METEOROID AND ORBITAL DEBRIS RECORD OF THE LONG DURATION EXPOSURE FACILITY;

M. Zolensky[1], T. See[2], D. Atkinson[3], M. Allbrooks[3], C. Simon[4], M. Finckenor[5], J. Warren[2], E. Christiansen[1] and F. Cardenas[2]; [1]Solar System Exploration Division, NASA Johnson Space Center, Houston, TX 77058, [2]Lockheed ESC, C23, 2400 NASA Rd 1, Houston, TX 77058, [3]POD Associates, 2309 Renard Place SE, Albuquerque, NM 87106, [4]McDonnell Center for Space Sciences, Washington University, St. Louis, MO 63130, [5]NASA Marshall Space Flight Center, MSFC, AL 35812

INTRODUCTION: The Long Duration Exposure Facility (LDEF) was recovered in January, 1990, following 5.7 years exposure of 130 m^2 of surface area in low-Earth orbit (250-179 miles altitude). The LDEF was an open-grid cylindrical structure on which a series of rectangular trays used for mounting experiment hardware were attached. These trays faced in 14 directions, 12 along the sides (called "rows") and two ends. In addition, portions of the LDEF frame, tray attachment clamps and half of the tray lip (flanges) faced into directions between each of the 12 side tray-facing directions. Since the LDEF was gravity stabilized, elements of the LDEF faced in 26 different directions which were fixed relative to the spacecraft's velocity vector. Thus, studies of the impact record of the LDEF will permit the resolution of the flux and trajectories of meteoroid and space debris particulates. The LDEF was host to several individual experiments designed to characterize aspects of the meteoroid and space-debris environment in low-Earth orbit. However, the most complete way to accomplish this goal was to exploit the impact record of the entire LDEF. The Meteoroid and Debris Special Investigation Group (hereafter M&D SIG) was organized to achieve this end [1].

During the deintegration of the LDEF at the Kennedy Space Center in spring of 1990 we harvested detailed data including stereo images of all large impacts (approximately 5000), and briefly surveyed smaller impact features large enough to be observed visually (approximately 30,000 impact features). The digitized images of impact features are now being reduced to yield accurate impact crater diameter and depth data. We present here a preliminary accounting of the impact record of the aluminum frame of the LDEF, which has the benefit of being a single, homogeneous material continuously exposed in all 26 facing directions of the LDEF for its entire 5.7 year lifetime. All M&D SIG results are documented elsewhere in excruciating detail [1].

DATA-ACQUISTION PROCEDURES: We photodocumented all impact craters measuring ≥0.5 mm in diameter present on structural surfaces, and all penetration holes ≥0.3 mm in diameter in thin materials such as thermal-control blankets. A total of approximately 5,000 features satisfied these criteria The dual size threshold was employed due to the differing processes involved in hypervelocity impact into foils vs. materials with far greater thicknesses; the dual size threshold will be helpful when our impact results are later recalculated in terms of impactor mass. Our impact feature documentation was performed with three dedicated, Wild Leitz M8 stereomicroscopic imaging systems with digitized output from Sony CCD video cameras. Electronic Coordinate Registration Systems permitted the measurement of impact feature locations on each LDEF experiment and frame member. The M&D SIG survey of the LDEF frame was conducted following the removal of all of the experiment trays and thermal panels from the spacecraft. All LDEF frame members consisted of 6061-T6 chromic-anodized aluminum.

To foster continued studies, we have carefully selected a large variety of materials from LDEF displaying impact features, and returned them to the Curatorial Facility at the Johnson Space Center (JSC). All surfaces obtained by the M&D SIG are available for allocation to qualified investigators.

RESULTS AND DISCUSSION: The total surface area of the exposed LDEF frame was 15.4 m^2, and varied from 0.53 to 0.79 m^2 in the 26 LDEF-facing directions. The total number of large (>0.5 mm in diameter) impacts present on the frame was 433, and the areal density of impacts varied from essentially 0 to 78.5 impacts/m^2. It is therefore clear that the population of impact features and space-exposed area of the LDEF frame are statistically large enough to warrant serious consideration here. There should be a forward-facing (in the velocity vector) enhancement of the impact frequency, relative to that of the rear-facing (trailing) direction [2]. On the LDEF the nominal leading and trailing directions were Rows 9 and 3, respectively. The ratio of impact frequency for Row 9:Row 3, for large (>0.5 mm diameter) impact features, is approximately 10, compatible with some previous estimates [2], but Row 9 does not contain the maximum crater density.

One might expect a regular increase in the impact frequency from Row 3 (a minimum) towards Row 9 (the maximum). This result is clearly not observed from the preliminary raw data for the LDEF frame presented in Figure 1a. Maxima in the impact frequency are observed on either side of Row 9, but Row 9 itself shows a dramatic impact frequency decrease. While a minor impact frequency decrease might be expected in the exact apex direction, this value is far exceeded by the observed 50% decrease relative to adjacent directions (H. Zook and D. Kessler, personal communications, 1990). Enhancement in the impact frequency (for large particles) of the north side LDEF (towards Row 12) over that of the opposite side has been independently reported [3], and has been blamed on the orbital inclination of the spacecraft.

In Figure 1b we present the results of fitting of a Gaussian curve, through the method of least squares, to the impact frequency data for the LDEF frame. The ratio of leading:trailing edge impact frequency for the Gaussian curve is approximately 20:1. If the results for the impact frequency of the LDEF frame are accurate, as further studies by both the M&D SIG and various LDEF Principal Investigators should determine, then it suggests that some principal components of the particulate complex in low-Earth orbit have non-random trajectories. These would be particles larger than approximately 0.1 mm in diameter, judging by the crater diameters. Modeling suggests that micrometeoroids predominate in this size range [2]. These results should facilitate future modeling of the meteoroid flux at the Earth.

REFERENCES: [1] See et al. (1990) Meteoroid and Debris Impact Features Documented on the Long Duration Exposure Facility, Planetary Science Branch Publication 84; [2] Zook (1990), LPSC XXI, 1385-1386; [3] McDonnell et al. (in press) in Origin and Evolution of Interplanetary Dust.

FIGURE 1 **(a)** The relative impact frequency (for large impactors) observed for the 12 LDEF rows, and their intermediate facing directions. Row 9 is the nominal leading direction, Row 3 is the nominal trailing direction. The length of the heavy lines indicate the magnitudes of the relative impact frequency in each direction. the open squares along Rows 12 and 6 indicate the magnitude of the relative impact frequency of the space-facing end of the LDEF; **(b)** plot of impact frequency for each LDEF row, with the measured frequencies indicated by vertical bars centered on the measured values. Superimposed on these data is a Gaussian curve (dotted) fit by the method of least squares.