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Debris/Ice/TPS Assessment and Integrated Photographic Analysis of Shuttle Mission STS-63

Gregory N. Katnik, Barry C. Bowen, J. Bradley Davis

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COLOR ILLUSTRATIONS

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Gregory N. Katnik, Barry C. Bowen, J. Bradley Davis,
Vehicle Engineering/Mechanical System Division/ET-SRB Branch,
Kennedy Space Center, Florida

Technical Memorandum 110649 March 1995

DEBRIS/ICE/TPS ASSESSMENT
AND
INTEGRATED PHOTOGRAPHIC ANALYSIS
OF
SHUTTLE MISSION STS-63

2 February 1995

Prepared By:

J. Bradley Davis
Digital Imaging Systems
NASA/Kennedy Space Center

Barry C. Bowen
Infrared Scanning Systems
NASA/Kennedy Space Center

Jorge E. Rivera
Mechanical/Structural Systems
NASA/Kennedy Space Center

Robert F. Speece
Thermal Protection Systems
NASA/Kennedy Space Center

Approved:

Gregory N. Katnik
Shuttle Ice/Debris Systems
NASA/Kennedy Space Center
TV-MSD-7

James G. Tatum
Chief, ET/SRB Mechanical Systems
NASA/Kennedy Space Center
TV-MSD-7

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FOREWORD

The Debris Team has developed and implemented measures to control damage from debris in the Shuttle operational environment and to make the control measures a part of routine launch flows. These measures include engineering surveillance during vehicle processing and closeout operations, facility and flight hardware inspections before and after launch, and photographic analysis of mission events.

Photographic analyses of mission imagery from launch, on-orbit, and landing provide significant data in verifying proper operation of systems and evaluating anomalies. In addition to the Kennedy Space Center Photo/Video Analysis, reports from Johnson Space Center and Marshall Space Flight Center are also included in this document to provide an integrated assessment of the mission.

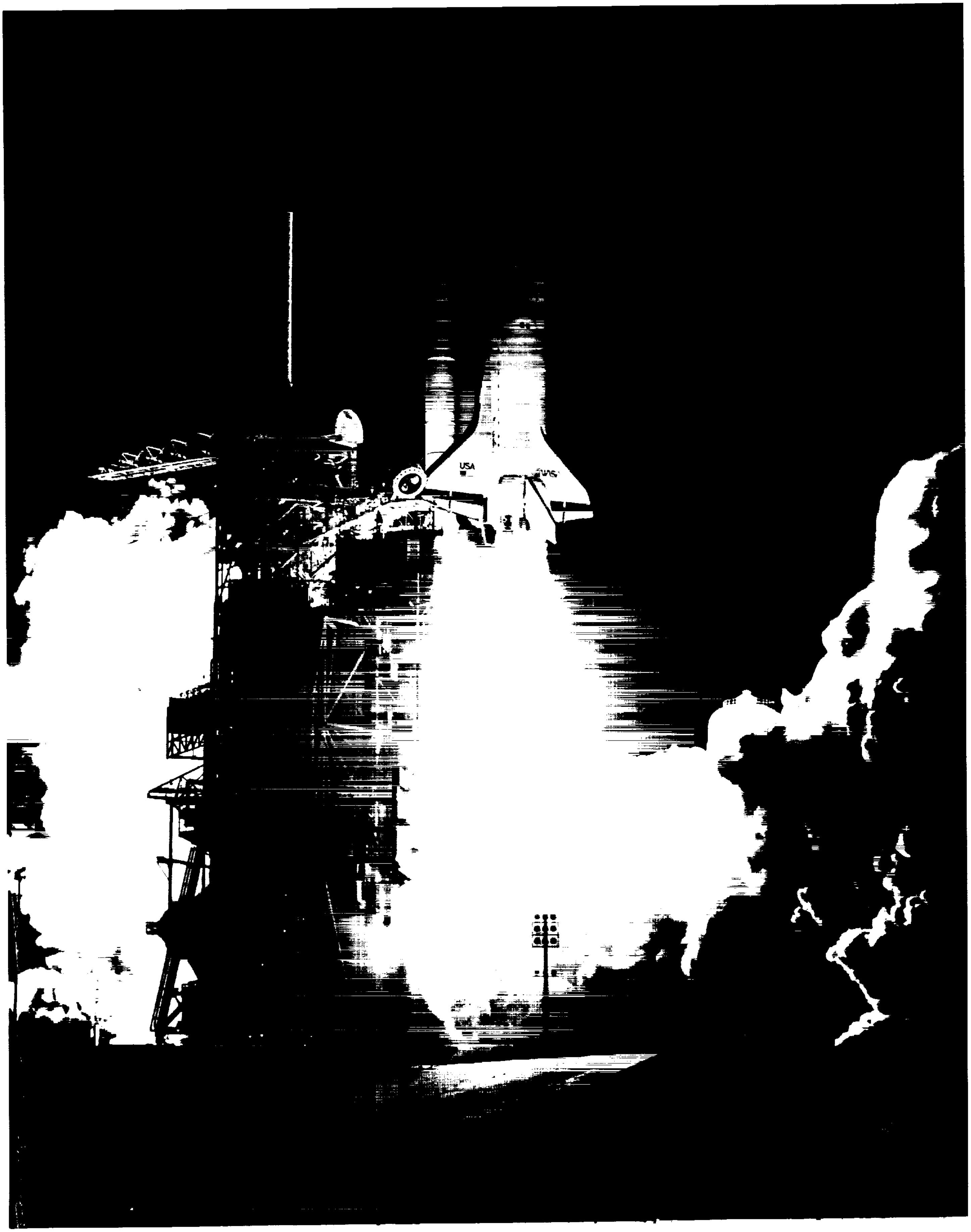

Photo 1 : Launch of Shuttle Mission STS-63

1.0 SUMMARY

A pre-launch debris inspection of the pad and Shuttle vehicle was performed on 1 February 1995. The detailed walkdown of Launch Pad 39B and MLP-2 also included the STS-63 primary flight elements OV-103 Discovery (20th flight), ET-68 (LWT 61), and BI-070 SRB's. Loose thermal curtain tape on the right SRB was the only vehicle anomaly. Four facility debris items were documented for resolution prior to ET cryoload.

The planned launch on 2 February 1995 was scrubbed for 24 hours due to the failure of an Orbiter Inertial Measurement Unit (IMU). The problem was detected prior to cryogenic loading.

The vehicle was cryoloaded on 2 February 1995. There were no Launch Commit Criteria (LCC), OMRS, or NSTS-08303 criteria violations. No IPR's were taken. Due to the ambient weather conditions at this time of year, the potential existed for acreage icing. Frost, but no detectable ice, formed on the +Y side of the External Tank during the countdown. There were no protuberance icing conditions outside of the established data base.

Minor damage to the ET nosecone/footprint area was visible after the GOX vent hood was retracted. A 2-inch long by 1-inch wide piece of topcoat along with superficial layer of CPR foam was missing from an area 10 inches aft of the +Y louver and just aft of the XT-371 interface. The topcoat adhered to the GOX vent seal during seal deflation/hood retraction.

After the 00:22:04 a.m. (local) launch on 3 February 1995, a debris walk down of Pad 39B was performed. No flight hardware or TPS materials were found. There was no visual indication of a stud hang-up on any of the south holddown posts. The HDP #2 shoe and EPON shim was blackened more than usual as if some burning of grease or shim epoxy had been caused by the SRB exhaust plume. All the T-0 umbilicals operated properly. Overall, damage to the launch pad was minimal.

A total of 101 films and videos were analyzed as part of the post launch data review. No vehicle damage or lost flight hardware was observed that would have affected the mission. One PR was generated as a result of the film review. Film item E-33 showed approximately 16 inches of RSS coax cable attached to the External Tank at the intertank umbilical carrier assembly. The cable should have remained with the GUCP during disconnect and retraction. A KSC lab report attributed the cable failure to tensile overload. There was no evidence of a pre-existing condition, such as cuts or excessive bending, that contributed to the failure. A suspect PR and TPS were worked on ET-69 to verify proper configuration of the cable prior to STS-67 launch.

A white wispy streak of vapor streamed aft between Orbiter SSME #1 and the vertical stabilizer (right side) at T+43 seconds MET. The streak did not appear to be related to localized flow condensation and was most likely water/steam "flashing" from the water spray boilers.

DTO-312 was not performed by the flight crew due to RCS propellant usage limitations. OV-104 was not equipped to carry umbilical cameras

The Solid Rocket Boosters were inspected at Hanger AF after retrieval. Both left and right Solid Rocket Boosters sustained extensive structural damage from water impact loads due to high seas. The LH Forward Assembly, LH nozzle, and one of the nozzle actuators were lost during towback to the port. The RH frustum was missing no TPS but had 19 debonds over fasteners and 1 debond over acreage. The LH frustum was missing no TPS but had 34 MSA-2 debonds over fasteners.

Orbiter performance as viewed on landing films and videos during final approach, touchdown, and rollout was nominal. Drag chute operation was also normal.

A post landing inspection of OV-103 Discovery was conducted on runway 15 at the Kennedy Space Center. The Orbiter TPS sustained a total of 125 hits, of which 14 had a major dimension of 1-inch or larger. Based on these numbers and comparison to statistics from previous missions of similar configuration, the total number of hits was average and the number of hits 1-inch or larger was less than average. The Orbiter lower surface sustained a total of 84 hits, of which 7 had a major dimension of 1-inch or larger.

The largest tile damage site measured 5.5-inches by 1.5-inches by 0.75 inches deep and was located on the lower surface outboard of the LH2 ET/ORB umbilical directly aft of the LH MLG. The damage site was clean and did not exhibit the typical signs of re-entry heating. RTV was missing from the main landing gear tire pressure transducer wiring harness. No RTV was found on the runway. The RTV most likely came off during gear deployment and caused the damage prior to touchdown. An EO will eliminate excessive RTV on the wiring harness.

Orbiter post landing microchemical sample results revealed a variety of residuals in the Orbiter window samples from the window protective covers, facility environment, SRB BSM exhaust, Orbiter TPS, RCS thruster paper covers, and paints/primers from various sources. These residual sampling data do not indicate a single source of damaging debris as all of these materials have previously been documented in post-landing sample reports.

This set of post flight debris samples led to no new findings. However, a trend in lower surface tile damage site residual material has been established. SRB Hypalon paint inclusions have been detected in lower surface tile damage sites on STS-63, -66, -68, and -65. All of the samples show the paint material had been exposed to heat effects. Hypalon paint does not adhere well to Booster Trowelable Ablator (BTA) closeouts during ascent aeroheating and reentry. Post-flight assessment of the SRB's has revealed blistered/missing Hypalon paint from BTA on the frustums.

A total of seven Post Launch Anomalies, but no In-Flight Anomalies (IFA's), were observed during the STS-63 mission assessment.

2.0 PRE-LAUNCH BRIEFING

The Debris/Ice/TPS and Photographic Analysis Team briefing for launch activities was conducted on 31 January 1995 at 1530 hours. The following personnel participated in various team activities, assisted in the collection and evaluation of data, and contributed to reports contained in this document.

J. Tatum	NASA - KSC	Chief, ET/SRB Mechanical Systems
G. Katnik	NASA - KSC	Shuttle Ice/Debris Systems
B. Davis	NASA - KSC	Digital Imaging Systems
R. Speece	NASA - KSC	Lead, Thermal Protection Systems
B. Bowen	NASA - KSC	Infrared Scanning Systems
K. Tenbusch	NASA - KSC	ET Thermal Protection Systems
J. Rivera	NASA - KSC	Lead, ET Mechanisms/Structures
M. Bassignani	NASA - KSC	ET Mechanisms, Structures
M. Valdivia	LSOC - SPC	Chief, ET Mechanical Systems
R. Seale	LSOC - SPC	ET Mechanical Systems
M. Jaime	LSOC - SPC	Lead, ET Mechanical Systems
Z. Byrns	NASA - KSC	Ground Systems/Operations Integration
J. McClymonds	RI - Downey	Shuttle Aerodynamics
S. Clarke	Rockwell LSS	Systems Integration
J. Cook	MTI - LSS	SRM Processing
S. Otto	MMMSS- LSS	ET Processing
K. Ely	MMMSS- LSS	ET Processing
H. Bowman	LSOC - SPC	Safety

3.0 LAUNCH

STS-63 was launched at 95:034:05:22:03.994 GMT (00:22:04 a.m. local) on 3 February 1995.

3.1 PRE-LAUNCH SSV/PAD DEBRIS INSPECTION

A pre-launch debris inspection of the launch pad and Shuttle vehicle was performed on February 1, 1995, from 1630 to 1800 hours. The detailed walkdown of Pad 39B and MLP-2 also included the primary flight elements OV-103 Discovery (20th flight), ET-68 (LWT 61), and BI-070 SRB's. Loose thermal curtain tape on the right SRB was the only vehicle anomaly.

Five facility debris items were entered in Appendix K for resolution prior to ET cryoload: 1) platforms and scaffolding not yet removed from the MLP zero level; 2) loose cotter pin tether and grounding strap on east emergency egress crossover; 3) loose thermal tape on the RH SRB aft skirt near HDP #2; 4) loose MLP zero level cover bolts; and 5) loose SRB hoist pedestal covers and bolts.

The planned launch on 2 February 1995 was scrubbed for 24 hours due to the failure of an Orbiter Inertial Measurement Unit (IMU). The problem was detected prior to cryogenic loading.

3.2 FINAL INSPECTION

The Final Inspection of the cryoloaded vehicle was performed on 2 February 1995 from 1800 to 1945 hours during the two hour built-in-hold at T-3 hours in the countdown. There were no Launch Commit Criteria (LCC), OMRS, or NSTS-08303 criteria violations. No IPR's were taken. Due to the ambient weather conditions at this time of year, the potential existed for acreage icing. There were no protuberance icing conditions outside of the established data base.

Ambient weather conditions at the time of the inspection were:

	T-3 Hours	T-0 Launch
Wind Speed (knots):	09	10
Wind Direction (degrees):	259	233
Relative Humidity (percent):	66	84
Temperature (degrees F):	61	55
Dew Point (degrees F):	50	50

A portable Shuttle Thermal Imager (STI) infrared scanning radiometer was utilized to obtain vehicle surface temperature measurements for an overall thermal assessment of the vehicle, as shown in Figures 1 and 2.

3.3 ORBITER

No Orbiter tile or RCC panel anomalies were observed. All RCS thruster paper covers were intact and dry with the exception of L4D. This cover was damp. Typical ice/frost accumulations were present at the SSME #1 and #2 heat shield-to-nozzle interfaces. An infrared scan revealed no unusual temperature gradients on the base heat shield or engine mounted heat shields.

3.4 SOLID ROCKET BOOSTERS

SRB case temperatures measured by the fixed STI radiometers ranged from 57-61 degrees F. In comparison, temperatures measured by the SRB Ground Environment Instrumentation (GEI) ranged from 59-67 degrees F. All measured temperatures were above the 34 degrees F minimum requirement. The predicted Propellant Mean Bulk Temperature (PMBT) supplied by MTI was 59 degrees F, which was within the required range of 44-86 degrees F.

SSV INFRARED SCANNER SURFACE TEMPERATURE SUMMARY DATA

TIME: 1820-1945
DATE: Feb. 2, 1995
VEH. STS- 63, OV-103

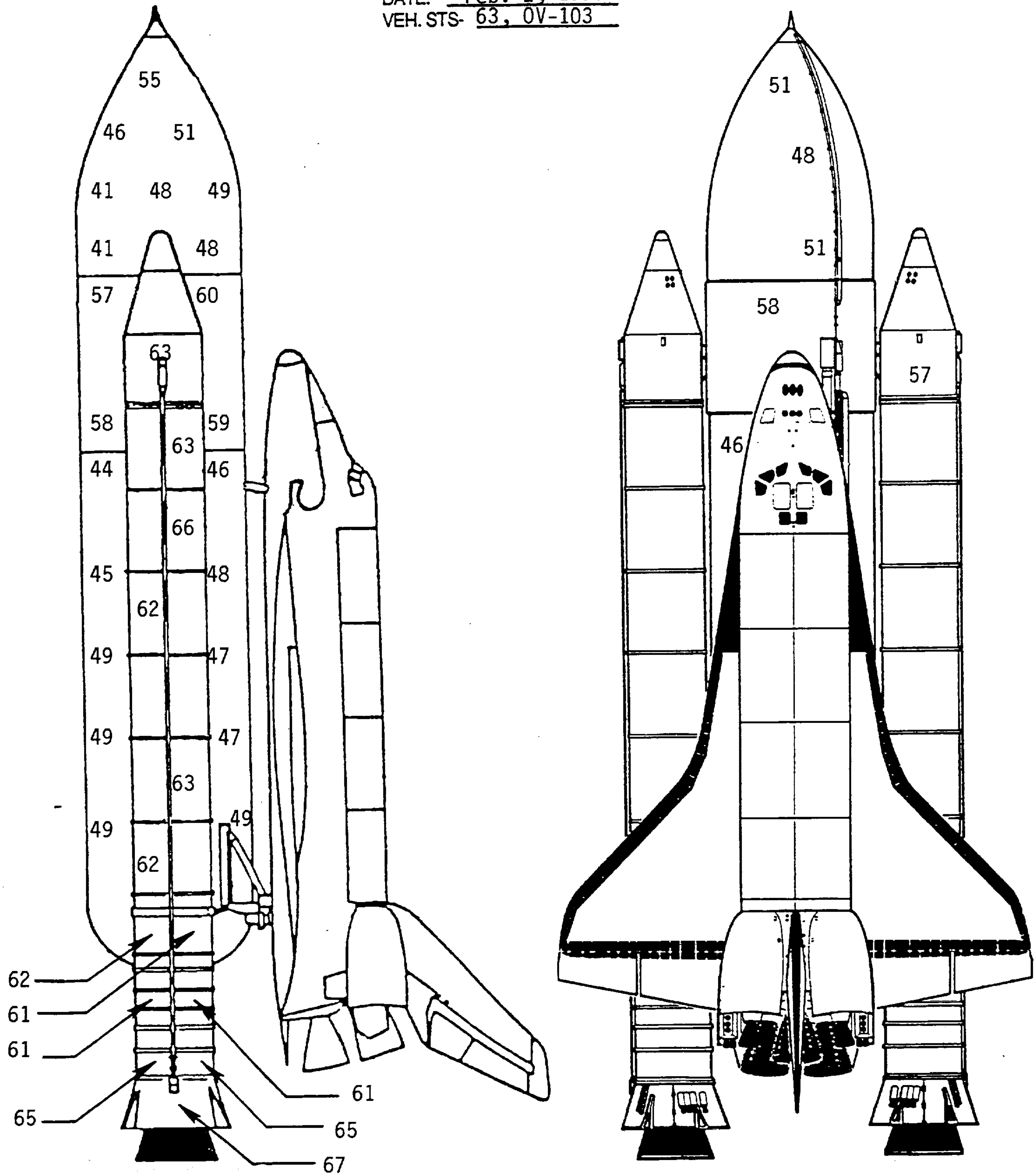

Figure 1 : Vehicle Surface Temperature STI Measurements

SSV INFRARED SCANNER
SURFACE TEMPERATURE
SUMMARY DATA

TIME: 1820-1945
DATE: Feb. 2, 1995
VEH. STS- 63, OV-103

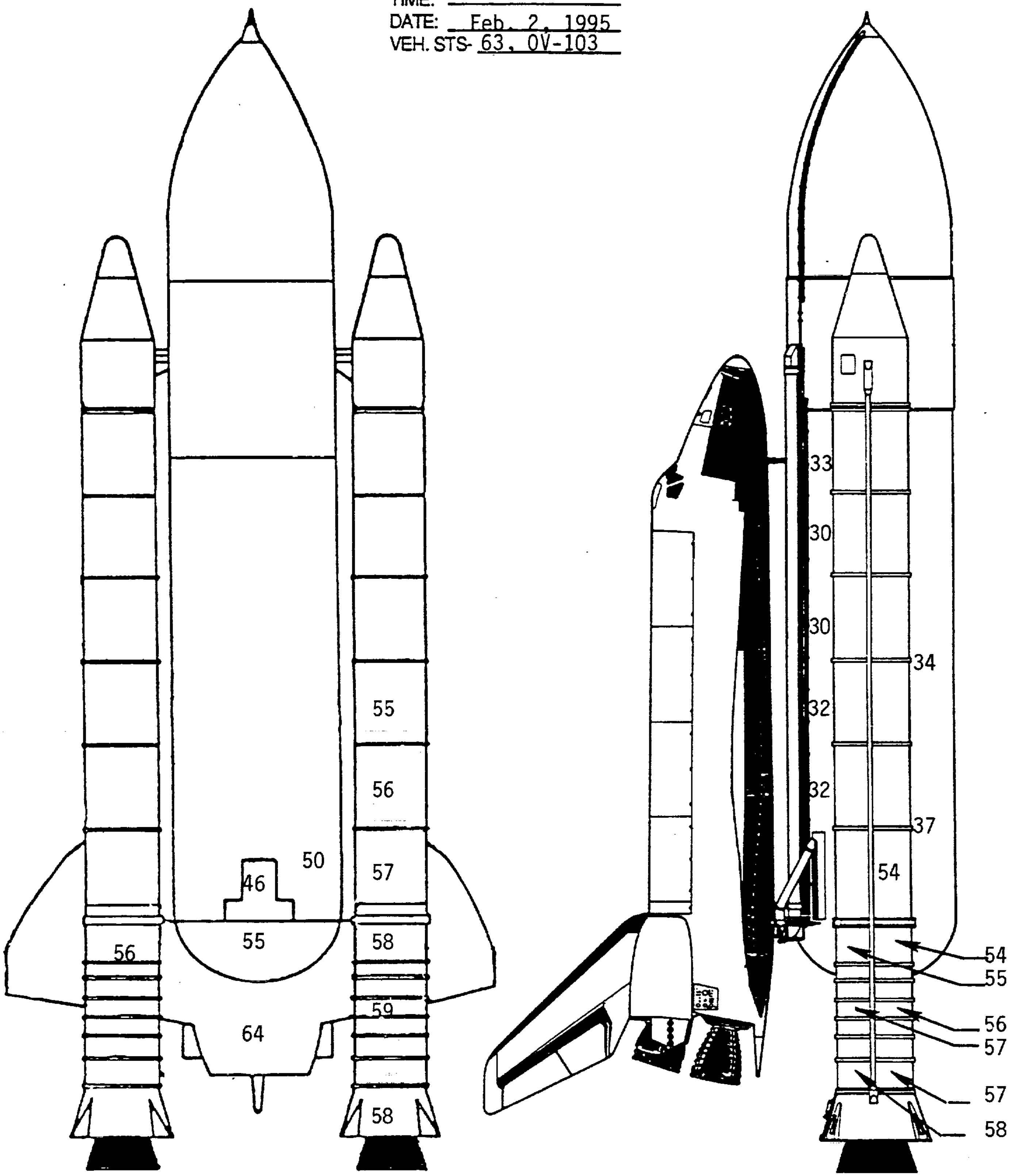

Figure 2 : Vehicle Surface Temperature STI Measurements

3.5 EXTERNAL TANK

The ice/frost prediction computer program 'SURFICE' was run from 2045 to 0530 hours GMT and the results tabulated in Figure 3. The program predicted condensate with no ice/frost accumulation on the TPS acreage surfaces for most areas of the ET with the exception of the LH2 tank barrel section (XT-1120 through XT-1380) during cryoload. The program predicted the surface temperature in this area would fall below 32 degrees Fahrenheit starting at 0045 GMT.

The Final Inspection Team observed very light condensate, but no ice or frost accumulations, on the LO2 tank. The portable STI measured surface temperatures that averaged 49 degrees on the ogive and 44 degrees F on the barrel section. SURFICE predicted temperatures of 48 degrees F on the ogive and 43 degrees F on the barrel section. There were no TPS anomalies.

The intertank acreage exhibited no TPS anomalies. Typical ice/frost accumulation, but no unusual vapor, was present on the ET umbilical carrier plate. The portable STI measured an average surface temperature of 60 degrees F on the intertank.

There were no LH2 tank TPS acreage anomalies. Very light condensate, but no ice or frost accumulations, were present on the acreage. The portable STI measured surface temperatures that averaged 48 degrees on the upper LH2 tank. The lower LH2 tank was generally 48 degrees F with the exception of the frost-covered +Y+Z and +Y-Z quadrants, which measured 32 degrees F. SURFICE predicted temperatures of 39 degrees F on the upper LH2 tank and 45 degrees F on the barrel section. Frost had also formed along the PAL, pressurization line, and cable tray ramp-to-acreage interfaces.

There were no anomalies on the bipod jack pad closeouts. A crack, 8 inches long by 1/2-inch wide, was present in the -Y ET/SRB cable tray forward surface TPS. The crack extended approximately 10 inches aft on the inboard side of the vertical strut. The presence of the crack was acceptable for flight per the NSTS-08303 criteria. Small ice/frost spots had formed on the +Y vertical strut drain hole and strut aft surface-to-acreage interface.

Typical amounts of ice/frost had accumulated in the LO2 feedline bellows and support brackets.

There were no TPS anomalies on the LO2 ET/ORB umbilical. Acreage ice/frost was more widespread than usual but still acceptable for flight. Some ice and frost had formed on the aft side of the umbilical. Ice/frost fingers on the separation bolt pyrotechnic canister purge vents were typical.

Ice and frost in the LH2 recirculation line bellows and on both burst disks was typical. The LH2 feedline bellows were covered by some ice/frost and condensate.

Less than usual amounts of ice/frost had accumulated on the LH2 ET/ORB umbilical purge barrier top and outboard sides. Typical ice/ frost fingers were present on the pyro canister and plate gap purge vents. There was no ice/frost on the 17-inch flapper valve actuator access port foam plug. Ice/frost had formed on the aft pyro canister closeout bondline. No unusual vapors or cryogenic drips had appeared during tanking, stable replenish, and launch.

STS- 63	TEST S0007 LAUNCH	DATE: 2 Feburary, 1995	T-0 TIME: 05:22:04 DATE: 2/3/95	NASA KSC Ice/Frost/Debris Team
ORBITER 103	ET 68, SRB BI-070, MLP 2, PAD B	LO2 CHILLDOWN TIME: 19:57 SLOW FILL TIME: 20:34 FAST FILL TIME: 20:46 REPLENISH TIME: 22:52	LH2 CHILLDOWN TIME: 19:57 SLOW FILL TIME: 20:07 FAST FILL TIME: 20:53 REPLENISH TIME: 22:41	

TIME	CONDITIONS					LO2 TANK STA 370 TO 540					LO2 TANK STA 550 TO 852					LH2 TANK STA 1130 TO 1380					LH2 TANK STA 1380 TO 2058				
(EST)	TEMP F	REL. HUM. %	DEW PT F	WIND VEL KNTS	WIND DIR DEG	REG	LOCAL VEL KNTS	SOFI TEMP	COND RATE IN/HR	ICE RATE IN/HR	REG	LOCAL VEL KNTS	SOFI TEMP	COND RATE IN/HR	ICE RATE IN/HR	REG	LOCAL VEL KNTS	SOFI TEMP	COND RATE IN/HR	ICE RATE IN/HR	REG	LOCAL VEL KNTS	SOFI TEMP	COND RATE IN/HR	ICE RATE IN/HR
1545	69.00	41.0	44.44	12	245	II	7.08	54.79	0.0000	-0.1225	II	7.08	48.12	0.0000	-0.0952	II	3.84	40.83	0.0007	-0.0374	II	16.32	56.14	0.0000	-0.2364
1600	68.00	45.0	45.99	14	244	II	8.26	55.19	0.0000	-0.1437	II	8.26	48.98	0.0000	-0.1158	II	4.48	42.33	0.0009	-0.0486	II	19.04	56.58	0.0000	-0.2831
1615	68.00	45.0	45.99	12	254	II	7.08	53.96	0.0000	-0.1241	II	7.08	47.29	0.0000	-0.0965	II	5.16	43.58	0.0007	-0.0600	II	14.52	54.12	0.0000	-0.2117
1630	68.00	46.0	46.58	13	254	II	7.67	54.64	0.0000	-0.1361	II	7.67	48.17	0.0000	-0.1084	II	5.59	44.52	0.0006	-0.0688	II	15.73	54.89	0.0000	-0.2349
1645	68.00	43.0	44.77	16	254	II	9.44	56.13	0.0000	-0.1578	II	9.44	50.43	0.0000	-0.1299	II	6.88	45.71	0.0000	-0.0847	II	19.36	56.71	0.0000	-0.2785
1700	68.00	44.0	45.38	14	257	II	8.26	55.16	0.0000	-0.1413	II	8.26	48.96	0.0000	-0.1136	II	6.02	44.56	0.0003	-0.0726	II	16.94	55.55	0.0000	-0.2457
1715	68.00	44.0	45.38	13	255	II	7.67	54.56	0.0000	-0.1317	II	7.67	48.10	0.0000	-0.1041	II	5.59	43.97	0.0004	-0.0656	II	15.73	54.86	0.0000	-0.2269
1730	66.70	48.3	46.65	12	256	II	7.08	52.79	0.0000	-0.1216	II	7.08	46.34	0.0001	-0.0940	II	5.16	43.14	0.0010	-0.0577	II	14.52	52.90	0.0000	-0.2080
1745	66.10	51.2	47.65	10	260	II	5.90	50.80	0.0000	-0.1030	II	5.90	45.20	0.0008	-0.0757	II	4.30	41.60	0.0014	-0.0439	II	12.10	50.54	0.0000	-0.1721
1800	64.30	57.7	49.15	8	248	II	4.72	48.14	0.0003	-0.0816	II	4.72	43.13	0.0016	-0.0545	II	3.44	38.96	0.0019	-0.0276	II	9.68	47.75	0.0008	-0.1318
1815	63.60	59.2	49.17	10	250	II	5.90	48.85	0.0001	-0.0996	II	5.90	44.57	0.0015	-0.0721	II	4.30	40.85	0.0020	-0.0404	II	12.10	48.71	0.0003	-0.1675
1830	63.10	60.2	49.13	9	263	II	5.31	48.08	0.0003	-0.0880	II	5.31	43.43	0.0017	-0.0607	II	3.87	39.46	0.0020	-0.0318	II	10.89	47.88	0.0008	-0.1455
1845	61.90	63.8	49.54	9	260	II	5.31	47.65	0.0006	-0.0855	II	5.31	42.97	0.0019	-0.0582	II	3.87	38.93	0.0022	-0.0295	II	10.89	47.48	0.0013	-0.1418
1900	61.20	65.7	49.66	9	259	II	5.31	47.34	0.0008	-0.0836	II	5.31	42.65	0.0021	-0.0563	II	3.87	38.57	0.0023	-0.0279	II	10.89	47.20	0.0015	-0.1390
1915	60.20	64.8	48.22	8	254	II	4.72	45.46	0.0008	-0.0670	II	4.72	40.28	0.0020	-0.0401	II	3.44	35.91	0.0022	-0.0154	II	9.68	45.21	0.0016	-0.1089
1930	59.70	65.0	47.90	9	250	II	5.31	45.66	0.0007	-0.0736	II	5.31	40.88	0.0020	-0.0466	II	3.87	36.74	0.0022	-0.0201	II	10.89	45.53	0.0014	-0.1224
1945	59.20	66.5	48.03	8	246	II	4.72	44.81	0.0009	-0.0636	II	4.72	39.60	0.0021	-0.0368	III	2.56	31.99	0.0021	0.0004	II	10.88	45.34	0.0015	-0.1205
2000	58.90	66.8	47.36	8	243	II	4.72	44.56	0.0009	-0.0622	II	4.72	39.33	0.0021	-0.0354	III	2.56	31.99	0.0021	0.0011	II	10.88	45.10	0.0016	-0.1181
2015	58.60	69.7	48.71	8	234	II	4.72	44.82	0.0011	-0.0637	II	4.72	39.60	0.0023	-0.0368	III	2.56	31.99	0.0022	0.0006	II	10.88	45.40	0.0019	-0.1211
2030	58.70	69.7	48.81	9	234	II	5.31	45.57	0.0010	-0.0732	II	5.31	40.79	0.0023	-0.0461	II	2.88	33.16	0.0023	-0.0042	II	12.24	46.20	0.0017	-0.1415
2045	58.00	75.0	50.11	8	224	II	4.72	45.23	0.0014	-0.0659	II	4.72	40.00	0.0026	-0.0388	III	2.56	31.99	0.0025	0.0001	II	10.88	45.85	0.0026	-0.1257
2100	58.00	75.0	50.11	8	228	II	4.72	45.23	0.0014	-0.0659	II	4.72	40.00	0.0026	-0.0388	III	2.56	31.99	0.0025	0.0001	II	10.88	45.85	0.0026	-0.1257
2115	58.00	73.0	49.38	10	227	II	5.90	46.05	0.0012	-0.0817	II	5.90	41.62	0.0025	-0.0544	II	3.20	34.23	0.0025	-0.0085	II	13.60	46.75	0.0019	-0.1606
2130	58.00	74.0	49.75	8	228	II	4.72	45.03	0.0014	-0.0648	II	4.72	39.80	0.0025	-0.0378	III	2.56	31.99	0.0024	0.0004	II	10.88	45.65	0.0024	-0.1237
2145	58.00	73.0	49.38	8	228	II	4.72	44.84	0.0013	-0.0638	II	4.72	39.61	0.0025	-0.0368	III	2.56	31.99	0.0023	0.0007	II	10.88	45.45	0.0023	-0.1217
2200	58.00	75.0	50.11	9	233	II	5.31	45.88	0.0014	-0.0751	II	5.31	41.09	0.0026	-0.0478	II	2.88	33.34	0.0025	-0.0049	II	12.24	46.57	0.0024	-0.1457
2215	58.00	75.6	50.33	10	235	II	5.90	46.56	0.0014	-0.0849	II	5.90	42.13	0.0027	-0.0575	II	3.20	34.72	0.0026	-0.0104	II	13.60	47.27	0.0023	-0.1670
2230	57.60	75.8	50.01	10	237	II	5.90	46.17	0.0014	-0.0825	II	5.90	41.74	0.0027	-0.0551	II	3.20	34.29	0.0026	-0.0088	II	13.60	46.90	0.0023	-0.1625
2245	57.80	76.0	50.28	11	238	II	6.49	46.90	0.0013	-0.0932	II	6.49	42.79	0.0027	-0.0656	II	3.52	35.70	0.0027	-0.0148	II	14.96	47.63	0.0022	-0.1852
2300	58.00	77.0	50.83	10	237	II	5.90	46.82	0.0015	-0.0867	II	5.90	42.41	0.0028	-0.0592	II	3.20	34.98	0.0027	-0.0113	II	13.60	47.55	0.0025	-0.1704
2315	57.00	79.0	50.54	9	237	II	5.31	45.57	0.0016	-0.0733	II	5.31	40.76	0.0029	-0.0460	II	2.88	32.93	0.0027	-0.0033	II	12.24	46.31	0.0029	-0.1430
2330	57.00	80.0	50.88	10	235	II	5.90	46.33	0.0017	-0.0836	II	5.90	41.89	0.0030	-0.0561	II	3.20	34.36	0.0028	-0.0090	II	13.60	47.10	0.0029	-0.1650
2345	56.00	81.0	50.23	9	234	II	5.31	44.87	0.0017	-0.0692	II	5.31	40.02	0.0029	-0.0420	II	2.88	32.14	0.0027	-0.0005	II	12.24	45.64	0.0031	-0.1358
0000	55.00	83.0	49.91	10	236	II	5.90	44.73	0.0018	-0.0736	II	5.90	40.22	0.0031	-0.0463	II	3.20	32.62	0.0029	-0.0023	II	13.60	45.57	0.0032	-0.1469
0015	55.00	84.0	50.23	10	236	II	5.90	44.91	0.0019	-0.0747	II	5.90	40.40	0.0031	-0.0474	II	3.20	32.78	0.0029	-0.0029	II	13.60	45.75	0.0033	-0.1491
T-0	55.00	84.0	50.23	10	233	II	5.90	44.91	0.0019	-0.0747	II	5.90	40.40	0.0031	-0.0474	II	3.20	32.78	0.0029	-0.0029	II	13.60	45.75	0.0033	-0.1491
AVG.	60.93	65.47	48.65	10.03			5.92	48.03				5.92	42.88				3.67	36.71				13.00	48.49		

