CREATION OF HIGH RESOLUTION TERRAIN MODELS OF BARRINGER METEORITE CRATER (METEOR CRATER) USING PHOTOGRAMMETRY AND TERRESTRIAL LASER SCANNING METHODS

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Introduction

Barringer Meteorite Crater or Meteor Crater, AZ, has been a site of high interest for lunar and Mars analog crater and terrain studies since the early days of the Apollo-Saturn program [1]. It continues to be a site of exceptional interest to lunar, Mars, and other planetary crater and impact analog studies because of its relatively young age (est. 50 thousand years) [2, 3] and well-preserved structure. High resolution (2 meter to 1 decimeter) digital terrain models of Meteor Crater in whole or in part were created at NASA Stennis Space Center to support several lunar surface analog modeling activities using photogrammetric and ground based laser scanning techniques. The dataset created by this activity provides new and highly accurate 3D models of the inside slope of the crater as well as the downslope rock distribution of the western ejecta field. The data are presented to the science community for possible use in furthering studies of Meteor Crater and impact craters in general as well as its current near term lunar exploration use in providing a beneficial test model for lunar surface analog modeling and surface operation studies.

Photogrammetric Model from High Resolution Satellite Imagery

A stereo pair of images over Meteor Crater was acquired from the QuickBird satellite in October 2006 to extract a high resolution terrain model using standard photogrammetric software tools (Leica Photogrammetry Suite and BAE Socet Set). The images were acquired during early winter season and some shadowing was present in several of the southern inside rim areas of the crater that could not be corrected using contrast techniques, therefore not allowing a quality extraction solution for some of the internal high slope areas. A large number of tie points (256) were automatically and manually entered and a digital elevation model (DEM) with an approximate 1.69 meter RMS resolution was created. Extraction quality maps for the external perimeter of the crater showed high confidence levels and this data was retained for the purposes of the project for merge with the higher resolution internal laser scanned product (Fig. 1).

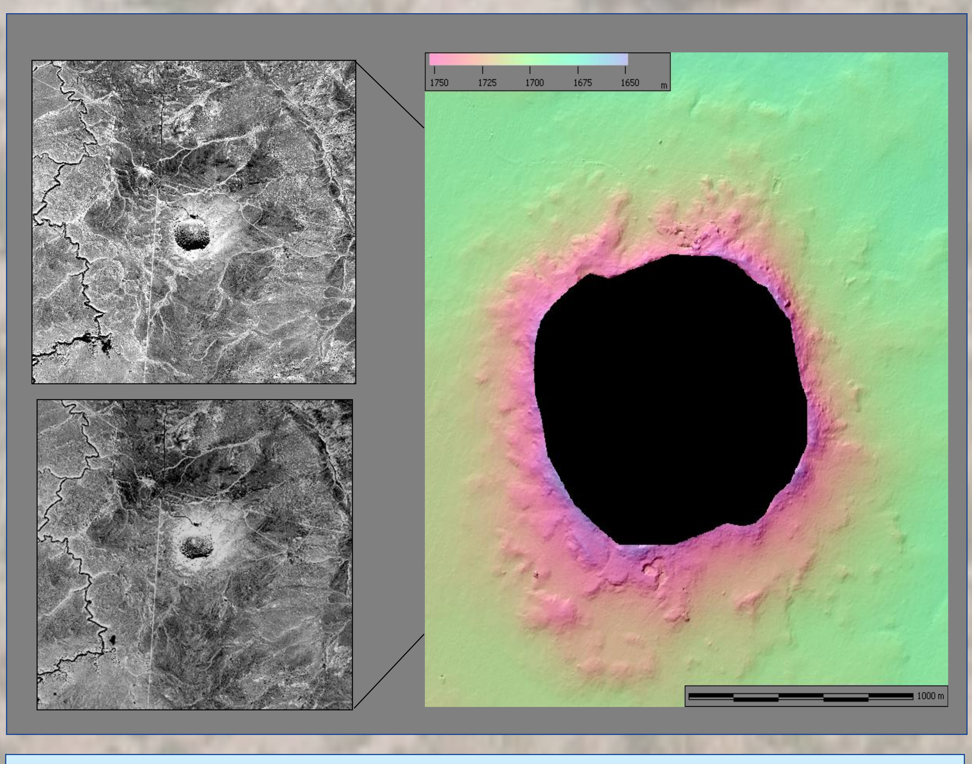

Figure 1. *Photogrammetrically extracted external perimeter DEM for Meteor Crater.*

