A new Traverse Map of the Apollo 17 Landing Site based on Lunar Reconnaissance Orbiter Camera (LROC) Images

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ABSTRACT:

From high-resolution LROC stereo imagery a 1.5 m raster DTM of the Apollo 17 landing site was processed and used for the rectification of a 0.5 m/pixel resolution LROC orthomosaic, the base of a new Apollo 17 Traverse Map at a scale of 1:15,000. To map the positions from where the Apollo 17 astronauts recorded panoramic image series, e.g. at the so-called “traverse stations” and at the ALSEP site, and to derive astronaut hardware and surface feature positions, Apollo surface photography as well as the LROC orthomosaic were used to determine accurate geolocations by applying least-squres adjustment techniques.

1. INTRODUCTION

High-resolution images of the lunar surface provided by the current Lunar Reconnaissance Orbiter (LRO) Mission enable us to (virtually) re-visit the places of previous lunar landings. Image resolutions of typically 50 cm/pixel and up to 25 cm/pixel in exceptional cases, along with favourable lighting conditions reveal smallest surface structures and features, e.g. astronaut remains, their foot tracks, Apollo Lunar Surface Experiment Package (ALSEP) instruments, rocks, etc. In conjunction with the great number of surface photography recorded by the astronauts to document their work, geologic sampling sites and the places they explored during their extravehicular activities (EVAs), the orbital images provide a mean to reconstruct astronaut positions by improving the cartographic context of their historic "on site" imagery.

2. LROC NAC DTM AND ORTHOMOSAIC

Stereo image pairs (0.5-1.3 m/pixel resolution) of the Taurus-Littrow Valley provided by the Lunar Reconnaissance Orbiter Camera Narrow Angle Camera (LROC NAC) (Robinson, 2010) were used to process a 1.5 m gridded Digital Terrain Model (DTM), see Figure 1. The DTM consists of 5 stereo models and was processed using the DLR Stereo Photogrammetric Processing System (Gwinner, 2009). The most recent SPICE kernels were integrated to account for gravity and temperature related influences on the position and pointing of the camera. The DTM was used to ortho-rectify 10 LROC NAC images of that area, which were combined to a 0.5 m/pixel orthomosaic. The ALSEP central station, which can be spotted in the image, was used for laterally referencing the orthomap to its coordinates as given by (Davies, 2000). For vertical control we co-registered the NAC DTM to the cross-over improved LOLA tracks available in that area (Gläser, 2013).

3. PANORAMA STATIONS AND TRAVERSES

The positions from where the Apollo 17 astronauts recorded panoramic image series were precisely determined by "tying" the historic astronaut imagery to the LROC NAC orthomosaic. Within a free network adjustment azimuth angles to prominent objects were observed in panoramic frames and fitted to reference points provided by the LROC NAC orthomosaic (Haase, 2012a). For each traverse station the positions of two to three panorama sites were determined as well the parking position of the Lunar Roving Vehicle (LRV), respectively. In the Traverse Map the LRV positions were chosen to define the locations of "traverse stations".
The astronauts' traverses between the nine stations were reconstructed by adapting the traverses taken from the NASA Apollo 17 Traverse Map (sheet 43D1S2(25)) published in 1975 by the Defense Mapping Agency Topographic Center (DMA TC).

4. ALSEP COMPONENTS AND EXPLOSIVE PACKAGES

By applying free network adjustments we determined the positions of the two panoramic image sequences, which were recorded by the astronauts at the ALSEP station (Haase, 2012b). Single frames of these panoramas provide stereo views to the ALSEP hardware allowing for forward ray intersection. This enabled us to derive accurate geolocations of all of the ALSEP components, even if the features are too small to be detected in the LROC NAC orthomosaic, e.g. the array of four Geophones and the antenna of the Lunar Seismic Profiling Experiment (LSPE).
To re-analyse LSPE data detected by the four Geophones, we determined and mapped the positions of the Explosive Packages (EPs) deployed by the astronauts along their traverses. Their locations, i. e. their detonations, are also not distinguishable in the NAC images. Therefore we used Apollo "locator" images and "rover pans" depicting the EPs to derive their positions by measuring angular directions and applying free network adjustments (Haase, 2013).

