APOLLO 16 AND 17 SPATIO-TEMPORAL TRAVERSE MAPPING. T. A. Roseborough[1], N. R. Gonzales[1], A. R. Schoonover[1], V. Tewary[1], J. A. Woody[1], M. L. Bouwens[1], K. B. Patel[1], G. Sondrup[1], R. W. Wagner[1], M. R. Henriksen[1], J. R. Leland[1], M. S. Robinson[1], [1]School of Earth and Space Exploration, Arizona State University, P.O. Box 873603, Tempe, AZ 85287 (vroseborough@ser.asu.edu)

Introduction: Apollo 16 and 17 were the final human exploration missions to the Moon. With renewed interest in a human return to the Moon, the Apollo missions have more relevance than ever. Using a combination of Lunar Reconnaissance Orbiter Camera (LROC) images and Apollo mission data, we derived spatio-temporal traverse maps of astronaut and rover movements for the Apollo 16 and 17 missions.

Data Sources: As with our spatio-temporal maps for previous missions [1-3], we used photo, video, and audio data from the Apollo missions [4,5], as well as mission documents such as the Lunar Surface Procedures (LSP) [6,7] and press kits [8,9]. Initial traverse mapping was guided by previous efforts [10-15].

Apollo 16. Apollo 16 did not have synchronized audio [16] and video [17] files; we performed this synchronization ourselves. In addition to the above references, Brian McInall mapped rover and astronaut traverses near the LM and at selected stations, available at [18].

Apollo 17. Apollo 17 had three additional resources: [19,20], which identified station, equipment, sample, and photograph locations, as well as [21], which combined mission video, transcripts, and photography to give a real-time look at the mission [22].

Methods: Following the methodology described in [1,2,3] for previous missions, we mapped onto the LROC Narrow Angle Camera (NAC) 50 cm orthomosaic and 60 cm orthomosaic from the Apollo 16 and 17 landing site digital terrain models (DTMs), respectively [23]. To amplify the astronaut tracks in our available 25 cm sampled NAC images, we aligned a set of overlapping images and took a pixel-by-pixel average.

Astronaut traverses. Using a combination of high-resolution images and mission data and reconstructions from [4,5,21], we identified each moment that an astronaut moved to a new position on the surface, and placed a path between consecutive points. If tracks were visible in the image maps, we mapped them accordingly; if not, we assumed a straight path between points, except in cases where the astronauts would have needed to circumnavigate blocks or equipment.

Rover traverses. We verified rover paths and, in some cases, adjusted from those presented in [10-15] by identifying rover tracks from images with varying incidence and phase angles. Most changes were near the Lunar Modules (LM), including the Apollo 16 "Grand Prix," and the Apollo 17 EVA 1 start and end.

Uncertainties: Temporal uncertainty was estimated from the differences between the timestamps of audio recordings synchronized to the videos and the transcript timestamps [4] and is estimated to have a maximum of 100s for Apollo 16, and 30s for Apollo 17.

We determined spatial uncertainty through comparison with equipment locations in [24]; for Apollo 16, it was up to 3.4 m latitudinally and 2.5 m longitudinally. The Apollo 17 spatial error was up to 4.1 m latitudinally and 5.6 m longitudinally. We have not determined how this uncertainty changes further from the LM.

Rover tracks fall into two categories: observable and approximated. The observed tracks, identifiable in NAC images, are accurate within the uncertainty of the basemaps. The approximated tracks are represented by straight lines, though may have some bends to avoid geographic obstacles. For Apollo 16, the longest stretch of approximated track is ~43 m; for Apollo 17, where the tracks are less visible due to the nature of the underlying regolith, it is ~477 m. To estimate the spatial uncertainty of the approximated tracks, we measured deviation in a straight-line stretch of known tracks of similar length to these longest approximated tracks. These deviations were ~9% for Apollo 16 and ~12% for Apollo 17.

The rover traverse timing was interpolated assuming a constant rover velocity. These calculations assume that locations and transcript times are accurate for the associated timestamps.

Summary: New spatio-temporal maps of the two final Apollo missions with accurate placements of samples, images and equipment allows for detailed studies of the data collected during these missions, but would also aid in geologic mapping and future mission planning. Interactive versions of these maps are available online at [25] and [26].

