LUNAR SOIL MOVEMENT REGISTERED BY THE APOLLO 17 COSMIC DUST EXPERIMENT

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A. INTRODUCTION

In December, 1973, a Lunar Ejecta and Meteorites (LEAM) experiment was placed in the Taurus-Littrow area of the moon by the Apollo 17 Astronauts. Objectives of the experiment were centered around measurements of impact parameters of cosmic dust on the lunar surface. During preliminary attempts to analyze the data it became evident that the events registered by the sensors could not be attributed to cosmic dust but could only be identified with the lunar surface and the local sun angle. The nature of these data coupled with post-flight studies of instrument characteristics, have led to a conclusion that the LEAM experiment is responding primarily to a flux of highly charged, slowly moving lunar surface fines. Undoubtedly concealed in these data is the normal impact activity from cosmic dust and probably lunar ejecta, as well. This paper is based on the recognition that the bulk of events registered by the LEAM experiment are not signatures of hypervelocity cosmic dust particles, as expected, but are induced signatures of electrostatically charged and transported lunar fines.

B. THE INSTRUMENT AND FIELDS OF VIEW

The design and performance of the instrument is adequately described elsewhere in the literature (1). They are similar to those for the PIONEERS 8 and 9 cosmic dust experiments, except that the lunar experiment contains an EAST, an UP and a WEST sensor system. The front film and grid system is that portion of the basic sensor which recorded the data on charged microparticles presented here.

The LEAM experiment is located at $20^{\circ}.164$ N latitude and $30^{\circ}.774$ E longitude on the moon. Its WEST sensor is directed 25° south of west; its UP sensor is directed normal to the lunar surface; and its EAST sensor axis is directed 25° north of east to include in its field-of-view the solar apex direction. The field-of-view of each sensor is a square cone with a half-angle of approximately 60°. However, the mountainous terrain blocks about 60% of the EAST and WEST sensors' fields-of-view.

C. A CASE FOR LUNAR SURFACE ACTIVITY

There are several characteristics of the data which, when considered in a process of

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elimination, categorically exclude extra-lunar sources as an explanation of the observed phenomena:

1) The onset of sunrise enhancement often begins as much as 60 hours before actual sunrise. This observation rules out: (a) Thermal noise from the experiment which remains at a stable, electronically ideal temperature of 250° K up till a few hours before sunrise; (b) Direct effects of electromagnetic radiation from the sun; and (c) Direct effects from the solar wind.

2) The sunrise enhancement persists for 30 to 60 hours after sunrise and wanes by two orders of magnitude while the sun is in full view. This rules out: (a) Beta meteoroids or cosmic dust ejected in a direction radially outward from the sun as seen by PIONEERS 8 and 9; (b) Again, and independently, the solar wind; and (c) Again, and independently, electromagnetic radiation, or ions, or electrons from the sun.

3) The phenomena were absent during two lunar eclipses. This observation rules out again, and independently; (a) Beta meteoroids; and (b) Solar electromagnetic radiation, electrons, and ions.

Another data characteristic which principally led to an investigation of the possibility that the instrument was detecting charged dust particles was the peculiar distribution of pulse-height -- a function of the particle's energy. Data from similar experiments in PIONEERS 8 and 9 showed a sharply decreasing distribution toward large pulse heights or the high energy particles. The LEAM data, however, showed the bulk of events represented by large pulse heights. A detailed circuit analysis of the sensors' electronics proved that the instrument would register highly charged, slowly moving particles, and would assign large pulse heights to the events as a function of the particle's speed and charge. Computer simulations of the sensors' response to charged microparticles verified the results of the circuit analysis. The precise mechanism by which the experiment responds to charged microparticles will be studied further in laboratory experiments on the spare unit. Results from that study will be reported later.

D. THE DATA

A single problem exists in the performance of the experiment on the moon. Experiment temperatures are higher than anticipated. To avoid dangerous overheating, the electronics are turned OFF during each lunar day for a period of about 8.3 earth days. To date of this publication, the instrument has been ON for 445 earth days out of 22 lunations. During that exposure it has registered a total of 7,972 events, 4900 of which are "coincidence" events requiring a simultaneous (within 1 μ sec) pulse from the front film and grid.

