DESCRIPTION OF PIONEER F AND G ASTEROID BELT PENETRATION EXPERIMENT

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A NASA Langley Research Center meteoroid detection experiment will be performed on both the Pioneer F and G missions. The objective of this experiment is to obtain data that will indicate the population of meteoroids in the 10^{-9} to 10^{-8} g mass range in interplanetary space and, in particular, the region of the asteroid belt, and establish a first indication of the meteoroid penetration hazard to spacecraft in the asteroid belt. Specifically, the experiment will detect meteoroid penetrations of stainless steel targets 25 and 50 μm (1 and 2 mils) thick as the Pioneer spacecraft travel in interplanetary space through the asteroid belt to Jupiter and beyond.

The large asteroids that are visible from Earth are, of course, much too sparse to present a hazard to spacecraft. The spacecraft designer is concerned about the population of the more numerous smaller mass particles in the asteroid belt. The environmental model (NASA SP-8038, 1970),[1] which is generally used in spacecraft design, for the distribution of these smaller mass asteroidal particles is presented in figure 1. In this model, the concentration of asteroidal meteoroids as a function of mass is based on an extrapolation of the data of number and mass for visible asteroids, with the number of smaller asteroids being limited to the estimated number that will reflect no more sunlight than is observed in the counterglow. The variation of the number of asteroidal meteoroids of all masses as a function of radial distance from the Sun, space longitude, etc., is assumed to vary as the asteroids are observed to vary.

The possibility of large errors existing in this model is recognized. The model represents an extrapolation of some 20 to 30 orders of magnitude from the asteroid data, which have intrinsic uncertainties resulting from the unknown albedo, density, and shape. There are also uncertainties in the limits placed on the model by the observed intensity of the counterglow. If a pessimistic view of all of these uncertainties is taken in spacecraft design considerations, the meteoroid shielding requirements would inflict severe weight penalties. It is therefore important to better define the population of

[1]See also p. 595.

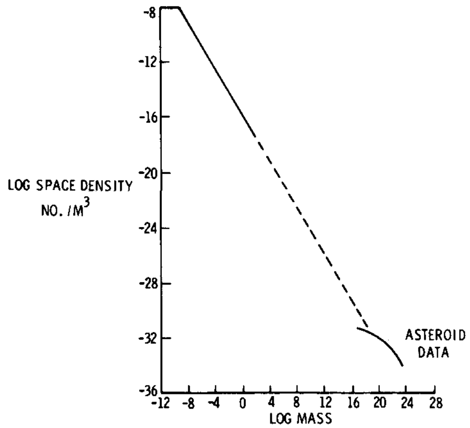

Figure 1.–Interplanetary meteoroid environment at 2.5 AU.

the smaller asteroidal particles, and flight experiments are necessary to generate the required environment definition.

APPROACH

The asteroid belt penetration experiment objectives, as previously stated, will be accomplished by measuring the time, and thus the frequency, of meteoroid penetrations in stainless steel targets during interplanetary flight. The pressurized cell type of detector is being used to detect penetrations. In principle, the detector consists of a cavity that is gas pressurized and is equipped with a pressure monitoring device. If and when a meteoroid penetrates the test material, the gas in the cavity will leak out and the loss in pressure will be detected. The number of cells that have been punctured will be determined at each interrogation of the spacecraft.

Impact tests have shown that cell penetrations can be expected from impacts of meteoroids of approximately 10^{-9} g mass or larger. These tests indicate that each 25 μm (1 mil) cell penetration could be interpreted as an impact of approximately a 10^{-9} g mass meteoroid or larger and each 50 μm cell penetration could be interpreted as an impact of 10^{-8} g mass meteoroid or larger. Additional impact tests are being conducted to better define the requirements for detector penetration.

The pressure cells to be flown on the Pioneer F spacecraft will all have 25 μm (1 mil) thick target material. The decision on the target thickness for the pressure cells on the Pioneer G spacecraft will be dependent on the data from Pioneer F. If the expected number of 25 μm penetrations is detected on the Pioneer F mission, then 50 μm thick test material will be flown on Pioneer G. If the 25 μm penetrations detected by Pioneer F are fewer than expected, and if additional data are needed to form a reasonable 25 μm data sample, then the Pioneer G spacecraft will also fly 25 μm target material.

