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Mapping the Apollo 17 Astronauts' Positions Based on LROC Data and Apollo Surface Photography

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Abstract

The positions from where the Apollo 17 astronauts recorded panoramic image series, e.g. at the so-called "traverse stations", were precisely determined using ortho-images (0.5 m/pxl) as well as Digital Terrain Models (DTM) (1.5 m/pxl and 100 m/pxl) derived from Lunar Reconnaissance Orbiter Camera (LROC) data. Features imaged in the Apollo panoramas were identified in LROC ortho-images. Least-squares techniques were applied to angles measured in the panoramas to determine the astronaut's position to within the ortho-image pixel. The result of our investigation of Traverse Station 1 in the north-west of Steno Crater is presented.

1. Image Data Sets

To support scientific and operational experiments during three extra-vehicular activity (EVA) periods in the Taurus-Littrow-Valley the Apollo 17 astronauts took more than 2,200 images using a calibrated, photogrammetrically modified Hasselblad Data Camera. At all 9 stations along their traverse path they routinely recorded complete 360°-panoramic image series consisting of at least 15 frames. Back on earth, the assembled panorama mosaics allowed for the mapping of the traverse stations in the *Apollo 17 Traverses Lunar Photomap*, which to date serves as the only and hence the most accurate source available for the analysis of lunar surface operations.

Most recent, high-resolution image data provided by LROC's Narrow Angle Camera (LROC NAC) [2] allows for the reanalysis of lunar surface imagery (e.g. from Apollo missions) using modern, digital-based evaluation methods. From LROC NAC stereo-imagery a 1.5 m gridded DTM was derived covering an area of 3.2 km x 3.4 km around the Apollo 17 landing site. This was used for the rectification of a 0.5 m/pxl resolved LROC NAC ortho-image. Stereographic map projection centered at the approximate position of the astronaut whilst taking panorama images was used to preserve angles.

2. Precise Determination of Traverse Stations

Traverse Station 1 During EVA 1 (December 12, 1972) at 05:26 UTC the required 'Station 1 Pan' was obtained by astronaut J. Schmitt. It comprises of 33 frames depicting the surroundings of Station 1, located about 1.1 km south-east of the Lunar Module (LM). A completely assembled panorama mosaic as well as single frames (available on [1]) were used to determine azimuth angles between lunar landmarks such as rocks, crater rims, mountains, or anthropogenic objects unambigiously identifiable in LROC data.

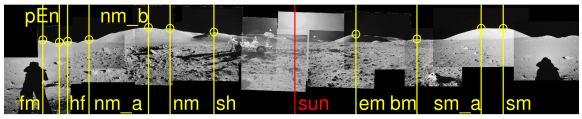

Figure 1: The assembled 'Station 1 Pan' with the measured azimuth angles to the summits of the mountains surrounding the Apollo 17 landing site. The labels are the initials of the mountains' names (source: [1]).

Initial Values Completely assembled, but slightly distorted 360°-panoramas taken from [1] met the accuracy required for a first-step, 100-m-scale positioning. Angles to the summits of adjacent mountains as well as to the sun were measured and pre-oriented towards North by using time and ephemeris data (see Figure 1). It was then plotted on the 100-m-raster DTM GLD100 [3] with heights chosen to be represented by colors and contour lines. The net of angles was slightly turned and shifted until, visually, a best possible fit was accomplished (see Figure 2). This provided initial values for the camera position and North Azimuth which helped to narrow down the search area in the 0.5-m-resolved LROC NAC ortho-image.

