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Debris/Ice /TPS Assessment and Integrated Photographic Analysis for Shuttle Mission STS-61

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DEBRIS/ICE/TPS ASSESSMENT
AND
INTEGRATED PHOTOGRAPHIC ANALYSIS
OF
SHUTTLE MISSION STS-61

December 2, 1993

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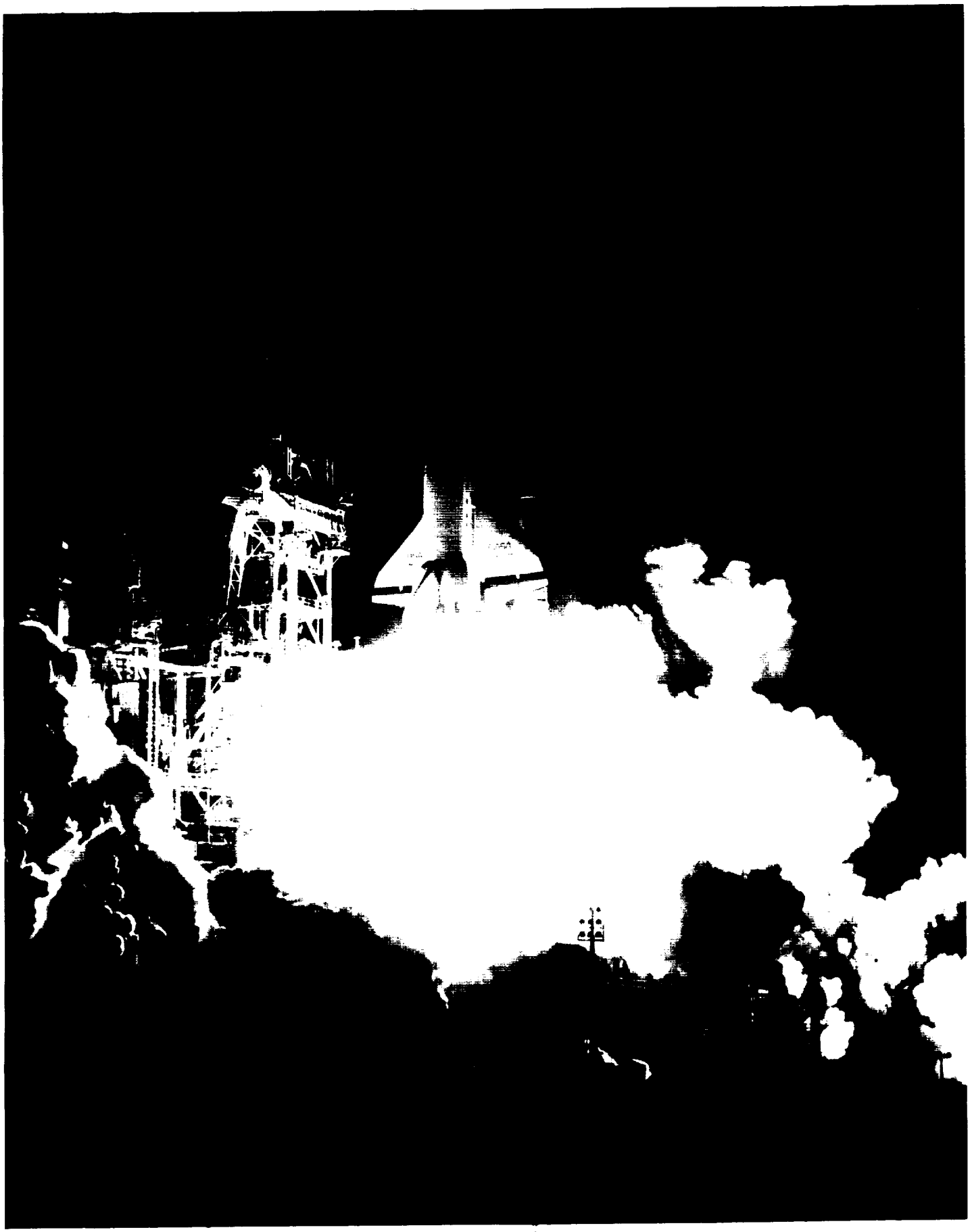
FOREWORD

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 (KSC) Photo/Video Analysis, reports from Johnson Space Center, Marshall Space Flight Center, and Rockwell International - Downey are also included in this document to provide an integrated assessment of the mission.



Shuttle Mission STS-61 was launched at 4:27 a.m. local 12/2/93

1.0 Summary

A pre-launch debris inspection of the pad and Shuttle vehicle was conducted on 30 November 1993. The detailed walkdown of Launch Pad 39B and MLP-2 also included the primary flight elements OV-105 Endeavour (5th flight), ET-60 (LWT 53), and BI-063 SRB's. There were no significant facility or vehicle anomalies.

The vehicle was cryoloaded on 30 November 1993. There were no Launch Commit Criteria (LCC), OMRS, or NSTS-08303 criteria violations. There were no ice/frost conditions outside of the established data base and no IPR's were taken.

The launch was scrubbed at T-5 minutes due to local weather LCC violations. A post drain inspection of the vehicle revealed no significant anomalies.

The vehicle was cryoloaded a second time on 1 December 1993. There were no Launch Commit Criteria, OMRS, or NSTS-08303 criteria violations. There were no ice/frost conditions outside of the established data base and no IPR's were taken.

After the 4:27 a.m. launch on 2 December 1993, a debris inspection of Pad 39B was performed. No flight hardware or TPS materials were found. Damage to the pad overall was minimal.

The GH2 vent line was latched on the second tooth of the latching mechanism and had no loose cables (static retract lanyard). However, the GH2 vent line was outside the south forward flexhose support struts and offset 8-10 inches from the haunch centerline. As a result, the latching mechanism was not centered. The crossbeam between the GUCP legs showed signs of contact with the static retract lanyard.

Further inspection revealed the GH2 vent line had engaged both latch bars, scraped paint near the eighth tooth, and rebounded back to the second tooth. Launch vibration may then have caused the line to move south and disengage from the north latch bar. An IPR documented the GH2 vent line movement and latching process. Troubleshooting will include a planned replacement of the shock absorber, re-evaluation of the latch plate/teeth mechanism, and a series of drop tests.

A total of 127 films and videos were analyzed as part of the post launch data review. No major vehicle damage or lost flight hardware was observed that would have affected the mission. No stud hang-ups occurred on any of the holddown posts. All T-0 umbilicals operated properly.

Orbiter ET/ORB umbilical motion picture film revealed nominal separation of the SRB's from the ET. No detailed engineering data of the External Tank after separation from the Orbiter was obtained.

The Solid Rocket Boosters were inspected at Hanger AF after retrieval. Both frustums had a combined total of 39 MSA-2 debonds over fasteners. A 2" x 0.5" x 0.2" divot occurred on the leading edge of a GEI cork run (right forward segment XB-1099 at 220 degrees). The remaining material was sooted and most likely lost during ascent (IFA STS-61-I-01). Post flight lab analysis determined the loss was not a material/processing failure. The most probable cause of the cork loss is believed to be a debris impact during ascent. Since no debris sources were identified on the RH SRB forward of the damage site, ice from the ET LO2 feedline bellows has been cited as the leading candidate.

The LH frustum was missing three BSM aero heat shield covers. Preliminary post flight assessment revealed the covers had opened and latched properly. The fracture planes on the cover attach rings were not sooted, which may indicate the covers were lost late in flight or at water impact.

A post landing inspection of OV-105 was conducted after the landing at KSC. The Orbiter TPS sustained a total of 120 hits, of which 13 had a major dimension of 1-inch or larger. The Orbiter lower surface had a total of 59 hits, of which 7 had a major dimension of 1-inch or larger. Based on these numbers and comparison to statistics from previous missions of similar configuration, both the total number of debris hits and the number of hits 1-inch or larger was less than average.

Orbiter post landing microchemical sample results revealed a variety of residuals in the Orbiter window samples that were attributed to SRB BSM exhaust, Orbiter TPS, window protective covers, natural landing site products, and paints/primers from various sources. These residual sampling data do not indicate a single source of damaging debris as all of the materials have been documented previously in post-landing sample reports. The residual sample data also showed no debris trends when compared to previous mission data.

A total of five Post Launch Anomalies, including one In-Flight Anomaly, were observed during the STS-61 mission assessment.

2.0 PRE-LAUNCH BRIEFING

The Ice/Debris/TPS/Photographic Analysis Team briefing for launch activities was conducted on 30 November 1993 at 0800 hours. These personnel participated in various team activities, assisted in the collection and evaluation of data, and contributed to reports contained in this document.

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B. Smith	LSOC - SPC	ET Processing
Z. Byrns	NASA - KSC	Level II Integration
J. Stone	RI - DNY	Debris Assess, LVL II Integ
W. Atkinson	RI - LSS	Vehicle Integration
K. Thompson	RI - LSS	Vehicle Integration
R. Hillard	MTI - LSS	SRM Processing
S. Otto	MMMSS- LSS	ET Processing

3.0 SCRUB - LOCAL WEATHER

The first launch attempt of STS-61 was scrubbed at T-5 minutes (extended hold) due to local weather LCC violations.

3.1 PRE-LAUNCH SSV/PAD DEBRIS INSPECTION

A pre-launch debris inspection of the pad and Shuttle vehicle was conducted on 30 November 1993 from 0830-0930 hours. The detailed walkdown of Launch Pad 39B and MLP-2 also included the primary flight elements OV-105 Endeavour (5th flight), ET-60 (LWT 53), and BI-063 SRB's. There were no significant debris issues or vehicle anomalies.

Foam insulation and primer on an ET intertank stringer near the GUCP was damaged prior to final ordnance operations by a wind blown debris catcher/net buckle under the ET GH2 vent line access platform. Although not a cryogenic surface, the area was repaired prior to cryoload.

3.2 ICE/FROST INSPECTION

The Ice/Frost Inspection of the cryoloaded vehicle was performed on 30 November 1993 from 2315 to 0045 hours during the two hour built-in-hold at T-3 hours in the countdown. There were no Launch Commit Criteria, OMRS, or NSTS-08303 criteria violations. There were no conditions outside of the established data base and no IPR's were taken. Ambient weather conditions at the time of the inspection were:

Temperature:	68.8 Degrees F
Relative Humidity:	69.1 Percent
Wind Speed:	14.9 Knots
Wind Direction:	041 Degrees

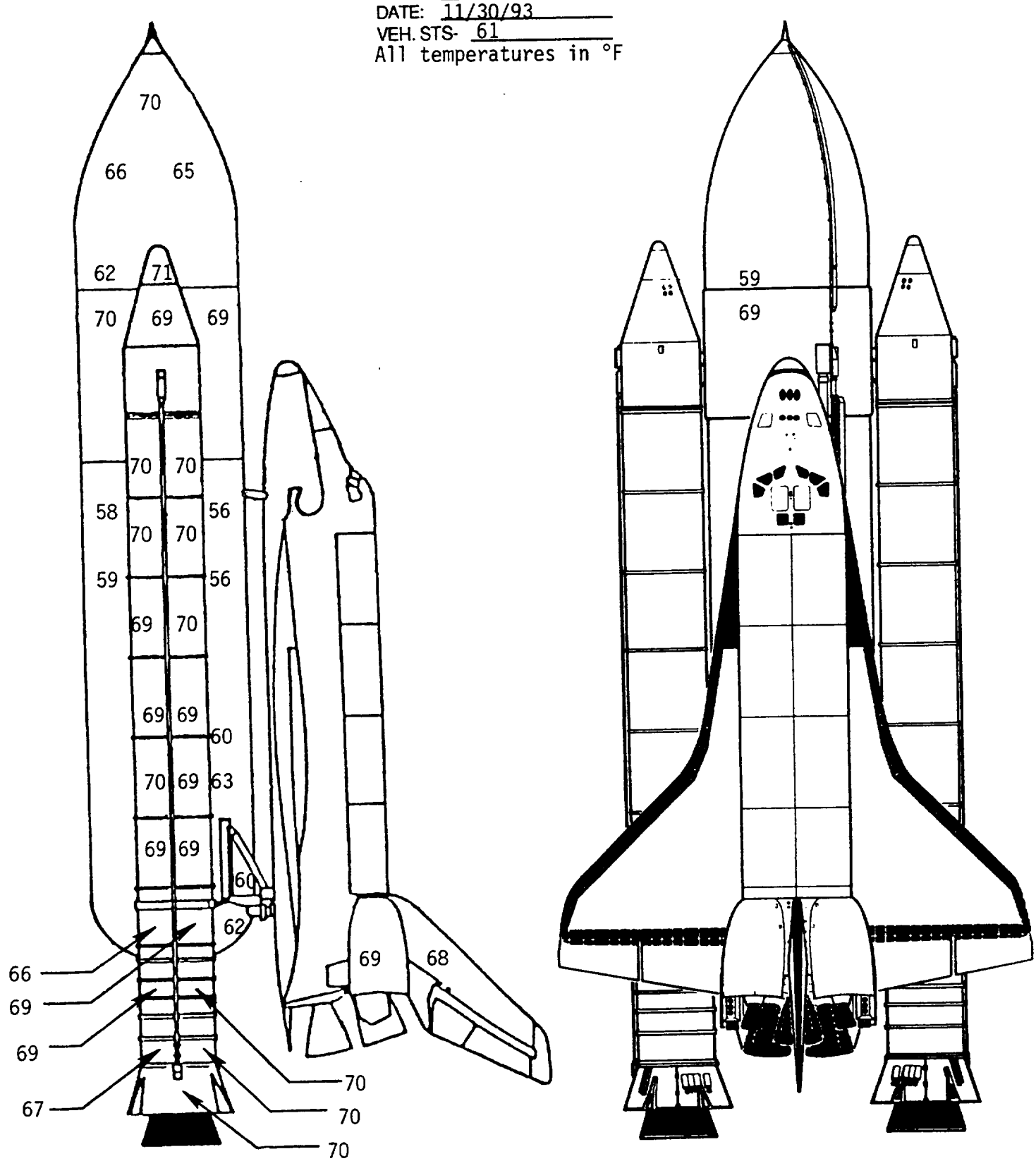
A portable Shuttle Thermal Imager (STI) was used to obtain vehicle surface temperature measurements (ref Figures 1 and 2) for a thermal assessment of the vehicle .

3.3 ORBITER

No Orbiter RCC panel or TPS anomalies were observed. All RCS thruster paper covers were intact, though the paper on thruster R4U had a yellow tint. Typical ice and frost accumulations were present at the SSME heat shield-to-nozzle interfaces. The base heat shield tiles were dry. An infrared scan revealed no unusual temperature gradients on the base heat shield or engine mounted heat shields.

FIGURE 1. **SSV INFRARED SCANNER SURFACE TEMPERATURE SUMMARY DATA**

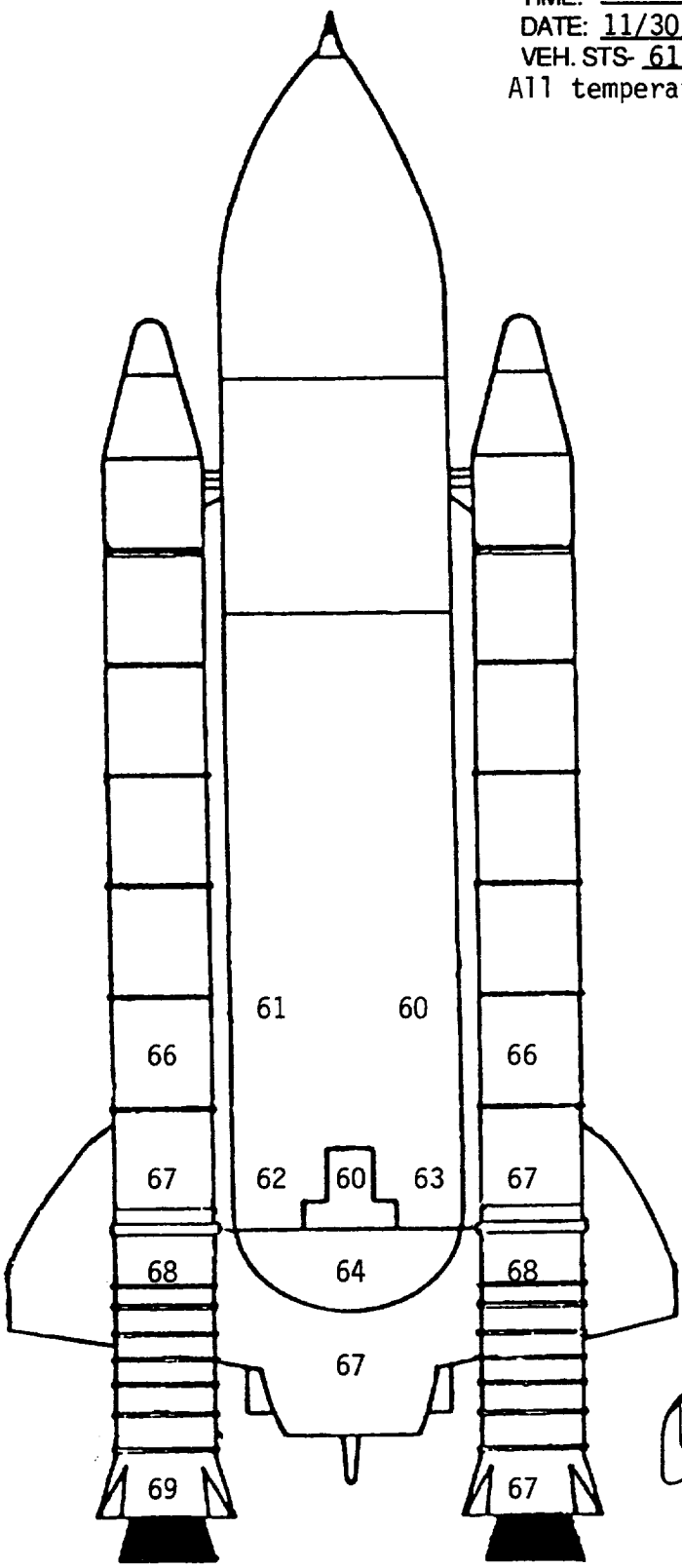
TIME: 2315 - 0045
DATE: 11/30/93
VEH. STS- 61
All temperatures in °F

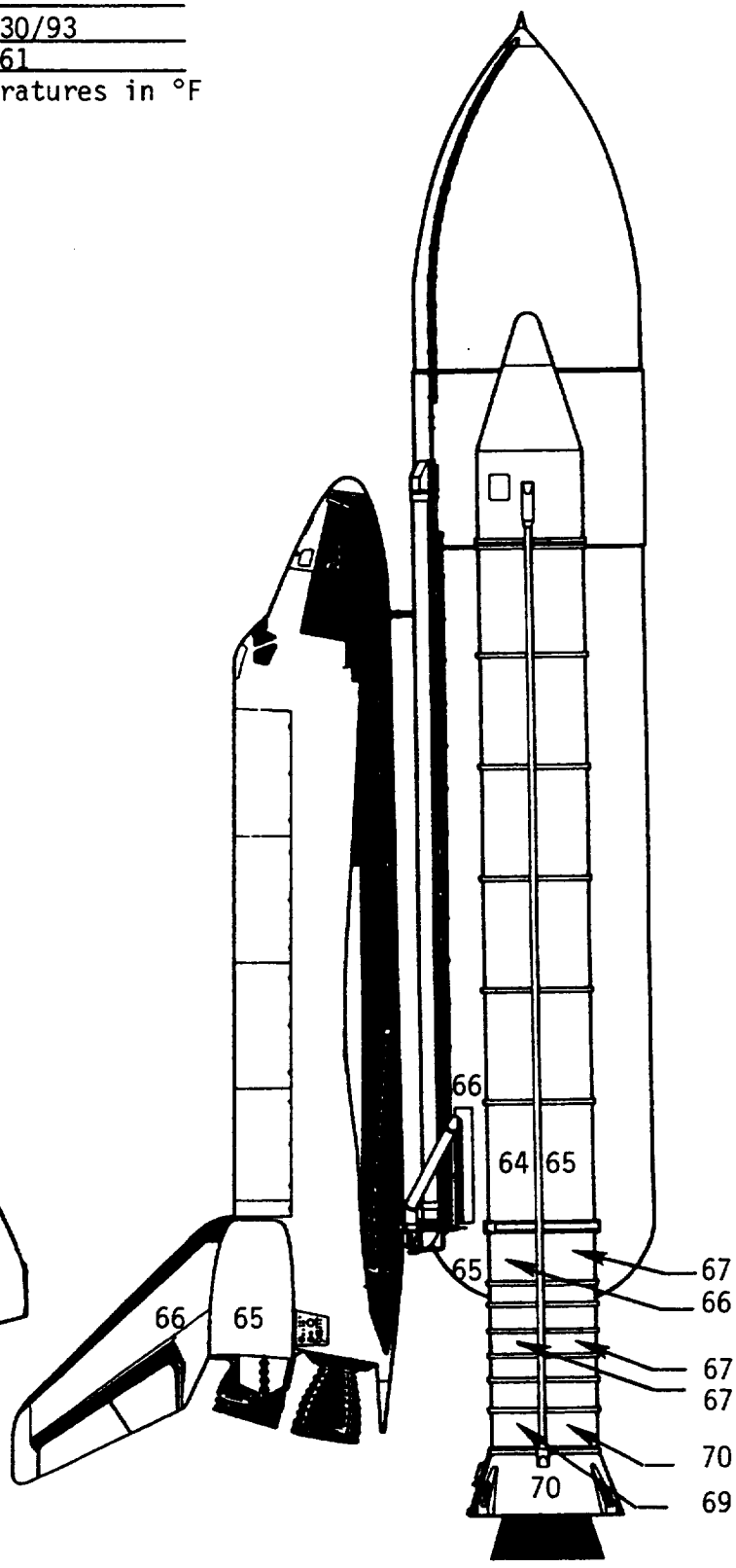


EGG/V-343D

FIGURE 2. **SSV INFRARED SCANNER SURFACE TEMPERATURE SUMMARY DATA**

TIME: 2315 - 0045
DATE: 11/30/93
VEH. STS- 61
All temperatures in °F





3.4 SOLID ROCKET BOOSTERS

The STI portable infrared scanner recorded RH and LH SRB case temperatures of 66-70 degrees F. In comparison, temperatures measured by a hand-held Minolta/Land Cyclops spot radiometer averaged 68 degrees F. All measured temperatures were above the 34 degrees F minimum requirement. The predicted Propellant Mean Bulk Temperature (PMBT) supplied by MTI was 70 degrees F, which was within the required range of 44-86 degrees F.

3.5 EXTERNAL TANK

The ice/frost prediction computer program 'SURFICE' was run from 2030 to 0530 hours and the results tabulated in Figure 3. The program predicted condensate with no ice/frost accumulation on the TPS acreage surfaces during cryoload.

Light condensate, but no ice or frost accumulation, was observed by the Ice Team on the LO2 tank. There were no TPS anomalies. The portable STI measured surface temperatures that averaged 66 degrees F on the ogive and 61 degrees F on the barrel section. In comparison, the Cyclops radiometer measured temperatures that averaged 65 degrees F on the ogive and 61 degrees F on the barrel; SURFICE predicted temperatures of 60 degrees F on the ogive and 54 degrees F on the barrel.

The intertank acreage exhibited no TPS anomalies. Typical ice/frost accumulations and no unusual vapors were present on the ET umbilical carrier plate. The on-pad repair to the area of intertank CPR near the GUCP was intact and showed no anomalies.

There were no LH2 tank TPS acreage anomalies. Light amounts of condensate, but no ice/frost, was present on the acreage and aft dome. The portable STI measured surface temperatures that averaged 57 degrees F on the upper LH2 tank and 62 degrees F on the lower LH2 tank. In comparison, the Cyclops radiometer measured temperatures that averaged 57 degrees F on the upper and 62 degrees F on the lower LH2 tank, respectively; SURFICE predicted temperatures of 56 degrees F on the upper LH2 tank and 58 degrees F on the lower LH2 tank.

There were no anomalies on the bipod jack pad closeouts. A crack, 12-inches long by 3/8-inch wide, was present in the -Y vertical strut cable tray forward surface TPS near the longeron closeout interface. The crack exhibited no offset and was not filled with ice or frost. The presence of the crack was acceptable for flight per the NSTS-08303 criteria and no IPR was required.

Less than usual amounts of ice/frost were present in the LO2 feedline bellows and support brackets.

