OPTICAL OBSERVATIONS OF IMPACT FEATURES ON SOLAR MAX THERMAL BLANKETS & LOUVERS; J. Warren[1], H. Zook[2] & J. Allton[1], [1]Lockheed EMSCO, P.O. Box 58561, Houston Tx 77358, [2]SN3/NASA Johnson Space Center, Houston Tx 77058.

The Solar Maximum Mission satellite was launched in the peak of the 11 year solar cycle for the purpose of studying solar flares. It decayed from a 570 km circular orbit under atmospheric drag to a 500 km circular orbit inclined at 28.5° until it was captured and repaired by the Space Shuttle 41-C crew in April 1984. Thermal blankets and aluminum louvers, exposed to the space environment for 4.15 years, were removed from Solar Max, returned to Earth, and examined for evidence of impacts from micrometeoroids and orbital debris. The 22 pieces of thermal blanket and 44 louvers contained 23,750 cm^2 of space-exposed area. Individual blanket pieces recorded different spatial densities of particle impacts. This was due to varied shielding from the satellite itself. The optical scanning and documentation of features ≥40 μm, which is now complete, revealed a total of 492 holes and 1419 craters, including a few interesting features of smaller size.

The thermal blanket from the Main Electronics Box (MEB) was constructed like a sandwich. The outer layer was 75 μm-thick Kapton with a thin film of aluminum deposited on the interior side. The bottom layer of the sandwich was 25 μm-thick Kapton, also with aluminum on the interior side. Between the Kapton sheets were 15 sheets of 6 μm-thick Mylar aluminized on both sides, each sheet loosely separated by ~100 μm-thick Dacron netting. The thermal blankets from the Attitude Control System (ACS) had outer layers of 50 μm-thick Kapton aluminized on the interior side. Between these thicker sheets were sandwiched 15 layers of 8 μm-thick Kapton aluminized on both sides and separated by Dacron netting. The louvers, removed from the ACS box, were comprised of 2 layers of 125 μm-thick aluminum foil separated by about 3 mm distance. Individual louvers were 25.0 cm long and 4.9 cm wide. Each louver was entirely scanned to identify and locate impact features. The thermal blankets were scanned in areas that were directly exposed to the space environment as evidenced by the surface erosion by atomic oxygen (1). The aluminum backing on the Kapton sheets gave the blankets a shiny, metallic gold color. Erosion produced a frosted, matte finish, and these areas were scanned optically by one of two procedures (10X or 29X magnification).

Table 1 shows the size distribution of impact craters and holes on the exterior of the Solar Max pieces examined. In addition to size and location, crater or hole rims were described as smooth or rough, with high or low relief, and round, oblong or irregular in shape. Presence of possible projectile material was noted. Halos, observed around most craters and holes, usually exhibited one or more of 3 morphologies: 1) "gaseous" halos, dark circular features with indistinct boundaries; 2) "spalled" halos, irregularly shaped features with distinct "peeled back" boundaries; or 3) "crystallized" halos, bright circular features immediately adjacent to the crater rim. The hole shown in Figure 1 exhibits gaseous and spalled halos. In addition to the surface impact features, nearly 400 impact features on the inner layers of the blankets were also sampled. Figure 2 shows similarly shaped penetration depth curves for the MEB and ACS blankets.

The rigid, two-layer louvers allowed measurement of impact angles via location on the top and bottom louver layers of features resulting from a single event (Fig. 3). The observed angles are highly shifted toward the normal compared to a theoretical distribution for particles approaching a flat surface from all directions equally. These data support the notion that ejecta from the top layer "bend" toward the normal before striking the bottom layer. Also, oblique angle penetration is more difficult for a given momentum. Effects of spacecraft motion, differences in individual louver orientation (from 0° to 30° off the horizontal), and Earth shielding should be minor. The two apparent high obliquity impacts merit further investigation.

The completion of the optical scanning of the space-exposed Solar Max blankets and louvers provides a 2300-point data and sample set available for studies of meteoroid and orbital debris flux, impact penetration mechanics, and projectile composition.

REFERENCE: (1) Leger L.J. et al. Low Earth Orbit Atomic Oxygen Effects on Surfaces, AIAA-84-0548, 22nd Aerospace Sci. Mtg., Jan. 1984.