SYSTEM DESCRIPTION

Some details of the systems comprising the penetration experiment are discussed in the following paragraphs. The weight of the experiment hardware is approximately 13.3 N (3 lbf) and the power required by the experiment is 1 W.

Pressurized Cell Penetration Detector

The experiment has 0.47 m^2 (5 ft^2) of detector area composed of 216 individual pressurized cells. The 0.47 m^2 is made up of 12 panels, each with approximate overall dimensions of 20 by 30 cm (8 by 12 in.) and composed of 18 individual pressurized cells. Figure 2 is a photograph of one detector panel.

The panels are made of 21-6-9 stainless steel. Each of the panels is made by resistance welding a 25 μm (1 mil) thick and a 50 μm thick sheet of stainless steel together in an "air mattress" configuration to form the individual cells. The cells will be pressurized with a nitrogen and argon gas mixture. The mixture will be 75 percent argon and 25 percent nitrogen. Each cell will be pressurized to a pressure of 115 kN/m^2 (16.7 psia).

The pressure switch that is used to indicate the loss of pressure in each cell is a cold-cathode device. The switch, as can be seen in figure 2, consists of two electrodes in a pressure cavity that is connected by a copper tube to the pressure cell. Approximately 525 V is impressed continuously across the two

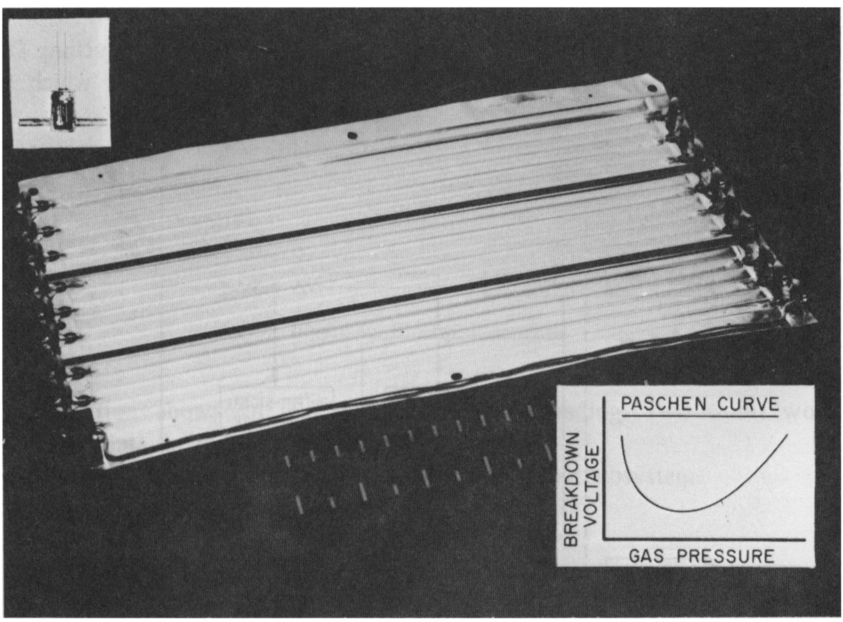

Figure 2.–Pioneer F and G penetration detector.

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electrodes, which are insulated from each other and from the panel. In the event of a cell puncture, the device will act as a glow tube because of ionization of the internal gas and it will conduct an electric current during a limited pressure range as the cell leaks down. The device will start conducting when the pressure in the cell drops below about 14 kN/m^2 (2 psia) and it will stop conducting when the pressure drops below about 0.14 kN/m^2. The tips of the two electrodes in the pressure cavity are electroplated with a small amount of ^{63}Ni to enhance ionization of the gas.