STS- 61	TEST S0007 Scrub - RTLS Weather															DATE: 30 November 1993					T-0 TIME: DATE:				NASA KSC Ice/Frost/Debris Team
ORBITER 105	ET 60	SRB BI-063	MLP 2	PAD B	LO2 CHILLDOWN TIME: 19:59 SLOW FILL TIME: 20:37					FAST FILL TIME: 20:49 REPLENISH TIME: 22:44						LH2 CHILLDOWN TIME: 19:59 SLOW FILL TIME: 20:08					FAST FILL TIME: 20:32 REPLENISH TIME: 22:56					
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
2030	68.80	60.6	54.86	16	42	II	9.44	57.45	0.0000	-0.2124	II	9.44	53.32	0.0010	-0.1826	II	11.20	53.76	0.0008	-0.2135	II	19.36	57.67	0.0000	-0.3775
2045	68.40	68.0	57.64	12	44	II	7.08	56.47	0.0007	-0.1749	II	7.08	53.02	0.0024	-0.1455	II	8.40	53.52	0.0025	-0.1694	II	14.52	56.43	0.0013	-0.3026
2100	68.60	63.6	56.00	14	56	II	8.26	56.35	0.0000	-0.1930	II	8.26	53.12	0.0017	-0.1635	II	9.80	53.58	0.0016	-0.1908	II	16.94	56.37	0.0000	-0.3390
2115	68.40	64.4	56.15	14	51	II	8.26	56.18	0.0000	-0.1930	II	8.26	53.11	0.0018	-0.1634	II	9.80	53.58	0.0018	-0.1908	II	16.94	56.17	0.0000	-0.3391
2130	68.40	63.8	55.89	14	49	II	8.26	56.17	0.0000	-0.1916	II	8.26	52.96	0.0017	-0.1621	II	9.80	53.43	0.0017	-0.1892	II	16.94	56.17	0.0000	-0.3365
2145	68.80	63.4	56.11	14	49	II	8.26	56.56	0.0000	-0.1945	II	8.26	53.27	0.0016	-0.1648	II	9.80	53.73	0.0016	-0.1924	II	16.94	56.56	0.0000	-0.3414
2200	68.80	65.4	56.96	14	49	II	8.26	56.81	0.0001	-0.1992	II	8.26	53.77	0.0019	-0.1695	II	9.80	54.23	0.0019	-0.1977	II	16.94	56.81	0.0002	-0.3501
2215	68.40	62.2	55.19	17	53	II	10.03	57.52	0.0000	-0.2248	II	10.03	53.65	0.0011	-0.1949	II	11.90	54.07	0.0009	-0.2279	II	20.57	57.79	0.0000	-0.4022
2230	68.60	67.6	57.68	13	50	II	7.67	56.87	0.0005	-0.1892	II	7.67	53.65	0.0023	-0.1595	II	9.10	54.13	0.0023	-0.1859	II	15.73	56.86	0.0009	-0.3303
2245	68.20	68.2	57.53	12	41	II	7.08	56.31	0.0007	-0.1736	II	7.08	52.86	0.0024	-0.1442	II	8.40	53.36	0.0025	-0.1680	II	14.52	56.28	0.0013	-0.3004
2300	68.20	69.0	57.85	12	33	II	7.08	56.50	0.0008	-0.1753	II	7.08	53.05	0.0025	-0.1457	II	8.40	53.55	0.0026	-0.1698	II	14.52	56.47	0.0015	-0.3034
2315	68.80	70.4	58.80	13	37	II	7.67	57.53	0.0006	-0.1955	II	7.67	54.31	0.0026	-0.1655	II	9.10	54.81	0.0027	-0.1928	II	15.73	57.54	0.0015	-0.3416
2330	68.80	67.6	57.87	15	40	II	8.85	57.57	0.0002	-0.2179	II	8.85	54.71	0.0021	-0.1877	II	10.50	55.18	0.0021	-0.2190	II	18.15	57.81	0.0004	-0.3859
2345	68.20	68.6	57.69	14	40	II	8.26	56.97	0.0005	-0.2010	II	8.26	53.96	0.0023	-0.1711	II	9.80	54.40	0.0023	-0.1996	II	16.94	57.00	0.0008	-0.3537
2400	68.80	71.6	59.27	14	36	II	8.26	58.06	0.0008	-0.2120	II	8.26	55.07	0.0027	-0.1818	II	9.80	55.54	0.0028	-0.2119	II	16.94	58.12	0.0015	-0.3736
0015	69.00	70.4	59.10	16	33	II	8.85	58.43	0.0006	-0.2271	II	8.85	55.60	0.0024	-0.1958	II	10.50	56.05	0.0025	-0.2283	II	18.15	58.48	0.0010	-0.4026
0030	69.00	68.2	58.31	18	47	II	9.44	58.12	0.0001	-0.2350	II	9.44	55.42	0.0020	-0.2046	II	11.20	55.86	0.0020	-0.2367	II	19.36	58.17	0.0002	-0.4188
0045	69.20	67.2	58.10	16	54	II	9.44	58.06	0.0000	-0.2346	II	9.44	55.38	0.0019	-0.2040	II	11.20	55.81	0.0019	-0.2361	II	19.36	58.12	0.0000	-0.4177
0100	69.20	65.6	57.44	19	57	II	11.21	59.16	0.0000	-0.2696	II	11.21	55.86	0.0013	-0.2387	II	13.30	56.25	0.0011	-0.2791	II	22.99	59.46	0.0000	-0.4873
0115	69.00	68.2	58.31	19	53	II	11.21	59.01	0.0000	-0.2752	II	11.21	56.30	0.0017	-0.2442	II	13.30	56.69	0.0016	-0.2854	II	22.99	59.28	0.0000	-0.4980
0130	68.80	67.6	57.87	19	51	II	11.21	58.81	0.0000	-0.2709	II	11.21	55.95	0.0016	-0.2399	II	13.30	56.34	0.0015	-0.2805	II	22.99	59.09	0.0000	-0.4900
0145	69.00	65.0	56.99	20	44	II	11.80	59.29	0.0000	-0.2781	II	11.80	55.75	0.0011	-0.2472	II	14.00	56.13	0.0009	-0.2892	II	24.20	59.64	0.0000	-0.5048
0200	69.00	65.4	57.16	17	49	II	10.03	58.20	0.0000	-0.2405	II	10.03	55.05	0.0015	-0.2101	II	11.90	55.47	0.0014	-0.2454	II	20.57	58.41	0.0000	-0.4306
0215	68.80	64.8	56.71	17	44	II	10.03	57.98	0.0000	-0.2365	II	10.03	54.70	0.0014	-0.2062	II	11.90	55.12	0.0013	-0.2410	II	20.57	58.20	0.0000	-0.4235
0230	68.80	62.2	55.58	18	46	II	10.62	58.32	0.0000	-0.2416	II	10.62	54.34	0.0009	-0.2114	II	12.60	54.75	0.0007	-0.2472	II	21.78	58.64	0.0000	-0.4344
0245	69.00	61.0	55.24	16	42	II	9.44	57.66	0.0000	-0.2155	II	9.44	53.63	0.0010	-0.1857	II	11.20	54.06	0.0009	-0.2170	II	19.36	57.87	0.0000	-0.3831
0300	69.00	63.4	56.30	17	44	II	10.03	58.16	0.0000	-0.2348	II	10.03	54.55	0.0012	-0.2046	II	11.90	54.97	0.0011	-0.2390	II	20.57	58.39	0.0000	-0.4201
0315	69.20	63.0	56.32	19	48	II	11.21	59.10	0.0000	-0.2614	II	11.21	55.21	0.0009	-0.2308	II	13.30	55.60	0.0007	-0.2696	II	22.99	59.44	0.0000	-0.4721
0330	69.00	64.0	56.56	19	50	II	11.21	58.93	0.0000	-0.2621	II	11.21	55.26	0.0010	-0.2314	II	13.30	55.65	0.0009	-0.2707	II	22.99	59.26	0.0000	-0.4736
0345	68.80	64.6	56.62	18	54	II	10.62	58.38	0.0000	-0.2488	II	10.62	54.94	0.0013	-0.2183	II	12.60	55.35	0.0011	-0.2552	II	21.78	58.65	0.0000	-0.4476
0400	68.80	70.8	59.15	22	56	II	12.96	59.79	0.0000	-0.3215	II	12.96	57.39	0.0017	-0.2896	II	15.40	57.75	0.0016	-0.3391	II	26.62	60.16	0.0000	-0.5888
0415	68.40	70.0	58.45	19	59	II	11.21	58.47	0.0000	-0.2732	II	11.21	56.13	0.0019	-0.2422	II	13.30	56.52	0.0019	-0.2832	II	22.99	58.71	0.0000	-0.4948
0430	69.00	64.2	56.65	21	56	II	12.39	59.57	0.0000	-0.2882	II	12.39	55.77	0.0008	-0.2572	II	14.70	56.14	0.0005	-0.3010	II	25.41	59.97	0.0000	-0.5250
0445	68.80	66.6	57.46	20	56	II	11.80	59.11	0.0000	-0.2808	II	11.80	55.95	0.0013	-0.2496	II	14.00	56.33	0.0012	-0.2922	II	24.20	59.45	0.0000	-0.5099
0500	68.60	65.2	56.68	21	58	II	12.39	59.20	0.0000	-0.2863	II	12.39	55.62	0.0009	-0.2554	II	14.70	55.99	0.0007	-0.2969	II	25.41	59.60	0.0000	-0.5218
0515	68.60	66.0	57.02	19	56	II	11.21	58.57	0.0000	-0.2634	II	11.21	55.36	0.0013	-0.2327	II	13.30	55.75	0.0012	-0.2722	II	22.99	58.88	0.0000	-0.4764
0530	69.00	62.0	55.69	20	51	II	11.80	59.23	0.0000	-0.2683	II	11.80	55.00	0.0008	-0.2376	II	14.00	55.38	0.0003	-0.2781	II	24.20	59.62	0.0000	-0.4865
AVG.	68.75	65.94	57.12	16.62	NE		9.81	57.97				9.81	54.68				11.84	55.10				20.11	58.14		

Period of Ice Team Inspection

FIGURE 3. "SURFICE" Computer Predictions

There were no TPS anomalies or unusual accumulations of ice/frost on the LO2 ET/ORB umbilical. Ice/frost fingers on the separation bolt pyrotechnic canister purge vents were typical.

Condensate was present in the LH2 recirculation line bellows and the LH2 feedline bellows.

Typical amounts of ice/frost had accumulated on the LH2 ET/ORB umbilical. Typical ice/frost fingers had formed on the pyro canister and plate gap purge vents. Ice/frost was present on the bondline of the aft pyro canister closeout indicating a thermal short. There were no unusual vapors or cryogenic drips during tanking and stable replenish.

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

Anomaly 001 documented a crack 12-inches long by 3/8-inch wide in the -Y vertical strut cable tray forward surface TPS. The crack exhibited no offset and was not filled with ice or frost.

Anomaly 002 (documentation only) recorded ice/frost formations on the LO2 and LH2 ET/ORB umbilicals, pyro can purge vents, purge barrier, and LH2 recirculation line bellows/burst discs.

Anomaly 003 (documentation only) recorded ice/frost formations on the LO2 feedline support brackets and bellows.

Anomaly 004 documented two ice/frost formations via OTV at the cable tray support ramp XT-1528 and aft of the +Y ET/SRB cable tray-to-vertical strut fairing closeout.

3.6 FACILITY

All SRB sound suppression water troughs were filled and properly configured for launch (LCC requirement). There was no debris on the MLP deck or in the SRB holddown post areas.

No leaks were observed on either the LO2 or LH2 Orbiter T-0 umbilicals, the GH2 vent line, or the GUCP.

Pre-launch configuration of ET intertank and GUCP. TPS on a stringer near the GUCP was damaged by a wind blown debris net buckle under the GH2 vent line access platform. Although not a cryogenic surface, the area was repaired prior to cryoload.

Pre-launch configuration of bipod jack pad closeouts

Top photo shows pre-launch configuration of -Y vertical strut cable tray forward surface TPS. A crack, 12" x 3/8", appeared after cryoload (bottom photo). The crack exhibited no offset.

3.7 POST DRAIN VEHICLE INSPECTION

A post-drain inspection was performed at Pad-39B from 1030 to 1130 hours on 1 December 1993.

The tumble valve cover on the External Tank was intact. The nosecone footprint area was inaccessible for inspection.

No anomalies (divots or cracks) were observed on the LO2 tank, intertank, or LH2 tank acreage.

Ice remained in the LO2 feedline support brackets, but no loose foam or TPS damage was visible.

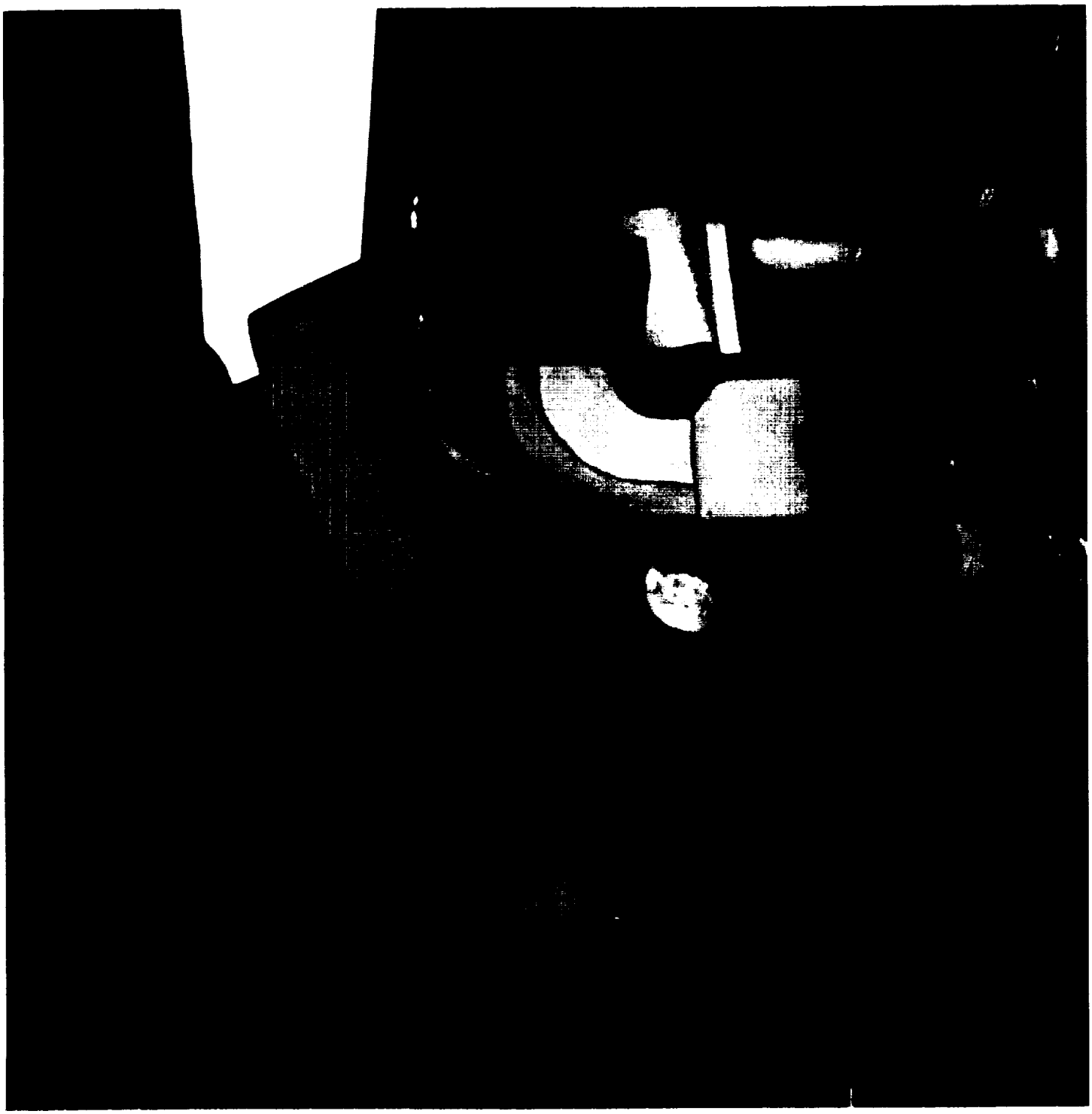
Bipod jack pad closeouts were intact and flush with adjacent LH2 tank-to-intertank flange closeout foam.

A small crack in the -Y ET/SRB vertical strut cable tray forward surface TPS (reported during the Ice Team Inspection) was still visible.

No anomalies were observed on the Orbiter, Solid Rocket Boosters, or MLP deck.

No significant vehicle damage was discovered as a result of the post drain inspection.

No anomalies were visible on the GUCP, GH2 vent line, or the TPS repair to the intertank stringer near the GUCP



After drain, ice was still present on the LH2 ET/ORB umbilical outboard side, upper plate gap purge vent, pyro can purge vent, and cable tray drain hole. No anomalies were observed.

4.0 LAUNCH

STS-61 was launched at 93:336:09:26:59.983 GMT (04:27 am local) on 2 December 1993.

4.1 PRE-LAUNCH SSV/PAD DEBRIS INSPECTION

A second pre-launch SSV/pad debris inspection was not performed due to the 24 hour scrub turnaround.

4.2 ICE/FROST INSPECTION

The Ice/Frost Inspection of the cryoloaded vehicle was performed on 1 December 1993 from 2255 to 0001 hours during the two hour built-in-hold at T-3 hours in the countdown. There were no Launch Commit Criteria, OMRS, or NSTS-08303 criteria violations. There were no conditions outside of the established data base and no IPR's were taken. Ambient weather conditions at the time of the inspection were:

Temperature:	68.5 Degrees F
Relative Humidity:	68.5 Percent
Wind Speed:	14 Knots
Wind Direction:	055 Degrees

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 4 and 5.

4.3 ORBITER

No Orbiter tile or RCC panel anomalies were observed. All RCS thruster paper covers, including the wet covers on the R4U and L4L nozzles, were intact. Typical ice and 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.

4.4 SOLID ROCKET BOOSTERS

SRB case temperatures measured by the PSTI averaged 65-69 degrees F. In comparison, temperatures measured by a spot radiometer ranged from 65 to 68 degrees F and the SRB GEI measured temperatures ranging from 68 to 72 degrees F. This was the first flight using reduced GEI instrumentation with only four case acreage temperature sensors per SRM. All measured temperatures were above the 34 degrees F minimum requirement. The predicted Propellant Mean Bulk Temperature (PMBT) supplied by MTI was 70 degrees F, which was within the required range of 44-86 degrees Fahrenheit.

FIGURE 4. **SSV INFRARED SCANNER SURFACE TEMPERATURE SUMMARY DATA**

TIME: 2255 - 0001
DATE: 12/1/93
VEH. STS- 61
All temperatures in °F

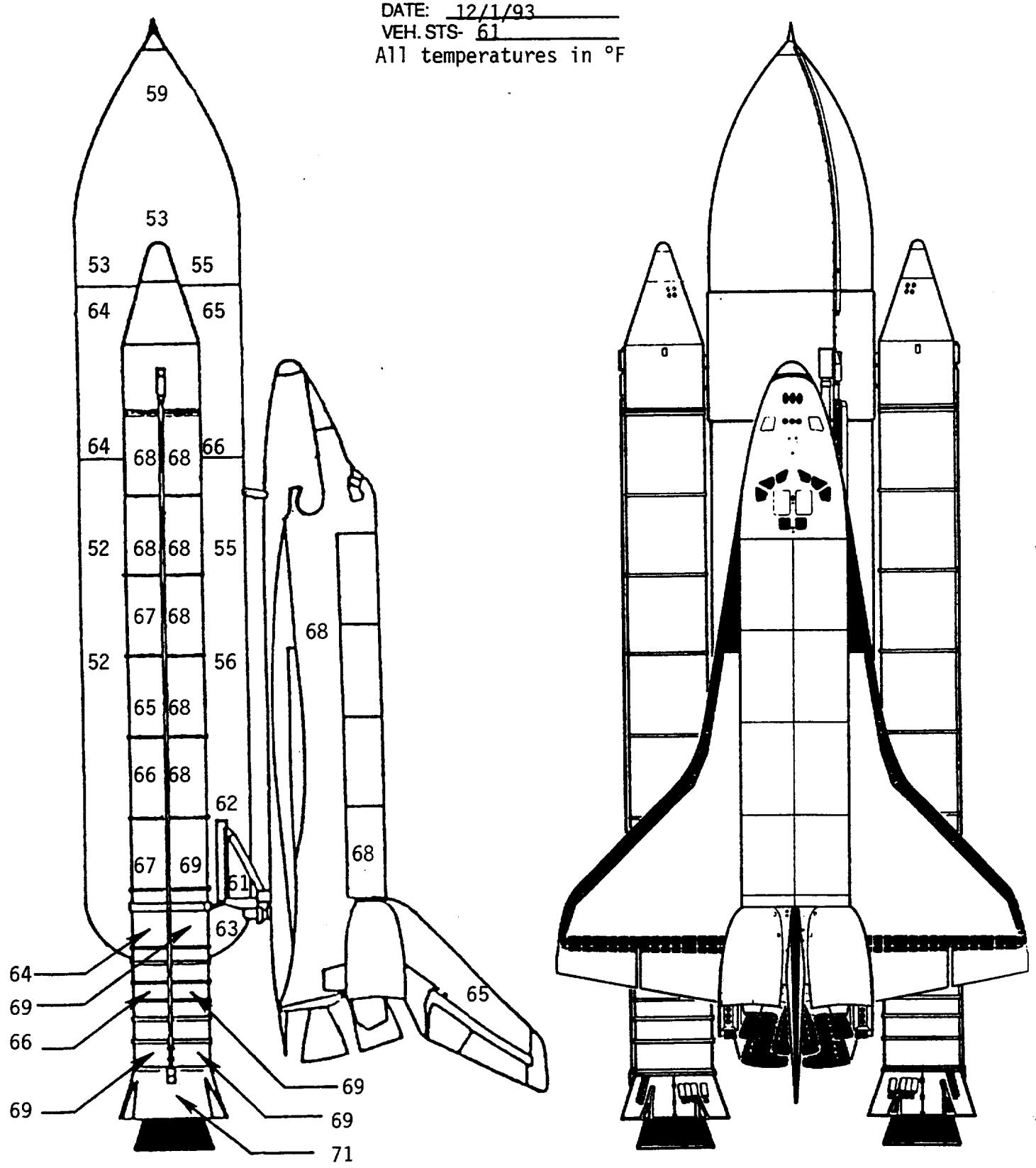
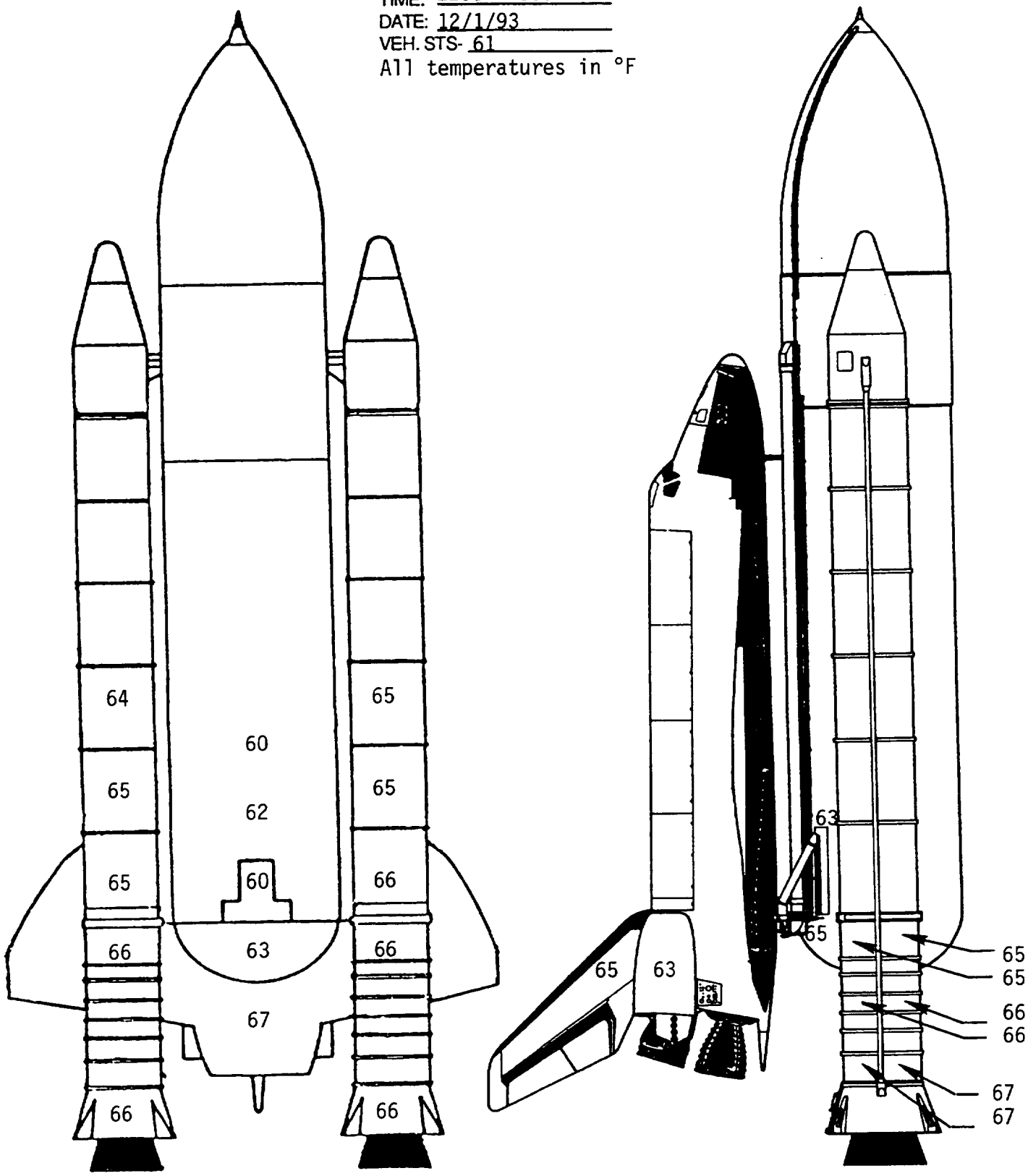


FIGURE 5. **SSV INFRARED SCANNER SURFACE TEMPERATURE SUMMARY DATA**

TIME: 2255 - 0001
DATE: 12/1/93
VEH. STS- 61
All temperatures in °F



4.5 EXTERNAL TANK

The ice/frost prediction computer program 'SURFICE' was run from 2000 to 0400 hours and the results tabulated in Figure 6. The program predicted condensate with no ice/frost accumulation on the TPS acreage surfaces during cryoload.

The Ice Team observed no ice/frost accumulations on the LO2 tank though light condensate was present on the LO2 tank ogive and barrel sections. There were no TPS anomalies. Surface temperatures as measured by the infrared radiometer averaged 58 degrees F on the ogive and 54 degrees F on the barrel section. In comparison, SURFICE predicted temperatures of 57 degrees F on the ogive and 53 degrees F on the barrel.

The intertank acreage exhibited no TPS anomalies. Typical ice/frost accumulation, but no unusual vapor, was present on the ET umbilical carrier plate. The radiometer measured a surface temperature of 65 degrees F.

There were no LH2 tank TPS acreage anomalies. Condensate, but no ice or frost, was present on the acreage and aft dome. The portable STI measured surface temperatures that averaged 54 degrees F on the upper LH2 tank and 62 degrees F on the lower LH2 tank. In comparison, the Cyclops radiometer measured temperatures that averaged 52 degrees F on the upper and 60 degrees F on the lower LH2 tank, respectively; SURFICE predicted temperatures of 54 degrees F on the upper LH2 tank and 57 degrees F on the lower LH2 tank.

The bipod jack pad closeouts were intact and flush with adjacent foam. A small ice/frost spot formed on the -Y bipod spindle housing closeout bondline.

The crack in the -Y vertical strut cable tray forward surface TPS near the longeron closeout interface had not changed since the first tanking. An ice/frost accumulation 2-inches in diameter had formed on the aft side of the -Y vertical strut, but no TPS defect was visible.

Typical amounts of ice/frost were present in the LO2 feedline bellows and support brackets.

There were no TPS anomalies on the LO2 ET/ORB umbilical. Ice/frost fingers on the separation bolt pyrotechnic canister purge vents were typical.

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

STS- 61	TEST S0007 LAUNCH														DATE: 1 December 1993					T-0 TIME: 4:26:59.983 DATE: 12/2/93				NASA KSC Ice/Frost/Debris Team
ORBITER 105	ET 60	SRB BI-C63	MLP 2	PAD B	LO2 CHILLDOWN TIME: 19:23 SLOW FILL TIME: 20:09			FAST FILL TIME: 20:22 REPLENISH TIME: 22:24			LH2 CHILLDOWN TIME: 19:23 SLOW FILL TIME: 19:39			FAST FILL TIME: 20:22 REPLENISH TIME: 22:12										
TIME (EST)	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				
	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
2000	68.80	71.8	59.54	15	54	II	8.85	58.57	0.0007	-0.2285	II	8.85	55.73	0.0026	-0.1980	II	10.50	56.18	0.0027	-0.2309	II	18.15	58.62	0.0013	-0.4054
2015	68.60	73.2	59.88	16	51	II	9.44	58.90	0.0008	-0.2439	II	9.44	56.21	0.0027	-0.2131	II	11.20	56.65	0.0028	-0.2487	II	19.36	58.98	0.0013	-0.4355
2030	69.00	70.2	59.11	16	51	II	9.44	58.59	0.0004	-0.2404	II	9.44	55.91	0.0023	-0.2097	II	11.20	56.34	0.0024	-0.2447	II	19.36	58.66	0.0007	-0.4287
2045	68.40	70.4	58.60	16	55	II	9.44	58.04	0.0004	-0.2342	II	9.44	55.34	0.0023	-0.2037	II	11.20	55.77	0.0024	-0.2379	II	19.36	58.11	0.0007	-0.4179
2100	69.00	71.6	59.66	16	53	II	9.44	58.93	0.0006	-0.2441	II	9.44	56.25	0.0025	-0.2134	II	11.20	56.68	0.0026	-0.2489	II	19.36	59.00	0.0010	-0.4357
2130	68.40	67.8	57.56	19	54	II	11.21	58.40	0.0000	-0.2665	II	11.21	55.59	0.0016	-0.2357	II	13.30	55.99	0.0015	-0.2756	II	22.99	58.70	0.0000	-0.4822
2200	68.60	69.8	58.56	15	57	II	8.85	57.89	0.0005	-0.2213	II	8.85	55.04	0.0023	-0.1910	II	10.50	55.49	0.0024	-0.2229	II	18.15	57.94	0.0008	-0.3924
2230	68.20	68.2	57.53	16	54	II	9.44	57.32	0.0002	-0.2263	II	9.44	54.60	0.0020	-0.1960	II	11.20	55.04	0.0020	-0.2290	II	19.36	57.39	0.0002	-0.4034
2300	69.00	68.0	58.31	15	56	II	8.85	57.91	0.0003	-0.2215	II	8.85	55.07	0.0022	-0.1912	II	10.50	55.51	0.0022	-0.2230	II	18.15	57.95	0.0005	-0.3923
2330	68.00	69.0	57.66	13	55	II	7.67	56.60	0.0008	-0.1868	II	7.67	53.36	0.0024	-0.1571	II	9.10	53.85	0.0025	-0.1832	II	15.73	56.61	0.0012	-0.3262
0000	68.80	72.0	59.62	15	53	II	8.85	58.61	0.0007	-0.2290	II	8.85	55.78	0.0026	-0.1984	II	10.50	56.23	0.0027	-0.2314	II	18.15	58.67	0.0013	-0.4063
0030	68.40	69.6	58.29	13	47	II	7.67	57.14	0.0007	-0.1918	II	7.67	53.92	0.0025	-0.1620	II	9.10	54.41	0.0026	-0.1888	II	15.73	57.15	0.0013	-0.3351
0100	68.00	69.0	57.66	13	46	II	7.67	56.60	0.0006	-0.1868	II	7.67	53.36	0.0024	-0.1571	II	9.10	53.85	0.0025	-0.1832	II	15.73	56.61	0.0012	-0.3262
0130	68.20	73.0	59.41	13	47	II	7.67	57.74	0.0011	-0.1974	II	7.67	54.52	0.0029	-0.1673	II	9.10	55.01	0.0030	-0.1950	II	15.73	57.76	0.0020	-0.3454
0200	68.40	67.6	57.48	12	49	II	7.08	56.38	0.0006	-0.1741	II	7.08	52.92	0.0024	-0.1447	II	8.40	53.42	0.0025	-0.1685	II	14.52	56.33	0.0012	-0.3012
0230	68.40	72.8	59.53	12	48	II	7.08	57.59	0.0012	-0.1848	II	7.08	54.17	0.0029	-0.1550	II	8.40	54.67	0.0031	-0.1804	II	14.52	57.58	0.0022	-0.3205
0300	67.80	70.4	58.01	12	45	II	7.08	56.42	0.0009	-0.1746	II	7.08	52.96	0.0026	-0.1451	II	8.40	53.47	0.0028	-0.1691	II	14.52	56.41	0.0017	-0.3025
0330	68.00	66.4	56.60	14	46	II	8.26	56.25	0.0002	-0.1939	II	8.26	53.19	0.0020	-0.1642	II	9.80	53.66	0.0020	-0.1918	II	16.94	56.27	0.0004	-0.3410
0400	68.60	67.4	57.60	16	46	II	9.44	57.53	0.0000	-0.2285	II	9.44	54.82	0.0019	-0.1982	II	11.20	55.25	0.0019	-0.2314	II	19.36	57.59	0.0000	-0.4072
T-0	68.40	66.8	57.15	14	55	II	8.26	56.75	0.0003	-0.1987	II	8.26	53.70	0.0021	-0.1689	II	9.80	54.17	0.0021	-0.1971	II	16.94	56.76	0.0005	-0.3494
AVG.	65.19	69.75	58.39	14.55	NE		8.58	57.61				8.58	54.62				10.18	55.08				17.61	57.65		

Period of Ice Team Inspection

FIGURE 6. "SURFICE" Computer Predictions

Typical amounts of ice/frost had accumulated on the LH2 ET/ORB umbilical purge barrier. Typical ice/frost fingers had formed on the pyro canister and plate gap purge vents. Ice/frost was present on the aft pyrotechnic canister closeout bondline indicating a thermal short. The 17-inch flapper valve actuator access port foam plug was properly closed out. No unusual vapors or cryogenic drips had appeared during tanking, stable replenish, and launch.

