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TECHNICAL MEMORANDUM

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THE EXPLORER XVI MICROMETEOROID SATELLITE

SUPPLEMENT I, PRELIMINARY RESULTS FOR THE PERIOD JANUARY 14, 1963, THROUGH MARCH 2, 1963

Compiled by Earl C. Hastings, Jr.

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Langley Station, Hampton, Va.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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SUMMARY

Penetration experiments on the Explorer XVI micrometeoroid satellite indicate that as of March 2, 1963, 24 of the 0.001-inch-thick beryllium-copper pressure cells have been punctured, and 6 of the 0.002-inch-thick beryllium-copper pressure cells have been punctured. Corresponding puncture rates are 0.034 puncture/sq ft/day and 0.02 puncture/sq ft/day for these two thicknesses. A tentative conversion of these rates to rates for equivalent thicknesses of aluminum has been made and the results have been compared with previously predicted rates. The Explorer XVI data lie above the lowest estimate far below the highest estimate.

As of March 2, 1963, no breaks have occurred in either the 0.002-inch or the 0.003-inch copper-wire card detectors. Between January 14, 1963, and March 2, 1963, additional punctures of the 0.00025-inch aluminized Mylar shields of both of the cadmium sulfide cells have occurred.

Evaluation of the degradation of a bare test solar cell and of a test solar cell with 0.006-inch glass cover between December 16, 1962, and January 17, 1963, indicated values of roughly 14 percent and 12 percent, respectively (with respect to a 3/16-inch-silica-covered cell).

Telemeter temperatures and component surface temperatures have remained within acceptable operating limits.

INTRODUCTION

The initial report on the Explorer XVI satellite (ref. 1) described the satellite and presented, with some analysis, the available reduced data for the first 4 weeks in orbit (December 16, 1962, through January 13, 1963). The present report, which is the first supplement to reference 1, extends the period covered to March 2, 1963. Specifically, it presents additional puncture data for the pressure cells and for the wire card detectors, some results from the solar-cell degradation experiment, and further information on telemetry performance and satellite temperatures.

The different parts of the text have been contributed mainly by the following cognizant experimenters and specialists:

Contributor	Area
Charles A. Gurtler Langley Research Center	Pressurized-Cell Experiment
Wendell H. Lee Langley Research Center	Temperatures
Walt C. Long Langley Research Center	Telemetry Performance
John L. Patterson Langley Research Center	Power Supplies and Test Solar Cells
Luc Secretan Goddard Space Flight Center	Cadmium Sulfide Cells Copper-Wire Card Detectors

DESCRIPTION OF SPACECRAFT AND EXPERIMENTS

Figure 1 is a sketch of the Explorer XVI showing the five types of micrometeoroid sensors used. The location of the solar-cell test groups used in the degradation experiment is also shown. These experiments are described in detail in reference 1, which also presents tables of sensor areas and thicknesses. Since this report is intended only as a supplement to reference 1, these descriptions and tables are not repeated herein.

PRESSURIZED CELL EXPERIMENT

Data have been reduced for 78 interrogations during the period from January 14, 1963, to March 2, 1963. Forty-six of these interrogations contained data from both telemeters and 32 interrogations contained data from only one of the telemeters. As described in reference 1, the pressurized-cell sensors are divided into two identical groups, which are telemetered separately on the two telemeters. When only one of the telemetric transmissions from an interrogation is reducible, data are received in effect from only half of the sensors. Data are not lost in such cases, since they can be recovered in subsequent interrogations; however, there may be less precision in identifying the time of a puncture. Table I shows a history of the interrogations. The passes marked with an asterisk indicate the interrogations from which only one telemetric transmission was reducible.