Period of Final Inspection Team on Pad

Figure 3 : SURFICE Computer Predictions

The summary of Ice/Frost Team observations/anomalies, which were all acceptable for launch per the NSTS-08303 criteria, consisted of five OTV recorded items:

Anomaly 001 documented an 8-inch by 1/2-inch crack in the forward surface TPS of the -Y vertical strut/ET-SRB cable tray. The crack extended approximately 10 inches aft on the inboard side of the vertical strut.

Anomaly 002 documented two 1-inch diameter ice/frost spots on the +Y vertical strut aft side: at the drain hole and at the strut-to-aft dome interface.

Anomaly 003 documented ice/frost formations in the LO2 feedline support brackets and bellows.

Anomaly 004 documented ice/frost formations on the LO2 ET/ORB umbilical purge vents and the LH2 ET/ORB umbilical purge vents, recirculation line bellows, and purge barrier.

Anomaly 005 documented a 2-inch long by 1-inch wide piece of topcoat along with superficial layer of CPR foam missing from an area 10 inches aft of the +Y louver and just aft of the XT-371 interface. The topcoat adhered to the GOX vent seal during seal deflation/hood retraction. An effort is in work to establish the need for topcoat/foam peel-off/adhesion acceptance criteria during seal retraction.

3.6 FACILITY

All SRB sound suppression water troughs were filled and properly configured for launch (LCC requirement).

No leaks were observed on either the LO2 or LH2 Orbiter T-0 umbilicals, the GH2 vent line, or the Ground Umbilical Carrier Plate (GUCP).

Minor damage to the ET nosecone/footprint area was visible after the GOX vent hood was retracted. A 2-inch long by 1-inch wide piece of topcoat along with superficial layer of CPR foam was missing from an area 10 inches aft of the +Y louver and just aft of the XT-371 interface. The topcoat adhered to the GOX vent seal during seal deflation/hood retraction.

Photo 2 : Overall View of LH2 Tank

Light frost, but no detectable ice, formed on the LH2 tank +Y side

Photo 3 : ET LO2 Feedline

Typical ice/frost had formed in the LO2 feedline bellows and support brackets

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Photo 4 : -Y ET/SRB Vertical Strut

A crack, 8 inches long by 1/2-inch wide, was present in the -Y ET/SRB cable tray forward surface TPS. The presence of the crack was acceptable for flight per the NSTS-08303 Criteria.

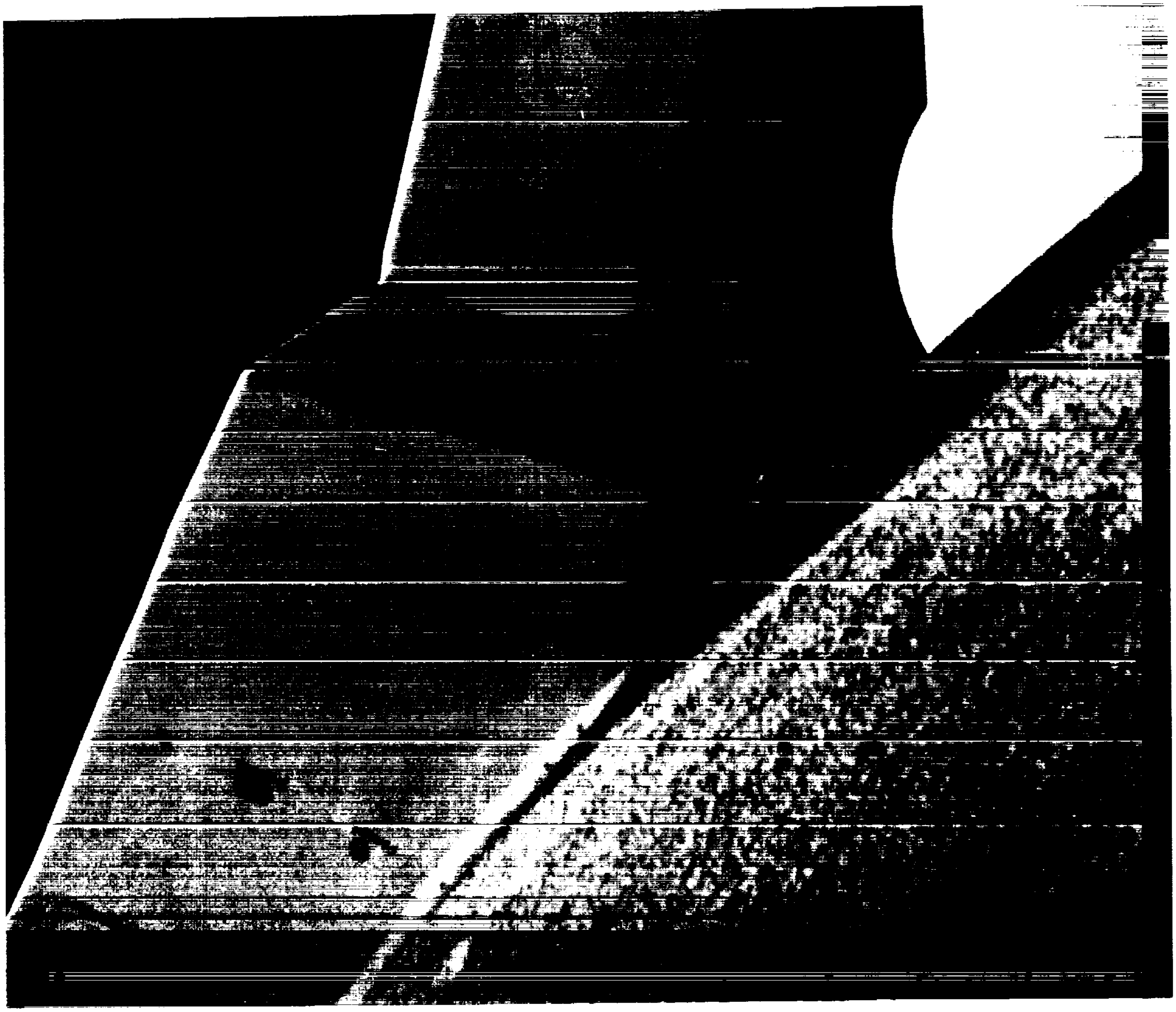

Photo 5 : -Y ET/SRB Vertical Strut

The crack extended approximately 10 inches aft on the inboard side of the vertical strut. The presence of the crack was acceptable for flight per the NSTS-08303 criteria.

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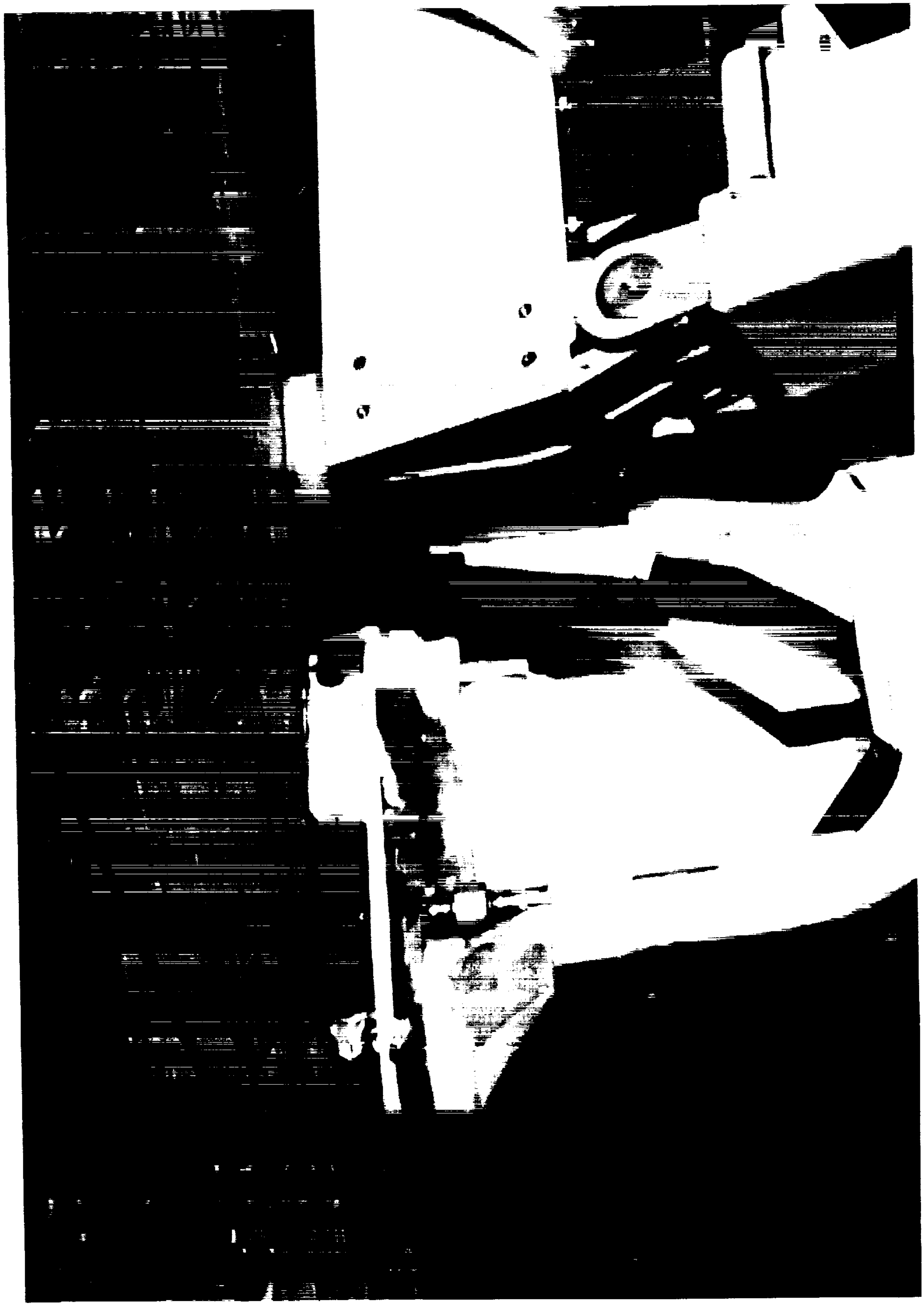

Photo 6 : LO2 ET/ORB Umbilical

Ice/frost formations on the umbilical and purge vents were acceptable for flight

Photo 7 : LH2 ET/ORB Umbilical

Typical ice/frost formations on the umbilical were acceptable for flight

4.0 POST LAUNCH PAD DEBRIS INSPECTION

The post launch inspection of the MLP, FSS and RSS was conducted on 3 February 1995 from Launch + 2 to 4 hours.

No flight hardware or TPS materials were found. A facility bolt, one inch in length, was recovered on the west side of the MLP deck.

South SRB HDP erosion was typical. All south HDP shoe EPON shim material was intact. There was no visual indication of a stud hang-up on any of the south holddown posts. The HDP #2 shoe and EPON shim was blackened more than usual as if some burning of grease or shim epoxy had been caused by the SRB exhaust plume. All of the north HDP doghouse blast covers were in the closed position. Erosion of the blast covers was also typical. Minor damage to the SRB aft skirt purge lines and T-0 umbilicals was similar to previous launches.

The Tail Service Masts (TSM) and Orbiter Access Arm (OAA) appeared undamaged. Minor damage to the GOX vent hood included a 4-inch by 4-inch piece of instafoam missing from a vent duct and a loose bracket shim on the south tip purge line.

The GH2 vent line was latched on the 8th tooth of the latching mechanism, had no loose cables (static retract lanyard), and appeared to have latched properly with no rebound.

Recent construction of Substation 1032 at the base of the northeast pad slope included an aluminum rain gutter with two downspouts. The Debris Team and Pad Managers expressed concern about the effects of the SRB plume/shock wave on the lightweight aluminum pieces. Thicker aluminum angle stock was bolted to the wall and to the underside of the gutter in an attempt to strengthen the structure. However, post launch inspection of the pad revealed substantial damage to the gutter. One 8 foot section lay in the pad acreage near camera site #2. The rest of the gutter was deformed and bent upward.

Minor, but typical, pad damage included:

Broken stadium lights on the east and northwest sides of the pad surface

Bent access platform grating on the MLP zero level east side

Missing cable tray cover on the FSS 235 foot level

Debris inspections of the pad acreage and flame trench were completed on 6 February 1995. No flight hardware or TPS material was found with the exception of SRB throat plug material scattered across the pad acreage southeast of the MLP. The presence of this material confirmed the identity of the objects falling out of the SSME exhaust plume in film item E-62.

Post launch pad inspection anomalies are listed in Section 10.

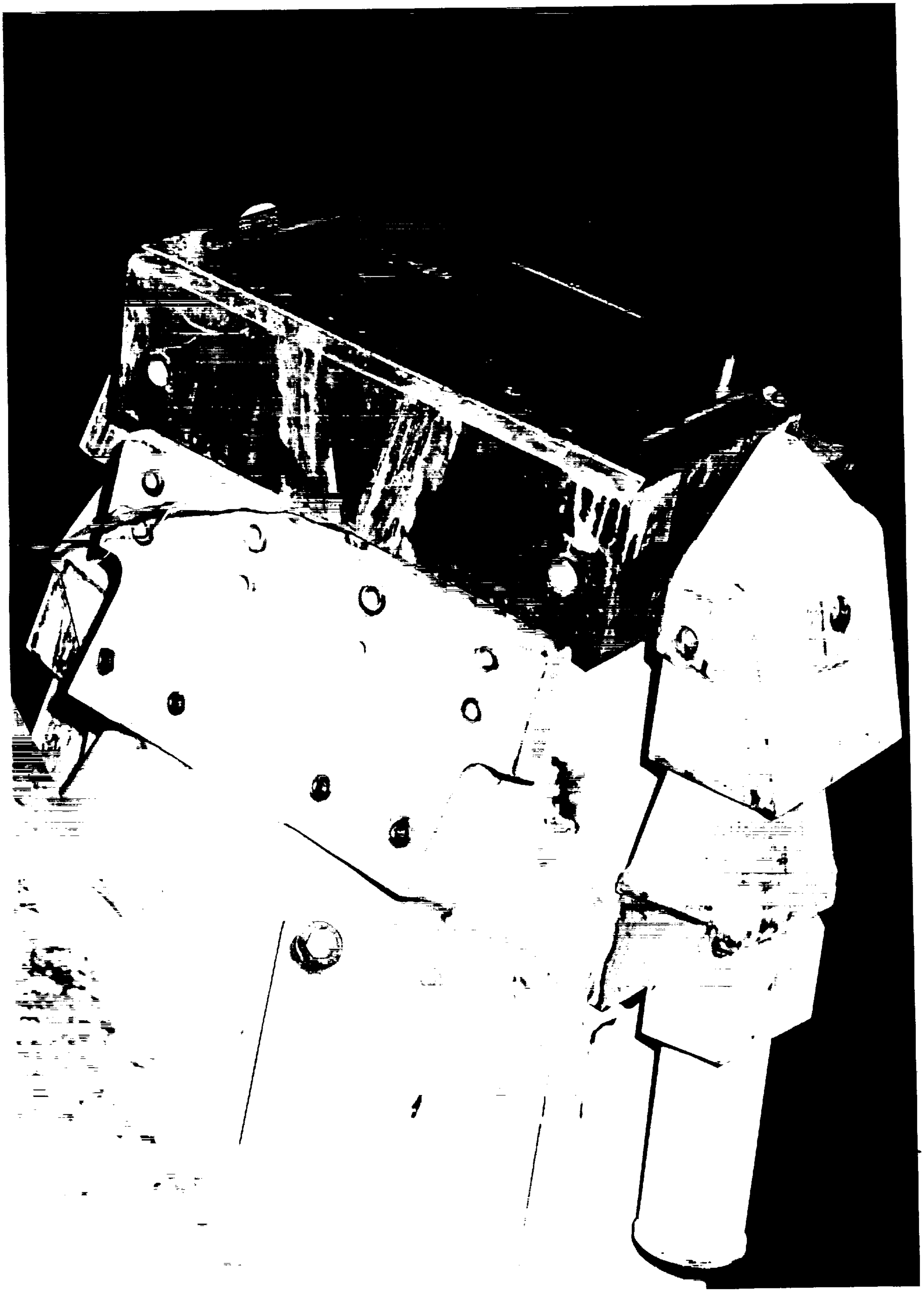

Photo 8 : Blackened HDP #2 Shoe/EPON Shim

5.0 FILM REVIEW

Anomalies observed in the Film Review were presented to the Mission Management Team, Shuttle managers, and vehicle systems engineers. One PR was generated as a result of the film review.

OTV 160 and OTV 162 showed a 2-inch long by 1-inch wide piece of topcoat along with superficial layer of CPR foam was missing from an area 10 inches aft of the +Y louver and just aft of the XT-371 interface in the GOX seal footprint. The topcoat adhered to the GOX vent seal during seal deflation/hood retraction. An effort is in work to establish the need for topcoat/foam peel-off/adhesion acceptance criteria during seal retraction.

Film item E-33 showed approximately 16 inches of RSS coax cable attached to the External Tank at the intertank umbilical carrier assembly. The cable should have remained with the GUCP during disconnect and retraction. A KSC Material Science Laboratory report (95-1M0019) attributed the cable failure to tensile overload. There was no evidence of a pre-existing condition, such as cuts or excessive bending, that contributed to the failure. Suspect PR ET-69-EL-0002 and TPS S70-1261-00-001-012 were taken to verify proper configuration of the cable on ET-69 (STS-67).

Post flight anomalies are listed in Section 10.

5.1 LAUNCH FILM AND VIDEO SUMMARY

A total of 101 films and videos, which included thirty-eight 16mm films, twenty 35mm films, four 70mm films, and thirty-nine videos, were reviewed starting on launch day.

No vehicle damage or lost flight hardware was observed that would have affected the mission.

Dark carbon-type residue from the GOX seals, which had appeared on the STS-64 and STS-68 ET nosecones, was not present on the STS-63 ET-68 nosecone after the GOX vent hood was retracted (OTV 113, 160, 162). However, frost had formed on the southwest louver bolt heads. The presence of frost was not a constraint to launch (OTV 162).

Fore-and-aft movement of the Orbiter base heat shield in the centerline area between the SSME cluster occurred during engine start-up. The motion was similar to that observed on previous launches (E-76, -77).

SSME ignition, Mach diamond formation, and gimbal profile appeared normal (OTV 151, 170, 171). Ice/frost accumulations on the SSME #2 nozzle-to-heat shield interface were typical (OTV 150). Free burning hydrogen had drifted under the body flap and upward to the base heat shield/ RH OMS pod during ignition (OTV 163, 170, 171). Streaks occurred in the SSME #1 and #2 plumes during startup (E-2, -3, -6).

A small, dark piece of debris, origin unknown, first appeared near the OMS pod and moved to the right field of view at high speed. No vehicle contact was observed (E-3).

A 2-inch by 1-inch piece of tile surface coating material was lost from the base heat shield outboard of SSME #3 (E-17, OTV 149) during SSME ignition. Small pieces of tile surface coating material were lost from seven places on the base heat shield outboard of SSME #2 (E-18, OTV 150) and from one place on the aft surface of the left RCS stinger (E-19). Three light spots on base heat shield tiles between SSME #2/#3 and the body flap were also identified as areas of missing tile surface coating material (E-6).

SSME ignition caused numerous pieces of ice to fall from the ET/Orbiter umbilicals. Some pieces of ice contacted the umbilical cavity sill and were deflected outward, but no tile damage was visible (OTV 109, 163, 164). Falling pieces of ice from the LH2 feedline bellows contacted the LH2 recirculation line, but no TPS damage was apparent (OTV 109, 164).

The External Tank "twanged" approximately 32 inches during SSME ignition (E-79).

The holddown post films revealed no stud hang-ups. No ordnance fragments or frangible nut pieces fell from any of the DCS/stud holes. North holddown post doghouse blast covers closed normally. A piece of thermal curtain tape was loose on the RH booster (E-9, -25, -77). Two small pieces of instafoam from the LH aft skirt aft ring area near HDP #8 broke off and fell into the SRB exhaust hole (E-14). At least eight flat, dark objects, which may have been sound suppression cloth parts tags, were ejected out of the RH SRB exhaust hole near HDP #4 (E-7).

Grease or EPON shim epoxy was visible burning on the HDP #2 shoe at T+8 seconds MET (E-8)

The Orbiter LH2 and LO2 T-0 umbilicals disconnected and retracted properly (E-17, -18; OTV 149, 150). After the GUCP disconnected from the External Tank, approximately 16 inches of RSS coax cable was visible still attached to the intertank umbilical carrier assembly (E-33; OTV 104, 167). The cable should have remained with the GUCP. GH2 vent line capture and latch was nominal, though some slack in the static retract lanyard caused slight contact with the GUCP legs/crossbeam (E-42; OTV 160, 167).

Numerous objects, both light and dark in color, dropped out of the SSME exhaust plume over the southeast part of the pad after the vehicle cleared the tower (E-62). The objects were thought to be pieces of SRB throat plug material and sound suppression water trough material, a finding later confirmed by the Post Launch Pad Acreage Inspection.

As many as 10 pieces of ice from the LO2 feedline upper bellows fell aft during liftoff and tower clear. Some of these pieces contacted the Orbiter, but no damage was apparent (E-40, -54).

Pieces of ET/ORB umbilical purge barrier material and RCS thruster paper covers fell aft during ascent (E-213, -220, -224).

A white wispy streak of vapor streamed aft between Orbiter SSME #1 and the vertical stabilizer (right side) at T+43 seconds MET. The streak did not appear to be related to localized flow condensation and was most likely water/steam "flashing" from the water spray boilers (E-205, -207, -220, -222, -223).

Body flap movement (amplitude and frequency) was similar to previous flights (E-207, -212, -213).

Numerous small pieces of SRB propellant or aft skirt instafoam dropped out of the SRB exhaust plume from T+59 through T+75 seconds MET (TV-4B; E-218).

Programmed movement of the elevons for load relief during ascent was visible (E-207, -212).

A white object moved vertically in the left FOV of TV-5 after SRB separation. The object was not near the vehicle and may have been a star imaged by the moving tracker.

ET aft dome charring and exhaust plume recirculation was typical. SRB plume tailoff and separation appeared normal. Numerous pieces of slag dropped out of the exhaust plume before, during, and after SRB separation - a common event (TV-13; E-207, -212, -220, -224).

Photo 9 : Missing Topcoat from ET Nose Cone

A small piece of topcoat along with superficial layer of CPR foam adhered to the GOX vent seal during seal deflation/hood retraction.

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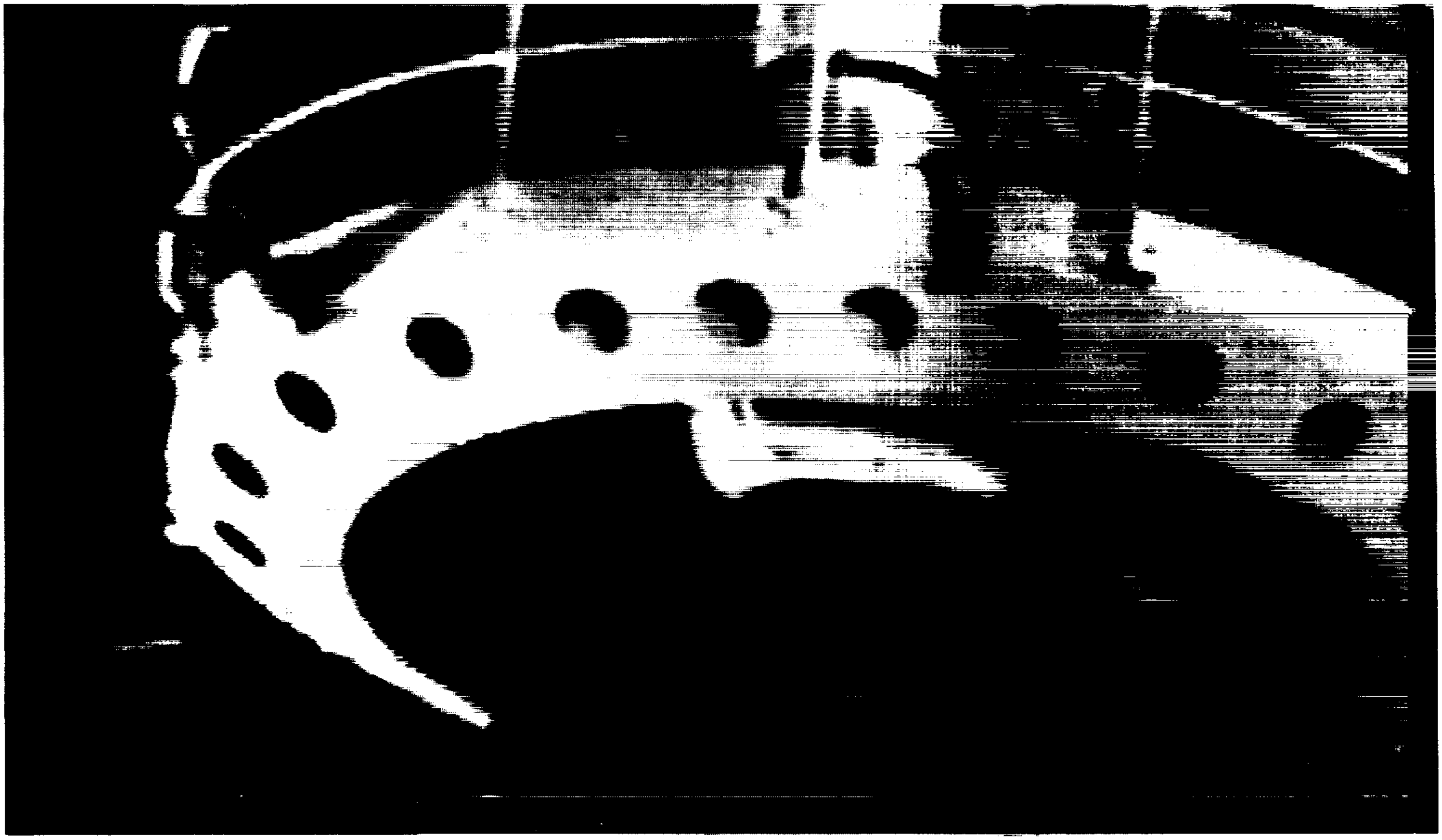

Photo 10 : Missing Topcoat from ET Nose Cone

A 2-inch long by 1-inch wide piece of topcoat along with superficial layer of CPR foam was missing from an area 10 inches aft of the +Y louver and just aft of the XT-371 interface as a result of GOX vent seal deflation/hood retraction.

