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TECHNICAL NOTE

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RESULTS OF MICROMETEORITE PENETRATION EXPERIMENT ON THE EXPLORER VII SATELLITE (1959 IOTA)

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SUMMARY

The results of a micrometeoroid penetration experiment aboard satellite 1959 IOTA (Explorer VII) are presented. The sensors and their arrangement aboard the satellite are described, and the telemetry record obtained during flight is analyzed critically. It is concluded that one penetration through one cell occurred on the 16th day, and that it was caused by a particle approximately 10 microns in diameter.

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INTRODUCTION

Explorer VII (1959 ι) was launched on October 13, 1959 by a Juno II rocket from the Atlantic Missile Range, Cape Canaveral, Florida. A part of the instrumentation of this satellite was designed to measure micrometeorite penetration or molecular sputtering by utilizing photoconducting CdS cells. This publication presents a description of these experiments and of the results obtained from them.

Figure 1 shows a cross section of a CdS cell, which has been described elsewhere (Reference 1). On 1959 Iota, three CdS cells were mounted on a magnesium plate located on the satellite's equator in thermal contact with the battery brackets through solid copper bars. The three CdS cells, facing outward perpendicular to the satellite's spin axis, were identical in design and in effective area (18 mm^2), but had covers differing from each other in the following manner:

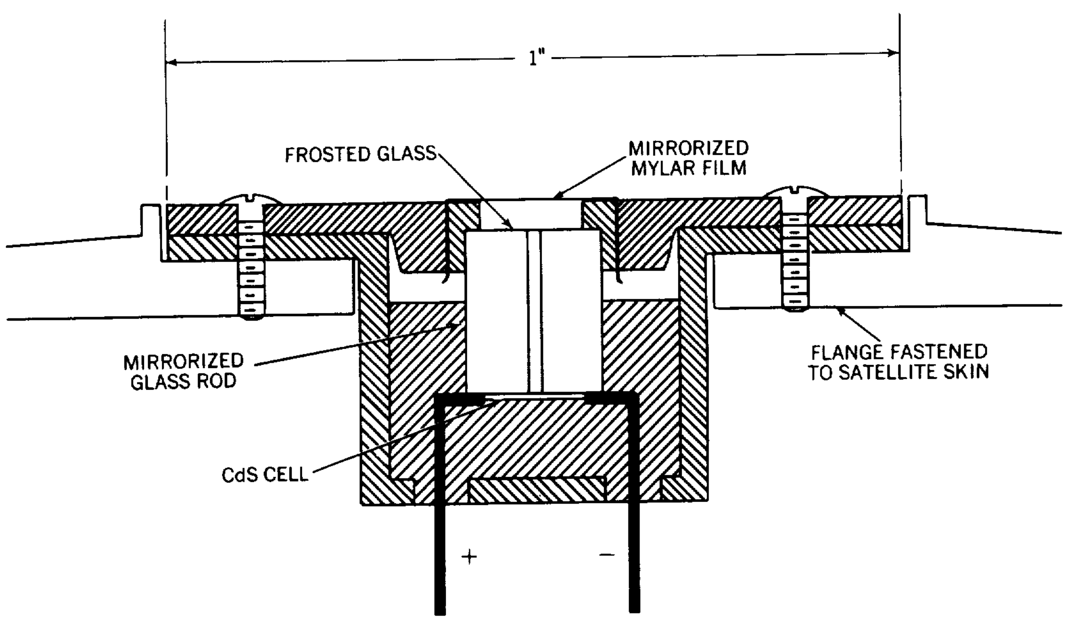

Figure 1–Cross section of a CdS cell such as the ones used on Explorer VII.

Cell 1 was covered with 1/4-mil Mylar film coated with an opaque layer of aluminum, approximately 1000 angstroms thick, on the front side only. This cell would be sensitive to both sputtering and penetration.

Cell 2 was covered in the same manner on *both* sides. This cell would be sensitive primarily to penetration.