TABLE I

Pass	Greenwich date	Greenwich mean time at interrogation	Accumulated punctures for detector thickness of -		
			0.001 in.	0.002 in.	0.005 in.
395	Jan. 14, 1963	0516	10	1	0
399	Jan. 14, 1963	1256	10	1	0
*405	Jan. 14, 1963	2221	11	1	0
*406	Jan. 15, 1963	0008	11	1	0
407	Jan. 15, 1963	0208	11	1	0
424	Jan. 16, 1963	0805	11	1	0
*429	Jan. 16, 1963	1724	11	1	0
*432	Jan. 16, 1963	2113	11	1	0
*436	Jan. 17, 1963	0433	11	1	0
442	Jan. 17, 1963	1555	11	1	0
446	Jan. 17, 1963	2139	11	1	0
450	Jan. 18, 1963	0455	11	1	0
*456	Jan. 18, 1963	1617	11	1	0
461	Jan. 18, 1963	2348	11	1	0
473	Jan. 19, 1963	2041	11	1	0
477	Jan. 20, 1963	0351	11	1	0
*483	Jan. 20, 1963	1512	12	1	0
490	Jan. 21, 1963	0223	12	1	0
502	Jan. 21, 1963	2306	12	1	0
*511	Jan. 22, 1963	1559	12	1	0
*516	Jan. 22, 1963	2337	12	1	0
*520	Jan. 23, 1963	0644	12	2	0
525	Jan. 23, 1963	1623	12	2	0
529	Jan. 23, 1963	2155	12	3	0
533	Jan. 24, 1963	0536	12	3	0
*538	Jan. 24, 1963	1454	12	3	0
*547	Jan. 25, 1963	0540	12	3	0
*552	Jan. 25, 1963	1518	12	3	0
557	Jan. 25, 1963	2246	12	3	0
565	Jan. 26, 1963	1348	12	3	0
570	Jan. 26, 1963	2118	12	4	0
584	Jan. 27, 1963	2141	12	4	0
598	Jan. 28, 1963	2212	13	4	0
*607	Jan. 29, 1963	1458	13	4	0
613	Jan. 30, 1963	0019	13	4	0
*623	Jan. 30, 1963	1721	13	4	0
628	Jan. 31, 1963	0241	14	4	0
*634	Jan. 31, 1963	1353	14	4	0
639	Jan. 31, 1963	2130	14	4	0
*643	Feb. 1, 1963	0502	14	4	0
654	Feb. 1, 1963	2333	14	5	0
*666	Feb. 2, 1963	2025	14	5	0
674	Feb. 3, 1963	1121	14	5	0
679	Feb. 3, 1963	1848	14	5	0
695	Feb. 4, 1963	2250	14	5	0
*698	Feb. 5, 1963	0507	14	5	0
*707	Feb. 5, 1963	2014	15	5	0
710	Feb. 6, 1963	0116	16	5	0
*720	Feb. 6, 1963	1857	17	5	0
722	Feb. 6, 1963	2145	18	5	0
725	Feb. 7, 1963	0401	18	5	0
736	Feb. 7, 1963	2208	18	6	0
742	Feb. 8, 1963	0931	18	6	0
*747	Feb. 8, 1963	1654	18	6	0
*750	Feb. 8, 1963	2235	18	6	0
*761	Feb. 9, 1963	1723	18	6	0
*784	Feb. 11, 1963	1041	18	6	0
790	Feb. 11, 1963	1959	18	6	0
*800	Feb. 12, 1963	1304	18	6	0
814	Feb. 13, 1963	1326	18	6	0
852	Feb. 16, 1963	0853	18	6	0
*857	Feb. 16, 1963	1729	18	6	0
860	Feb. 16, 1963	2206	18	6	0
870	Feb. 17, 1963	1535	18	6	0
*882	Feb. 18, 1963	1139	18	6	0
893	Feb. 19, 1963	0812	19	6	0
920	Feb. 21, 1963	0706	22	6	0
928	Feb. 21, 1963	2015	22	6	0
938	Feb. 22, 1963	1305	22	6	0
943	Feb. 22, 1963	2302	22	6	0
963	Feb. 24, 1963	0821	22	6	0
*967	Feb. 24, 1963	1540	22	6	0
*980	Feb. 25, 1963	1412	22	6	0
*993	Feb. 26, 1963	1254	22	6	0
996	Feb. 26, 1963	1829	22	6	0
1006	Feb. 27, 1963	1118	22	6	0
*1037	Mar. 1, 1963	1745	22	6	0
1047	Mar. 2, 1963	1035	24	6	0

Data have been reduced from a number of additional interrogations recorded during the first 29 days that were not listed in table IX of reference 1. It is now possible to identify the days on which the punctures occurred during the period of January 4, 1963, to January 12, 1963. Table II shows the first interrogation in which each new puncture was recorded during the first 29 days.

TABLE II

Pass	Greenwich date	Greenwich mean time at interrogation	Time since last interrogation, hr min	Accumulated punctures for detector thickness of -		
				0.001 in.	0.002 in.	0.005 in.
54	Dec. 20, 1962	1223	1 50	1	0	0
77	Dec. 22, 1962	0418	1 49	2	0	0
85	Dec. 22, 1962	1857	1 51	3	0	0
102	Dec. 24, 1962	0055	1 51	4	0	0
137	Dec. 26, 1962	1253	1 56	5	0	0
219	Jan. 1, 1963	1121	14 48	6	0	0
264	Jan. 4, 1963	1822	9 27	6	1	0
297	Jan. 7, 1963	0248	1 56	7	1	0
310	Jan. 8, 1963	0114	5 45	8	1	0
353	Jan. 11, 1963	0408	22 32	9	1	0
378	Jan. 12, 1963	2326	7 33	10	1	0

Figure 2 is a plot showing the history of the 24 punctures in the 0.001-inch sensors that occurred during the first 76 days of orbit time, and figure 3 is a plot showing the history of the 6 punctures that occurred in the 0.002-inch sensors during the same period.

