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SUBJECT: An Engineering Measurement to Obtain the Lunar Surface Thermal Characteristics on EASEP/ALSEP by Analysis of Thermometer Data from the Dust, Thermal and Radiation Engineering Measurement Package (DTREM) - Case 340

DATE: April 21, 1969

FROM: P. J. Hickson

ABSTRACT

An engineering measurement is outlined for the Early Apollo Science Experiments Package (EASEP), which will obtain lunar surface brightness temperature in the range 84°K (-308°F) to 408°K (274°F) with an error less than 3K° at the higher temperature. This measurement is expected to materially assist the quantitative evaluation of EASEP/ALSEP lunar surface thermal performance, including the experiments and RTG, and aid in the design of modified or improved ALSEP's.

(NASA-CR-103645) AN ENGINEERING MEASUREMENT TO OBTAIN THE LUNAR SURFACE THERMAL CHARACTERISTICS ON EASEP/ALSEP BY ANALYSIS OF THERMOMETER DATA FROM THE DUST, THERMAL AND RADIATION ENGINEERING MEASUREMENT

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MEMORANDUM FOR FILE

I. INTRODUCTION

The Early Apollo Science Experiments Package (EASEP) will be emplaced on the lunar surface by the astronaut during the first lunar landing (G1 mission). The Dust Detector Experiment (DDE) on EASEP has been substantially modified and renamed the Dust, Thermal and Radiation Engineering Measurements package (DTREM). This memorandum will outline the nature of the modification and the reasons for it, including considerable detail of the thermal engineering measurement, since it was originally proposed by the author.

In the DDE the power output of 3 solar cells, 2 vertical and 1 horizontal, is compared to the predicted power output, the power decrements being a measure of the (dust) covered area of each cell. Each cell is accompanied by a thermistor because of the strong temperature dependence of solar-cell power. In the DTREM package the three solar cells are reduced in area and, together with two thermistors, replace the single horizontal cell. The remaining thermistor is replaced by a nickel resistance thermometer which remains vertical but is thermally isolated from the package and views the lunar surface (measures lunar surface temperature). The three horizontal cells have various thicknesses of quartz cover-glass, and hence measure proton radiation damage at three incident particle energies. The DTREM package does not have the capability of measuring dust accretion on vertical surfaces, either due to LM ascent or long term processes. It can, however, measure dust deposited on horizontal surfaces with the same resolution as the DDE package.

II. REASONS FOR THE THERMAL ENGINEERING MEASUREMENT

The lunar surface thermal environment has been a major constraint on the design of the ALSEP/EASEP central station, power supply, and each of its eight experiments. The packages are therefore, to the greatest extent possible, designed to be thermally isolated from the lunar surface to provide relatively narrow temperature limits for the electronics, and most experiment sensors, during lunar surface operations. Nevertheless, the ALSEP central station thermal design is complex, and the central station has a modest heat input from the lunar surface through its sunshield reflector. The lunar surface is a minor radiative heat sink for the RTG, and the ALSEP passive seismometer uses the lunar surface under its shroud as a thermal control surface. Also, Advanced ALSEP concepts are now being considered and altered thermal designs proposed.

In view of the above, the author has suggested that a measurement of the lunar surface temperature be made. Other lunar surface characteristics such as the thermal ("inertia") parameter and the thermal emission angle dependence should be measured if such measurements prove possible. These measurements would:

1. Materially assist the quantitative evaluation of EASEP/ALSEP lunar surface thermal performance, including the experiments and the RTG, and indirectly aid in ALSEP modification for Advanced ALSEP's.

2. Provide data on the degradation rate of the thermal coatings used or viewed, assuming that data from several lunar cycles is collected.

3. Provide an additional data point for the lunar landing site, perhaps of aid or interest to sample return, spacecraft, or astronaut suit evaluation.

4. Provide a scientifically interesting data point should anomalies be encountered and identified.

5. Provide corroboration and extension of earlier results since a similar measurement. was carried out on Surveyors I, III, V, VI, and VII.*

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*See J. W. Lucus, et al, JPL Technical Reports TR 32-1023, p. 45, TR 32-1177, p. 115, TR 32-1246, p. 89, TR 32-1262, p. 109, TR 32-1264, p. 187.