Scanning of Interior of Crater

A laser scan of the interior of the crater was contracted by NASA to be performed by Darling Environmental and Surveying of Tucson, AZ, using the Optech ILRIS 3D scanner from a central location on the crater floor. The Optech was selected for scanning the internal geometry of the crater because of its 1000 m effective scanning range, allowing for a single day/session 360 degree scan along with a bore-sighted 6 megapixel digital camera for simultaneous capture of crater wall imagery. Reflective targets were placed at locations along the crater rim and floor to increase geopositional accuracy of the scan session. High order kinematic GPS points were gathered by NASA/SSAI personnel with a Trimble GPS system at the locations of the reflective targets and at the U.S. Geological Survey (USGS) geodetic survey mark located at Barringer Point on the northwest crater rim to reference the scan datasets into the WGS84 datum for later merging with the photogrammetrically derived data. A 5-hour scan session was performed with the Optech scanner and the data processed into XYZ point cloud files (Fig. 2).

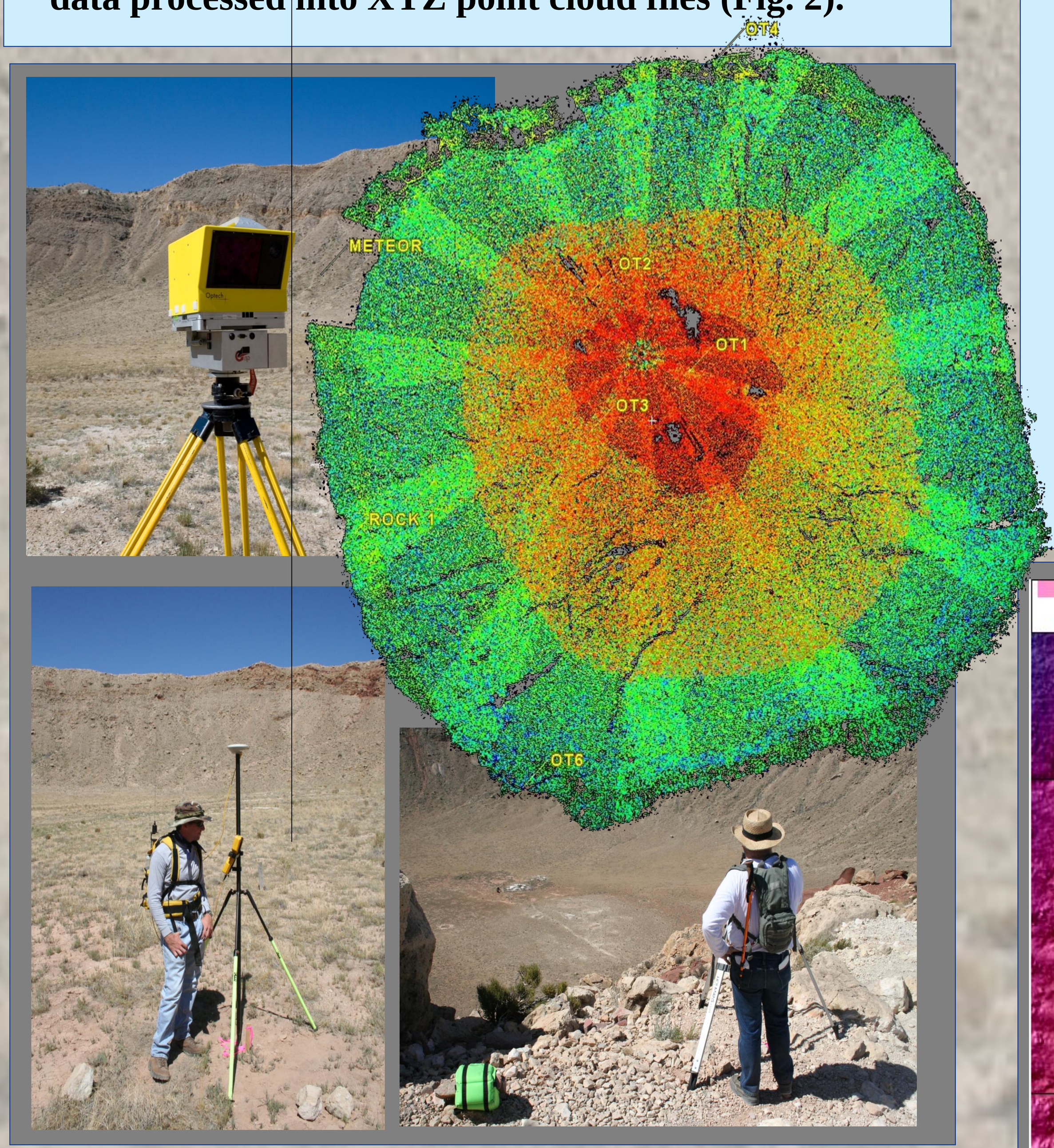

Figure 2. *Optech point cloud scan of crater interior with optical targets marked.*

Scanning of Western Ejecta Field of Meteor Crater

A laser scan of the western ejecta field outside of the crater was also performed at six different locations by the survey team using the Leica HDS-3000 laser scanner. The Leica was selected for scanning the western ejecta field because of its 360x270 degree field of view capture capability and 6 mm positional accuracy at 50 meters.

