METEOROID DIRECTIONALITY ON LDEF AND ASTEROIDAL VERSUS COMETARY SOURCES

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Zook (1) deduced, under a "randomness" assumption, the relative flux and velocity values for meteoroids that impact on the apex (or "East", or "leading") side of an Earth-orbiting spacecraft compared to those values on the antapex (or "West", or "trailing") side of that spacecraft. The expected apex to antapex meteoroid flux ratio depended on the atmospheric meteoroid velocity distribution that was used, and ranged from 6 to 9, at constant meteoroid mass. In addition, because meteoroids strike from the apex direction at typically higher velocities (due to spacecraft orbital motion) than from the antapex direction, smaller--and more numerous--meteoroids make more impact craters of a given size on an apex-facing surface than on an antapex-facing surface. This means that the ratio, $R_c = N_{ap}/N_{an}$, of the number of impact craters of a fixed size on the apex side compared to the number of the same size on the antapex side, depends not only on relative fluxes at constant mass but on the slope of the log(meteoroid flux) versus log(meteoroid mass) curve. This analysis was done (2), following Naumann (3), for craters of 50 and 500 μm dimensions. The average impact velocity on each face was used to find R_c, which ranged from 8 to 30, depending on which meteoroid velocity distribution and which crater size (which determines the meteoroid log-log flux-mass slope) was chosen.

The Naumann (3) analysis also applies to meteoroids striking surfaces at oblique angles. To make a crater of a certain fixed depth, larger--and less numerous--meteoroids are required at oblique angles on a surface than at perpendicular, or normal, impact (at fixed velocity). There is also a dependence (3) on parameters in the penetration equation (P vs m, ρ, v, and angle), for which there is not adequate room to discuss here, but which depends little, or not at all, on crater size. The oblique angle effect should show up quite dramatically in the relative crater frequency of a given size crater on the "Top", or space-facing end of LDEF, compared to the "Bottom", or Earth-facing end of LDEF. There is a lesser effect from Top to "Side" (North or South-facing). The spacecraft orbital velocity should have no effect on these ratios, unless there is local shielding by the spacecraft. These ratios are shown in Table 1 for three different crater diameters.

Table 1. Top-Bottom and Top-Side crater number ratios versus crater diameter, mass and slope.

Crater dia.(μm)	mass(g)	slope	Top/Bottom	Top/Side
500	$7.8*10^{-7}$	-0.90	105	1.36
100	$8.1*10^{-9}$	-0.48	45	1.40
2	$1.2*10^{-13}$	-0.41	39	1.40

To obtain the numbers in Table 1, it was assumed that penetration depth depends on v and impact angle to the 2/3 power, that crater diameter is twice the penetration depth, that penetration depth depends on projectile diameter to the power 19/18, and that one should choose the crater width, not length, for "diameter" of elongate craters. The "nominal" meteoroid masses were obtained for normal impact at 20 km/s into 6061 T6 aluminum, and the slopes were obtained from the meteoroid flux versus mass relationship of Grün et al. (4). It was also assumed that LDEF is at a mean altitude of 465 km above the Earth, and that the effective atmospheric height is 165 km, below which meteoroids can not pass before impacting LDEF. This means that the minimum angle to the normal with which meteoroids can impact the Bottom side of LDEF is 72.5 degrees, before spacecraft velocity is considered. The reason for the strikingly high number of 105 for frequency of 500 μm wide craters on the Top surface of LDEF compared to the Bottom of LDEF is due to the slope of the flux mass curve at these large meteoroid masses. It was assumed that no local spacecraft shielding occurred.

Table 2 depicts the relative number/area of craters expected, depending on the crater diameter and meteoroid velocity distribution used, on each of six different sides (including north and south sides) of LDEF that are perpendicular to each other; the number/area on the antapex-facing surface is taken to be 1, and so all other surfaces should show meteoroid fluxes relative to the antapex direction. Spacecraft motion is accounted for, and the angle and velocity dependencies of (3) are integrated over all angles and velocities. The three velocity distributions used are those of Dohnanyi (5), Erickson (6)-Kessler (7) (=E-K), and Southworth and Sekanina (8) (=S&S); see Zook (9) where they are compared.

Table 2. Relative meteoroid crater production rates on LDEF as a function of crater size (on 6061-T6 Al), and as a function of the velocity distribution used.

Crater dia.(μm)	Vel. Dist.	Apex	Top	Side	Antapex	Bottom
500	Dohnanyi	12.2	6.4	4.7	1	0.06
100	Dohnanyi	9.9	5.9	4.2	1	0.13
2	Dohnanyi	9.4	5.7	4.1	1	0.15
500	E-K	19.2	8.7	6.4	1	0.08
100	E-K	14.4	7.6	5.4	1	0.17
2	E-K	13.4	7.3	5.2	1	0.19
500	S&S	32.8	12.8	9.4	1	0.12
100	S&S	21.2	10.1	7.2	1	0.23
2	S&S	19.3	9.6	6.9	1	0.25

It will be of great interest to determine which one of the meteoroid crater distributions given in Table 2 above best fits the actual meteoroid impact crater data on LDEF (after orbital debris impacts have been accounted for). Or, do any of them fit?

Jackson and Zook (10) find that dust particles from the main belt of asteroids are expected to have mean velocities of 6 to 7 km/s relative to the Earth by the time they have drifted to Earth encounter (before the Earth's gravitational acceleration is accounted for). These average velocities would suggest that dust from the asteroid belt comprises from 5% (Dohnanyi vel. dist.) to 30% (S&S vel. dist.) of the meteoritic dust at 1 AU. Higher relative fluxes will, however, enter the Earth's atmosphere because of the greater flux increase of low velocity particles due to the Earth's gravitational concentration (11).

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