5. ORTHOMAP 1:15,000

To keep distortions small and to be consistent with the historic

Traverse Map, the LROC NAC image mosaic was projected in a Transverse Mercator Projection with true scale at 30.7°E (=central meridian). A sphere with R=1737.4 km was used as reference shape. The printed map has a scale of 1:15,000 and covers an area of about 14 km x 12 km of the Taurus-Littrow Valley, from 30.4294° to 30.9162° in longitude and from 19.9771° to 20.3639° in latitude. Planetocentric coordinates are related to the Mean Earth/Polar Axis (ME) lunar reference system, as recommended by the International Astronomical Union/International Association of Geodesy (IAU/IAG) Working Group on Cartographic Coordinates and Rotational Elements and according to LRO project standards. The map includes a graticule, contour lines with equidistances of 50 m, the astronauts' traverses and rover stops. IAU-approved as well as non IAU-approved, but commonly used feature names, e.g. craters, massifs, and mountains, are labeled. Center coordinates and diameters of named craters were re-measured for mapping purposes and for the provision of supplementary information.

6. OUTLOOK

Currently we work on large scale, individual Traverse Station maps and an ALSEP map to complete the Apollo 17 cartographic set. The traverse map and related data will be published via the Planetary Data System (PDS). In addition to the printable PDF version we will release geospatial data file formats, e.g. shapefile and .kml, for Geographic Information System (GIS) and Google Earth applications.

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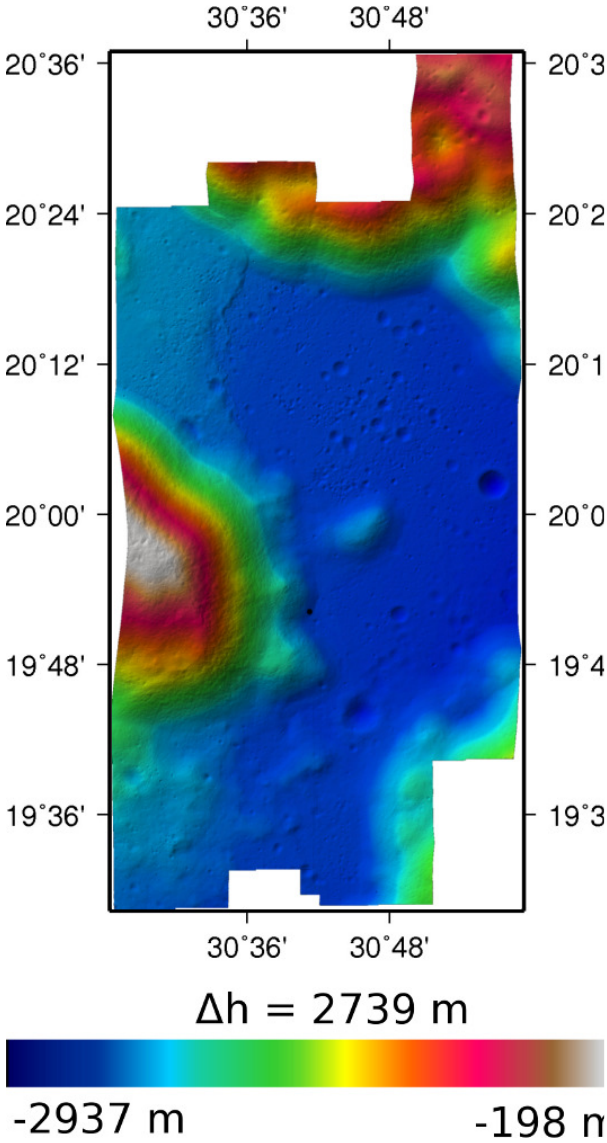

Figure 1: LROC NAC DTM (1.5 m/pixel) of the Apollo 17 landing site located in the Taurus-Littrow Valley on the southeastern edge of the Mare Serenitatis.