Although the packages carry no instruments specifically to measure lunar surface temperatures or surface thermal characteristics, the ALSEP central station contains 32 thermometers, of which 19 are on the internal electronics, 2 on the sunshield, 5 on the (bottom of the) thermal plate, 2 on the vertical structure, 2 on the bottom structure, and 2 across the multilayer insulation (thermal bag). In addition to these, there are 6 thermometers on the RTG, 3 on the Dust Detector Experiment (DDE), and some on each ALSEP candidate experiment, including for example, one thermometer on an ASE geophone of ALSEP III. The DDE thermometers are unique in their degree of isolation from the central station. Because the successful Surveyor landings have recently resulted in decreased interest in the lunar dust levels above the DDE dust measurement resolution of ±5 per cent, it became possible to propose and implement a modification to the DDE which improved the DDE thermometer's isolation from the package and improved its coupling to the lunar surface. At the present time, the modification has been implemented on EASEP only and is being considered for retro-fit to ALSEP.

III. OBJECTIVES OF THE DTREM THERMAL MEASUREMENT

The measured data will be analyzed to obtain:

1. an average equivalent brightness temperature of the unshadowed lunar surface viewed,
2. an equivalent range of the surface thermal parameter $(k\rho c)^{-1/2}$, where k is the thermal conductivity, ρ is the mass density and c is the heat capacity of the lunar surface layer, and
3. the angular dependence of the surface thermal emission.

To accomplish these measurements, the solar-cell-and-thermistor on side #3 of the EASEP DDE was replaced by a high precision nickel resistance thermometer of wide dynamic range (84°K to 408°K), and the new DTREM was then reoriented so that side #3 now faces outboard of the central station toward the north. The new thermometer is insulated from the DTREM structure so that its temperature is determined mainly by the thermal radiative exchange with the lunar surface and black space.

The third objective is doubtful on EASEP because the thermometer will face north, i.e., normal to the sun-to-surface direction. On ALSEP the thermometer should face east on at least one mission to get phase-dependent data and sun-dependent coating degradation.

The output of other thermometers, particularly the other two thermometers in the DTREM package and the two on the ALSEP sunshield (or one on each EASEP solar panel), may materially assist this analysis. Such analysis necessarily includes a detailed error analysis for which a further look at the ALSEP thermal vacuum test data may prove useful. Additional thermal testing of the DTREM may be proposed later should the preliminary data analysis warrant it.

It has been proposed that the DTREM design be retrofitted to the other three ALSEP flight packages, and this proposal is under consideration by MSC/LSPO. It has been further proposed that an additional DTREM thermometer be assigned to this experiment and that its dynamic range and location be set to measure temperatures needed to quantitatively define the unavoidable heat leaks. (The heat leaks from the thermometer to the DTREM structure depend on the structure temperature which must be estimated in lieu of measurement). This latter proposal was not accepted for the EASEP DTREM.

IV. DESCRIPTION OF EQUIPMENT

The thermometer is a Tylan nickel wire resistor, nominally 5500 ohms at the ice point, which is connected to ground and also through a 15000 ohm temperature insensitive precision dropping resistor to the +12 volt ±1% regulated ALSEP power line.* The thermometer voltage drop is fed through the analog multiplexer to the ALSEP 8-bit A to D converter (0 to 5V input) and hence appears once every 90th ALSEP telemetry frame (or once every 54.34 seconds) as format word 33. The address of the analog channel, here number 56, appears in the same format frame in bits 23 to 29 inclusive. The thermometer has a dynamic range of 408°K (274°F) to 84°K (-308°F) and the ΔT corresponding to 1/2 bit is almost constant at 0.8K° over this entire range. According to the manufacturer, the temperatures read differ from absolute temperature scale values by less than

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*The +12 volt supply is measured as analog channel number 50 (or measurement AE-9) 3.62 seconds before temperature AX-3 or channel 56 is measured and so introduces only a small (<1/4%) measurement error.

0.8K° over the entire range since three calibration points, the steam point, the ice point and the carbon dioxide point (373.2°K, 273.2°K, and 194.7°K) are taken for each sensor. The thermometer and its circuit have good stability characteristics and drift less than 0.1K°/year. The thermometer output is not controlled by the DTREM off-on commands (solar cell amplifiers only).