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

Anomaly 001 documented a crack 12-inches long by 3/8-inch wide in the -Y vertical strut cable tray forward surface TPS. The crack exhibited no offset and was not filled with ice or frost. The crack had not changed since the first tanking.

Anomaly 002 (documentation only) recorded ice/frost formations on the LO2 and LH2 ET/ORB umbilicals, pyro can purge vents, purge barrier, LH2 recirculation line bellows/burst discs, and LH2 cable tray drain hole.

Anomaly 003 (documentation only) recorded ice/frost formations on the LO2 feedline support brackets and bellows.

Anomaly 004 documented ice/frost formations on the forward and aft sides of the +Y vertical strut fairing closeout.

4.6 FACILITY

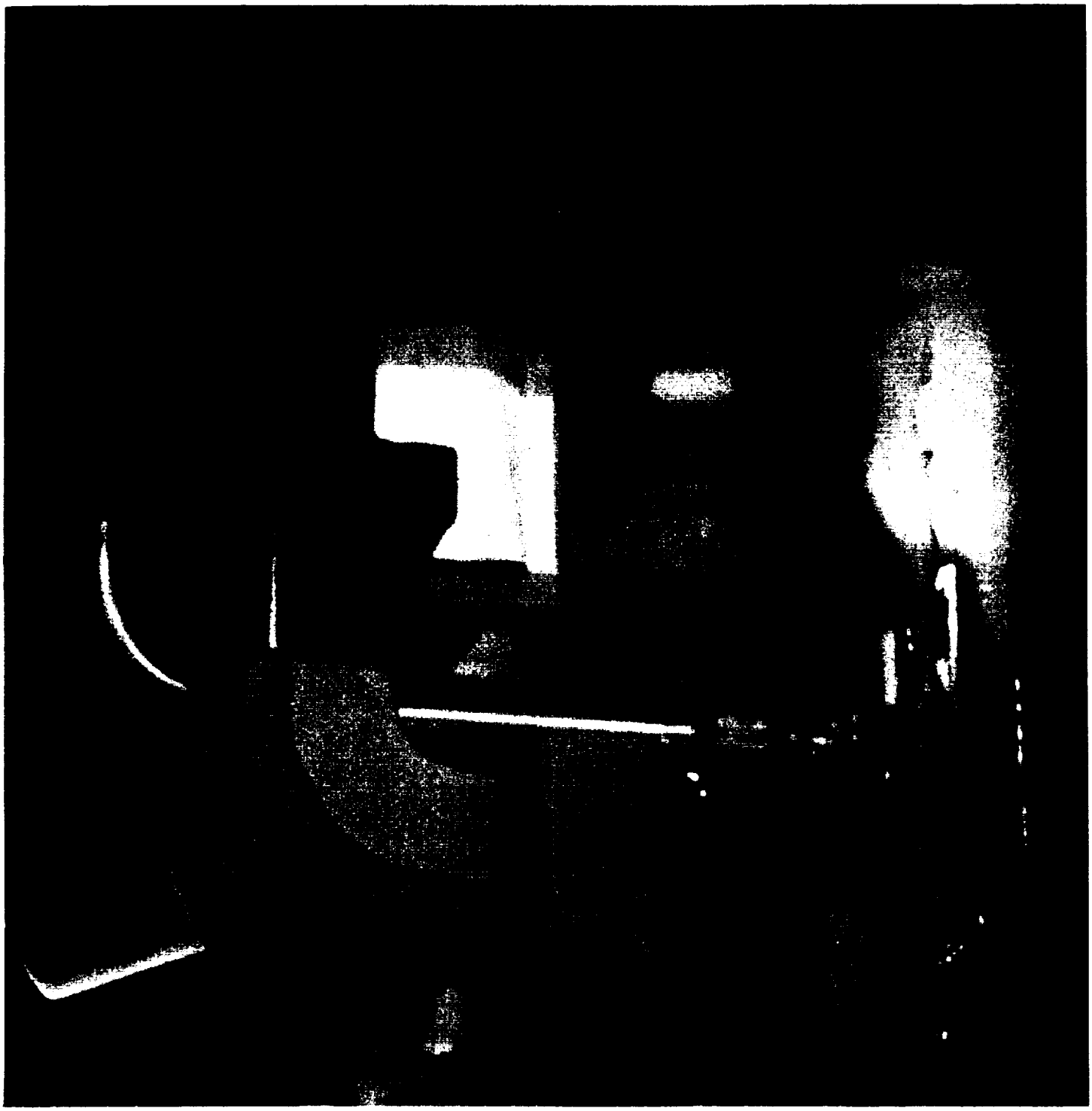
All SRB sound suppression water troughs were filled and properly configured for launch (LCC requirement).

No leaks were observed on either the LO2 or LH2 Orbiter T-0 umbilicals, the GH2 vent line, or the GUCP.

No ET nosecone/ footprint damage was visible after the GOX vent hood was retracted.

Although wetted by internal vapors, the paper cover on the RCS L4L thruster nozzle was intact

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



Typical amounts of ice/frost had accumulated on the ET/ORB LH2 umbilical. Ice/frost on the plate gap and pyro can purge vents, cable tray drain hole, LH2 recirculation line bellows and burst discs was also typical. No cryogenic drips or unusual vapors appeared during tanking and stable replenish.

5.0 POST LAUNCH PAD DEBRIS INSPECTION

The post launch inspection of the MLP, FSS and RSS was conducted on 2 December 1993 from Launch + 1.5 to 3.5 hours.

No flight hardware or TPS materials were found. A 1" x 1/4" bolt was found on the west surface of the MLP deck near the FSS crossover and originated from the facility.

A bolt was loose and a second missing from the E-15 camera protective cover. A bolt was missing and a cover plate was opened on the E-27 camera protective cover. Both cameras are located on the north end of the RH SRB exhaust hole.

South SRB HDP erosion was typical. All south HDP EPON shoe shim material was intact. There was no visual indication of a stud hang-up on any of the south holddown posts. All of the north HDP doghouse blast covers were in the closed position. The SRB aft skirt purge lines and T-0 umbilicals exhibited typical exhaust plume damage.

The Tail Service Masts (TSM), Orbiter Access Arm (OAA), and GOX vent arm showed only minor damage. A platform handle on the south side of the LH2 TSM was loose.

The GH2 vent line was latched on the second tooth of the latching mechanism and had no loose cables (static retract lanyard). However, the GH2 vent line was outside the south forward flexhose support struts and offset 8-10 inches from the haunch centerline. As a result, the latching mechanism was not centered. The crossbeam between the GUCP legs showed signs of contact with the static retract lanyard.

Further inspection revealed the vent line had engaged both latch bars, scraped paint near the eighth tooth, and rebounded back to the second tooth. Launch vibration may then have caused it to move south and disengage from the north latch bar. An IPR documented the vent line moving past the eighth tooth and latching on the second tooth. Troubleshooting will include a planned replacement of the shock absorber, re-evaluation of the latch plate/teeth mechanism, and a series of drop tests.

Typical damage to the facility included several loose/detached signs and panel doors on the FSS and RSS. This type of damage usually occurs after the vehicle clears the tower and is not considered a debris threat.

All seven emergency egress slidewire baskets were secured on the FSS 195 foot level and sustained no launch damage.

Debris inspections of the pad acreage, north flame trench, beach, and areas outside the pad perimeter were performed. No flight hardware or TPS material was found. Post launch pad inspection anomalies are listed in Section 10.

The Tail Service Masts showed only minor damage. A platform handle on the south side of the LH2 TSM was loose.

The GH2 vent line was latched on the 2nd tooth of the latching mechanism and had no loose cables (static retract lanyard). However, the line was outside the south forward flexhose support struts and offset 8-10 inches from the haunch centerline.

6.0 FILM REVIEW AND PROBLEM REPORTS

Anomalies observed in the Film Review were presented to the Mission Management Team, Shuttle managers, and vehicle systems engineers. No In-Flight Anomalies were generated as a result of the film review. Post flight anomalies are listed in Section 10.

6.1 LAUNCH FILM AND VIDEO SUMMARY

A total of 98 films and videos, which included thirty-six 16mm films, twenty 35mm films, two 70mm films, and forty videos, were reviewed starting on launch day.

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

Prior to ignition, free burning hydrogen drifted under the body flap and upward to the LH OMS pod. SSME ignition, Mach diamond formation, and gimbal profile appeared normal (OTV 151, 163, 170, 171).

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 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).

Ten small particles appeared in the area between the RH OMS pod and the vertical stabilizer and fell aft at 09:26:56.721 GMT. The particles most likely originated from the top surface of the OMS pod (E-2, 19).

One light colored particle fell past the SSME #1 nozzle during ignition. The particle appeared to originate from the base heat shield area, not the RH OMS pod (E-76).

Surface coating material was lost from base heat shield tiles outboard of SSME #3 (4 places), outboard of SSME #2 (2 places), and between the SSME cluster (2 places) (E-17, 18, 19, 20).

A parts tag was loose on the RH SRB aft skirt nitrogen purge line (E-8).

A 6" x 1/2" tile gap filler, or shim, appeared in the body flap hinge gap and fell aft during SSME ignition at 09:26:56:883 GMT (E-17).

The Orbiter LH2 and LO2 T-0 umbilicals disconnected and retracted properly (OTV 149, 150, 163). GUCP disconnect from the External Tank was nominal (E-33).

The GH2 vent line appeared to latch properly in film items E-42 and E-48, though a small amount of GH2 vent line movement was visible in film item E-50 during the latching process. There was no excessive slack in the static retract lanyard. Post launch inspection found the GH2 vent line latched on the second tooth of the latching mechanism.

No stud hang-ups occurred on any of the holddown posts. No ordnance fragments or frangible nut pieces fell from any of the DCS/stud holes. Debris, most likely SRB throat plug material, was visible north of the MLP over the SRB flame trench after T-0 (TV-4B).

A piece of the ET/ORB umbilical purge barrier (baggie) fell aft of the Orbiter and past the left SRB shortly after the roll maneuver (TV-4B).

Pieces of RCS paper covers were visible passing over the Orbiter wings (E-59, 213, 222).

Three flashes occurred in the SSME plume during ascent (E-218, 223).

Numerous small pieces of aft skirt instafoam or chunks of propellant dropped out of the SRB plume during ascent (E-57, 218, 223, TV-4B, TV-5). This common event is more visible during night launches.

At least seven pieces of SRB thermal curtain tape were partially detached from the SRB thermal curtains. One 4 foot piece of tape detached completely later in flight (E-207, 212).

TPS eroded/ablated in four places on the ET LH2 aft dome manhole cover (E-207).

Body flap movement (amplitude and frequency) was similar to previous flights (E-208, 212, 220, 222).

ET aft dome charring and exhaust plume recirculation were typical (E-208, 212, 220, TV-13). Slag fell out of the SRB plumes before, during, and after separation (TV-4B). SRB plume tailoff and separation appeared normal.

TPS eroded/ablated in four places on the External Tank LH2 aft dome manhole cover - a normal occurrence. Pieces of SRB thermal curtain tape partially detached from the SRB thermal curtains in flight - also an expected occurrence.

6.2 ON-ORBIT FILM AND VIDEO SUMMARY

DTO-0312 was performed by the flight crew. Eighteen hand held still images were obtained of the External Tank 36 minutes after separation from the Orbiter. OV-105 was equipped to carry umbilical cameras: 16mm motion picture with 5 mm lens and 35mm still views. Due to dark conditions, data was not obtained for External Tank separation.

No major vehicle damage or lost flight hardware was observed that would have been a safety of flight concern.

SRB separation appeared normal. A piece of SRB thermal curtain tape appeared in the plume recirculation under the ET aft dome (frame 770).

Erosion of TPS on the -Y vertical strut aft side and blistering of the fire barrier on the LH2 ET/ORB umbilical was typical. Erosion of TPS from the LH2 cable tray aft surface was somewhat greater than usual.

Very small pieces of TPS fell aft past the camera field of view before, during, and after SRB separation.

6.3 LANDING FILM AND VIDEO SUMMARY

A total of fifteen videos, four 16mm films, and seven 35mm large format films, were reviewed.

Orbiter performance on final approach appeared normal. There were no anomalies when the landing gear was extended. Touchdown of the left and right main gear was nominal and almost simultaneous.

The drag chute was deployed after breakover, but before the nose gear contacted the runway. Drag chute deployment appeared nominal. The chute was blown slightly westward (-Y side of the Orbiter) by prevailing winds.

No unusual APU exhaust plumes were observed either visually or in the infrared imagery.

Touchdown of the nose landing gear was smooth.

SRB separation appeared normal. A piece of SRB thermal curtain tape appeared in the plume recirculation under the ET aft dome and fell past the LH SRB (arrow). Erosion of TPS on the -Y vertical strut aft side and blistering of the fire barrier on the LH2 ET/ORB umbilical was typical. Erosion of TPS from the LH2 cable tray aft surface was somewhat greater than usual.

7.0 SRB POST FLIGHT/RETRIEVAL DEBRIS ASSESSMENT

Both Solid Rocket Boosters were inspected for debris damage and debris sources at CCAFS Hangar AF on 6 December 1993 from 0830 to 1100 hours. From a debris standpoint, both SRB's were in good condition.

7.1 RH SOLID ROCKET BOOSTER DEBRIS INSPECTION

The RH frustum was missing no TPS but had 22 MSA-2 debonds over fasteners (Figure 7). Minor blistering of the Hypalon paint had occurred in localized areas. The BSM aero heatshield covers were locked in the fully opened position, though the upper right and lower left cover attach rings had been bent by parachute riser entanglement.

The RH forward skirt acreage exhibited no debonds or missing TPS. Both RSS antennae covers/phenolic base plates were intact. Minor blistering of the Hypalon paint occurred on the systems tunnel cover and around the ET/SRB attach point. No pins were missing from the frustum severance ring.

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. A 2" x 0.5" x 0.2" divot occurred on the leading edge of a GEI cork run (right forward segment XB-1099 at 220 degrees). The remaining material was sooted and most likely lost during ascent (IFA STS-61-I-01). Post flight lab analysis determined the loss was not a material/processing failure. The most probable cause of the cork loss is believed to be a debris impact during ascent. Since no debris sources were identified on the RH SRB forward of the damage site, ice from the ET LO2 feedline bellows has been cited as the leading candidate.

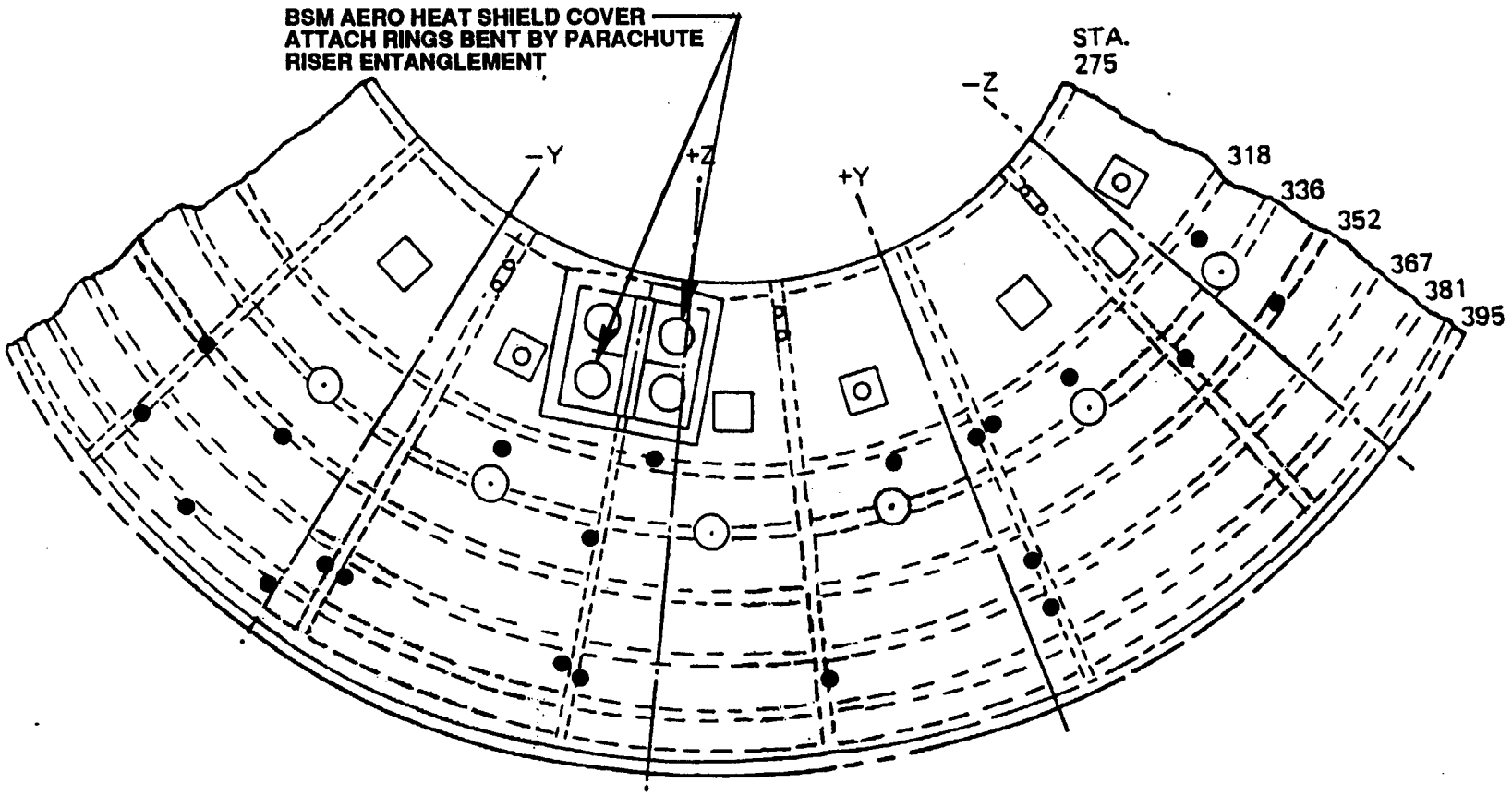
Separation of the aft ET/SRB struts appeared normal. The ET/SRB aft struts, ETA ring, IEA, and IEA covers appeared undamaged. The aft booster stiffener ring splice plate closeouts were intact and no K5NA material was missing.

The phenolic material on the kick ring was delaminated. Aft skirt acreage TPS was generally in good condition.

All four Debris Containment System (DCS) plungers were seated and appeared to have functioned properly (Figure 8). EPON shim material is no longer bonded to the HDP #3 and #4 aft skirt structure.

STS-61

FIGURE 7. **RIGHT SRB FRUSTUM**



MISSING TPS

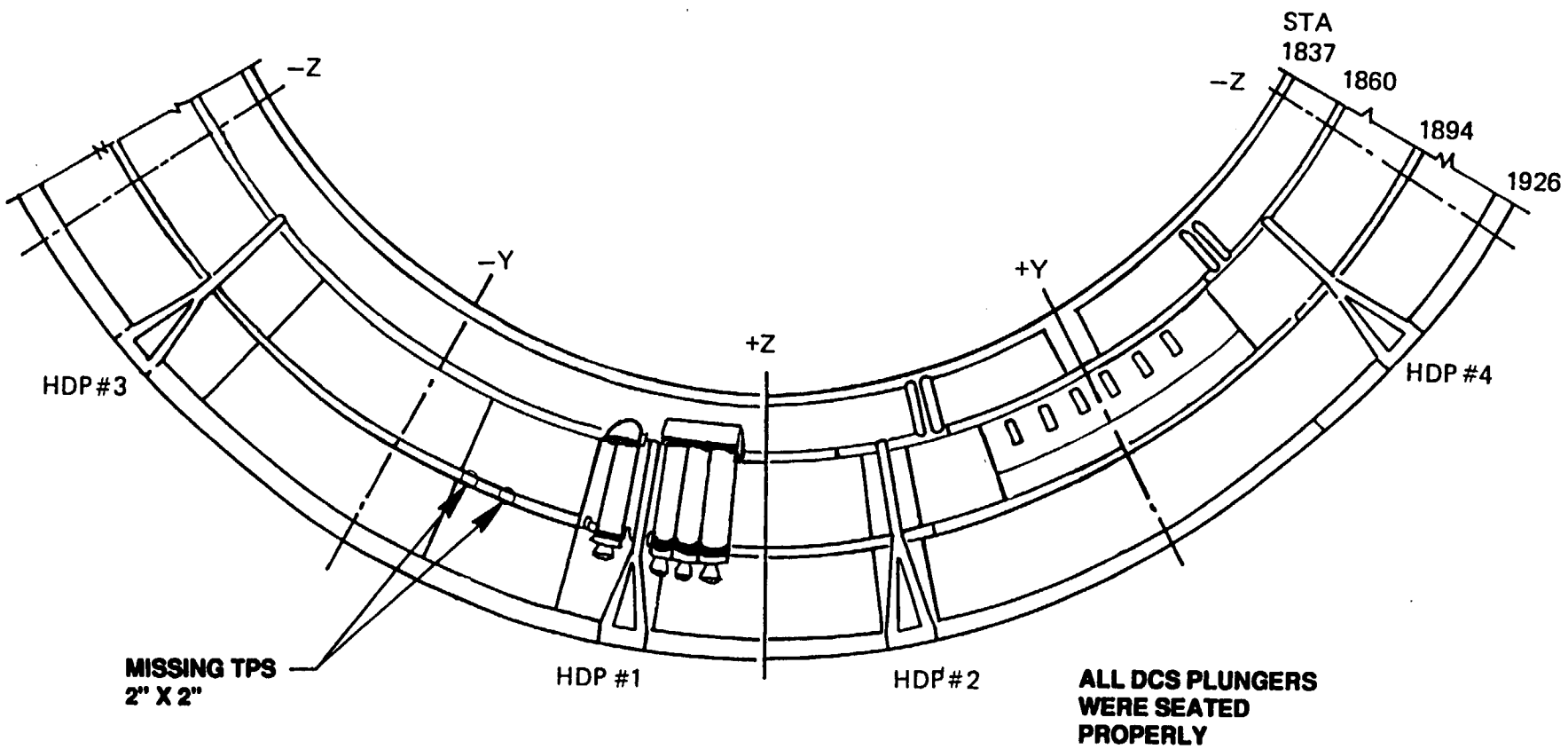
NONE

DEBONDS

● **22**

STS-61

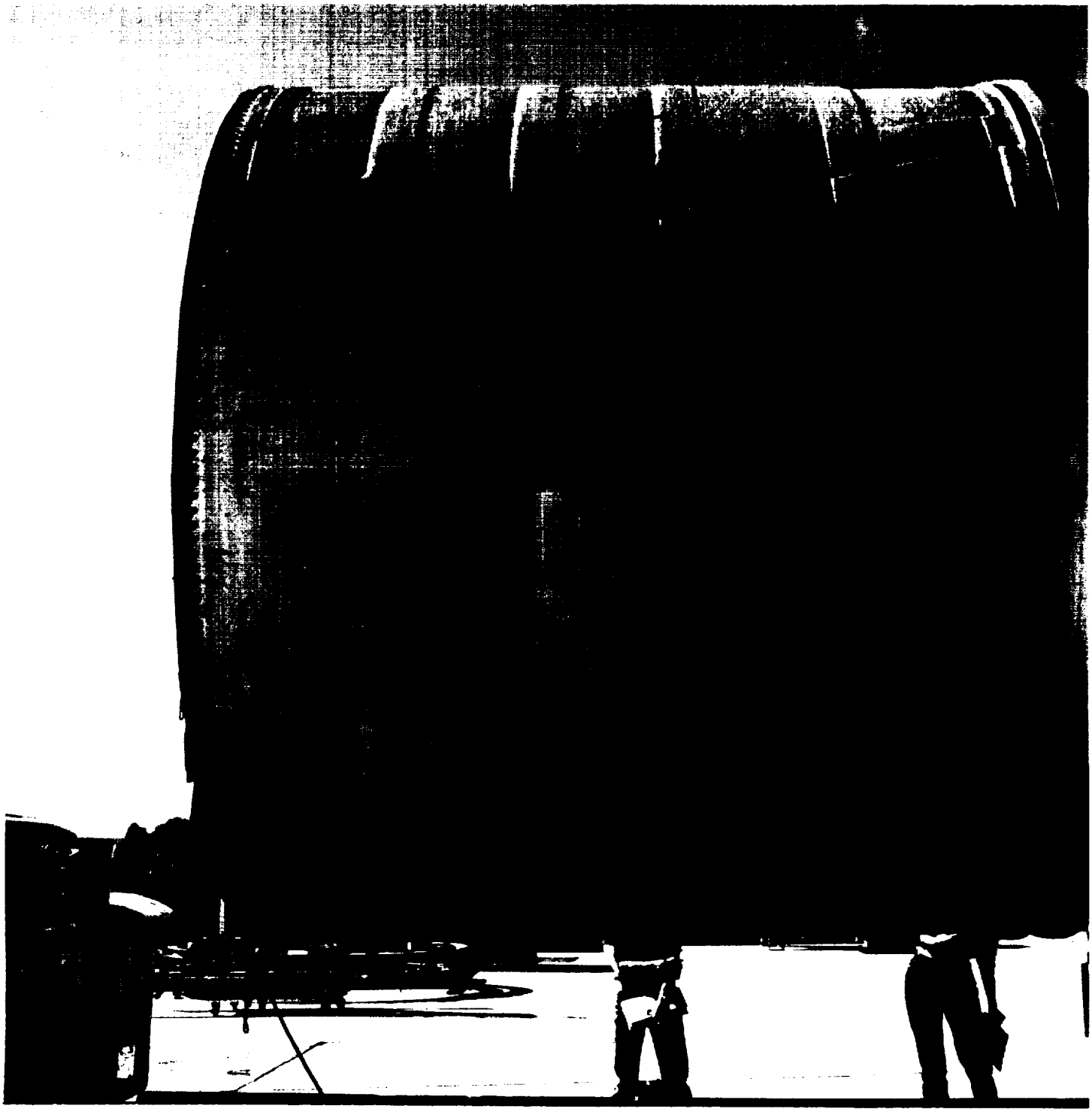
FIGURE 8. **RIGHT SRB AFT SKIRT EXTERIOR TPS**



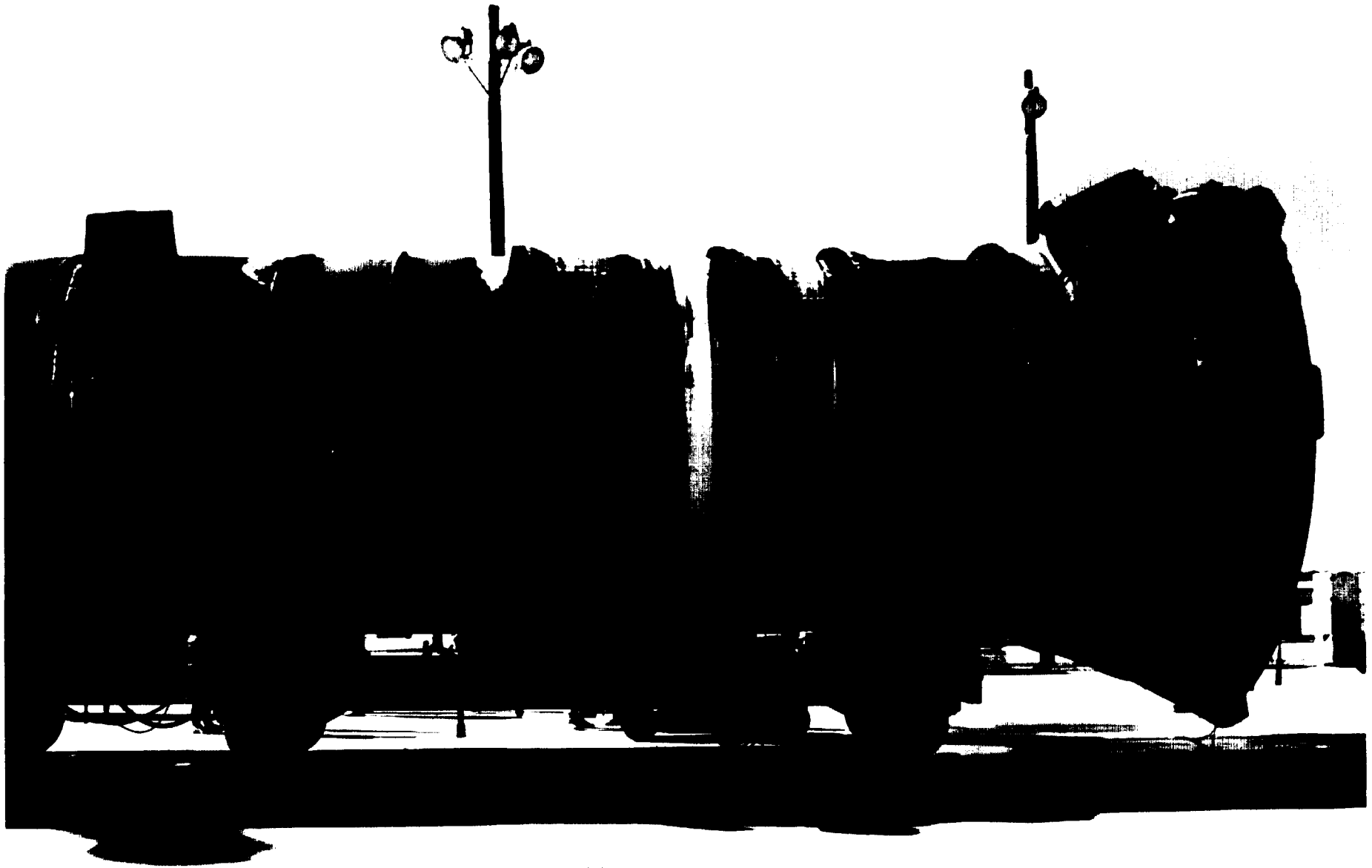
**EPON SHIM MATERIAL
IS NO LONGER
BONDED TO HDP # 3 AND #4
AFT SKIRT STRUCTURE**

EGG/V 326C

The RH frustum was missing no TPS, but had 22 MSA-2 debonds over fasteners. The BSM aero heat shield covers were locked in the fully opened position, though two of the cover attach rings had been bent by parachute riser entanglement.



