



**Aerospace
Systems Division**

Deletion of Geophone Temperature Sensor	ATM-948
	PAGE <u>1</u> OF <u>4</u>
	DATE 1/22/71

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NO.	REV. NO.
ATM-948	
PAGE <u>2</u>	OF <u>4</u>
DATE 1/22/71	

General

Initially the LSP design included a geophone temperature sensor in one of the geophones. After consideration of all factors, this temperature sensor has been deleted with concurrence of the principal investigator. This ATM is written to provide the rationale for not incorporating the temperature sensor in the LSP design.

Background

Each set of geophones is functionally tested, and characteristics measured with the geophone calibration pulse at -65°C , ambient, and $+125^{\circ}\text{C}$ by the subcontractor during acceptance testing. Since the geophones are not functionally tested below -65°C , especially with the geophone calibration pulse, there are no tests that verify the geophones will provide meaningful seismic data at temperatures below -65°C . Therefore, on the lunar surface, the performance characteristics of the geophones can be measured by calibration with a geophone calibration pulse and compared with test data only at temperatures above -65°C .

In order to provide for a geophone temperature sensor which would indicate when the geophones are above -65°C , it would be necessary to provide a second shielded cable to the nearest geophone. This additional cable would weigh approximately 0.40 lbs and the geophone reel for this geophone would have to be designed to stow and deploy two geophone cables. By deleting the geophone temperature sensor, we have been able to shorten the geophone cases by $1/4"$, which also has made possible weight decreases.

It has been determined that the geophone temperatures on the lunar surface can be predicted by calculations to $+28^{\circ}\text{C}$. By determining when the geophone temperature is -37°C nominal (to allow for the 28° inaccuracy), it can be assumed that the geophone is above -65°C . This decreases the total available listening period that would be available if the geophone temperature were accurately known, however, the temperature of the lunar soil changes rapidly from lunar night temperature to lunar day temperature when compared to the total lunar cycle. The time for the lunar surface temperature to change 28°C at -65°C is 3.9 hours during lunar sunrise and 5.9 hours during lunar sunset. Thus use of a calculated versus a measured geophone temperature has the effect of reducing the possible listening period of approximately 14 days in each 28-day lunar cycle by 9.8 hours.



**Aerospace
Systems Division**

Deletion of Geophone Temperature Sensor

ATM-948

PAGE 3 OF 4

DATE 1/22/71

Determination of Geophone Temperature by Calculation

The four geophones deployed on the lunar surface will follow the lunar surface closely due to the passive nature of the geophones and their intimate thermal coupling to the lunar surface, therefore the geophones are essentially at the same temperature as the lunar surface.

The lunar surface temperature history over a lunar cycle is available in document LED-520-IF entitled "Design Criteria and Environments for the LM". Off equator location temperatures are determined by the following expression:

$$T(\theta) = T(\theta = 0) [\text{Cos } \theta]^{\frac{1}{4}}$$

when θ = latitude in degrees.

The application of the LED-520-IF data has been validated by Apollo 11 and 12 data.

The low soil conductance and density as measured on Apollo 11 core samples was found to be similar to the low conductance soil properties of LED-520-IF.

The best in situ lunar surface temperature measurement available to date is the temperature monitor of the Apollo 12 Cold Cathode Gauge Experiment. This package is similar to the geophones in that it is a passive device and is in good thermal contact with the lunar surface. Data from Apollo 12 indicates that the Cold Cathode Gauge Experiment does follow the predicted lunar surface temperature within $\pm 28^{\circ}\text{C}$.

All design criteria and analytical expressions derived for predicting the lunar surface temperature assume a flat surface. When a particular landing site is selected the variance in local terrain could be considered in order to refine temperature calculations. Features of the local terrain may be obtained from available telescopic photographs.

Correlation of ALSEP Apollo 17 primary structure temperature sensor readings with those of Apollo 12, 14, 15 and 16 and other independent measurements on these flights should provide adequate correction for local terrain conditions.



**Aerospace
Systems Division**

Deletion of Geophone Temperature Sensor

ATM-948

PAGE 4 OF 4

DATE 1/22/71

Conclusion

The geophone calibration pulse data alone provides measurements of geophone characteristics. Geophone temperature sensor data is primarily useful only to determine when the geophones are above -65°C . The additional weight, design complexity, and more involved deployment operations required if the geophone temperature sensor were incorporated, does not seem to justify incorporating the sensor. The only effect of using a calculated temperature is to decrease the available passive listening period in a 28-day lunar cycle by approximately 10 hours.