

**RESTORATION OF THE APOLLO 15 HEAT FLOW EXPERIMENT DATA FROM 1975 TO 1977.** S. Nagihara<sup>1</sup>, Y. Nakamura<sup>2</sup>, P. T. Taylor<sup>3</sup>, D. R. Williams<sup>3</sup>, and W. S. Kiefer<sup>4</sup>, <sup>1</sup>Department of Geosciences, Texas Tech University, Lubbock, TX 79409 (seiichi.nagihara@ttu.edu), <sup>2</sup>Institute for Geophysics, University of Texas at Austin, Austin, TX 78758, <sup>3</sup>Goddard Space Flight Center, Greenbelt, MD 20711, <sup>4</sup>Lunar and Planetary Institute, Houston, TX 77058.

**Introduction:** The Apollo 15 Heat Flow Experiment (HFE) was conducted from July 31, 1971 through January 15, 1977 [1]. Two heat flow probes were deployed roughly 8.5-m apart. Probe 1 and Probe 2 penetrated to 1.4-m and 1-m depths into the lunar regolith, respectively (Fig. 1). Temperatures at different depths and the surface were logged with 7.25-minute intervals and transmitted to Earth. At the conclusion of the experiment, only data obtained from July 1971 through December 1974 were processed and archived at the National Space Science Data Center (NSSDC) by the principal investigator of the experiment, Marcus Langseth of Columbia University [2]. It is not known what happened to the HFE data tapes he used after his death in 1997. Current researchers have strong interests in re-examining the HFE data for the full duration of the experiment [3-5]. We have recovered and processed large portions of the Apollo 15 HFE data from 1975 through 1977 by assembling data and metadata from various sources.

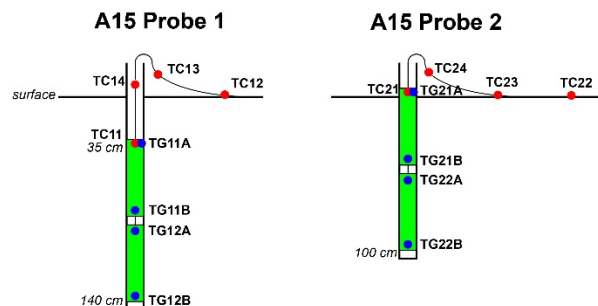


Figure 1. Schematic drawings of the two heat flow probes deployed at the Apollo 15 site and the positions of the temperature sensors. The red dots denote the thermocouples and the blue dots do the platinum resistance temperature detectors [after 6].

**Sources of Data and Metadata:** *ARCSAV tapes.* HFE was a part of the Apollo Lunar Surface Experiments Package (ALSEP). From April 1973 through February 1976, the personnel at the Johnson Space Center (JSC) recorded all the raw, unprocessed ALSEP data received from the Moon on 7-track, open-reel magnetic tapes for archival purpose. They were called ‘ARCSAV tapes’. These tapes, however, were never delivered to NSSDC. Sometime after the conclusion of the Apollo

program, they were lost. In 2010, ARCSAV tapes containing data from April through June of 1975 were found at the Washington National Records Center [7]. We have extracted HFE data from these tapes and processed them. Binary files extracted from these tapes have recently been archived at NSSDC.

*Work Tapes.* From March 1976 to the conclusion of the ALSEP experiments in September 1977, the University of Texas at Galveston took over the production of ALSEP archival tapes from JSC. Raw data from the Moon were recorded on 9-track, open-reel tapes, which were called ‘Work Tapes’. Copies of these tapes have been archived at NSSDC. We extracted HFE data from them and processed them.

*ALSEP Performance Summary Reports.* The personnel at JSC kept weekly logs summarizing the operational status of each of the ALSEP instruments from 1973 to 1977. The logs were called ALSEP Performance Summary Reports (PSRs). Paper copies of a full set of PSRs have been preserved at the Lunar and Planetary Institute (LPI) in Houston, Texas. Recently, we have made their scanned copies available at LPI’s web site at [www.lpi.usra.edu/lunar/ALSEP](http://www.lpi.usra.edu/lunar/ALSEP). These reports recorded the temperature readings from the lowermost sensor of Probes 1 and 2, once a week. They are useful for the present study for three reasons. First, the HFE data processed from the raw data extracted from the aforementioned archival tapes can be checked against the temperature readings reported on the PSRs for their reliability. Second, for the periods in which ARCSAV tapes have not been found (January through March 1975, and July 1975 through February 1976), the temperature readings on these reports represent the only HFE data available. Third, the operational status of the heat flow probes documented in these reports is helpful in data interpretation.

*Acceptance Data Packages.* Previous researchers have been aware that the data reduction procedure for the HFE probes were outlined in Langseth’s final report [6] and the Apollo Scientific Experiments Data Handbook [8]. However, it has not been possible to fully reconstruct the data processing algorithm based solely on the information given in them. In the last several years, we conducted extensive searches of the memos and reports left behind by Langseth and the NASA contractors who were directly involved in the designing, fabrication, and calibration of the HFE instrumentation. We

then pieced together the data processing algorithm [9]. Much of the most useful metadata was found in the voluminous reports called ‘Acceptance Data Packages’ written by NASA’s contractors when they completed fabrication of the HFE instrumentation. These reports have been kept at the National Archives facility in Fort Worth, Texas. Their scanned copies are now being made available through LPI’s website.