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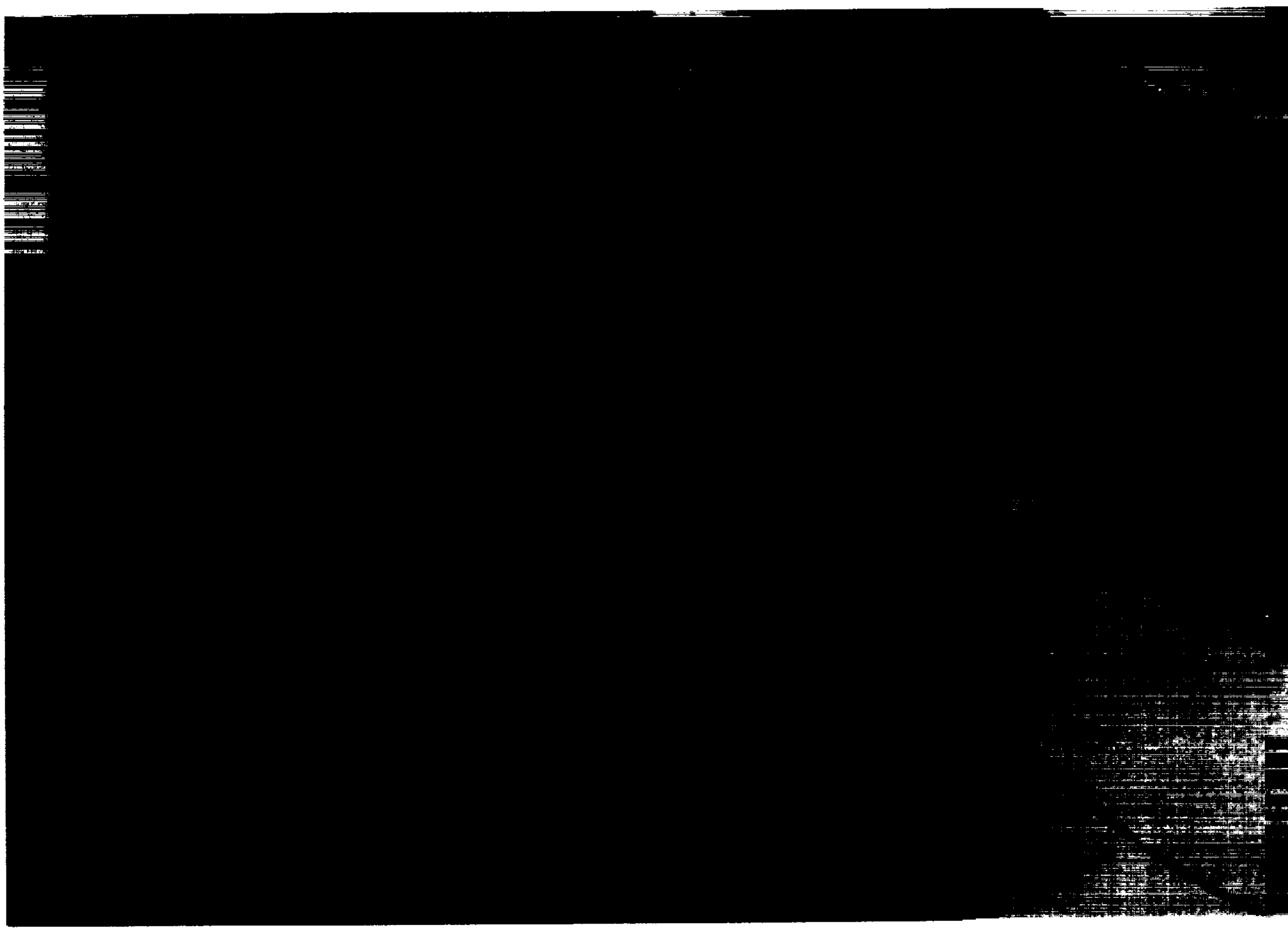

Photo 11 : ET RSS Coax Cable

Approximately 16 inches of RSS coax cable attached to the External Tank at the intertank umbilical carrier assembly should have remained with the GUCP during disconnect and retraction

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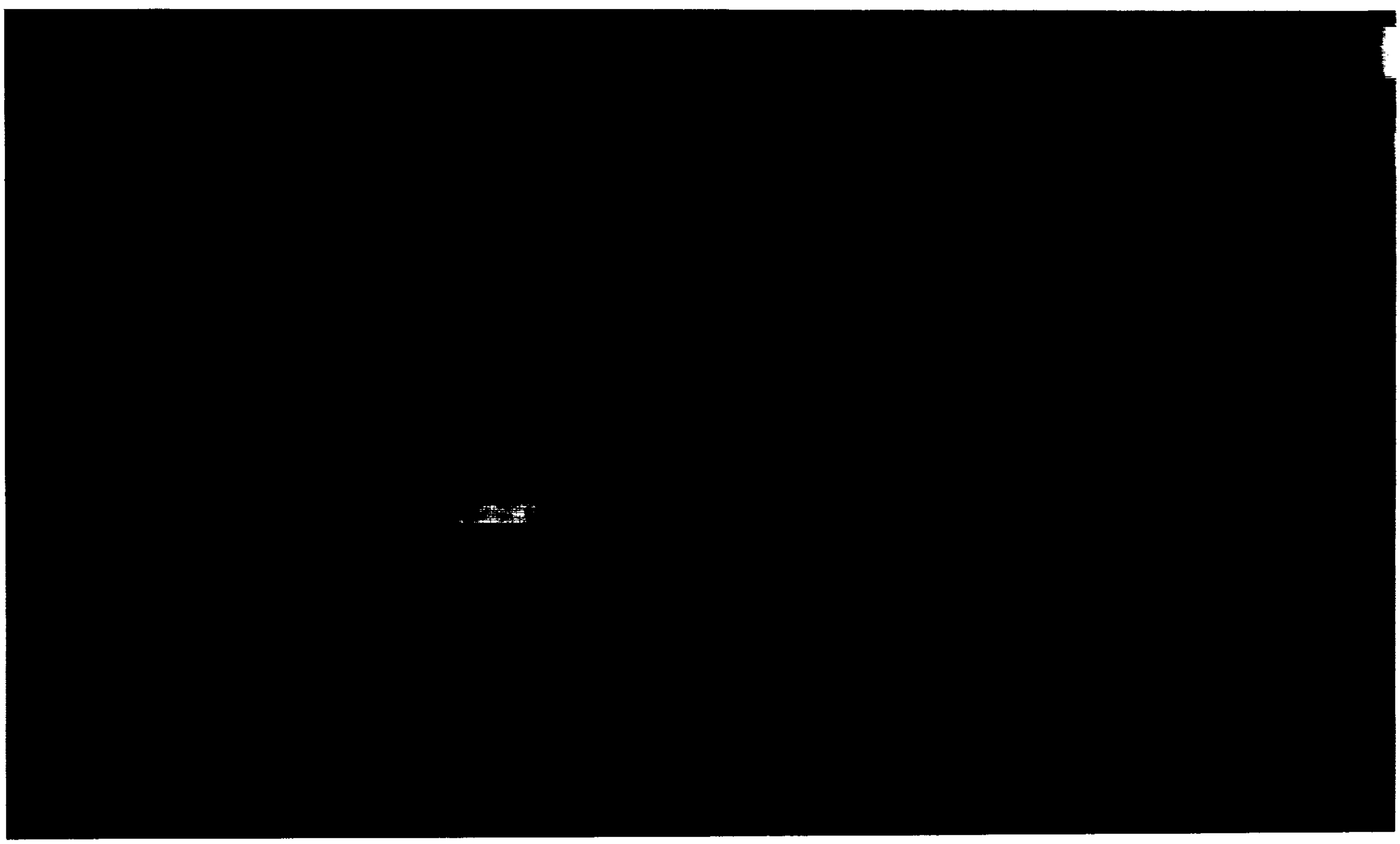

Photo 12 : HDP #2 EPON Shim Burning

Grease or EPON shim epoxy was visible burning on the HDP #2 shoe at T+8 seconds MET

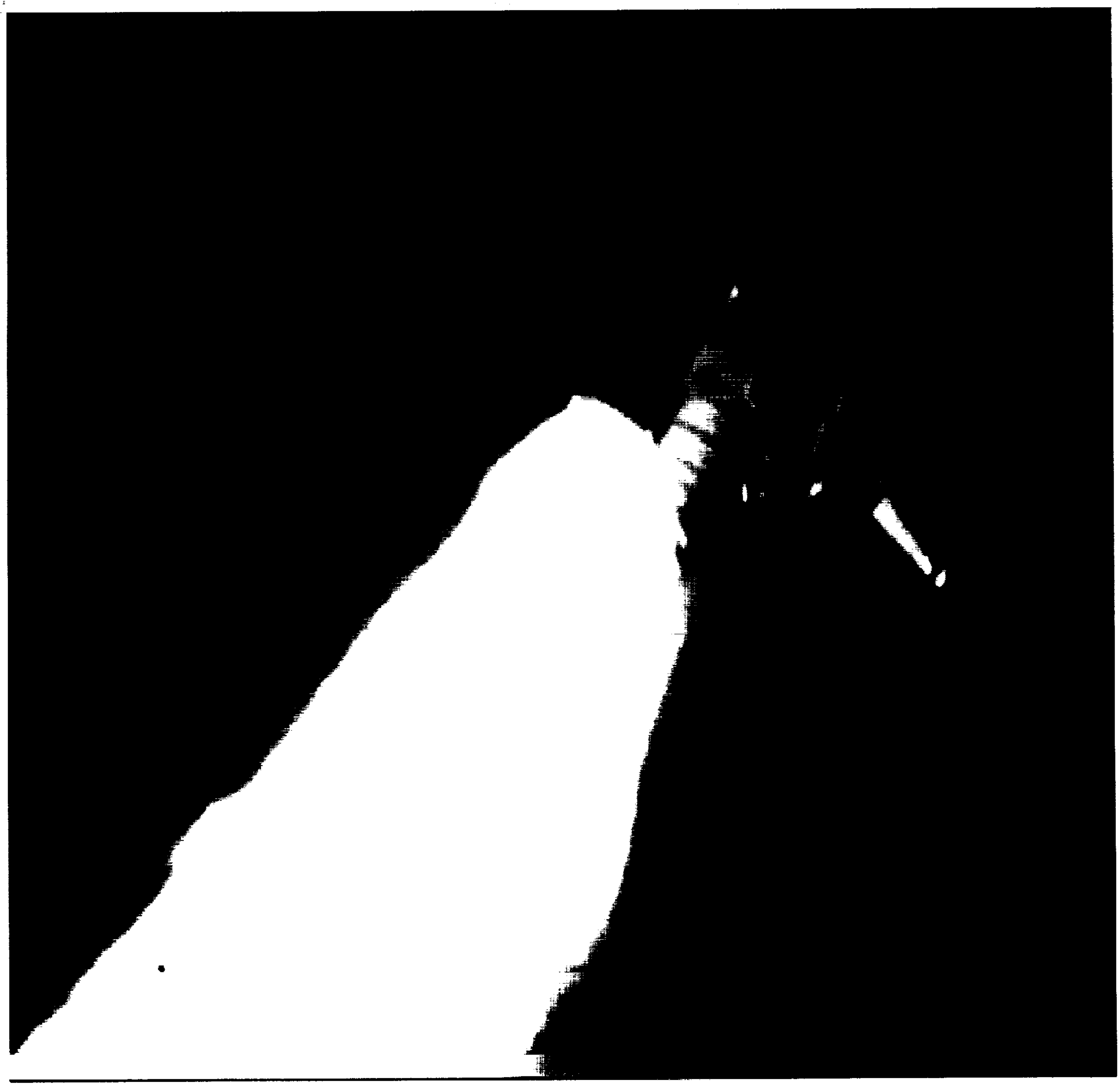

Photo 13 : Vapor Streak at T+43 Seconds MET

A white wispy streak of vapor streamed aft between Orbiter SSME #1 and the vertical stabilizer (right side) at T+43 seconds MET. The streak did not appear to be related to localized flow condensation and was most likely water/steam "flashing" from the water spray boilers.

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5.2 ON-ORBIT FILM AND VIDEO SUMMARY

DTO-312 was not performed by the flight crew due to RCS propellant usage limitations. OV-104 was not equipped to carry umbilical cameras

5.3 LANDING FILM AND VIDEO SUMMARY

Ten 35mm large format films and nine videos of landing were reviewed.

Orbiter performance on final approach appeared normal. Some "slipping and crabbing" was visible on final approach. There were no anomalies when the landing gear was extended. Touchdown of the left and right main gear was nominal and virtually simultaneous. The LH MLG tire touched down on the runway centerline. The Orbiter drifted a little further west before correction back to centerline. Contrails on the wing tips were typical.

The drag chute was deployed after breakover, but before the nose gear contacted the runway. Drag chute deployment appeared nominal. Two pieces of black material, which are made of Teflon cloth and used in packing of the chute to prevent abrasion, were visible falling to the runway during chute deployment.

Touchdown of the nose landing gear was smooth.

Rollout and wheel stop were uneventful. No large tile damage sites were visible on the Orbiter lower surface.

6.0 SRB POST FLIGHT/RETRIEVAL DEBRIS ASSESSMENT

The Solid Rocket Boosters were inspected for debris damage and debris sources at CCAFS Hangar AF on 7 February 1995. Both left and right Solid Rocket Boosters sustained extensive structural damage from water impact loads due to high seas. The LH Forward Assembly, LH nozzle, and one of the nozzle actuators were lost during towback to the port.

6.1 RH SOLID ROCKET BOOSTER DEBRIS INSPECTION

The RH frustum was missing no TPS but had 19 debonds over fasteners and 1 debond over acreage (Figure 4). Hypalon paint was blistered/missing where BTA closeouts had been applied along the 395 ring frame and around the BSM's. Some of the underlying BTA was sooted. The BSM aero heat shield covers had locked in the fully opened position though all four cover attach rings had been deformed by parachute riser entanglement.

The RH forward assembly had no debonds or missing TPS. Hypalon paint was blistered/missing over the areas where BTA had been applied. Structurally, the forward assembly was buckled in an area near the flight door. Cork closeout and 4 pins were missing from the forward assembly-to-forward segment joint at the 240 degree location. Twelve pins were missing from the frustum severance ring.

Three of the SRM segment cases exhibited buckling-type indentations caused by water impact loads. The systems tunnel cable tray and covers were also damaged. The Field Joint Protection System (FJPS) closeouts were generally in good condition. Trailing edge damage to the FJPS and the GEI cork runs were attributed to debris resulting from severance of the nozzle extension.

Separation of the aft ET/SRB struts appeared normal. The ET/SRB struts appeared to be undamaged. Damage to the ETA ring, IEA, and IEA covers was caused by water impact loads. The aft booster stiffener ring splice plate closeouts were intact and no K5NA material was missing.

The phenolic material on the kick ring exhibited minor delamination. Aft skirt acreage MSA-2 appeared to have been intact for the ascent phase of flight. Hypalon paint was blistered/missing over the areas where BTA had been applied. The HDP Debris Containment System (DCS) plungers were seated and appeared to have functioned properly.

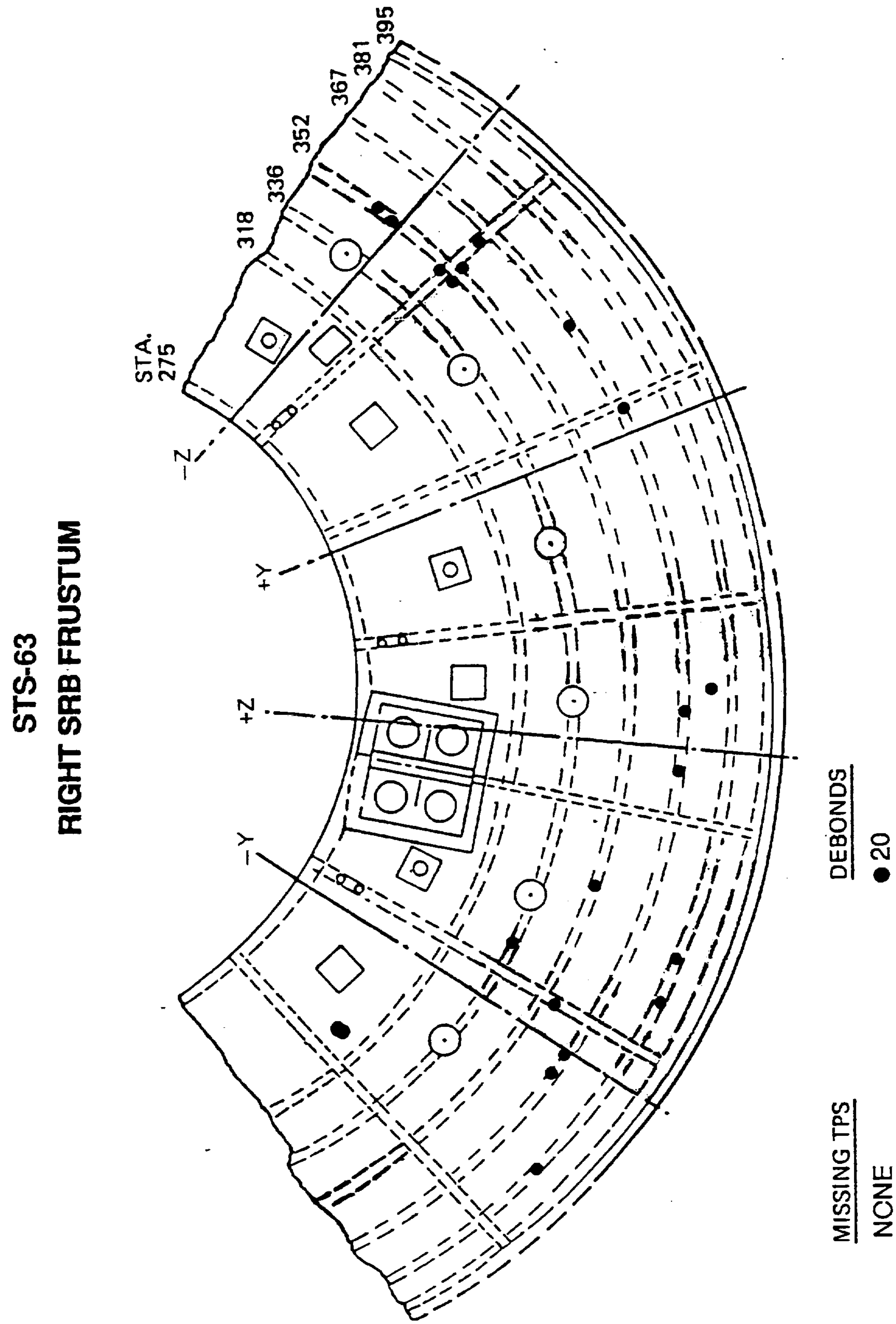

Figure 4 : RH SRB Frustum

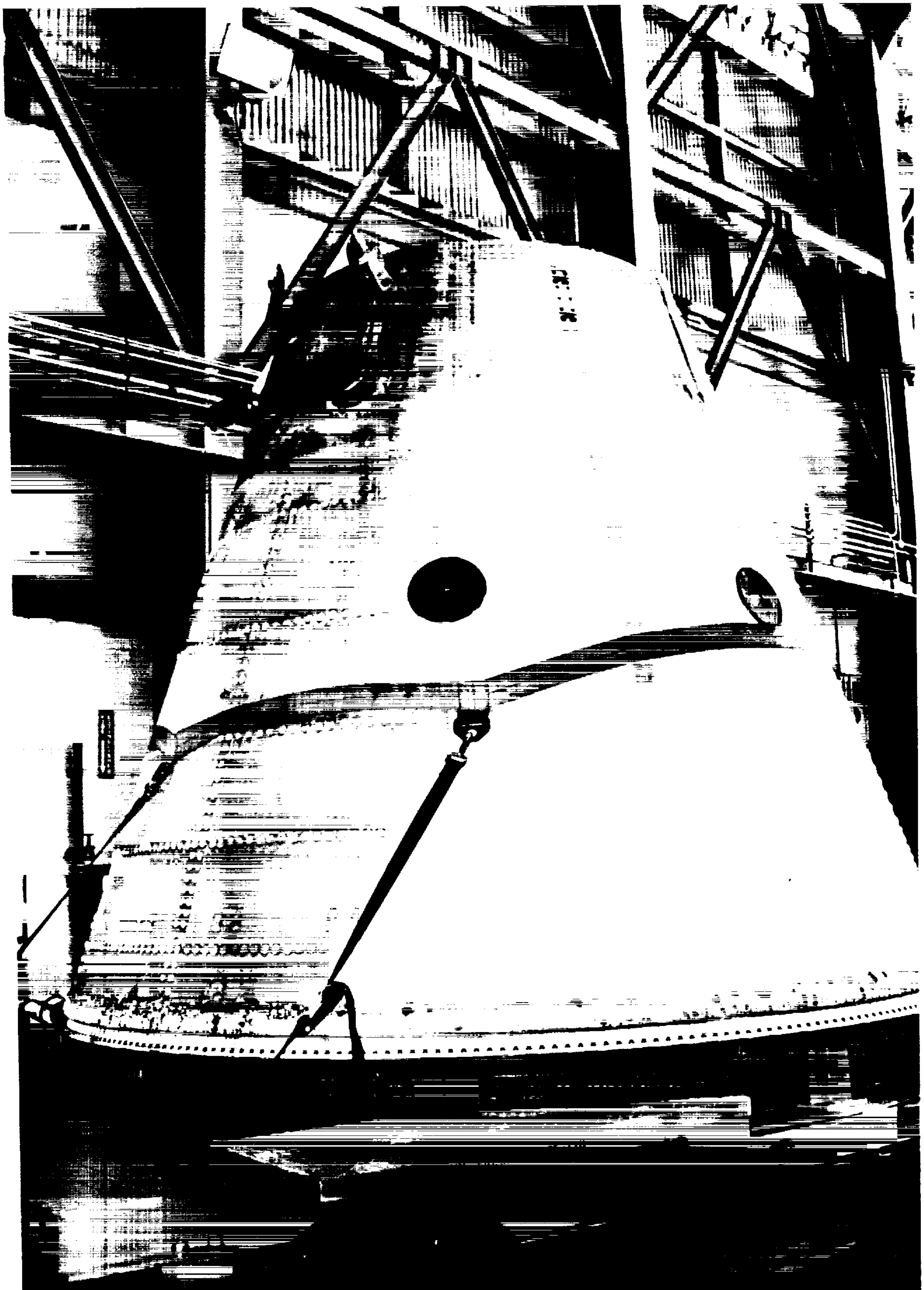

Photo 14 : RH Frustum

The RH frustum was missing no TPS but had 19 debonds over fasteners and 1 debond over acreage. Hypalon paint was blistered/missing where BTA closeouts had been applied along the 395 ring frame and around the BSM's.

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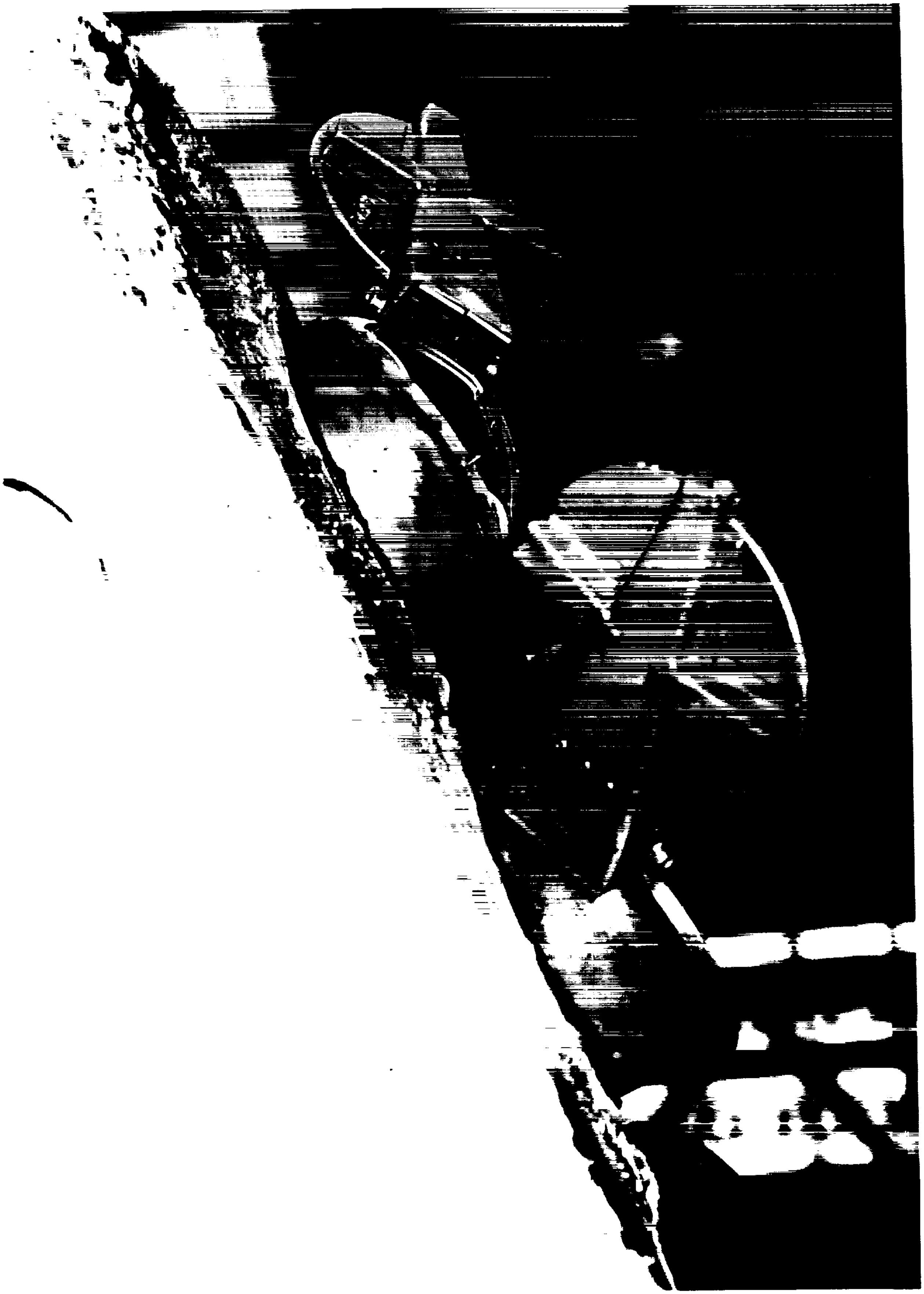

Photo 15 : BSM Aero Heat Shield Covers

The BSM aero heat shield covers had locked in the fully opened position though all four cover attach rings had been deformed by parachute riser entanglement.

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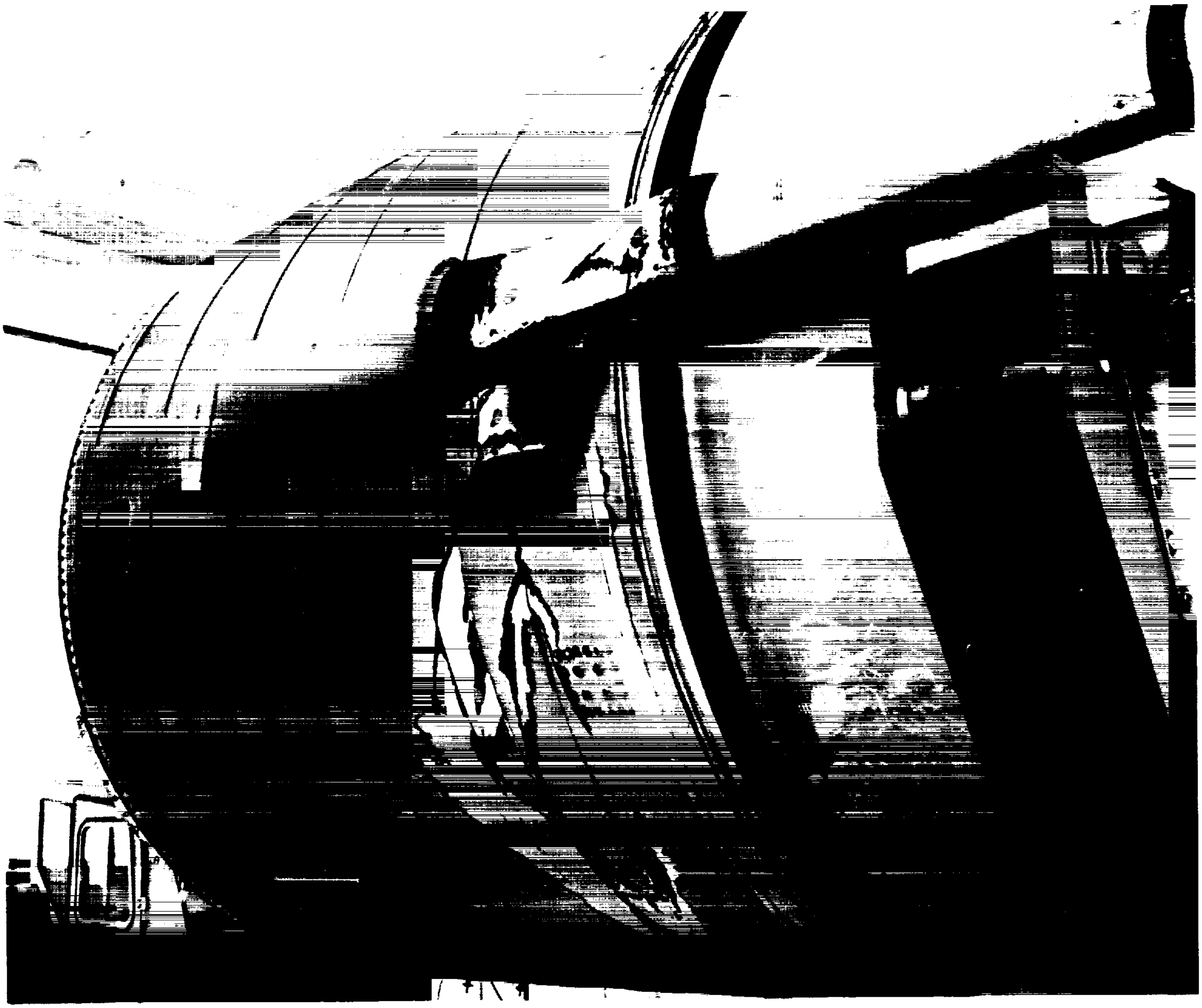

Photo 16 : RH Forward Assembly

The RH forward assembly had no debonds or missing TPS as a result of flight conditions. Hypalon paint was blistered/missing over the areas where BTA had been applied. Structurally, the forward assembly was buckled in an area near the flight door due to water slapdown loads. The systems tunnel was also damaged.