Figure 1 shows the number of coincident events per 3-hour period recorded by the EAST sensor for each of 6 lunations in 1973. Each lunation starts before sunset as the experiment is turned ON and continues past sunrise when the instrument is turned OFF. The time

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(abscissa) is in hours before and after sunrise. Of note on this figure is the consistent nature of the phenomena, relative to times of sunrise and sunset. In the 22 lunations analyzed, and processed, to date, there is no evidence of seasonal or cyclic effects. There is an interesting dearth of activity for the EAST and WEST sensors following sunset. The center of this quiet

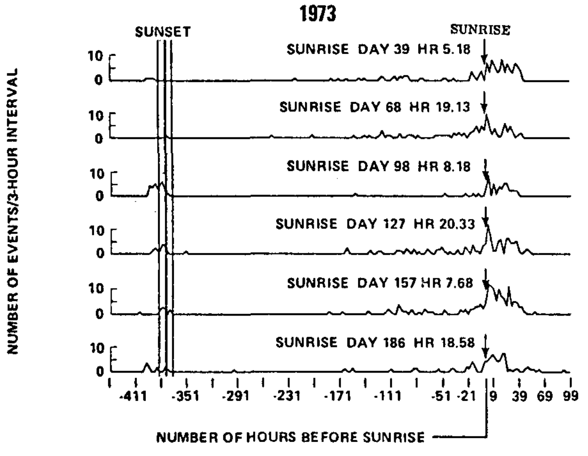

Figure 1. Number of Events per 3 Hour Interval

period occurs when the moon is preceding and aligned with the earth's orbital path. This quiet period is seen more clearly on Figure 2, which represents data from all 3 sensors over a period of 22 lunations summed into a period of one lunation. The only activity of note exhibited by the UP sensor is centered around the sunrise terminator. The EAST and WEST sensors

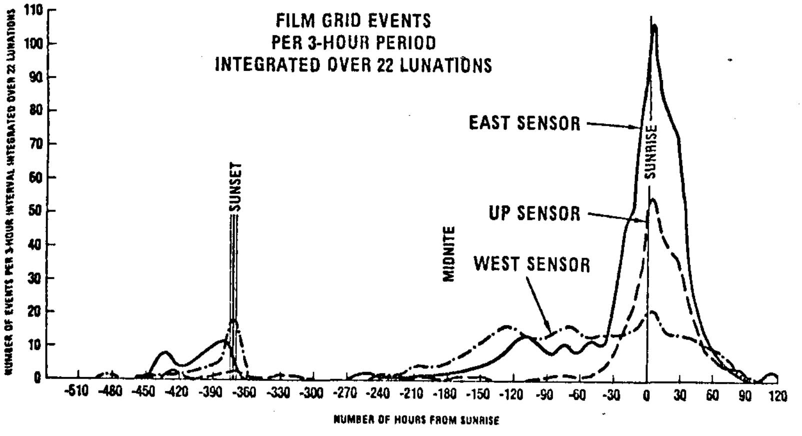

Figure 2.

show a general increase in event rates up to a first maximum near the sunset terminator, then a sharp decline to essentially no activity at 360 hours before sunrise. The quiet period lasts for 60 to 80 hours in both sensors; then the event rate slowly increases in both sensors

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to a quasi-plateau at about 120 hours before sunrise. The EAST sensor shows an order of magnitude increase during the passage of the sunrise terminator. The WEST sensor shows no significant sunrise terminator enhancement. The zero flux indicated after sunrise terminator enhancement is not necessarily real but represents that time when the experiment is OFF.