References: [1] Gonzales et al. (2019) *LPS L,* Abs. #3089. [2] Gonzales et al. (2020) *LPS LI,* Abs. #1578. [3] Gonzales et al. (2022) *LPS LIII,* Abs. #2672. [4] ALSJ (https://www.hq.nasa.gov/alsj/main.html). [5] March to the Moon (http://tothemoon.ser.asu.edu/gallery/Apollo). [6] Apollo 16 LSP (https://www.hq.nasa.gov/alsj/a16/a16flsp.pdf). [7] Apollo 17 LSP (https://www.hq.nasa.gov/alsj/a17/a17lsp-HSI208994.pdf). [8] Apollo 16 Press Kit (1972) Release No.: 72-64K. [9] Apollo 17 Press Kit (1972) Release No.: 72-220K. [10] Apollo 16 PSR (1972) NASA SP-315. [11] Apollo 17 PSR (1973) NASA SP-330. [12] USGS Professional Paper 1048 (1981) [13] USGS Professional Paper 1080 (1981) [14] Stooke (2018) *LPS IL,* Abs. #1007. [15] Stooke (2020) *LPS LI,* Abstract #1001. [16] NASA JSC (2010) (https://archive.org/details/Apollo16). [17] NASA JSC, Apollo Film Archives, Vol. 2 [18] Apollo 16 ALSJ Image Library (https://www.hq.nasa.gov/alsj/a16/images16.html). [19] Haase, I. et al. (2018) *Earth Space Sci., 6,* 59-95. [20] Haase, I. et al. (2012) *J. Geophys. Res. Planets, 117,* E00H20. [21]

Apollo 17 in Real Time (https://apolloinrealtime.org/17/). [22] Feist et al. (2018) *LPSC IL*, Abs #2681. [23] Henriksen et al. (2017) *Icarus, 283,* 122-137. [24] Wagner et al. (2017) *Icarus, 283,* 90-103. [25] Apollo 16 Temporal Traverse Map (https://www.lroc.asu.edu/featured_sites/view_site/66). [26] Apollo 17 Temporal Traverse Map (https://www.lroc.asu.edu/featured_sites/view_site/67).

