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A Collector for Interplanetary Dust Particles and Space Debris

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Abstract. We are constructing a collector for capturing Interplanetary Dust Particles (IDPs) and space debris on space shuttle. The unit consists of three pieces of thin polyester film, equally spaced 7 cm apart, and an aerogel disk of 3 cm thickness. For each particle captured in the aerogel disk, we determine its direction of impact and its speed, from which we can trace its trajectory. The purpose of the experiment is to study the compositions of IDPs from different origins.

1. Introduction

It has been known for some time that there are numerous dust particles (IDPs) in interplanetary space, concentrated near the ecliptic plane. The origins of these particles are not well known, but two possibilities have been suggested: (1) material from comets and (2) fragments of asteroids and/or planetary ring bodies produced by meteoritic impacts.

In the past, the capture of IDPs was done in the atmosphere with collectors placed on balloons and U-2 aircraft and in space using spacecraft such as Gemini, Apollo, Skylab, and lately, the Long Duration Exposure Facility (Zolensky et al., 1993). In these experiments, dust particles are collected without any information on their impact directions and speeds. Using other detection instruments, such as microphone sensors, polarized polymer film detectors and plasma sensors, only speed and cumulative flux are measured. To improve the technique of sample collection, we designed a new collector. For each captured particle, we record the time and direction of the impact, and, with a proper calibration, we can also determine the speed of the particle. The unit will be flown in a Get Away Special (GAS) container with a Motorized Door Assembly (MDA) on a space shuttle.

2. The Collector and Its Operation

A simplified cross-sectional diagram of the collector system is shown in Fig. 1. It consists of three pieces of polyester film equally spaced at 7.0 cm apart, and an aerogel disk covered with another polyester film. The polyester film is 12