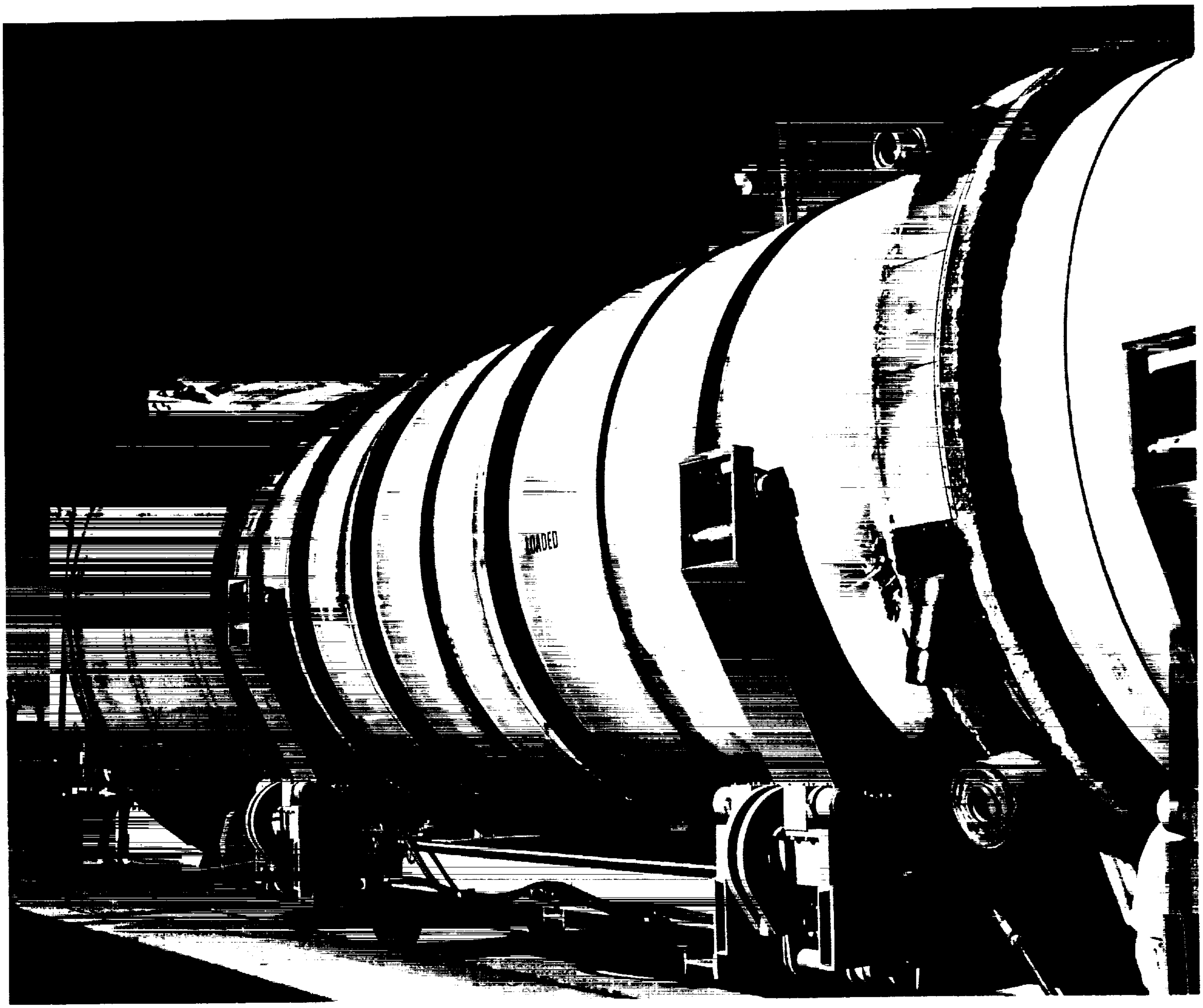

Photo 17 : RH Aft Booster/Aft Skirt

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Photo 18 : Condition of Aft Skirt Acreage TPS

6.2 LH SOLID ROCKET BOOSTER DEBRIS INSPECTION

The LH frustum was missing no TPS but had 34 MSA-2 debonds over fasteners (Figure 5). Hypalon paint was blistered/missing where BTA had been applied along the 395 ring frame and around the BSM's. Some of the underlying BTA was sooted. The BSM aero heat shield covers had locked in the fully opened position though two of the cover attach rings had been deformed by parachute riser entanglement.

The LH forward assembly was lost during towback.

Three of the SRM segment cases exhibited buckling-type indentations caused by water impact loads. The systems tunnel cable tray and covers were also damaged. The Field Joint Protection System (FJPS) closeouts were in good condition. In general, minor trailing edge damage to the FJPS and the GEI cork runs were attributed to debris resulting from severance of the nozzle extension.

Separation of the aft ET/SRB struts appeared normal. The ET/SRB aft struts, ETA ring, IEA, and IEA covers appeared undamaged. The stiffener ring splice plate closeouts were intact and no K5NA material was missing.

Three layers of phenolic material had delaminated on the kick ring - a typical occurrence. Aft skirt acreage TPS was generally in good condition. Hypalon paint was blistered over areas where BTA had been applied. The HDP Debris Containment System (DCS) plungers were not examined because GSE to secure the nozzle plug had been placed in the stud holes.

SRB Post Launch Anomalies are listed in Section 10.

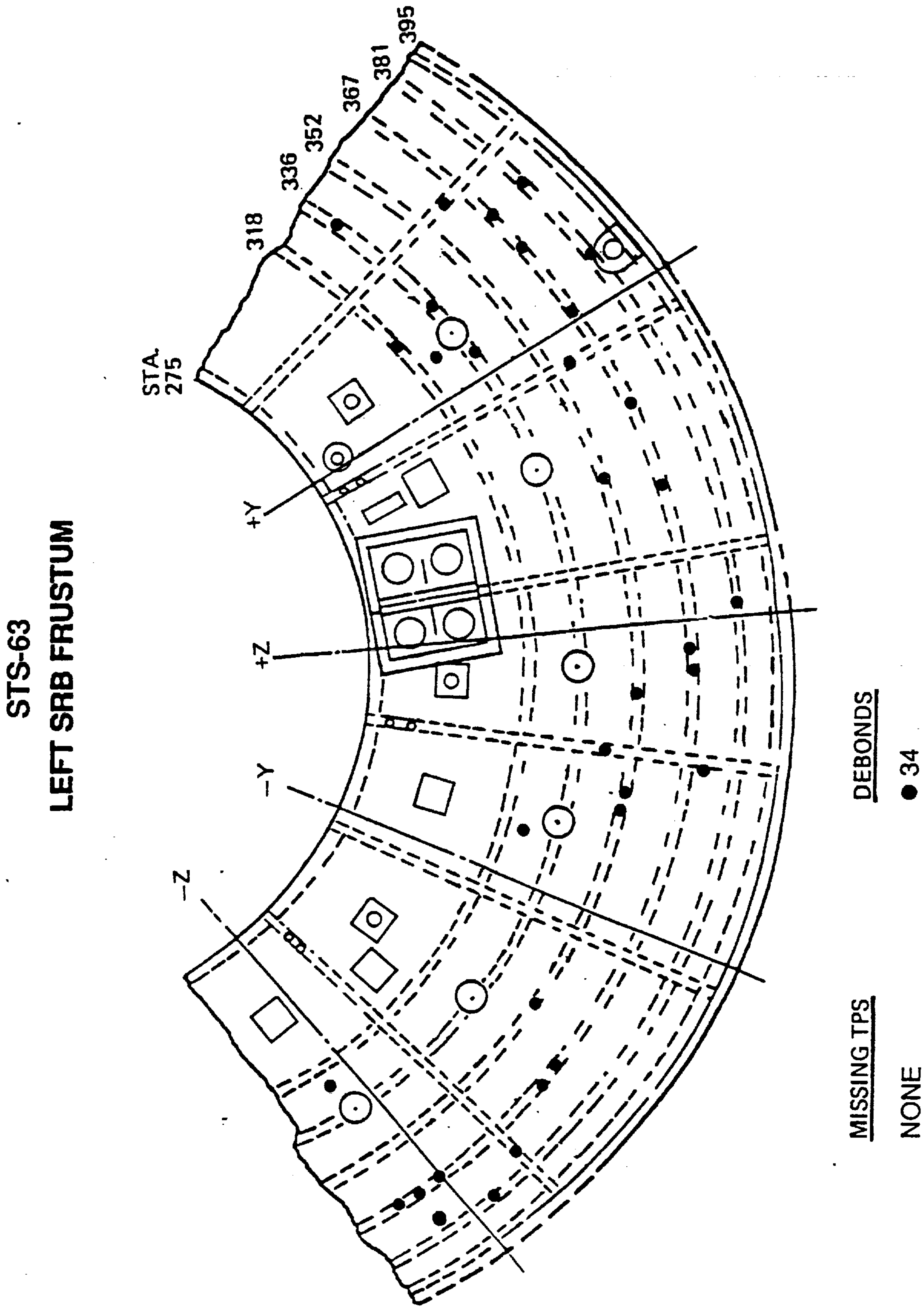

Figure 5 : LH SRB Frustum

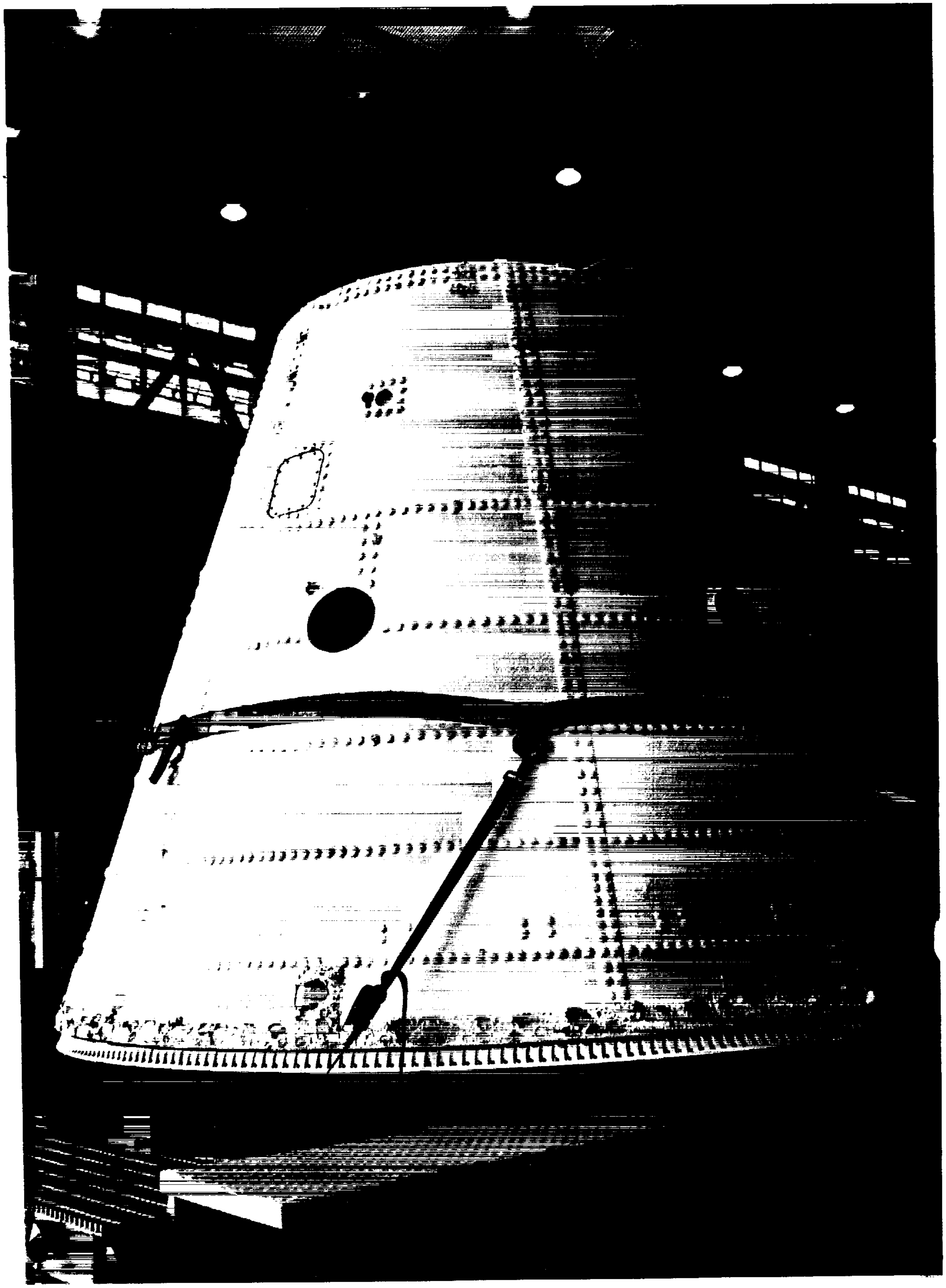

Photo 19 : LH Frustum

The LH frustum was missing no TPS but had 34 MSA-2 debonds over fasteners. Hypalon paint was blistered/missing where BTA had been applied along the 395 ring frame. Some of the underlying BTA was sooted.

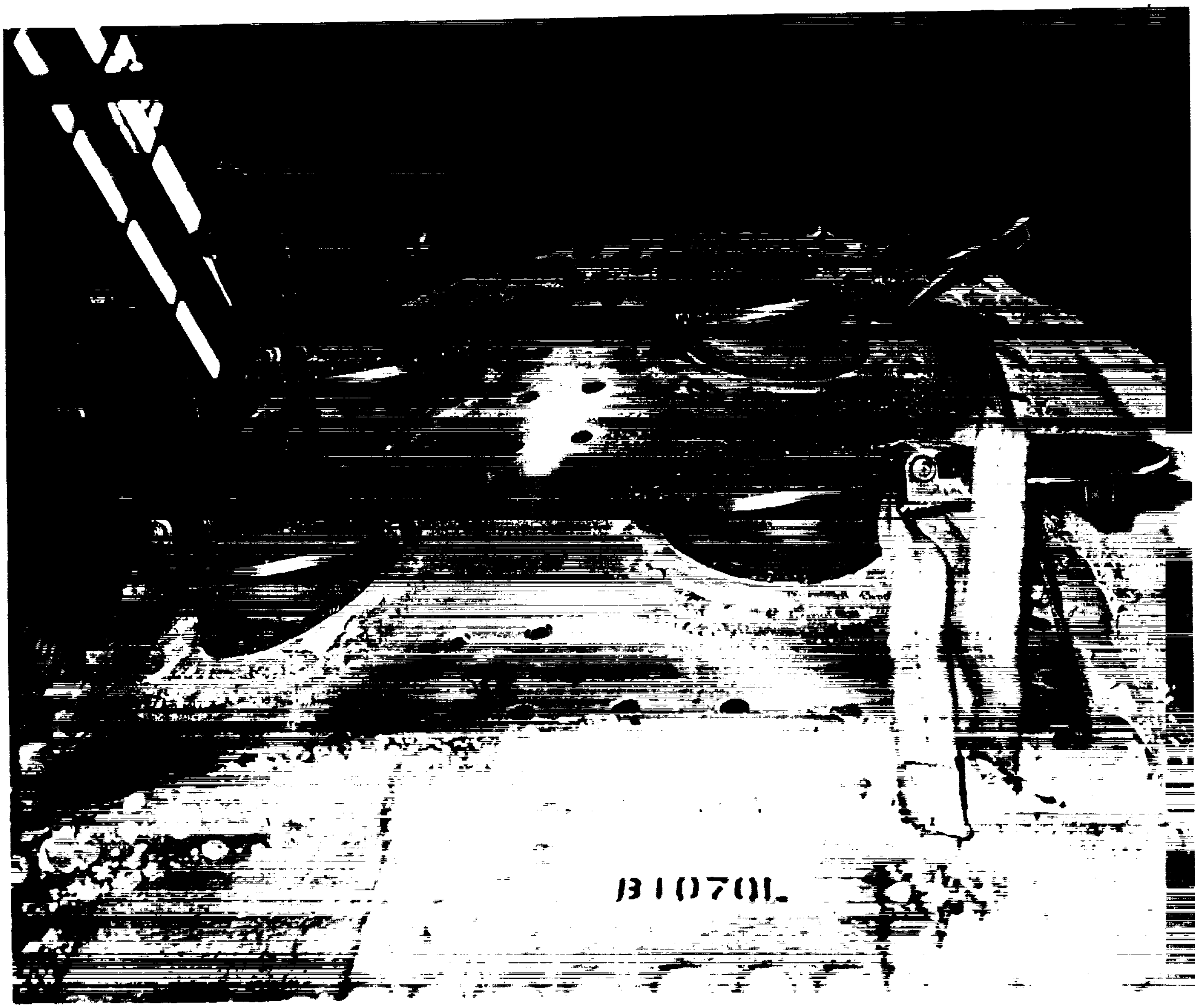

Photo 20 : BSM Aero Heat Shield Covers

The BSM aero heat shield covers had locked in the fully opened position though two of the cover attach rings had been deformed by parachute riser entanglement

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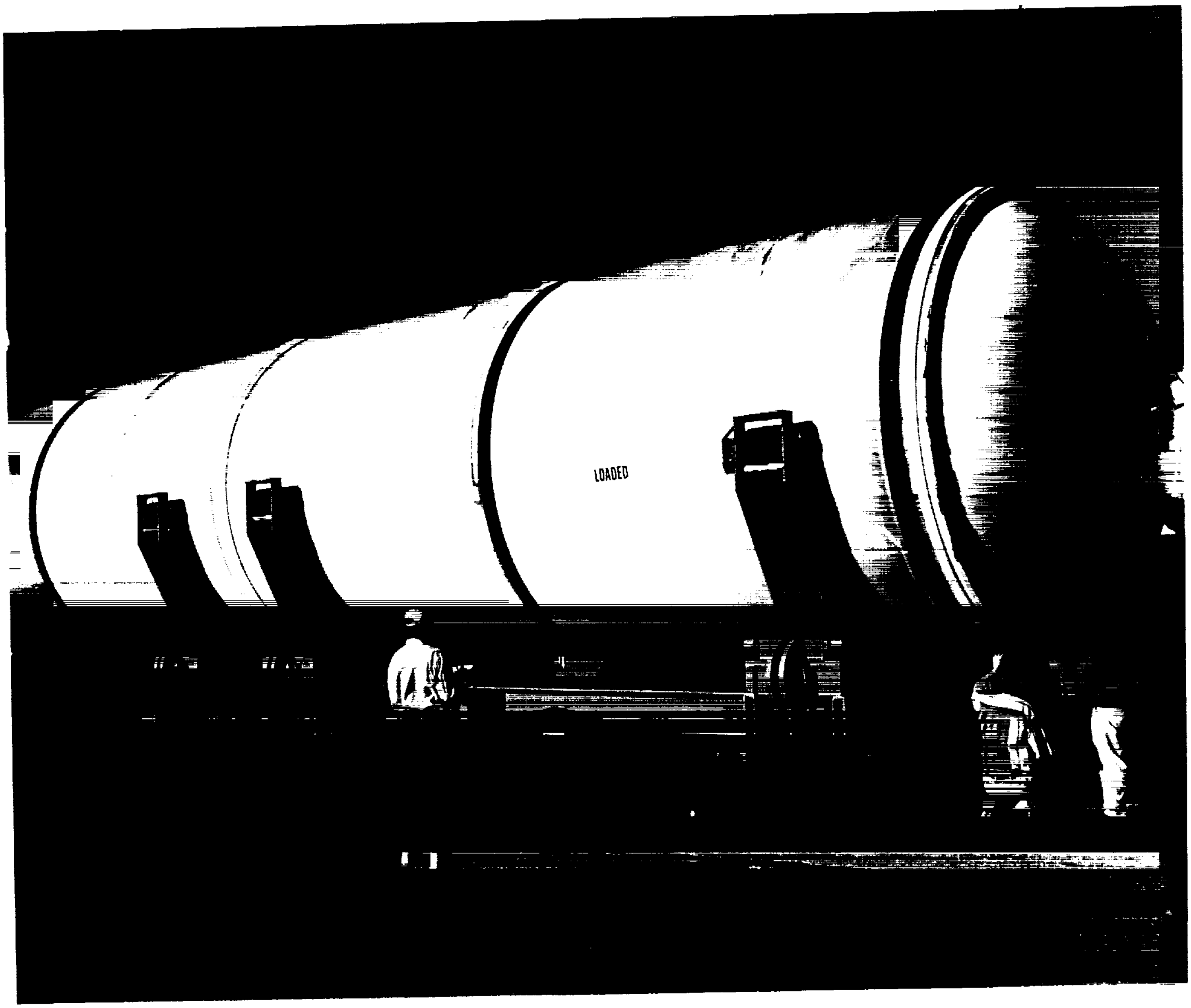

Photo 21 : LH Forward Assembly Lost During Towback

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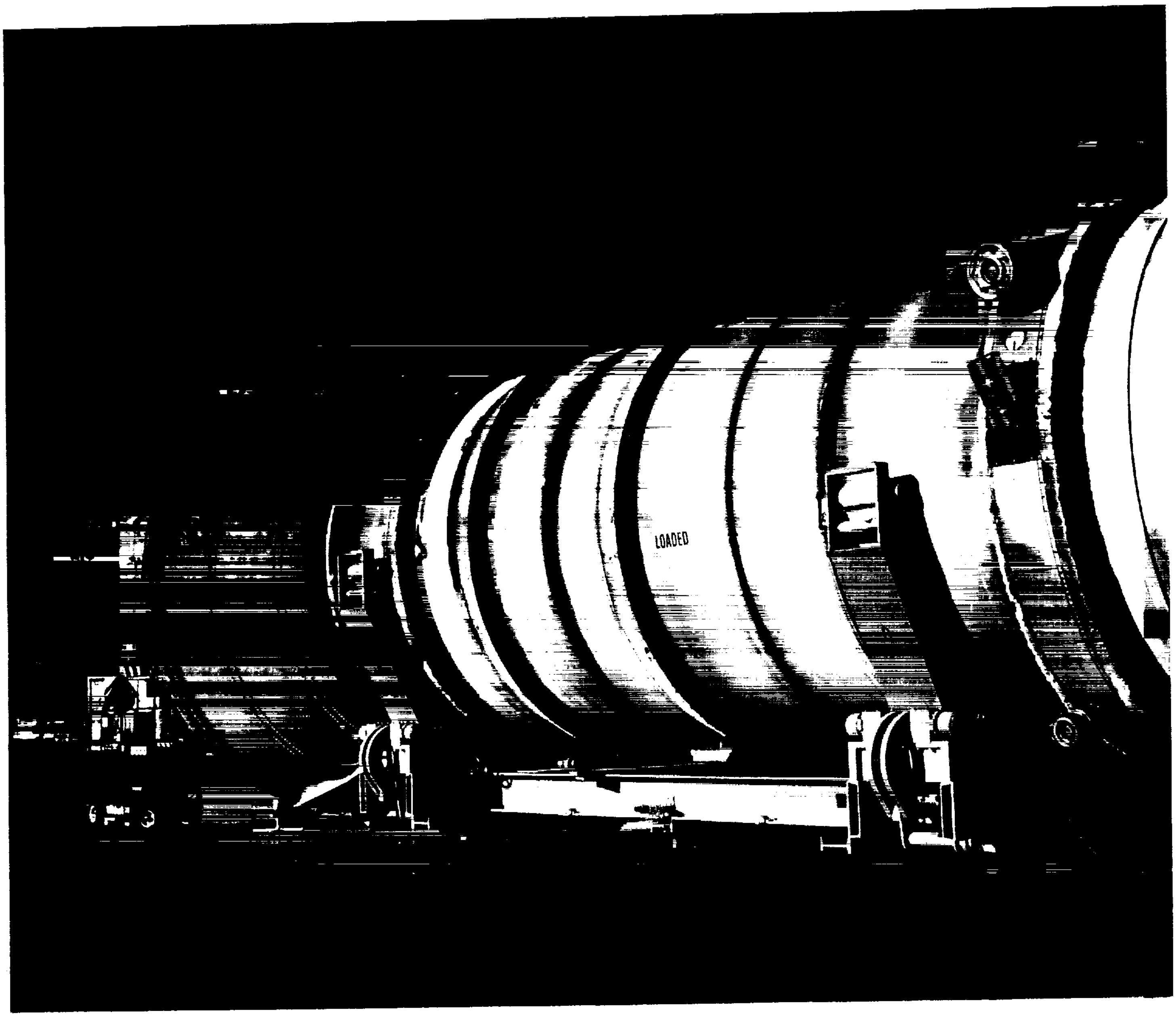

Photo 22 : LH Aft Booster/ Aft Skirt

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Photo 23 : Condition of Aft Skirt Acreage TPS

7.0 ORBITER POST LANDING DEBRIS ASSESSMENT

A post landing debris inspection of OV-103 (Discovery) was conducted 11-12 February 1995 at the Kennedy Space Center on Shuttle Landing Facility (SLF) runway 15 and in the Orbiter Processing Facility bay #2. This inspection was performed to identify debris impact damage and, if possible, debris sources. The Orbiter TPS sustained a total of 125 hits, of which 14 had a major dimension of 1-inch or larger. This total does not include the numerous hits on the base heat shield attributed to SSME vibration/acoustics and exhaust plume recirculation. A comparison of these numbers to statistics from 51 previous missions of similar configuration (excluding missions STS-23, 25, 26, 26R, 27R, 30R, and 42, which had damage from known debris sources), indicates the total number of hits was average while the number of hits 1-inch or larger was less than average (Figures 6-9).

The following table breaks down the STS-63 Orbiter debris damage by area:

	HITS > 1"	TOTAL HITS
Lower surface	7	84
Upper surface	4	22
Right side	0	3
Left side	0	3
Right OMS Pod	0	3
Left OMS Pod	3	10
TOTALS	14	125

The Orbiter lower surface sustained a total of 84 hits, of which 7 had a major dimension of 1-inch or larger.

The largest tile damage site measured 5.5-inches by 1.5-inches by 0.75 inches deep and was located on the lower surface outboard of the LH2 ET/ORB umbilical directly aft of the LH MLG. The damage site was clean and did not exhibit the typical signs of re-entry heating. RTV was missing from the main landing gear tire pressure transducer wiring harness. No RTV was found on the runway. The RTV most likely came off during gear deployment and caused the damage prior to touchdown. An EO will eliminate excessive RTV on the wiring harness. No other TPS damage was attributed to material from the wheels, tires, or brakes. The tires were in good condition after a landing on the KSC runway.

No ice adhered to the payload bay door and the waste water dump nozzles appeared normal. No unusual tile damage was visible on the leading edges of the OMS pods and vertical stabilizer.

The number of hits aft of the LH2 and LO2 ET/ORB umbilicals, which are believed to be impacts from umbilical ice, were less than usual.

No tile damage from micrometeorites or on-orbit debris have been identified to date.

An 8-inch dark streak was visible on the left wing RCC panel #6. A 10-inch white streak appeared on the right wing RCC panel #5.

ET/Orbiter separation devices EO-1, EO-2, and EO-3 functioned properly and the debris plungers were seated. All ET/Orbiter umbilical separation ordnance retention shutters were closed. No significant amounts of foam or red purge seal adhered to the LH2 ET/ORB umbilical near the 4-inch flapper valve. No debris was found on the runway beneath the ET/ORB umbilical cavities.

Orbiter window #4 exhibited moderate-to-heavy hazing. Windows #3 and #5 exhibited light-to-moderate hazing. Only a very light haze was present on the other windows. Surface wipes will be taken from all windows for laboratory analysis. Tile damage on the window perimeter tiles was typical. A tile damage site, 5 inches long by 0.4 inches wide, was located in the area between windows #4/5 and #7/8. Although the tile material appeared to have been depressed to a depth of approximately 0.1 inch, none of the tile surface coating material was missing.

Tile damage on the base heat shield was typical with the exception of a damage site that involved three tiles between SSME #2/3 and the body flap hinge. This tile damage site, which measured approximately 10 inches long by 1 inch wide by 0.25 inch deep, had been observed in the launch film review (film item E-6) prior to T-0. The damage occurred sometime during SSME start-up. Tiles on the vertical stabilizer "stinger" and around the drag chute door were intact and undamaged. The Dome Mounted Heat Shield (DMHS) closeout blankets were frayed/ripped on SSME #1 at the 6 o'clock position and torn on SSME #2 at the 3 o'clock position.

There were no unusual surface cracks on vertical stabilizer tiles.

Runway 15 had been swept/inspected by SLF operations personnel prior to landing and all potentially damaging debris was removed.

The post landing walkdown of Runway 15 was performed immediately after landing. No flight hardware was found on the runway. All Orbiter drag chute hardware, including two dark pieces of packing cloth to prevent chute abrasion, was recovered. No organic (bird) debris was found on the runway.

In summary, the total number of Orbiter TPS debris hits was average while the number of hits 1-inch or larger was less than average when compared to previous missions (Figures 10-11). The type of TPS damage was typical and not attributable to any single debris source.

Orbiter Post Launch Debris Anomalies are listed in Section 10.

