

ArcGIS DIGITIZATION OF APOLLO SURFACE TRAVERSES. N. E. Petro¹, J. E. Bleacher¹, L. R. Gaddis², W. B. Garry³, S. C. Mest^{1,3}, F. Lam⁴. ¹NASA/GSFC, Code 698, Greenbelt, MD, 20771, ²USGS Astrogeology, Flagstaff, AZ, ³Planetary Science Institute, Tucson, AZ, ⁴Richard Montgomery H.S., Rockville, MD. (Noah.E.Petro@nasa.gov)

Introduction: The Apollo surface activities were documented in extraordinary detail, with every action performed by the astronauts while on the surface recorded either in photo, audio, film, or by written testimony [1]. The samples and *in situ* measurements the astronauts collected while on the lunar surface have shaped our understanding of the geologic history of the Moon, and the earliest history and evolution of the inner Solar System. As part of an ongoing LASER-funded effort, we are digitizing and georeferencing data from astronaut traverses and spatially associating them to available, co-registered remote sensing data. Here we introduce the products produced so far for Apollo 15, 16, and 17 missions.

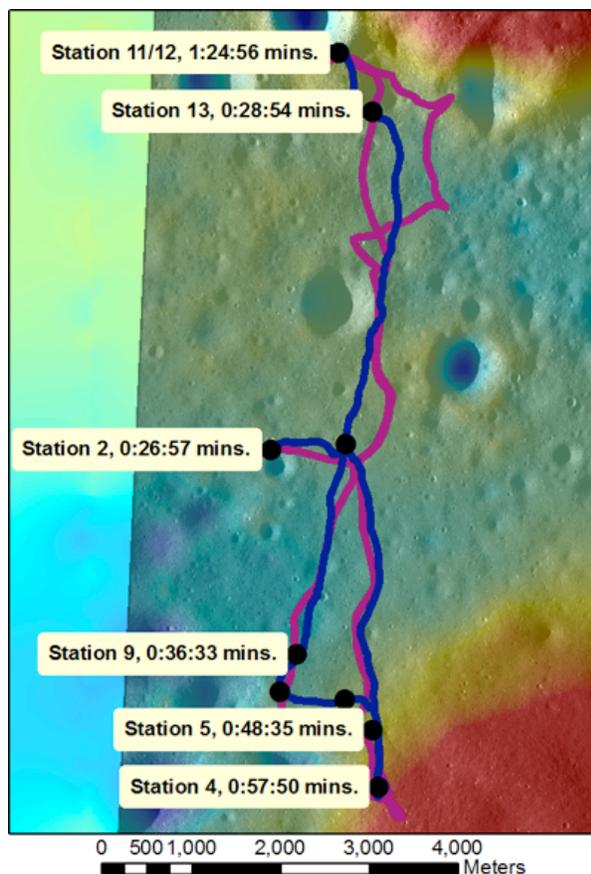


Figure 1. Planned (magenta) and actual (blue) Apollo 16 traverses [2] with Station locations and stay times identified. At higher resolution, additional detail is available (Figure 2). Image base is LRO NAC frame M102064759R tied to LOLA gridded topography.

Digitizing and georeferencing Apollo surface traverse information with existing remote sensing data not only archives and centralizes EVA data and documentation; it also enables us to expand our understanding of their spatial and compositional context. In light of NASA's ongoing terrestrial field testing and planning for future *in situ* exploration, the georeferenced traverse and ancillary data are timely in that they enable us to examine the Apollo traverses using modern analysis tools, which in turn provides context for how we will assess ongoing field technology tests.

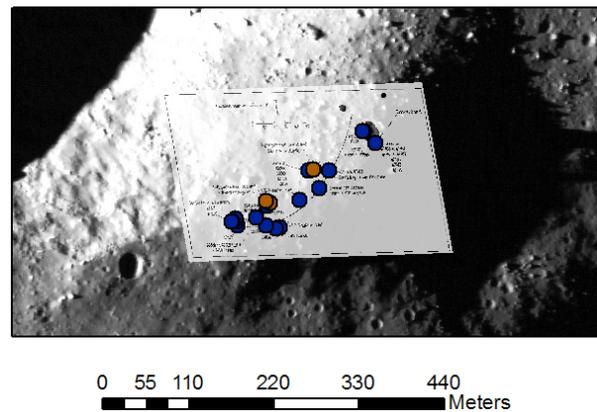


Figure 2. Detail of Apollo 16 Station 11/12 on the south rim North Ray crater showing locations of panoramas (orange dots) and individual sample sites (blue dots). Base image is LRO NAC frame M102064759R.

Archiving and Digitizing Traverse Data: The digitization of Apollo traverse data requires that base images and traverse maps (Figure 1) be imported into ArcGIS, and then geometrically rectified to a controlled base map. We have been using a high-resolution LOLA gridded topographic map (March 2011 PDS Delivery), as a well-controlled geodetic base. In part because they have the highest available spatial resolution (~0.25 to 1.5 m/pixel), we incorporate the publicly released Lunar Reconnaissance Orbiter Camera (LROC) narrow-angle camera (NAC) images of the Apollo landing sites as our working base images (Figures 1 and 2).