Table III shows the time-area products and puncture rates. The puncture rate for the 0.001-inch material is 0.034 puncture/sq ft/day, based on the 24 punctures that occurred up to March 2, 1963. This rate has changed very little from the rate of 0.035 puncture/sq ft/day based on 10 punctures for the first 29 days, as reported in reference 1. The puncture rate for the 0.002-inch material is 0.02 puncture/sq ft/day based on 6 punctures. It should be noted that five of these punctures occurred during the interval between January 23, 1963, and February 7, 1963. The 0.001-inch sensors, with a total exposed area of a little over twice that of the 0.002-inch sensors had only 6 punctures during this same period of time. Puncture rate is expected to be inversely proportional to the cube of the thickness, as indicated by the slopes of the curves in figure 11 of reference 1. Accordingly, during any given period, there should be approximately 16 times as many punctures in the 0.001-inch sensors as in the 0.002-inch sensors. Even if the satellite encountered a shower in which all the particles had enough energy to puncture the 0.002-inch sensors, twice as many punctures of the 0.001-inch sensors would be expected. It is apparent that the punctures were not caused by a local catastrophic impact, since no two of the punctures were recorded in any one orbit and since the punctured 0.002-inch sensors were distributed around the satellite. (The different columns of 0.002-inch sensors are separated by at least two columns of 0.001-inch sensors.) There has been no indication of any malfunction of the instrumentation.

TABLE III

Material thickness, in.	Number of punctures	Time-area products for first 76 days, sq ft-days	Puncture rate, puncture/sq ft/day
0.001	24	711	0.034
.002	6	299	.02
.005	0	161	

Figure 4 shows three curves of predicted puncture rate as a function of thickness for aluminum sheet (from ref. 2). The puncture rates of beryllium-copper, as shown in table III, have been converted to estimated puncture rates in aluminum sheet by consideration of the factors discussed in reference 1. The converted puncture rates are shown in figure 4.

COPPER-WIRE CARD DETECTORS

Between January 14 and March 2, 1963, there were no breaks recorded in any of the 0.002-inch or 0.003-inch copper-wire card detectors. The accumulated total breaks on these sensors between December 16, 1962, and March 2, 1963, is therefore zero.

CADMIUM SULFIDE CELLS

As of January 13, 1963, three punctures were indicated in the shield of one of the cadmium sulfide cells and none in the shield of the second cell (ref. 1). Analysis of results from these experiments through March 2 has not been completed, but it is evident that, through this date, the experiments are operating properly and that additional punctures have occurred on both cells.

POWER SUPPLIES AND TEST SOLAR CELLS

Telemetered values of battery voltages indicated that the power supplies were still functioning normally as of March 2, 1963. No downward trend could be detected.

The degradation of the test solar-cell groups is given herein only for the first 32 days of orbital lifetime (December 16, 1962, through January 17, 1963). Because of the unfavorable attitude of the vehicle rotation axis with respect to the sun, only a small fraction of all interrogations made between January 17 and March 2 contain data taken with good illumination of the test cells; and, of these few, not enough data have yet been reduced to permit an accurate determination of the degradation for this period. For acceptable data to be obtained, not only must the forward face of the nose cone (where test solar-cell groups 1 to 3 are located) be in sunlight during a portion of the interrogation, but the orientation of the vehicle with respect to the sun and the earth must be such that the illumination due to earthshine is relatively small or can be determined from the output of the test cells located on the cylindrical section of the nose cone (groups 4 and 5 in ref. 1).

Each of the test cell groups consists of five series-connected p-on-n type solar cells having nominal efficiencies of 8 percent. Each group is loaded at 39.2 ohms and the voltage across this resistance is telemetered. Figure 5 gives a history of these voltage outputs of test solar-cell group 1 (bare) and group 2 (0.006-inch glass covers) relative to the voltage output of group 3 (3/16-inch fused-silica window). Since the vehicle motions have not been completely analyzed, only relative degradations can be given at this time. However, the degradation of the reference cells shielded with 3/16-inch fused silica is believed to be quite small, because the fused silica is a special grade found in ground tests to be practically nondarkening under large doses of ionizing radiation. On this basis the data indicate that the bare cells have degraded roughly 14 percent, and those shielded with 0.006-inch glass have degraded roughly 12 percent. These degradation values are somewhat less than those predicted on the basis of recent estimates (by Goddard Space Flight Center) of the high-energy electron flux in the orbit of Explorer XVI.

TELEMETRY PERFORMANCE

Telemetry performance has been satisfactory from launch up to the present date. A total of 475 interrogations were received and recorded by the Minitrack Tracking and Telemetry Network during the first 1,047 passes of the satellite. To date, 210 data listings have been reduced for the A telemeter and 220 data listings have been reduced for the B telemeter by using the automatic data reduction machinery at Langley Research Center (ref. 1). Most of the remaining tapes are noisier and can be reduced only by using a laborious manual technique; hence they are reduced only when they contain essential data. The satellite signal levels have been reported running between -119 dbm and -90 dbm at the stations, with most signals better than -100 dbm (where dbm represents decibels in which the reference power is taken to be 1 milliwatt). (A minimum level of -110 dbm is required for the automatic data reduction machinery.)

