**RESTORATION OF THE APOLLO HEAT FLOW EXPERIMENTS METADATA.** S. Nagihara[1], M. K. Stephens[1], P. T. Taylor[2], D. R. Williams[2], H. K. Hills[3], and Y. Nakamura[4], [1]Department of Geosciences, Texas Tech University, Lubbock, TX 79409 (seiichi.nagihara@ttu.edu), [2]Goddard Space Flight Center, Greenbelt, MD 20711, [3]ADNET Systems, NSSDC, Greenbelt, MD 20711, [4]Institute for Geophysics, University of Texas at Austin, Austin, TX 78758.

**Introduction:** Geothermal heat flow probes were deployed on the Apollo 15 and 17 missions as part of the Apollo Lunar Surface Experiments Package (ALSEP). At each landing site, the astronauts drilled 2 holes, 10-m apart, and installed a probe in each. The holes were 1- and 1.5-m deep at the Apollo 15 site and 2.5-m deep at the Apollo 17 sites. The probes monitored surface temperature and subsurface temperatures at different depths. At the Apollo 15 site, the monitoring continued from July 1971 to January 1977. At the Apollo 17 site, it did from December 1972 to September 1977 [1]. Based on the observations made through December 1974, Marcus Langseth, the principal investigator of the heat flow experiments (HFE), determined the thermal conductivity of the lunar regolith by mathematically modeling how the seasonal temperature fluctuation propagated down through the regolith. He also determined the temperature unaffected by diurnal and seasonal thermal waves of the regolith at different depths, which yielded the geothermal gradient. By multiplying the thermal gradient and the thermal conductivity, Langseth obtained the endogenic heat flow of the Moon as 21 mW/m$^2$ at Site 15 and 16 mW/m$^2$ at Site 17 [2].

It appears that Langseth never examined the HFE data obtained from January 1975 to September 1977. His final report on HFE, written in 1977, only describes the data obtained through December 1974 [3]. The National Space Science Data Center (NSSDC) archives the HFE dataset he processed, and it also terminates in December 1974. Langseth passed away in 1997 without publishing any more work on the HFE data.

HFE data from January 1975 to September 1977 have not been archived anywhere (Fig. 1), even though current researchers have strong interests in re-examining the HFE data for the full duration of the experiments [4-6]. For about a half of the period in question (April through June 1975 and March 1976 through September 1977), unprocessed raw HFE data, as transmitted from the Moon, can be extracted from the original ALSEP archival magnetic tapes preserved from the Apollo era [7]. However, current researchers have not had access to all the information necessary for processing the HFE raw data into temperature values.

Here we report our progress in fully reconstructing the HFE metadata necessary for processing the raw data from the archival tapes. The metadata have been gathered from previously unpublished reports, memos, etc. scattered at multiple organizations.

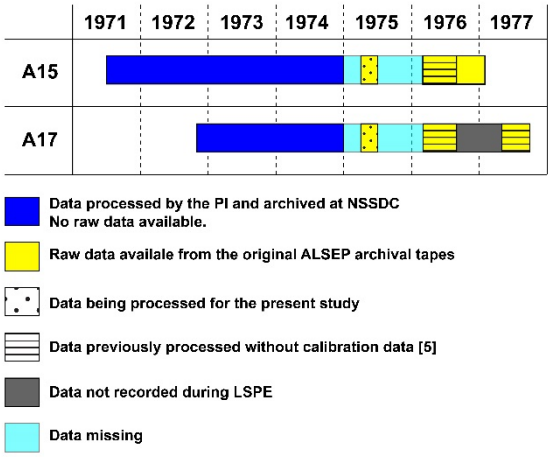


**Figure 1. Data archival status of the Apollo 15 and 17 HFE data.**

**Previously available HFE metadata:** The overall system configuration of the HFE probes has been well documented [2,3,8]. Originally, HFE was planned for Apollo 13, 15, 16, and 17. These missions carried heat flow probes of identical system design. Only Apollo 15 and 17 were able to deploy the probes successfully. Each probe was ~2.7-m long overall and consisted of two major sections (Fig. 2). The lower 1-m section was split in two, half-meter parts and used resistance temperature detectors (RTDs) made of platinum in measuring temperatures of the regolith. Each half-meter part contained 4 RTDs placed at different depths. These RTDs were electronically split in two pairs, and each pair was a part of a Wheatstone bridge. One of the two pairs was called 'Gradient Bridge' and the other was called 'Ring Bridge', and their electrical configurations were slightly different from one another. The upper ~1.7-m section of the probe contained a chain of 4 thermocouples placed at different depths along a cable.

The raw HFE data transmitted from the Moon primarily consisted of voltage measurements across the individual RTD bridges and thermocouples. Separate data reduction schemes were developed for the gradient bridges, the ring bridges, and the thermocouples during the Apollo era. Previously published re-

ports/articles [3,8] do not provide enough detail for current researchers to be able to fully reconstruct these schemes. No calibration data have been reported for any of the probes used in these Apollo missions.

