BELLCOMM, INC.

SUBJECT: ALSEP Environmental Specification
Revision: Lunar Dust - Case 340

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FROM: N. W. Hinners

MEMORANDUM FOR FILE

I. Introduction

The current environmental specification for the Apollo Lunar Surface Experiments Package (ALSEP) calls for satisfactory operation of the package on the lunar surface even when exterior surfaces and the components are completely covered with lunar surface material or "dust." As one might suspect, this presents a difficult thermal control problem for certain components (e.g., the passive seismology experiment). Combined with recent press reports that Surveyor I has given no indication of lunar dust, this has led to a desire to re-evaluate the environmental specification in the hopes that it may be relaxed and thus relieve some of the engineering problems.

In this memorandum, therefore, I shall: state the situations which present a potential dust hazard; specify the original reasons for suspecting a dust problem; examine new evidence for or against the presence of highly cohesive dust; draw conclusions as to whether or not to relax the specification; and finally, present operational modes of reducing any potential hazard.

II. Potential Dust Hazard Situations

It is useful to examine the different ways in which dust may come into contact with ALSEP, for, while each presents a common problem, each warrants a different solution.

First, during the deployment process, the astronaut(s) carries the ALSEP from the LM storage compartment to the deployment site some 300 feet from the landing point. During deployment an astronaut may either drop or tip the ALSEP components (the ALSEP specification calls for survival of a drop shock) at which time thermal control surfaces come into contact with the soil. Secondly, it is possible that the LM ascent engine exhaust plume will entrain surface dust, some of which will then impinge on the ALSEP. Lastly, one must consider the possibility that dust will come into contact with ALSEP after astronaut departure and during the 12 months of operational lifetime.

III. Original Reasons for Specification

The original specification of 100 percent dust cover of external surfaces was put in for the reason that the lunar surface was believed to be covered to some unknown depth (estimates ranged from centimeters to kilometers) with small particles which might be highly cohesive. Placed in motion either by electrostatic levitation or as secondary meteoroid ejecta such material could potentially stick to thermal control surfaces, thus unfavorably altering the absorption and emission properties.

Belief in small surface particles was occasioned primarily by the theory that the constant meteoroid bombardment must be pulverizing the lunar surface material (ref. 1) and from analysis of the lunar photometric function and polarization (ref. 2). The thought that small particles would be highly cohesive is an outgrowth of the following considerations:

1. The very low lunar atmosphere, combined with a high surface UV flux, might result in "clean" surfaces with excellent bonding qualities;
2. Small particles have a large surface to mass ratio in which case surface forces become important; and
3. Analysis of the photometric function indicates that the lunar surface might be composed of small particles forming a bulk material of high (~80%) porosity. Particles supporting such an open structure must possess a high degree of cohesion.

IV. New Information

New information bearing on the problem comes from the U.S. spacecraft Rangers VII, VIII, IX, Surveyor I, Orbiter I, the U.S.S.R. spacecraft Lunas 9 and 10, and further laboratory work.

Photographs from the Rangers and Orbiter and the meteoroid flux measurements of Luna 10 strongly support the belief that the lunar surface topography is dominated by impact features. Analyses of crater counts and of crater morphology, even allowing for measurement errors and differences in detailed interpretation, indicate that the surface has been "gardened" to a minimum depth of many tens of centimeters (refs. 3 and 4).

Surveyor I and Luna 9 pictures are consistent with the above and supply the additional information that the average particle size is small. Gault, Quaide, and Oberbeck (ref. 5) report that in the Luna 9 area the predominant grain size is less than a few millimeters. Preliminary results from analysis of the Surveyor mission (ref. 6) indicate a "basic grain size" less than 0.5 mm. We might add that any sensible size distribution would include the presence of abundant particles down to some tens of microns in diameter, consistent with photometric interpretations.

Concerning cohesion of the surface material, Gault and co-workers at Ames Research Center have long (> one year) (ref. 7) maintained that the crater shapes observed in high resolution Ranger lunar photographs were indicative of impacts into weakly cohesive or non-cohesive particulate material. Their conjecture was based upon laboratory simulation of lunar cratering into various soils. Recent analysis of craters in Luna 9 pictures, again based upon the laboratory work of Gault, et al, (ref. 5) enables one to make a yet more convincing argument for low or non-existent cohesion. Further, the preliminary Surveyor report indicates that the granular material possesses "a distinct but small amount of cohesion." That cohesion has been estimated to be between 1×10^3 and 4×10^3 dynes/cm^2. It may be noteworthy that the picture of the footpad which moved into the soil shows no obvious soil coating. Remember, however, that it is not clear that we see the significant surfaces.

