Muehlberger

A MULTIPLE FOIL LUNAR ENVIRONMENTAL ANALYSER (FLEA PACKAGE) FOR THE EVALUATION OF:

- Meteoroid Primary Impact Penetration, Radiant, Velocity and Composition.
- Meteoroid Impact Ejecta and Comminution Products.
- Solar Wind Composition.
- Medium Energy Solar Flare Composition.
- Solar Wind Sputter Rate.
- Meteoroid Bumper Efficiency.

by

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SUMMARY

The conception of a multiple thin foil sensor has been investigated and is suggested as a very valuable tool for the accumulation of data over long exposure periods on the lunar surface. Data will lead to the evaluation of specific parameters of the meteor environment, of the solar wind spectrum and of the overall environmental erosion rates from both impact and sputtering. Information yielded is shown to be more complete and superior to that obtained from single impacts on polished surfaces, and in analysis procedures it offers scope for radically reduced electron microscope scanning time at high resolution; this is achieved by the preliminary optical location of foil penetration areas. Four exposure areas of 10 cm x 10 cm using high quality rolled metal foil of several microns thickness would be supported on a 1 cm grid spacing and incorporated in a rugged unit weighing less than 200 grms. weight. Several hundred meteoroid penetrations of $\geqslant$ 3 microns would be expected in 10 years exposure.

Techniques for production, testing, calibration and analysis are shown to be available and fully tested, and no extension of current capabilities is required. A rapid assembly of such a unit could be accomplished in good time for deposition by the Apollo 17 astronauts.

INTRODUCTION

Evaluation of the lunar and interplanetary meteoroid environment has been a very prominent area of investigation even prior to the advent of space probes, and the meteoroid environment is certainly foremost in the forces affecting lunar surface morphology and evolution. Crater studies from lunar samples have answered some questions but have opened up other voids in our knowledge; considerable uncertainties exist even in the current micron and submicron flux rates, the sputter rates in the solar wind and in the contribution from splashes and condensations from impact plasma. Real-time micrometeoroid detection by the Pioneer 8 and 9 satellites has added new reliability to this area but again questions such as the particle's penetrating power and their composition, the contribution to erosion from lunar ejecta, comminution products and volcanic products remain largely unanswered.

Real-time impact and ejecta measurements are only now beginning to be investigated on the lunar surface with the LEAM micrometeoroid experiment.

Similarly in the solar wind field, basic flux rates are known, but the long term effects on thin foils and knowledge of the flux of minor components would benefit from data accumulated over a long timescale.

The opportunity to accumulate such data over a period of many years opens up new possibilities: investigations covering two major fields are now proposed in an experimental package of extreme simplicity but yet of great potency.

PROPOSAL

The multiple Foil Lunar Environment Analyser (FLEA) comprises 4 layers of high quality rolled metal foil of 2 and 5 microns thickness and a highly polished back-stop plate. The foils are high purity titanium and aluminum and are 'pin-hole free.' Ideally equal areas of 10 cm x 5 cm would be used for each metal, yielding 100 cm^2 of impact area. Support would be on diecast frames of 1 cm grid spacing and of $\geqslant$ 95% transparency; a spacing of 0.5 mm for the top foil and 1 mm for successive foils and the back-stop plate would be used, enabling clear correlation of multiple holes and impact radiant determination. The foils would be scanned optically prior to launch to detect any imperfections, which would be anticipated to be $<$ 1 per 50 cm^2. Location is sensitive to holes $\geqslant 0.5\mu$ diameter and positional accuracy is better than 50μ.

After exposure the layers and their diecast frames would be separately scanned, revealing and locating penetrations and hence their positions during the exposure configuration. Incident radiants of meteors would be obtained for multiple penetrations, or a simple flux rate for single perforations. Stereoscan electron microscopy can then be concentrated on holes thus located and on the predicted impact positions on intermediate foils and the back plate.

