IMPROVED HIGH-RESOLUTION LUNAR DTMS VIA THE COMBINED USE OF LROC NAC AND LOLA DATA.

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Introduction: The best use of lunar and planetary data is achieved by properly registering them so that derived data products are positionally correct to known levels of accuracy. We describe here work to rigorously register LRO LROC NAC and LOLA [1, 2, 3] image and lidar data to make high resolution lunar digital terrain models (DTMs) suitable for landing site planning, surface operations, geologic mapping, and resource location purposes. Properly combining image and lidar data has been a goal of the Astrogeology Science Center since the acquisition of such data during the Mars Global Surveyor [4] mission in the 1990s. Data provided by the LRO mission is particularly suited to such processing, given the high resolution, high precision, and high volume of such data for the Moon, and in particular the availability of NAC stereo and the five simultaneous tracks of data obtained by the LOLA instrument.

We have made DTMs of three areas in the South Pole-Aitken (SPA) basin interior region of the Moon, due to the availability of multiple areas of LROC NAC stereo image coverage there and the importance of sites there for lunar sample return [5]. Specifically, we have used data from the SPA Constellation program site (200.1°E, 60.0°S; 24 images) [6], and two nearby sites (“SPA N+1”, 198.3°E, 57.1°S; 8 images; “SPA N+2”, 198.1°E, 55.6°S; 20 images).

Procedure: For each site, we use BAE Systems Socet Set®* software to manually control the images to each other and to available LOLA data and make a “preliminary” DTM, following standard procedures [7]. The resulting control network is exported to an ISIS [8] compatible format. Simultaneous LOLA data are collected and put into a binary format. We have extensively modified a version of the ISIS *Jigsaw* program [9] to read and use the LOLA range data as constraints during the photogrammetric adjustment solution. This process is similar to that used by Yoon and Shan [10] for processing of simultaneous MGS MOC and MOLA data and used more recently with Chang’E-2 image and LOLA data [11]. The *Jigsaw* version used did not have the option to constrain the NAC left and right cameras to have the same geometry, so the LOLA ranges are used to independently constrain the geometry (exterior orientation) for both cameras. Numerous solutions were achieved with the SPA N+1 data to determine the best weights on the observations and constraints on the parameters.

Following a successful new solution that includes both the image and lidar data, the output control network is exported back to Socet Set. (Ideally one might like to export the solved-for exterior orientation parameters, e.g., in the form of SPICE [12] data, but that is not possible with the current software.) A new control network solution is performed with tight constraints in Socet Set thus causing the image data to be controlled to the same geometry as with the *Jigsaw* solution. At this point a new (“final”) DTM is generated for comparison with the “preliminary” version, to see what if any improvement in the DTM has resulted from the rigorous combined image/lidar solution.

Results: Our presentation will show comparisons with (unadjusted) LOLA track data and the preliminary and final DTMs for each of the three sites, both statistically and graphically. Figure 1 shows such results graphically for the lower half of the SAB N+1 site. It shows that the final DTM has smaller elevation differences from the input LOLA data than the preliminary DTM. The DTM controlled with the rigorous combination of NAC and LOLA data provides better elevation results than DTM controlled following standard procedures. For the ~82,200 LOLA points, the mean difference and standard deviation in elevation with the preliminary DTM is -0.98 and 2.1 m, while for the final DTM is -0.25 and 1.5 m. Qualitatively the final DTMs also have a generally smoother appearance than the preliminary DTMs.

Operationally, if the rigorous solution method is used, it may not be necessary in the future to (manually) control the NAC images in Socet Set before obtaining a solution, since the rigorous solution should control the images automatically to the LOLA track data (and, as a bonus, improve the relative positioning of the LOLA track data as well).

Products: We plan to archive to the PDS Annex [13] the network *Jigsaw* solution results, the updated LOLA track data, and the (moderately edited) preliminary and final DTMs for the three sites.

Future work: In this fiscal year, the image/lidar-related *Jigsaw* and related software code is being incorporated into a new version (6.0+) of ISIS.

