HYPERVELOCITY PARTICLE FLUXES IN LOW-EARTH ORBIT DERIVED FROM CRATERS AND PENETRATION HOLES IN LDEF THERMAL BLANKETS

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INTRODUCTION: The Long Duration Exposure Facility (LDEF) exposed ~20.5 m^2 of thermal protective blankets as part of the Ultra-Heavy Cosmic Ray [1] and the Space-Exposed Experiment Developed for Students (SEEDS) experiments. Individual blankets (~1.2 m^2 each) pointed in nine different directions relative to LDEF's velocity vector, and following their ~5.7 years of exposure, ~700 penetrations >300 µm in diameter were documented on these surfaces by the preliminary examination team [2]. Each blanket was 180-190 µm thick, composed largely of Teflon (~125 µm thick); a vapor-deposited mirror of Ag (<0.1 µm thick) was behind this outer, space-facing Teflon layer, which in turn was backed by organic primers and thermal protective paint ~50-60 µm thick. These blankets represent one of the most outstanding opportunities to learn about the flux of hypervelocity particles in low-Earth orbit (LEO) [3].

We recently completed a systematic series of impact experiments to characterize the cratering and penetration behavior of pure Teflon^{FEP} [4]. The objective was to determine the dimensional relationships between the projectile size (D_p) and the resulting crater (D_c) or penetration-hole diameters (D_h) as a function of impact velocity (1-7 km/s) and target thickness (T). These experiments specifically addressed the transition from cratering to penetration processes to alleviate some of the previous, systematic discrepancies between typical cratering and penetration equations [*e.g.*, 5, 6, 7, 8 & 9]. Consequently, we are now in a position to extract projectile-size distributions and fluxes from individual craters and penetration holes in these Teflon thermal blankets.

OBSERVATIONS: Using optical techniques, we gathered data on the size-frequency distribution of penetrations and craters >80 µm in diameter on selected blanket sections. Two representative blankets were selected for this purpose, one 22° off LDEF's leading edge (A10), and one close to the trailing edge (F04), ~180° from A10. These two orientations should essentially yield maximum and minimum particle fluxes for the gravity-gradient stablized, non-spinning LDEF platform [3 & 10]. A total of 237 impact features >80 µm in diameter were documented on 1683 cm^2 of the A10E00AB blanket, while only 22 impacts were found on 1656 cm^2 of the F04E00AB surface. Utilizing the 5.7 year total exposure time, the relative production rates of craters and penetration holes for the A10 and F04 blanket sections were computed and are illustrated in Figure 1. The largest crater observed was ~235 µm in diameter, a somewhat unusual value for a target that is only ~190 µm thick. Generally, these larger craters resulted in the Teflon layer being prominently bulged, thinned, and stretched (Figure 2a). The smallest penetration hole measured ~150 µm in diameter (Figure 2b). In the SEM photographs of Figure 2 note the removal of the optically opaque (black) paint layer on the target's rear surface, leaving a large annulus of bare Teflon.