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Table 1. NUMBERS OF HOLES & CRATERS BY SIZE FOR EXTERIOR SURFACES

TARGET / AREA		IMPACT FEATURE DIAMETER (Micrometers) Total*	≥40	≥80	≥100	≥120	≥160	≥200	≥300
Thermal Blankets**									
MEB (2)	holes	57	57	54	52	47	33	27	9
2090 cm2	craters	309	306	62	33	11	0	0	0
	holes + craters	**366**	**363**	**116**	**85**	**58**	**33**	**27**	**9**
ACS#12	holes	71	71	52	45	38	20	10	4
1820 cm2	craters	63	58	7	6	3	1	1	1
	holes + craters	**134**	**129**	**59**	**51**	**41**	**21**	**11**	**5**
ACS#6	holes	50	50	39	36	23	16	10	3
1530 cm2	craters	90	88	14	6	4	1	0	0
	holes + craters	**140**	**138**	**53**	**42**	**27**	**17**	**10**	**3**
ACS#5	holes	41	40	30	26	20	12	9	3
2120 cm2	craters	78	78	13	12	8	4	3	0
	holes + craters	**119**	**118**	**43**	**38**	**28**	**16**	**12**	**3**
ACS#7	holes	31	29	17	15	11	6	2	1
1830 cm2	craters	57	52	6	4	4	1	1	0
	holes + craters	**88**	**81**	**23**	**19**	**15**	**7**	**3**	**1**
ACS#9	holes	32	32	29	26	15	12	6	2
2170 cm2	craters	46	43	9	7	4	1	1	1
	holes + craters	**78**	**75**	**38**	**33**	**19**	**13**	**7**	**3**
Other ACS blankets									
6820 cm2	holes	145	142	119	106	80	53	40	17
	craters	165	154	44	30	20	14	8	2
	holes + craters	**310**	**296**	**163**	**136**	**100**	**67**	**48**	**19**
All Blankets									
18360 cm2	holes	427	421	340	306	234	152	104	39
	craters	808	779	155	98	54	22	14	4
	holes + craters	**1235**	**1200**	**495**	**404**	**288**	**174**	**118**	**43**
Louvers (44)									
5390 cm2	holes	65	65	65	65	65	64	59	34
	craters	611	371	132	90	58	24	9	2
	holes + craters	**676**	**436**	**197**	**155**	**123**	**88**	**68**	**35**
All Blankets & Louvers									
23750 cm2	holes	492	486	405	371	299	216	163	73
	craters	1419	1150	287	188	112	46	23	6
	holes + craters	**1911**	**1636**	**692**	**559**	**411**	**262**	**186**	**79**

* Impact features ≥ 40 um were systematically recorded. Some interesting features <40 um were also sampled.
** Each blanket piece experienced differential space exposure due to differences in local spacecraft shielding.

FIG 1. Halo types observed around a 90 µm hole in the ACS thermal blanket.

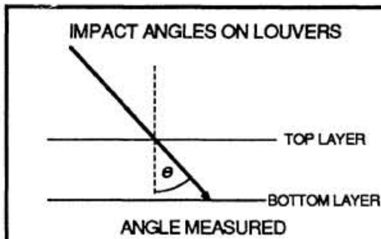

FIG. 3A.

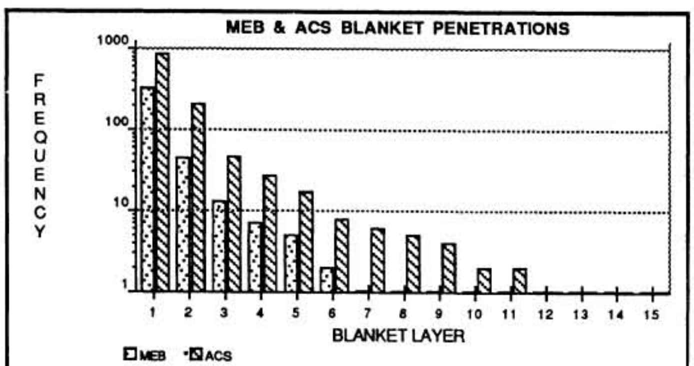

FIG. 2. Frequency of holes, craters, and splatters observed on the interior layers of the thermal blankets. Layer 1 is the exterior surface.

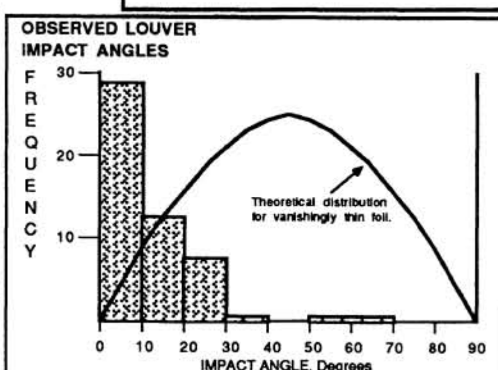

Fig. 3b.