SPATIAL DENSITY, SIZE-FREQUENCY AND IMPLICATIONS OF CRATERS >20 μm ON GOLD AND ALUMINUM SURFACES EXPOSED BY LDEF; J. Warren[1], T.H. See[1], F. Cardenas[1], M. Laurance[2], S. Messenger[2], D. Brownlee[2], and F. Hörz[3]; [1]Lockheed-ESC, C23 2400 NASA Road 1, Houston, TX, 77058, [2]University of Washington, Seattle, WA 98195; [3]NASA/Johnson Space Center SN2, Houston, 77058.

INTRODUCTION: The Long Duration Exposure Facility (LDEF) orbited the Earth for ~5.7 years and represents an unprecedented opportunity to study hypervelocity impact features caused by natural and man-made particles typically <1 mm in size [1]. The Chemistry of Micrometeoroids Experiment exposed ~1 m^2 of gold (>99.99 Au) on LDEF's trailing edge (location A03) and ~1 m^2 of aluminum (1100 series; >99% Al; six individual plates) at location A11, some 60° off LDEF's leading edge. The modular trays that accommodated these substrates were fabricated from 6061-T6 aluminum and possessed substantial lips (total of ~0.39 m^2 for both experiment-trays) with sizeable crater populations [1]. This report summarizes the crater populations of all of these surfaces and discuss implications related to particle-size frequency and exposure history of the Au-collectors.

METHODS: The Au-surfaces were investigated in the FOILS Laboratory at the Johnson Space Center (JSC) employing a PC-controlled mechanical stage for scanning purposes, while the experiment-tray lips were scanned with a manually driven mechanical stage also at JSC. The small scale relief of the Au (finished by burring methods) permitted craters as small as 10 μm in diameter to be recognized. In contrast, only features >40 μm in diameter could be recorded on the experiment-tray lips. The optical systems and scanning methods employed are described in [1]. All JSC crater-diameter measurements refer to "rim-crest-to-rim-crest" dimensions (D_r). A single 1100 series Al-plate was transferred to the University of Washington in its "as retrieved" configuration where it was optically scanned to locate impact features. Craters on this single Al-plate were then dislodged by means of a punch and placed into an SEM for detailed dimensional characterization. The depth and diameter (D_i) for features on this plate were measured with respect to the original target surface. A small representative area of this collector was also scanned at 25X to characterize the size-frequency distribution of small craters. The entire ~1 m^2 instrument was initially surveyed for craters ≥500 μm in diameter at the Kennedy Space Center (KSC) during the deintegration of the LDEF spacecraft [1]. All available crater-counts on the A03 and A11 instruments are displayed in Figure 1.

CONVERSION OF CRATER DIMENSIONS INTO PROJECTILE DIAMETERS: Comparison of the crater populations illustrated in Figure 1 is not straight forward because of the different diameter criteria (D_r and D_i) that were employed. In addition, the diverse Al- and Au-materials possess different cratering efficiencies, and the mean encounter velocities on a non-spinning spacecraft, such as LDEF, depend strongly on the specific instrument pointing direction relative to the spacecraft's orbital velocity vector [2]. Therefore, interpretation of these crater populations in terms of particle fluxes necessitates conversion of observed crater diameters into a set of associated impactor dimensions (and eventually projectile masses) for each material and orientation. Laboratory-derived relationships between crater-morphometry and projectile dimensions as a function of impact velocity were provided by [3] for gold and by [4] for aluminum 6061-T6 (with suggestions on how to extrapolate to other aluminum alloys, such as the 1100 series). Ongoing small-scale impact experiments [5] suggest that $D_r = 1.3\ D_i$. At normal incidence, mean encounter velocities of 13.4 km/s and 20 km/s for locations A03 and A11 respectively, were calculated by [2 and 6]; a constant density of 2.2 g/cm was assumed for all projectiles. Following these procedures and assumptions, the measured crater diameters were converted into impactor dimensions as illustrated in Figure 2.

RELATIVE SIZE FREQUENCIES: The size-frequency distribution of impactors encountered at the LDEF A03 location seems to differ modestly from that at A11 as indicated by the somewhat shallower slopes at the larger impactors; the "forward" facing A11 surfaces intercepted more "small" particles. Note that this applies especially to the experiment-tray lips made from identical materials. Conversion of crater to projectile diameters in this case is only afflicted by possible uncertainties in velocity scaling, but the velocity exponent of 2/3 is generally deemed to be well founded. However, within statistical error (see Figure 1) the impactor populations could also be identical. While scanning of the A03 surfaces is complete, additional craters can and will be counted on the remaining five A11 aluminum-collector plates; we know that some of these plates contain larger craters than the single plate represented in Figure 1., and this seems to be the reason why the KSC- and experiment-tray lip data are somewhat higher than the A11 "plate" results.

ABSOLUTE FREQUENCIES: Absolute particle frequencies may be used to argue for variable, effective fluxes as a function of viewing direction. However, until the above mentioned issue of the relative size frequency is resolved, diverse flux- enhancement factors could be extracted from Figure 2 for the A11 location relative to A03, all sensitively depending on specific projectile size. The statistically most reliable counts apply to the range of 10-20 μm diameter impactors; at $D_p = 10$ the difference in particle flux between the A11 and A03 locations is approximately 5.

Comparison of the absolute frequency on the two A03 surfaces (of identical surface orientation) relates to relative exposure times of the gold collectors and experiment-tray lips. The latter were exposed continuously, while the Au-surfaces were mounted on clamshell-type devices that could be opened and closed. The particle flux, at D_p=10 μm, is ~1.8 times larger on the experiment-tray lips than on the gold collectors. This implies that the clamshells were "closed" for substantial fractions of the entire LDEF mission which lasted 2145 days. Nominal instrument performance would have exposed the gold for 1279 days, leading to a factor of 1.68 longer exposure of the experiment-tray lips relative to the Au-surfaces. The observed crater densities are consistent with this ratio and seem to indicate nominal instrument performance throughout LDEF's lifetime.

REFERENCES: [1] See *et al.,* (1990), *LDEF M&D SIG Report*, JSC Publication No. 24608, 583 p; [2] Zook, H. (1989), *LPSC XXI*, Abs., p. 1385-1386; [3] Hörz, F. (unpublished: $D_r = 1.12\ V^{0.63}$ for Au); [4] Cour-Palais, B.G. (1987), *Journ. Impact Eng., V5*, p. 221-238 as updated by Christiansen, E.L. (1990, Pers. Comm.): $0.5D_i = 5.24\ D_p^{1.056}\ H^{-0.25}\ (d_p/d_t)^{0.5}\ (V_i/V_c)^{2/3}$; H = Brinell hardness; d_p and d_t = projectile and target densities; V_1= impact velocity; V_c = target sound velocity); [5] Hörz *et al.,* (1991), This volume; [6] Peterson, R. (pers. comm; unpublished CDCF report).