Reflective targets were implemented to increase accuracy of the scan session, and high order fast static GPS points were gathered with the Trimble GPS system at the locations of the reflective targets and at the scan locations. The scans were processed and combined into XYZ point cloud files using the Leica scanner processing software (Fig. 3).

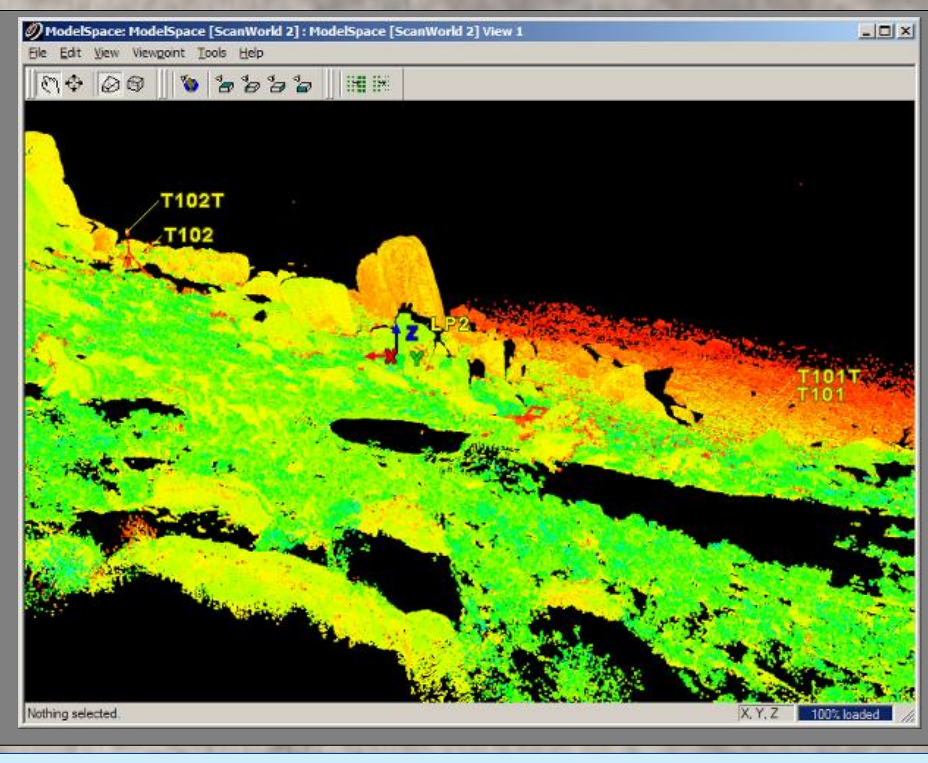

Figure 3. *Leica HDS3000 laser scan of western ejecta field showing Whale Rock in upper center and reflective targets in upper left and middle right.*

Processing of Data

The XYZ point cloud files from both laser scan sessions yielded a great volume of data with the western ejecta field data being ~ 1.5 GB in size. Some occluded areas of terrain data resulted from large rock outcroppings and boulders in the scanners' viewsheds. Various interpolation filters were applied with varying spatial kernels to provide contiguous gridded DEMs from the point cloud data. Custom point cloud processing routines written in IDL were used to process the data and apply linear, nearest neighbor, inverse distance, and natural neighbor interpolation filters for 1, 2, 5, and 10 decimeter point spacing (Fig. 4).