RH forward skirt acreage exhibited no debonds or missing TPS



Post flight condition of the RH aft booster and aft skirt. 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.

7.2 LH SOLID ROCKET BOOSTER DEBRIS INSPECTION

The LH frustum had 17 MSA-2 debonds over fasteners. A 2"x1" divot in the MSA-2 occurred between the +Y/-Z axes and the 275/318 ring frames (Figure 9). Minor blistering of the Hypalon paint had occurred in localized areas. The lower right BSM aero heat shield cover was locked in the fully opened position. The other three BSM aero heatshield covers were missing. Preliminary post flight assessment revealed the covers had opened and locked properly. The fracture planes on the cover attach rings were not sooted, which may indicate the covers were lost late in flight or at water impact.

The LH forward skirt acreage exhibited no debonds or missing TPS. Both RSS antennae covers/phenolic base plates were intact. Minor blistering of the Hypalon paint occurred near the ET/SRB attach point and on the systems tunnel cover. No pins were missing from the frustum severance ring.

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.

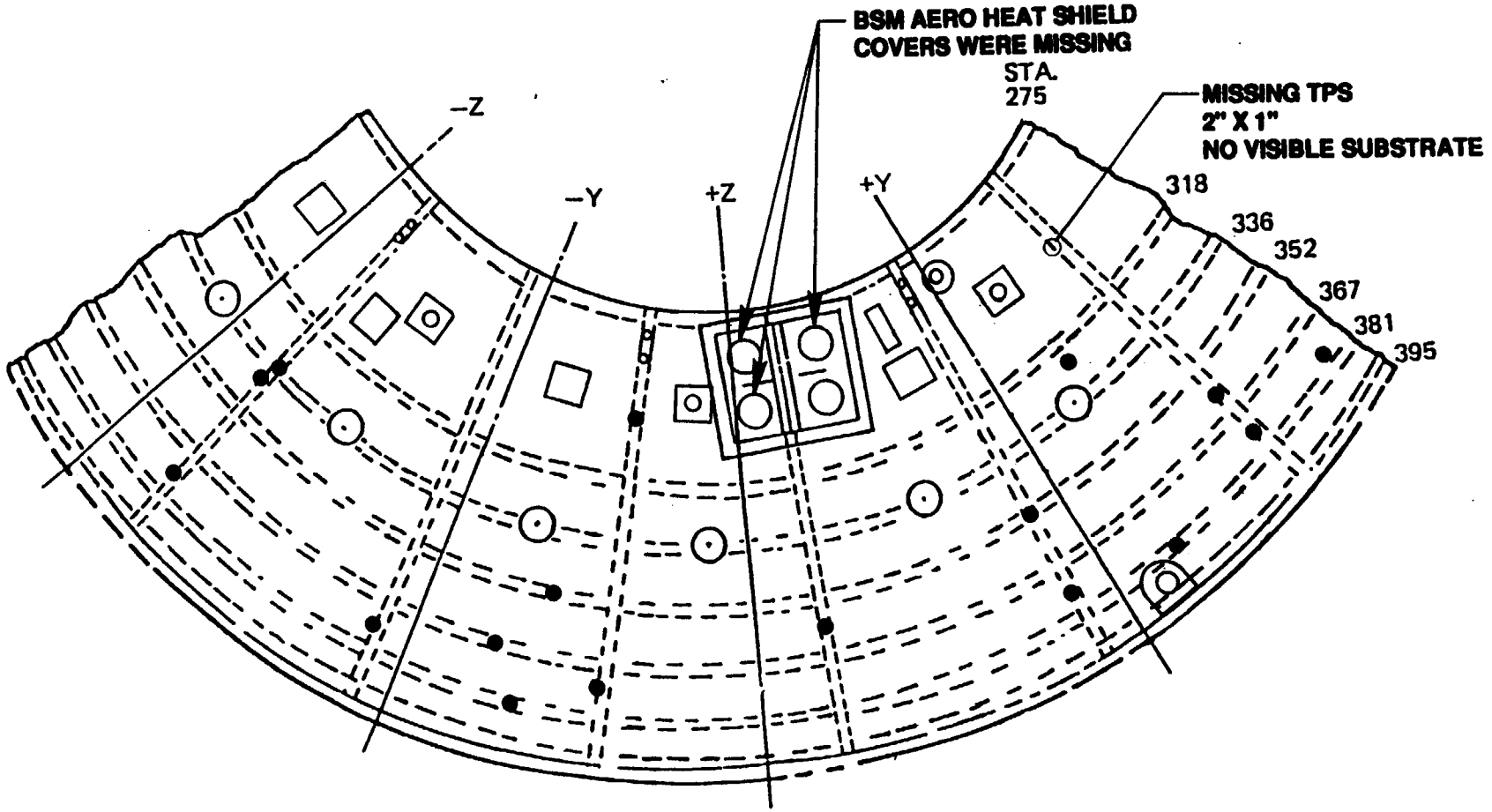
The phenolic material on the kick ring was delaminated. Aft skirt acreage TPS was generally in good condition. Hypalon paint was blistered/missing from the BTA closeouts. A 2-inch crack occurred in the BTA on the aft ring.

All four Debris Containment System (DCS) plungers were seated and appeared to have functioned properly. EPON shim material is no longer bonded to the HDP #7 and #8 aft skirt structure.

SRB Post Launch Anomalies are listed in Section 10.

STS-61

FIGURE 9. **LEFT SRB FRUSTUM**

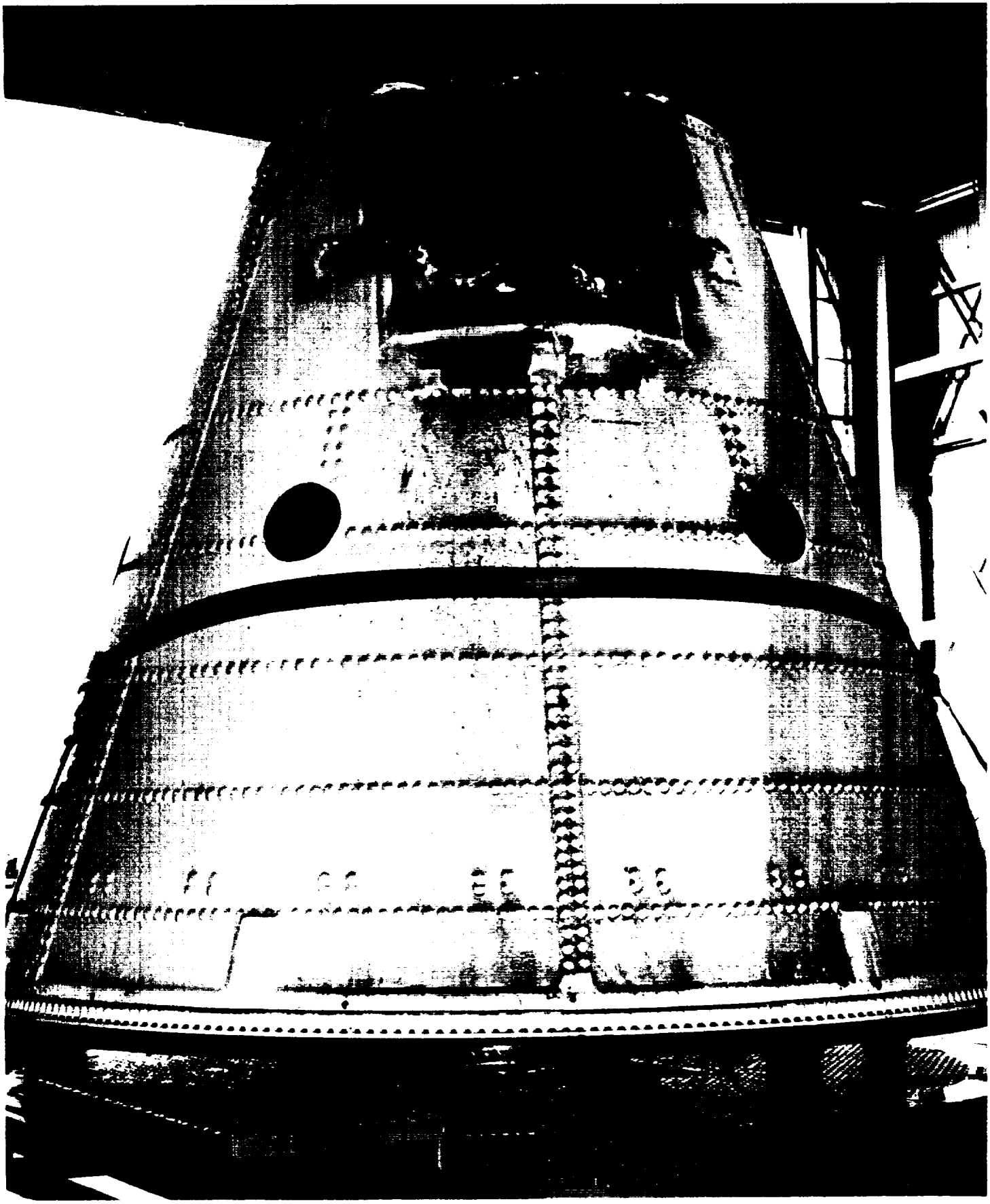


MISSING TPS

○ 1

DEBONDS

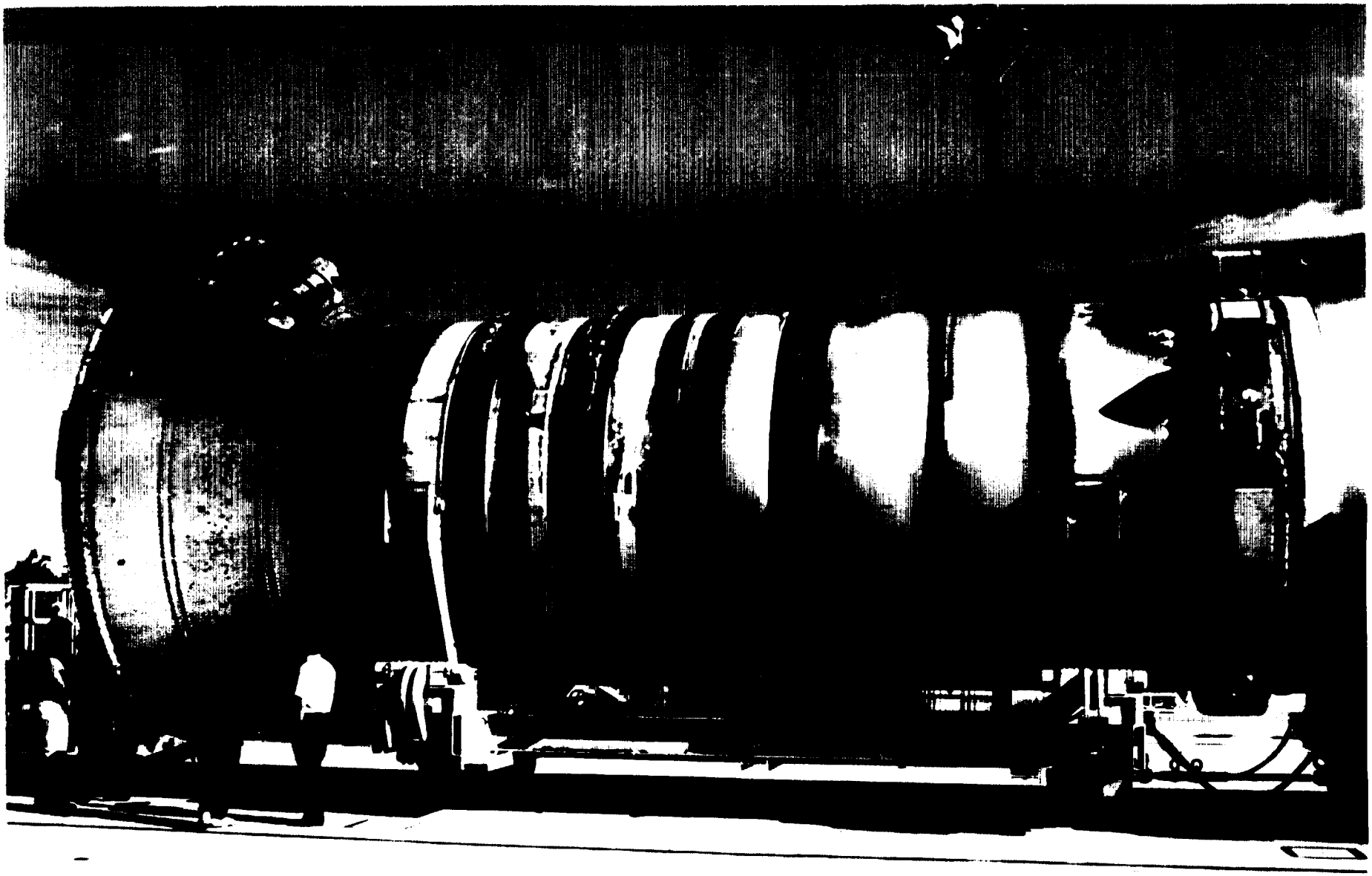
● 17



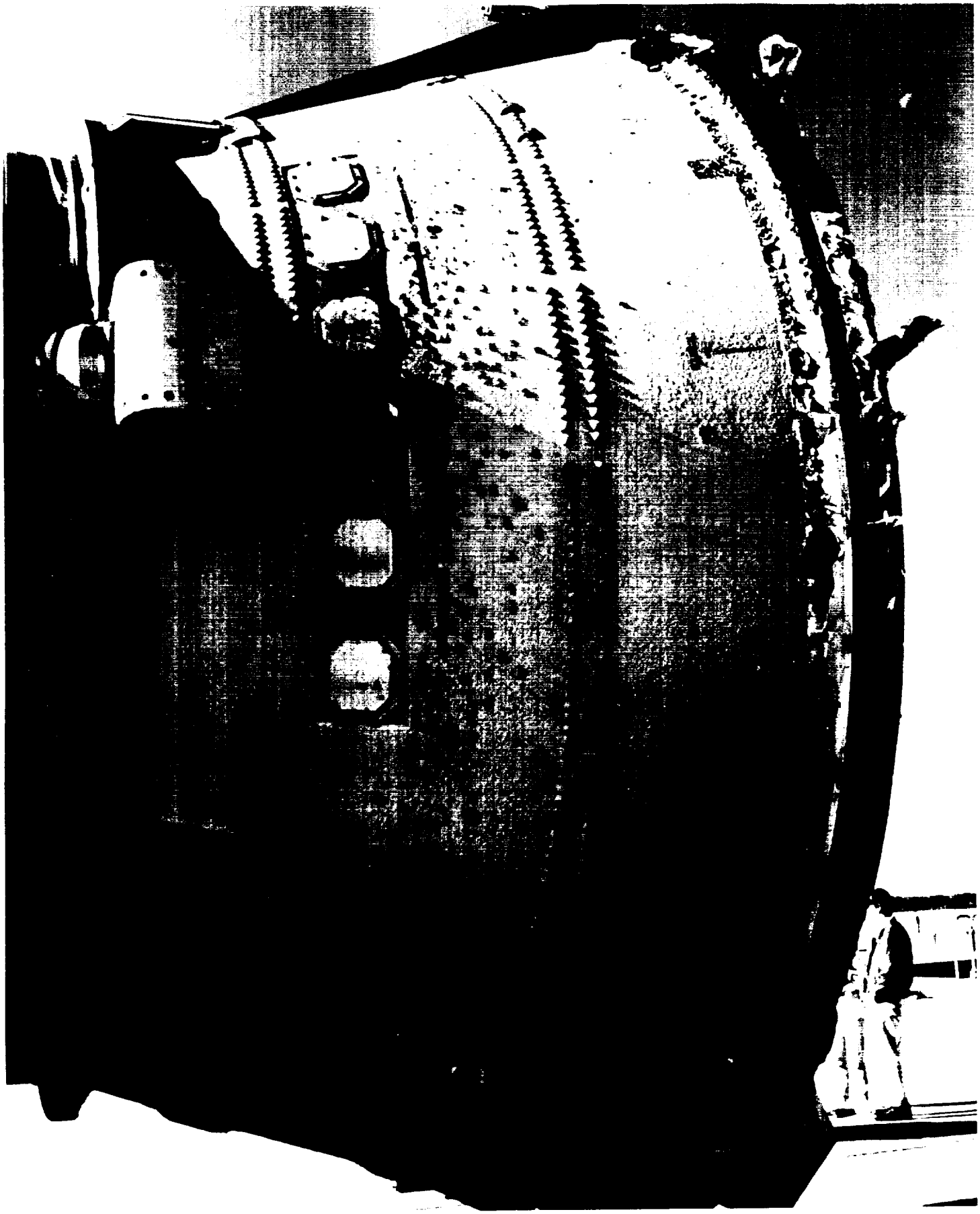
The LH frustum had a total of 17 MSA-2 debonds over fasteners. The lower right BSM aero heatshield cover was locked in the fully opened position. The other three covers were missing.

Preliminary post flight assessment revealed the BSM aero heat shield covers had opened and locked properly. The fracture planes on the cover attach rings were not sooted, which may indicate the covers were lost late in flight or at water impact

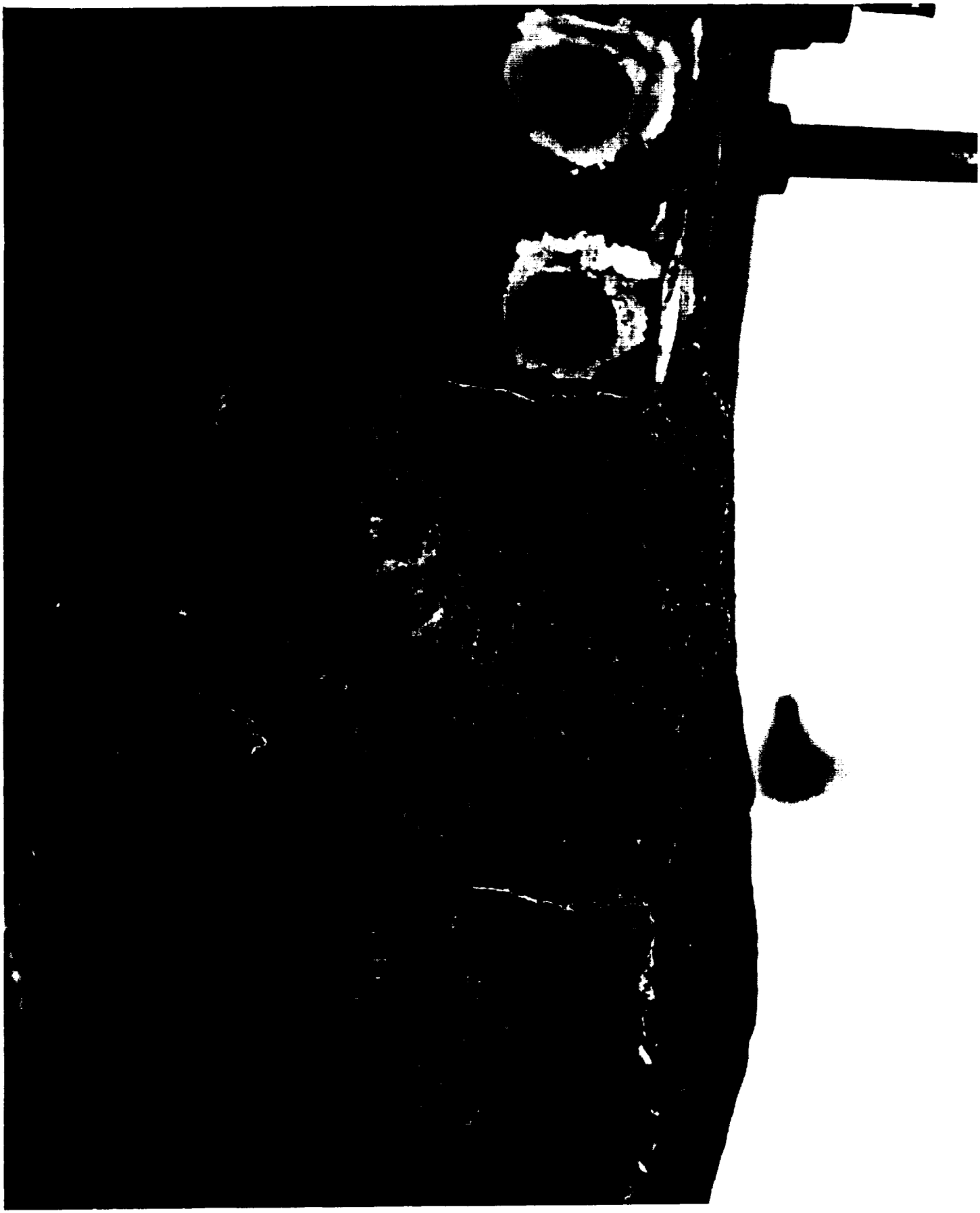
The LH forward skirt acreage MSA-2 exhibited no debonds or missing TPS. Both RSS antenna covers/phenolic base plates were intact.



Post flight condition of the LH aft booster and aft skirt. 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.



Aft skirt acreage TPS was generally in good condition. Hypalon paint was blistered and/or missing from the Booster Trowellable Ablator (BTA) closeouts.



A 2-inch crack occurred in the BTA applied to the aft ring

8.0 ORBITER POST LANDING DEBRIS ASSESSMENT

A post landing debris inspection of OV-105 (Endeavour) was conducted 13 December 1993 at the Kennedy Space Center on Shuttle Landing Facility (SLF) runway 33 and in the Orbiter Processing Facility bay #1. This inspection was performed to identify debris impact damage and, if possible, debris sources. The Orbiter TPS sustained a total of 120 hits, of which 13 had a major dimension of one inch or greater. 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 43 previous missions of similar configuration (excluding missions STS-23, 25, 26, 26R, 27R, 30R, and 42, which had damage from known debris sources), indicates both the total number of hits and the number of hits 1-inch or larger was less than average (reference Figures 10-13).

The Orbiter lower surface sustained a total of 59 hits, of which 7 had a major dimension of 1-inch or greater. The distribution of hits on the lower surface does not suggest a single source of ascent debris, but indicates a shedding of ice and Thermal Protection System (TPS) debris from random sources.

The following table breaks down the STS-61 Orbiter debris damage by area:

	HITS > 1"	TOTAL HITS
Lower surface	7	59
Upper surface	2	53
Right side	0	1
Left side	0	2
Right OMS Pod	4	4
Left OMS Pod	0	1
TOTALS	13	120

The largest tile damage sites on the lower surface measured 5" x 1.5" x 0.125" (RH wing chine) and 2" x 2.5" x 0.25" (left inboard elevon). The shallow depth may be indicative of impacts from low density objects.

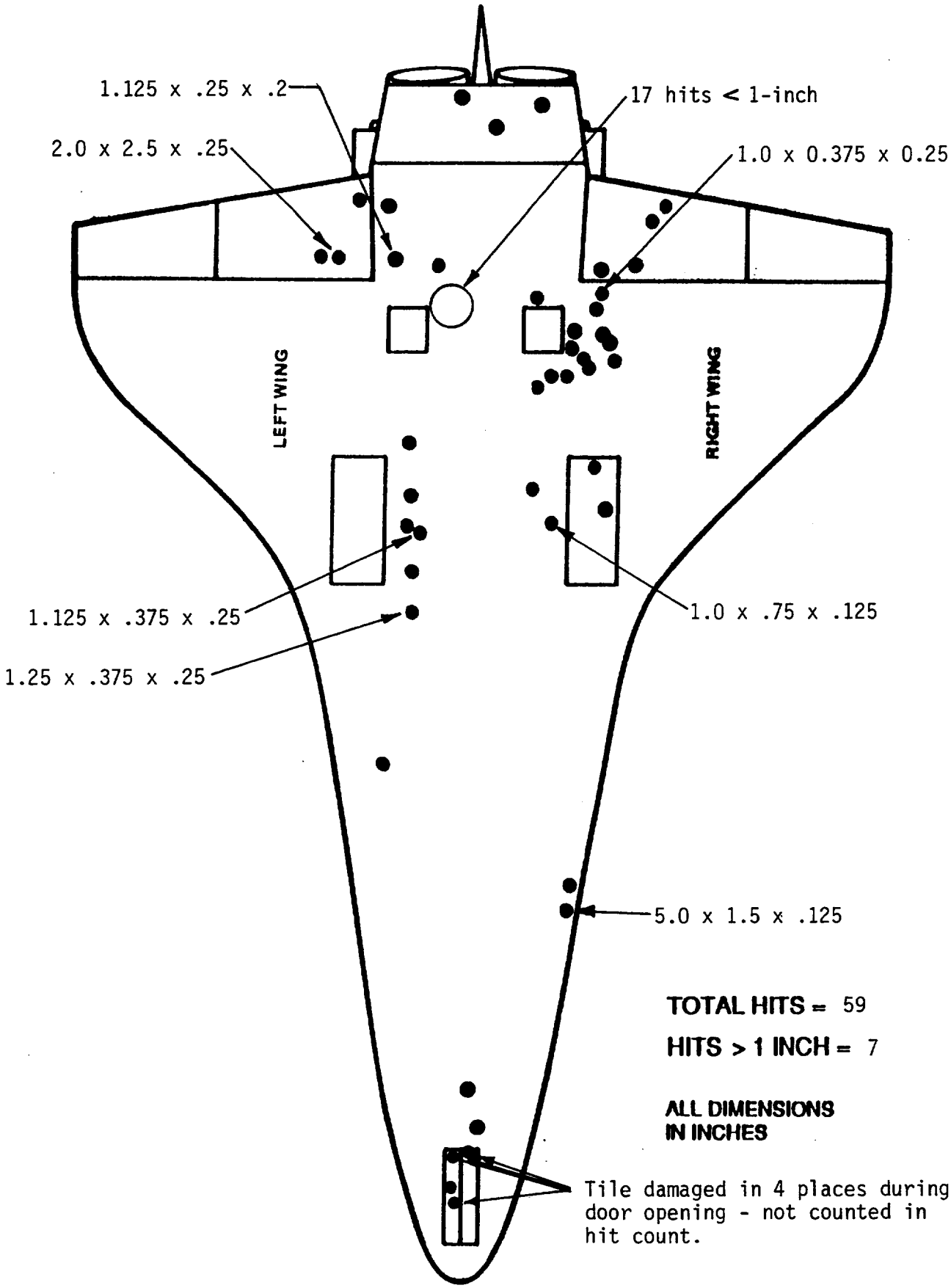
A cluster of 17 hits near the LH2 ET/ORB umbilical may be indicative of impacts from higher density materials, such as ice.

Black deposits were present on LH wing RCC panel #6 and T-seal #3.

Two small hits near the forward LH RCS pod, originally thought to be micrometeorite hits, were the result of vibration damage to previous tile repairs.