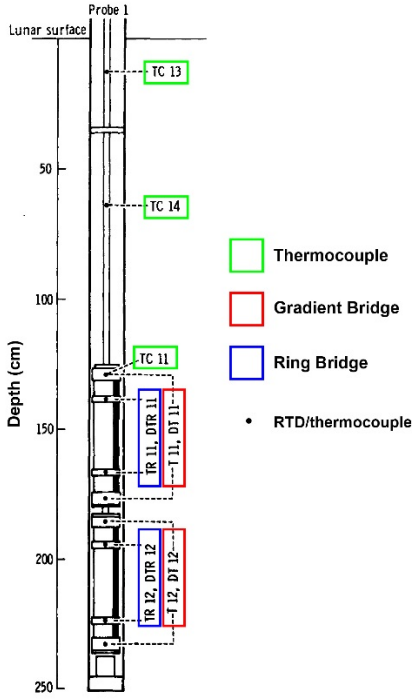


**Figure 2. Three different types of temperature sensors used for the Apollo heat flow probes. (after [8])**

**Recently recovered HFE metadata:** The heat flow probes that flew on the Apollo missions were fabricated and tested in 1967-1968 by Bendix Corporation (NASA's primary contractor for the ALSEP hardware) and its contractor Arthur D. Little, Inc. (ADL). ADL and its contractor Rosemont Engineering performed most of the calibration tests. We found copies of the original reports that tabulated all the calibration data at the National Archives of Fort Worth [9]. A total of 7 units/sets of heat flow probes were made and tested. When these reports were written in 1968-1969, it was not decided which of these units would fly on which Apollo mission. Therefore, the probes were simply referenced by their serial numbers (SN-1, SN-2, etc.) in these reports. We were able to match these serial numbers, the flight model numbers used by Bendix, and the Apollo mission numbers, based on some undated notes left by Langseth at Lamont-Doherty Earth Observatory and internal Bendix memos archived in Fort Worth.

The information from [9] and a progress report from Langseth to NASA written in 1969 [10], recovered from NASA's document database, enabled us to reconstruct the data reduction algorithm for the gradient bridge, the ring bridge, and the thermocouples. Langseth modified the data processing algorithm for the RTD bridges from those originally suggested by ADL [3]. We have not been able to fully reconstruct the modified procedure. However, we expect that the original and the modified algorithms yield little difference in their temperature determination, because they both use the same set of calibration data.

**Recovering temperature values:** Using ADL's calibration data and data reduction schemes, we processed Apollo 15 gradient bridge data from April 16, 1975 (Fig. 3), extracted from an ALSEP archival tape we recently recovered at the Washington National Records Center [7]. The temperatures of the sensors below 90-cm depth are generally within ~0.1 K from those of December 1974 [2]. The temperatures of the shallower sensors are also reasonable considering the seasonal fluctuation.

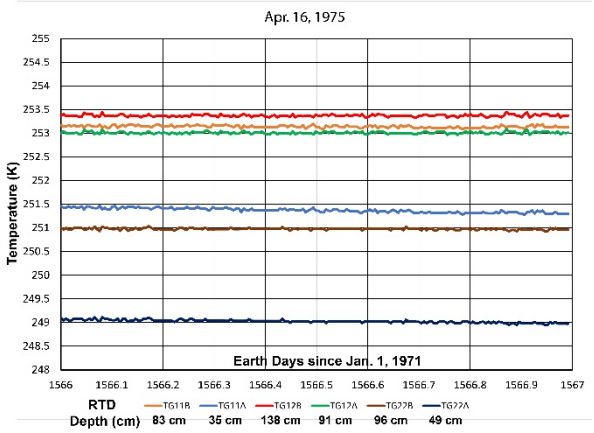


**Figure 3. 24-hour temperature record from the gradient bridges of the Apollo 15 heat flow probes recovered by this study.**

**References:** [1] Bates J. R. et al. (1979) *ALSEP Termination Rept*. [2] Langseth M. G. et al. (1976) *Proc. LSC 7th*, 3143-3171. [3] Langseth M. G. (1977) Lunar heat-flow experiment: Final technical report, Lamont-Doherty Geol., Obs., p.289. [4] Wieczorek M. A. and Huang S. (2006) *LPSC XXXVII*, abstract #1682. [5] Saito et al. (2006) *Bull. Japanese Soc. Planet. Sc.,16*, 158-164. [6] A. J. Dombard (2010) *Ground-based Geophysics on the Moon*, 3015. [7] Nagihara et al. (2014) *LPSC XXXXV*, abstract #1153 [8] Lauderdale W. W. & Eichelman W. F. (1974) *Apollo Scientific Experiments Data Handbook*, NASA TM X-58131 p. 1011. [9] Arthur D. Little, (1968) *E181C40, Acceptance Data Package*, National Archives of Fort Worth. [10] Langseth M. G. (1969) *Quarterly Progress Rep., #1*, Lamont-Doherty Geol. Obs. p. 125.