Further testing of the uses of this rigorous image/lidar combination method is desirable. At a minimum we see a need to attempt solutions with the NAC left and right images constrained to the same geometry and the lidar data simultaneously, rather than solving for each camera, something not possible with the current version of *Jigsaw*. Using non-simultaneous LOLA track data for (elevation) constraints would better absolutely control DTMs away from areas of simultaneous tracks. Testing could also be done to see how much improvement has been made in the relative positioning of the solved for LOLA data. Beyond usage with LRO data are many other lunar and planetary missions that have collected or plan to collect image and lidar data. The products and results of all those missions could be improved using combined solutions.

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*(Any use of trade, firm, or product names is for descriptive purposes only and does not imply endorsement by the U.S. Government.)

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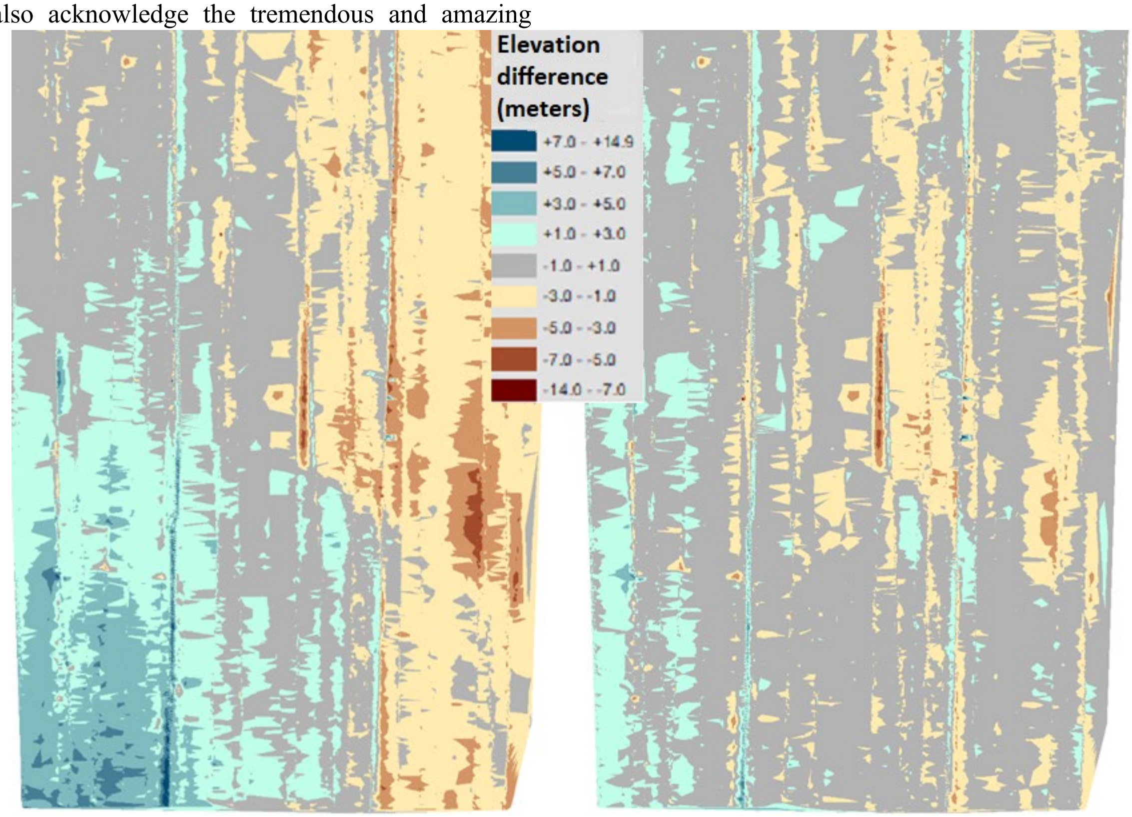

Figure 1: For the SAB N+1 site and the lower half of the (10 km across) area mapped, elevation differences are shown in meters, between all available (unadjusted) LOLA track data (~82,200 points) and the Socet Set derived DTM with 1.5 m post spacing. The left image shows differences for the preliminary DTM and the right image shows differences for the final DTM (based on the combined NAC/LOLA solution). The resulting differences are smaller for the latter DTM, with differences mostly in the ±1 m range (shown in gray). For both images, north is up and east is to the right in an equirectangular projection.