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Accurate Geolocation of Apollo 17 ALSEP Instruments

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Abstract

Accurate coordinates of the Apollo Lunar Surface Experiment Package (ALSEP) instruments were determined by an integrated analysis of Apollo 17 surface photography and Lunar Reconnaissance Orbiter Camera (LROC) images. Angular measurements made in the surface images were fitted to an LROC Narrow Angle Camera (NAC) orthoimage (0.25 m pixel scale) by least-squares techniques. We obtained camera and ALSEP instrument positions with respect to the lunar fixed Mean Earth/Polar Axis (ME) reference system. Coordinate accuracies were assessed to be within one LROC NAC pixel.

1. Introduction

On 12 December 1972, during their first Extra Vehicular Activity (EVA), the Apollo 17 astronauts deployed the ALSEP [1] ~190 m west of the lunar module (LM) Challenger. Approximate positions of the scientific instruments are known from maps based on surface photography and astronaut records (Figure 1). To provide an improved cartographic framework of the ALSEP site, we determined precise coordinates of the ALSEP components using historic surface photography in connection with high-resolution, orbital images provided by the Lunar Reconnaissance Orbiter (LRO) mission. This work supports analysis of existing in-situ observations recorded by the ALSEP instruments, e.g. seismic measurements made by the four Geophones (Geo1-Geo4) of the Lunar Seismic Profiling Experiment (LSPE).

Apollo Surface Imagery For photogrammetric analyses and documentation purposes, the astronauts recorded three panoramic image sequences at the ALSEP station (triangles in Figure 1) using calibrated Hasselblad cameras. Single frames of these panoramas, capturing surface features from different perspectives, were used to derive angular directions from the different camera positions to the ALSEP hardware, respectively (Figures 2 and 3).

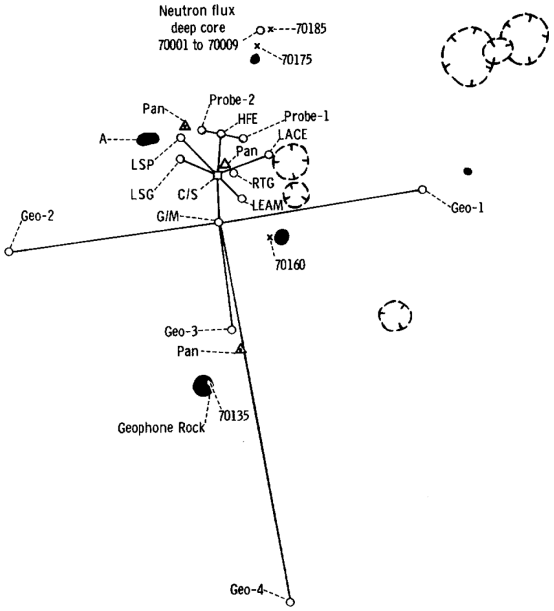

Figure 1: Planimetric Map of the ALSEP Area (source: [1])

LROC NAC Orthoimage In August, 2011, for a period of 28 days, LRO was maneuvered from its nominal 50±15 km polar orbit to a low-periapsis orbit. This allowed the on-board camera system LROC [2] to obtain images from altitudes as low as 22 km above the lunar sphere [3]. During that month the LROC NAC acquired a high resolution image (M168000580) of the Apollo 17 landing site. The pixel size in across-track direction is 0.27 m/pxl and 0.56 m/pxl in along-track (non-square pixels are due to limitations in exposure time). By means of an LROC NAC derived high-resolution Digital Terrain Model (DTM) of that area [4], the image was orthorectified and sampled to 0.25 m/pxl. The most accurate estimate of coordinates of the ALSEP's central station (CS) given by [5] were used to control the orthoimage to the ME-frame. Coordinates of key features, which were identified in the Hasselblad as well as the orbital image, were derived from the orthoimage and served as reference points in a network adjustment.