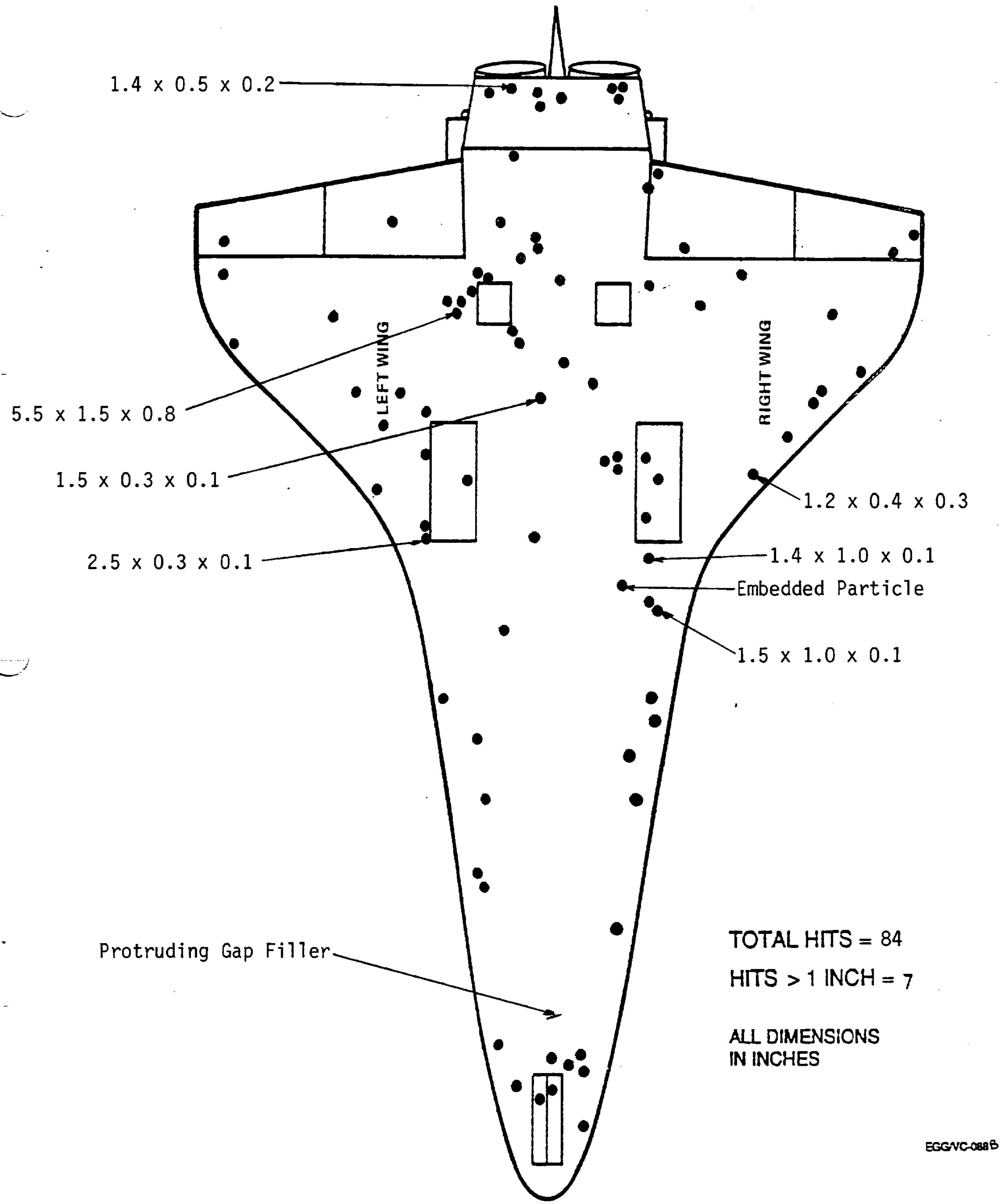

Figure 6 : Orbiter Lower Surface Debris Map

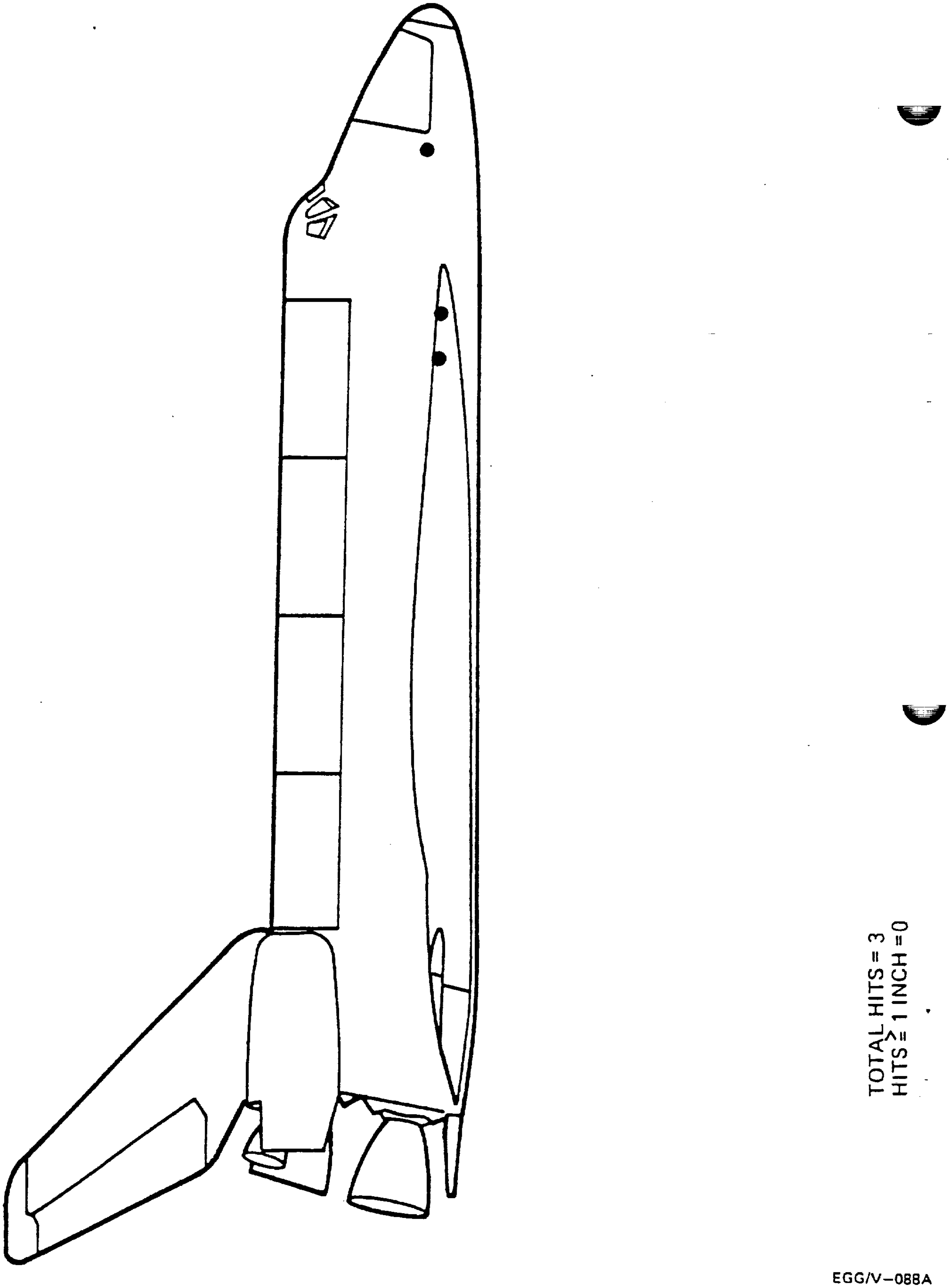

Figure 7 : Orbiter Right Side Debris Map

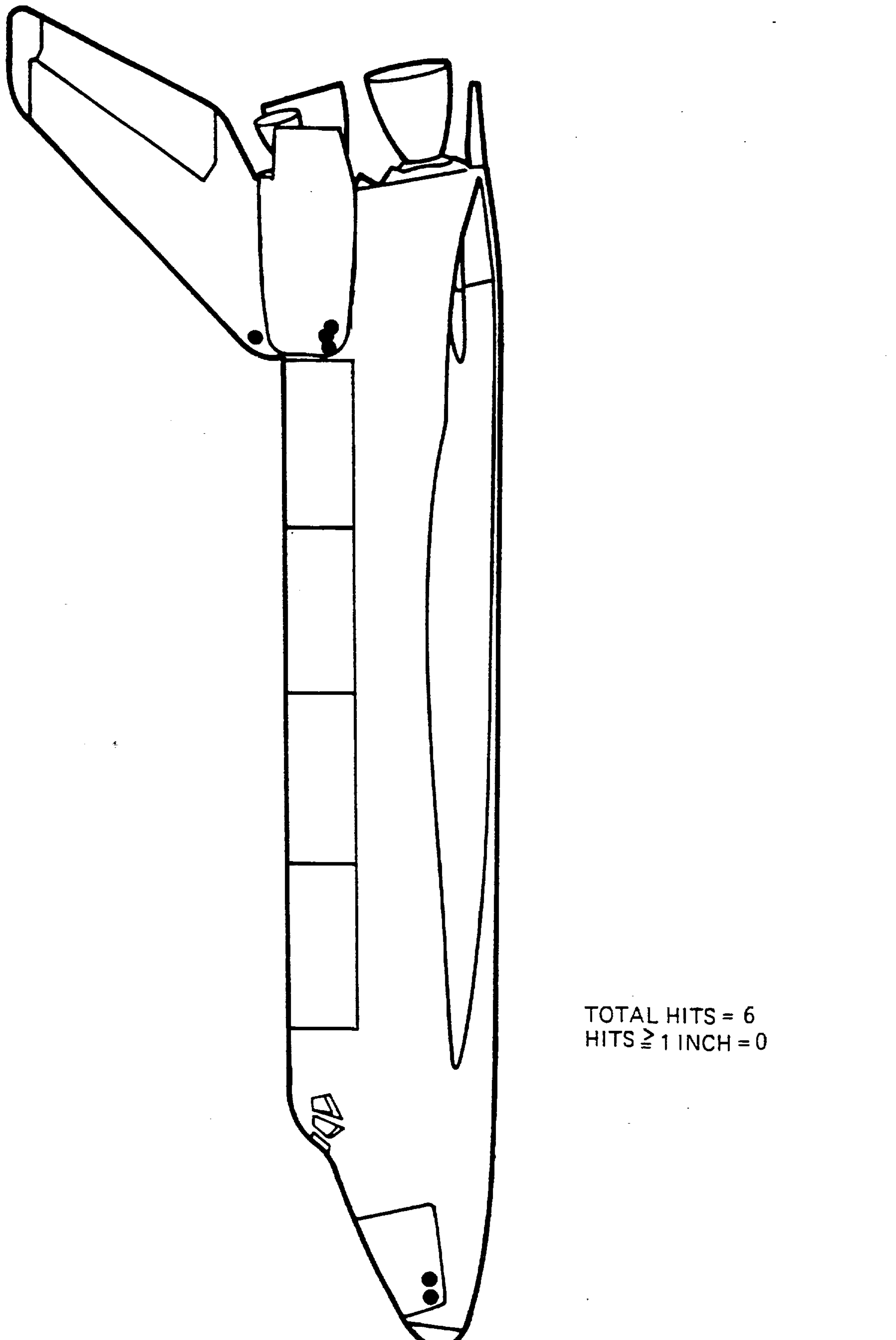

Figure 8 : Orbiter Left Side Debris Map

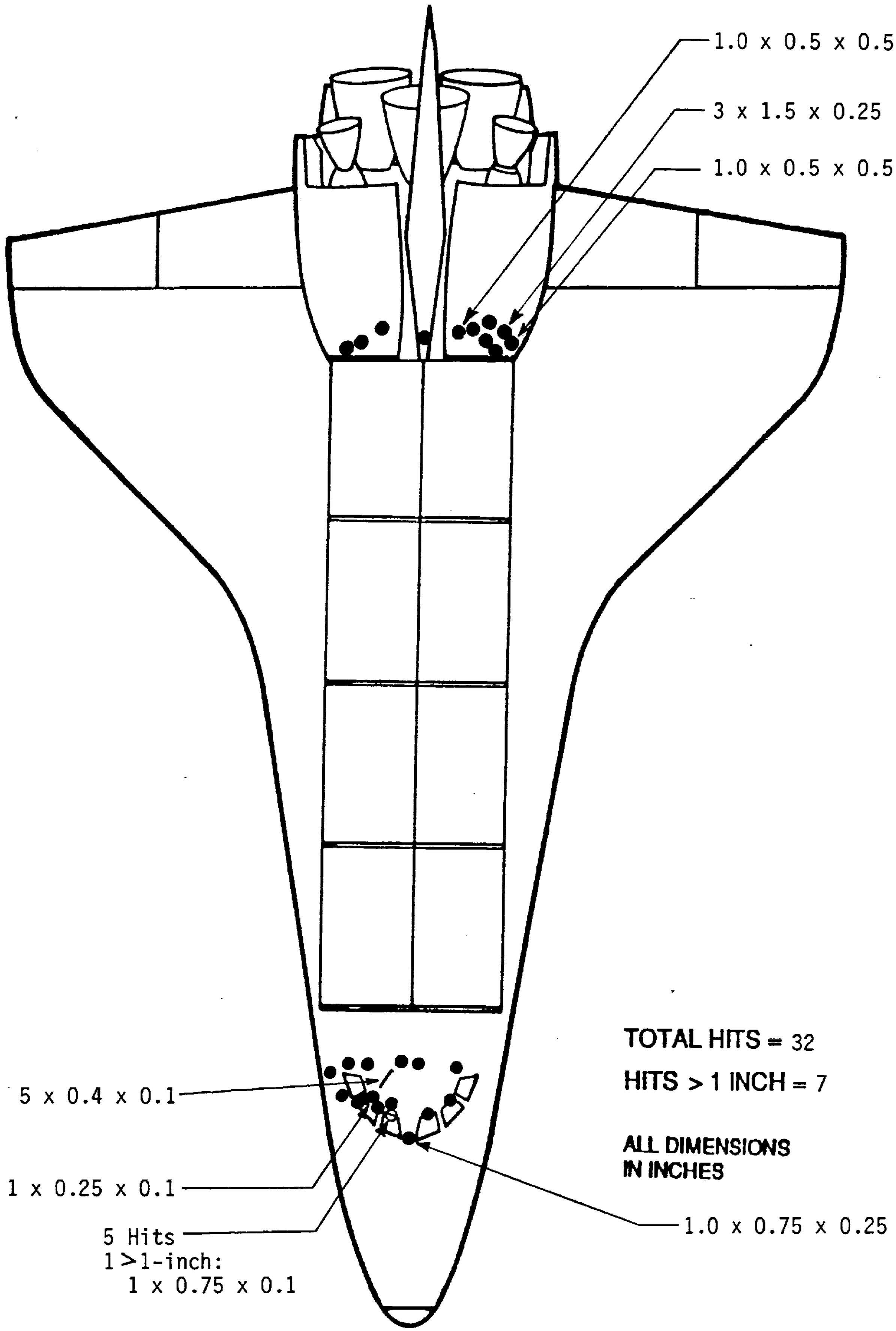

Figure 9 : Orbiter Upper Surface Debris Map

	LOWER SURFACE		ENTIRE VEHICLE	
	HITS > 1 INCH	TOTAL HITS	HITS > 1 INCH	TOTAL HITS
STS-6	15	80	36	120
STS-8	3	29	7	56
STS-9 (41-A)	9	49	14	58
STS-11 (41-B)	11	19	34	63
STS-13 (41-C)	5	27	8	36
STS-14 (41-D)	10	44	30	111
STS-17 (41-G)	25	69	36	154
STS-19 (51-A)	14	66	20	87
STS-20 (51-C)	24	67	28	81
STS-27 (51-I)	21	96	33	141
STS-28 (51-J)	7	66	17	111
STS-30 (61-A)	24	129	34	183
STS-31 (61-B)	37	177	55	257
STS-32 (61-C)	20	134	39	193
STS-29	18	100	23	132
STS-28R	13	60	20	76
STS-34	17	51	18	53
STS-33R	21	107	21	118
STS-32R	13	111	15	120
STS-36	17	61	19	81
STS-31R	13	47	14	63
STS-41	13	64	16	76
STS-38	7	70	8	81
STS-35	15	132	17	147
STS-37	7	91	10	113
STS-39	14	217	16	238
STS-40	23	153	25	197
STS-43	24	122	25	131
STS-48	14	100	25	182
STS-44	6	74	9	101
STS-45	18	122	22	172
STS-49	6	55	11	114
STS-50	28	141	45	184
STS-46	11	186	22	236
STS-47	3	48	11	108
STS-52	6	152	16	290
STS-53	11	145	23	240
STS-54	14	80	14	131
STS-56	18	94	36	156
STS-55	10	128	13	143
STS-57	10	75	12	106
STS-51	8	100	18	154
STS-58	23	78	26	155
STS-61	7	59	13	120
STS-60	4	48	15	106
STS-62	7	36	16	97
STS-59	10	47	19	77
STS-65	17	123	21	151
STS-64	18	116	19	150
STS-68	9	59	15	110
STS-66	22	111	28	148
AVERAGE	14.1	90.5	21.3	131.5
SIGMA	7.2	43.3	10.0	55.5
STS-63	7	84	14	125

MISSIONS STS-23, 24, 25, 26, 26R, 27R, 30R, AND 42 ARE NOT INCLUDED IN THIS ANALYSI SINCE THESE MISSIONS HAD SIGNIFICANT DAMAGE CAUSED BY KNOWN DEBRIS SOURC

Figure 10 : Orbiter Post Flight Debris Damage Summary

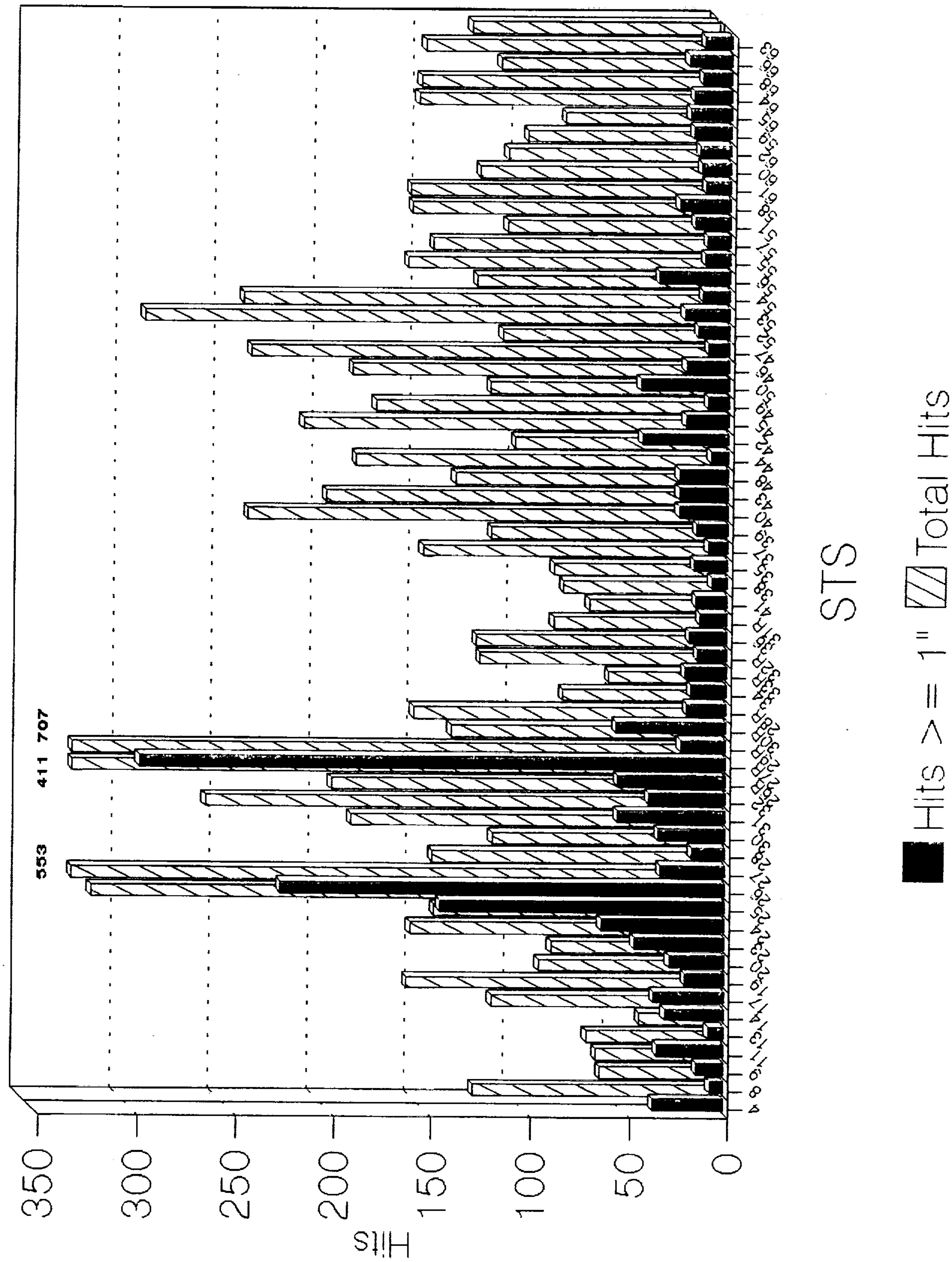

Figure 11 : Orbiter Debris Damage Comparison Chart

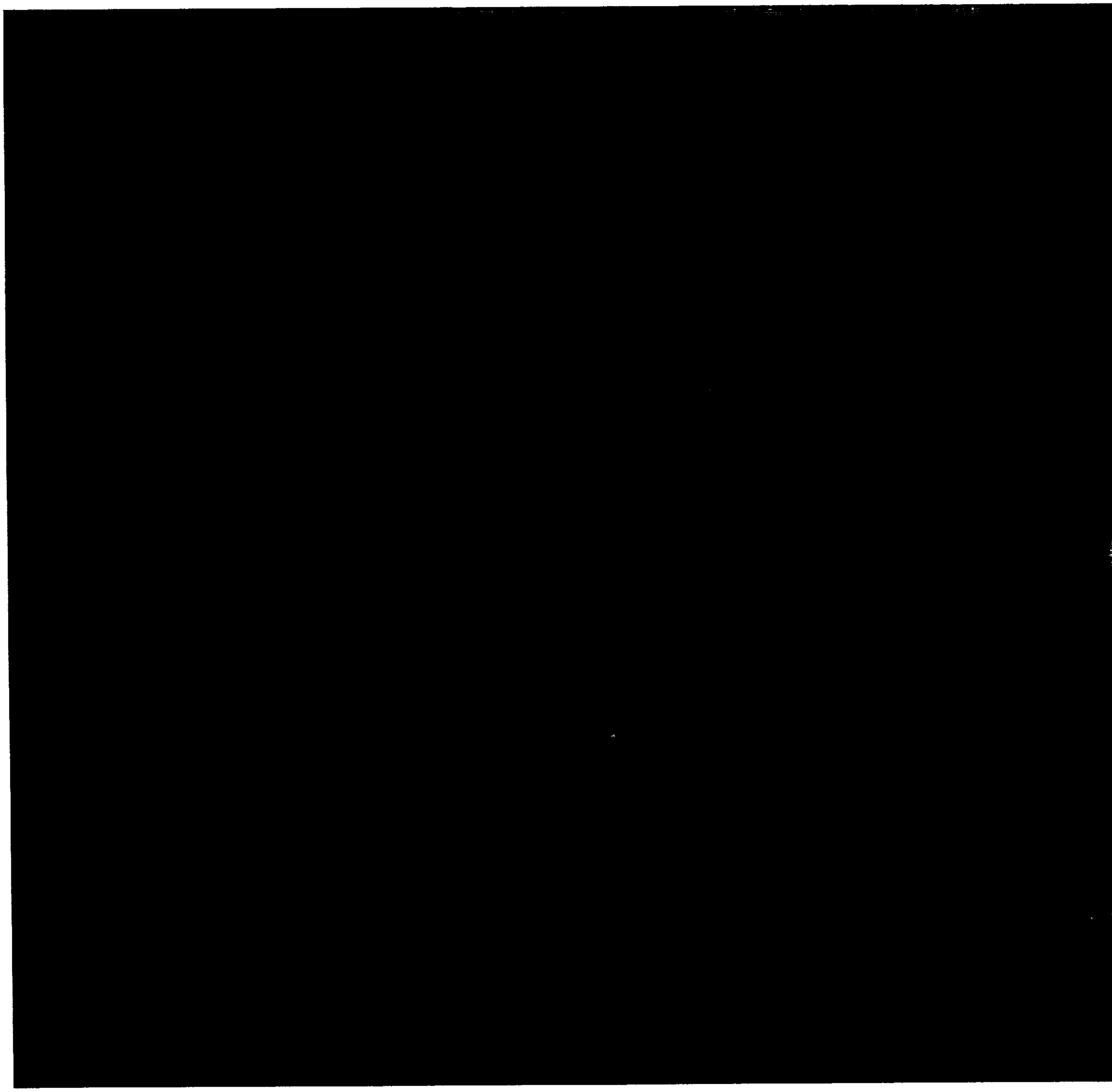

Photo 24 : OV-103 Landing on KSC Runway 15

Centerline camera shows wings-level touchdown just west of runway centerline

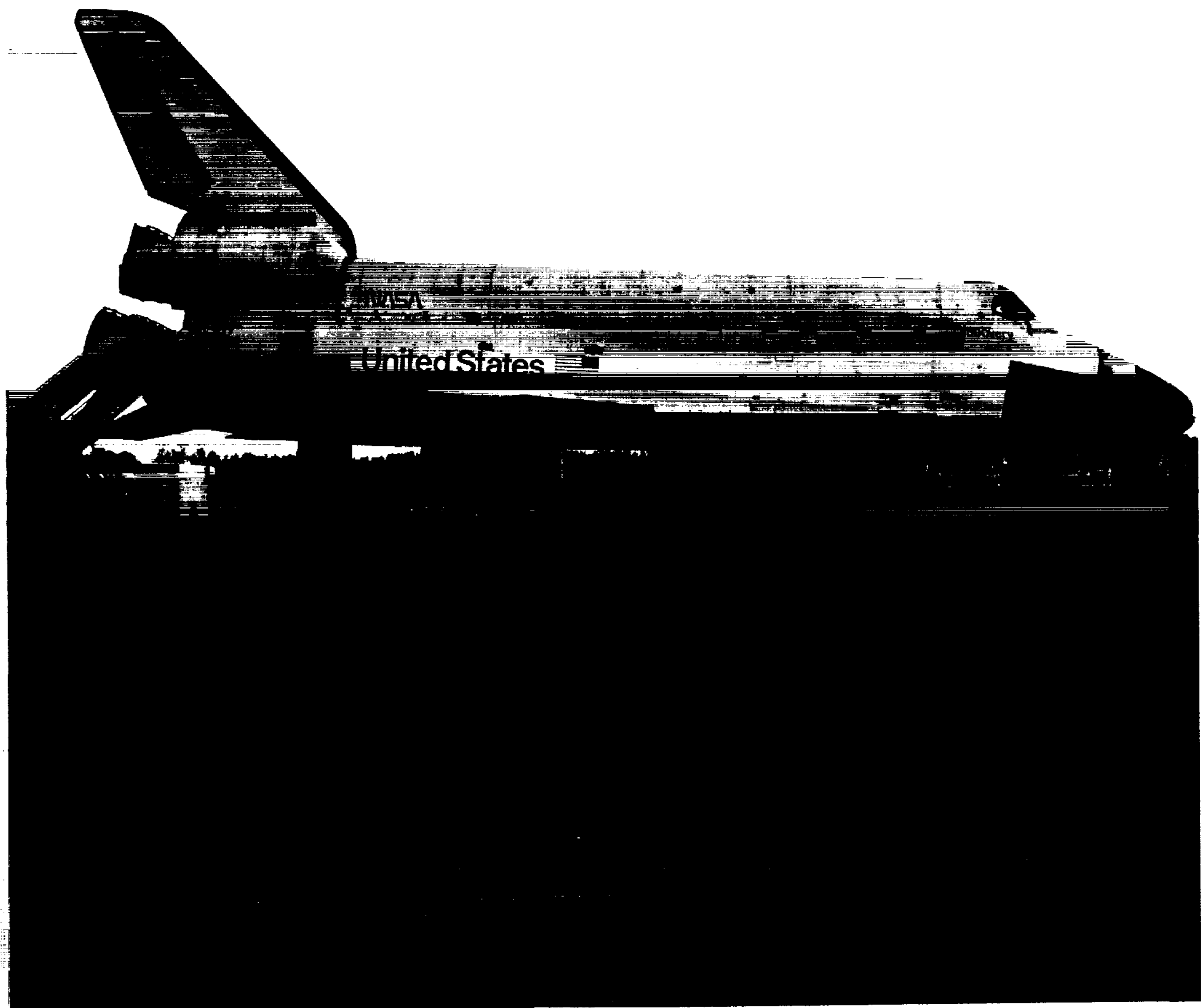

Photo 25 : Overall View of Orbiter Right Side

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Photo 26 : Overall View of Orbiter Left Side

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Photo 27 : Lower Surface Tile Damage

The largest tile damage site measured 5.5-inches by 1.5-inches by 0.75 inches deep and was located on the lower surface outboard of the LH2 ET/ORB umbilical directly aft of the LH MLG.

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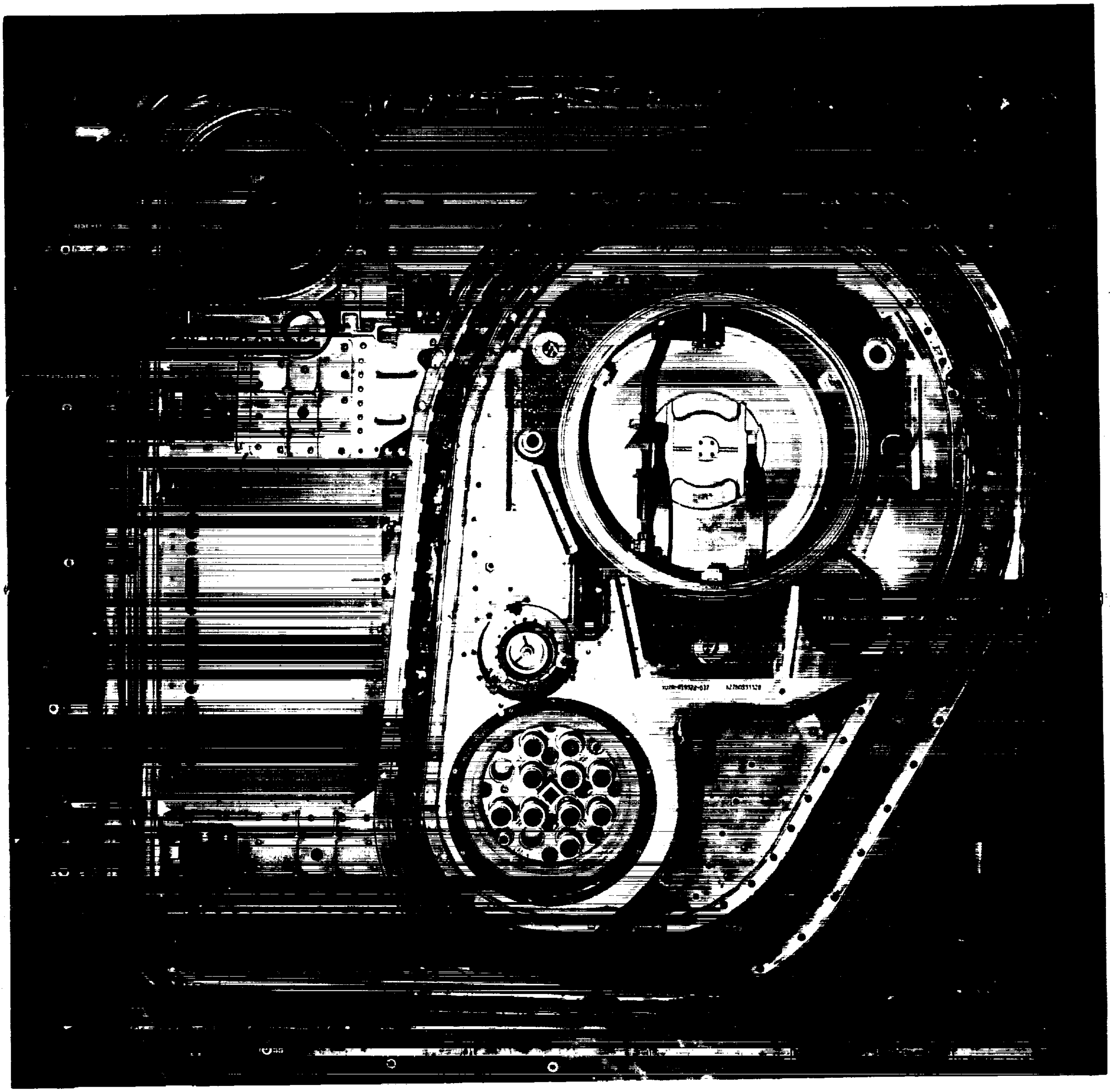

Photo 28 : LO2 ET/ORB Umbilical

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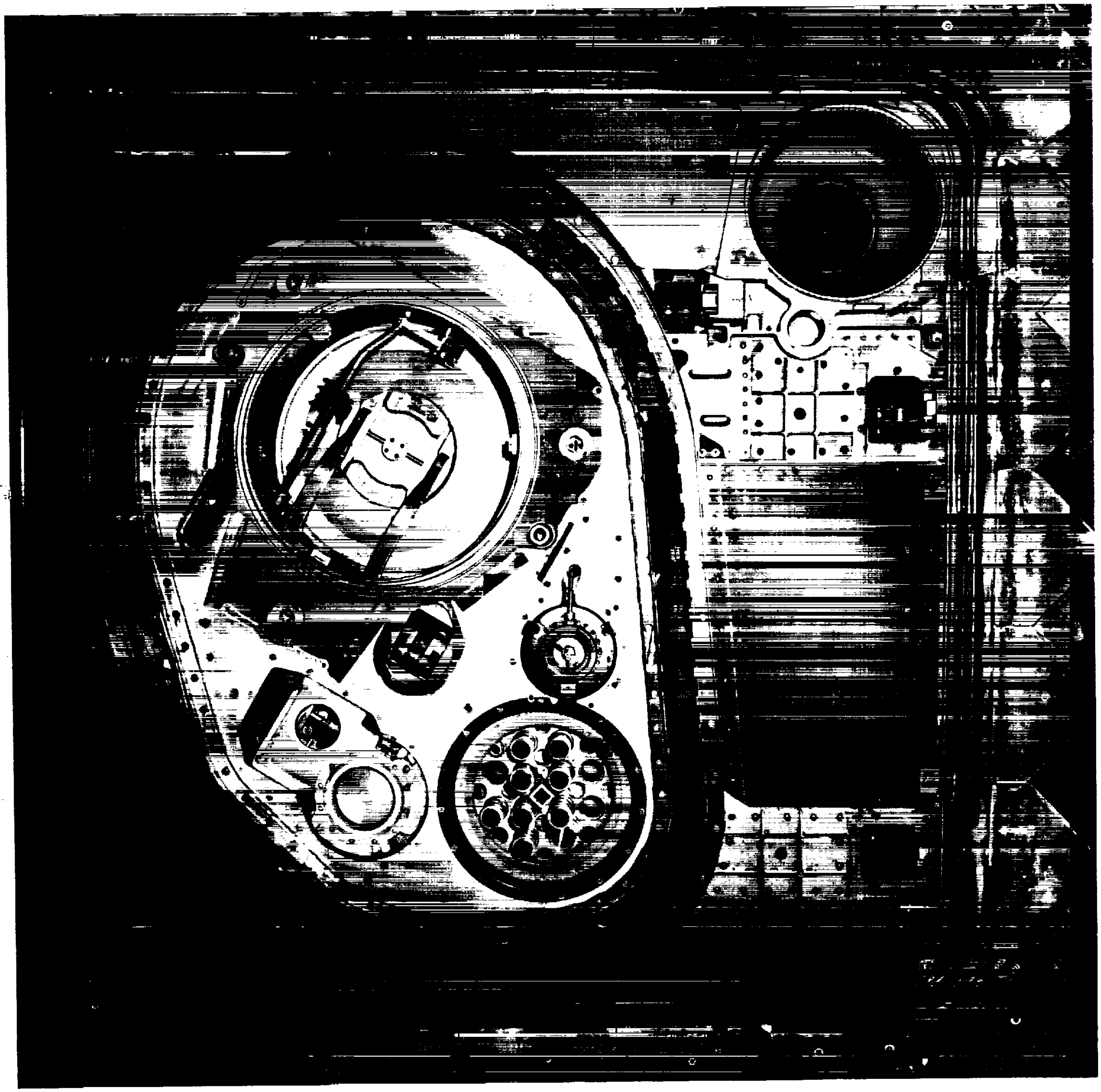