The satellite orbit became 100-percent sunlit on February 7, 1963, and the telemeter temperature stabilized at 120° F. Although this temperature is somewhat warmer than that desired, ground experiments indicate that short exposure periods (1 to 2 weeks) at this temperature will not noticeably reduce the telemeter lifetime.

TEMPERATURES

Between January 14, 1963, and the entrance of the orbit into full sunlight, the Explorer XVI telemetry temperature continued at about 80° F. The constant 120° F temperature experienced by the telemetry after the orbit became fully sunlit is 10° F above the predicted maximum temperature. During this time the spacecraft attitude was very nearly that for which maximum temperature conditions would be encountered. Future telemetry temperatures therefore should never rise above about 130° F. Since February 15, 1963, these temperatures have decreased because the vehicle is no longer in continuous sunlight. As of March 2, 1963, the telemetry temperature was 78° F.

The following table lists the maximum and minimum component temperatures given by available data for the present reporting period:

TABLE IV

Component	Maximum temperature, °F (a)	Minimum temperature, °F (b)
Cadmium sulfide cells	113	64
Pressurized cells	117	49
Steel-covered grid detectors	64	-18
Wire card detectors	73	1
Power solar cells	84	25

[a]Recorded during the ninth (last) day of 100-percent sunlit orbits.
[b]Recorded 30 minutes after entering darkness on a 66.9-percent sunlit orbit having 34 minutes total darkness.

Table XI of reference 1 lists maximum and minimum component temperatures experienced during the first 4 weeks of orbit. Those values were generally lower than the values shown here in table IV. One factor contributing to this difference is the change that has occurred in the satellite spin mode. The values listed here are more likely to be typical of the surface-temperature limits to be expected, since the initial spin mode will not recur.

Reference 1 also points out that the telemetry temperatures during the first 450 hours were much higher than calculations had predicted for the conditions experienced. Because of this discrepancy, a vacuum test of the backup payload was conducted with the batteries charging and the radio beacon operating. It was found that a telemetry-temperature rise of 12° F was associated with the battery charging rates encountered and about 8° F was produced by radio-beacon operation. This total rise of 20° F was 12° F higher than the value that had been estimated in the design analysis. This rise, however, was still far below the initial values experienced by Explorer XVI. Future tests may provide additional data on the reason for these elevated temperatures.

CONCLUDING REMARKS

As of March 2, 1963, all experiments on Explorer XVI were still working properly. Data presented in this report indicate the following:

1. A total of 24 of the 0.001-inch beryllium-copper pressure cells have been punctured, yielding a puncture rate of 0.034 puncture/sq ft/day.

2. A total of 6 of the 0.002-inch beryllium-copper pressure cells have been punctured, yielding a puncture rate of 0.02 puncture/sq ft/day. Five of these punctures occurred in a single 15-day period during which the puncture rate for the 0.001-inch cells remained about average.

3. These puncture rates have been converted to rates in equivalent thicknesses of aluminum which were then compared with previous estimates. The Explorer XVI data lie above the lowest estimate but far below the highest estimate.

4. No breaks have occurred in the 0.002-inch or 0.003-inch copper-wire card detectors.

5. Additional punctures have occurred in the 0.00025-inch aluminized Mylar shields of both of the cadmium sulfide cells since January 13, 1963.

6. Results of the solar-cell degradation experiment on Explorer XVI through January 17, 1963, indicate that the bare test solar cell had degraded roughly 14 percent relative to a cell with a 3/16-inch fused-silica cover, and that a test solar cell with a 0.006-inch glass cover had degraded roughly 12 percent relative to the same reference.

7. Temperatures of the components and telemeter systems have remained within acceptable operating limits.

Langley Research Center,
National Aeronautics and Space Administration,
Langley Station, Hampton, Va., March 28, 1963.

REFERENCES

1. Hastings, Earl C., Jr., compiler: The Explorer XVI Micrometeroid Satellite - Description and Preliminary Results for the Period December 16, 1962, Through January 13, 1963. NASA TM X-810, 1963.

2. Davidson, John R., and Sandorff, Paul E.: Environmental Problems of Space Flight Structures. II. Meteoroid Hazard. NASA TN D-1493, 1963.