Electronics

A functional block diagram of the experiment electronics is shown in figure 3. The experiment is divided into two essentially independent parts for maximum experiment reliability. One electronic system is used for half of the penetration detectors and another electronic system is used for the other half. A common dc/dc power converter takes power from the spacecraft power system and supplies power for the pressure switches, for each of the two signal conditioning circuits, and for each of the two recycling event counters. The pulse resulting from the discharge of any pressure switch will be shaped and stored by a counter. With a discharge, an event counter will advance one count and will be locked out so it cannot advance again for a period of 86 min. This is to insure that any multiple pulsing on the initiation of a switch discharge will not be interpreted by the system as multiple penetrations. The probability of another legitimate impact and switch discharge during this lockout period is small.

Each of the event counters has a capacity of 32 counts before recycling. The time of a sensor puncture will be assumed to be the time at which an

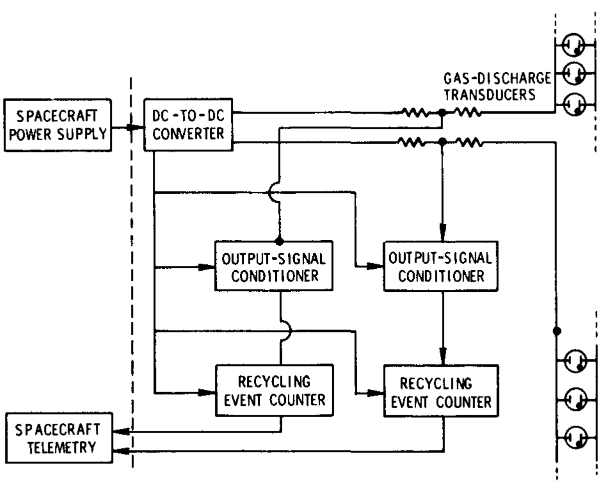

Figure 3.–Instrumentation schematic.

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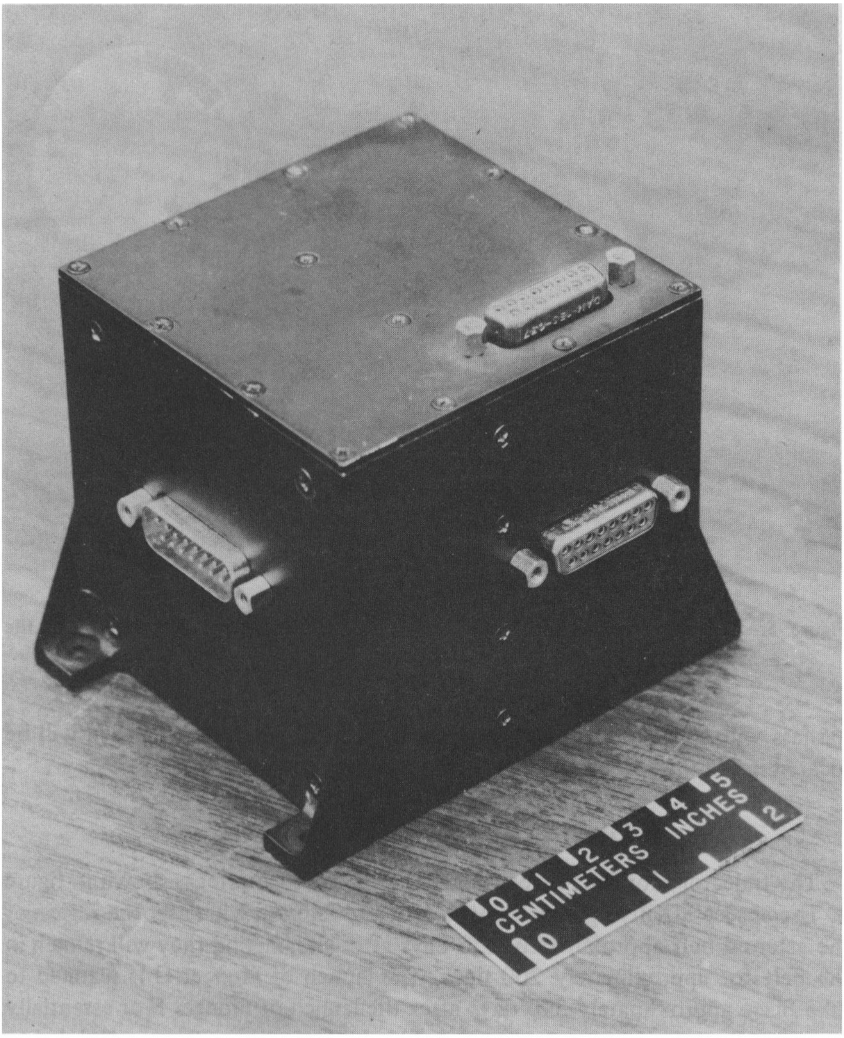

