IN THE FOOTSTEPS OF THE FIRST: APOLLO 14 SPATIOTEMPORAL MAP. N.R. Gonzales[1], J.A. Schulte[1], and M.S. Robinson[1], [1]School of Earth and Space Exploration, Arizona State University, Tempe, AZ 85287 (ngonzales@ser.asu.edu, jschulte@ser.asu.edu).

Background: On February 5th, 1971, the first American in space become the first human to set foot on the lunar highlands. Nearly a year after Apollo 12 had proven it was possible to land within one km of a target site, Apollo 14 became the first mission to venture into a more difficult landing zone, amidst the hummocky Fra Mauro terrain.

Once there, astronauts Alan Shepard and Ed Mitchell would spend two EVAs (Extravehicular Activities) - each approximately 4 hours long - setting up the Apollo Lunar Surface Experiment Package (ALSEP) with experiments not used on prior missions, hiking across the rolling lunar hills towards Cone Crater, and getting in some memorable golf shots.

Introduction: Piecing together the geologic history of the area, and learning what it is like to explore the Moon from an astronaut's perspective, requires precise knowledge of sample and photo sites, as well as an understanding of the equipment used. By using a minute-by-minute approach we created a spatiotemporal map [1] (Fig. 1) that documents where the astronauts were and what they were doing at any given time. We also produced shapefiles that document equipment, sample, and photo sites, as well as geologic observations. The minute-by-minute approach also allows a closer view of challenges the lunar environment posed for the astronauts, and what can be improved upon when we return.

Methodology: As an extension of the Apollo 11 and 12 works [2,3], this Apollo 14 spatiotemporal map uses the same process, and types of sources (mission reports [4-7] and prior studies [8]) with two exceptions. One: Python scripts were used to collect and format transcript data from [9] to allow for a more complete record of the timeline of the mission activities, and to speed up the mapping process. Two: similar to Apollo 11, but not 12, the data from the Passive Seismic Experiment (PSE) has not been incorporated.

To partially automate Apollo 14 data collection and organization, two web-scraping scripts were written using Python. The first script retrieved and organized the transcripts found in [9] to allow the authors to connect the timing of events with spatial data, sample, and photographic details. The second script downloaded and cataloged TV and 16mm Data Acquisition Camera (DAC) footage from [9] so that gaps in the footage could be identified and one complete, continuous video of each EVA could be reconstructed.

It should be noted that, like Apollo 12, much of Apollo 14 occurred out of view of the TV or DAC cameras. The TV cameras used on early Apollo missions were wired directly into the Lunar Module (LM) and thus not portable, until the introduction of the transmitter equipped Lunar Roving Vehicle (LRV) on Apollo 15. Because the TV camera was stationary, a significant part of 14 activities were not caught on video. The EVA-2 trek to Cone Crater was mostly out of TV camera view, and the DAC was not in use.

Error Analysis. The traverse shapefiles inherit the accuracy of the NAC controlled images used as basemaps. These images were controlled to the PSE location in the NAC digital terrain model [10], and the LM and PSE locations match [11] to within 0.8 m in latitude and 0.6 m in longitude, which is within the confidence intervals of [11]. This mission did not focus on video and photo documentation of astronaut activities as much as later missions. Also, the geology stations have more tasks and therefore the astronauts moved around more at each station than in [2,3]. Thus, each mapped shapefile point is precise to within 1 m when video of activities exists, or has a 5 m (EVA-1) or 8 m (EVA-2) max radius of error without video.

Audio and video footage were reassembled to support the mapping of the astronaut locations. The audio [12] was used as the anchor to assemble the video clips into one long video and calculate the timing of events. We found that the audio tracks from [12] were digitized at a slightly faster speed than they were recorded and have an average discrepancy of 40 seconds with a max discrepancy of 60 s, when compared to the transcript [9]. As was done on Apollo 12 [3], the audio (including dialog and non-verbal sounds) [12] was used to calculate the timing of events within a few minutes of the nearest transcript dialog [9] to ensure any discrepancies would only result in short timing errors of +/-1 minute. The video clips [9,13,14] were of varying resolution quality and were therefore only used to determine approximate locations.

Results, Conclusions, and Future Work: By mapping the events minute-by-minute, we can more accurately determine locations and timings of events, particularly when the activities were not within view of the TV or DAC cameras. For example, tracking when a shovel was retrieved from the Mobile Equipment Transporter (MET), or making note of when a microphone bumps a helmet interior, we can determine where the astronauts were at a given time. This detailed mapping process enables a complete analysis of what worked and what did not during the Apollo traverses, providing information with respect to similar issues Artemis planners may face, such as dust mitigation, mobility, and effectiveness of tools.

For example, the difficulties astronauts faced when using the wheelbarrow-like MET on Apollo 14 provided a clear indicator of which tracks seen in the NAC images were left behind by which astronaut. The astronaut carting the MET had to travel slowly to prevent the loss of equipment or samples when the MET bounced, got stuck in soft regolith, traveled uphill, or if they changed direction. The faster an astronaut travels, the more dust they kick up and the darker and wider their track appears in the Hasselblad [9,15] and NAC images (Fig. 1). When they are travelling between stations, identifying which astronaut was pulling the MET, helped determine which tracks were from which astronaut. When both astronauts carried the MET together, the single set of tracks appear darker and wider.