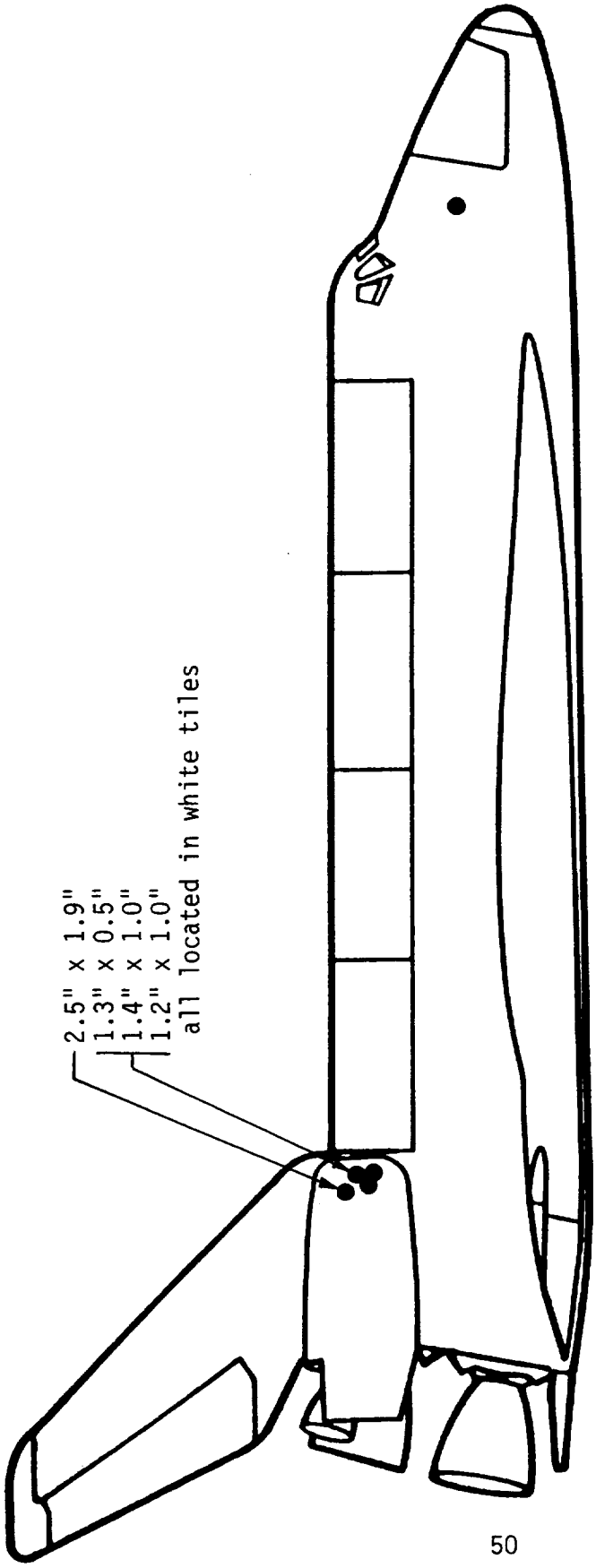
STS-61

FIGURE 10. **DEBRIS DAMAGE LOCATIONS**



STS-61

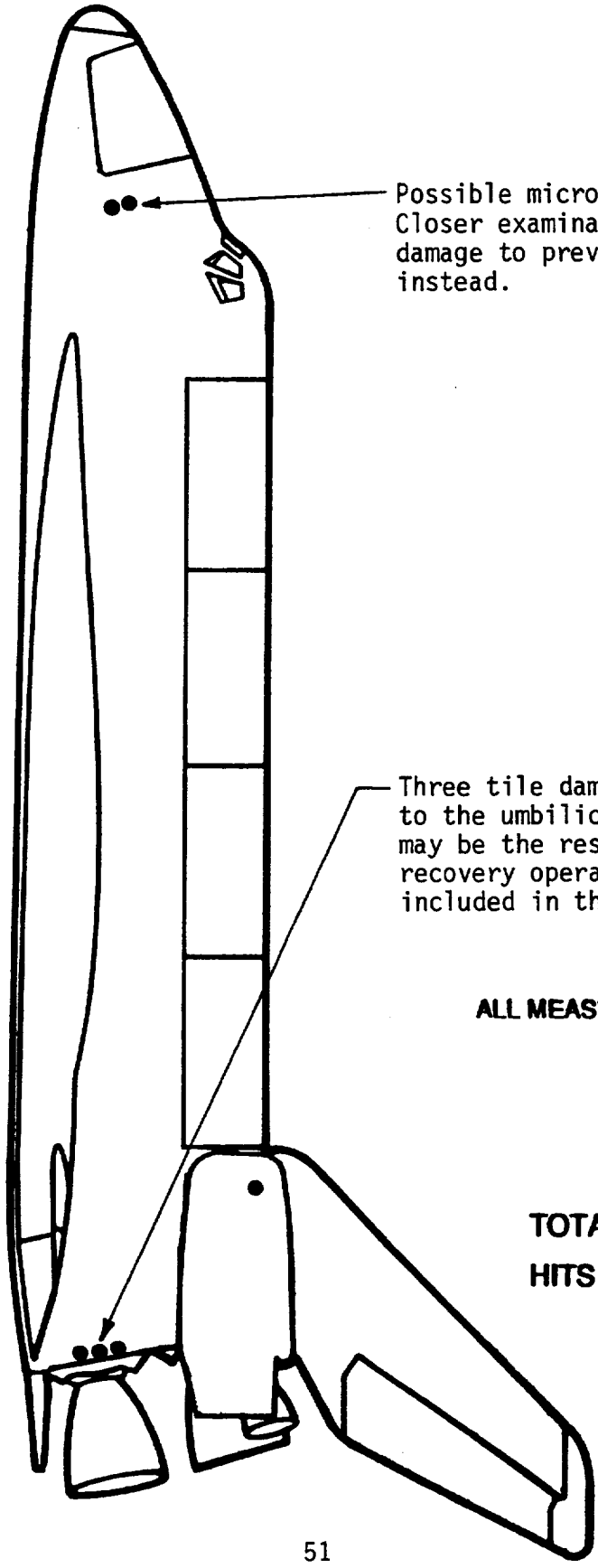
FIGURE 11. **DEBRIS DAMAGE LOCATIONS**



TOTAL HITS = 5

HITS > 1 INCH = 4

FIGURE 12. **DEBRIS DAMAGE LOCATIONS**



Possible micrometeorite hits. Closer examination revealed damage to previous tile repairs instead.

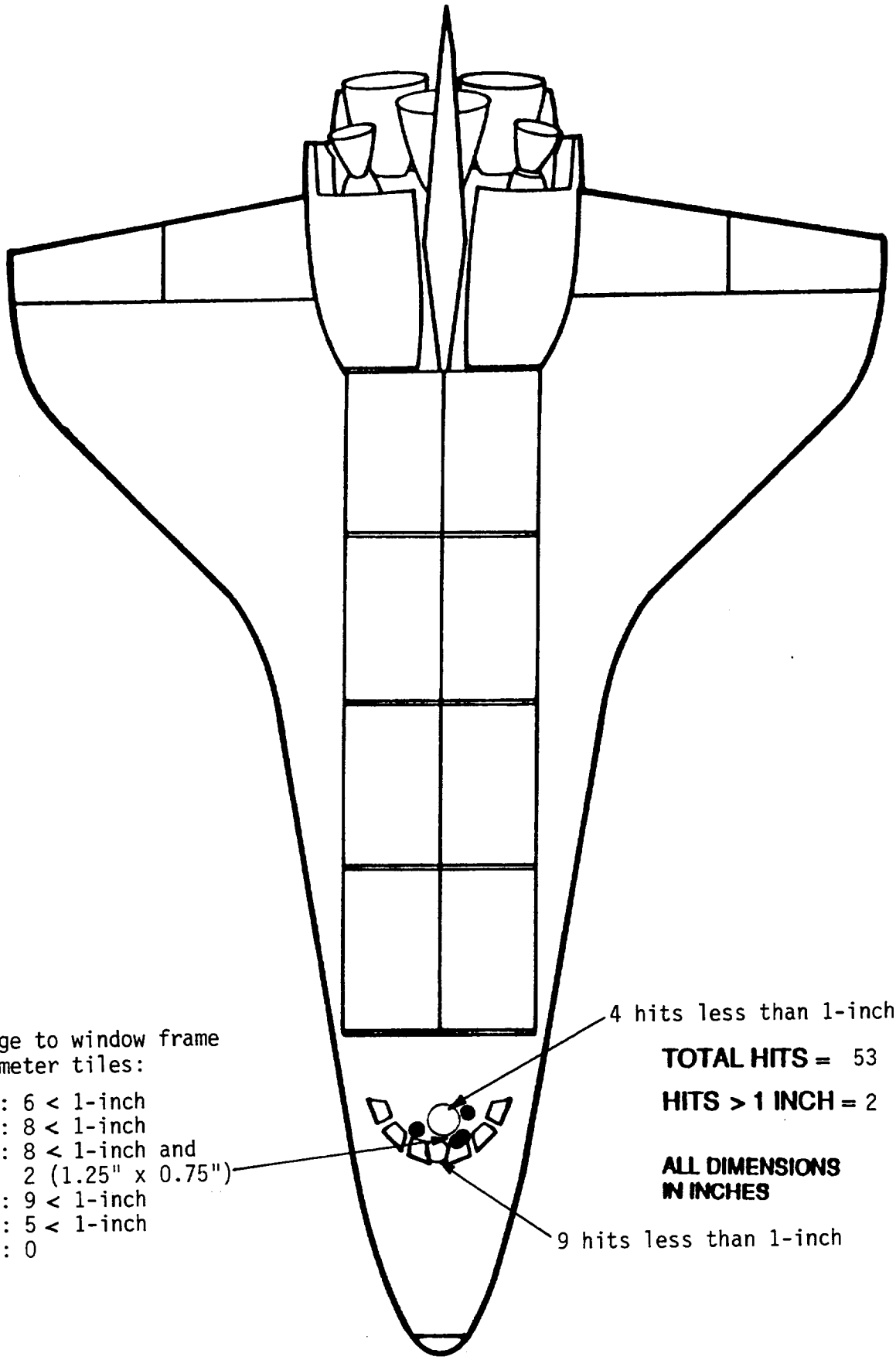
Three tile damage areas adjacent to the umbilical cooling flexline may be the result of handling during recovery operations and are not included in the total count.

ALL MEASUREMENTS IN INCHES

TOTAL HITS = 3

HITS > 1 INCH = 0

FIGURE 13. **DEBRIS DAMAGE LOCATIONS**



No TPS damage was attributed to material from the wheels, tires, or brakes. The right main landing gear inboard tire showed tread wear from the landing on the KSC runway.

ET/Orbiter separation devices EO-1, EO-2, and EO-3 functioned nominally. All ET/Orbiter umbilical separation ordnance retention shutters were closed properly. No debris was found on the runway beneath the ET/ORB umbilical cavities. An insignificant amount of foam, but no red purge seal, adhered to the LH2 ET/ORB umbilical plate near the LH2 4-inch recirculation line flapper valve.

Orbiter windows #3 and #4 were moderately hazed with some streaks on window #4. Only a light haze was present on the other windows. Surface wipes were taken from all windows for laboratory analysis. Damage to the window perimeter tiles was typical.

Tile damage on the base heat shield was typical. The Dome Mounted Heat Shield (DMHS) closeout blanket MR patches on all three SSME's were in excellent condition and no material was missing. Tiles on the vertical stabilizer "stinger" and around the drag chute door were intact and undamaged.

Runway 33 had been swept/inspected by SLF operations personnel prior to landing and all potentially damaging debris was removed.

The post landing walkdown of Runway 33 was performed immediately after landing. All Orbiter drag chute hardware was recovered and showed no signs of abnormal operation. No organic (bird) debris was found on the runway. Two Q-felt plugs, most likely from the base heat shield area, were recovered in the vicinity of the drag chute.

The Shuttle Thermal Imager (STI) was used to measure the surface temperatures of several areas on the vehicle (per OMRSD V09AJ0.095). Seven minutes after landing, the Orbiter nosecap RCC was 200 degrees F. Twenty-two minutes after landing, the RH wing leading edge RCC panel #9 was 83 degrees F and panel #17 was 72 degrees F (Figure 14).

In summary, both the total number of Orbiter TPS debris hits and the number of hits 1-inch or larger was less than average when compared to previous missions (reference Figures 15-16).

Orbiter Post Launch Debris Anomalies are listed in Section 10.

FIGURE 14. **STS-61 RCC TEMPERATURE MEASUREMENTS AS RECORDED BY THE SHUTTLE THERMAL IMAGER**

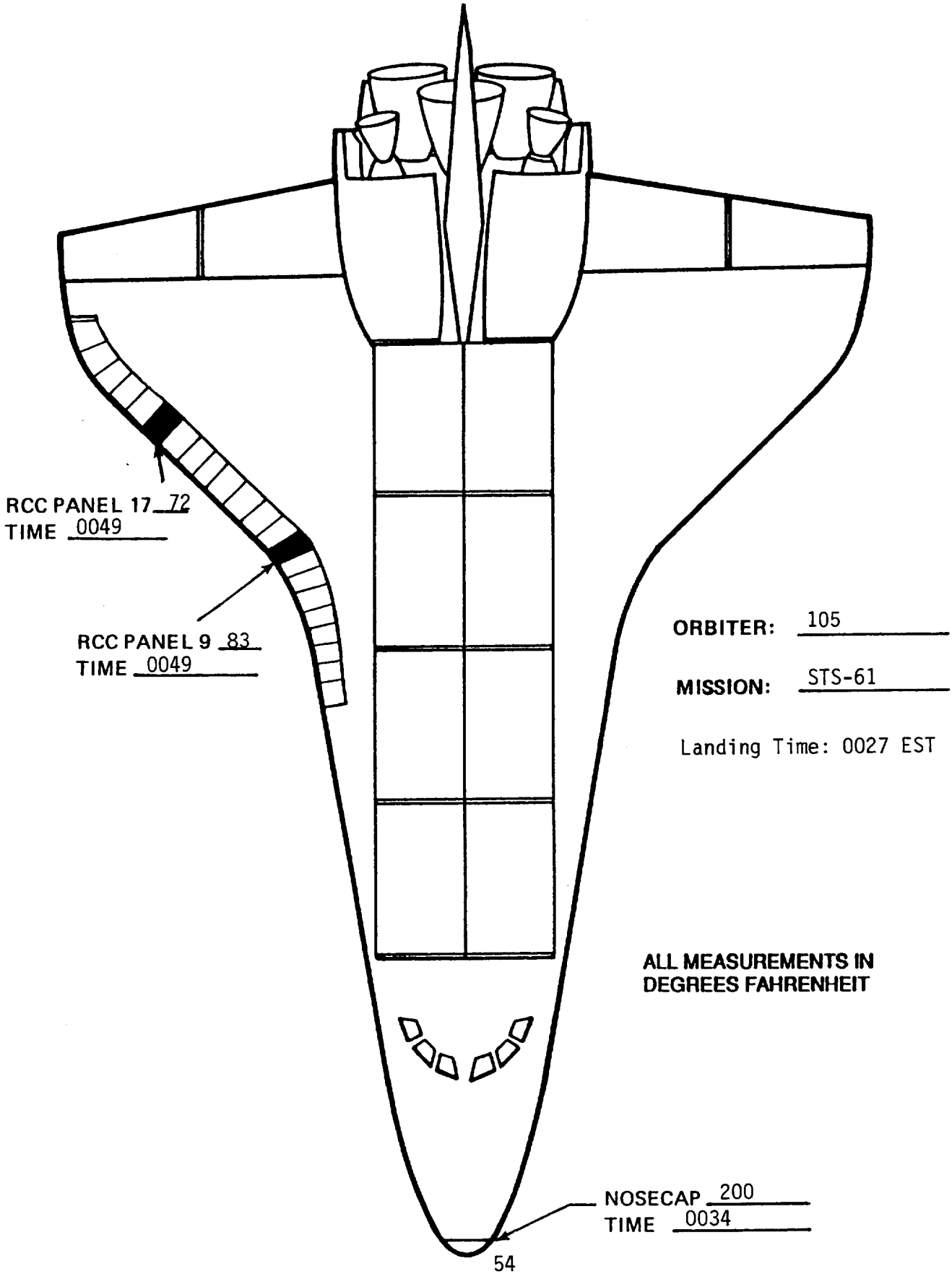
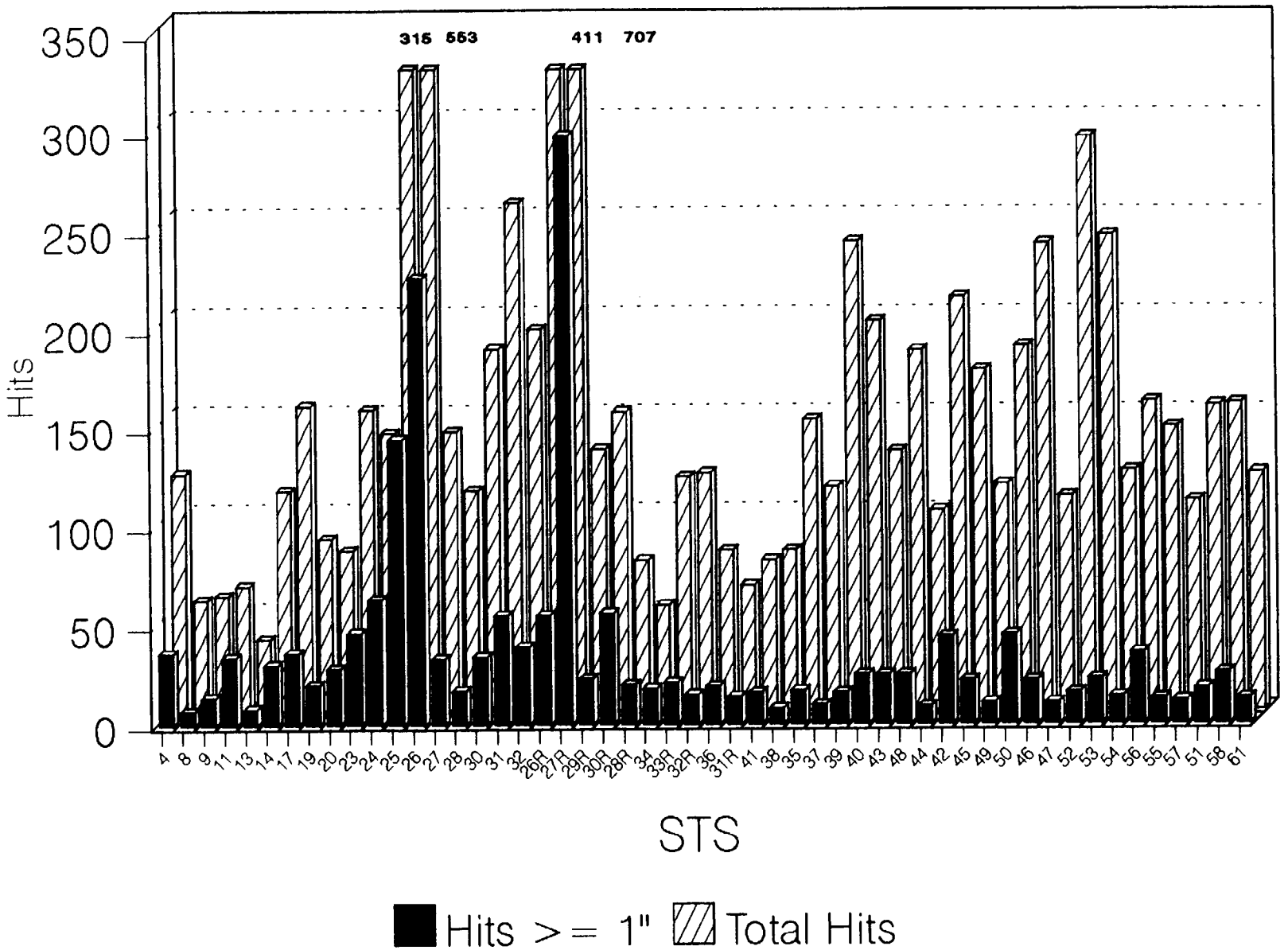


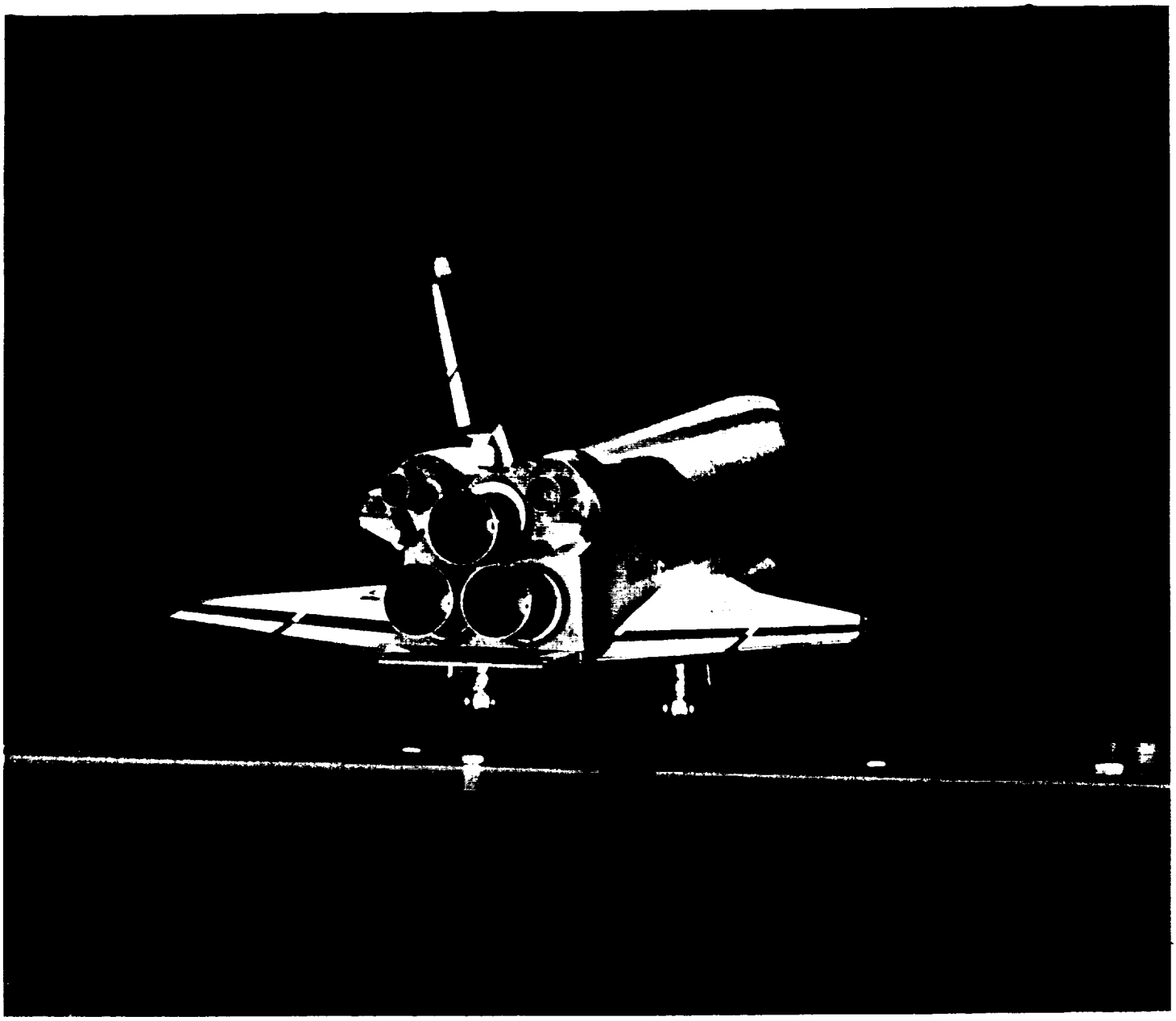
FIGURE 15: ORBITER POST FLIGHT DEBRIS DAMAGE SUMMARY

	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
AVERAGE	14.6	93.4	21.9	133.7
SIGMA	7.3	44.3	10.6	59.2
STS-61	7	59	13	120

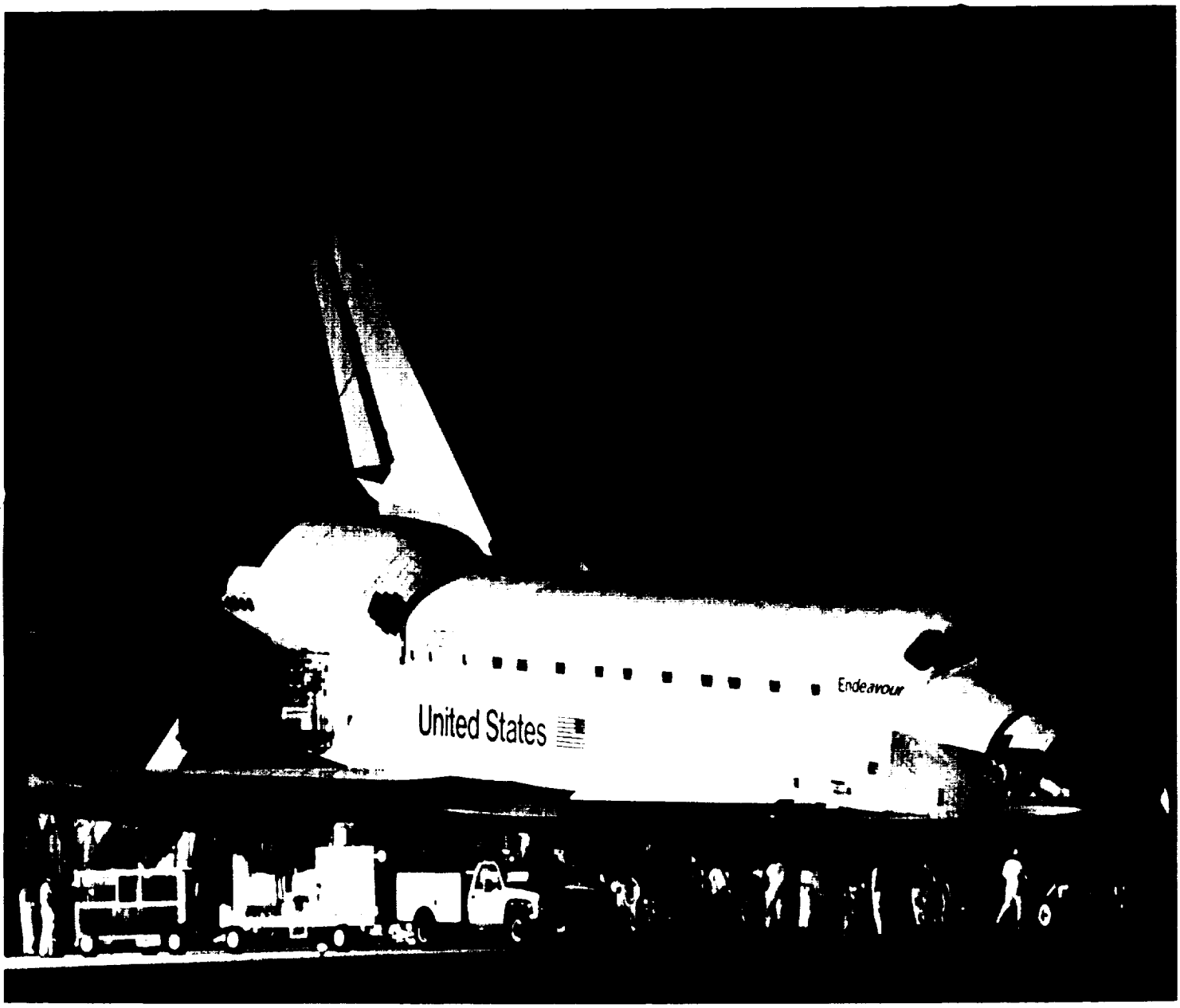
MISSIONS STS-23, 24, 25, 26, 26R, 27R, 30R, AND 42 ARE NOT INCLUDED IN THIS ANALYSIS SINCE THESE MISSIONS HAD SIGNIFICANT DAMAGE CAUSED BY KNOWN DEBRIS SOURCES