Cell 3 had a 1-mil aluminum cap with a perforation 0.0075 mm^2 in area for calibration purposes.

Cell 2 was in addition, equipped with a 5-kilohm bead thermistor for temperature measurements of these sensors.

The resistances of these three sensors, the thermistor, and two calibration resistors were multiplexed into a resistance-controlled oscillator whose nominal frequency range was from 680 to 780 cps. The subcarrier frequency phase-modulated a 108.5-Mc tracking transmitter (Reference 2). The multiplexed channels were allocated as follows:

Channel	Sensor
1	Calibration 700 Ω resistor
2	CdS Cell 1
3	CdS Cell 2
4	CdS Cell 3 (perforated cap for calibration)
5	Temperature sensor
6	Calibration 20K resistor

CALIBRATION

The CdS cells were calibrated in terms of their response to the sun or to a xenon arc for various amounts of light input as regulated by calibrated holes through opaque covers. Rotating the CdS cells at 360 rpm in the light beam simulated the effect of the rotating satellite. Photometric measurements were taken in correlation with microscopic measurements of the area of the hole. The accuracy of these measurements was an order of magnitude better than the resolution expected from the CdS cells in their response to light stimuli. The change of response to sunlight as a function of the sun's angle with the normal to the cells was also determined. Finally, the CdS cells were calibrated for temperature changes within the expected temperature range (-10° to +60° C; see Reference 3).

RESULTS

The three CdS sensors and the thermistor performed normally and the data obtained from them are presented in the following paragraphs.

Cell 1, with a single aluminum coating, indicated a perforation of its cover before termination of the coasting period (between first and second-stage powered flight). The cause of this perforation, which occurred 540 seconds after lift-off and several telemetry frames after the ejection of the protective shroud, could not be determined. The hole is estimated to have been 0.16 ± .04 mm in diameter; its size (approximately 0.1 percent of the cell's total area) remained virtually constant through the lifetime of the experiment.

The calibration cell (Cell 3) responded as expected to sunlight until the end of battery life, and was used in the computation of the correction applied to the results obtained from Cell 2.

Cell 2 registered darkness from the launching on October 13 until October 26, 1959 (see Figure 2 for a selected daylight pass on October 24). On October 29 the telemetering record (Figure 3) suggests that sunlight is entering the cell. Records for October 27 and 28 were not sufficiently clear to distinguish a deviation as small as that seen in Figure 3. When this record is compared with Figure 4, a nighttime record made on November 7, 1959, it is evident that the Cell 2(Channel 3) *scale* reading is about 3 percent (of the 100-cps interval plotted) lower in daylight than in darkness for all times after October 29.

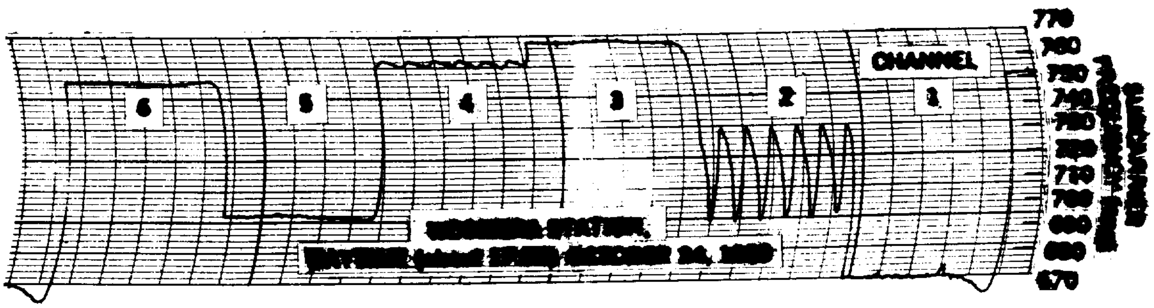

Figure 2—Explorer VII telemetry record of a selected daylight pass on October 24, 1959.