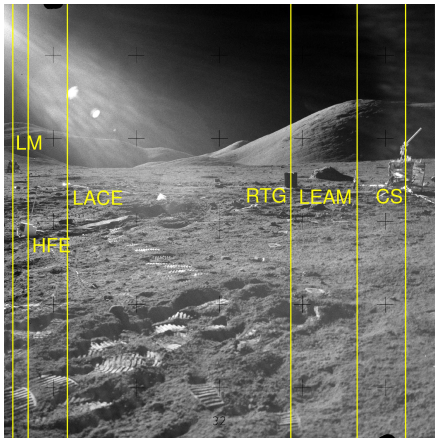

Figure 2: Frame AS17-136-20701 of the northwestern ALSEP panorama looking southeastward toward the ALSEP. The yellow lines depict image rows of identical directions.
(image source: http://www.hq.nasa.gov/alsj/frame.html)

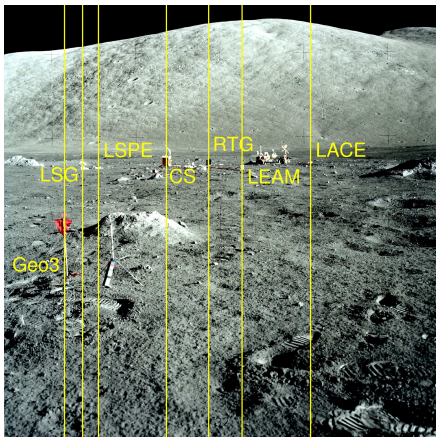

Figure 3: Frame AS17-147-22549 of the southernmost ALSEP panorama (acquired next to the Geophone Rock) enabled us to measure angular directions to nearly all of the instruments.

2. Method

The Hasselblad frames were used to derive angular directions from the point of image acquisition to a surface feature. Horizontal angles within the images were measured after deriving individual horizontal field-of-views (FOV) from the Hasselblad calibration data. Based on these angular measurements, three independent networks of directions were fitted to the reference points provided by the LROC NAC orthoimage. The networks intersect at those feature locations, which were observed from different

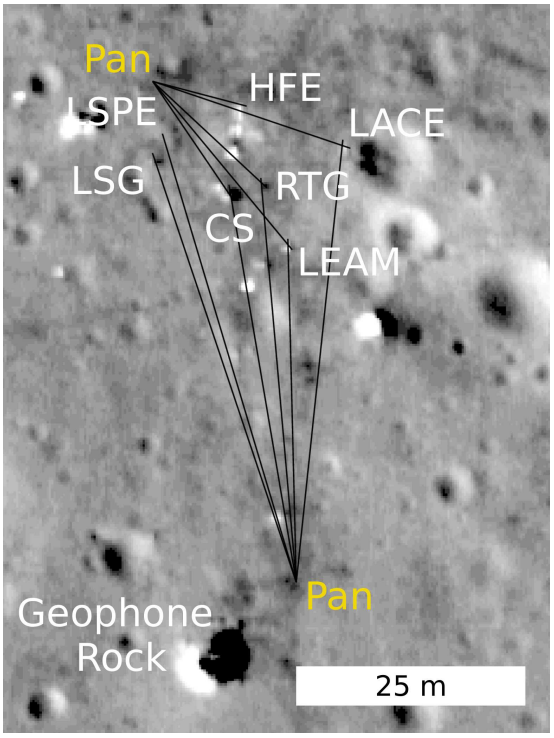

Figure 4: Angular measurements from Figures 2 and 3 were plotted onto the LROC NAC orthoimage (M168000580). In this sample plot, positions of four ALSEP instruments (CS, RTG, LEAM, and LACE) were clearly identified by ray-intersection (image: NASA/GSFS/ASU/TUB).

astronaut positions (Figure 4). Coordinates of the individual ALSEP instruments, astronaut positions and accuracies were assessed within a free network adjustment. Initial coordinates for the unknown camera and instrument locations were provided by [4] and the LROC NAC orthoimage.

6. Summary

Precise ME-coordinates of Apollo 17 astronaut and ALSEP instrument positions were determined at 25-cm level on the basis of high-resolution LROC NAC orthoimages and Apollo Hasselblad frames.

[1] Wolfe, E. W. et al (1981), USGS Prof. Paper, #1080 [2] Robinson, M. S. et al (2010), Spa. Sci. Rev., doi: 10.1007/s11214-010-9634-2 [3] Archinal, B. A. et al (2011), Celest. Mech. Dyn. Astr., doi:10.1007/s10569-010-9320-4. [4] Haase, I. et al (2012), *J. Geophys. Res.*, doi: 10.1029/2011JE003908 [5] Davies and Colvin (2000), J. Geophys. Res., doi:10.1029/1999JE001165