FIGURE 16. # COMPARISON TABLE

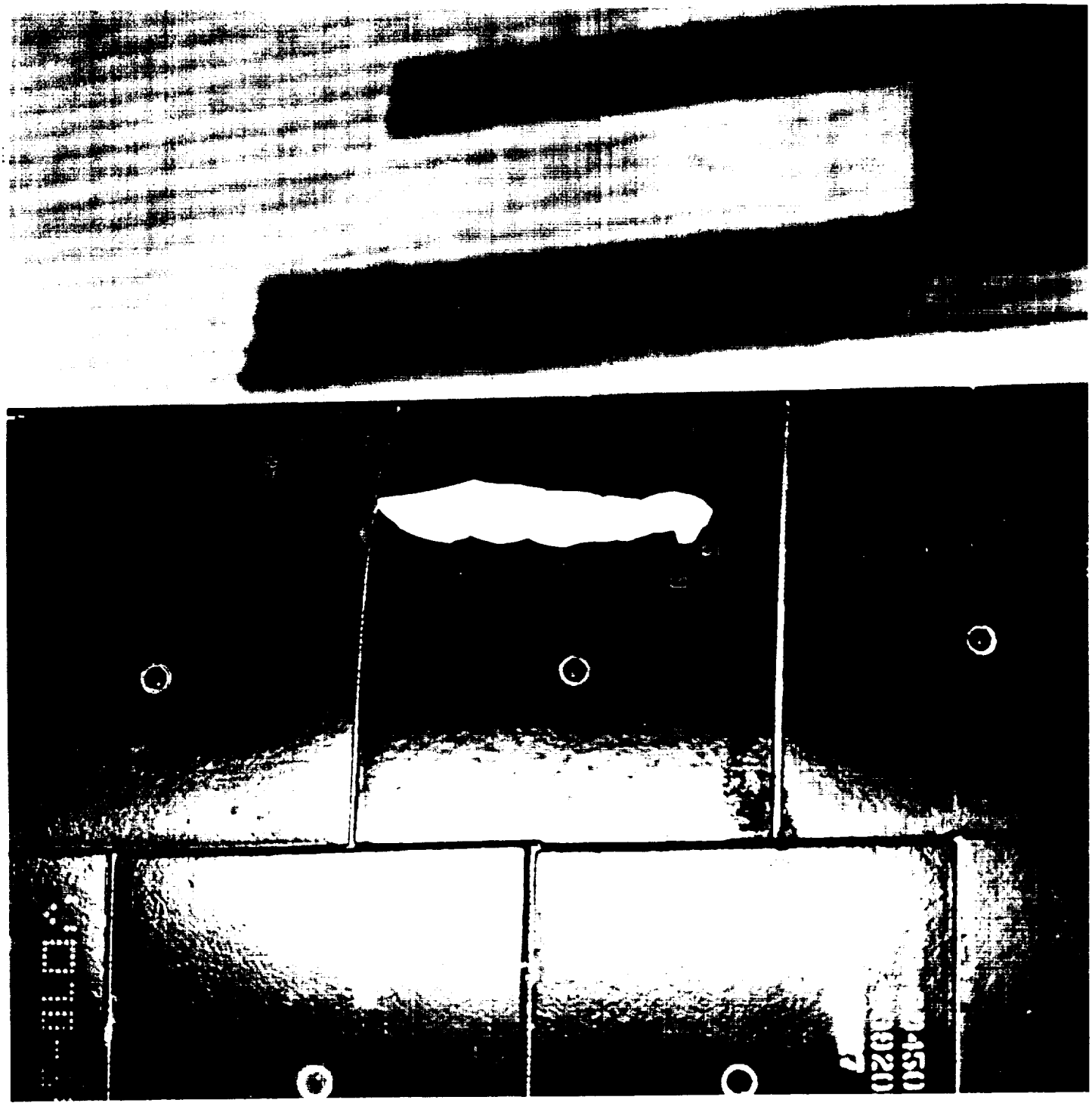




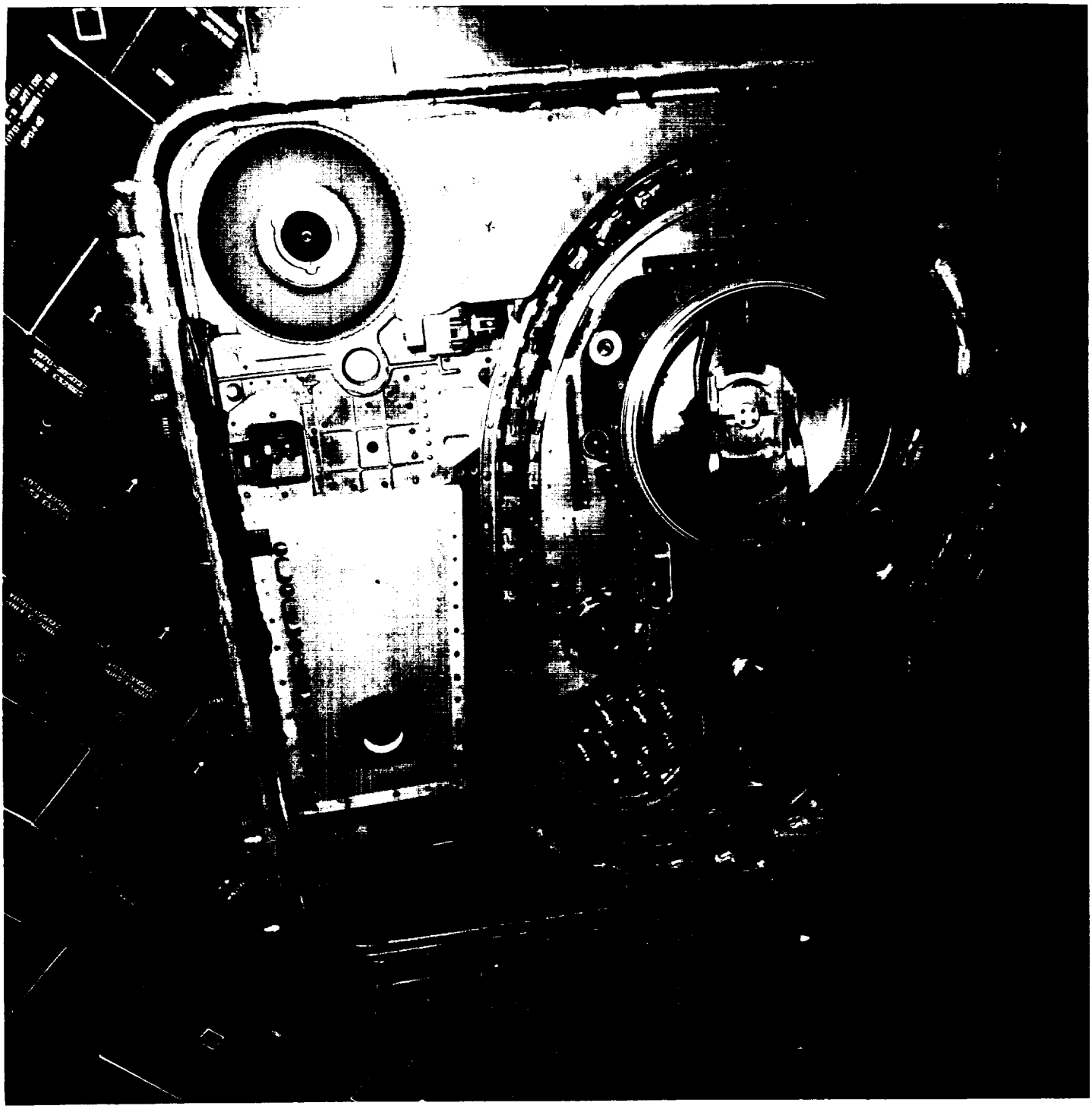
OV-105 Endeavour made the second night landing
at the Kennedy Space Center



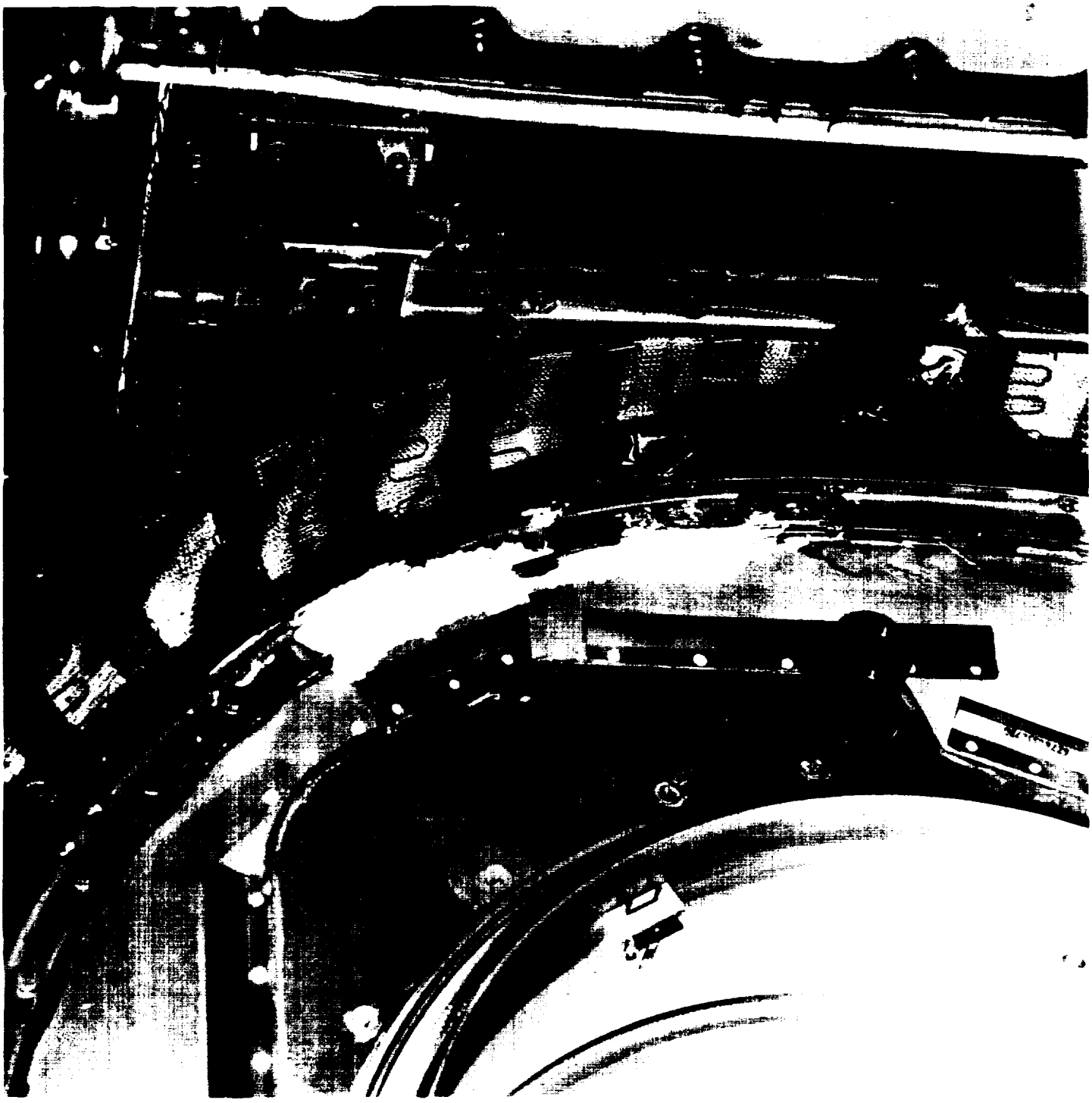
Overall view of the Orbiter right side
Note damage to a tile on the RH wing chine area



The Orbiter lower surface tiles sustained a total of 59 hits, of which 7 had a major dimension of 1-inch or greater. The largest tile damage site on the lower surface was on the RH wing chine and measured 5" x 1.5" x 0.125".

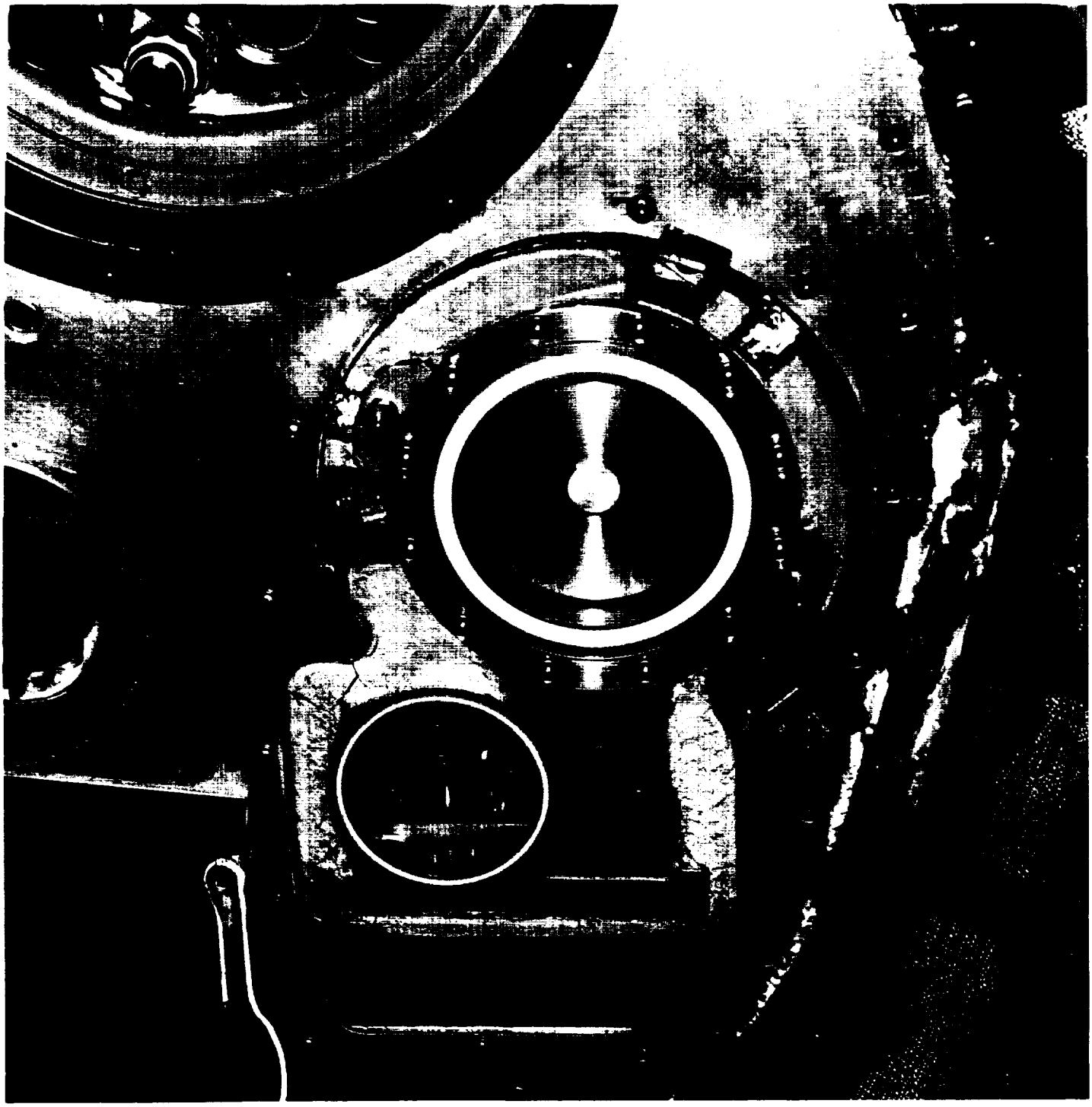


Overall view of the LO2 ET/ORB umbilical. All separation ordnance devices functioned properly. No flight hardware was found on the runway below the umbilical when the ET door was opened.

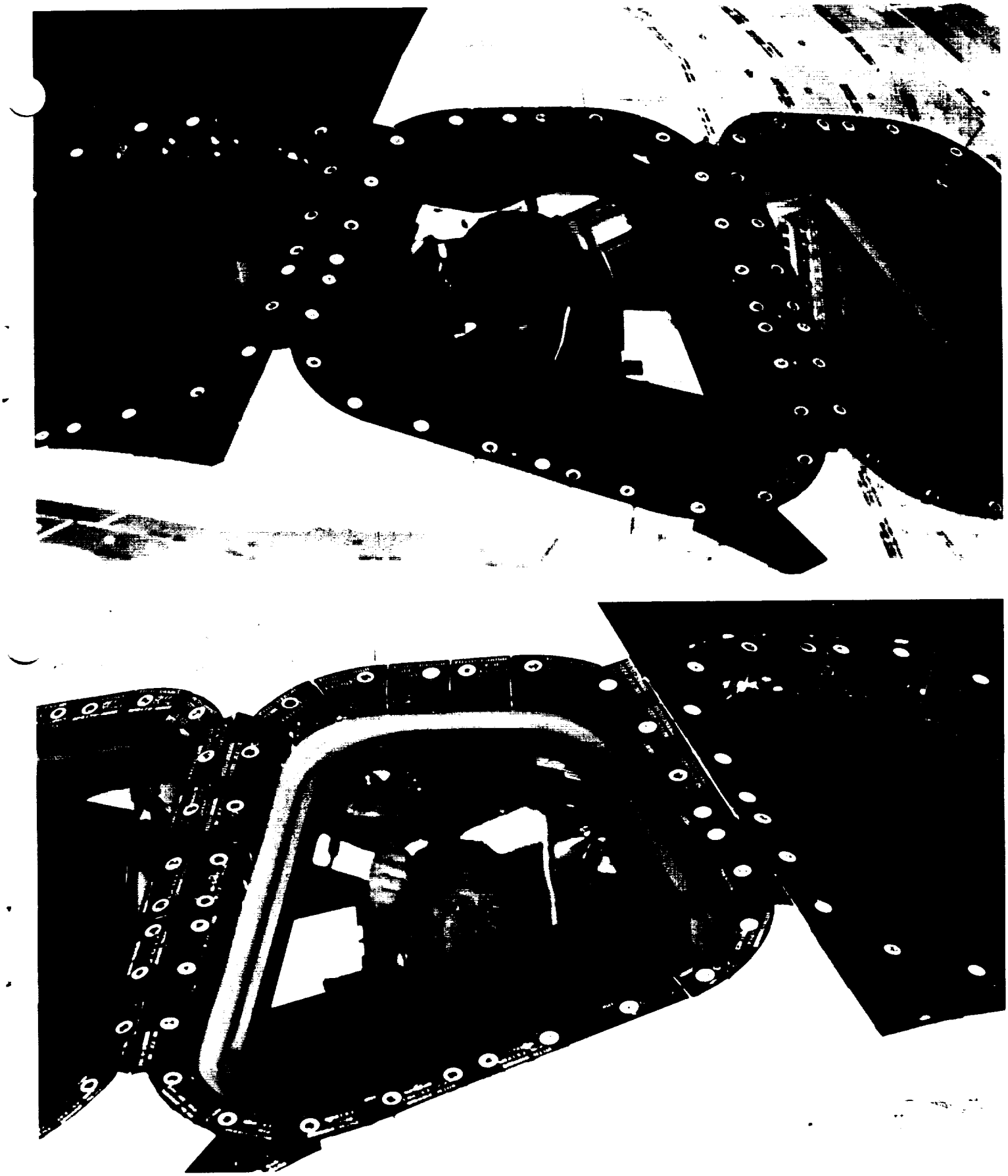


Forward inboard pyro canister closeout foam
adhered to the LO2 ET/ORB umbilical plate

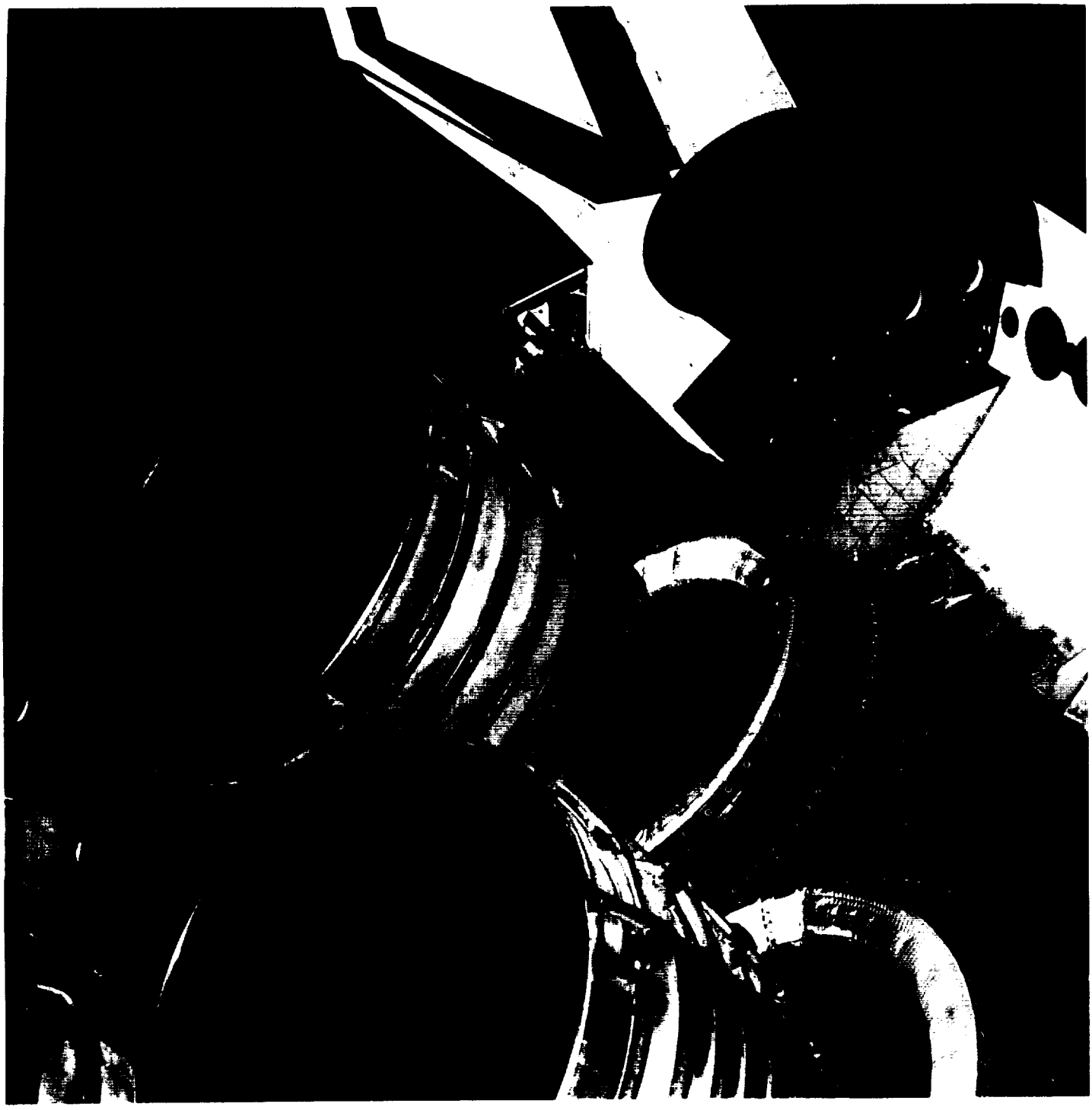
Overall view of the LH2 ET/ORB umbilical. All separation ordnance devices functioned properly. No flight hardware was found on the runway below the umbilical when the ET door was opened.



No significant amounts of ET foam or red purge seal adhered to the LH2 ET/ORB umbilical plate near the LH2 4-inch line flapper valve.



Orbiter windows #3 and #4 were moderately hazed. Some streaks were present on window #4. Damage to window perimeter tiles was typical.



Tile damage on the base heat shield was typical. No tiles were damaged by the drag chute door or risers. Dome Mounted Heat Shield closeout blankets were in excellent condition.

9.0 DEBRIS SAMPLE LAB REPORTS

A total of eight samples were obtained from OV-105 Endeavour during the STS-61 post landing debris assessment at Kennedy Space Center. The samples consisted of 8 wipes from Orbiter windows #1 - #8. The samples were analyzed by the NASA KSC Microchemical Analysis Branch (MAB) for material composition and comparison to known STS materials. Debris analysis involves placing and 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.

ORBITER WINDOWS

Samples from the Orbiter windows indicated exposure to SRB BSM exhaust, Orbiter Thermal Protection System (TPS), paints and primer from various sources, natural landing site products, and carbon steel welding spheres. Textile and building insulation fibers were also present. All of these materials have been previously observed and occurred only in trace quantities. There was no apparent vehicle damage related to these residuals.

STS-61 ORGANIC ANALYSIS

The final results of the STS-61 organic analysis are shown in Figure 17. Types of identified materials are those associated with window covers (plastic polymers, rubber) and RCS thruster cover adhesive. No new findings resulted from this particular analysis.

NEW FINDINGS

This set of post-flight debris residual samples revealed a second occurrence of an unusual finding in the window samples. Blue paint particles were found in trace amounts that appeared similar to those noted in STS-58 analysis testing. Due to the small quantity of this sample, no conclusive organic "fingerprint" analysis could be performed.

STS	Sample Location				
	Windows	Wing RCC	Lower Tile Surface	Umbilical	Other
61	Metallics - BSM Residue (SRB) RTV, Tile filler (ORB TPS) Insulation Glass (ORB TPS) Fiber - Building insulation, textile Earth minerals - (Landing site) Blue paint particles Organics - Plastic polymers, rubber RTV-RCS Nozzle thruster cover(SRB) Paint and primer				
58	Metallics - BSM Residue (SRB) RTV, Tile (ORB TPS) Insulation Glass (ORB TPS) Glass fiber - Structural insulation Earth minerals - (Landing site) Blue paint/zinc alloy Organics-Plastic polymers, adhesive RTV-RCS Nozzle thruster cover(SRB) Paint				
51	Metallics - BSM Residue (SRB) - Solder (Launch Site) RTV, Tile, Tile coating (ORB TPS) Insulation Glass (ORB TPS) Glass fiber 'E-glass' Organics-Plastic polymer,filled plastic(PVC) Paint		Silica tile material Black and white paints Organics - Plastic polymer,RTV,paint		Left OMS pod- -tile,RTV,silicon carbide
57	Metallics-BSM Residue(SRB) RTV,Tile,Tile coating(ORB TPS) Insulation Glass(ORB TPS) Glass fiber-"E"-glass Calcite,Alpha-Quartz,Salt(Lndg.Site) Paint and Primer Organics-plastic polymer,RTV,paint				
55	Metallics - BSM Residue (SRB) RTV, Tile (ORB TPS) Insulation Glass (ORB TPS) Glass fiber - 'E-glass' Calcite,Muscovite,Salt(Landing Site) Anhydrite (Landing Site) Paint Organics-Plastic polymer,rubber,adh.				

FIGURE 17. Orbiter Post Landing Microchemical Sample Results

STS	Sample Location				
	Windows	Wing RCC	Lower Tile Surface	Umbilical	Other
56	Metallics - BSM Residue (SRB) - Solder (Launch Site) RTV, Tile, Tile coating (ORB TPS) Insulation Glass (ORB TPS) Glass fiber 'E-glass' Organics-Plastic polymer,filled plastic(PVC) Paint		Silica-rich tile (ORB TPS) Tile coating, RTV (ORB TPS)		
54	Metallics - BSM Residue (SRB) RTV, Tile (ORB TPS) Insulation Glass (ORB TPS) Calcite,Alpha-Quartz,Salt(Lndg. Site) Organics - plastic (loctite) Organics-Plastic polymer,filled plastic(PVC) Paint	Metallics - BSM Residue (SRB) Tile, Insulation Glass (ORB TPS) Calcium - Silica, Salt (Landing Site) Organics - plastic polymers Paint			
53	Metallics - BSM Residue (SRB) - Solder (Launch Site) RTV, Tile (ORB TPS) Insulation Glass (ORB TPS) Calcite, Salt (Landing Site) Organics - Fibrous mat'l,RTV,Grease Organics-filled rubber,plastic polymers Paint			LO2 Umbilical Door - - Closeout Mat'l (ORB TPS) - Hydrocarbon "grease-like" sub.	RH SRB Aft Skirt Damage site - - Tile, Tile coating mat'l (ORB TPS)
52	Metallics - BSM Residue (SRB) RTV, Tile (ORB TPS) Insulation Glass (ORB TPS) Calcite, Salt (Landing Site) Organics-Fibrous mat'l,red RTV Organics-filled rubber,plastic polymers Paint				HRSI Tile Damage Site- -Tile Mat'l and silicon carbide (ORB TPS) -Paints -Calcite,salts (Landing Site)
47	Metallics - BSM Residue (SRB) RTV, Tile (ORB TPS) Insulation Glass (ORB TPS) Calcite, Salt (Landing Site) Window Polish Residue (ORB) Organics-Fibrous mat'l,red RTV Organics-filled rubber,plastic polymers Paint		Silica-rich Tile (ORB TPS)		

FIGURE 17. Orbiter Post Landing Microchemical Sample Results

STS	Sample Location				
	Windows	Wing RCC	Lower Tile Surface	Umbilical	Other
46	Metallics - BSM Residue (SRB) RTV, Tile (ORB TPS) Insulation Glass (ORB TPS) Calcite,Alpha-Quartz,Salt(Lndg. Site) Organics-Adhesive,Foam,red RTV Organics-filled rubber,plastic polymers Paint				Crew Hatch Window - Metallics - BSM Residue (SRB) - Alpha-Quartz, Salt (Landing Site) - RTV, Tile (ORB TPS) - Paint - Organics
50	Metallics - BSM Residue (SRB) RTV, Tile (ORB TPS) Insulation Glass (ORB TPS) Window Polish Residue (ORB) Mica, Calcium, Salt (Landing Site) Organics-Adhesive,Foam Organics-Plastic Polymers Paint		Silica-Rich Tile (ORB TPS)		Orbiter Vertical Stabilizer - Tile Coating (ORB TPS) - Structural Coating Glass "E-Glass"
49	Metallics - BSM Residue (SRB) RTV, Tile (ORB TPS) Insulation Glass (ORB TPS) Mica, Calcium, Salt (Landing Site) Organics Paint	RTV, Tile (ORB TPS) Rust - BSM Residue (SRB) Muscovite, Salt (Landing Site) Organics Paint	RTV, Tile (ORB TPS) Insulation Glass (ORB TPS) Rust - BSM Residue (SRB) Calcium Mat'l,Salt (Landing Site Soil) Organics Paint		
45	Metallics - BSM Residue (SRB) RTV, Tile (ORB TPS) Insulation Glass (ORB TPS) Calcite, Salt (Landing Site) Window Polish Residue (ORB) Organics Paint		Iron - Rich Mat'l Paint		
42	Metallics - BSM Residue (SRB) RTV, Tile (ORB TPS) Insulation Glass (ORB TPS) Calcite, Salt (Landing Site) Muscovite (Landing Site) Organics Paint		Metallics - BSM Residue (SRB) Tile, Tile Coating (ORB) Salt (Landing Site) Paint	Organics	RH Fuselage - Tile Coating (ORB)
44	Metallics - BSM Residue (SRB) RTV, Tile (ORB TPS) Insulation Glass (ORB TPS) Calcite, Salt (Landing Site) Muscovite (Landing Site) Organics Paint			Organics Silica-Magnesium Mat'l	

