FACE-DEPENDENT IMPACT PROBABILITIES UPON LDEF FOR HELIOCENTRIC PARTICLE ORBITS

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ABSTRACT. If the impact record upon LDEF is to be interpreted so as to determine the flux, orbits, sizes and compositions of natural meteoroids and dust, and space debris, then it is necessary to relate the microcraters and perforations recorded to the likely source orbit of the particle in each case. Here a single-particle approach is used to calculate the relative impact probabilities upon six orthogonal faces of LDEF for particles coming from heliocentric orbits confined to the ecliptic; the results are presented as functions of impact velocity and impact angle for each face. The flux from geocentric orbits to the Space-and Earth-pointing faces is much lower than to the other faces; experiments positioned on those faces are thus likely to be less contaminated by space debris. Particles from heliocentric orbits can impact both the Space and Earth faces, but the latter is less likely to be hit due to the shadowing effect of the planet. The cratering ratios for the East (or leading) face compared to the West (or trailing) and the Earth-directed faces are strongly dependent upon the velocities of the particles and can therefore indicate of the velocity distribution of meteoroids and interplanetary dust.

1. Introduction

The Long Duration Exposure Facility (hereafter LDEF) was recovered in January 1990 having spent close to six years in a near-circular orbit of inclination 28°.5 and initial altitude of about 477 km; increased atmospheric drag meant that this had decayed to about 340 km at the time of its recovery. Since LDEF maintained the same orientation in its orbit throughout its flight, the amount of cratering on its different faces can tell us much about the flux and orbital distribution of the various classes of impactor. These comprise, as a broad division, man-made space debris in geocentric orbits and natural meteoroids and interplanetary dust from heliocentric orbits. This paper deals predominantly with the second of these classes. Throughout the faces of LDEF under consideration are limited to the six orthogonal faces known as the East (or leading) face, which is taken to be the plane perpendicular to and facing the direction of motion of LDEF, the West (or trailing) face, the Space face which always points directly away from the Earth, the Earth face which is the opposite to this, and the North and South faces which are constrained to LDEF's orbital plane.

The case of particles (such as man-made space debris) in geocentric orbits has been investigated elsewhere (Olsson-Steel, 1990; Steel and McDonnell, 1991) and it was shown that very few impacts are expected upon either the Space- or Earth-directed faces due to

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the low eccentricity (and hence low radial velocity) of such particles. The range of impacts velocities and angles were also presented therein, and it was found that in terms of the amount of cratering, for geocentric orbits we expect for LDEF:

Space/Earth/West $<<$ North/South $<$ East

In this paper we are interested in how the fluxes to these faces from heliocentric orbits might compare with this relationship.

2. Method

Work in this area, using velocity distributions (as opposed to the single particle approach used here), has been carried out by Zook and co-workers (Warren et al, 1989; Zook, 1987, 1990). The method used in this paper will be detailed elsewhere (Steel and Cervera, in preparation). Briefly, the technique we have developed is as follows. At the present stage of our program we are able to calculate impact probabilities, including the velocity and angle of impact probability distributions, for particles of different initial velocities approaching the Earth *along the ecliptic only.* The computations carried out involve considering all possible positions of LDEF in its orbit to be equally likely, and all possible directions of the pole of its orbit also to be equally likely over its orbital lifetime; this is valid in view of its high precession rate. In all cases gravitational focussing is included, and this is to a certain extent responsible for the exposure of the Earth face of LDEF which would otherwise be shielded from meteoroids: if there was no gravitational focussing then the Space:Earth ratio would be the same as the ratios of the solid angles of the sky visible from each of these faces, this being about 20:1.

3. Results

The results for different meteoroid velocities are shown in Table 1. The altitude of LDEF has been taken as 477 km, and any particle with a perigee height below 150 km has been assumed to be absorbed by the atmosphere; particles with perigees between 150 and 477 km can hit LDEF as they recede from the planet, and thus may strike the Earth-directed face of the satellite. In each case the relative probabilities, normalized to the East face, are given for the West, Space, Earth, and North/South faces. For the last-named pair the exposure would be expected to be identical, but for the others the exposures will be different (*e.g.* the East and West faces are expected to contrast strongly).

Table 1. Relative impact probabilities upon the different faces of LDEF for particles coming from heliocentric orbits confined to the ecliptic, as a function of velocity.