Meteor composition may be investigated by microprobe analysis of decelerated debris in a similar manner to current impact crater probe studies. The multiple foil also acts in an interesting way as a discriminator of meteor impact velocity and density: low velocity but dense ejecta will penetrate without destruction and record of their passage through two or more foils without expansion of the impact areas will identify their low velocity. Hypervelocity primary particles at low density will be selectively destroyed at the first foil; for those penetrating, only debris and spall damage on the top face of the second foil will be detected. Primary hypervelocity impacts from high density particles will generally yield a smooth penetration on the first foil and a larger smooth hypervelocity crater on the second. Spall damage and crater profiles will again assist in the discrimination of hypervelocity impact particles.

The quiet solar wind (0.7 KeV protons, 2.8 KeV helium, etc.) is completely absorbed by the first foil. Composition analysis may be performed therefore on the low energy component which should parallel current collector measurements. Above 100 KeV energy however, transmission through the first foil will be significant, and the multiple foil arrangement will act as a simple spectrometer for energies in the range $\geqslant$ 100 KeV. Solar flare protons will come to rest primarily in the first few foils, but 1 MeV protons penetrate to the back plate.

The sputtering rate is deduced by measurement of the thickness of an optical coating of 100 Å on the top and rear surface of the top foil. This comparison thus eliminates basic evaporation rate errors. Using some accepted estimates of the sputter rate of 1 Å per year (Wehner and others), an erosion of 10 Å could be measured after 10 years by interferometric techniques without difficulty, but if new and very much lower estimates are born out (McDonnell and Ashworth) the experiment would yield only an upper limit, but this would be of major significance.

Relative penetration rates of the successive foils would yield a clear and direct answer to meteor bumper efficiency in the lunar environment and by inference in interplanetary space at 1 A. U., which would be relevant to long exposure missions and to the degradation of optical components in space.

SCIENTIFIC BACKGROUND

Thin foil meteor penetration experiments have yielded reliable data on the environment and their value proven. The penetration spectrum of particles in space has been well established on the Explorer and Pegasus series and is currently being extended to interplanetary space on Pioneer F. In the laboratory mechanisms of thin foil penetration have been studied by numerous experiments; on the theoretical side computational codes have been developed which go a long way towards understanding the impact processes of single and multiple foil penetrations. We shall be able to draw on a wealth of both experimentation and theory to interpret the impact data expected from the FLEA package.

Optical scanning techniques are fully proven in this application and also the electron microscopy and microprobe techniques which are required.

Interpretation of the radiants of incident meteors which cause double penetrations is subject to uncertainty in one coordinate due to the lunar rotation. In the orthogonal coordinate of elevation however, we see that for the landing site chosen, the inclination of the radiant relative to ecliptic may be obtained. This data is very valuable for interplanetary evolutionary studies and meteor dynamics. For secondary impacts caused by lunar ejecta, the radiant is always known relative to the impact point for a fixed sensor, and hence the point of origin on the lunar surface can be estimated. Hence also an estimate of the total ejecta mass may be made from a knowledge of the detected mass and its distance from the impact position thus estimated.

Solar wind composition measurements from thicker foils are currently established over shorter exposure periods but the added information obtained by multiple foils analysis of the absorbed solar wind will prove very interesting. This analysis can be performed just as the single foil solar wind composition measurements, but it would be repeated for each foil and the back plate.

Very high quality foil has now been developed and available for some 5 years to the specifications proposed and quality is excellent from the standpoint of strength, imperfections and chemical purity. Standard thickness measurements to limits of better than 2% will yield very precise impact penetration parameters.

Construction and evaluation of the package proposed is "off the shelf" and currently available techniques of data analysis do not have to be stretched.

ENVIRONMENTAL STABILITY OF FLEA SYSTEM

Unsupported thin foils (12 μ) of very much larger areas than this unit have been successfully launched under 60 g. peak acceleration conditions, and also submicron foils on a 3 mm mesh support. The 2 and 5 micron foils proposed, supported by a 1 cm spacing frame, will offer excellent mechanical superiority in any conditions anticipated during Apollo flights.

