Damage Areas on LDEF Aluminum Panels: Preliminary Results

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INTRODUCTION

The Long Duration Exposure Facility (LDEF) was a twelve-sided, closed-cylender containing 57 science and technology experiments with a total exposure area of 130 m^2. LDEF was launched into a circular, low-Earth orbit (LEO) at an altitude of 450 km on April 7, 1984 and retrieved January 12, 1990. During its nearly six years in orbit, the LDEF descended to an altitude of 326 km and the orbital plane precessed approximately 8° per day.[1] During it's tenure in space, the LDEF was gravity-gradient stabilized with one end constantly facing the Earth, and the opposite constantly facing space. In addition, Row 9 was constantly oriented 7° from the normal to the velocity direction, or RAM.

Because of its exposure time and total exposed surface area, the LDEF provides a unique opportunity to characterize the natural and man-made particle populations in LEO. Previously, the most significant opportunities for this type of study were in the form of thermal blankets and thin aluminum membranes collected during the repair of the Solar Maximum Mission satellite.[2] In addition to the micrometeoroid and debris environment, the LDEF revealed a wealth of information on the radiation, contamination, vacuum, atomic oxygen, and ultraviolet radiation environments in LEO.

This study concentrated on collecting and analyzing measurements of impact craters from five painted aluminum surfaces at different locations on the satellite. These data are being used to: (1) characterize the effects of the LEO micrometeoroid and debris environment on satellite designs and components, (2) update the current theoretical micrometeoroid and debris models for LEO, (3) help assess the survivability of spacecraft and satellites that must travel through or reside in LEO, and the probability of their collsion with already resident debris, and (4) help define and evaluate future debris mitigation and disposal methods.

METHOD

Impact crater measurements were collected from three separate components of the LDEF satellite: two leading edge components - an experiment sun shield from Bay C12 and the active grapple plate from Bay C10, and one trailing edge component - the inactive grapple plate from Bay C01. Each of these components was composed of aluminum and coated with thermal paint. In addition, four aluminum tray sections from Bay E09 are in the process of being measured. To make the measurements, the scanning microscope table in the Facility for Optical Interpretation of Large Surfaces (FOILS) Lab at NASA Johnson Space Center was used. This facility is a Class 100 clean room designed specifically for analyzing space hardware. Once collected, all data is entered into an interactive database for storage and archival.

SUMMARY

Features examined in these analyses displayed interesting morphological characteristics, commonly exhibiting a concentric ringed appearance. Virtually all features > 0.2 mm in diameter possessed a spall zone in which all of the paint was removed from the aluminum surface. These spall zones varied in size from approximately 2 - 5 crater diameters. The actual craters in the aluminum substrate varied from central pits without raised rims, to morphologies more typical of craters formed in aluminum under hypervelocity laboratory conditions for the larger features. Most features also possessed what is referred to as a "shock zone"[2] as well. These zones varied in size from approximately 1 - 20 crater diameters. In most cases, only the outer-most layer of paint was affected by this impact related phenomenon. Several impacts possessed ridge-like structures ringing the area in which this outer-most paint layer was removed. In many ways, such features resembled the lunar impact basins, but on an extremely reduced scale. Overall, there were no noticeable penetrations, bulges or spallation features on the backside of the tray. Table 1 summarizes the preliminary results of this analysis. On Row 12, approximately 85° from the leading edge (RAM direction), there was approximately one impact per 15 cm^2. On the trailing edge, there was approximately one impact per 72 cm^2. Currently, craters on four aluminum experiment trays from Bay E09, directly on the leading edge are being measured and analyzed. Preliminary results have produced more than 2200 craters on approximately 1500 cm^2 - or approximately 1 impact per 1.5 cm^2.

CONCLUSIONS

The LEO debris environment is a REAL problem that needs to be addressed. With the current debris growth rate of 5%/yr expected to rise to 20% in the next few decades it is time to enact and follow adherrable space debris policies.

REFERENCES

(1) Zook H.A. (1990) LPSC XXII, pp. 1385-1386. (2) See T. (1990) NASA JSC #24608.