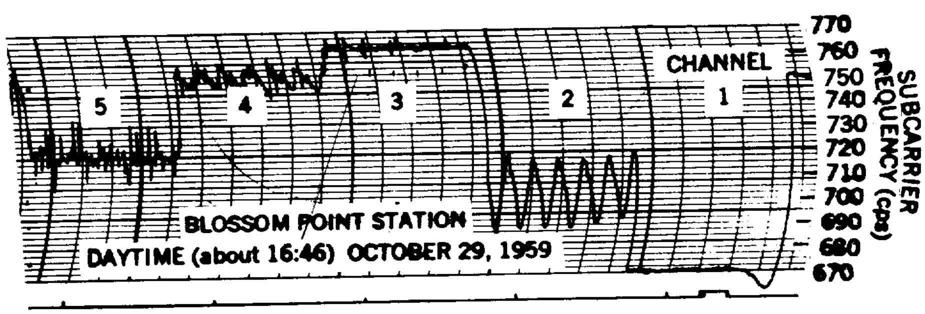

Figure 3—A daytime pass on October 29, 1959.

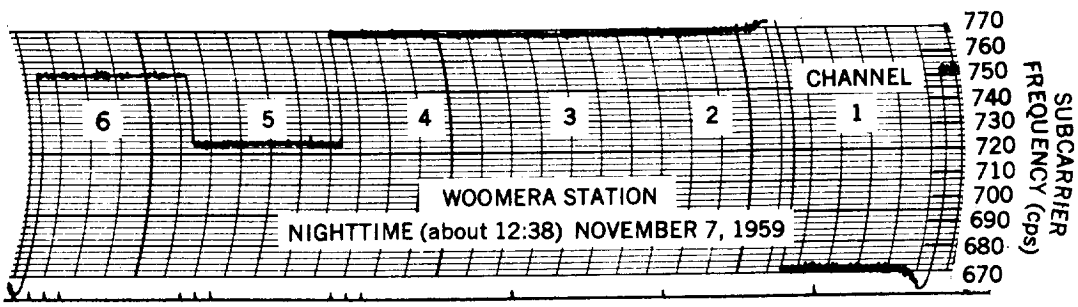

Figure 4—A nighttime pass on November 7, 1959.

Further evidence of light penetration can be seen from the Cell 1 and Cell 3 records (Channels 2 and 4) in Figure 3. They show characteristic sawtooth patterns corresponding to the spin rate of the satellite; the steeper slope in the sawtooth corresponds to the beginning of the light input to the cell, and the lesser slope to the dark phase of the spin cycle. The amplitude and shape of the sawtooth signal are functions of the amount of light entering the cell.

In the case of Cell 2 which was located physically and connected electrically in sequence between Cells 1 and 3, it is expected that the sawtooth pattern of Cell 2 should follow the pattern of Cell 1 and blend into the pattern of Cell 3, since the switching time from cell to cell is extremely short. Careful observation of the October 29 record (Figure 3) shows that a very small pattern does indeed seem to be present (Channel 3), marked by a repetition of ticks that fall in cycle with the sawtooth discussed above.

It is concluded that the 3 percent change in frequency, while being approximately at the limit of detectability, is definitely readable. In terms of ohmic resistance, it indicates a change from the 100K dark reading to 60-70K, which on a rotating satellite and at normal light incidence, corresponds to an opening having an area of 10^{-4} mm^2. This apparent area of the opening must be corrected for the sun angle. Direct analysis of the signal from the calibration cell (Cell 3) shows that the actual area is twice the apparent area. Thus, the area of the opening in Cell 2 is 2×10^{-4} mm^2, corresponding to a hole diameter of 16 microns. Further corrections for temperature were not necessary because the temperature at this time was near room temperature (Figure 5).