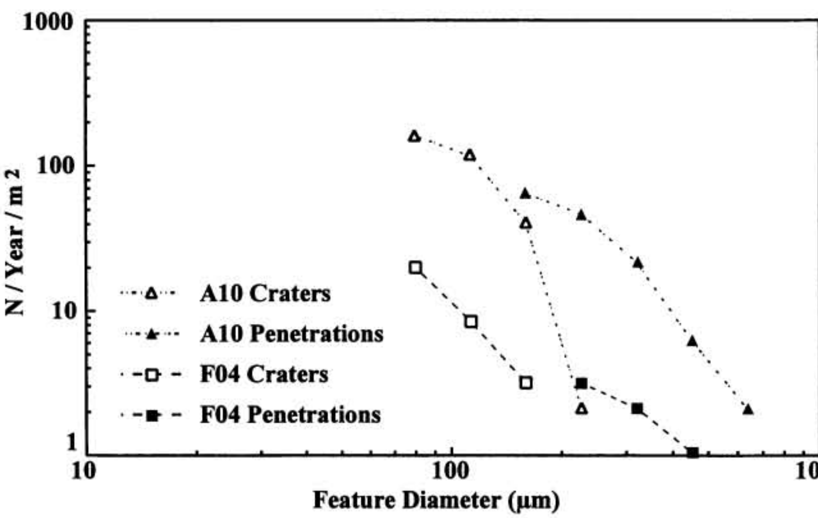

Figure 1. Relative production rates for craters and penetrations in LDEF Teflon thermal blankets from bays A10 (forward facing) and F04 (rearward facing).

INTERPRETATIONS: The measured D_c and D_h values were converted (graphically) to projectile size (D_p) using the calibration curves from our impact experiments with pure Teflon^{FEP} targets [4]. Furthermore, we assumed encounter velocities for natural cosmic-dust particles [10] of 19.7 and 12.7 km/s for the leading- and trailing-edge locations, respectively, and 7.5 km/s (A10) and 2.2 km/s (F04) for orbital debris [11]. Obviously, a mixture of the two populations exist in LEO and must be accounted for because of the significant differences in particle velocities [3]. Compositional analyses of impactor residues [12] suggest that ~56% of all impacts in the forward-facing (A11) location may be due to natural particles, and that this fraction increases to ~89% for the rearward-facing (A03) site. These percentages were used as weighting factors to assign the fraction of craters and penetration holes associated

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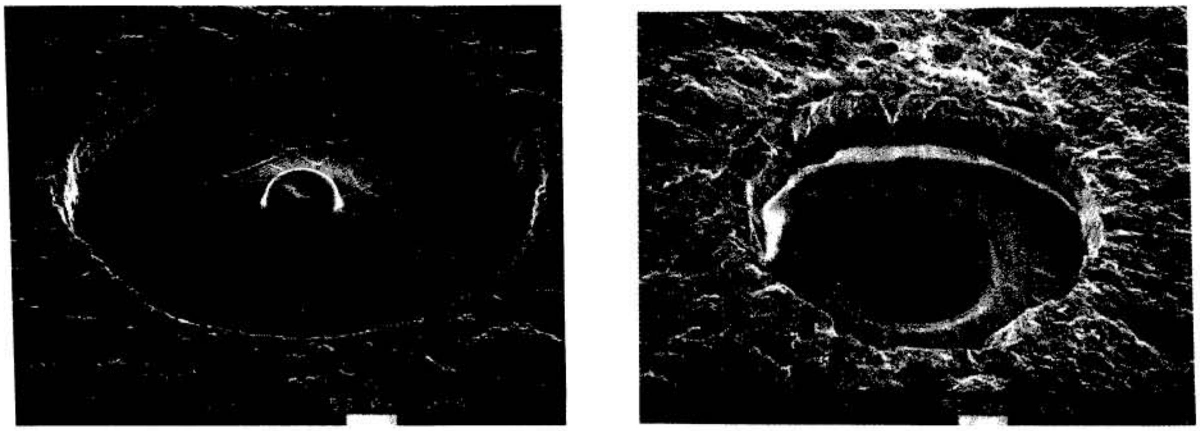

Figure 2. (A) Bulged rear side of unusually large crater in Teflon thermal blanket; diameter of bulge is ~65 µm and (B) Back-side view of small penetration hole (D_h ~ 170 µm).

with specific encounter velocities on the A10 and F04 LDEF locations. Figure 3 presents the cumulative projectile-size distribution and fluxes derived for such a mixed particle population, separated into projectiles sizes derived from craters and penetration holes (broken lines), as well as the sum of both (solid lines). Note the relatively smooth merger of crater-derived impactors with those extracted from penetration holes; such a smooth transition is the result of the new calibration data and the associated view that relatively small penetration holes should essentially be treated (and measured) as craters [4].