LDEF Data

LDEF Aluminum Plate	Number Impacts Observed	Total Damage Area	Average Damage Area (um^2)	Mean Crater Dia. (um)	Mean Spall Dia. (um)	Number Impacts/ cm^2
C12	253	3.14%	1.09×10^{8}	322.5	658.9	0.0665
	approximately 1 impact per 15.0 cm^2					
C10	94	2.09%	4.36×10^{7}	299.0	696.0	0.0542
	approximately 1 impact per 18.5 cm^2					
C01	30	0.26%	1.88×10^{7}	316.5	877.1	0.0138
	approximately 1 impact per 72.3 cm^2					

Table 1: Preliminary Results of LDEF Impact Measurements

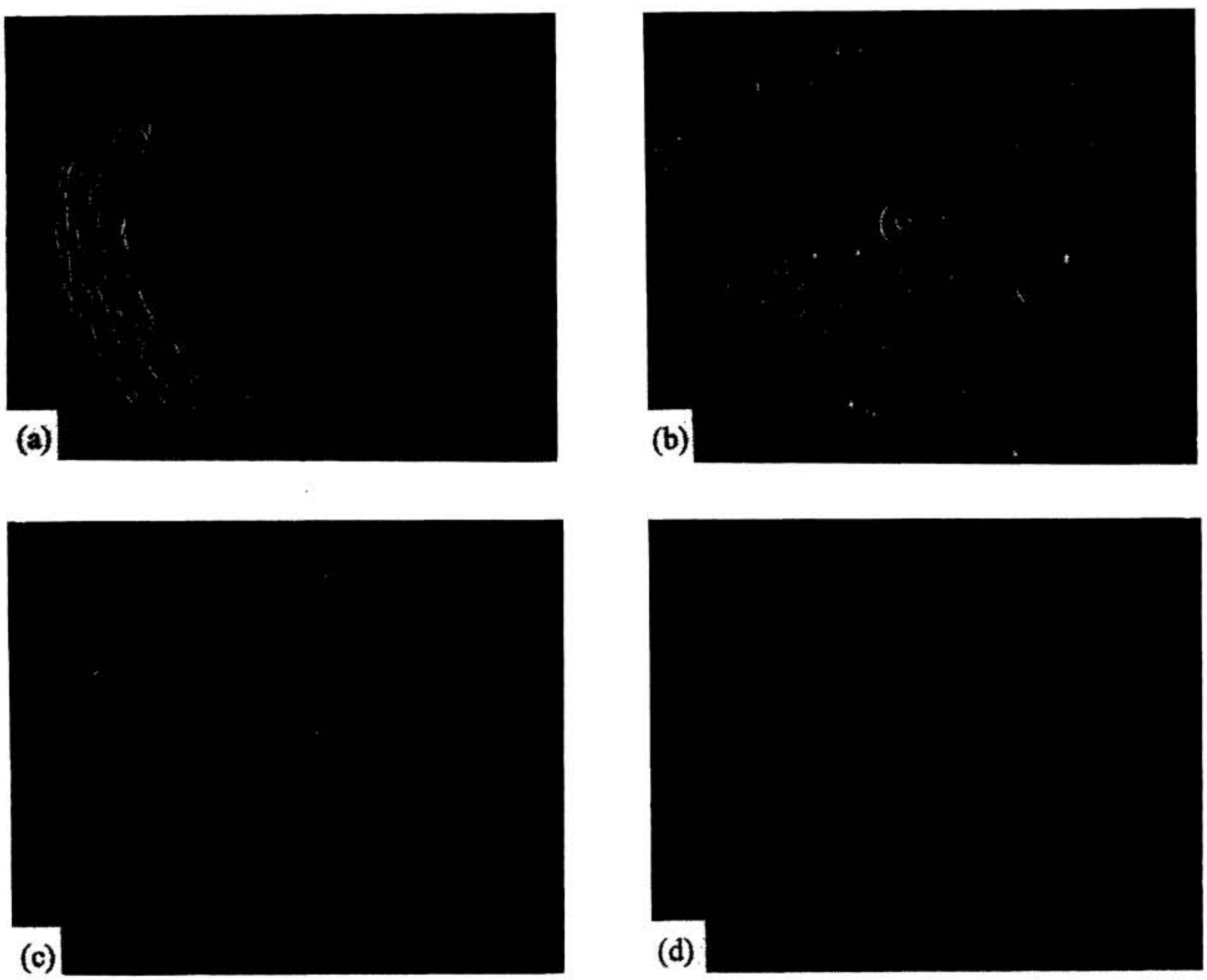

Figure 1: (a) rings, 4.5 mm across, C12 (b) ring 5.0 mm across, crater 200 µm, C12 (c) rings, 5 mm across, crater 150 µm, C12 (d) attached dome 700 µm, crater 200 µm, C10.