The DTREM package is approximately a cube 3.63 cm wide x 3.17 cm deep by 4.08 cm high of G-10 fiberglass, with 0.23 cm thick walls and with east, west, and vertical apertures each 1.5 cm x 2.0 cm. See Figure 1. The DTREM package has been rotated 90° clockwise so that aperture #3 faces north. The top aperture (#2) is covered by a kovar sheet to which the 3 solar cells (top) and 2 thermistors (back) are attached, as proposed by Dr. S. Freden of Manned Spacecraft Center. The south aperture (#1) faces the PSE and is covered by a dummy fiberglass cover. The north aperture (#3) is covered by the temperature detector. The temperature detector is a 3.17 cm x 2.44 cm fiberglass cover, 0.09 cm thick, containing the 1.52 cm square winding of nickel resistance wire (temperature sensor) 0.03 cm inside its front surface. The detector is separated from the DTREM structure by 20 layers of superinsulation (about 0.19 cm thick), which are pierced by a pair of thermal isolator standoffs and nylon bolts. Each thermal isolator standoff is a stack of 18 washers, each of area 0.11 cm^2 and thickness 0.01 cm.

The DTREM is held by 2 bolts to a fixture attached to the ALSEP sunshield structure (or EASEP primary structure). The DTREM flat cable (reeled in flight) has 17 conductors (2 for each solar cell and each thermometer, 1 spare, 2 for each ALSEP sunshield thermometer) and plugs into the central station. The cable faces west in the proposed EASEP design.

V. SKETCH OF EASEP DATA ANALYSIS

The lunar surface brightness temperature is found from the detector energy-rate balance, i.e., the net rate of energy flow out of the detector is equal to the net rate of energy into the detector. We write the equation in the form:

$$\varepsilon_D \sigma T_D^4 = \sigma F_{SD} \varepsilon_D \varepsilon_S T_S^4 + \dot{q}$$

where D stands for detector, S for lunar surface and $\dot{q}$ is the net algebraic sum of all heat leaks to the detector.* The temperature detector stands vertically on the outer edge of EASEP about 20 cm above the lunar surface and faces north. See Figure 1 and 2. The estimated radiation configuration factors of the temperature detector to the various surfaces of EASEP are listed in Table I. Table II is a list of the factors contributing to $\dot{q}$ with some worst-case estimates of their magnitude. Since T_D and $\dot{q}$ are measured or can be calculated, the lunar surface brightness temperature (T_S for $\varepsilon_S = 1$) is found from the equation at each sun angle. To the extent that the heat leaks in Table II can be measured or accurately estimated, they can be applied as corrections to measured values of $\varepsilon_D \sigma T_D^4$. As a first cut at an error estimate, we might regard the relative error of each heat leak to be about 10%. The sum of the leaks at lunar noon is 17.6 mW/cm^2 so taking the error as 1.8 and the corrected measured surface emission as 55.0, then the surface temperature error is ±3K° at lunar noon.

VI. OPERATIONAL SUPPORT REQUIRED

To achieve the estimated accuracy, the configuration factor F_{SD} must be known to within 1%. It is therefore essential that a stereo pair of pictures be taken of the deployed EASEP or ALSEP. The pictures must be taken from the south side of EASEP pointing toward the north so that the lunar surface view of the DTREM thermometer can be accurately determined. Because EASEP is in the pictures, the stereo base need not be measured out and successive pictures from different locations is sufficient. An effective stereo base of 50 cm is suggested.

VII. IMPLEMENTATION PLAN

The author will work on the error analysis and data analysis scheme essentially full time until they are understood and are ready for the computer. Computer analysis of data tapes is assumed (about 16,000 temperatures/month data for EASEP).

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*ε is the hemispherical emissivity, σ is Boltzmann's constant, T the absolute temperature and F the configuration factor.

Present activity involves input to DDE specification changes for EASEP and probably several visits to MSC and Spectrolab, the hardware subcontractor to MSC.

The results of this measurement will be reported in an appropriate MSC document. For the 60-day quick-look report, it is expected that a curve of surface brightness temperature versus time will be produced using the data from the first month.