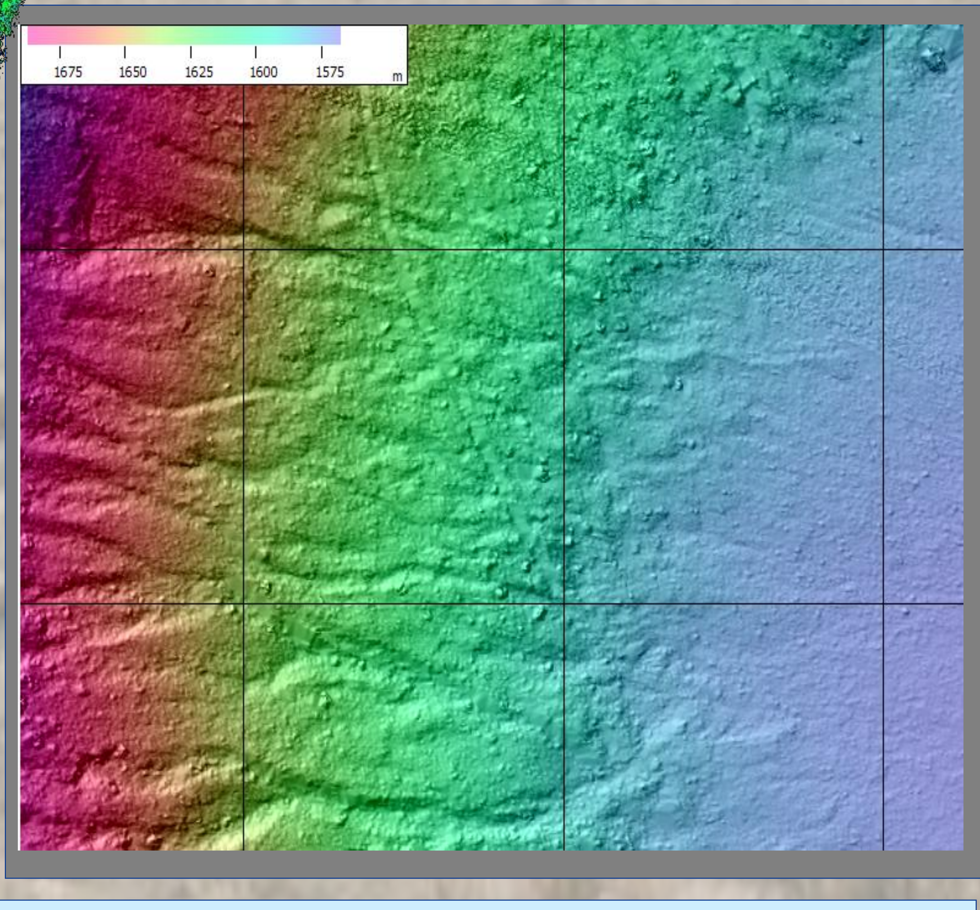

Figure 4. *Gridded Optech scanner data of northwest crater floor at 5 decimeter point spacing with linear filter applied.*

The resulting DEMs from the photogrammetric satellite imagery extraction of the outside of the crater and the processed laser scan data inside of the crater were gridded into approximate 1 meter resolution and merged, and the seams of the datasets were checked for holes and goodness of fit. Because of the disparity in the sensor acquisition techniques used for the two datasets (ground based and satellite), some data gap filling with existing USGS DEM data and additional interpolation was required between the two datasets to provide a contiguous gridded DEM (Fig. 5).

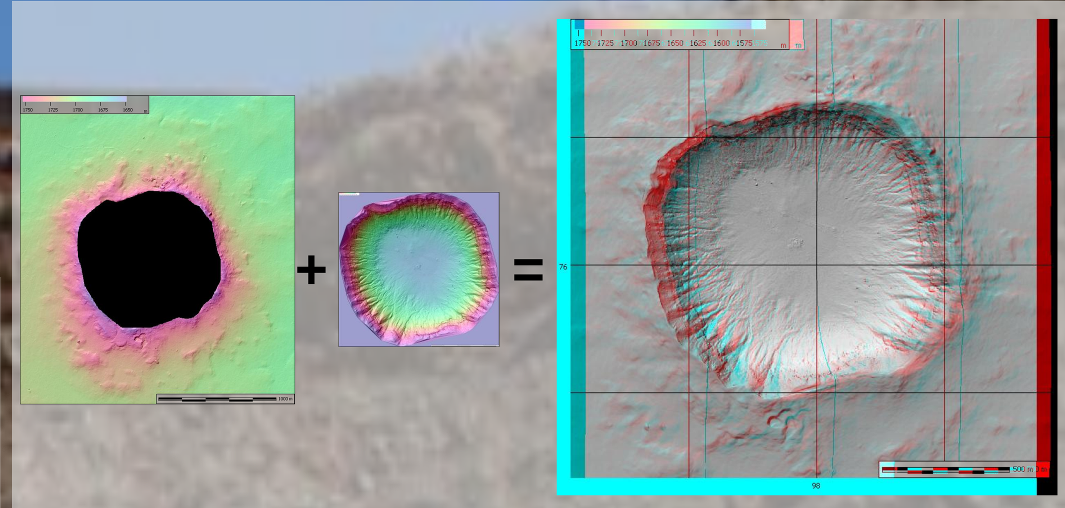

Figure 5. *Final merged DEM product (stereo).*

Results and Conclusions

The dataset from the singular interior scan of the crater resulted in a very large point cloud that was processed and gridded to approximate 0.5 and 1.0 meter point spacing. The ridges and draws of the downslope of the crater wall are very well defined, and high quality surface roughness maps from boulder and rock distributions could be easily derived with the data. The dataset resulting from the multiple angle scans of the western ejecta field provided a higher resolution data product of 1 decimeter or greater and a truer 3D DEM because of a two-tiered 360 degree scan approach up to the crater rim (Fig. 6).