Figure 4.—Electronic module.

interrogation shows an increase in a counter reading. Two 6 bit words accommodate the output from the two counters.

Figure 4 is a photograph of the packaged electronic subsystem.

SPACECRAFT MOUNTING

An artist's sketch of the Pioneer F and G spacecraft is shown in figure 5. The 12 penetration detector panels will be mounted on the back side of the spacecraft high-gain antenna dish as is shown in the inserted sketch. A wiring

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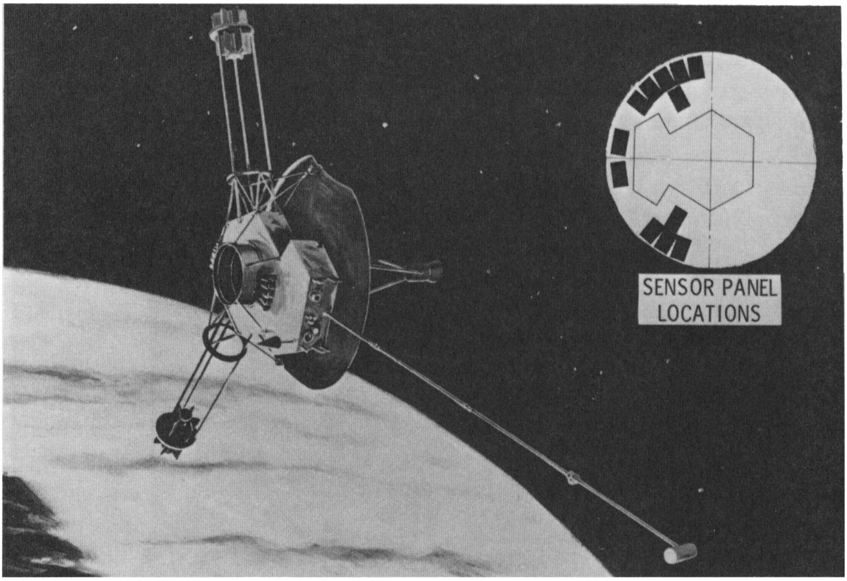

Figure 5.–Pioneer F and G spacecraft. Sensor panels are located on the back of the antenna dish.

harness will connect the panels to the experiment electronics, which will be located inside the spacecraft scientific instrument compartment.

TRAJECTORY AND ORIENTATION

The trajectory for the Pioneer F and G missions to Jupiter is shown in figure 6. The spacecraft, flying near the plane of the ecliptic, will enter the region of the asteroid belt approximately 150 days after launch, and they will remain in the belt for approximately 200 days. The launch of Pioneer G is planned to take place approximately 390 days after the launch of Pioneer F or essentially just after Pioneer F traverses the asteroid belt. The spacecraft are scheduled to reach Jupiter approximately 600 days after launch.

The spacecraft will spin about an axis through the center of the high-gain antenna dish. With the exception of the first few hours of the mission, the spin axis will essentially be oriented such that it intersects the Earth throughout the mission. This spacecraft orientation places the detector panels in a reasonably good viewing position to intercept asteroidal particles.