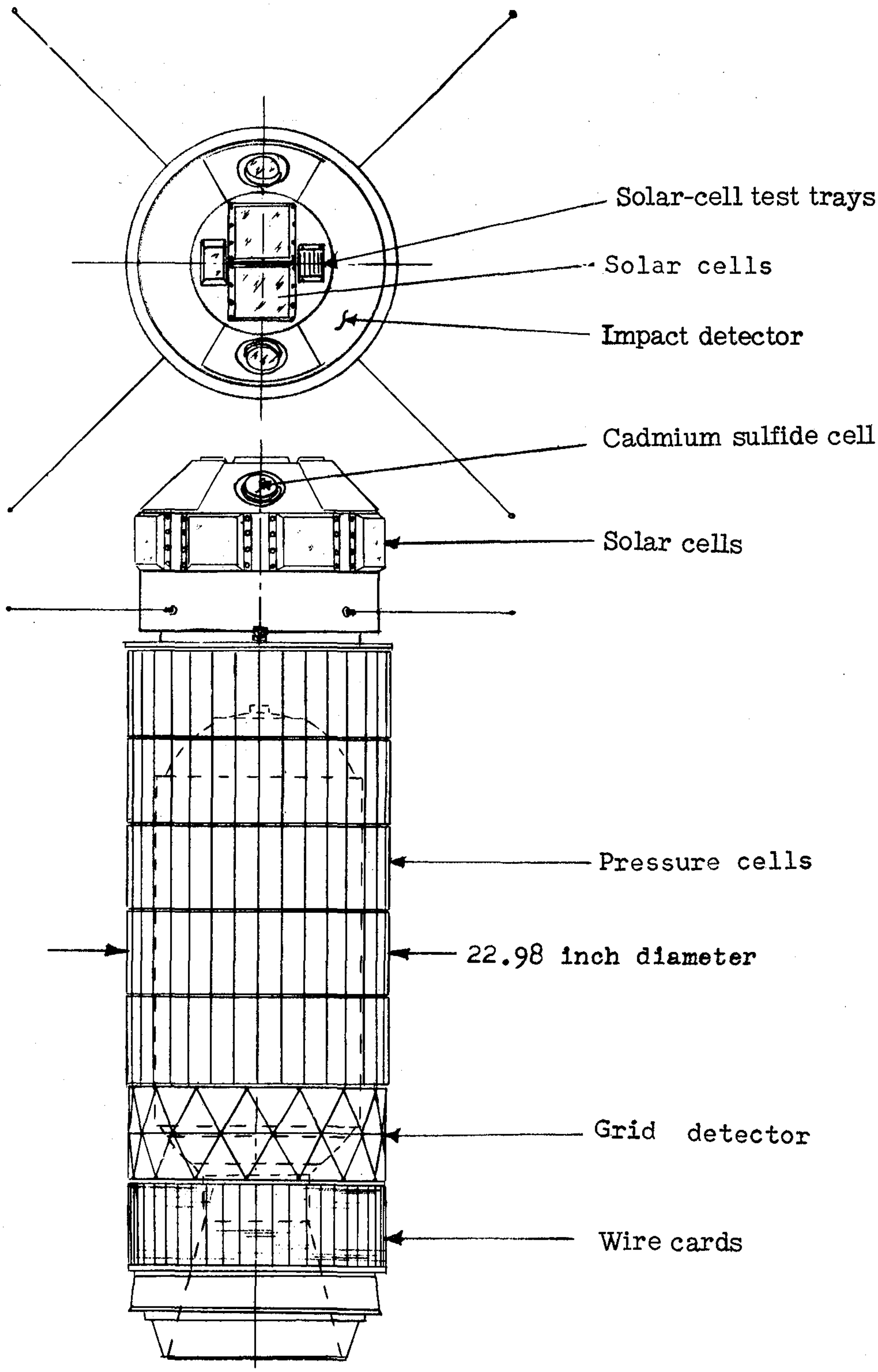

Figure 1.- Sketch of Explorer XVI showing location of sensors.