P. J. Hickson

2015-PJH-kse P. J. Hickson

Attachments
  Tables I and II
  Figures 1 and 2

TABLE I

Estimated Radiation Configuration Factors from the Temperature Detector to Various Surfaces

Surface	Configuration Factor	
	EASEP	ALSEP
(plane) lunar surface	0.43*	0.5
black sky	0.34	0.5
carry handle	0.11	
boom	0.06	
astronaut handle	0.03	
west solar panel	0.029	
east solar panel	0.00	

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*Includes shadowed and unshadowed lunar surface. The lunar surface shadowed by the solar panels would have a configuration factor, depending on sun angle, between 0.0 and 0.25.

TABLE II

Worst-Case Estimated Power Inputs to
the DTREM Temperature Detector on EASEP

Quantity	Lunar Noon Value, mW/cm^2	Sunrise (10° sun) Value, mW/cm^2
lunar surface emission	55.0	3.7
conduction, thermal isolators	5.2*	
IR emission, carry handle	3.0	
direct solar, (5° tilt)	2.3	2.3
IR emission, west solar panel	1.8	0.09
IR emission, boom	1.6	
IR emission, astronaut handle	0.8	
conduction, nylon bolt	0.8*	
direct solar, top edge	0.8	0.14
solar, reflected from lunar-surface	0.6	0.10
conduction, sensor leads	0.4*	0.16
self-heating	0.3	
conduction, superinsulation	---	---
solar, diffuse reflection, carry handle	---	2.4
solar, diffuse reflection, boom	---	1.3
solar, diffuse reflection, astronaut handle	---	0.6
IR emission, shadowed lunar surface		

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*Assumes the temperature detector to DTREM structure temperature difference is 10K°.

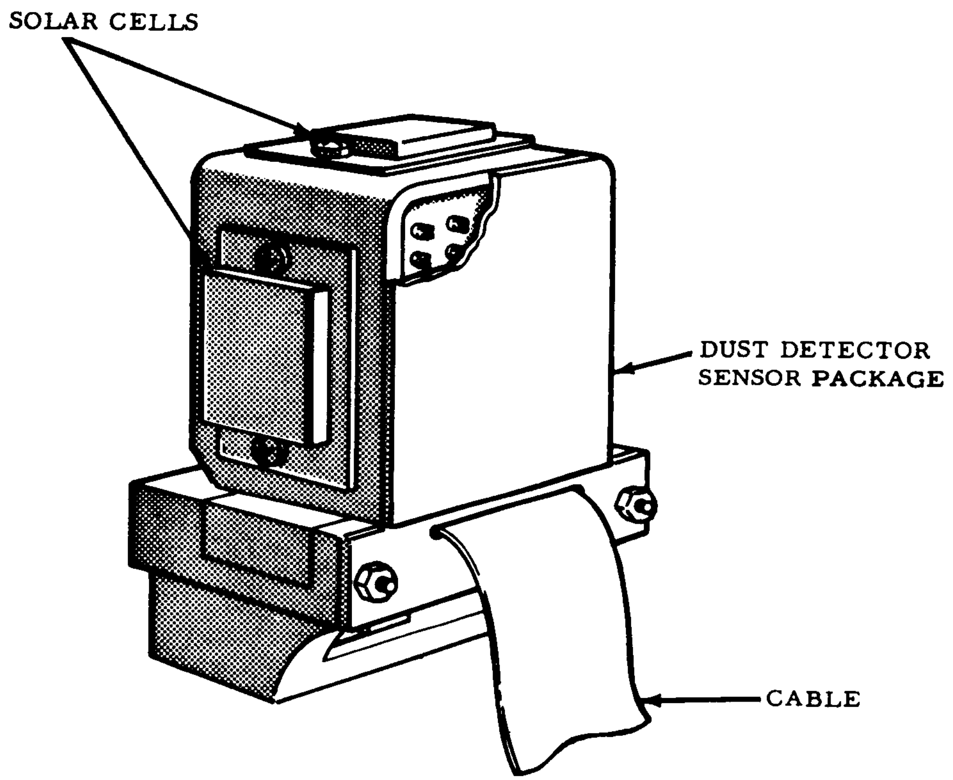

FIGURE 1 - UNMODIFIED DUST DETECTOR EXPERIMENT (DDE)