As a matter of interest, the average primary cosmic dust (not including lunar ejecta) at 1 AU, as measured by the PIONEERS 8 and 9 experiments, would be represented on Figure 2 as 0.4 particles/3-hour interval. However, the majority of primary particles intercepted by the PIONEER experiments were Beta meteoroids -- particles ejected by radiation pressure quasi-radially outward from the sun. Hence these should impact the UP sensor in the OFF mode. Accordingly, the average cosmic dust flux is too low to be properly represented on the scale in Figure 2.

If one assumes a mass of 10^{-12} grams for the average particle intercepted by the LEAM, the churning rate for the EAST sensor becomes 4×10^{-18} gm cm^{-2} sec^{-1}; or in 4.5 billion years it becomes 0.6 gm cm^{-2}.

Figure 3 graphically illustrates the direction and relative flux of particles intercepted by the 3 LEAM sensor systems. The arrow directions show a general direction of particle movement into the sensors. The arrow size shows the relative flux of particles intercepted.

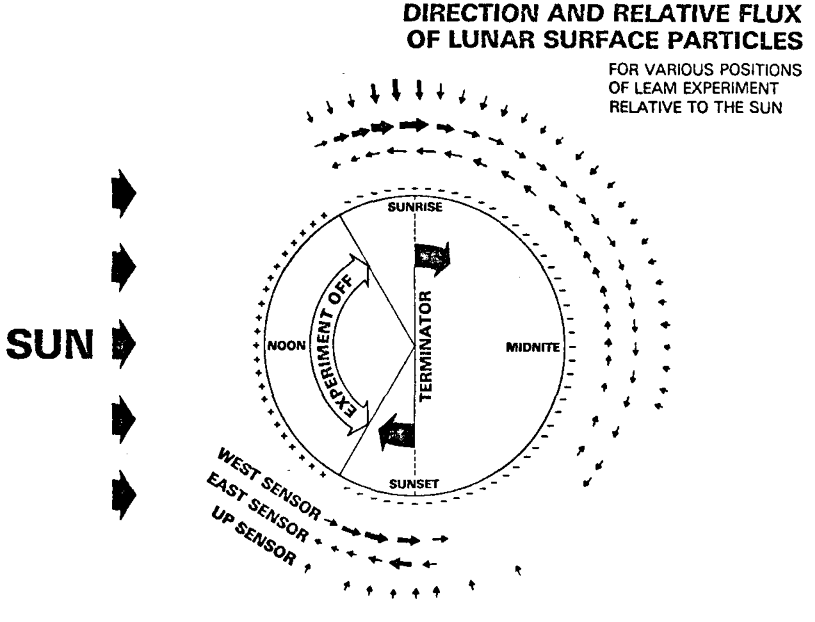

Figure 3. Direction and Relative Flux of Lunar Surface Particles

The plus and minus signs indicate polarity of the lunar surface potentials on the sunlit and dark sides. The quiet zone after sunset is shown. The fact that particles are moving both EASTWARD and WESTWARD, particularly during passage of the sunset terminator, suggests

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a transport of both negatively and positively charged particles.

Electrostatic transport of lunar fines has been postulated as the major mechanism for lunar soil movement for more than 2 decades (2). More recently, the effect of electrostatic forces on lunar fines is offered as the only plausible explanation for the luminous streamers and scattered light seen and described by the APOLLO 17 Astronauts (3). As for LEAM data, there remains little doubt that essentially all of the events recorded by that instrument are from lunar surface fines carrying a high surface charge. There are three mutually dependent factors which govern the feasibility of electrostatic transport: 1) The lunar surface potential; 2) adhesive forces; and 3) The surface charge on the particle. Approximate values for the first two factors have been derived from measurements on the lunar surface. Relatively accurate values for the third factor will be made available via laboratory calibrations of the LEAM spare unit to slowly moving, highly charged microspheres. When a relationship between the LEAM pulse heights and the particle charge and speed (< 1 km-sec^{-1}) is obtained and it is assumed that electrostatic transport is primarily initiated at or near the terminators, the following information may reasonably be derived: 1) The particle trajectory; 2) The lunar surface potentials and electric field strength; 3) Particle size distribution; and 4) adhesive forces.

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