Temperature stability is proven in both full sunlight and darkness for similar foils and the fatigue from temperature cycling will be considerably less than has currently been experienced in many space flights. Successful deployment of these foils in numerous particle counters over many years demonstrates their ruggedness in space applications such as this.

DATA EVALUATION

The optical scanning technique which has been developed specifically for this type of use at GSFC presents a permanent record of detected holes, their position and area. It is expected that only 10 such holes will be detected prior to launch; these will then be photographed by electron microscope and thus serve as calibration areas for optical scanning before launch and after recovery.

Approximately 300 to 500 primary impacts are expected on the front film and an average separation of 3 mm (compared to the top foil separation of 0.5 mm permits clear correlation of double penetrations; perhaps 50 penetrations of the second foil and 10 of the third would be expected from primary impacts. Only one or two would penetrate all foils to be arrested on the back plate, which is provided as a safeguard to yield data on even the largest possible size of particle anticipated from varying estimates of the particle flux. Secondary lunar ejecta of lower velocity could nevertheless penetrate more efficiently than primary particles since disruption and spreading of the particle mass is less significant. These particles of velocity $\sim 1\,\mathrm{km\ sec^{-1}}$ would be retained in the foils or the back plate for examination.

Solar wind composition studies would be performed in association with an established group in this field. No extensive pre-launch testing would be required in this area.

The wide range of information available from this experimental concept would also offer scope for exchange of foil areas for examination by research groups engaged in the meteor field, solar wind studies, and in the evaluation of environmental specifications.

SUPPORT DETAILS AND PERSONNEL

Equipment and Facilities

In-house availability of proven scanning techniques electron microscopy and probe analysis coupled with the direct experience of both proposers in this field offers excellent footing for such an experiment. Laboratory calibration studies by hypervelocity microparticles is provided by a 2 MeV Van der Graaff accelerator at GSFC which offers unequaled calibration procedures.

Personnel

J. A. M. McDonnell has been actively engaged in direct study of the interplanetary environment by rockets and satellites since 1960; he is experienced in thin film penetration phenomena and in the interpretation of penetration data from space experiments. He is currently a lunar sample P. I. investigating micro-erosion from meteoroid impacts, thermal cycling and solar wind sputtering, and plans to remain in this field of study.

O. E. Berg is a well established figure in rocket and satellite instrumentation. Since investigations on Aerobee rockets, Explorer and OGO satellites, the sophisticated micrometeorite sensors of Pioneer 8 and 9 have under his direction added new dimensions to the field of real time micrometeorite sensing. He is currently also a P. I. in the Apollo 17 (LEAM) mission and would be in an incomparable position to relate data from this very different but complementary experiment which is proposed.