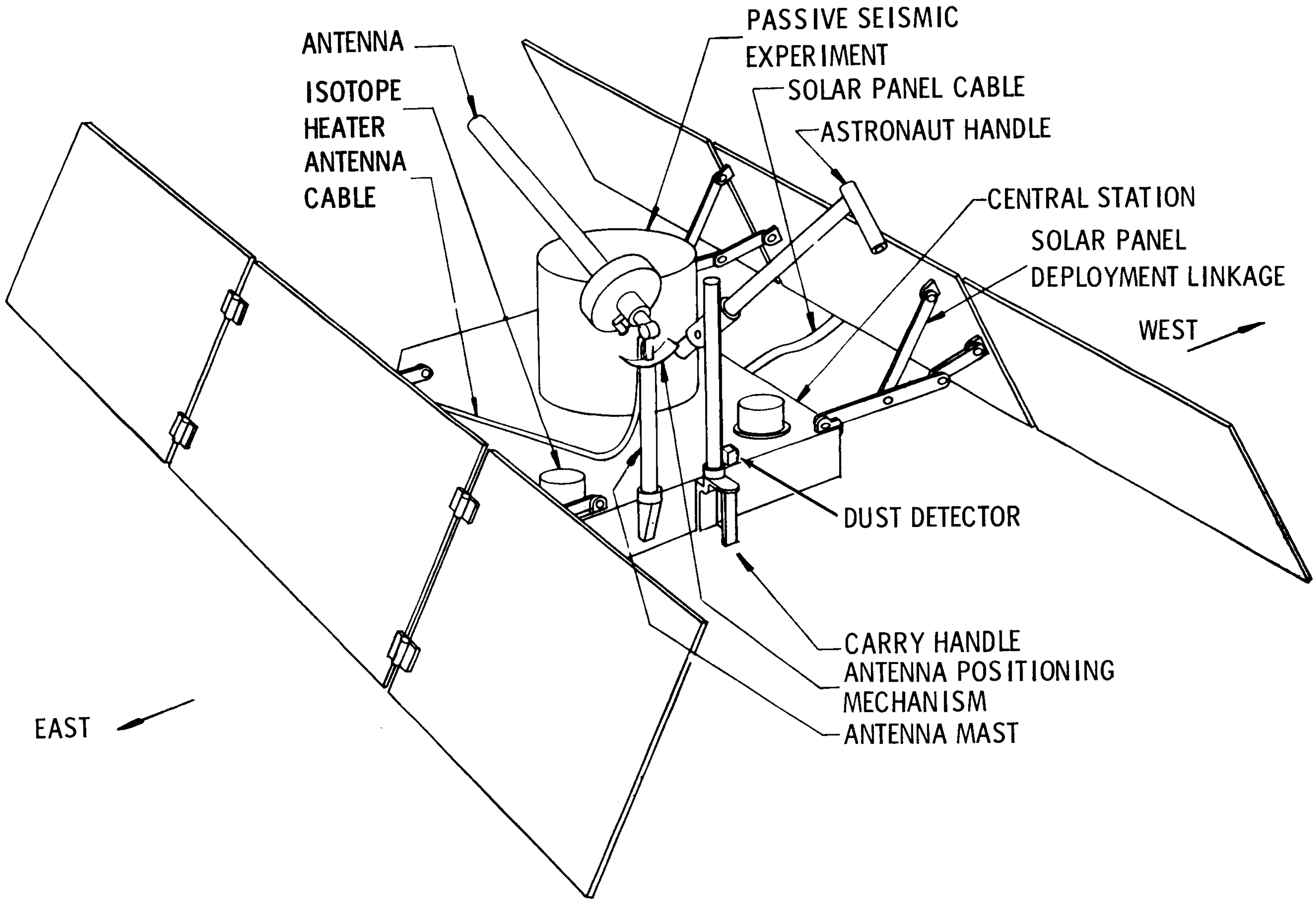

FIGURE 2 - EASEP DEPLOYED CONFIGURATION

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