Velocity at infinity (km/sec)	Velocity at LDEF (km/sec)	East	West	North/ South	Earth	Space
5.0	11.9	1.0	0.074	0.267	0.056	0.539
10.0	14.7	1.0	0.164	0.230	0.042	0.737
15.0	18.5	1.0	0.251	0.258	0.045	0.854
20.0	22.7	1.0	0.332	0.285	0.050	0.943
30.0	31.9	1.0	0.462	0.326	0.057	1.069
40.0	41.4	1.0	0.555	0.353	0.062	1.152
50.0	51.2	1.0	0.622	0.371	0.065	1.208
60.0	61.0	1.0	0.672	0.384	0.068	1.250
70.0	70.8	1.0	0.710	0.395	0.069	1.283

The number of impacts upon different faces of LDEF by particles coming from heliocentric orbits will depend upon their velocity relative to the Earth (*i.e.* the orbit of the particle). In order to interpret the LDEF data correctly, it will be necessary to know both the collision velocities and impact angles to be expected for a variety of particle orbits, since these affect the sizes of the craters produced (or the thickness of material perforated) for particles of constant mass. In the Figures we present the relative impact probabilities as a function of velocity (Fig. 1) and impact angle (Fig. 2) for an initial meteoroid velocity of 20 km/sec. As can be seen from Fig. 1, not only does the East face have the highest impact probability (*cf.* Table 1) but also these impacts would mostly occur at higher velocities (above 29 km/sec); in addition, they occur at near-normal incidence upon that face (impact angles below 30°: Fig. 2), which means that we may expect much higher cratering/perforation rates on the East face. The Space face would receive impacts across the full range from 14 to 31 km/sec, with increasing likelihood at higher velocities, and with an angular distribution peaking near 30°. This contrasts with the Earth face which according to these calculations receives impacts only at low velocities ($<$ 17 km/sec) or high velocities ($>$ 29 km/sec), all of these being at oblique incidence (impact angles $>$ 65°); however, these results are to a certain extent artefacts of the model used whereby the impactor is assumed to be coming from a trajectory in the ecliptic. Nevertheless, it is clear that the Space:Earth microcratering/perforation ratio will be affected by the rather different impact velocity and angle characteristics, so that the ratio derived from the LDEF surfaces will be rather different to the values given in Table 1.

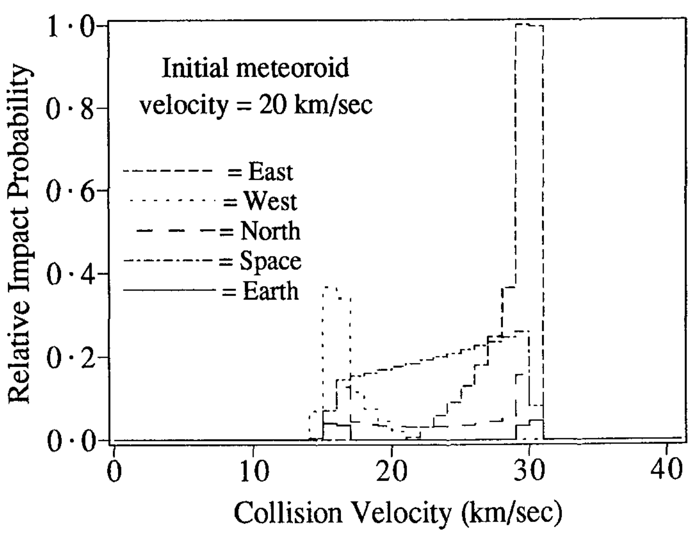

Figure 1. The relative impact probabilities upon the different faces of LDEF as a function of collision velocity for a particle coming from a heliocentric orbit confined to the ecliptic and with an original geocentric velocity of 20 km/sec (equivalent to 22.7 km/sec at the height of LDEF).

4. Conclusion

As noted above, these represent only preliminary results. For particles coming from heliocentric orbits a full consideration of the exposure of LDEF requires an expansion of

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the present program such that the effect of the actual trajectories of the incoming meteoroids and the obliquity of the ecliptic is included. For both geocentric and heliocentric orbits the velocity- and impact angle-dependence of the craters/perforations produced needs to be included if the LDEF data are to be properly interpreted. These facets of the problem will be dealt with in later papers.

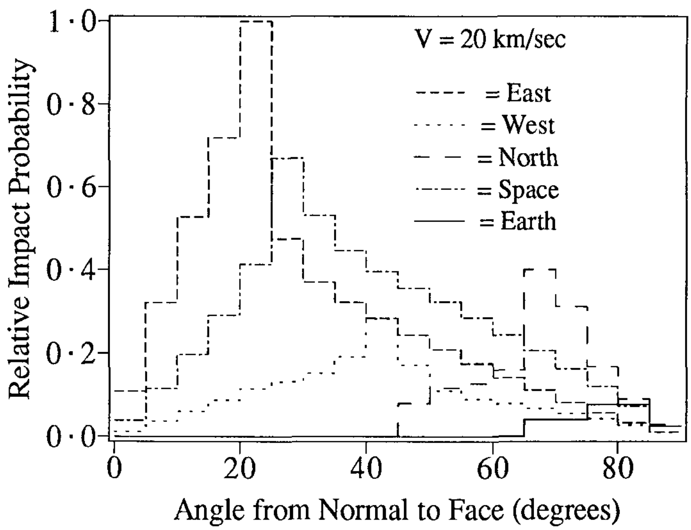

Figure 2. As Figure 1 except showing the relative impact probabilities as a function of impact angle upon each face.

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