PEDAL TO THE METAL: APOLLO 15 SPATIOTEMPORAL MAPPING OF ACT II OF MANNED LUNAR EXPLORATION. N. R. Gonzales[1], J. A. Schulte[1], V. Tewary[1], A. R. Schoonover[1], T. A. Roseborough[1], M. R. Henriksen[1], M. S. Robinson[1], [1]School of Earth and Space Exploration, Arizona State University, Tempe, Az 85287 (ngonzales@ser.asu.edu).

Introduction: Apollo 15 was the first-time humans stood at the precipice of a sinuous rille on a terrestrial world that was not Earth! This was the first time tire tracks from a Lunar Roving Vehicle (LRV) accompanied human footprints. It was the LRV that opened the doors to a new type of lunar exploration, allowing astronauts Commander (CDR) David Scott and Lunar Module Pilot (LMP) James Irwin to explore more in less time than ever before. Apollo 15 alone provided scientists with samples and photos of an area larger than all three prior Moon landings combined! This time around, the astronauts would step outside the spaceship three times: for one 6-hour, one 7-hour, and one 4.5-hour excursion [1].

Methods: The goal of this map was to take all the individual pieces of data (samples, photos, transcripts, mission reports, LRV parking spots, mobile and stationary equipment locations, etc.) and map them in chronological order to recreate the finite details and more accurately map the coordinates of each activity. Mapping each activity in chronological order and in context with all other activities at each station increases the accuracy of each coordinate. We incorporated the original Apollo data [2-6] and prior works that reconstructed traverse activities [1,7-9] into this map, making this the most detailed map, to date. We developed the spatiotemporal traverses for each astronaut using the same process as [10-12]. The individual astronaut traverses only include the areas where the astronauts were on foot. We also mapped the location and orientation of the LRV parking spots where astronauts would interact with the LRV (loading and unloading equipment and samples) for every station (see Fig. 1 for LRV polygons).

The finished LRV tracks (seen in Fig. 1) are a modified version of the LRV tracks from [7]. The LRV parking spots are the point of commonality between the astronaut and LRV traverses. As such, we adjusted the LRV traverses from [7] to match the parking spots marked while mapping the individual astronaut traverses (see Fig. 1). The modified LRV traverses are used on the Lunar Reconnaissance Orbiter Camera (LROC) website [13].

We received the LRV traverses from [7] as an annotated photo. The tracks were then made into shapefiles, and timestamps were added to each point of dialog, parking spot, and geologic feature that [7] marked along the tracks. Then, we linearly interpolated the timing for LRV movements between the temporal markers.

Error Analysis: Astronaut traverse (latitude, longitude, time) uncertainties remain the same as [10-12], however this time the equipment used by the Apollo astronauts was different. The LRV had a color television camera that was controlled by an operator in Houston [2]. The astronauts used the Data Acquisition Camera (DAC; 16 mm movie film) occasionally, but not as often as prior missions.

Temporal accuracy of the astronaut traverses was determined by comparing the offset between the audio tracks [3] and the transcripts [1]. We estimate time uncertainty to range from 1-225 s.

To determine the spatial accuracy of the astronaut traverses, we measured the coordinates of the LM, Passive Seismic Experiment (PSE), LRV, and a few boulders at stations farthest from the LM in each NAC image. These coordinates were then compared to coordinates in [14], which produced an error of 0.41 m +/-0.27 m latitudinally, and 2.69 m +/-0.53 m longitudinally. The farther the astronauts travel from the Lunar Module (LM), the less accurate the coordinates are.

The spatial accuracy of the LRV can be divided into two categories: 1) interpolated, and 2) tracks seen in NAC images. The tracks seen in NAC images are accurate to the basemaps. When tracks were not visible, we interpolated them as straight lines. To estimate accuracy, we compared the longest stretch of interpolated tracks (~315 m) to a straight stretch of tracks seen in the NAC images of the same approximate length. Of the tracks seen in the NAC images, the max deviation from the roughly straight path is approximately +/-23 m.