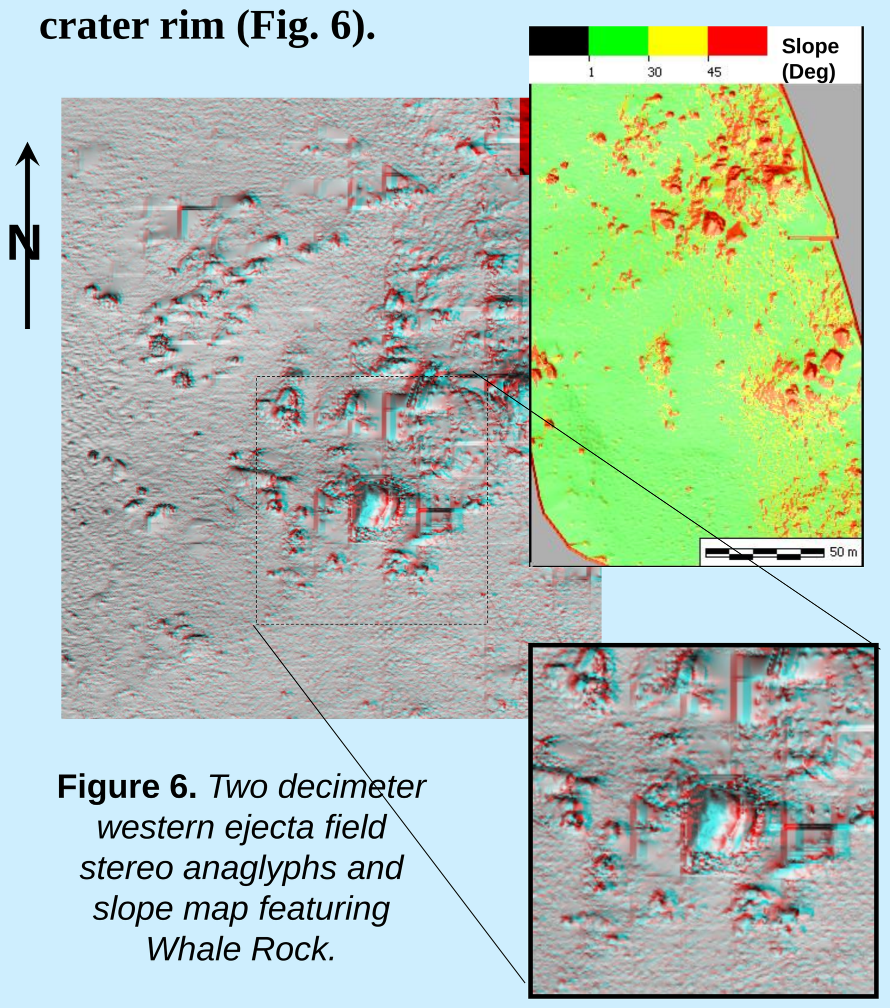

Figure 6. *Two decimeter western ejecta field stereo anaglyphs and slope map featuring Whale Rock.*

Enhancement Potential

1) Scanning the interior of the crater from three points arranged in a large triangle near the start of the upslope of opposing sides of the crater floor to allow for less boulder and outcrop occlusion and greater characterization of the crater floor topology.
2) Acquiring the satellite imagery over the crater closer to summer solstice to maximize the quality of the extracted DEM.
3) Adding an airborne lidar dataset into the mix of these other data acquisitions to provide an additional piece of the data acquisition model.

REFERENCES

[1] G. G. Schaber (2005), *Open-File Report 2005-1190,* U.S. Department of the Interior, U.S. Geological Survey. [2] V. M. Peet, M. S. Ramsey, and D. A. Crown (2006), *LPSC XXXVII, 2323.pdf.* [3] D. A. Kring (2007), *Guidebook to the Geology of Barringer Meteorite Crater, Arizona, Lunar and Planetary Institute,* LPI Contribution No. 1355.

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