGS derived DEM precision. To account for spatial autocorrelation of the elevation data a distance weighted kernel will be used to average the derived pixel cell.

To test the precision of the derived DEMs and the correlation between ASP stereo.default arguments the authors are also soliciting volunteers to process sets of LROC-NAC stereopairs using the same LRO-NAC stereopairs as used to generate the high resolutions DEMs available via LMMP. Contact the authors via the email address above for details.

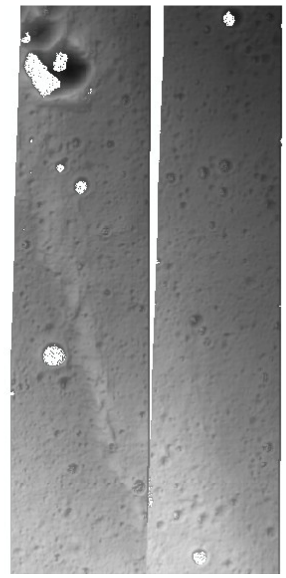

Figure 1: ASP derived DEM in the region of the Apollo 11 landing. No data displayed as white.

Conclusion: This research provides a starting point by which additional study into the vertical accuracy and precision of ASP generated DEMs can be investigated. Potential systemic and / or structural error within ASP derived DEMs is also investigatable using the data generated and collected through this work. The methodologies applied to perform DEM generation and accuracy assessment are available to all users through open source planetary software and traditional GIS Systems.

References:

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