The LRV traverse timestamps are only as accurate as the transcripts [1], from which they were derived. However, the LRV traverses assume that the LRV was traveling at a constant speed between each point.

Conclusions: Reconstructing as many “steps” as possible, pun intended, has allowed us to place the astronauts, rover, samples, and photos, to within 3 m and 225 s. Increasing the accuracy of the sample, photo, and mobile equipment site coordinates from those found in the Preliminary Science Report [4] allows for more detailed studies of the regolith samples [15], aids geologic mapping [16], and supports future landed mission planning.

An interactive version of these spatiotemporal traverse maps for Apollo 15 is now available on the LROC website [13]!

References: [1] ALSJ (https://www.hq.nasa.gov/alsj/a15/a15.html). [2] Lunar Roving Vehicle Operations Handbook, July Revision

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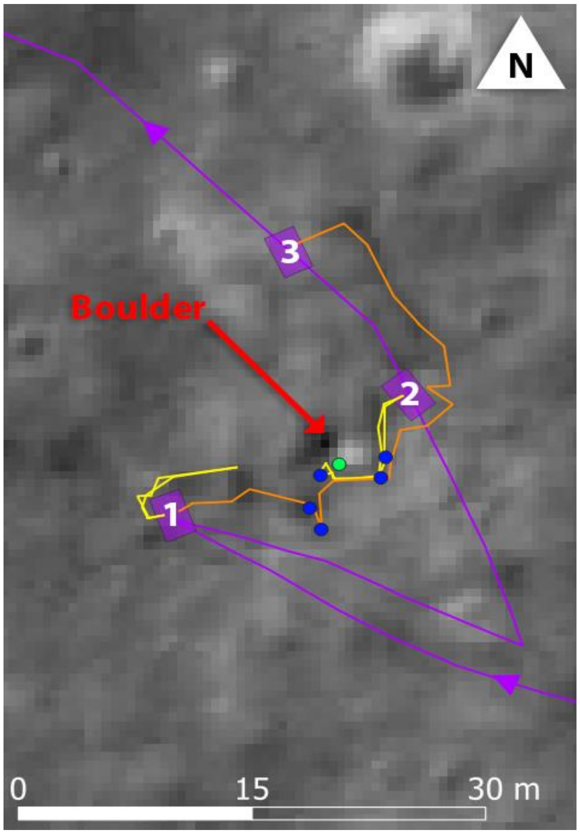

Figure 1. Station 6A Activities (NAC image M111578606)**.** LRV tracks marked in purple are modified versions from [7]. The three LRV parking spots at this station are marked as purple rectangles that show the actual size of the rover (roughly 2 m by 3 m [5]), and actual orientation. Note that this station is the highest in elevation (relative to the LM), and that the parking spots at this station were on the steepest slope, ~22° [17]. CDR and LMP walking paths are marked in yellow and orange, respectively. Green dots show sample collection sites, and dark blue dots the Hasselblad photo sites. Note the boulder in the middle of the station (boulder coordinates: 3.6711, 25.9764), that can also be seen in Fig. 2.

Figure 2. Hasselblad photo AS15-86-111659 [6] at Station 6A. This photo was taken by CDR Scott. The boulder in the foreground is seen Fig. 1 (see adjacent green and blue dots). The LRV is at the second parking spot and its location was determined from this photo (shadows point ~west). This image also provides locations of both astronauts at the timestamp of the image (found in the transcript) that the photo was taken (see Fig. 1). To find the time at which this photo was taken we used the transcript to find the time the CDR stated he started and finished the task, and then divided by the number of photos he took while standing at the same spot. Note that the TV camera may be seen on the rover in the background (wrapped in gold insulating foil) and was pointed at the deck, indicating that it was not turned on while at this station. Usually, the TV camera was the best source of both spatial and temporal data, however, in cases like this (where the TV camera remained off during all activities at this station), the audio tracks, transcripts, and Hasselblad photographs were used instead [10-12].