Photo 29 : LH2 ET/ORB Umbilical

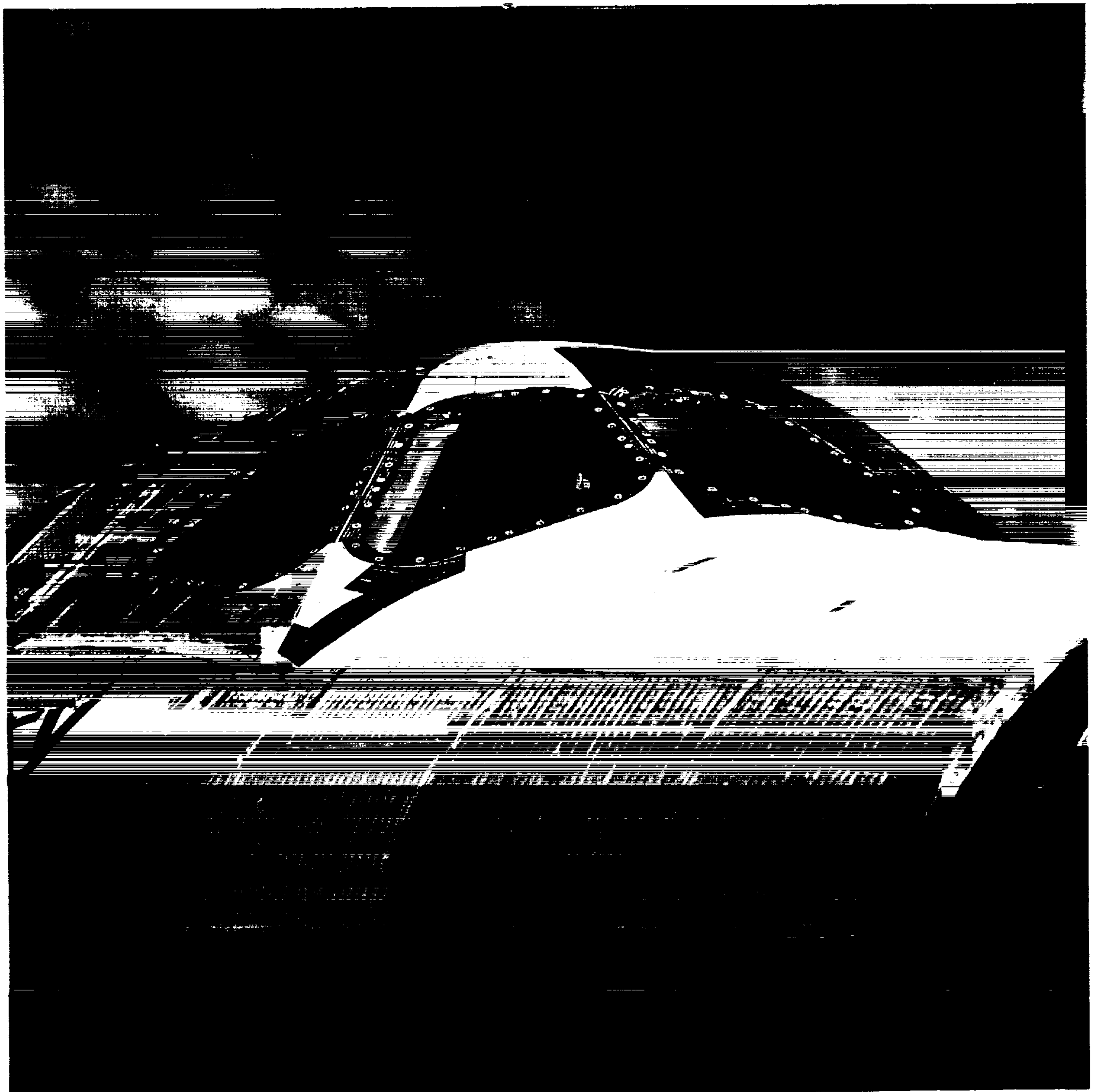

Photo 30 : Orbiter Windows

Orbiter window #4 exhibited moderate-to-heavy hazing.

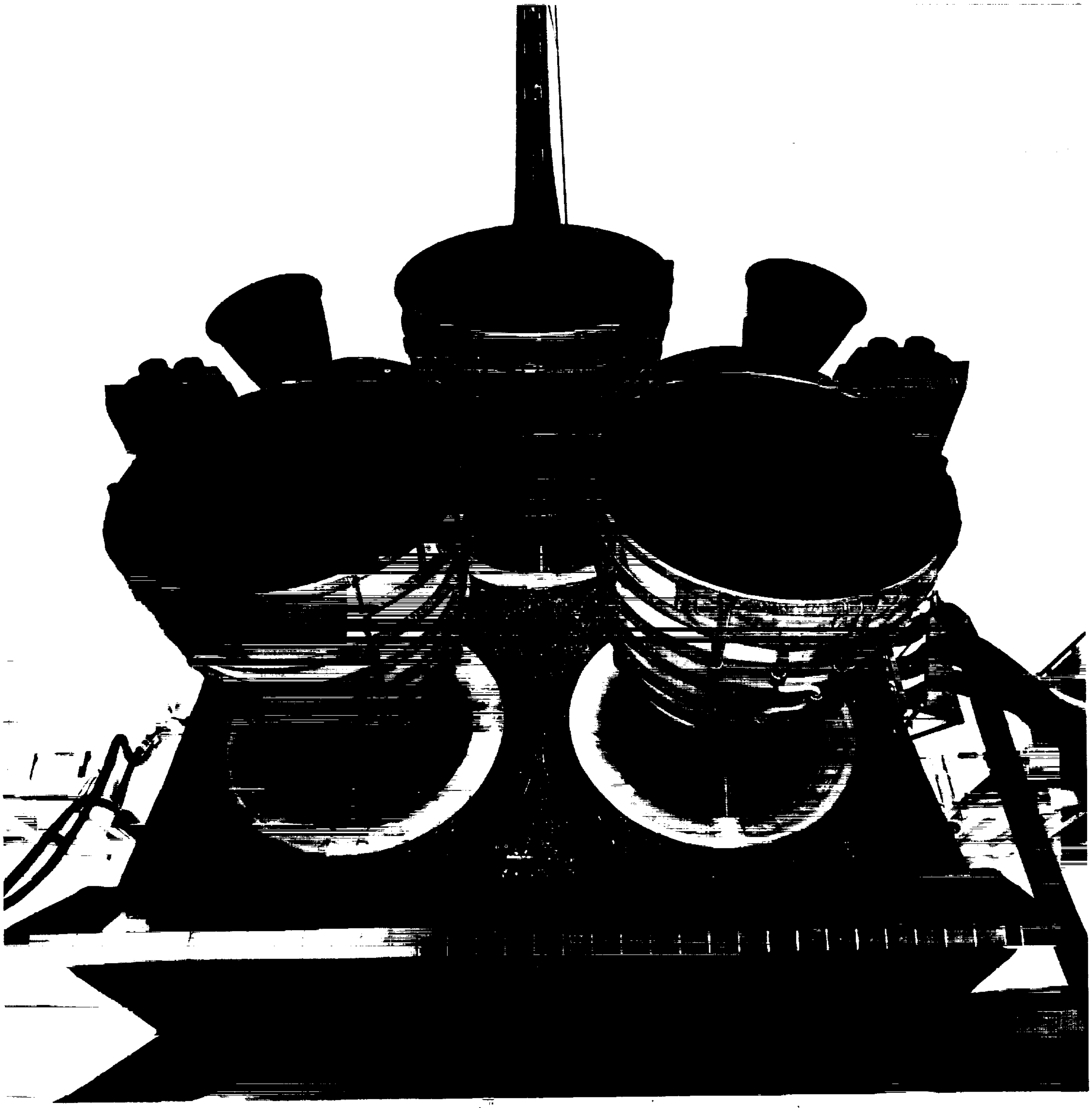

Photo 31 : Overall View of Base Heat Shield

Tile damage on the base heat shield was typical with the exception of a damage site that involved three tiles between SSME #2/3 and the body flap hinge. Dome Mounted Heat Shield (DMHS) closeout blankets were frayed/ripped on SSME #1 at the 6 o'clock position and torn on SSME #2 at the 3 o'clock position.

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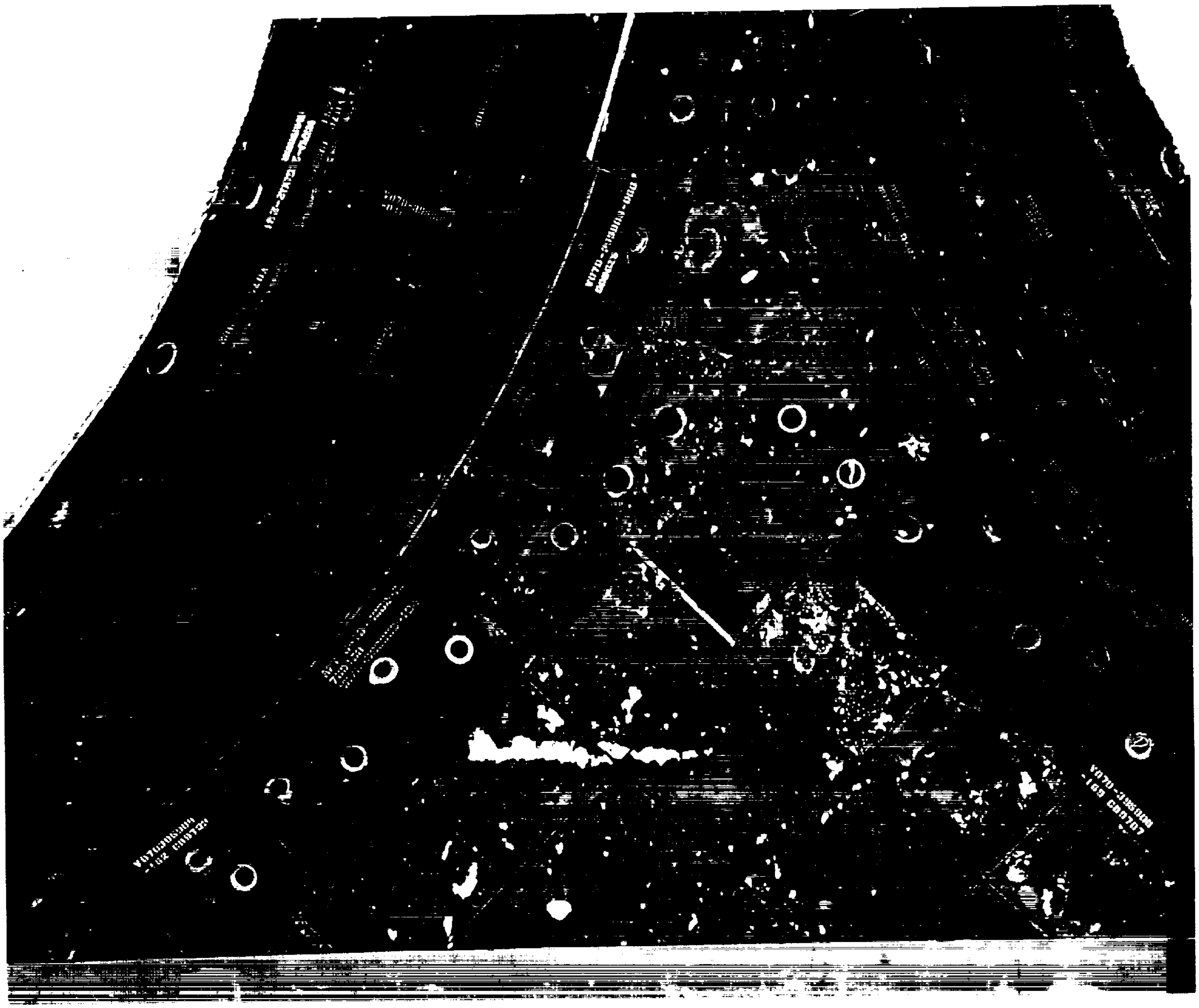

Photo 32 : Base Heat Shield Tile Damage

This tile damage site, which measured approximately 10 inches long by 1 inch wide by 0.25 inch deep, had been observed in the launch film review prior to T-0. The damage occurred sometime during SSME start-up.

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9.0 DEBRIS SAMPLE LAB REPORTS

A total of nine samples were obtained from OV-103 Discovery during the STS-63 post landing debris assessment at Kennedy Space Center, Florida. The submitted samples consisted of 8 wipes from Orbiter windows #1-8 and 1 lower surface tile damage site sample from the RH wing. The samples were analyzed by the NASA KSC Microchemical Analysis Branch (MAB) for material composition and comparison to known STS materials. Debris analysis involves both the placing and the correlating of particles and residues with respect to composition, thermal (mission) effects, and availability. Debris sample results/analyses are listed by Orbiter location in the following summaries. Also included in this report are results from a RH wing lower surface tile damage site sample from the STS-66 mission. The sample had not been taken until after the ferry flight to KSC.

9.1 ORBITER WINDOWS

Samples from the Orbiter windows indicated exposure to facility environment, SRB BSM exhaust (facility insulation, metallic particulate), landing site materials (earth minerals), Orbiter Thermal Protection System (tile, tile repair, RTV and high temperature insulation), paints and primer from various sources. Paint particulate continues to be present in a variety of colors: black, white, red, and yellow. The yellow paint particulate contained lead, which is typically found in facility/GSE paint. There was no apparent vehicle damage related to these residuals.

9.2 RH WING LOWER SURFACE TILE

The sample from the RH lower surface tile damage site revealed tile particles and Hypalon (SRB) paint. This finding, previously observed on STS-68 and STS-65, is discussed under new findings.

9.3 ORGANIC ANALYSIS

The results of the STS-63 organic analysis are shown in Figure 12. Identified materials include those associated with window covers (plastic polymers), RTV from RCS thruster nozzle cover adhesive and from Orbiter Thermal Protection System, and paint from various sources. There was no apparent vehicle damage related to these residuals.

9.4 STS-66 RH WING LOWER SURFACE TILE

After Orbiter OV-104 Atlantis ferry flight to KSC and mission STS-66 post flight processing, debris material was found in a RH wing lower surface tile damage site. The recovered material sample was identified by laboratory analysis to contain tile particles and Hypalon (SRB) paint. This sampling result is consistent with that of STS-63, STS-68, and STS-65.

9.5 NEW FINDINGS

This set of post flight debris samples led to no new findings. However, a trend in lower surface tile damage site residual material has been established. SRB Hypalon paint inclusions have been detected in lower surface tile damage sites on STS-63, -66, -68, and -65. All of the samples show the paint material had been exposed to heat effects. Hypalon paint does not adhere well to Booster Trowelable Ablator (BTA) closeouts during ascent aeroheating and reentry. Post-flight assessment of the SRB's revealed blistered/missing Hypalon paint from BTA closeouts on the frustums and forward assemblies. Program management decided to assign no IFA, but surveillance of the trend will continue.

STS	Sample Location				
	Windows	Wing RCC	Lower Tile Surface	Umbilical	Other
63	Metallics - Fac.Env./BSM Residue (SRB) RTV, Tile, Tile filler (ORB TPS) Insulation Glass (ORB TPS) Building type insulation Fiber-sample cloth Earth minerals (Landing site) Organics-Plastic polymers, SRB sealant RTV-RCS thruster nozzle cover Paint and primer		Silica-rich tile(ORB TPS) Hypalon paint (SRB)		
66	Metallics - Fac.Env./BSM Residue (SRB) RTV, Tile, Tile filler (ORB TPS) Insulation Glass (ORB TPS) Fiber-sample cloth Earth minerals (Landing site) Organics-Plastic polymers, SRB sealant RTV-RCS thruster nozzle cover Paint and primer		Silica-rich tile (ORB-TPS) Hypalon paint (SRB)		
68	Metallics - Fac.Env./BSM Residue (SRB) RTV, Tile, Tile filler (ORB TPS) Insulation Glass (ORB TPS) Fiber-sample cloth Earth minerals (Landing site) Organics-Plastic polymers, SRB sealant RTV-RCS thruster nozzle cover Paint and primer		Silica-rich tile (ORB-TPS) Hypalon paint (SRB)		ET GOX Vent Seal land area and GOX Seal Sample- Metallic Particulate WINDOW DEBRIS SAMPLE- 'Butc Paper'
64	Metallics - Fac.Env./BSM Residue (SRB) RTV, Tile, Tile filler (ORB TPS) Insulation Glass (ORB TPS) Fiber-sample cloth Earth minerals (Landing site) Organics-Plastic polymers, SRB sealant RTV-RCS thruster nozzle cover Paint and primer				
65	Metallics - Fac.Env./BSM Residue (SRB) RTV, Tile, Tile filler (ORB TPS) Insulation Glass (ORB TPS) Fiber-sample cloth Earth minerals (Landing site) Organics-Plastic polymers, SRB sealant RTV-RCS thruster nozzle cover Paint and primer		Silica-rich tile (ORB-TPS) Hypalon paint (SRB)		
59	Metallics - Fac.Env./BSM Residue (SRB) RTV, Tile, Tile filler (ORB TPS) Insulation Glass (ORB TPS) Fiber-Building insulation, wipe cloth Earth minerals - (Landing site) Organics- Plastic polymers, sealant RTV-RCS nozzle thruster cover Paint and primer				

Fo[illegible] n on previous missions refer to mission reports prior to STS-59

Figure 12 : Orbiter Post Landing Microchemical Sample Results

10.0 POST LAUNCH ANOMALIES

Based on the debris walkdowns and film/video review, 7 post launch anomalies, but no In-Flight Anomalies (IFA's), were observed on the STS-63 mission.

10.1 LAUNCH PAD/SHUTTLE LANDING FACILITY

1. The gutter on the newly constructed building for Substation 1032 sustained substantial damage from the SRB plume/shock wave. One 8 foot section of gutter lay in the pad acreage near camera site #2. An attempt to strengthen the gutter prior to launch was unsuccessful.

2. Post launch film review showed approximately 16 inches of RSS coax cable attached to the External Tank at the intertank umbilical carrier assembly. The cable should have remained with the GUCP during disconnect and retraction of the GH2 vent line. A KSC lab report attributed the cable failure to tensile overload. There was no evidence of a pre-existing condition, such as cuts or excessive bending, that contributed to the failure. Suspect PR ET-69-EL-0002 and TPS S70-1261-00-001-012 were taken to verify proper configuration of the cable on ET-69 (STS-67).

10.2 SOLID ROCKET BOOSTERS

1. Both right and left frustums had a total of 54 MSA-2 debonds.

2. A trend in Orbiter lower surface tile damage site residual material has been established. SRB Hypalon paint inclusions have been detected in lower surface tile damage sites on STS-63, -66, -68, and -65. All of the samples show the paint material had been exposed to heat effects. Hypalon paint does not adhere well to Booster Trowelable Ablator (BTA) closeouts during ascent aeroheating and reentry. Post-flight assessment of the SRB's revealed blistered/missing Hypalon paint from BTA closeouts on the frustums and forward assemblies. Program management decided to assign no IFA, but surveillance of the trend will continue.

10.3 EXTERNAL TANK

1. A 2-inch long by 1-inch wide piece of topcoat along with superficial layer of CPR foam was missing from an area 10 inches aft of the +Y louver and just aft of the XT-371 interface. The topcoat adhered to the GOX vent seal during seal deflation/hood retraction. An effort is in work to establish the need for topcoat/foam peel-off/adhesion acceptance criteria during seal retraction.

10.4 ORBITER

1. The largest tile damage site measured 5.5-inches by 1.5-inches by 0.75 inches deep and was located on the lower surface outboard of the LH2 ET/ORB umbilical directly aft of the LH MLG. The damage site was clean and did not exhibit the typical signs of re-entry heating. RTV was missing from the main landing gear tire pressure transducer wiring harness. No RTV was found on the runway. The RTV most likely came off during gear deployment and caused the damage prior to touchdown. An EO will eliminate excessive RTV on the wiring harness.

2. Tile damage on the base heat shield was typical with the exception of a damage site that involved three tiles between SSME #2/3 and the body flap hinge. This tile damage site, which measured approximately 10 inches long by 1 inch wide by 0.25 inch deep, had been observed in the launch film review (film item E-6) prior to T-0. The damage occurred sometime during SSME start-up.

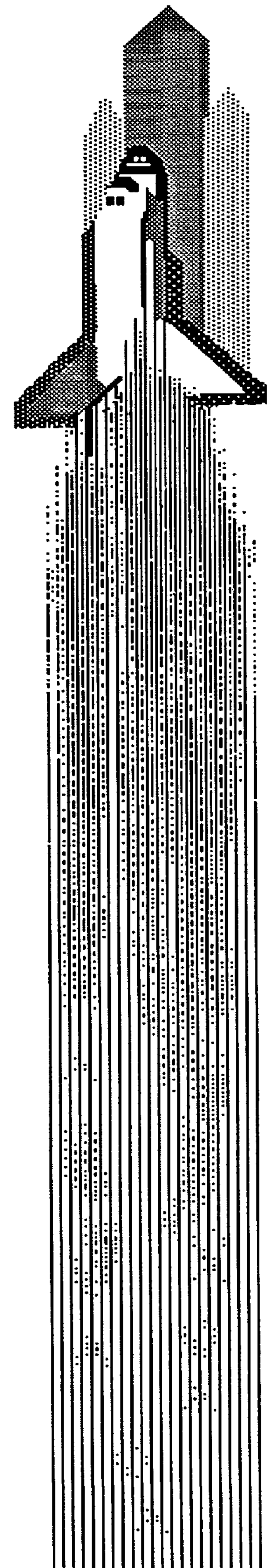
APPENDIX A. JSC PHOTOGRAPHIC ANALYSIS SUMMARY

Space Shuttle

Image Science and
Analysis Group

STS-63 Summary of Significant Events

March 17, 1995



Space Shuttle
Image Science and
Analysis Group

STS-63 Summary of Significant Events

Project Work Order - SN-52V

Approved By

Lockheed

J. M. Disler 3/16/95

J. M. Disler, Project Analyst
Image Science and Analysis Group

J. M. Disler 3/16/95

for M. H. Trenchard, Project Manager
Image Analysis Projects

3/16/95

for Jess G. Carnes, Operations Manager
Basic and Applied Research Department

NASA

Mike Gaunce

Mike Gaunce, Lead
Image Science and Analysis Group
Earth Science Branch

Prepared By

Lockheed Engineering and Sciences Company
for
Earth Science Branch
Earth Sciences and Solar System Exploration Division
Space and Life Sciences Directorate

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LIST OF FIGURES AND TABLES

1. OV-103 STS-63 FILM/VIDEO SCREENING AND TIMING SUMMARY

1.1 SCREENING ACTIVITIES

1.1.1 Launch

Discovery (OV-103) launched on mission STS-63 from Pad B at 05:22:04.005 Coordinated Universal Time (UTC) on February 3, 1995 (day 34) as seen on camera E8. Solid rocket booster (SRB) separation occurred at 034:05:24:09.021 UTC as seen on camera E207.

On launch day, 24 videos were screened. Following launch day, 52 films were reviewed.

No anomalies were observed during launch.

DTO-312 photography of the STS-63 external tank was not acquired due to darkness.

1.1.2 On-Orbit

At the request of the MER Manager, the IS&AG conducted an analysis of Shuttle downlink video to estimate the size and velocity of nitrogen tetroxide particles ("snowballs") leaking from the R1U RCS thruster (a similar analysis was conducted on the R4U leak on STS-42). This information was provided to the MER manager in support of the decision on the rendezvous approach distance to the Mir.

In addition, the Image Science and Analysis Group (IS&AG) provided image analysis support to the Orbital DEbris RAdar Calibration Spheres (ODERACS) experiment. The velocities of dipoles and spheres ejected from a Get-Away-Special can located in the Shuttle cargo bay were calculated from video data. This analysis data was provided to the ODERACS principal investigators within thirty minutes of deployment.

The IS&AG also provided suggestions of viewing angle and lighting conditions to the Life Support Systems Branch for the investigation of the waste water purge process. This investigation attempted to replicate ice buildup conditions noted on the previous mission (STS-66). The IS&AG inputs were requested to optimize the quality of the acquired video data of the waste water purge process. IS&AG personnel recommended lighting, camera, and view angle parameters to provide the best data.

Finally, Detailed Test Objective 1118 (MIR Micrometeoroid & Debris Impact Photo Survey) was successfully conducted on STS-63 during the MIR space station rendezvous on February 6, 1995. Approximately one thousand still photographs and ten hours of video of the MIR Space Station were acquired. Preliminary screening of the data has been completed, and an overall assessment of the data has been prepared. Analysis of the MIR survey imagery data is in progress. This assessment is being factored into the MIR imagery survey planning for STS-71. A final report documenting the analysis and results from this DTO will be generated and distributed by the end of April 1995.

1.1.3 Landing

Discovery landed on runway 15 at Kennedy Space Center (KSC) on February 11, 1995 (day 42). Ten videos of the Orbiter approach and landing were received. NASA Select, a composite created from the available landing views, was also screened.

Event Description	Timing	Camera
Landing gear doors opened	11:50:03.550 UTC	EL17
Left main gear touchdown	11:50:19.054 UTC	KTV33L
Right main gear touchdown	11:50:19.188 UTC	KTV33L
Nose wheel touchdown	11:50:32.835 UTC	KTV33L
Wheel stop	11:51:39.703 UTC	KTV11L

Table 1.1.3 Landing Event Times

A continuous black streak across several tiles was visible at the starboard base of the vertical stabilizer during the post-landing walk-around video inspection. Subsequent communication with inspectors at KSC and engineers at JSC has indicated that this streak was caused when densification slurry used in the launch pad repair of a vertical stabilizer leading edge tile had dripped aft across white AFRSI blankets.

The following additional items were noted during the post landing walk around: Tile damage on the base heat shield between SSME #2 and #3, frayed Dome Mounted Heat Shield (DMHS) close-out blankets on SSME #1 and #2, orange discoloration near the forward/starboard RCS area, and possible discoloration on the upper side of the body flap.

1.2 TIMING ACTIVITIES

All launch videos had timing and launch film cameras E1, E2, E3, E4, E5, E6, E7, E8, E9, E10, E11, E12, E13, E14, E15, E16, E17, E18, E19, E20, E25, E26, E52, E54, E59, E79A had in-frame alphanumeric timing (film cameras E222 and E224 had in-frame alphanumeric timing that was incorrect). These videos and films were used to time specific mission events during the initial screening. The following additional events were timed on two film cameras:

Camera	Frame	Comments	Timing (UTC)
E205	4449	Recirculation start	34:05:23:34.506
	5667	Recirculation end	34:05:23:52.068
	6839	SRB Separation	34:05:24:08.993
E207	5662	Recirculation start	34:05:23:35.467
	6300	Recirculation end	34:05:23:46.003
	7695	SRB Separation	34:05:24:09.021

Table 1.2 Film Camera Timing Events

2. SUMMARY OF SIGNIFICANT EVENTS ANALYSIS

2.1 DEBRIS

2.1.1 Debris near the Time of SSME Ignition

2.1.1.1 LH2 and LO2 Tail Service Mast (TSM) T- 0 Umbilical Disconnect Debris

(Cameras E17, E18, E19, E20, E77, OTV149, OTV150, OTV151)

Normal ice debris was noted falling from the LH2 and LO2 TSM T-0 umbilical disconnect areas at SSME ignition through liftoff. None of the debris was observed to strike the vehicle. No follow-up action was requested.

2.1.1.2 LH2 and LO2 ET/Orbiter Umbilical Disconnect Debris

(Cameras E1, E5, E6, E9, E12, E26, E30, E31, E34, E40, E52, E60, OTV109, OTV154, OTV163)

Normal ice debris was noted falling from the LH2 and LO2 ET/Orbiter umbilical disconnect areas at SSME ignition through liftoff. Multiple pieces of light colored debris (probably ice) were seen striking the LH2 umbilical sill and the 4 inch recirculation line during SSME startup (as seen on OTV109). No damage to the SLV was apparent in either case. No follow-up action was requested.

2.1.2 Debris near the Time of SRB Ignition

2.1.2.1 Holddown Post Debris

(Camera E13)

A single piece of dark debris was seen near the forward end on the LSRB holddown post M-6 debris containment system (DCS) at SRB ignition. No follow-up action was requested.

2.1.2.2 SRB Flame Duct Debris

(Cameras E4, E7, E8, E9, E11, E12, E13, E14, E15, E16, E52)

As on previous missions, several pieces of debris were noted originating from the SRB flame duct area after SRB ignition. The majority of this debris was seen near the holddown posts. Several light colored pieces of debris were seen on the north side of the launch vehicle just after liftoff (05:22:05.322 UTC) which were possibly from the flame duct. None of the SRB flame duct debris was seen to contact the vehicle. No follow-up action was requested.

2.1.2.3 Debris between Orbiter and ET between Liftoff and Tower Clear

(Camera E34, E54)

Multiple pieces of light colored debris were seen falling aft between the Orbiter and the external tank between liftoff and tower clear. The debris pieces appeared to originate from the forward bellows area of the external tank LO2 feedline. One piece of debris appeared to contact the tiles on the underside of the Orbiter. No damage to the launch vehicle was visible on the available views. No follow-up action was requested.

2.1.3 Debris after Liftoff

(Cameras E40, E52, E207, E212, E213, E220, E222, E223, E224, ET207)

Multiple pieces of debris were seen falling aft of the Shuttle Launch Vehicle (SLV) between tower clear and early ascent on the launch tracking views. Most of the debris sightings were probably reaction control system (RCS) paper or ice from the ET/Orbiter umbilicals. None of the debris was observed to strike the vehicle. No follow-up action was requested.

2.1.3.1 Debris along SRB Plume During Ascent

(Cameras E208, E218, ET208, KTV4B)

Multiple pieces of light colored debris were seen falling aft of the vehicle along the SRB plume between 59 and 72 seconds MET and again, a few seconds prior to SRB separation. Debris in these time periods has been seen on previous missions. No follow-up action was requested.