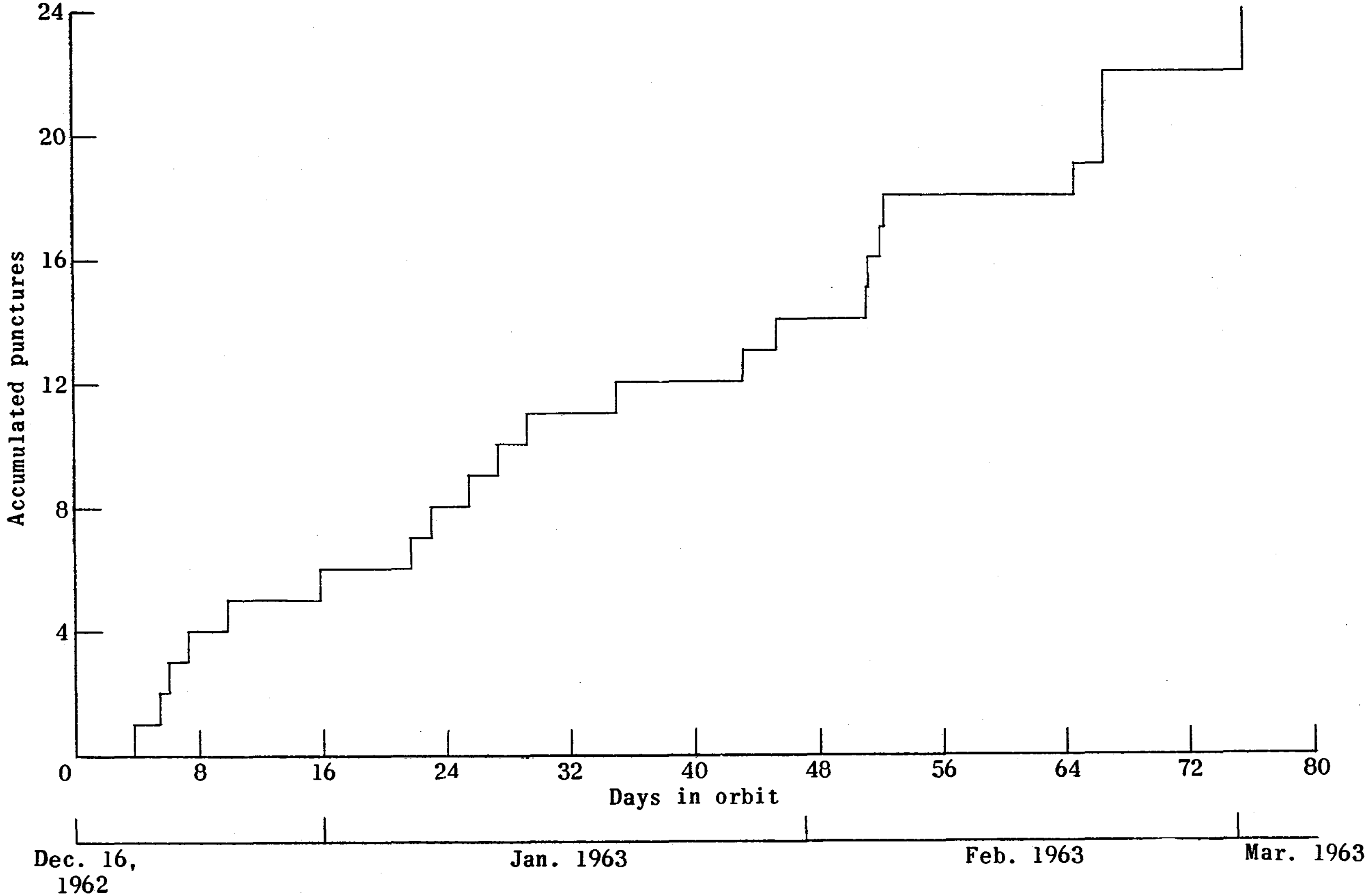

Figure 2.- History of punctures for 0.001-inch sensors.