FIGURE 17. Orbiter Post Landing Microchemical Sample Results

STS	Sample Location				
	Windows	Wing RCC	Lower Tile Surface	Umbilical	Other
48	Metallics - BSM Residue (SRB) RTV, Tile (ORB TPS) Insulation Glass (ORB TPS) Calcite, Salt (Landing Site) Muscovite (Landing Site) Organics Paint			Metallics Silica - Rich Mat'l (Landing Site) Orb Umbilical C/O Mat'l (ORB) Paints	
43	Metallics - BSM Residue (SRB) RTV, Tile (ORB TPS) Insulation Glass (ORB TPS) Calcite, Salt (Landing Site) Window Polish Residue (ORB) Organics Paint		RTV, Tile (ORB TPS) Metallics - BSM Residue (SRB) Salt (Landing Site) Organics Paint		Runway - FRSI Coating (ORB)
40	Metallics - BSM Residue (SRB) RTV, Tile (ORB TPS) Insulation Glass (ORB TPS) Calcite, Salt (Landing Site) Window Polish Residue (ORB) Organics Paint	Metallics - BSM Residue (SRB) RTV, Tile (ORB) Insulation Glass (ORB TPS) Ensolite Foam (RCC Prot. Covers) Organics Paint	RTV,Tile (ORB TPS)	Metallics - BSM Residue (SRB) RTV, Tile (ORB TPS) Insulation Glass (ORB TPS) Organics (ORB Umb C/O) Paint	
39		Metallics - BSM Residue (SRB) RTV, Tile (ORB) Insulation Glass (ORB TPS) Ensolite Foam (RCC Prot. Covers) Organics Paint Hypalon Paint (SRB)	Tile (ORB TPS) Insulation Glass (ORB TPS)		
37	Metallics - BSM Residue (SRB) RTV, Tile (ORB TPS) Insulation Glass (ORB TPS) Calcite, Salt (Landing Site) Organics	Metallics - BSM Residue (SRB) RTV, Tile (ORB) Insulation Glass (ORB TPS) Calcite, Salt (Landing Site) Organics Paint	RTV, Tile ((ORB TPS) Insulation Glass (ORB TPS) Metallics - BSM Residue (SRB) Calcite, Salt (Landing Site) Organics		
35	Metallics - BSM Residue (SRB) RTV, Tile (ORB TPS) Insulation Glass (ORB TPS) Calcite, Salt (Landing Site) Window Polish Residue (ORB) Organics Paint	Metallics - BSM Residue (SRB) RTV, Tile (ORB) Organics	RTV, Tile (ORB TPS) Metallic - Rust, Aluminum Welding Slag (Facility)		

FIGURE 17. Orbiter Post Landing Microchemical Sample Results

STS	Sample Location				
	Windows	Wing RCC	Lower Tile Surface	Umbilical	Other
38		RTV, Tile (ORB TPS) Hypalon Paint (SRB) Ensolite Foam (RCC Prot. Cover)	Tile (ORB TPS)		
41	Metallics - BSM Residue (SRB) RTV, Tile (ORB TPS) Insulation Glass (ORB TPS) Calcite, Salt (Landing Site) Organics	Tile (ORB TPS) Salt (Landing Site)	Tile (ORB TPS)	Calcite (Landing Site) Fluorocarbon (Viton-ORB Umb) Foam (ORB C/O)	Fwd FRSI - Silicon Mat'l (ORB TPS)
31R	Metallics - BSM Residue (SRB) RTV, Tile (ORB TPS) Insulation Glass (ORB TPS) Calcite, Salt (Landing Site) Organics	Metallics - BSM Residue (SRB) RTV, Tile (ORB TPS) Insulation Glass (ORB TPS) Mica (Landing Site) Organics Foam Insulation (ET/SRB) Paint	RTV, Tile (ORB TPS) Insulation Glass (ORB TPS) Mica (Landing Site) Paint		
36	Metallics - BSM Residue (SRB) RTV, Tile (ORB TPS) Insulation Glass (ORB TPS) Mica, Salt (Landing Site) Paint	Rust - BSM Residue (SRB) Tile (ORB TPS) Paint Organics	RTV, Tile (ORB TPS) Insulation Glass (ORB TPS) Mica (Landing Site) Organics Microballoon (ET/SRB)	Rust - BSM Residue (SRB) RTV, Insulation Glass (ORB TPS) Microballoon (ET/SRB) Calcite (Landing Site) Foam, Organics (ORB Umb C/O)	
32R	Metallics - BSM Residue (SRB) RTV, Tile (ORB TPS) Insulation Glass (ORB TPS) Mica, Salt (Landing Site) Paint		Metallics - BSM Residue (SRB) Tile (ORB TPS) Carbon Fibers Titanium	Metallics - BSM Residue (SRB) RTV, Insulation Glass (ORB TPS) Phenolic Microballoon (ET/SRB) Quartz, Calcite (Landing Site) Organics	
33R	Metallics - BSM Residue (SRB) RTV, Tile (ORB TPS) Insulation Glass (ORB TPS) Micaceous Mat'l, Salt (Landing Site) Window Polish Residue (ORB) Paint	Metallics - BSM Residue (SRB) Tile (ORB TPS) Insulation Glass (ORB TPS) Mica, Spar, Salt (Landing Site) Organics	RTV, Tile (ORB TPS)	Rust - BSM Residue (SRB) RTV, Insulation Glass (ORB TPS) Phenolic Microballoon (ET/SRB) Paint Organics	Crew Hatch Window - Rust - BSM Residue (SRB) - Alpha Quartz (TPS/Landing Site) - Paint - Organics
34	Metallics - BSM Residue (SRB) RTV, Tile (ORB TPS) Insulation Glass (ORB TPS) Alpha-Quartz, Silicates, Salt (L/S) Window Polish Residue (ORB)	Metallics - BSM Residue (SRB) RTV, Tile (ORB TPS) Insulation Glass (ORB TPS) Paint	RTV, Tile (ORB TPS) Stainless Steel Washer	RTV (ORB) Foam (ORB) Viton Rubber (ORB) Metallics - BSM Residue (SRB) Phenolic Microballoon (ET/SRB) Silicates, Calcium (Landing Site) Paint	
28R	Silicone (ORB FRCS Cover Adhesive)	Silicates (Landing Site) Paint Charred Silicone Brass Chip	RTV, Tile (ORB TPS) Clay, Sand, Quartz (Landing Site) Metallics - BSM Residue (SRB)	Sand, Silicates (Landing Site) Foam (ORB) RTV (ORB TPS) Koropon, Kapton (ORB) Metallics - BSM Residue (SRB)	OMS Pod - PVC Laminate (ORB TPS 'Shim')

FIGURE 17. Orbiter Post Landing Microchemical Sample Results

STS	Sample Location				
	Windows	Wing RCC	Lower Tile Surface	Umbilical	Other
30R	Metallics - BSM Residue (SRB) RTV, Tile (ORB TPS) Insulation Glass (ORB TPS) Clay, Salt (Landing Site) Paint		Metallics - BSM Residue (SRB) RTV, Tile (ORB TPS) Gap Filler (ORB TPS) Clay, Feldspar (Landing Site)		Upper Tile - Tile,Gap Filler (ORB TPS)
29R	RTV, Tile (ORB TPS) Metallics - BSM Residue (SRB) Ablator, Hypalon Paint (SRB)		Tile (ORB TPS) Insulation Glass (ORB TPS) Paint Muscovite - Metallics (Landing Site)	Tile (ORB TPS) Umbilical Foam (ORB) Paint Ablator, Hypalon Paint (SRB) Metallics - BSM Residue (SRB)	Upper Tile - Tile (ORB TPS)
27R	RTV, Tile (ORB TPS)	Hypalon Paint (SRB)	RTV, Tile (ORB TPS) Ablator, Hypalon Paint (SRB)		OMS Pod - Iron Fiber - PDL Foam, FRL Paint (ET) - Ablator, Hypalon Paint (SRB)
26R			RTV, Tile (ORB TPS) Paint Rust		

Sample locations vary per mission and not all locations are sampled for every mission.
( ) - identifies the most probable source for the materail.
Metallics - includes mostly Aluminum and Carbon Steel alloys

FIGURE 17. Orbiter Post Landing Microchemical Sample Results

10.0 POST LAUNCH ANOMALIES

Based on the debris walkdowns and film/video review, five post launch anomalies, including one In-Flight Anomaly (IFA), were observed on the STS-61 mission.

10.1 LAUNCH PAD/SHUTTLE LANDING FACILITY

1. Post launch inspection of the MLP deck revealed a 1" x 1/4" facility bolt on the west surface of the MLP deck near the FSS cross over. A bolt was loose and a second missing from the E-15 camera protective cover. A bolt was missing and a cover plate was opened on the E-27 camera protective cover. Both cameras are located on the north end of the RH SRB exhaust hole.

2. The GH2 vent line was latched on the second tooth of the latching mechanism and had no loose cables (static retract lanyard). However, the GH2 vent line was outside the south forward flexhose support struts and offset 8-10 inches from the haunch centerline. As a result, the latching mechanism was not centered. The crossbeam between the GUCP legs showed signs of contact with the static retract lanyard.

10.2 EXTERNAL TANK

1. No items.

10.3 SOLID ROCKET BOOSTERS

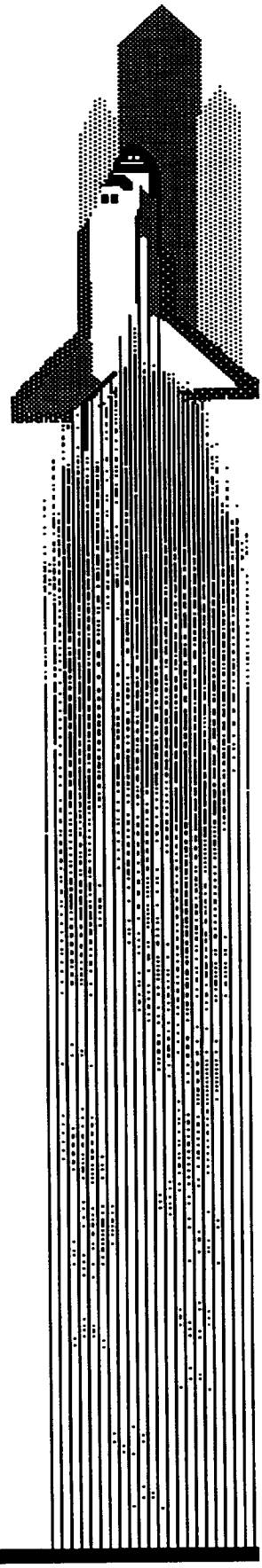
1. A 2" x 0.5" x 0.2" divot occurred on the leading edge of a GEI cork run (right forward segment XB-1099 at 220 degrees). The remaining material was sooted and most likely lost during ascent (IFA STS-61-I-01). Post flight lab analysis determined the loss was not a material/processing failure. The most probable cause of the cork loss is believed to be a debris impact during ascent. Since no debris sources were identified on the RH SRB forward of the damage site, ice from the ET LO2 feedline bellows has been cited as the leading candidate.

2. Three BSM aero heatshield covers were missing. Post flight assessment determined the covers had opened and latched properly.

10.4 ORBITER

1. A 6" x 1/2" tile gap filler, or GSE shim, originated in the body flap hinge gap and fell aft during SSME ignition.

Appendix A. JSC Photographic Analysis Summary



Space Shuttle

Photographic and Television Analysis Project

January 7, 1994

NASA
National Aeronautics and
Space Administration

Lyndon B. Johnson Space Center
Houston, Texas 77058

Space Shuttle Photographic and Television Analysis Project

STS-61 Summary of Significant Events

Project Work Order - SN-AFV

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1.0 Mission Summary

STS-61 was the ground breaking Hubble Space Telescope (HST) repair mission. The orbital inclination angle for this mission was 28.5 degrees and the initial orbiting altitude was 317 nautical miles. The crew on this mission consisted of: commander Richard Covey, pilot Kenneth Bowersox, payload commander, Story Musgrave, and mission specialists Thomas Akers, Jeff Hoffman, Claude Nicollier, and Kathryn Thornton.

1.1 Launch

The launch of Endeavour (OV-105) for STS-61 occurred from Pad B at 09:26:59.995 Coordinated Universal Time (UTC) on December 2, 1993 (Day 336) as seen on camera E-8. Solid rocket booster (SRB) separation occurred at 09:29:06.695 UTC as seen on camera ET-212.

On launch day, 24 videos were screened. Following launch day, 51 films were reviewed. Cameras E-1, E-9, and E-10 did not run. No potential anomalies were observed during launch.

Detailed test objective (DTO)-312, photography of the external tank after separation, was performed this mission using a handheld Hasselblad camera with a 250 mm lens. No anomalies were verified from the handheld pictures of the external tank (ET). A booster motor separation burn scar on the intertank is visible. A bright mark on the forward portion of the intertank can be seen which was determined to be an antenna. The orientation and details of the external tank are difficult to see because of the small image size of the tank. Eighteen frames of the ET were acquired by the astronauts. Coverage of the SRB separation was obtained by the 16 mm umbilical well camera.

Three left SRB frustum booster separation motor (BSM) aero heat shield covers were missing at the time of recovery. Preliminary post flight analysis at Kennedy Space Center (KSC) indicated that the covers had opened and latched properly and that the damage probably occurred at water impact. Further analysis will be conducted at Marshall Space Flight Center (MSFC).

1.2 On Orbit

No significant events were tracked on orbit.

1.3 Landing

Endeavour landed on runway 33 at KSC on December 13, 1993. Fourteen videos of the Orbiter's approach and landing were received. NASA Select, which uses multiple views real-time, was also received. Left main gear touchdown was at 347:05:25:32.537 UTC and right main gear touchdown occurred at 347:05:25:32.571 UTC as seen on camera KTV-33L. Nose wheel touchdown occurred at 347:05:25:45.432 UTC as seen on camera KTV-5L. Wheel stop was at 347:05:26:25 UTC as seen on camera KTV-33L.

On landing day, thirteen videos were screened. Five of the views were acquired from infrared cameras and one view was acquired from an intensified visible camera. Following landing day, twelve films were screened. No major anomalies were noted in any of the approach, landing or rollout video and film views screened. During the post landing walk around, slight tile damage was noted on the right side of the Orbiter forward of the wing. Also noted was a slightly frayed portion of the sill of the liquid oxygen (LO2) umbilical door.

1.4 Timing Activities

All launch videos had timing and launch film cameras E-2, E-3, E-4, E-5, E-6, E-7, E-8, E-11, E-12, E-13, E-14, E-15, E-16, E-17, E-18, E-19, E-20, E-25, E-26, E-52, E-54, E-57, E-59, and E-222 had in-frame alphanumeric timing. All of the landing videos had timing except cameras EL17 IR, EL18 IR, SLF North, and SLF South. The videos and films containing timing were used to time specific mission events during the initial screening.

2.0 Summary of Significant Events

2.1 Debris

2.1.1 Debris near the Time of Space Shuttle Main Engine (SSME) Ignition

2.1.1.1 ET/Orbiter Umbilical Disconnect Debris

(Cameras E-5, E-6, E-25, E-26, E-30, E-31, E-36, E-52, E-57, OTV-109, and OTV-163)

Normal ice debris was noted falling from the liquid hydrogen (LH2) and LO2 ET/Orbiter umbilical disconnect areas at SSME ignition through liftoff. On camera OTV-109, ice debris appeared to strike the sill below the LH2 umbilical. There was no apparent damage to the vehicle. No follow-up action has been requested.

2.1.1.2 Rectangular Shaped Debris Near the Body Flap

(Camera E-17)

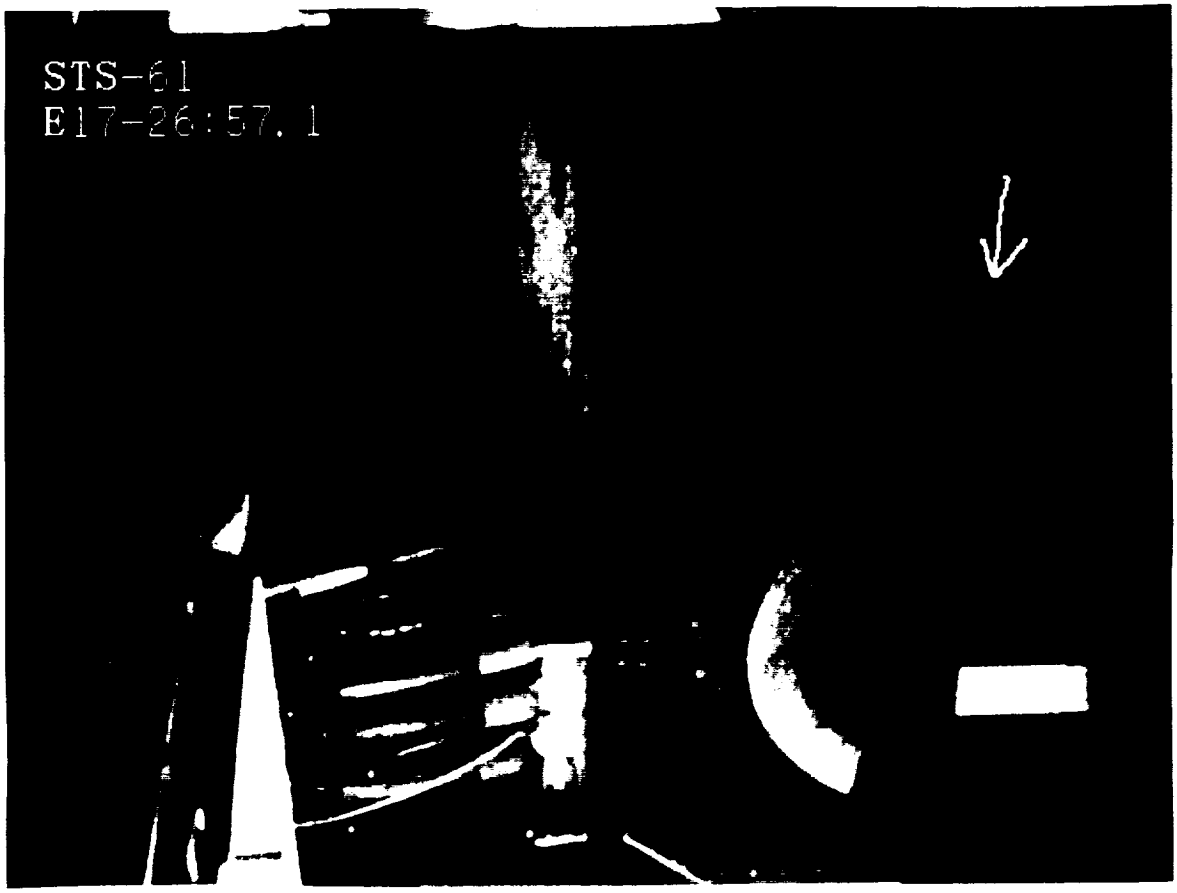


Figure 2.1.1.2 Thin rectangular shaped debris falls along the body flap

A thin rectangular shaped piece of light colored debris was noted coming from the body flap hinge area and fell aft along the body flap at SSME ignition. There was no apparent damage to the vehicle. No follow-up action has been requested.

2.1.1.3 LH2 and LO2 Tail Service Mast (TSM) T- 0 Umbilical Disconnect Debris *(Cameras E-2, E-17, E-18, E-19, E-20, E-76, E-77, OTV-109, OTV-149, OTV-170, and OTV-171)*

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 appeared to strike the vehicle.

2.1.2 Debris near the Time of SRB Ignition

2.1.2.1 SRB Flame Duct Debris *(Task #7)*
(Cameras E-7, E-8, E-11, E-12, E-13, E-14, E-15, E-16, and E-62)

Several pieces of debris were noted originating from the SRB flame duct area after SRB ignition. None of the debris was observed to strike the vehicle.

2.1.3 Debris after Liftoff

2.1.3.1 Debris Aft of the ET Between the SRBs
(Camera E-222)

A light colored piece of debris, possibly umbilical purge barrier material, was noted below the left wing and in between the SRBs. This type of debris has been seen on previous missions. See Figure 2.1.3.1.

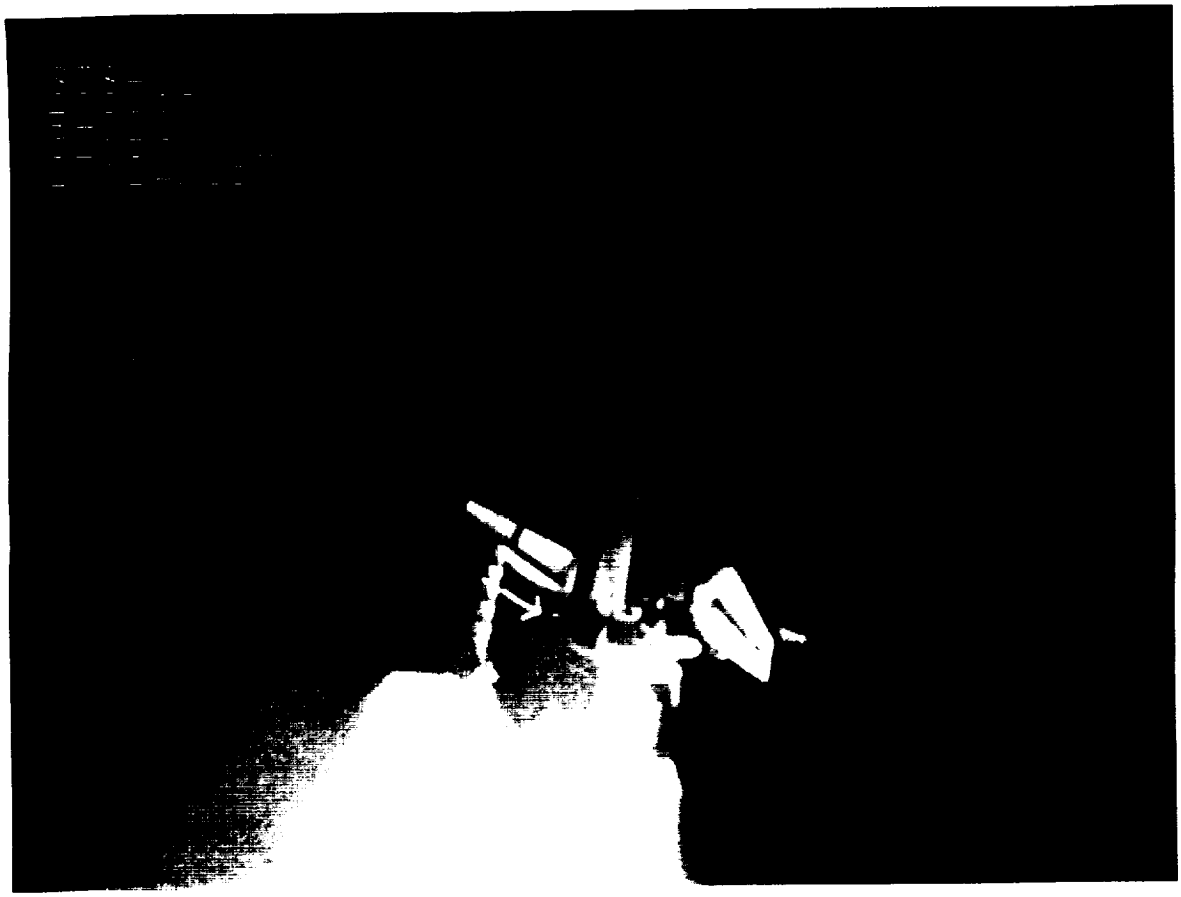


Figure 2.1.3.1 Debris shown between the SRBs at approximately 24 seconds mission elapsed time (MET).

2.1.3.2 Debris in SSME Plumes

(Cameras E-2, E-17, E-19, E- 54, E-76, E-207, E-212, E-213, E-220, E-222, E-223, and E-224)

Multiple pieces of debris were seen falling aft of the Shuttle Launch Vehicle (SLV) at liftoff, throughout the roll maneuver, and beyond 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 has been requested.

2.1.3.3 Debris Reported by Crew *(Task #10)*

The commander and pilot reported that no unusual debris was visible from windows W1, W2 or W3 during launch and ascent with the exception of several white marks resembling white paint on some of the windows.

2.2 Mobile Launch Platform (MLP) Events

2.2.1 Orange and Green Vapors (Possible Free-Burning Hydrogen)

(Cameras E-2, E-3, E-4, E-5, E-15, E-16, E-17, E-18, E-19, E-20, E-30, E-36, E-41, E-52, E-62, E-76, E-77, OTV-163, OTV-170, and OTV-171)

Figure 2.2.1 Green vapor shown to travel north below the body flap (Note: photo inadvertantly printed backwards)

Orange and green vapors have been seen on previous missions and are considered to be free burning hydrogen. They are seen below the SSME bells and travel northward under the body flap. This event is monitored to verify that the vapor does not carry up toward the ET/Orbiter umbilicals (which might present a potential hazard). The vapor seen on this mission remained well below the umbilicals.

2.2.2 Discoloration of RCS Cover
(Camera E-18)

A slight discoloration of the R4U RCS cover was noted prior to liftoff. Similar paper discolorations were seen on STS-43, STS-56, and STS-58.

2.2.3 Flashes in SSME Plumes after SSME Ignition
(Cameras E-3, E-15, and E-16)

Multiple flashes were noted in both SSME #2 and #3 plumes at SSME ignition. Flashes in SSME exhaust plumes have been seen on fifteen missions since reflight. No follow-up analysis was requested.

2.3 Ascent Events

2.3.1 Body Flap Motion *(Task #4)*
(Cameras E-207, E-208, E-212, and E-220)

During ascent, slight body flap motion was noted during maximum dynamic pressure (between 30 and 90 seconds MET). The magnitude of the motion seen on the STS-61 views was not sufficient to warrant further analysis.

2.3.2 Recirculation *(Task #1)*
(Cameras E-204, E-208, E-212, E-218, ET-204, ET-208, ET-212 and KTV-13)

The recirculation or expansion of burning gases at the aft end of the SLV prior to SRB separation has been seen on nearly all previous missions. The sighting of this event is dependent upon launch inclination angle and cloud cover during ascent. For STS-61, the start of recirculation was observed at about 93 seconds MET and the end was noted at approximately 113 seconds MET on camera E-208.

Cameras on which recirculation was observed for STS-61

CAMERA	START (seconds MET)	STOP (seconds MET)
ET-204	93	107
ET-208	94	114
ET-212	94	-
KTV-13	-	-
E-204	96	113
*E-208	93	113
E-212	~93	~109
E-218	-	-

*** BEST VIEW OF RECIRCULATION**

2.3.3 Linear Optical Distortions
(Cameras E-212, E-218, and ET-208)

Several linear optical distortions were noted during ascent. These effects, seen on many previous missions, were correlated to light waves being altered by the propagation of shock waves through the atmosphere. No further action is required.

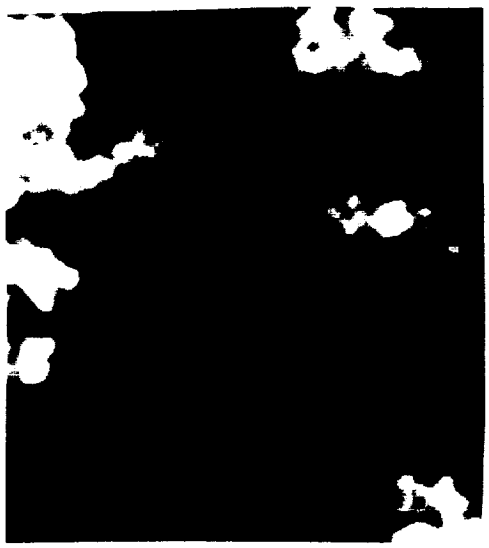
2.3.4 Debris Above and Below the SRB Exhaust Plumes
(Cameras E-207, E-208, E-212, E-213, E-218, ET-212, KTV-4B, and KTV-5)

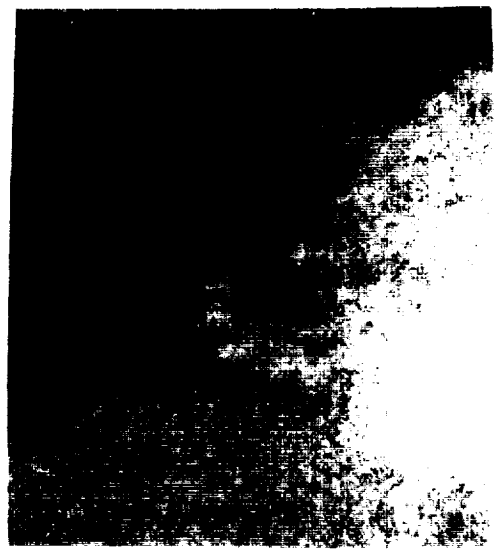
Several light pieces of debris were noted above and below the SRB exhaust plumes prior to SRB separation. This debris is considered to be slag debris which has been seen on many previous missions. No follow-up analysis was requested.

2.4 On Orbit

2.4.1 Analysis of Onboard Photography of the ET (DTO-312) *(Task #6)*

DTO-312 photography of the external tank after separation was acquired with a Hasselblad camera with a 250 mm lens (Method 2). Eighteen frames of the ET were acquired by the astronauts. The exposure and focus for all frames were good. Representative images are shown in Figures 2.4.1 (a) & (b).