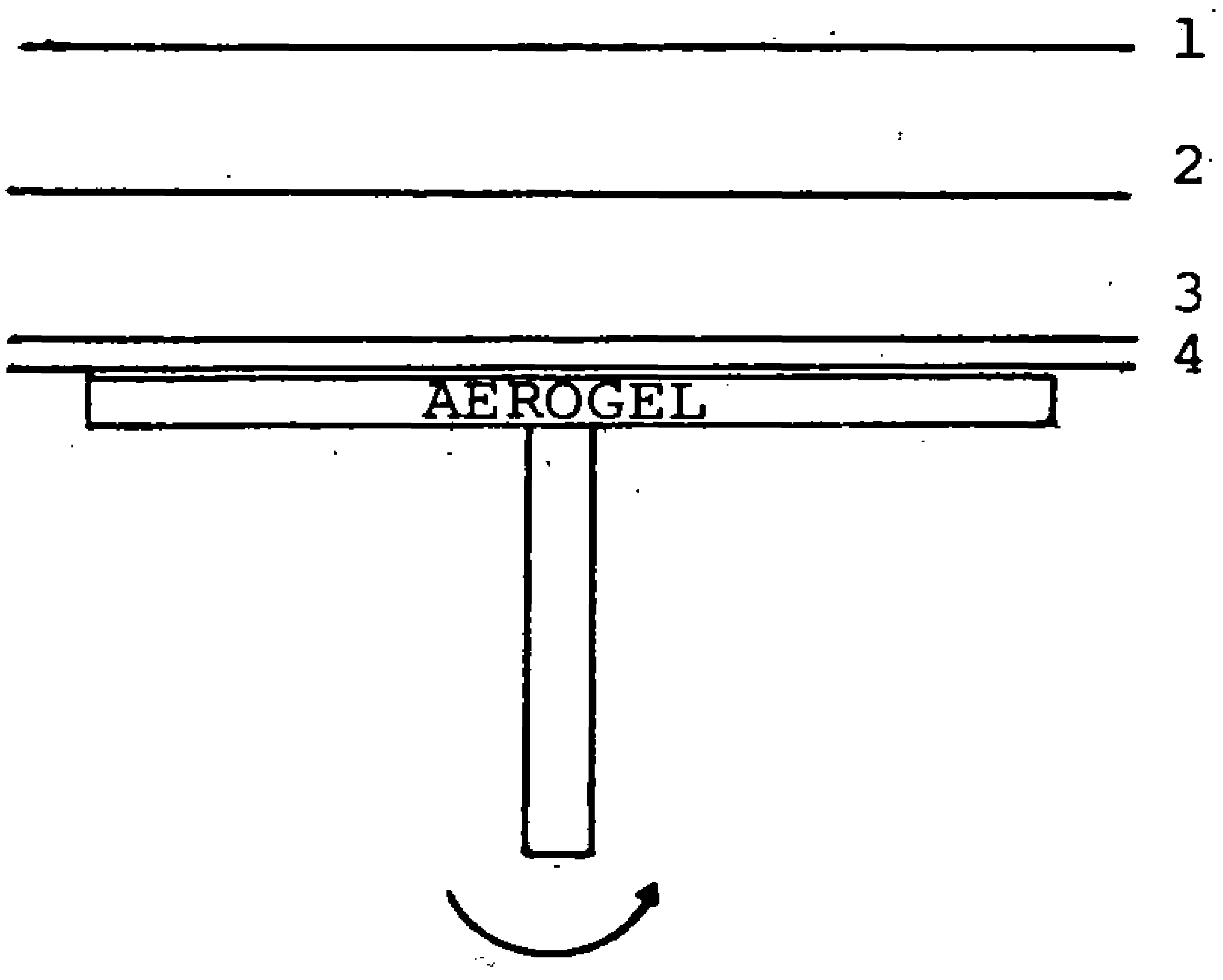

Figure 1. Schematic of the collector. 1, 2, 3 and 4 are polyester films. The aerogel plate is mounted on a rotating platform.

micron thick, 50 cm in diameter and coated with aluminum, about 5 nm thick. The aerogel disk, whose density is about 0.1 g/cm^3, is 3.0 cm thick and 39 cm in diameter. It is mounted on a platform that rotates at a speed $\omega \sim 36°/$ day when the motor is in operation. The use of an underdense medium for capturing IDP was suggested by Tsou et al. (1984) and Peng et al. (1987).

The collector will be placed in a NASA GAS-433 container, with MDA, which will be carried to space by a space shuttle.

When in space, an astronaut turns on three switches in succession to start the experiment: (1) energize the payload, (2) open the motorized door assembly of the GAS, and (3) start the motor that rotates the aerogel disk and an on board timer to record the motor starting time t_0. To end the experiment, the astronaut turns the three switches in reverse order. The on board timer records the motor termination time t_e.

3. Expected Results

After return of the collector to our clean laboratory, we first determine the coordinates of all the holes made in film 1, 2, and 3. The pin holes made by one penetrating dust particle must lie in a straight line. Let (x,y) be the coordinates of the intersection of the straight line with the fourth film which covers the aerogel disk. We expect to find a hole on the fourth film at a distance ρ, $\rho = \sqrt{x^2 + y^2}$, from the center. However, the polar angle of the dust position, θ', is different from $\theta = \tan^{-1}(y/x)$ because the disk has rotated since the penetration. The time t when the dust entered the collector is given by:

$$t = t_e - (\theta' - \theta)/\omega, \qquad (1)$$

By knowing the attitude of the shuttle at t, we can determine the arriving direction of the dust.

The speed of the particle can be estimated from the sizes of the impact pin holes in the four polyester films and the penetration depth in the aerogel disk, after the system is properly calibrated with particles of various sizes and masses at different speeds. The calibration yields a set of empirical curves expressing the hole size and penetration depth as functions of speed for different masses and sizes. Based on the measured dust particle size and estimated mass, a proper curve is chosen for the speed determination. For speed higher than the speeds available for the calibration, an extrapolation will be used. The direction of impact and the speed are needed quantities for tracing its trajectory according to theories, such as by Gustafson et al. (1987).

We expect to find a particle in the aerogel disk at each calculated distance ρ from the rotating axis. The search will be done with a low power microscope. Using a light shining under the aerogel disk, the dust particle track will appear as a dark line. Each particle is then removed from the aerogel disk in our clean laboratory for examination. The size, shape, transparency, color and lustre are determined and recorded under a petrographic research microscope. It is then examined using scanning electron microscopy and then with x-ray energy dispersive spectrometry. By comparing the x-ray spectrum with that of a laboratory standard, the relative elementary abundances can be determined. We can then clearly distinguish an IDP from space debris.

Finally, for an IDP, we measure the Raman shift spectrum (Wopenka, 1988; Xu et. al., 1992). From its carbon content, we then decide whether to study its complex aromatic molecules or measure its isotopic abuncances of Li and B. These properties are closely related to the nature of the parent body (Xu et. al., 1993).

Space debris are a major concern for space flight. We want to study the size, distribution, flux and trajectories of this population.

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