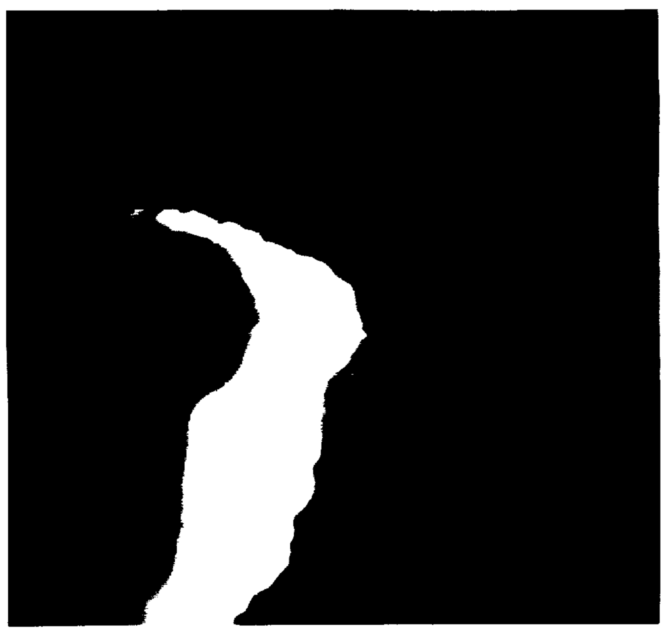

Figure 2.1.3.1 Debris Falls along SRB Plume during Ascent (KTV4B)

2.1.3.2 Debris Reported by the Crew *(Task #10)*

The crew debris report was not transcribed for STS-63.

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2. SUMMARY OF SIGNIFICANT EVENTS ANALYSIS

2.2 MLP EVENTS

2.2.1 Orange Vapor (Possibly Free-burning Hydrogen)

(Cameras E62, E76, E77, OTV163, OTV170, OTV171)

Orange vapor (possibly free-burning hydrogen) was seen above the aft end of the right OMS pod near the base of the vertical stabilizer and under the body flap during SSME ignition. This event has been noted on past missions and would become a concern if the vapor was near the ET/Orbiter umbilicals. On this mission the vapor was below the umbilicals and no follow-up action was requested.

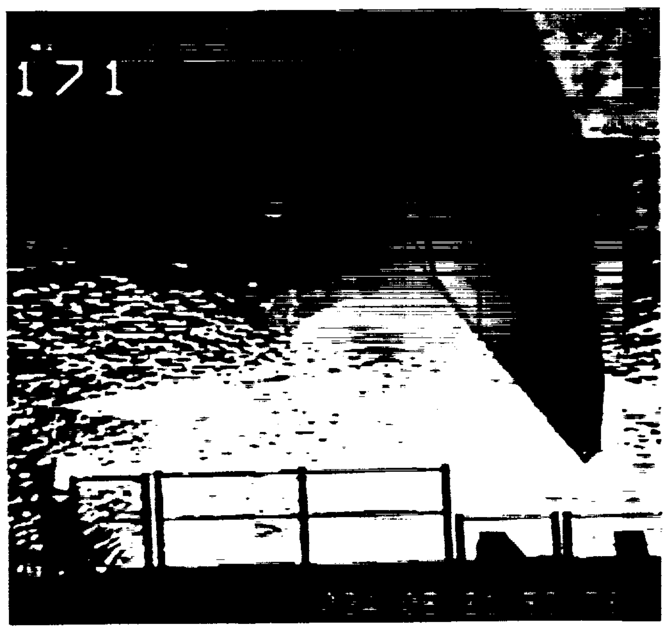


Figure 2.2.1 Orange Vapor near the Vertical Stabilizer during SSME Ignition (OTV171)

2.2.2 Base Heat Shield Erosion
(Cameras E17, E20)

A small area of base heat shield erosion was seen to form outboard of SSME # 3 at 05:22:00.995 UTC on camera E17. TPS erosion was seen on the base of the left RCS stinger at 05:22:00.741 UTC on camera E20. Base heat shield erosion has been seen on previous missions. No follow-up action was requested.

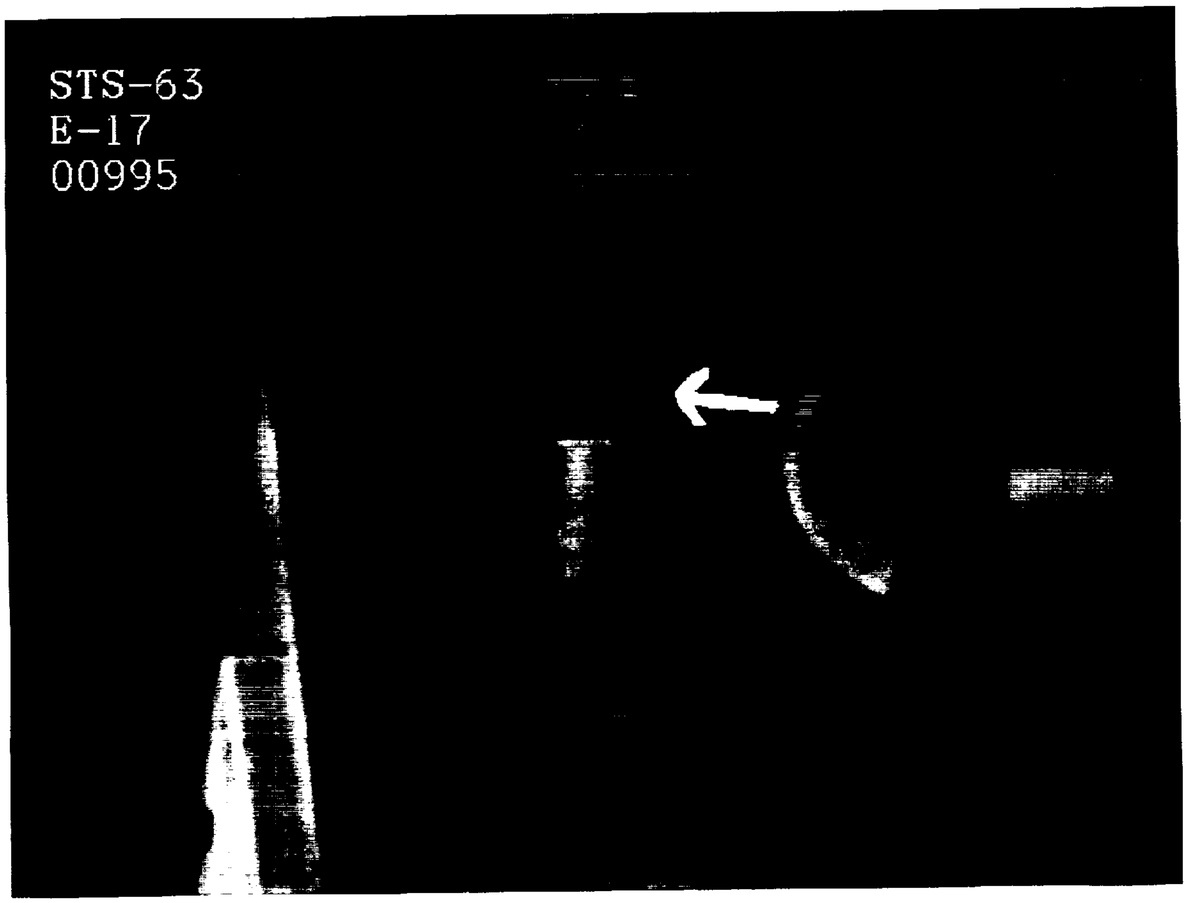


Figure 2.2.2 Base Heat Shield Erosion Outboard of SSME #3 (E17)

2.2.3 Orange Flashes in SSME Plume
(Cameras E1, E2, E5, E19)

As on previous missions, several orange flashes were noted in the SSME exhaust plume during SSME ignition. The orange flashes are probably caused by RCS paper debris detaching and falling into the SSME plumes. No follow-up action was requested.

2.2.4 Loose Thermal Curtain Tape
(Cameras E2, E5, E8, E9, E25, E77)

A loose piece of thermal curtain tape was seen on the RSRB aft skirt near holddown post M-2 at liftoff. Loose SRB thermal curtain tape has been seen on previous missions. No follow-up action was requested.

2.2.5 Pyro Initiator Controller (PIC) Wire Remained Attached to Shoe
(Cameras E10, E13)

Two Pyro Initiator Controller (PIC) wires remained attached to the holddown post foot after the foot had cleared the holddown post (HDP) shoe at liftoff. One wire was on the RSRB HDP M-3 and the other wire was on the LSRB HDP M-6. This event has been observed on previous missions and is not considered anomalous.

2.2.6 Flexing of the Base Heat Shield
(Cameras E20, E76, E77)

A slight flexing of the Orbiter base heat shield was noted at SSME ignition. Flexing of the base heat shield has been seen on previous missions. No follow-up action was requested.

2.2.7 White Flashes in SSME Plume
(Cameras E52, E218, E224)

White flashes were noted in the SSME plume during early ascent. White flashes in the SSME exhaust plume have been seen on previous missions. No follow-up action was requested.

2.3 ASCENT EVENTS

2.3.1 Body Flap Motion *(Task #4)*
(Cameras E17, E18, E207, ET207)

2.3.1.1 Body Flap Motion on the Pad

A continuing historical analysis of OV-103 missions is the driver for studying body flap motion seen on the pad. A subjective comparison between this mission and others since reflight indicated only slight on-pad motion on STS-63. The time of maximum on-pad motion was determined to lie just after SSME ignition. Points defining the aft port and starboard edges of the body flap were chosen on every fourth frame over a period of 400 frames on cameras E17 and E18. This corresponded to approximately 1 second of actual data. In addition, a control point on the tail service mast (TSM) was chosen to serve as a control for camera motion. Body flap thickness (assumed to lie in the plane of motion) was used as the scaling factor for this analysis. The maximum peak-to-peak motion measured approximately 1.0 inches on starboard side and 0.7 inches on port side.

A frequency-domain analysis was conducted to identify modes of vibration. The data revealed the existence of several specific modes of vibration. Analysis indicated frequency peaks at 3, 7.5, 9, 12.5, 17, 27, 36.5 and 48 hertz for the starboard side; and 5, 7.5, 9, 11.5, 17, 20, 23.5 and 40.5 hertz for the port side. Of these peaks, global rotation (9 hertz) could be correlated with an identifiable mode on both sides and a second bending moment (40.5 hertz) was identified on the port side of the flap. The significance of the presence of these modes depends upon the results of long-term trend analysis.

2.3.1.2 Body Flap Motion During Ascent

Film from camera E207 was reviewed for body flap motion visible during ascent. While body flap motion was seen on this mission, measurements indicated that the data appeared to lie within the noise. This event has been tracked on all missions since reflight. Deflection measurements did not indicate measurable motion.

2.3.2 White Streak at Base of Vertical Stabilizer

(Cameras E205, E207, E222, E223, ET207)

A white streak was noted at the base of the vertical stabilizer at approximately 43 seconds MET. The event resembled a streak previously seen on STS-68 near the right OMS pod at 36 seconds MET. On STS-68, damage to the right OMS pod was detected during the post mission inspection. No damage was detected during the STS-63 post mission inspection. No follow-up action was requested.

Figure 2.3.2 A White Streak at the Base of the Vertical Stabilizer at 43 Seconds MET (E223)

2.3.3 Linear Optical Effect
(Cameras E207, E208, E223, ET207, ET208, KTV13)

Multiple linear optical effects were seen between 68 and 98 seconds MET. Engineers at JSC have previously attributed this event to the manifestation of shock waves around the SLV. No follow-up action was requested.

2.3.4 Recirculation
(Cameras E205, E207)

The recirculation or expansion of burning gases at the aft end of the Shuttle Launch Vehicle (SLV) prior to SRB separation has been seen on nearly all previous missions. Recirculation on this mission was observed between approximately 93 and 103 seconds MET on camera E207.

2.3.5 Orange Flashes in SRB Plume prior to SRB Separation
(Camera E207)

Multiple orange flashes were noted in the SRB plume prior to SRB separation. This event has been noted on previous missions. Previous consultation with JSC engineers indicated that the flashes resulted from the natural irregularity of the plume which produced different shadings in different regions. No follow-up action was requested.

2.3.6 Large Flare One second prior to SRB Separation
(Camera ET207)

The view from video camera ET207 showed a large orange flare separating from the Orbiter image approximately one second prior to SRB separation. This event was not visible on any other available video or film views. The event was possibly caused by the viewing angle and the interaction of the atmosphere and shock waves. No follow-up action was requested.

2.4 ONBOARD PHOTOGRAPHY OF THE ET (DTO-312)

2.4.1 Analysis of Handheld Photography of the ET *(Task #6)*

DTO-312 photography of the STS-63 external tank was not performed on this mission due to darkness.

2.4.2 Umbilical Well Camera Analysis *(Task #5)*

The umbilical well cameras were not flown on the STS-63 mission (OV-103 is not configured for umbilical well cameras).

2.5 ON-ORBIT EVENTS

2.5.1 Orbital DEbris RAdar Calibration Spheres (ODERACS) Support
(Task #14)

The Image Science & Analysis Group (IS&AG) supported the ODERACS deployment. Analysts calculated exit velocities of three calibration spheres and three dipoles launched from a Get-Away-Special Can located in the aft section of the cargo bay. These

calculated velocities ranged from 1.44 to 3.66 meters per second and were used to help radar sites around the world track the spheres and dipoles. (See the accompanying table for actual velocities.

SEQ.	DESCR.	DIA. (inches)	EXP. VELOC. (meters/sec.)	CALC. VELOC (meters/sec.)	~EJECT.TIME (min:sec)UTC
1	white sphere	4.0	3.39	3.66	57:04.8
2	5.255" dipole		2.45	2.43	57:07.7
3	polished sphere	2.0	2.13	1.92	57:09.7
4	1.740" dipole		1.85	1.97	57:12.2
5	black sphere	6.0	1.61	1.52	57:17.5
6	5.255" dipole		1.40	1.44	57:20.0

Table 2.5.1 Expected/Calculated Velocity and Ejection Times of the Six Projectiles of the ODERACS Flight Experiment.

Tumbling of the dipoles was visible on the downlinked payload bay camera 'D' views. The six projectiles were visible. The three objects which were constantly visible were identified as the spheres. The three objects which appeared to be blinking were identified as the dipoles. The distinction between specific spheres or specific dipoles was not possible. The rotation rates of the three dipoles was determined by analysis of the rate of blinking. The rotation rates of the dipoles were 0.167, 0.286 and 0.437 cycles per second.

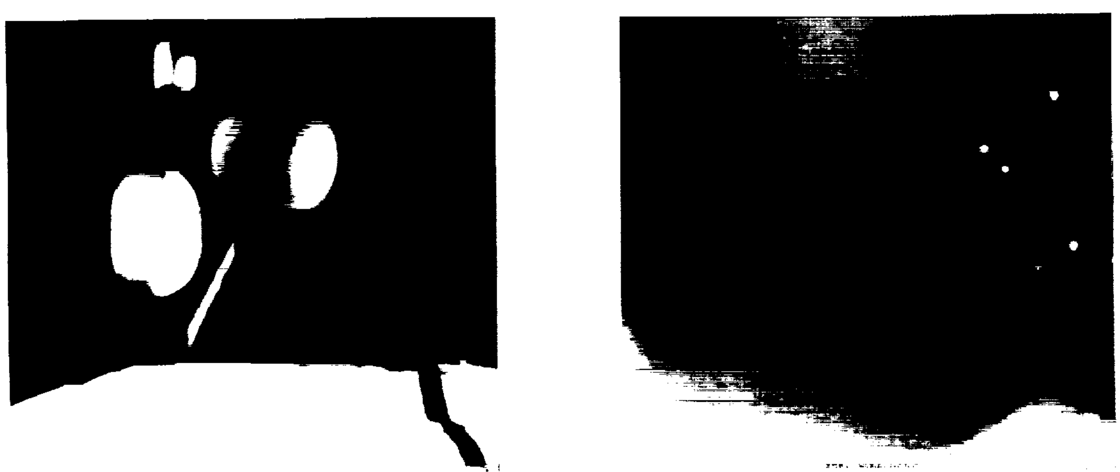


Figure 2.5.1 ODERACS Deployment

The picture on the left is a composite image created by merging six different video frames. This image depicts the three spheres and three dipoles as they clear the IMAX payload in the aft section of the cargo bay as seen from camera B. The composite image on the right shows these objects several minutes after deploy as seen from camera D. Velocities of these objects were calculated and forwarded to the Orbital Debris personnel in near real time (within 30 minutes of deploy).

2.5.2 Reaction Control System R1U Jet Leak Characterization *(Task #15)*

At the request of the MER Manager, the Image Science & Analysis Group conducted an analysis of Shuttle video downlink to estimate the size and velocity of nitrogen tetroxide particles ("snowballs") leaking from the R1U RCS thruster. A similar analysis was conducted on the R4U leak on STS-42. The available STS-63 video sequence ran from approximately 2:54:50 UTC to 3:05:00 UTC on February 4, 1995 (day 35).

The largest particle seen while the vertical stabilizer was in the field of view was estimated to be approximately 13 inches in diameter (at 03:01:40.428 UTC). However, the blooming of the video from the MLA camera in position D causes distortions that increase the apparent size of the particle. By way of comparison, a piece of downlink video taken from a different camera and available at a later time was analyzed. This video (with less distortion due to video blooming) showed a greatly reduced leak rate, with the largest particle being approximately 8 inches in size.

The most accurate values of velocity (though perhaps not the highest values) occurred at the edge of the leak dispersion cone since, at that point, there is only one plane of motion relative to the filed of view. During one of the bursts of oxidizer from the R1U jet, the maximum velocity was estimated to be 13.5 feet per second (reference time 03:01:43:459 UTC).

The accuracy of the analysis was hampered by the quality of the video, the amount of time the camera was held in a fixed position, and the amount of fixed hardware (i.e., the Orbiter) in the field of view. Blooming of the MLA payload bay camera view of the vertical stabilizer made it difficult to define scaling points. In addition, in some cases, it was difficult to distinguish lights from cities on the Earth from the oxidizer snowballs in the foreground during night passes.

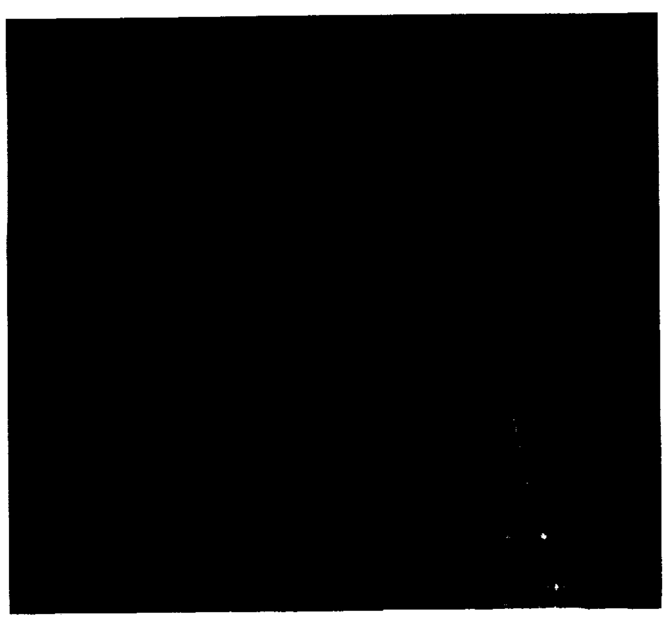


Figure 2.5.2 Exit Cone of RCS R1U Jet Leak near Vertical Stabilizer

2.5.3 Waste Water Purge Investigation

The IS&AG provided suggestions for viewing angle and lighting conditions for acquiring video of the waste water purge process at the request of the Life Support Systems Branch/EC3. This investigation attempted to replicate the conditions on STS-66 when ice buildup was noted on a cargo bay door. The problem encountered in previous video acquisitions was poor contrast due the white Orbiter surface in the background and inadequate lighting. The IS&AG suggested orienting the camera to acquire a dark background and coordinating the investigation with daylight and backlit conditions. Shuttle orientation and attitude requirements prevented using the sun as a backlighting source. Unfortunately, the resulting output data did not provide enough information to perform useful analysis.

2.6 LANDING EVENTS

2.6.1 Landing Sink Rate Analysis *(Task #3)*

The sink rate of the Orbiter was determined over a one second interval prior to main gear and nose gear touchdown. The measured main gear and nose gear sink rate values were below the maximum allowables of 9.6 feet per second for a 211,000 lb vehicle and 6.0 feet per second for a 240,000 lb. vehicle (the landing weight of the Orbiter was 224,130 lb).

2.6.1.1 Landing Sink Rate Analysis Using Film (Task #3)

Film camera EL7 was used to determine the landing sink rate of the main gear. The analysis considered approximately one second of imagery immediately prior to touchdown. Data was gathered at a sample rate of 100 frames per second. An assumption was made that the line of sight of the camera was perpendicular to the Orbiter y-axis. Scaling information was determined by using the distance between the main gear struts. The vertical difference of the projected main gear point for two successive frames was multiplied by the scaling factor to find the change in height of the main gear over that interval. The main gear height above the runway was determined by assigning the frame of touchdown a height of 0 feet, and cumulatively adding the previous frames. These heights were then regressed with respect to time. Sink rate equals the slope of this regression line. The main gear sink rate was determined to be 3.75 feet per second.

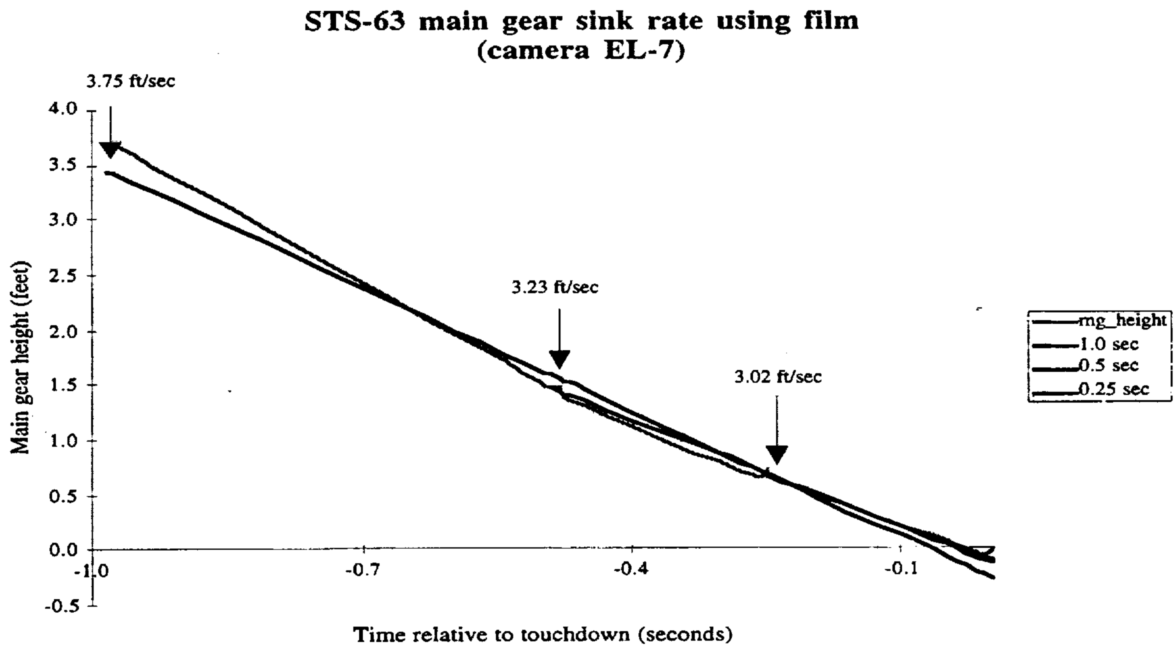


Figure 2.6.1.1 (a) Graph of Main Gear Height Versus Time Prior to Touchdown (Film)

Film camera EL9 was used to determine the landing sink rate of the nose gear. The analysis considered approximately one second of imagery immediately prior to touchdown. Data was gathered at a sample rate of 100 frames per second. An assumption was made that the line of sight of the camera was perpendicular to the Orbiter y-axis. Scaling information was determined by using the distance between the main gear struts. The vertical difference of the digitized nose gear point from the average of the main gear points was multiplied by the scaling factor to find the height of the nose gear for a single frame. An empirical offset correction was made to produce a calculated height at main gear touchdown of 0 feet. These heights were then regressed with respect to time. Sink rate equals the slope of this regression line. The nose gear sink rate was determined to be 3.20 feet per second.

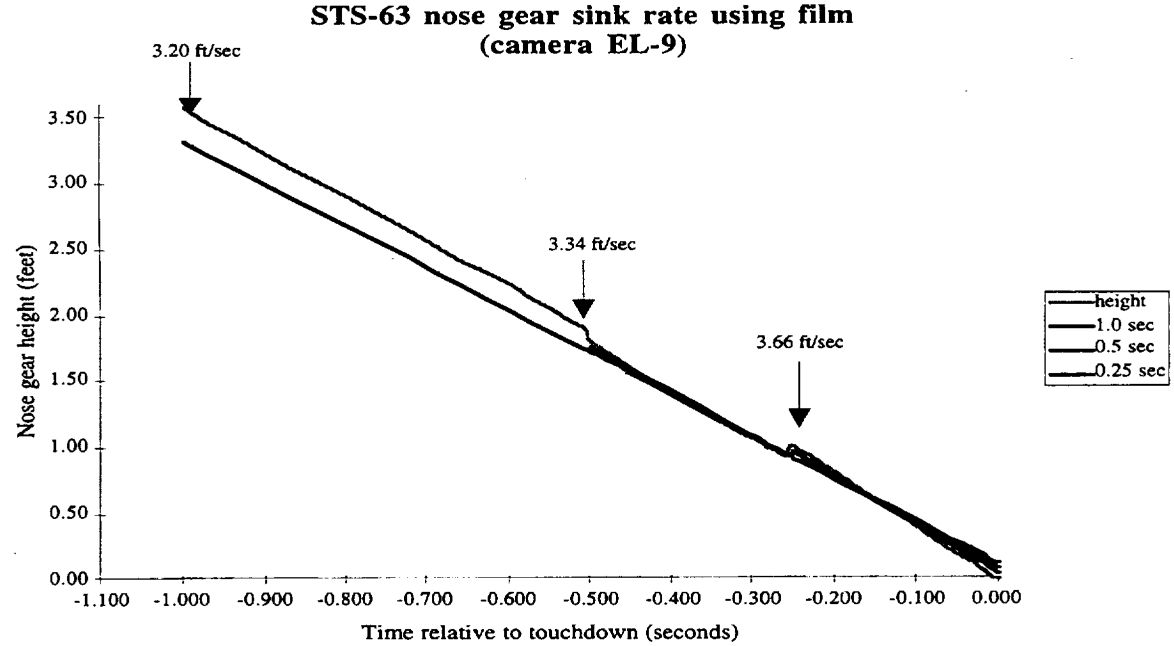


Figure 2.6.1.1 (b) Graph of Nose Gear Height Versus Time during Rollout (Film)

2.6.1.2 Landing Sink Rate Analysis Using Video
(Cameras SLF North and SLF South)

Video camera SLF North was also used to determine the landing sink rate of the main gear. Data was gathered at a sample rate of 30 frames per second. The main gear sink rate was determined to be 3.68 feet per second.

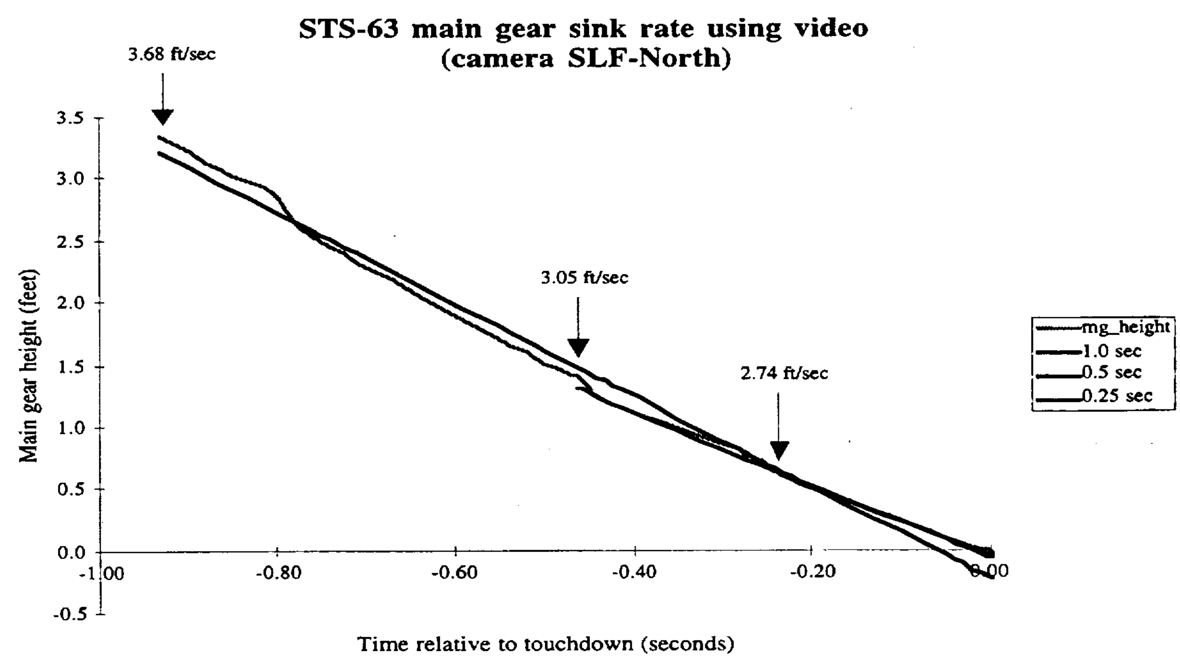


Figure 2.6.1.2 (a) Graph of Right Main Gear Height Versus Time prior to Touchdown (Video)

Video camera KTV33L was also used to determine the landing sink rate of the nose gear. Data was gathered at a sample rate of 30 frames per second. The nose gear sink rate was determined to be 3.63 feet per second.

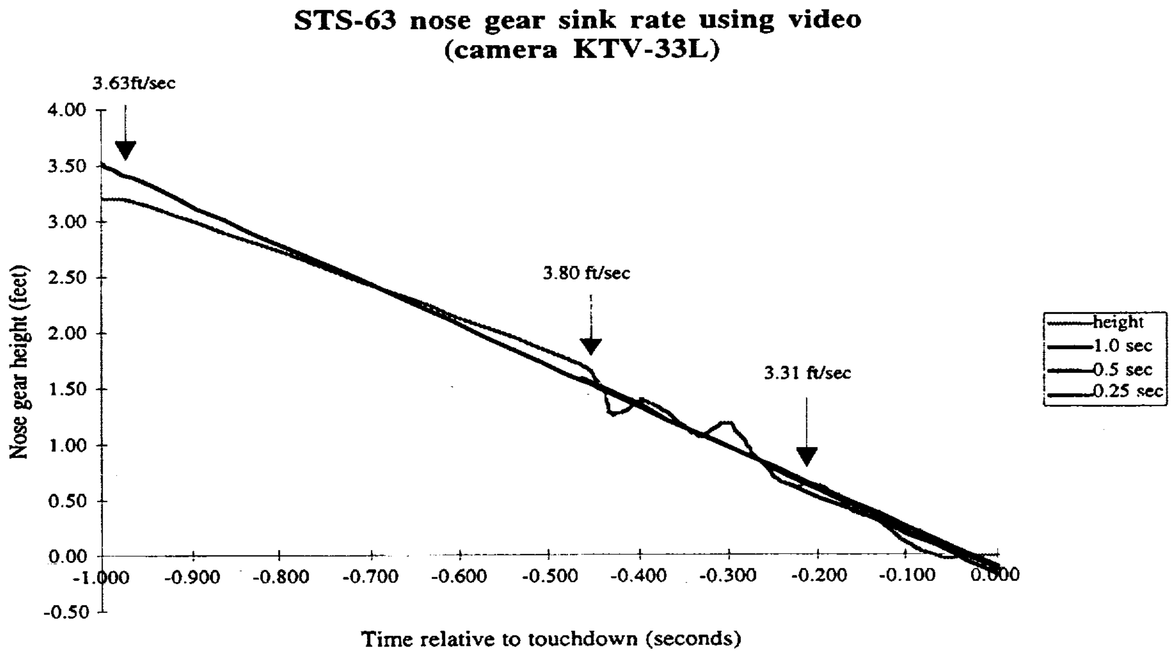


Figure 2.6.1.2 (b) Graph of Nose Gear Height Versus Time during Rollout (Video)

2.6.2 Drag Chute Performance *(Task #9)*

The performance of the drag chute during roll-out of STS-63 appeared normal. The drag chute has been taken off Detailed Test Objective (DTO) status beginning with STS-63. For future mission, the drag chute angular orientation will only be measured upon special request.