It is assumed that the asteroidal particles are in near-circular orbits and thus the relative impact velocity vector between the particles and the spacecraft will remain near the spin axis. As is illustrated in figure 7, the relative velocity vector will be only 28° off the spin axis at 1.6 AU, and it will diminish to only 8.5° off the spin axis at 2.5 AU. As the spacecraft leaves the asteroid belt at

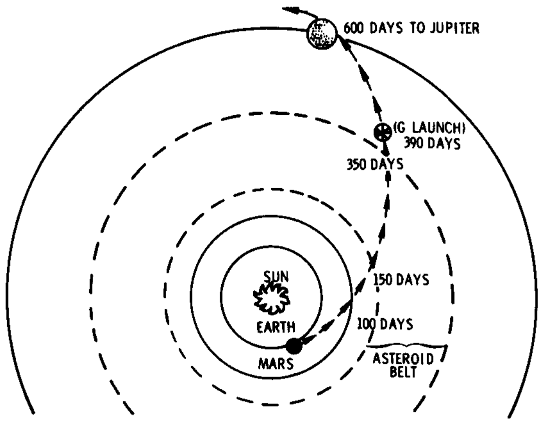

Figure 6.—Trajectory profile.

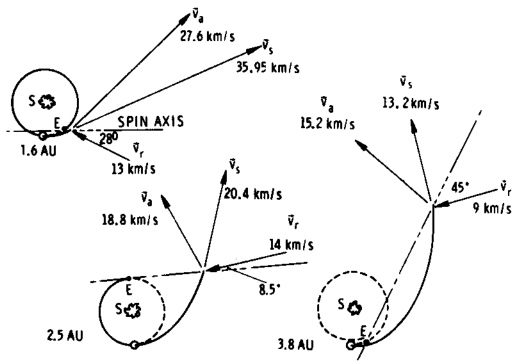

Figure 7.—Spacecraft orientation. v_a = velocity of asteroidal particles; v_s = velocity of spacecraft; v_r = relative impact velocity

about 3.8 AU, the relative velocity vector will increase to about 45° off the spin axis.

It is assumed that the cometary particles in interplanetary space are near omnidirectional and thus that the detector panel orientation is not critical for their detection.

ESTIMATE OF PENETRATIONS

Table I presents the number of detected penetration events that are indicated by Kessler's model of the interplanetary meteoroid environment (ref. 1). As already discussed, this model, and thus the predicted events, can be grossly in error and one would be presumptuous to place much confidence in such predictions.

TABLE I.—*Estimate of Penetration History*

Position, AU	Penetrations of 25 μm (1 mil) target				Penetrations of 50 μm (2 mil) target			
	Asteroidal	Cometary	Total	Cumulative	Asteroidal	Cometary	Total	Cumulative total
1.00 to 1.33	0	13	13	13	0	5	5	5
1.33 to 1.66	1	10	11	24	0	4	4	9
1.66 to 2.00	7	6	13	37	2	3	5	14
2.00 to 2.33	32	6	38	75	11	3	14	28
2.33 to 2.66	37	4	41	116	15	2	17	45
2.66 to 3.00	35	2	37	153	7	2	9	54
3.00 to 3.33	8	1	9	164	7	2	9	63
3.33 to 3.66	2	1	3	167	3	2	5	68
3.66 to 4.00	0	0	0	167	0	1	1	69
4.00 to 4.33	0	1	1	168	0	1	1	70
4.33 to 4.66	0	2	2	170	0	1	1	71
4.66 to 5.00	0	1	1	171	0	1	1	72

CONCLUDING REMARKS

The pressure cell type of penetration detector was chosen for the Pioneer F and G missions for a number of reasons. It is an extremely simple detector, the data from it are easy to interpret, and it is essentially unaffected by the environments encountered, other than, of course, the meteoroid environment.

Successful flight experiments on Explorers 13, 16, and 23, and all Lunar Orbiter spacecraft have proven the pressure cell penetration detector to be the most reliable meteoroid detector yet used in space. The actual penetration measurements are valuable to spacecraft technology. There remains, of course, an uncertainty in the interpretation of the penetration events in terms of the mass of the impacting meteoroid. However, there does exist a background of many years in penetration research and, based on this background, it is felt that the uncertainty in the interpretation of penetration data in terms of the mass of the impacting meteoroid is a minimum uncertainty.

REFERENCE

NASA SP-8038. 1970, Meteoroid Environment Model–1970 (Interplanetary and Planetary).

[*Editorial note: The Pioneer Mission to Jupiter is described in NASA SP-268.*]