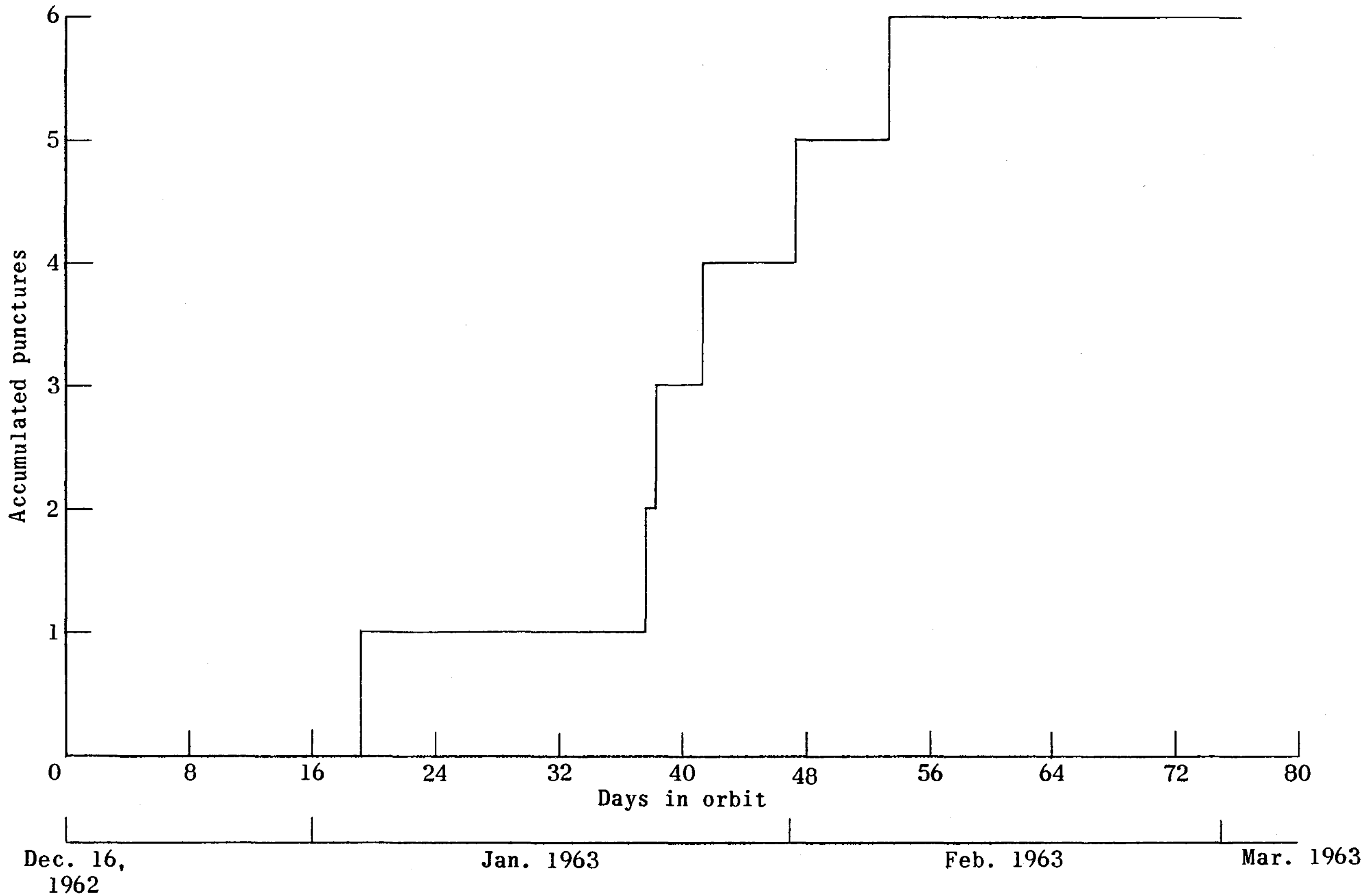

Figure 3.- History of punctures for 0.002-inch sensors.