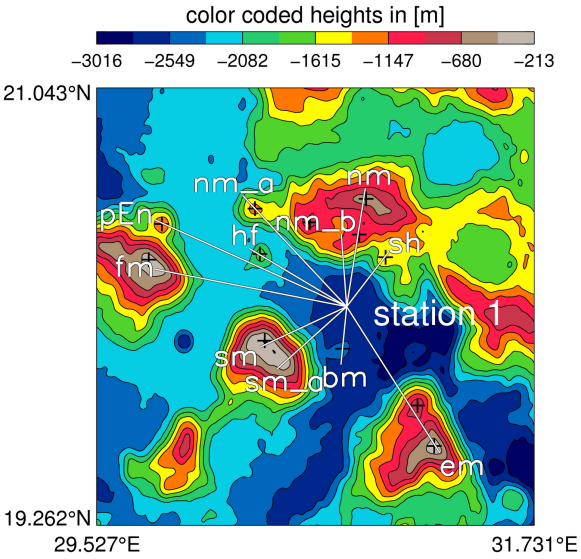

Figure 2: Azimuth angles at Station 1 to the summits of the mountains surrounding the Taurus-Littrow-Valley as measured in the 'Station 1 Pan' (plotted on a color-coded subset of GLD100). Elevations are referred to a zero vertical datum of 1,737.4 km.

Precise Coordinates For high accuracy measurements single frames were used to determine azimuth angles to 19 prominent objects in the vicinity of the astronaut's position. Angles measured in the overlapping areas of adjacent images show small differences up to 1-2° because of the astronaut's turns between the image acquisitions, manifesting in small changes of perspective. These discrepancies as well as measurement uncertainties were adjusted within a least-squares adjustment, best possibly fitting the observed angles to the appropriate reference points in the LROC NAC ortho-image. The position of the 'Station 1 Pan' was determined to be at 30.78616°E and 20.15647°N (related to the Mean Earth/Polar Axis (ME) Reference System) (see Figure 3). The point accuracy was assessed to be ±0.49 m and the accuracies of the adjusted North Azimuth angles are better than 0.5°.

3. Summary and Outlook

A procedure to determine the position from where an astronaut (or a roving vehicle) took images on the lunar surface is presented. The Apollo astronaut's position whilst taking the 'Station 1 Pan' was determined in LROC NAC ortho-images by applying a least-squares adjustment to the azimuth angles observed in the single panorama frames. Precise ME-

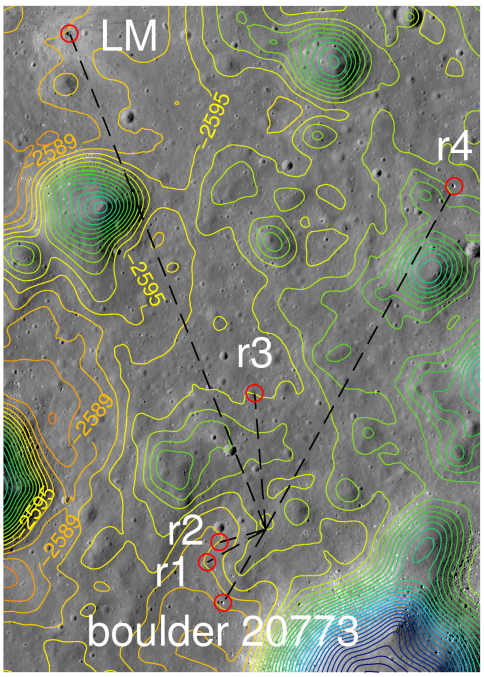

Figure 3: Adjusted North Azimuth angles of (selected) lunar landmarks radiating from the determined position of Station 1 (plotted on a LROC NAC ortho-image with an image resolution of 0.5 m/pxl). The distance between Station 1 and the LM is 1.119 km

Coordinates of the point of image acquisition as well as its accuracy is presented. Additionally, prominent surface features such as crater rims, boulders, and astronaut equipment imaged in the Apollo images are correctly identified in LROC NAC ortho-images.

In the further course of this study all 9 traverse stations and the ALSEP area as well as single frames recorded along the traverse path are going to be investigated using the described method. The precise positions of panorama stations will, inter alia, serve as a basis for a new, precise Apollo 17 Traverse Map.

References

[1] Jones, E. M., et al: Apollo Lunar Surface Journal, http://www.hq.nasa.gov/alsj/frame.html, current as of May 2011.

[2] Robinson, M. S., et al: Lunar Reconnaissance Orbiter Camera (LROC) Instrument Overview, Space Science Reviews, Vol. 150, pp. 81-124, 2010.

[3] Scholten, F., et al: GLD100 - The Global Lunar 100 Meter Raster DTM From LROC WAC Stereo Models, LPSC XLII, #2046, The Woodlands, Texas, 2011.