SURVEY-TYPE ANALYSES OF PROJECTILE RESIDUES ON SELECT LDEF SURFACES AND CRATERS; R.P. Bernhard[1], D.E. Brownlee[2], M.R. Laurance[2], W.L. Davidson[1], and F. Hörz[3], [1]Lockheed-ESC, 2400 NASA Road 1, C23, Houston, TX, 77058, [2]Dept. of Astronomy, Univ. Washington, Seattle, WA, 98195, [3]NASA Johnson Space Center, Houston, TX 77058.

This report summarizes preliminary compositional SEM/EDX analyses of projectile residues associated with impact craters on diverse aluminum surfaces exposed by the Long Duration Exposure Facility (LDEF). Following optical characterization [1] we dislodged, in a clean environment, 174 individual craters from an aluminum plate (>99% pure; 1100 series aluminum) and 180 craters from the sheet metal flanges (6061-T6 aluminum) of two instrument trays; one tray was located 60° off LDEF's leading edge (location A11) and the other resided on the trailing edge (location A03). The 1100-series surfaces were processed and analyzed at the University of Washington, while the 6061 Al tray lips were examined at the Johnson Space Center (JSC), essentially following the methods developed during similar analyses on surfaces returned from the Solar Maximum Satellite as described by [2] and [3], respectively. The objective was to produce a survey type overview of all impactors and to identify those natural projectiles that warrant more detailed investigations.

CONTAMINATION-ISSUES: None of the aluminum materials are of high intrinsic purity; the impurities are heterogeneously distributed in both Al alloys, especially Fe. Substantial and essentially ubiquitous surface contamination resulted from the anodizing process that involved sulfuric acid resulting in S as a major contaminant, as well as surface-correlated Mg, Si and Cl. In general, these surface contaminants were not present in crater interiors. The tray lips were found to be contaminated also by Na, minor K, and substantial Cl; on occasion bona fide NaCl crystals were found in crater interiors. As neither Na nor Cl appear to be present in measurable quantities within the 1100-series Al, which was essentially exposed to the same environment(s) as the tray lips, the suspicion is that the NaCl contamination was imported by the experiment-tray covers. The A03 surfaces were further contaminated by deposits of Ca+Si that -- in some case -- was so thick that it could be seen with the naked eye as honey-brown smears and streaks at the tray corners. In general, these aluminum materials and surfaces are of fairly heterogeneous composition at the scale of electron-beam instruments and thus, are poorly suited to extract projectile information on a crater by crater basis. Therefore, minimal effort was made to analyze all craters in great detail.

ALUMINUM COLLECTOR (1100 SERIES) FROM LOCATION A11: All craters >100 μm in diameter, and a representative suite of craters 40-100 μm in diameter (*i.e.,* 174 impacts) were dislodged from a single collector plate [1]. Using diffuse light in the optical microscope it was relatively easy to identify those impacts containing large amounts of impactor residue. Nevertheless, we analyzed all 174 craters by means of SEM. The impactor residues range from smooth, thin melt-films (common) to unmelted, angular mineral fragment (rare). The latter are without exception either pyroxene or olivine that resisted impact melting as opposed to the (fine-grained?) matrix. The residue is intimately mixed with target-aluminum in most cases; we encountered some 70 craters in this category (*i.e.,* craters that seemingly contain residue) whose composition could not be determined with confidence because of high dilution factors of projectile species with target elements. Those craters that appeared optically dark seem to yield the only analyzable residue, all interpreted as natural cosmic dust of chondritic composition, some containing unmelted olivine (forsterite) or pyroxene (enstatite).

ALUMINUM TRAY LIP, LOCATION A11: The A11 tray lip contained 216 craters >40 μm in diameter [1], 131 were dislodged, of which 86 have been analyzed by SEM. Compositions of analyzed craters were interpreted and classified into 3 groups adopting the procedures and criteria developed by [3]. These groups are defined as follows: (a) micrometeoritic: -- Fe, Mg, Ca, Si, and Al present, yet variable; or Fe, Ni, S particles or mafic compositions dominated by Mg, Si and Fe; also some unmelted pyroxenes and olivine fragment occurred in rare cases. (b) man-made debris -- containing Ti, Zn, Ag, S, C, Si, K, Fe and Al in highly variable concentrations, yet in such proportions that they seem unlikely to reflect natural silicates. (c) no (detectable) residue -- this may include the majority of those craters that were not dislodged for SEM investigations.

ALUMINUM TRAY LIP, LOCATION A03: The A03 tray lip resided on the trailing edge of LDEF and experienced the lowest mean encounter-velocities possible on any LDEF instrument (~13.4 km/s as opposed to ~20 km/s for the A11 location [4]). Unfortunately, the A03 tray lip was particularity rich in surface contamination such as Na, K and Cl, and was especially contaminated with Ca+Si-rich surface deposits which extend into crater-interiors. In view of the low encounter-velocities we dislodged all optically observed craters >50 μm in diameter, as well as a representative number of smaller ones (N=42). The relative frequency of A03 crater residues is illustrated in Figure 2.

CONCLUSIONS: This report describes our ongoing LDEF efforts related to the compositional variety and possible sources of dust-particles in low-Earth orbit. Our current observations may be generalized as follows: (1) Significant cosmic-dust studies seem possible via infinite halfspace targets, as natural impactor-residues can be identified, (2) Even on the forward facing A11 location some cosmic-dust components survived unmelted, (3) Many craters (>50% ?) contain no measurable residue and an additional, sizeable fraction yields marginal signal/noise ratios, because excessive amounts of target material and impurities tend to dilute the projectile residues at cosmic impact velocities. Dust collectors in Earth orbit must be of high purity materials and free of surface contaminants to avoid substantial analytical difficulties and uncertainties.

We are not entirely comfortable with the classifications and interpretations presented in Figures 1 and 2 on a crater-by-crater basis. The results are preliminary and the classification(s) will evolve. It is expected that the analysis of high purity Au-targets (>99.99%) -- to commence shortly -- will improve and shed additional light on the suggested classifications and particle origins. The data presented in Figure 1 and 2 are neither representative for all craters, nor are they sufficiently precise to warrant extraction of detailed implications/applications regarding the hypervelocity particle environment in low-Earth orbit.

REFERENCES: [1] Warren, J. *et al.,* (1991), this Volume; [2] Laurance, M.R. and Brownlee, D.E. (1986), *Nature, V323*, p. 136-138; [3] McKay, D.S. (1989), *NASA Conf. Publ. 3035*, p. 301-316; [4] Zook, H.A. (1991), this Volume.