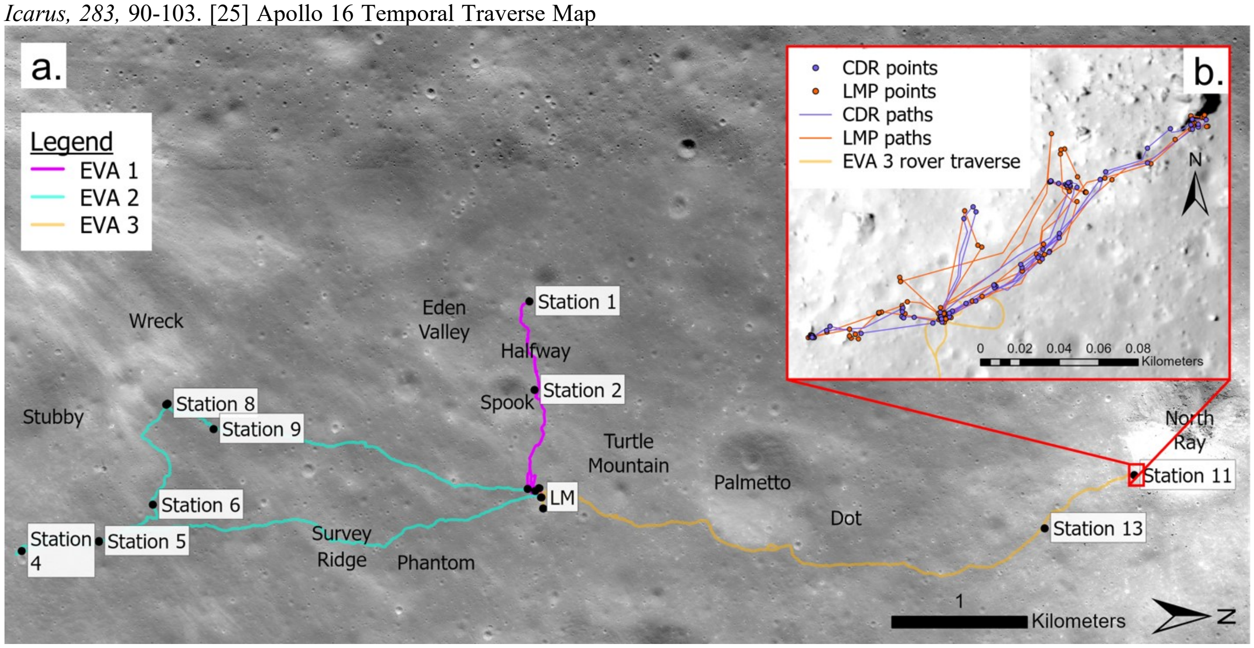

Fig. 1 a. Apollo 16 spatio-temporal traverse map. Note the north arrow pointing to the right. **b.** Station 11 mapping, with the commander ("CDR") and lunar module pilot ("LMP") traverses, as well as the rover traverse. Note the north arrow pointing up.

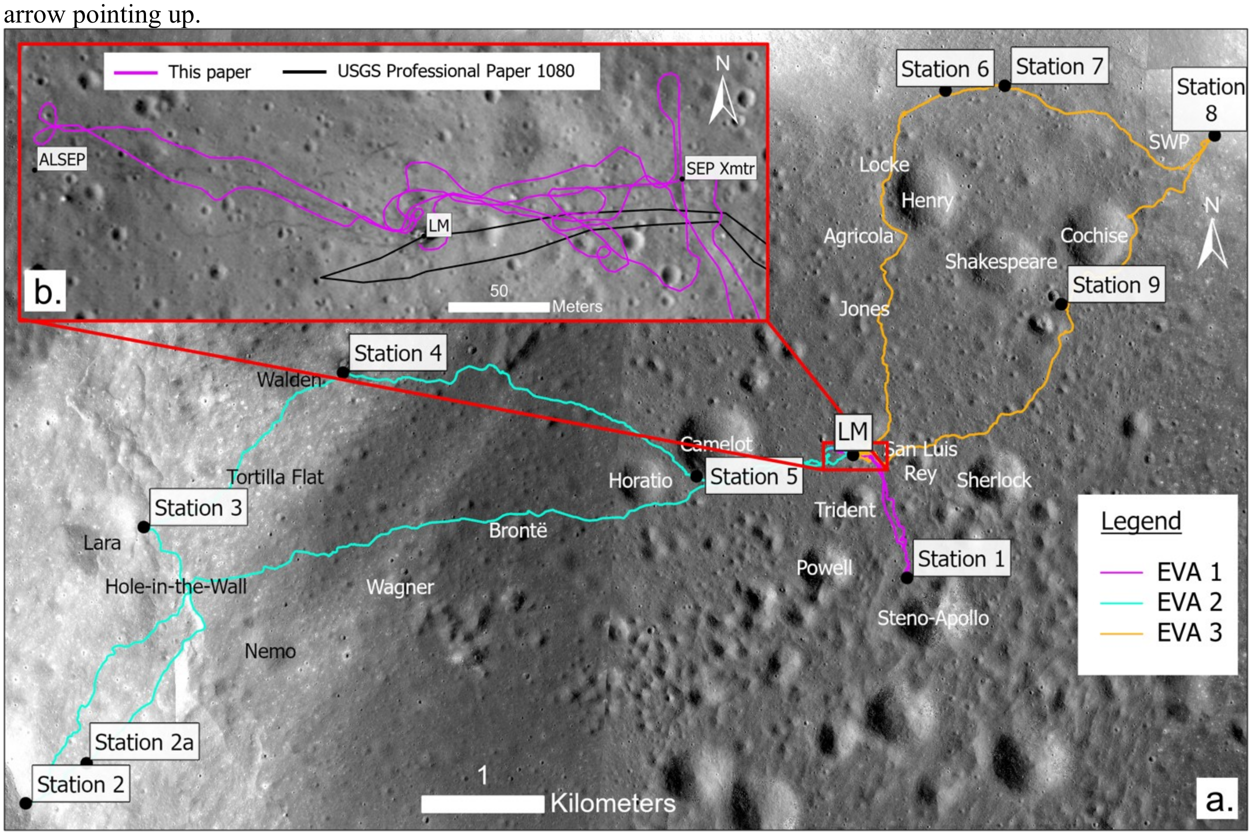

Fig. 2 a. Apollo 17 spatio-temporal traverse map. **b.** Comparison of our EVA 1 rover traverses around the LM (fuchsia) with those presented in [13] (black). We identified past track locations by examining Apollo 17 photos, video, and transcripts [4,5,21] in conjunction with LROC NAC basemap images.