A NEW ARCHIVE OF APOLLO SEISMIC DATA

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Introduction: Many seismic experiments were deployed on the Moon by the astronauts during the Apollo missions as part of the Early Apollo Scientific Experiment Package (EASEP) and Apollo Lunar Surface Experiments Package (ALSEP). The experiments began in 1969 with Apollo 11, and continued with Apollo 12, 14, 15, 16 and 17. Seismic data were collected and digitized on the Moon and telemetered to Earth. The data were recorded on magnetic reel-to-reel tapes, with timestamps representing the signal reception time on Earth. The taped data have been widely used, but were not easily accessible to new data users. We created easily-accessible archives from the ALSEP Passive Seismic Experiments [1]. Over 13,000 arrivals from seismic events were recorded on the Moon during the duration of the Apollo experiments [2]. We archived the data with IRIS (Incorporated Research Institutions for Seismology) and the PDS (Planetary Data System). Figure 1 shows data availability for the mission.

Data Archiving: The data were previously preserved from the original magnetic tapes [3]. We downloaded the tape copies from an archive maintained by the Japan Aerospace Exploration Agency (JAXA). We archived data from both the short-period and mid-period instruments. Note that the mid-period instruments were formerly known as 'long-period' instruments, but we use the current convention. The Apollo instruments had slightly varying sampling rates due to fluctuations of the data sampler, mainly caused by the sampler's sensitivity to the significant temperature variations on the Moon's surface [4,5]. This presents a major problem to the seismologist using the data, and also the archivist. The timestamp was recorded on Earth, using 'Standard Time' (an accurate time measurement used before the advent of Global Positioning Systems). However, sometimes the connection to the standard time signal was lost. During these periods, the computer recorded the time, but this was frequently very inaccurate. We developed code which detects incorrect timestamps.

We provide the data in miniSEED format (a standard format used in seismology for reading and sharing seismic data). Our code is written in Python and uses ObsPy (a widely used Python-based tool for seismic processing [6]).

We keep an additional 'track' which records the timestamp as recorded on Earth, and distribute this with the mid-period traces (MH1, MH2 and MHZ) and the short-period traces (SHZ). Figure 2 shows example data with five tracks.

Data Availability: The data are archived at IRIS (Incorporated Research Institutions for Seismology) with network code XA and DOI https://doi.org/10.7914/SN/XA_1969. The data are also archived at the Geosciences Node of the Planetary Data System: https://pds-geosciences.wustl.edu/. Easy access to these data will ensure that these valuable data continue to be used to learn more about the Moon. It will also support future missions, such as the Farside Seismic Suite (due to launch in 2025, [7]) and the Lunar Geophysical Network mission concept [8].

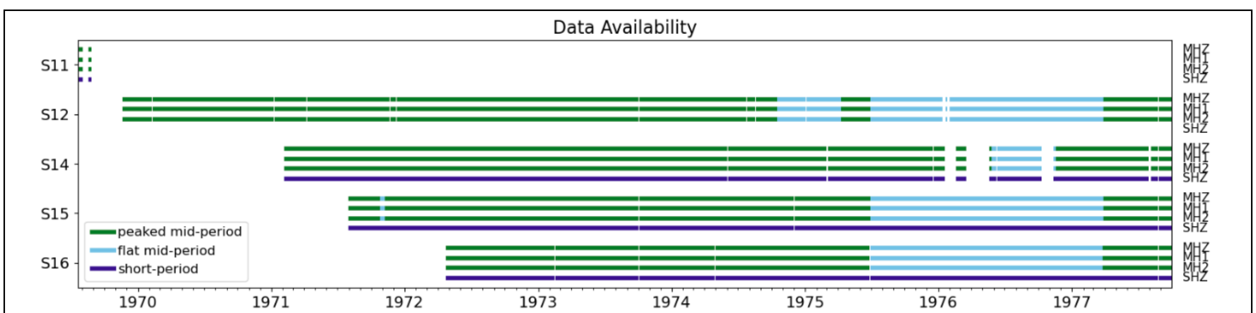

Figure 1: Seismic Data Availability. The experiments included three-component mid-period instruments (MHZ, MH1, and MH2) which operated in either peaked mode (green lines) or flat mode (light-blue lines) and short-period instruments (SHZ, dark-blue lines). From [1].

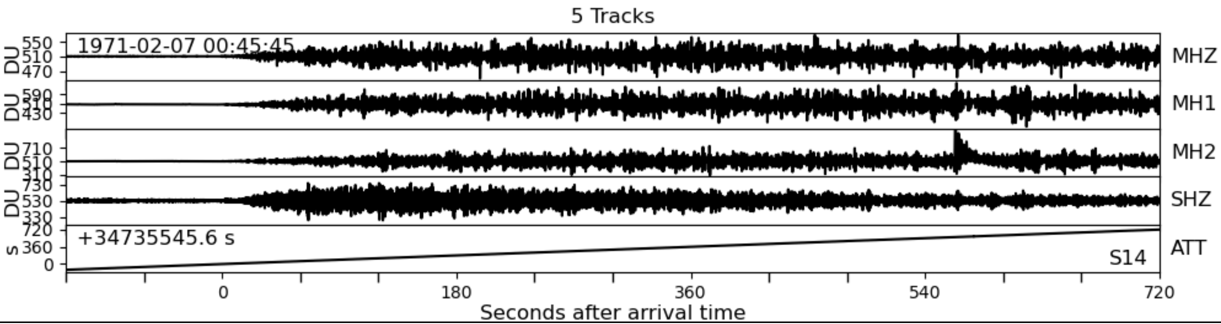

Figure 2: Data Tracks provided in the SEED Files. The top four traces show the data traces MHZ, MH1, MH2, and SHZ. The x-axis is seconds after the P arrival time, and the y-axis is in digital units (DU). The fifth trace ATT shows the timestamp (seconds since 1970-01-01) recorded at the ground station. The timing is in seconds relative to the arrival time (34735545.6 s after 1970-01-01). The event is the impact of Apollo 14's lunar ascent model, recorded at the Apollo 14 seismic station. From [1].

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