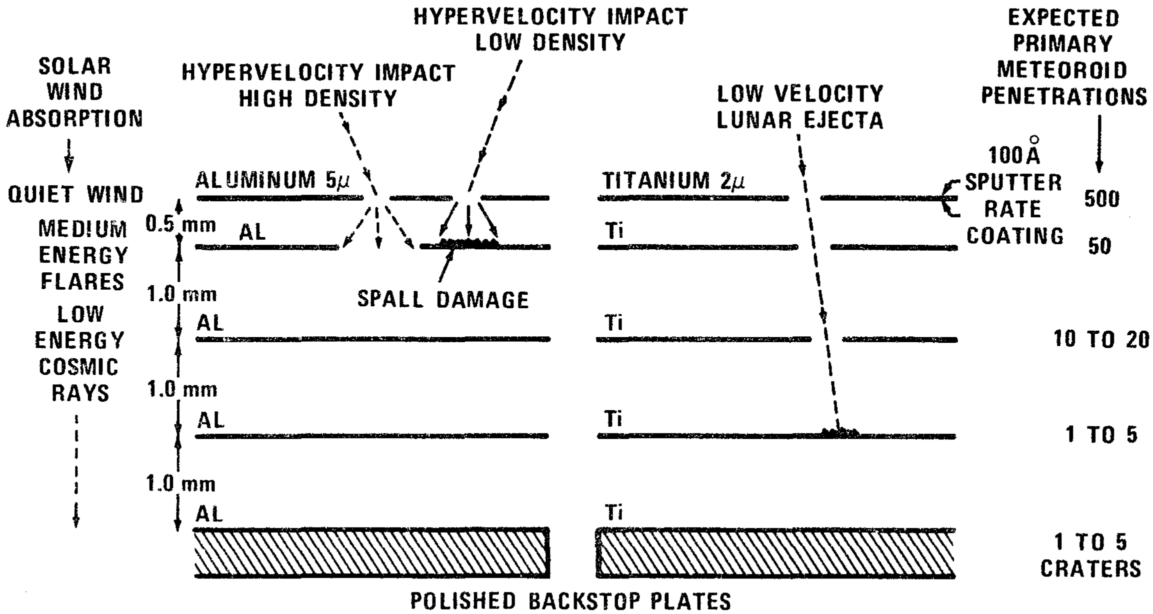

Figure 1. Schematic Illustration of Multiple Foil Lunar Environment Analyser (FLEA) Concept

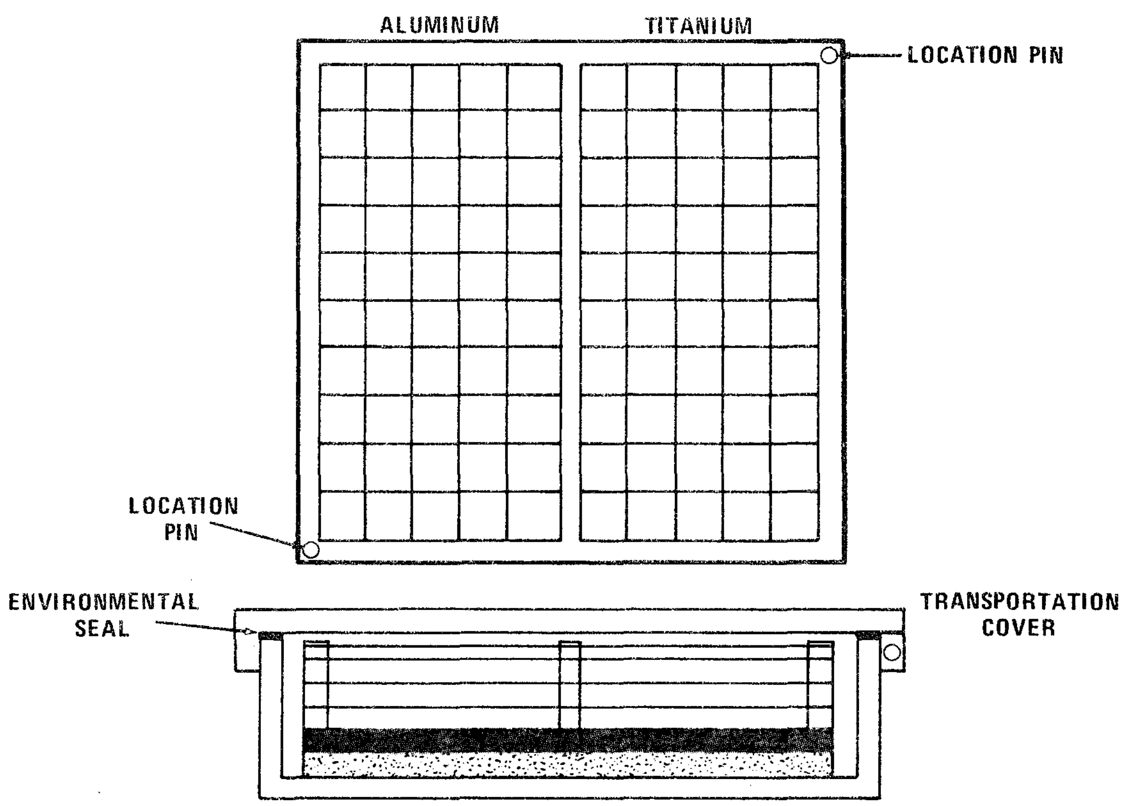

Figure 2. Schematic Plan of FLEA Package