Event Description	Timing	Camera
Drag chute initiation	11:50:26.628 UTC	KTV33L
Pilot chute at full inflation	11:50:27.360 UTC	KTV15L
Bag release	11:50:28.094 UTC	KTV15L
Drag chute inflation in reefed configuration	11:50:29.331 UTC	KTV33L
Drag chute inflation in disreefed configuration	11:50:32.434 UTC	KTV33L
Chute release	11:51:05.035 UTC	KTV11L

Table 2.6.2 Drag Chute Event Times

2.6.3 Orbiter Height above Threshold *(Task #13)*

The still camera designated for the height above threshold analysis was not operated. Therefore, this analysis will not be completed for the STS-63 mission.

2.7 OTHER NORMAL EVENTS

Other normal events observed include: normal SSME ignition sequence, body flap vibration after SSME ignition, ET twang prior to liftoff, right and left inboard and outboard elevon vibration after SSME ignition and at liftoff, RCS paper debris after SSME ignition, multiple pieces of white debris (probably ice from the ET/Orbiter umbilicals) fell along the body flap after liftoff, ice and vapor from the GUCP area during ET GH2 umbilical vent arm retraction, vapors from the ET gaseous hydrogen umbilical disconnect during early liftoff, multiple pieces of dark debris in the exhaust cloud after liftoff, acoustic waves in the SRB exhaust plume after liftoff, multiple pieces of light colored debris noted aft of the SLV during early ascent, vapor from both SRB stiffener rings after liftoff, ET aft dome outgassing, charring of the ET aft dome, flares in the SSME exhaust plume after the roll maneuver, dark puffs in SRB exhaust plume prior to SRB plume brightening, SRB plume brightening prior to SRB separation, SRB separation, and slag in the SRB exhaust plume after SRB separation.

Normal pad events observed were hydrogen ignitor operation, fixed service structure (FSS) deluge water spray activation, sound suppression water operation, a leak in a Mobile Launch Platform (MLP) J-pipe, multiple pieces of light colored debris falling from the Fixed Service Structure (FSS) during SSME ignition, and MLP deluge water operation.

2.8 OTHER

2.8.1 Terminal Events Timing Interval *(Task #11)*

A detailed timeline of the SSME and SRB ignition sequences was generated and sent to R. Fletcher/VF5.

APPENDIX B. MSFC PHOTOGRAPHIC ANALYSIS SUMMARY

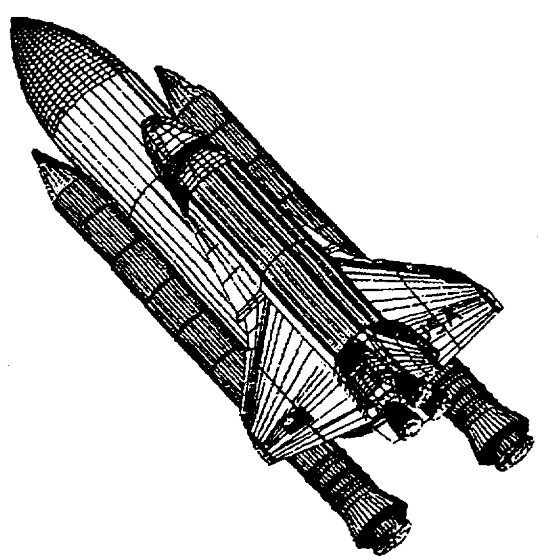
National Aeronautics and
Space Administration

George C. Marshall Space Flight Center
Marshall Space Flight Center, Alabama 35812

SPACE SHUTTLE

ENGINEERING PHOTOGRAPHIC ANALYSIS REPORT

STS-63



MSFC - Form 454 (Rev. October 1992)

ENGINEERING PHOTOGRAPHIC ANALYSIS REPORT

STS-63

FINAL

PREPARED BY:

M. COVAN, J. HIXSON
PHOTOGRAPHIC ANALYSIS/ROCKWELL/HSV

SUBMITTED BY:

JIM ULM
SUPERVISOR, LAUNCH OPERATIONS/ROCKWELL/HSV

APPROVED BY:

T. RIECKHOFF, MSFC/EP24
B. LINDLEY-ANDERSON, MSFC/EP24

STS-63 ENGINEERING PHOTOGRAPHIC ANALYSIS REPORT

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February 13, 1995

I. INTRODUCTION

The launch of space shuttle mission STS-63, the twentieth flight of the Orbiter Discovery occurred on February 2, 1995, at approximately 11:22 P.M. Central Standard Time from Launch Complex 39B (LC-39B), Kennedy Space Center (KSC), Florida. Extensive photographic and video coverage exists and has been evaluated to determine proper operation of the ground and flight hardware. Cameras (video and cine) providing this coverage are located on the fixed service structure (FSS), mobile launch platform (MLP), LC-39B perimeter sites, onboard the vehicle, and uprange and downrange tracking sites.

II. ENGINEERING ANALYSIS OBJECTIVES:

The planned engineering photographic and video analysis objectives for STS-63 included, but were not limited to the following:

a. Overall facility and shuttle vehicle coverage for anomaly detection
b. Verification of cameras, lighting and timing systems
c. Determination of SRB PIC firing time and SRB separation time
d. Verification of Thermal Protection System (TPS) integrity
e. Correct operation of the following:
    1. Holddown post blast covers
    2. SSME ignition
    3. LH2 and LO2 17" disconnects
    4. GH2 umbilical
    5. TSM carrier plate umbilicals
    6. Free hydrogen ignitors
    7. Vehicle clearances
    8. GH2 vent line retraction and latch back
    9. Vehicle motion

III. CAMERA COVERAGE ASSESSMENT:

Film was received from fifty of fifty-two requested cameras as well as video from twenty-four of twenty-four requested cameras. The following table illustrates the camera data received at MSFC for STS-63.

Camera data received at MSFC for STS-63

	16mm	35mm	Video
MLP	22	0	4
FSS	6	0	3
Perimeter	3	4	6
Tracking	0	15	11
Onboard	0	0	0
Totals	31	19	24

Total number of films and videos receive 74

> The individual motion picture and video camera assessments are available on the Engineering Photographic Analysis server on the World Wide Web. To view the report you will need NCSA Mosaic software. The server address is http://photo4.msfc.nasa.gov/msfc.html

a. Ground Camera Coverage:

All requested video cameras and film cameras operated properly except for items E-36 which experienced an obstruction in its field-of-view and E-57 which had a film jam at startup. No timing information was recorded from the KSC replays of the long range tracking cameras. The remote tracking of the perimeter cameras appeared to be excellent. Due to the night launch, all film and video products provided reduced information. None of the forward portion of the vehicle was visible after liftoff from the pad.

b. Onboard Camera Coverage:

No onboard film is expected. There were no umbilical cameras onboard this mission and the DTO to photograph the ET after separation was not planned to be performed because of RCS fuel limitations.

IV. ANOMALIES/OBSERVATIONS:

No anomalies were observed. However, several observations were made. Normal vehicle events which occur during launch that were observed include: GH2 vent arm retraction, RCS paper debris from the orbiter, elevon motion at liftoff, acoustic waves in the SRB exhaust plume at liftoff, vapor from the SRB stiffener rings after liftoff, ET aft dome outgassing, liner optical effects after the roll maneuver, flow recirculation, and SRB plume brightening prior to SRB separation.

Normal pad events which occur during launch are free hydrogen ignitor operation, sound suppression water operation, and MLP and FSS deluge water operation.

Orange vapors from the burning free hydrogen were noted during the SSME startup sequence near the base of the right OMS pod. This burning is shown in Figure 1 which was taken from camera OTV-170. These type vapors have been seen in this region before and their location appears to be influenced by the local wind conditions. No burning of the vehicle surfaces was observed.

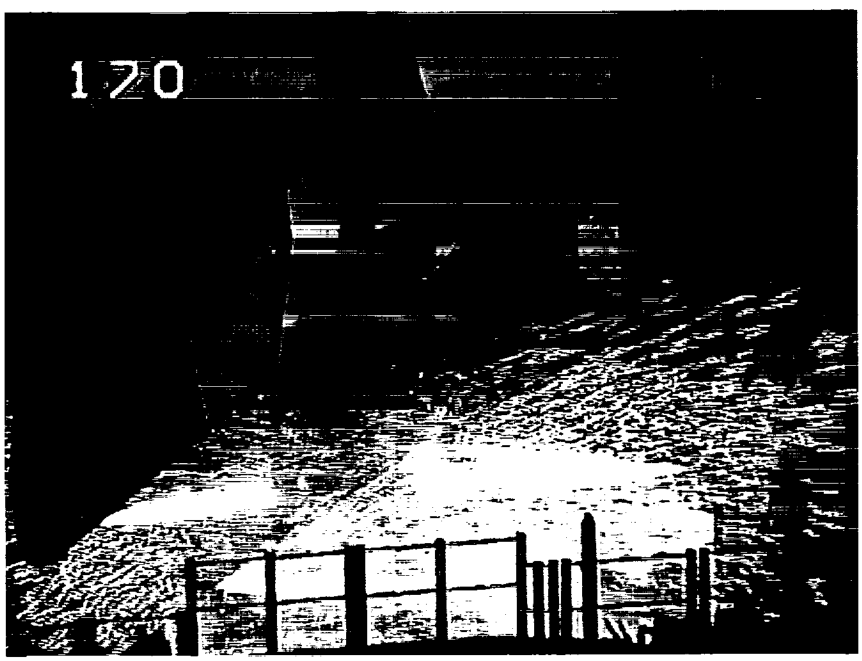

Figure 1 Free burning hydrogen rising to base of right OMS pod

Ice/frost was observed falling from the 17 inch disconnects as well as the LH2 recirculation and feedline bellows and the ET/orbiter attach struts during ignition and liftoff. Also a piece of debris fell from near the left ET/orbiter attach point at liftoff. Ice/frost was observed falling from the forward LOX feedline bellows during liftoff. One piece impacted the right wind and broke into two small pieces as shown in Figure 2. No damage to the vehicle was observed.

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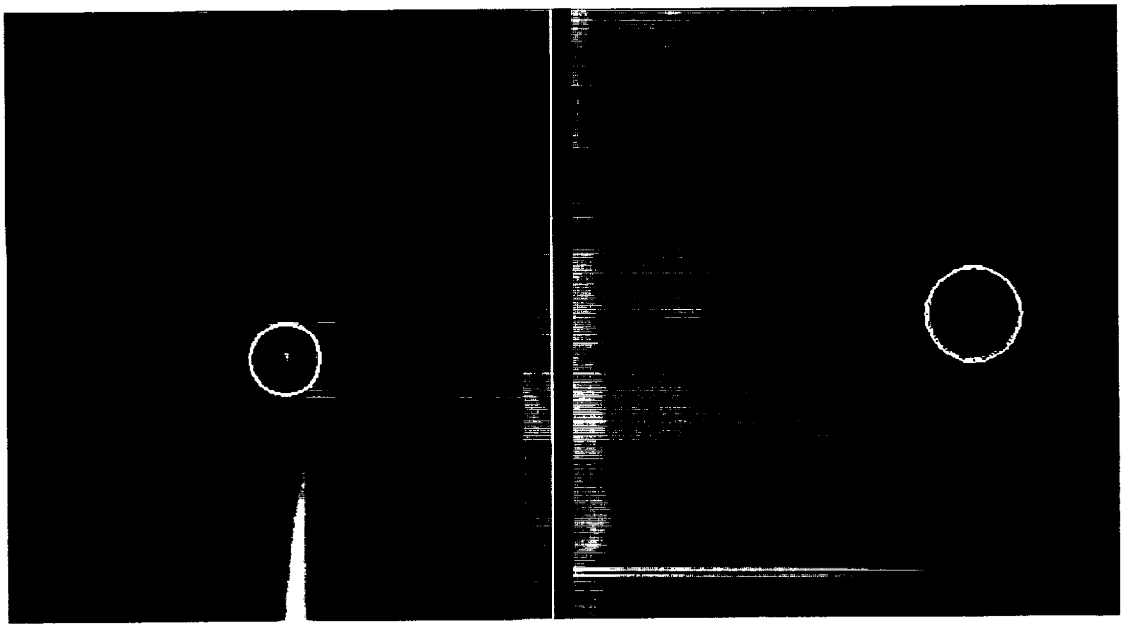

Figure 2 Ice from the forward LOX feedline bellows

Frost was observed around the ME-2 eyelid at liftoff. Figure 3 is a picture from camera E-18 of this frost.

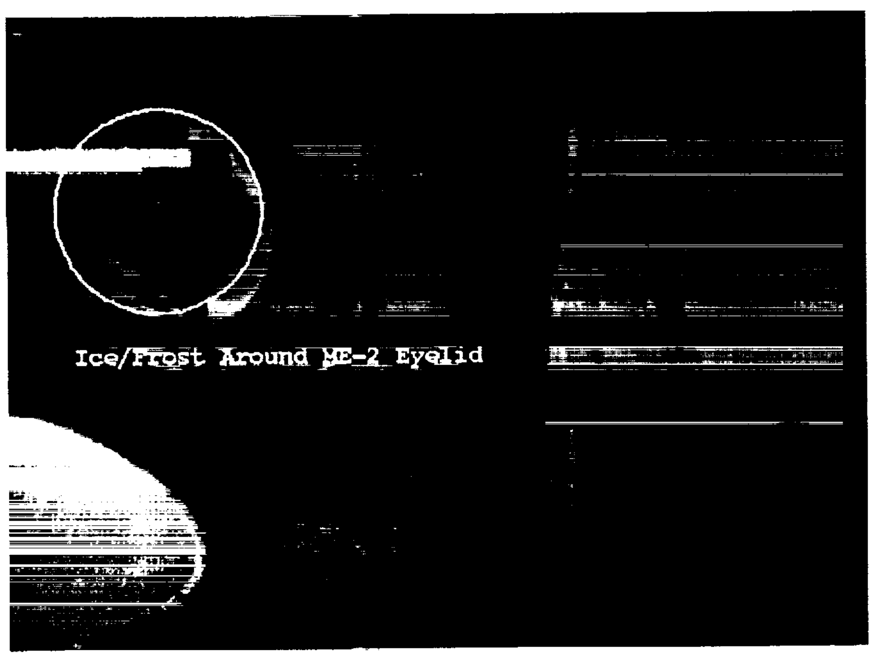

Figure 3 Frost around ME-2 eyelid.

One piece of loose thermal curtain tape was noted near holddown post M-2. Figure 4 shows this tape at liftoff as seen from camera E-8.

C-2.

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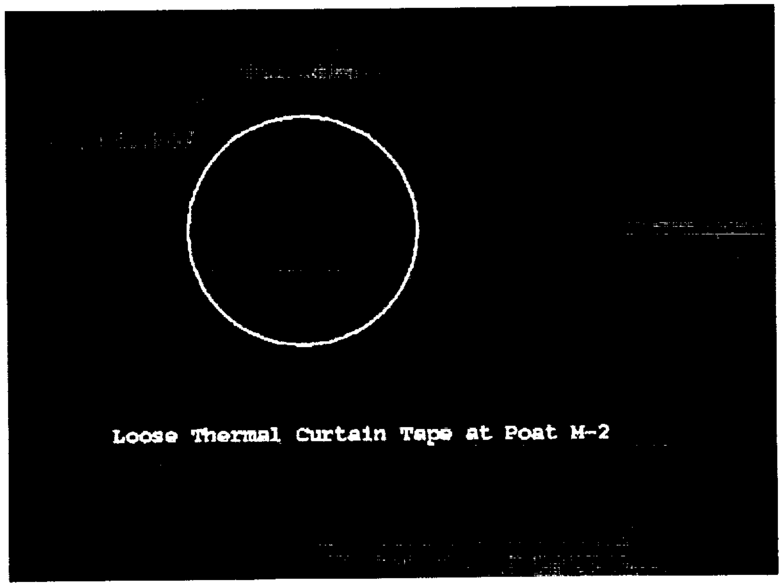

Figure 4 Loose thermal curtain tape on right SRB

Several (greater than 8) flat pieces of debris exited the SRB blast hole at post M-4 during SRM ignition. Examples of this debris from camera E-7 are shown in Figure 5. None of these particles impacted the vehicle.

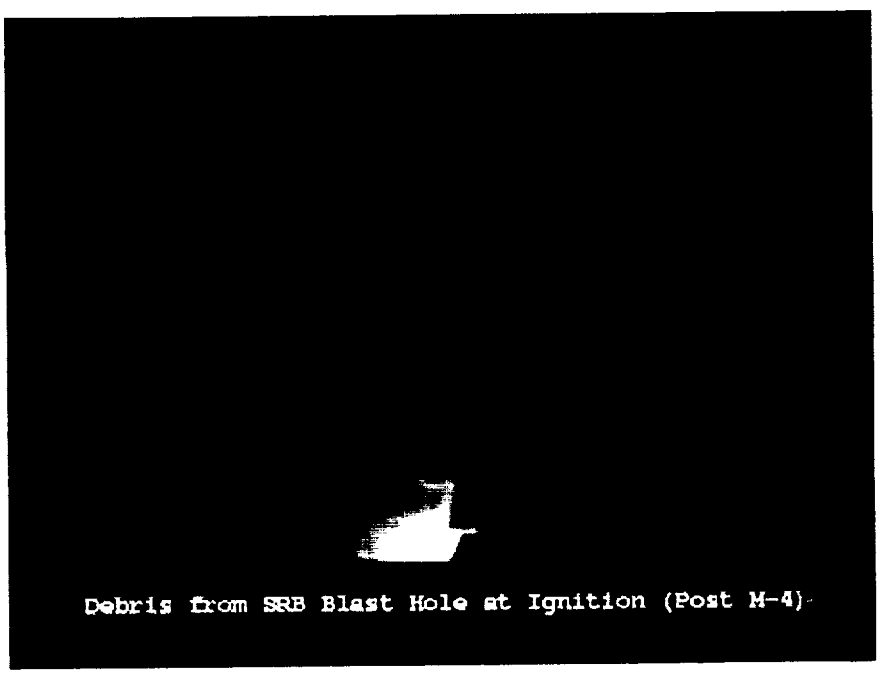

Figure 5 Debris from SRB blast hole

Several streaks were observed in the SSME plumes. A streak was observed in the ME-1 plume prior to liftoff at 05:22:03.358 as shown in Figure 6 and in the ME-2 plume at 05:22:05.319 as shown in Figure 7. There was a streak noted in the ME-1 plume during ascent at 05:42:41.305.

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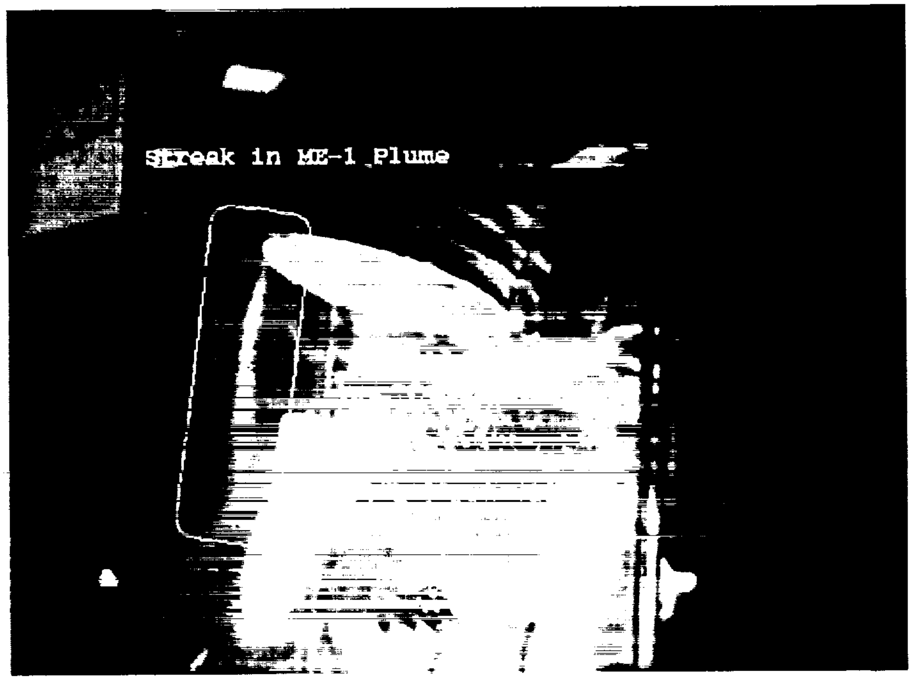

Figure 6 Streak in ME-1

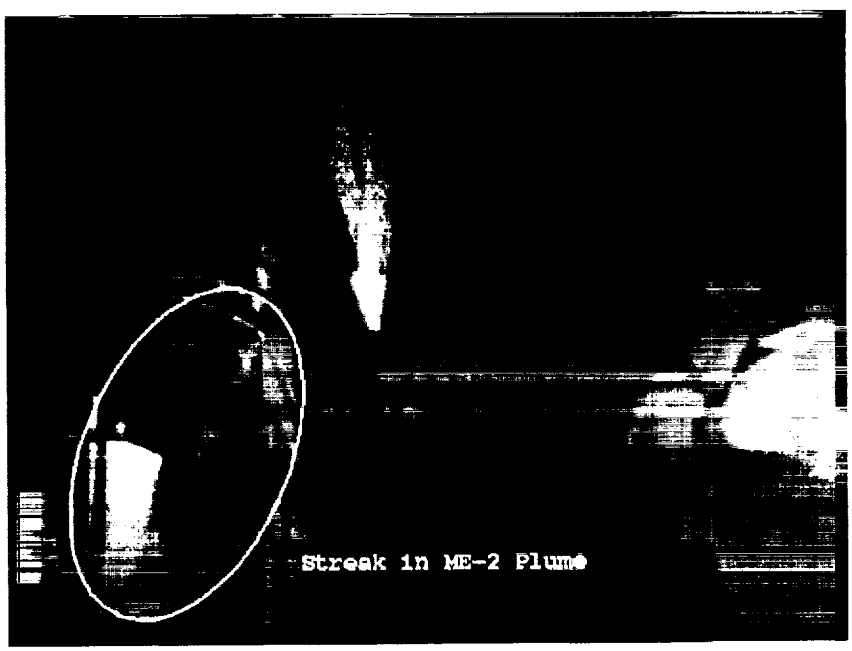

Figure 7 Streak in ME-2

What appears to be a vapor trail or debris streak was noted at approximately T+43 seconds MET between the base of the vertical stabilizer and the right OMS pod. This event is shown in Figure 8 which was taken from camera E-207. The source of these vapors is unknown since they only become visible when near the SSME plumes.

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COLOR PHOTOGRAPH

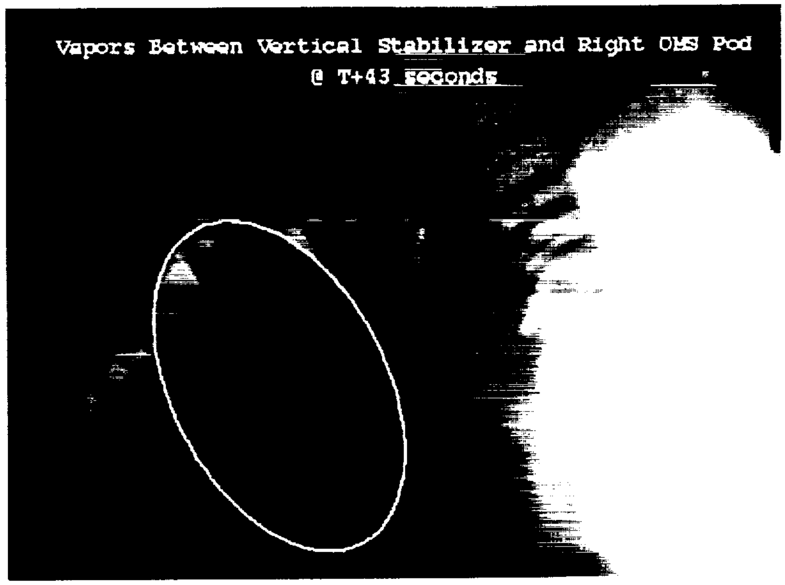

Figure 8 Vapors passing between vertical stabilizer and OMS pod

Figure 9 depicts only two glowing debris particles of several observed being ejected from the SRM plume during ascent at T+59 seconds to T+80 seconds MET from camera TV-4B. These type particles were also observed during the SRB separation event.

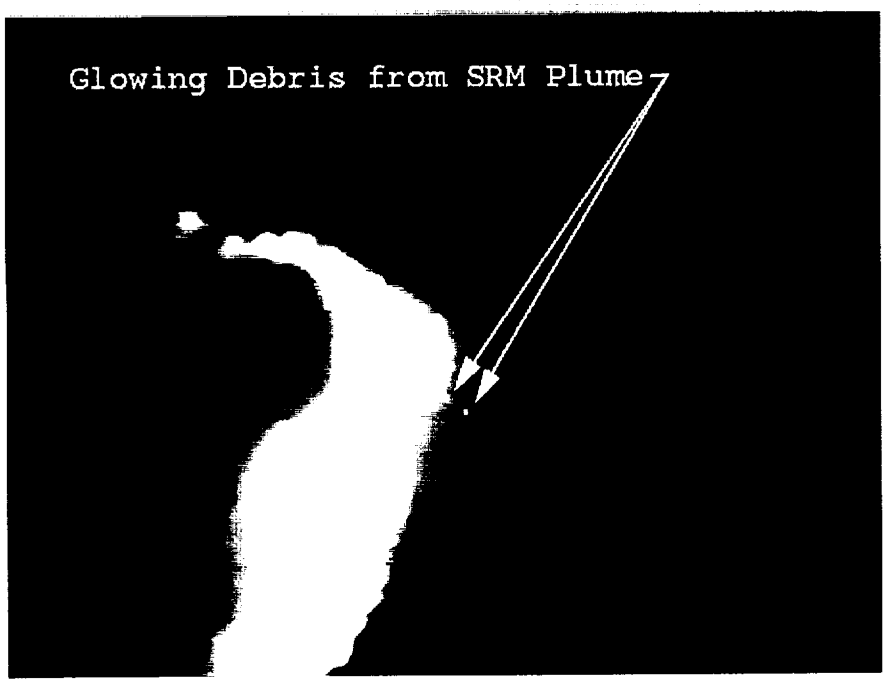

Figure 9 Glowing debris particles ejected from SRB plume

Figure 10 depicts a wire that was attached to the RSS checkout coax connector of the intertank. This wire remained attached while it was in the camera's field of view. This was noted from camera E-33.

ORIGINAL PAGE
COLOR PHOTOGRAPH

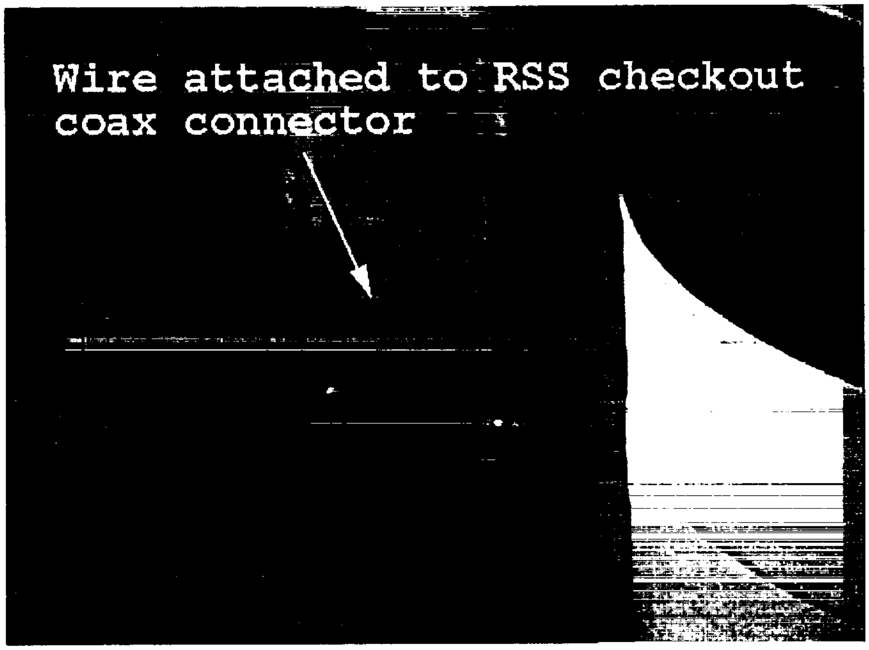

Figure 10 Wire from RSS checkout coax connector on intertank

V. ENGINEERING DATA RESULTS:

a. T-Zero Times:

T-Zero times are determined from cameras that view the SRB holddown posts numbers M-1, M-2, M-5 and M-6. These cameras record the explosive bolt combustion products.

HOLDDOWN POST	CAMERA POSITION	TIME (UTC)
M-1	E-9	05:22:04.002
M-2	E-8	05:22:04.002
M-5	E-12	05:22:04.003
M-6	E-13	05:22:04.003

b. ET Tip Deflection:

Maximum ET tip deflection for this mission was determined to be approximately 31 inches. Figure 11 is a data plot showing the measured motion of the ET tip in both the horizontal and vertical directions. A positive horizontal displacement represents motion in the -Z direction. These data were derived from film camera E-79A.

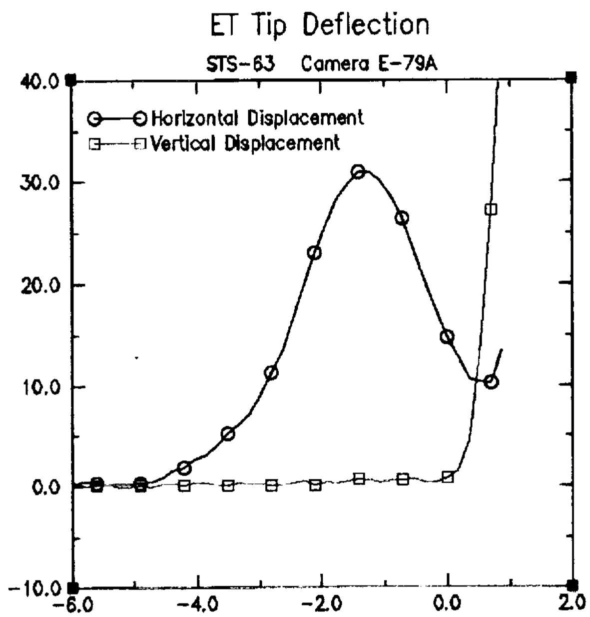

Figure 11 ET Tip Deflection

c. SRB Separation Time:

SRB separation time for STS-63 was determined to be 034:05:24:09.03 UTC as recorded by several tracking cameras.

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Gregory N. Katnik
Barry C. Bowen
J. Bradley Davis

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
NASA
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Mail Code: TV-MSD-7
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13. ABSTRACT *(Maximum 200 words)*

A debris/ice/thermal protection system assessment and integrated photographic analysis was conducted for Shuttle mission STS-63. Debris inspections of the flight elements and launch pad were performed before and after launch. Icing conditions on the External Tank were assessed by the use of computer programs, nomographs, and infrared scanner data during cryogenic loading of the vehicle followed by on-pad visual inspection. High speed photography of the launch was analyzed to identify ice/debris sources and evaluate potential vehicle damage and/or in-flight anomalies. This report documents the ice/debris/thermal protection system conditions and integrated photographic analysis of Shuttle mission STS-63, and the resulting effect on the Space Shuttle program.

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