Similar difficulties were faced on Apollo 12, when using the bucket-like Hand Tool Carrier (HTC), though the softness of the regolith meant that the astronaut carrying the HTC often also kicked up a lot of dust, and the tracks were not as easily identifiable. In contrast, the Surveyor Parts Bag (SPB) – a backpack-like attachment for their Portable Life Support System (PLSS) used on Apollo 12 – left the center of gravity of the astronaut closer to their body, which was easier to control, and allowed them to move freely, without needing to work against the inertia of a tool and sample carrier. Notably, PLSS-attached tool and sample carriers were the only type of human-carried containers that did not make walking more difficult for the astronaut.

The spatiotemporal traverse maps of Apollo 14 are available on the LROC website [1]. Maps of Apollos 15 and 16 are in the works. Efforts to develop a new list of lessons learned during the Apollo missions are also underway.

References: [1] Apollo 14 Temporal Map (http://lroc.sese.asu.edu/featured_sites/view_site/62). [2] Gonzales et al. (2019) LPSC L, Abs. #3089. [3] Gonzales et al. (2020) LPSC LI, Abs. #1578. [4] Apollo 14 Preliminary Science Report (1971) NASA SP-272. [5] Apollo 14 Mission Report (1971) MSC-04112. [6] Apollo 14 Press Kit (1971) Release No.: 71-3k. [7] Apollo 14 Lunar Surface Procedures (1970) MSC-3195-71. [8] McInall, B. Apollo 14 EVA-1 Traverse Map – in progress. [9] ALSJ, (https://www.hq.nasa.gov/alsj/a14/a14.html). [10] Henriksen et al. (2015) PDW II, Abs. #7033. [11] Wagner et al. (2017) Icarus, 283, 90-103. [12] NASA JSC (2010) (https://archive.org/details/Apollo14). [13] NASA JSC, Apollo Film Archives, Vol. 2. [14] Gray (2002) (http://spacehistory.tv/blog/?page_id=66). [15] (http://tothemoon.ser.asu.edu/gallery/apollo).

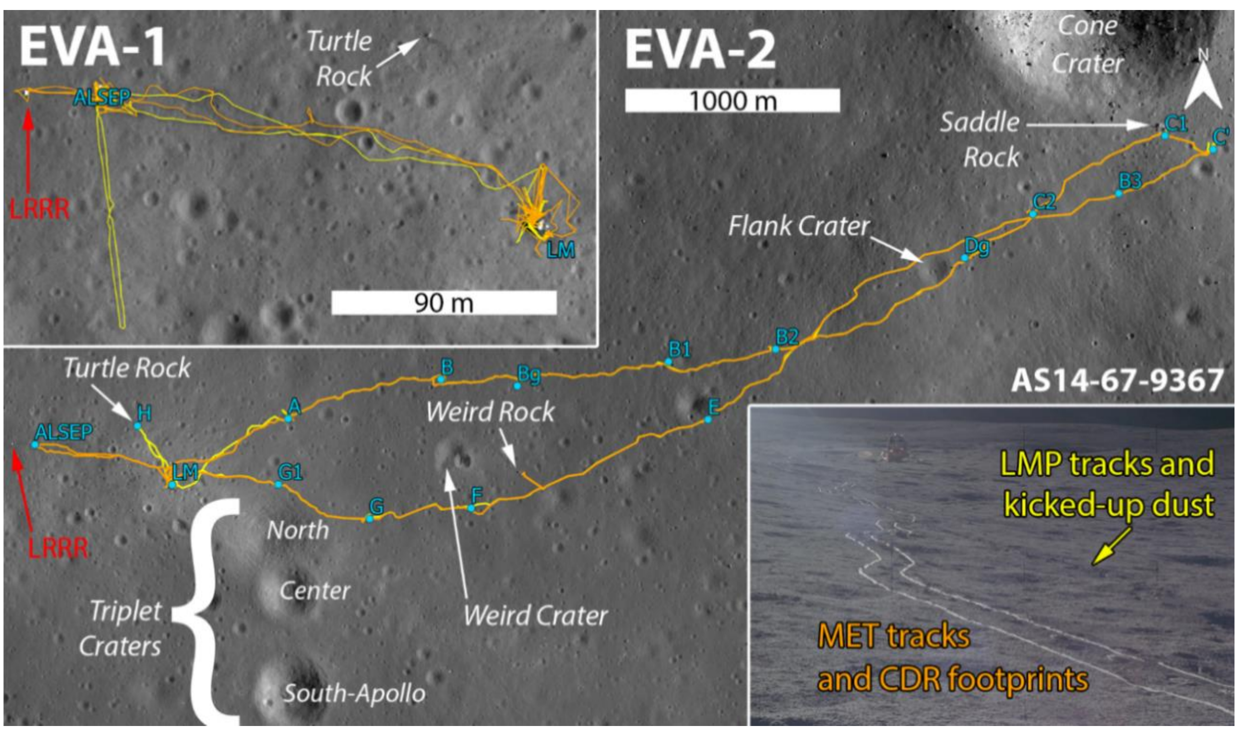

Figure 1. Both EVAs are shown on NAC image M114071006L, along with the astronaut-named features (white italics), geologic stations (teal blue) [4-7] visited in alphabetical order, and the Laser Ranging Retroreflector (LRRR). Orange traverse is the path of Commander (CDR) Shepard; yellow is that of the LM Pilot (LMP) Mitchell. Lower right inset image is a cropped version of Hasselblad photo AS14-67-9367 [9] from EVA-1 near the ALSEP site, looking ESE towards the LM. Note the kicked-up dust around the footprints of the astronaut that was not pulling the MET, indicating they were travelling at speed.