DISCUSSION: The summary flux for the A10 surface presented in Figure 3 is compatible with the flux values of Humes [5] and Kessler [11]. They derived ~2.5 impacts/year/m^2 by projectiles >100 µm in diameter for this LDEF location, which compares favorably with our ~2.8 value determined from the A10 thermal blanket; Drohlshagen [3] predicts ~10 events of this magnitude for A10. However, our F04 flux is only a factor of ~2.5 lower than that of A10, whereas [5 & 6] observe and postulate a factor ~10, and [3] a factor ~7. On the other hand, the relative fluxes of 50 µm impactors are more compatible with the above predictions and differ by a factor of ~10 between trailing and leading edges. We ascribe the apparent discrepancy at 100 µm scales to inadequate statistics in our own observations. However, modestly different size-frequencies of particles colliding with LDEF's trailing and leading edges is a possible interpretation as well.

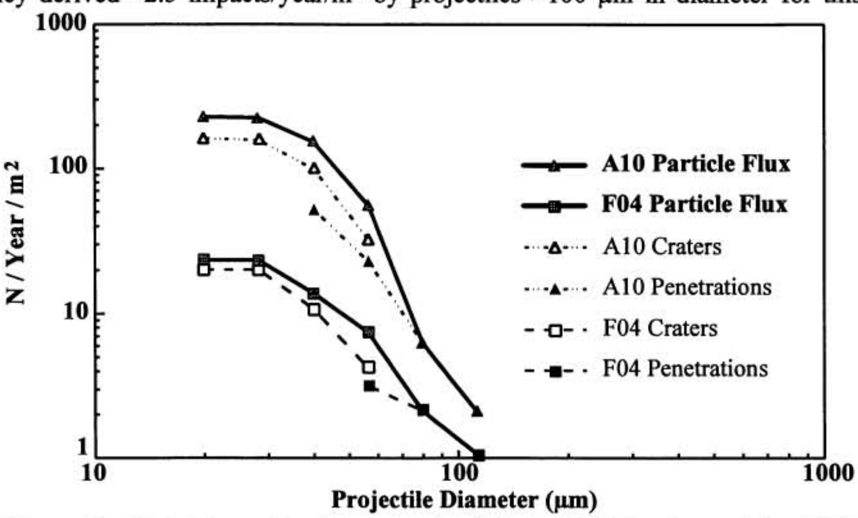

Figure 3. Modeled particle fluxes for the A10 and F04 locations of the LDEF spacecraft.

REFERENCES: [1] O'Sullivan D. *et al.* (1992), *LDEF - 1st Post Retrieval Sym. NASA CP 3134*, 367-377; [2] See, T.H. *et al.* (1990), *NASA JSC Publication # 24608*, 586 p.; [3] Drohlshagen, G. (1993), *LDEF - 2nd Post Retrieval Sym., NASA CP 3194*, 325-338; [4] Hörz *et al.* (1994), *LPSC XXV* (abstracts), 567-568 and (1994), *NASA-TM 104797*, 317 p.; [5] Warren *et al.* (1989), *LPSC 19th*, 641-657; [6] Humes, D. (1992), *LDEF - 1st Post Retrieval Sym. NASA CP 3134*, 399-418; [7] McDonnell, J.A.M. and Sullivan, K. (1992), in *Hypervelocity Impact in Space*, Univ. Canterbury Press, 39-47; [8] Berthaud, L. and Mandeville, J.C. (1993), in *ESA SD-01*, 459-464; [9] Watts, A. *et al.* (1993), NASA JSC Contractor Report *NCR 188259*, 170 p.; [10] Zook, H.A. (1992), *LDEF 1st Post Retrieval Sym. NASA CP 3134*, 569-581; [11] Kessler, D.E. (1993), *LDEF - 2nd Post Retrieval Sym. NASA CP 3194*, 585-594; [12] Hörz *et al.* (1993), *LDEF - 3rd Post Retrieval Sym.*, in press.