After calibrating and rectifying LROC frames in ISIS, the georeferenced NAC images are exported as JPEG 2000 files into ArcGIS and then tied to the

LOLA base. Digitized versions of the Apollo traverses and station maps [1] are rectified and then ‘sketched’ by adding digital polylines and points. Individual legs of each EVA are independent, so that detailed attribute data (start and stop times, duration, total distance) can be directly tied to each segment of a traverse. Stay times and other information at each station are recorded at each station point (Figure 1). Detailed timelines for the Apollo missions are available in multiple formats [1, 5], and we have mined these data for the times and locations that represent major EVA events (start and stop times, driving times, etc.).

Detailed station maps [e.g., 6] are registered to the LROC base image so that specific sampling sites, photograph locations, and experiment sites can be accurately identified (Figure 2). At each station, individual panorama/photograph and sample locations contain detailed ancillary information (e.g., hotlinks to images (Figure 3), links to the lunar sample compendium [7], additional sample information [8]).

For Apollo 16, the distances of traverses as calculated in ArcGIS are shorter than reported or measured on the surface [3]. This discrepancy is largely due to the detail available in existing traverse maps [3] that neglect small-scale deviations (driving around boulders and small craters for example). Finer scale definition of the LRV traverse paths [e.g., 4] will add detail not available in the earlier traverse maps. Incorporating higher fidelity tracking information will likely make measurements of the total distance align closer to the “odometer” distances reported (Table 1).

Ultimately, such discrepancies are valuable inputs into planning future surface operations; if a future planned route is measured at 20 km round trip, we might expect a 15% or 3 km margin (based on the difference between measured *and reported*). *Ultimately comparisons of all Apollo missions* traverse data will provide a robust assessment of how much fine-scale navigability is necessary on the lunar surface.

Analyses Enabled by Digitized Apollo Traverses: The digitization of Apollo surface traverses provides a lasting digital record of surface operations and serves as a source of comparison for terrestrial analog efforts. The Exploration Analogs and Mission Field Testing project was initiated by NASA HQ to ensure two things. One, to apply a rigorous approach and the consistent use of operational products, tools, methods and metrics across all NASA analog activities to enable iterative development, testing, analysis, and validation of evolving operations concepts. Two, to provide input into detailed EVA and surface operations analysis, development of assembly, maintenance and science tasks for selected architecture

scenarios. Ultimately, a single source of Apollo surface resources such as the GIS project developed here will provide valuable input into assessing analogue activities here on Earth.

Table 1. EVA Distances (in kilometers) as Measured in ArcGIS or Previously Reported.

EVA	ArcGIS Measured Distance	Odometer Distance [3]	Reported Distance [5]	Pre-Mission Planned Distance
1	3.44	4.2	4.2	3.2
2	9.31	11.3	11.3	9.7
3	10.06	11.1	11.5	12.5
Total	22.81	26.6	27.0	25.4

Availability for Community Use and Request For Input: Thus far the surface traverses for Apollo 15, 16, and 17 have been digitized in ArcGIS. With the growth and availability of public data sharing forums [9, 10] it has become simpler to share ArcGIS projects across computers. We will make beta versions of our traverse project available on these digital archives for community feedback and input into what would be most useful for the science and engineering communities.

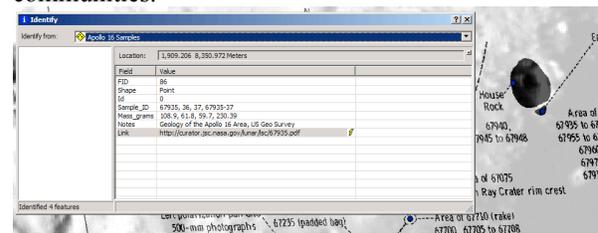


Figure 3. Example of metadata associated with the sample point for 67035 at Station 11/12. In addition to sample ID, mass, and notes, a link to the JSC Curatorial website.

Acknowledgements: We thank the NASA LASER program and the National Space Club Scholar Program for supporting this effort.

References: [1] Apollo Lunar Surface Journal, (<http://history.nasa.gov/alsj/frame.html>). [2] Ulrich, G. E., et al., (1981) Geology of the Apollo 16 Area, Central Lunar Highlands, Prof. Pap. 1048, 539. [3] Smith, E. C. and W. C. Mastin, (1973) *NASA Technical Note*, NASA TN D-7469. [4] Haase, I., et al., (2011) Mapping the Apollo 17 Astronauts' Positions Based on LROC Data and Apollo Surface Photography, EPSC-DPS Meeting 2011, 450. [5] Orloff, R. W., (2004) *Apollo By The Numbers: A Statistical Reference*, 348 p. [6] Ulrich, G. E., et al., (1981) *Geology of the Apollo 16 area, Central Lunar Highlands*. [7] Lunar Sample Compendium, (<http://curator.jsc.nasa.gov/lunar/compdium.cfm>). [8] Petro, N. E., et al., (2011) Digitization and Reanalysis of Apollo Surface Traverses, LPSC 42, 2032. [9] USGS Planetary GIS Web Server, (<http://webgis.wr.usgs.gov/>). [10] Bailen, M., et al., (2012) Astropedia - A Data Portal for the USGS Astrogeology Science Center, This volume.