One outstanding feature of both the Luna 9 and Surveyor I photographs is that there is no evidence for the highly porous, thus cohesive, "fairy castle" structure implied by analysts of the photometric function. If it exists, it is below the resolution of both Luna 9 and Surveyor I camera systems. Further, the work of Gault et al (ref. 5) on the Luna 9 photographs, analysis of the motion of the Surveyor footpad (ref. 6), interpretation of radar reflections (ref. 8) and theoretical considerations (ref. 9) also lead to the conclusion that at least the subsurface material is not highly porous. A porosity in the range of 30% to 50% in a weakly cohesive or non-cohesive granular medium would be consistent with all the aforementioned references. Any extremely porous material with concommitant high cohesion, must be limited to the upper few millimeters at best.

Arguments for strong cohesion which are based upon analysis of the photometric function are weakened by recent work of Oetking (ref. 10). Oetking contends that the great increase in lunar brightness at zero phase angle may be "common to most substances" rather than peculiar to the moon. He attributes errors in previous work to instrumental problems. Hapke, a strong proponent of the "fairy castle" structure, originally doubted the validity of Oetking's work but has since been "persuaded of the reality of the phenomenon" (ref. 11).

The last source of new information concerns the possible occurrence of dust on the Surveyor I. According to Mr. W. A. Hagemeyer, Jr. of JPL, in charge of thermal analysis (personal communication, September 2, 1966), the following can be said about the Surveyor results:

1. Thermal analysis of temperatures during two lunar days gives no indication of a dust coating.

2. Particles, or aggregates of particles, up to 1/10 of an inch in diameter have been observed on the covers of the electronics compartments. They appear to cover to the order of one percent of the top surface.

3. The particles mentioned above were seen in pictures taken on both lunar days. It appears that some which were present on day 1 are not present on day 2 and vice versa.

4. There is reasonable certainty that the shattered mirror on the thermal control surface of the electronics compartment did not shatter before the first lunar night exposure, thus ruling out fragments of mirror as an explanation for all the particles observed.

5. Laboratory tests in which sand is placed on the thermal surface and then photographed (TV) yields results similar to those obtained on Surveyor I.

Point 1 indicates that if surface material, visible or not, was adhering to Surveyor it was too low in amount to affect it thermally.

All considered, we are warranted at this time in concluding that lunar surface material is granular, predominantly sub-millimeter in size, weakly cohesive to non-cohesive, and not highly porous beneath optical depths.

In view of remaining uncertainties, to be discussed below, it would be prudent not to relax the ALSEP 100% dust cover specification completely. A partial relaxation is therefore suggested. If dust is going to present a problem, it is more apt to settle on and adhere to horizontal rather than vertical or non-horizontal surfaces. Thus, if it is necessary, in "hardship" situations, to relax the specification, as a first step it is recommended that it be changed to, "no dust covering for vertical and other non-horizontal surfaces," in that order, and that the horizontal surface specification remain, "100% dust covered."

V. ALSEP Considerations

The ALSEP environmental exposure differs from that of Surveyor in at least three ways. The astronaut emplaces the ALSEP - the ALSEP is subject to the ascent plume - and its life is longer.

Since the astronaut is present, the initial condition of the ALSEP can be clean. Since the surface material is believed to be at best weakly cohesive it may be quite feasible to equip the astronauts with a "dust-cloth" (carefully chosen so as not to generate static electricity) at a negligible weight penalty.

Secondly, the ascent engine blast is an entirely reasonable source of dust and debris. Since the possibility of dust impingement during ascent is enhanced by the presence of small, weakly cohesive granular material, certain operational precautions are warranted. One consists of deploying the ALSEP, if possible, at a spot away from the planned ascent ground trace and plume. Another possibility is to shield sensitive instruments from ascent impingement. Dust covers or natural barriers are potentially helpful in creating such shadow areas. For example, craters and ridges may provide a topographic difference of several tens of feet in elevation between the LM and ALSEP.

Lastly, consider the one year "passive" phase. The low cohesion, bolstered by the Surveyor results, indicating no thermal degradation after two lunar days, leads one to suspect that a 6X increase in exposure would not greatly alter the conclusions, all else being equal. This gives some confidence that ALSEP will experience little thermal degradation over 12 lunar days if it survives deployment and LM ascent in a "clean" state.

VI. Summary

A review of current knowledge of the lunar surface indicates that the bulk surface material is a fine grained (submillimeter) granular medium with normal porosity ($\sim$30-50%) and low cohesion. In considering the potential hazard of such material relative to thermal control surfaces on ALSEP, it is concluded that the requirement that the components operate while 100% covered with lunar dust may be partially relaxed, for "hardship" cases, to the point of requiring that only horizontal surfaces be so covered and that first vertical and then other non-horizontal surfaces be considered clean. In order to enhance the chances of no hazard, the following are recommended:

1. The astronauts should be equipped with a lightweight "dust-cloth" to clean off lunar soil inadvertently placed on the ALSEP.
2. A lunar surface site survey should be conducted prior to ALSEP deployment with the intent of finding a spot which has been swept clean of "dust" by the descent plume and/or which will be clear of the ascent engine plume impingement.
3. During a site survey, consideration should be given to the use of small craters and ridges for providing natural shadowing from the ascent plume.

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Attachment
References

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