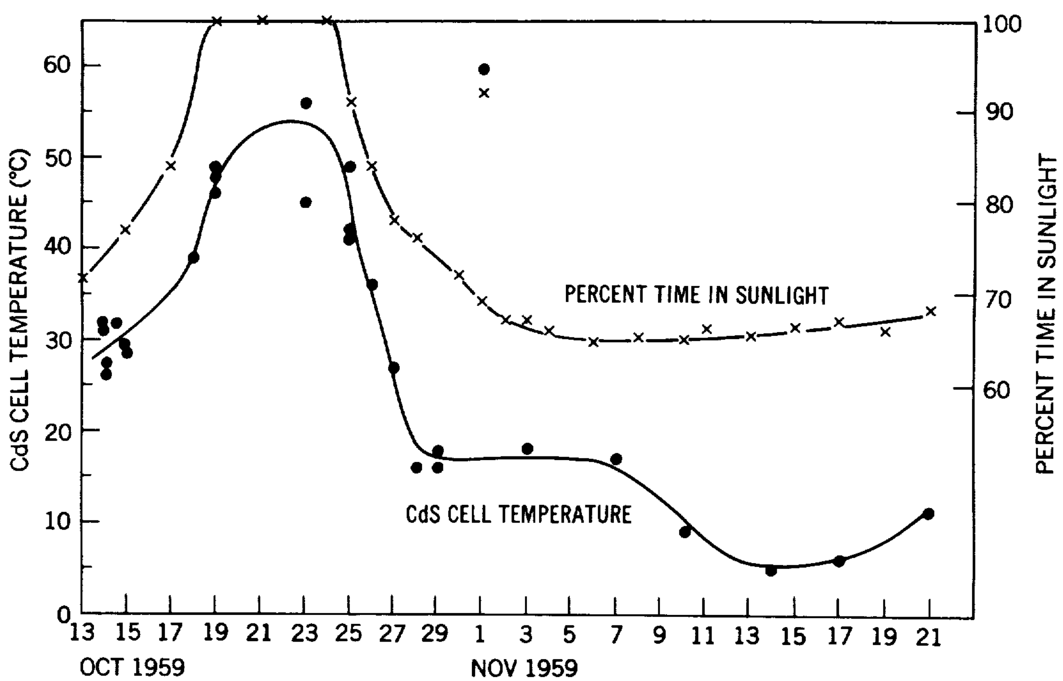

Figure 5—Measured CdS cell temperatures and calculated percent times in sunlight for Explorer VII from October 13 (launch) to November 21, 1959.

DISCUSSION

Satellite 1959 ι exposed the three CdS cells to the space environment of micrometeorites, trapped radiation, and sputtering for 38 days of active life. Cell 1 was perforated during the launching and Cell 3 was relatively insensitive because its primary function was calibration. The telemetry signals from Cell 2 show:

1. That for the first 13 days, neither sunlight nor energetic particles caused a readable response.
2. That on the 16th day sunlight was entering the cell, causing a response that corresponded to a hole size of 2×10^{-4} mm^2 (about 16 microns in diameter).
3. That after the 16th day recordings made when the satellite was in darkness showed normal dark response.
4. That the hole size did not change by a readable amount from the 16th day to the 38th.

It is concluded that the response on Cell 2 after the 16th day was due to a micrometeorite penetration of the 1/4-mil Mylar and opaque aluminum coatings on both faces.

The relation of the hole size to the penetrating particle has been defined in the recent work with the hypervelocity accelerator at Space Technology Laboratories, showing that a hole in 1/4-mil Mylar is about 3/2 times the size of the penetrating projectile (Reference 4). In the present case, then, the perforating particle would be 10 microns in diameter. Assuming a density of 1 to 3 gm/cm^3, the mass is between 5 and 15×10^{-10} gram. From the satellite microphone data (Reference 5) the influx rate for particles of mass 5 to 15×10^{-10} gram is between 6×10^{-2} and 8×10^{-3} impacts/m^2 per second. In this case the area is 18 mm^2, the time 38 days, and the probability of one hit lies between 0.9 and 0.27.

It should be noted that there is a finite possibility that the hole was produced by molecular sputtering; however, this is improbable because it requires a latent hole in the inner coating.

ACKNOWLEDGMENTS

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