**Restored HFE Data:** We have processed the raw HFE data extracted from the ARCSAV and Work Tapes from 1975 to 1977. The temperature values obtained for the lowermost sensor of the two probes (TG12B and TG22B in Fig. 1) were compared with the temperature readings for the same sensors reported in the ALSEP PSRs (Fig. 2).

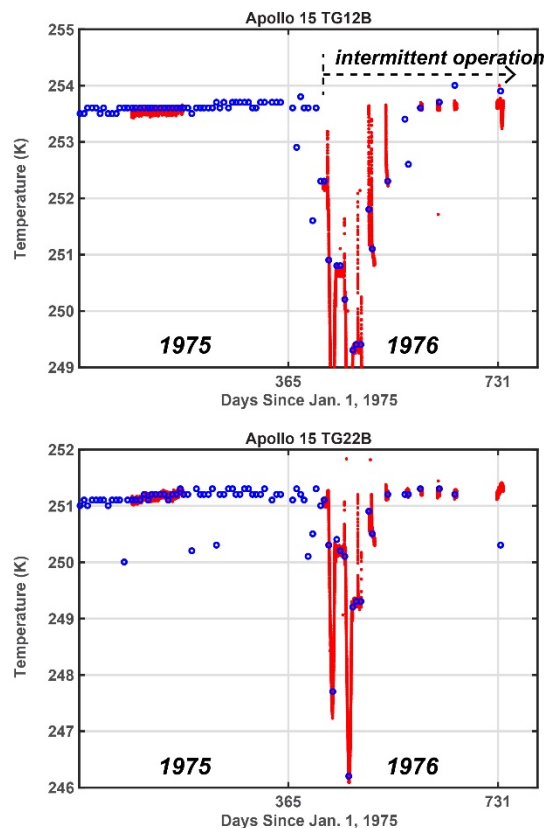


Figure 2. The temperature values obtained from the raw HFE data recorded on the ARCSAV and Work tapes (red dots) and those reported in the ALSEP PSR (blue circles) for the period of January 1975 through January 1977 are compared for the lowermost sensors of Probe 1 (top) and Probe 2 (bottom).

It should be noted that the actual HFE instrumentation resolved temperature measurements down to the order of 0.001 K, while the temperature values reported in the PSRs have been rounded to the order of 0.1 K. In

addition, the PSRs do not give the exact time of each temperature measurement, only the date. Figure 2 shows that the temperature values obtained from the tape data agree with those reported in the PSRs generally within 0.1 K.

According to the PSRs, the main electronics unit for the Apollo 15 HFE started having over-heating problems in March 1976, and the temperature data became erratic. From then on, the instrumentation was turned off frequently for extensive cool-down periods. The instrument appeared to stabilize in the late 1976, but the problem recurred in January 1977, when the instrument was commanded off permanently.

The main reason why some previous researchers wanted to examine the full records from the HFE was that both the Apollo 15 and 17 HFE data showed gradual, continuous warming in the subsurface below the thermal skin depth (~1 m) from the time of deployment through 1974 [3-5]. The reason for the warming has been debated. The newly restored data from 1975 to the early 1976, prior to the instrument failure, show that the warming continued at least through mid-1975, but it may have plateaued afterwards (Figs. 2 and 3).

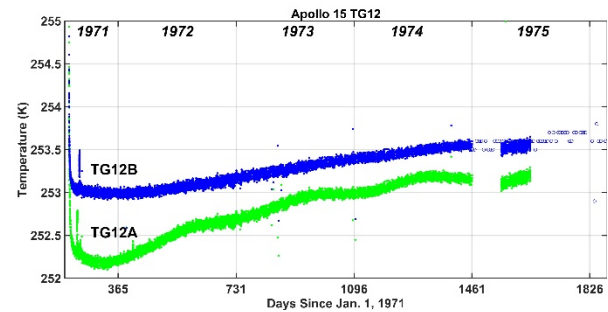


Figure 3. The temperature values from the two lowermost sensors of Probe 1 (TG12A and TG12 B) from the time of deployment to the early 1976. The data in 1975 and 1976 are those restored for the present study.

**References:** [1] Bates, J.R. et al. (1979) *ALSEP Termination Report*, NASA Ref. Pub. 1036. [2] Langseth M. G., et al. (2014) *Apollo 15 heat flow thermal conductivity RDR subsampled, v1.0*, Planetary Data System. [3] Wicczorek M. A. and Huang S. (2006) *LPSC XXXVII*, abstract #1682. [4] Saito et al. (2006) *Bull. Japanese Soc. Planet. Sc.*, 16, 158-164. [5] Dombard, A. J. (2010) *Ground-based Geophysics on the Moon*, abstract #3015. [6] Langseth M. G. (1977) *Lunar Heat-Flow Experiment, Final Tech. Rept.*, Lamont-Doherty Geol. Obs. CU-4-77, p. 289. [7] Nagihara, S. et al. (2011) *LPSC XXXXII*, abstract #1103. [8] Lauderdale, W. W. and Eichelman, W. F. (1974) *Apollo Scientific Experiments Data handbook*, NASA TM X-58131. [9] Nagihara, S. et al. (2014) *LPSC XXXXVI*, abstract #1243.