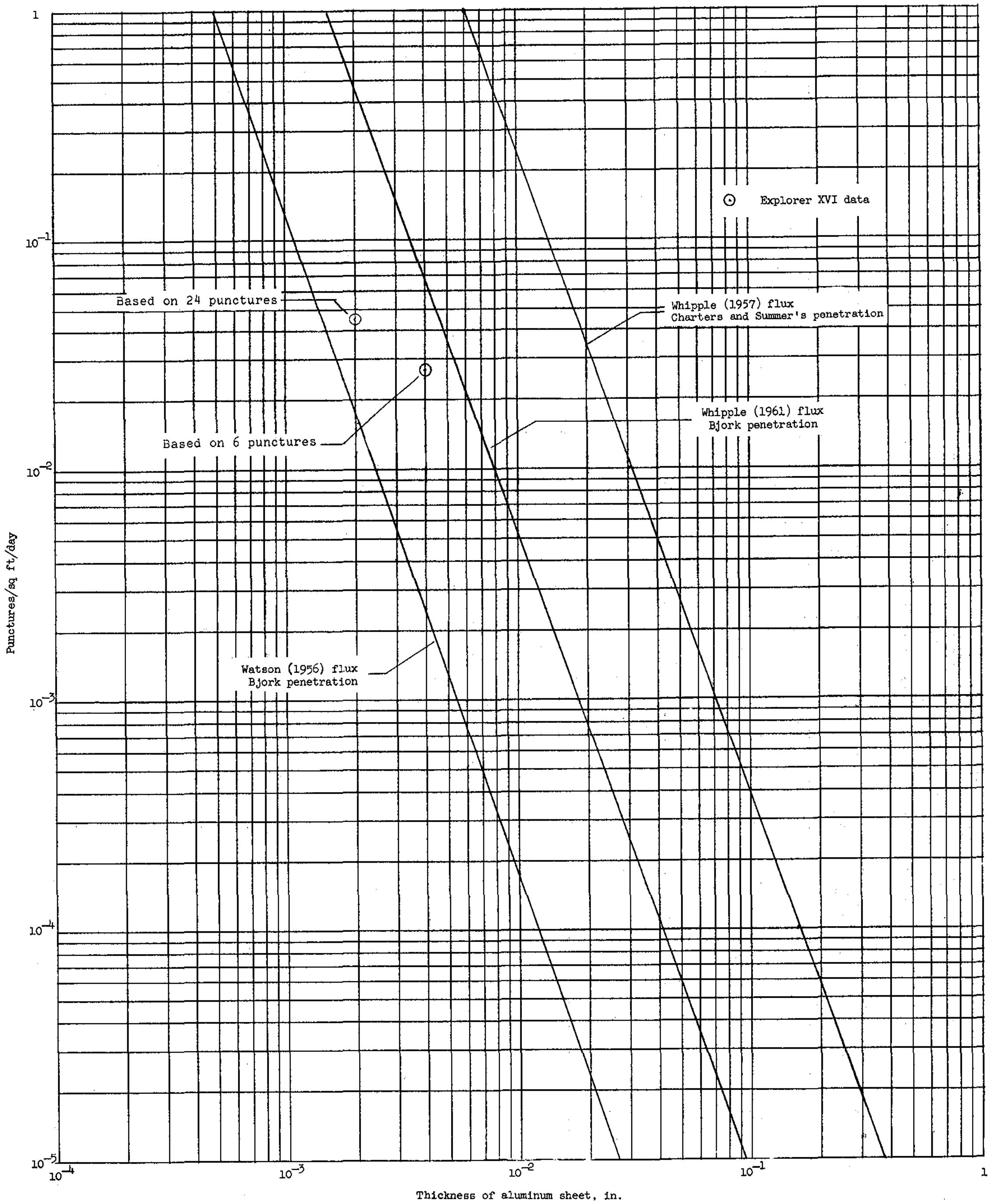

Figure 4.- Most probable rate of puncture of aluminum skin as a function of skin thickness, based on application of Bjork penetration theory to Whipple (1961) and Watson (1956) fluxes and Charters and Summers penetration theory to Whipple (1957) flux (assuming meteoroid density of 2.7 g/cu cm). Circles represent data from beryllium-copper pressure cells on Explorer XVI, as of March 2, 1963, tentatively interpreted in terms of aluminum.

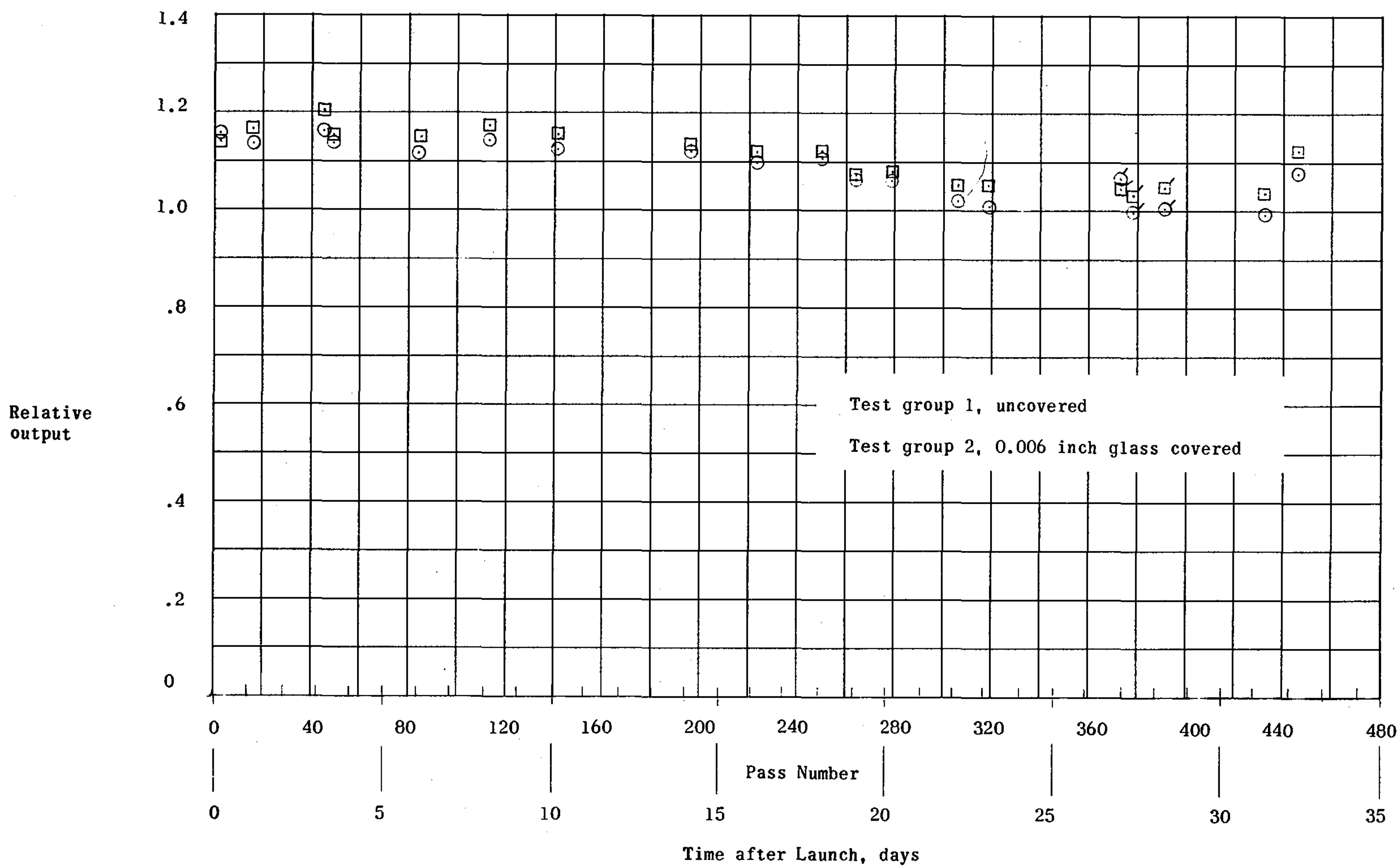

Figure 5.- Output time histories of test solar-cell groups 1 and 2 relative to group 3. The flagged data points are considered less reliable because they correspond to conditions in which an appreciable fraction of the output is due to earthshine.

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