Figures 2.4.1 (a) & (b) Handheld camera view of ET after separation (Frames STS061-71-003 & STS061-71-014)

The first time the crew saw the external tank was after Endeavour was maneuvered for the OMS burn to circularize their orbit. The pitch maneuver which is normally performed after ET separation for DTO-312 was not performed on STS-61 in order to conserve propellants for the HST capture. The first picture was taken at approximately 36 minutes MET (over eastern Mozambique) and the last picture was taken at approximately 39 minutes MET (over northern Madagascar). The external tank is very small on the pictures due the large distance between the orbiter and the ET. The distance between the external tank and the orbiter was measured to be ~ 10 kilometers for the first picture. Normally, this distance is ~ 1 kilometer.

No anomalies were verified from the pictures of the ET. A booster separation burn scar on the intertank is visible. A bright mark on the forward portion of the intertank can be seen which was determined to be an antenna.

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

2.4.2.1 16 mm Umbilical Well Camera Views of SRB and ET Separation

One 16 mm motion picture film (with a 5 mm lens) was acquired from the Orbiter LH2 umbilical camera. The 16 mm film sequence of the SRB separation is good quality due to the light from the boosters. The LSRB separation appeared normal. The 16 mm umbilical film sequence of ET separation is dark and unusable due to the nighttime conditions. A few frames of the 16 mm views of the external tank are partially exposed from what appears to be light from occasional RCS firings but they are of no value for analysis.

Figure 2.4.2.1 16 mm camera with 5 mm lens view of the LSRB prior to separation (Frame STS061-1013-809)

A dark, flexible strap like object was seen on the 16 mm umbilical well film prior to SRB separation. (See Figure 2.4.2.1) The object was not identified but is possibly a piece of tape. The object was first seen near the base of the external tank and then moved in front of the left SRB before leaving the field of view. The size of the object is unknown but is estimated to be no larger than 18 inches assuming the object is close to the LSRB rather than near the camera. A piece of debris, light colored on one side and dark or red colored on the other side is visible just after SRB separation. The debris is somewhat square-shaped and has a flat appearance. The debris is first visible near the aft -Y Orbiter/LSRB attach brace and then falls aft along the LSRB. This debris has not been identified but it may be a piece of TPS from the external tank.

Other items visible on the 16 mm film sequence of the SRB separation that were (typically) seen on previous mission umbilical well camera film views were: multiple small light colored pieces of debris of various shapes and sizes (probably from TPS erosion) are visible before, during, and after SRB separation; the base of the -Y electric cable tray, the aft ET/Orbiter attach brace and the ET/LSRB attach strut show the typical signs of TPS chipping and erosion; and the -Y side of the LH2 umbilical TPS has a blistered appearance similar to that of previous missions.

2.4.2.2 35 mm Umbilical Well Camera Views of ET Separation

The 35 mm film is dark and unusable. This film sequence, along with the 16 mm film sequence containing ET separation, is underexposed due to nighttime conditions.

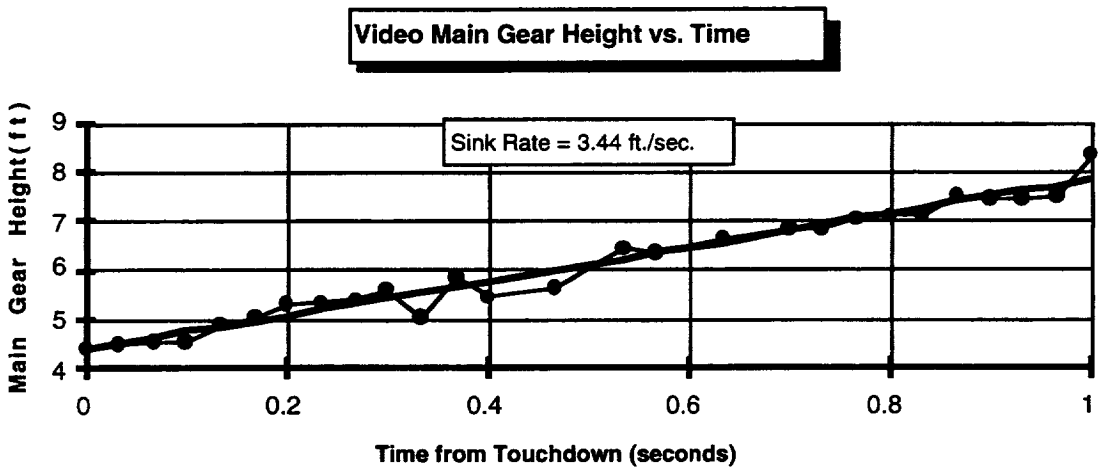
2.5 Landing Events

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

Landing sink rates are calculated from both film and video sources when available. On this mission, the best video view for generating sink rates was KTV-33L. For STS-61, nose gear sink rate was not calculated using film due to the dark lighting conditions of the night landing.

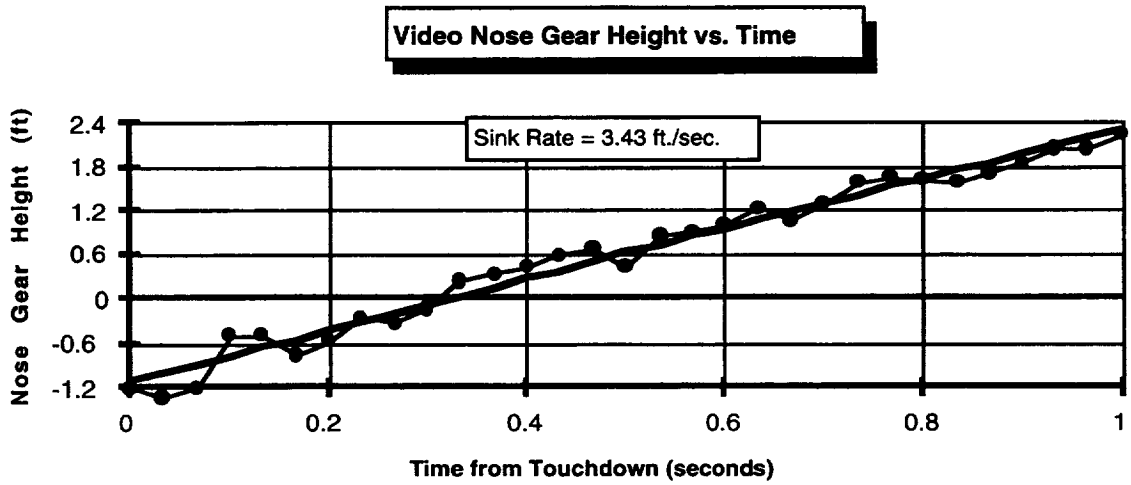
2.5.1.1 Sink Rate from Video
(Camera KTV-33L)

Camera KTV-33L was used to determine the sink rate of the main gear. Data was gathered approximately 1 second prior to landing through touchdown at a rate of 30.0 frames per second. Scalar information was determined by using the distance between the right and left main landing gear struts. An assumption was made that the line of sight of the camera was perpendicular to the Orbiter's z-axis. The y distance between the main gear and a reference point was then multiplied by the scale to find the height of the main gear. These heights were then regressed with respect to time, and the slope of the regression line is equal to the sink rate. The main gear sink rate was determined to be 3.44 feet per second.



*Note. These heights are with respect to a reference point NOT the runway.

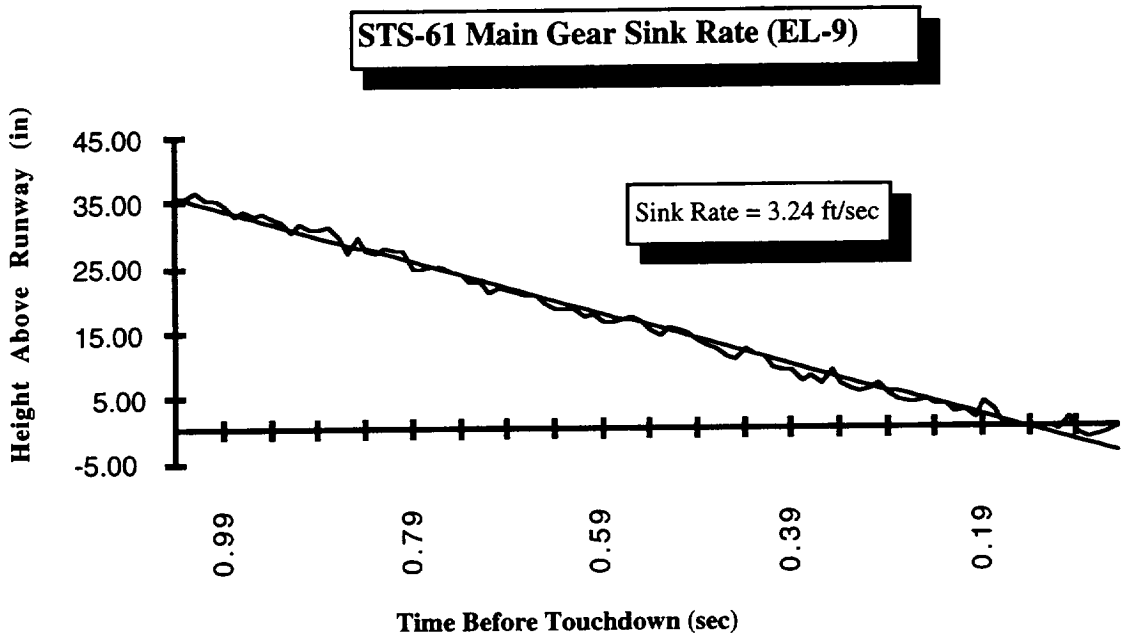
Camera KTV-33L was used to determine the sink rate of the nose gear. Data was gathered approximately 1 second prior to landing through touchdown at a rate of 30.0 frames per second. NOTE: The lack of light affected the resolvability of the nose gear throughout this time period. Scalar information was determined by using the distance between the right and left main landing gear struts. An assumption was made that the line of sight of the camera was perpendicular to the Orbiter's z-axis. The y distance between the nose gear and the main gear was then, multiplied by the scale to find the height of the nose gear. These heights were then regressed with respect to time, and the slope of the regression line was equal to the sink rate. The nose gear sink rate was determined to be 3.43 feet per second.



2.5.1.2 Sink Rate from Film

Camera EL-9 was used to determine the sink rate of the main gear. Data was gathered for approximately 1 second prior to landing at a rate of 100 frames per second. Scalar information was determined by using the distance between SSME bells #2 and #3. An assumption was made that the line of sight of the camera was perpendicular to the Orbiter's y-axis. Since the view was dark, and only the point of touchdown was visible, the motion of

each reference point was tracked for one full second. These heights were then regressed with respect to time, and the slope of the regression line was equal to the sink rate. The main gear sink rate was determined to be 3.24 feet per second.



2.5.2 Drag Chute Performance *(Task #9)*
(Cameras KTV-5L, KTV-11L, and KTV-15L)

The landing of Endeavour at the end of mission STS-61 marked the 12th deployment of the Orbiter drag chute. All components of the drag chute appeared to deploy as expected. The following are the times for specific drag chute events and cameras from which each time was taken.

Drag chute initiation	347:05:25:41.429 UTC (KTV-11L)
Pilot chute inflation	347:05:25:42.729 UTC (KTV-5L)
Drag chute inflation in reefed configuration	347:05:25:44.132 UTC (KTV-11L)
Drag chute inflation in disreefed configuration	347:05:25:47.532 UTC (KTV-15L)
Drag chute release	347:05:26:07.652 UTC (KTV-15L)

Standard analysis of the drag chute angles as a function of time was performed using views from film camera EL-7. This analysis is used to support the improvement of the aerodynamic math models currently in use. During the first twenty seconds of deployment, the maximum horizontal chute deflection was approximately 6.0 degrees.

2.6 Other Normal Events

Other normal events observed include: Fixed service structure (FSS) and MLP deluge water; ice buildup on the SSME vent nozzles; frost on the gaseous oxygen (GOX) vent louvers on

the ET, slight motion of the body flap between SSME ignition and liftoff; ice and vapor from the gaseous oxygen umbilical carrier plate (GUCP) during SSME startup and arm retraction; ice and vapor from both (TSM) umbilicals at liftoff; debris in the exhaust cloud at the pad after liftoff; ET aft dome outgassing and vapor from the SRB stiffener rings after liftoff; charring of the ET aft dome during ascent; flares in the SSME exhaust plume after the roll maneuver; expansion waves; SRB plume brightening; slag debris in the SRB exhaust plume during and after SRB separation.

Appendix B. MSFC Photographic Analysis Summary

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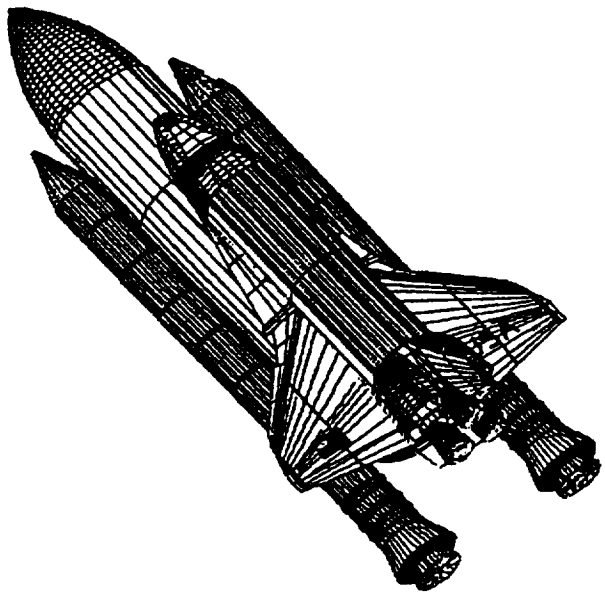
National Aeronautics and
Space Administration

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

SPACE SHUTTLE
ENGINEERING PHOTOGRAPHIC ANALYSIS REPORT
STS-61



ENGINEERING PHOTOGRAPHIC ANALYSIS REPORT

STS-61

FINAL

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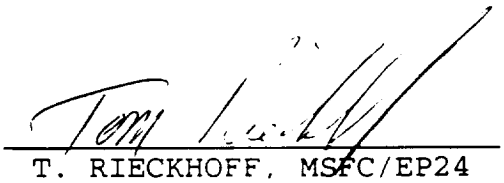

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STS-61 ENGINEERING PHOTOGRAPHIC ANALYSIS REPORT

TABLE OF CONTENTS

* Photographs in the individual camera assessments are representative photographs and are not necessarily photographs taken from this particular launch.

December 22, 1993

I. INTRODUCTION

Space Shuttle Mission STS-61, the fifth flight of the Orbiter Endeavour was conducted December 2, 1993 at approximately 3:26 A.M. Central Standard Time from Launch Complex 39B (LC-39B), Kennedy Space Center (KSC), Florida. Extensive photographic and video coverage was provided 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, and uprange and downrange tracking sites.

II. ENGINEERING ANALYSIS OBJECTIVES:

The planned engineering photographic and video analysis objectives for STS-61 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 forty-eight of fifty-three requested cameras as well as video from all twenty-three requested cameras. The following table illustrates the camera data received at MSFC for STS-61.

Camera data received at MSFC for STS-61

	16mm	35mm	70mm	Video
MLP	19	0	0	3
FSS	7	0	0	3
Perimeter	3	3	0	6
Tracking	0	15	0	11
Onboard	1	1	0	0
Totals	30	19	0	23
Total number of cameras received at MSFC				72

A detailed individual motion picture camera assessment is provided as Appendix B. Appendix C contains detailed assessments of the video products received at MSFC.

a. Ground Camera Coverage:

Photographic coverage of STS-61 was considered good. Coverage was degraded due to the low light levels at night. Film was not received from cameras E-1, 9, and 10 due to mechanical failures on each camera.

b. Onboard Camera Assessment:

The astronauts carried a 35mm hand-held camera to record film for evaluating the ET TPS integrity after ET separation. The normal DTO was not performed. However, pictures were acquired at a later time resulting in a smaller image size. Two 16mm motion picture cameras and one 35mm still camera were flown on this mission in the orbiter's umbilical well to record the SRB and ET separation. The 35mm and the 16mm umbilical film of ET separation was dark and unusable. These films were underexposed due to nighttime conditions. The 16mm film of SRB separation was of good quality and usable.

IV. ANOMALIES/OBSERVATIONS:

a. General Observations:

While viewing the film, several events were noted which occur on most missions. These included: pad debris rising and falling as the vehicle lifts off; debris induced streaks in the

SSME plume; ice falling from the 17" disconnects and umbilicals; and debris particles falling aft of the vehicle during ascent, which consist of RCS motor covers, hydrogen fire detection paper and purge barrier material. Body flap and inboard right elevon motions were noted during ascent.

b. Glowing debris from SRM plume

Figure 1 is a film frame from camera E-218 showing glowing debris particles being ejected from the SRM plume. Several pieces of glowing debris were noted during ascent. A copious amount of glowing debris was noted exiting from the SRM at separation. This debris is generally more visible during a night launch due to the stronger contrast with the night sky.

c. Loose thermal curtain tape

Figure 2 shows a film frame from camera E-207 showing a piece of thermal curtain tape which came from the left SRB. The tape was estimated to be approximately 7 feet long.

V. ENGINEERING DATA RESULTS:

a. T-Zero Times:

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

POST	CAMERA POSITION	TIME (UTC)
M-1	E-9	no run
M-2	E-8	336:09:26:59.993
M-5	E-12	336:09:26:59.992
M-6	E-13	336:09:26:59.992

b. ET Tip Deflection:

Maximum ET tip deflection for this mission was determined to be approximately 30 inches. Figure 3 is a data plot showing the measured motion of the ET tip in both the horizontal and vertical directions. These data were derived from camera OTV-161.

c. SRB Separation Time:

SRB separation time for STS-61 was determined to be 336:09:29:06.70 UTC as recorded by camera E-207.

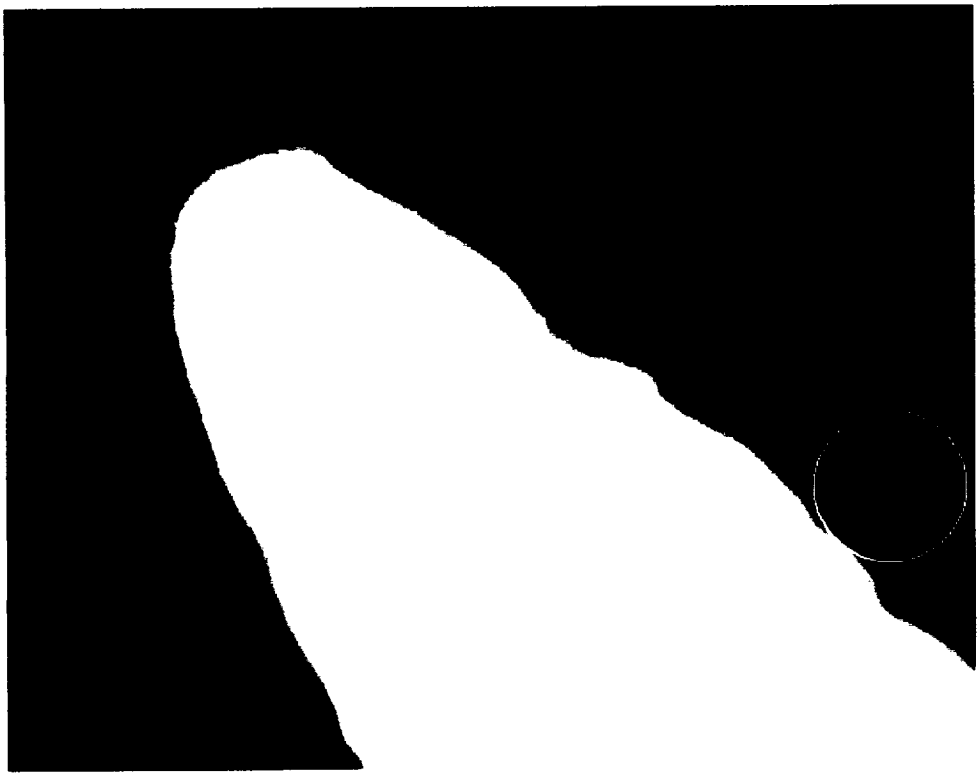


Figure 1.

Glowing Debris Particles from SRM Plume at T+81 Seconds

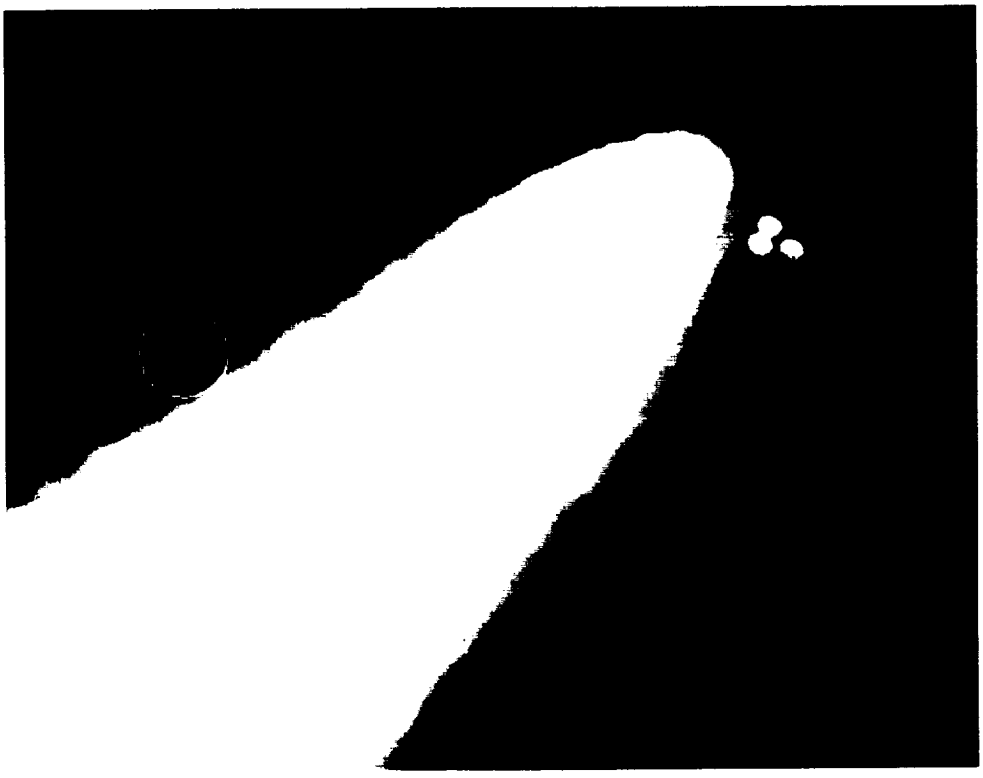
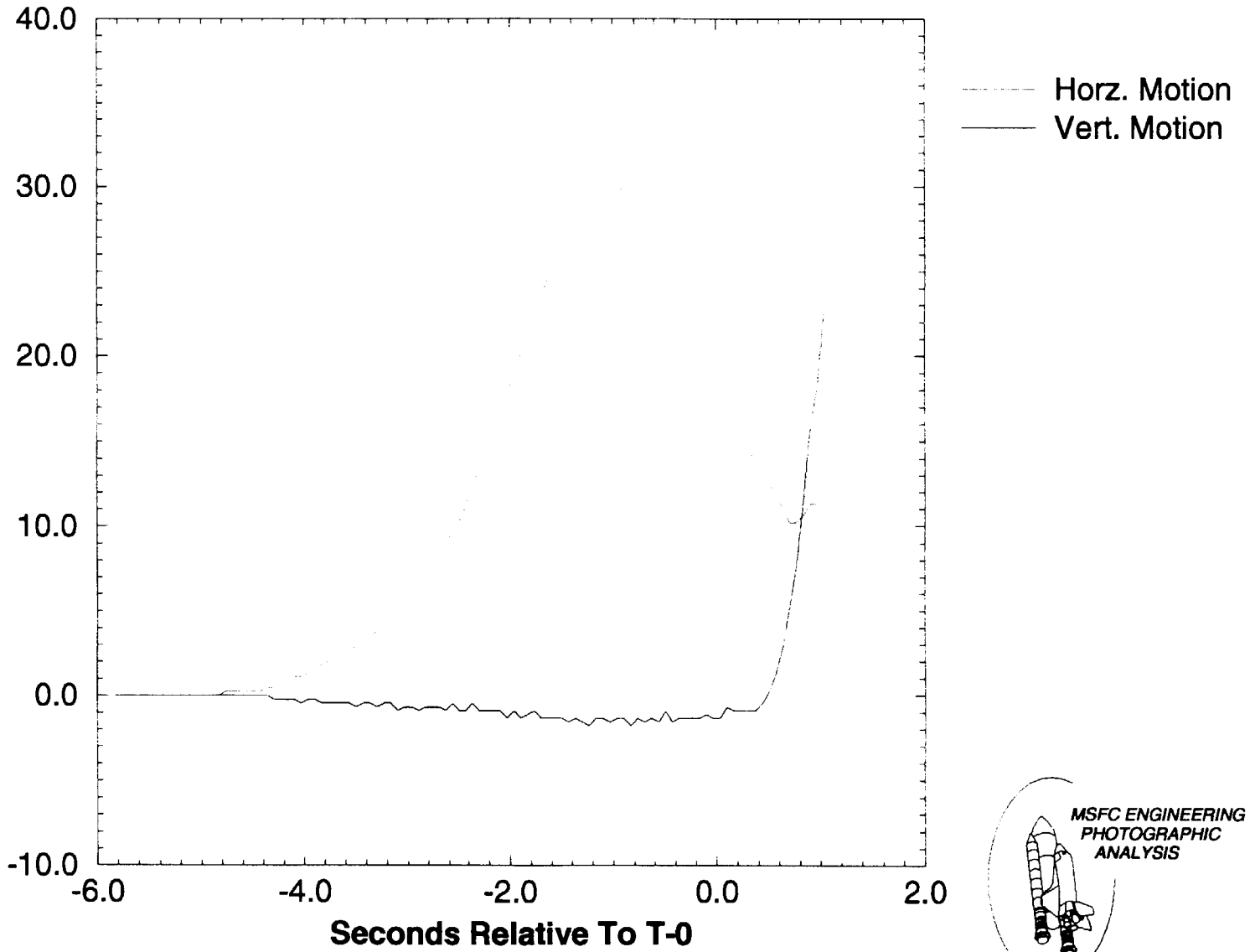


Figure 2.

Thermal Curtian Tape from Left SRB

ET Tip Deflection

STS-61



MSFC ENGINEERING
PHOTOGRAPHIC
ANALYSIS

Tue Dec 21 10:24:15 1993

Figure 3

Appendix C. Rockwell Photographic Analysis Summary

ROCKWELL ENGINEERING PHOTOGRAPHIC ANALYSIS SUMMARY REPORT FOR STS-61

Extensive photographic and video coverage was provided and has been evaluated to determine ground and flight performance. Cameras (cine and video) providing this coverage are located on the Launch Complex 39B Fixed Service Structure (FSS), Mobile Launch Platform (MLP), various perimeter sites, and uprange and downrange tracking sites for the STS-61 launch conducted on December 2, 1993, at 1:27 a.m. PST/GMT 336:09:26:59.983 from the Kennedy Space Center (KSC) and for the landing on December 13, 1993 at KSC at 12:26 a.m. EST (December 12, 1993/9:26 p.m. PST)/GMT 347:05:25:33. Rockwell received launch films from 78 cameras (54 cine, 24 video) and landing films from 23 cameras (12 cine, 11 video) to support the STS-61 photographic evaluation effort. Three films, E-1, E-9 and E-10 were not available due to camera malfunction.

Overall, the films showed STS-61 to be a clean flight. Several pieces of ice from the ET/Orbiter umbilical were shaken loose at SSME ignition, but no damage to the Orbiter Thermal Protection System (TPS) was apparent. The usual condensation and water vapors were seen at the ET aft dome and the SRB stiffener rings and dissipated after the completion of the roll maneuver. Charring of the ET aft dome, recirculation and brightening of the SRB plumes were normal. Booster Separation Motor (BSM) firing and SRB separation also appeared to be normal. However, upon retrieval, it was noted that three of the BSM aero heat shield covers were missing on the left SRB. Preliminary post flight analysis at KSC indicated that the covers were probably lost after SRB separation, perhaps due to parachute riser entanglement or water impact.

Nominal performance was seen for the MLP and FSS hardware. FSS deluge water was activated prior to SSME ignition and the MLP rainbirds were activated at approximately 1 second Mission Elapsed Time (MET), as is normal. All blast deflection shields closed prior to direct SRB exhaust plume impingement. Both TSM umbilicals released and retracted as designed. The ET GH_2 vent line carrier dropped normally and latched securely with a slight rebound. No anomalies were identified with the ET/ORB LH_2 umbilical hydrogen dispersal system hardware.

STS-61 was the nineteenth flight with the optimized attach link in the SRB holddown support post Debris Containment Systems (DCS's). No holddown post hangups were observed.

No major or significant events were observed or identified. Events noted by the Rockwell film/video users during the review and analysis of the STS-61 photographic items are summarized in the following comments. There events are not considered to be a constraint to next flight.

COMMENTS

1. On Cameras OTV-109, OTV-149, OTV-170, E-2, E-17, E-18, E-19, E-20, E-76 and E-77, normal ice debris was seen falling from the LH2 and LO2 TSM T/O umbilical disconnect areas at SSME ignition through liftoff. None of the debris appeared to strike the vehicle. No follow-up action is planned.

2. On cameras OTV-109, E-5, E-6, E-25, E-26, E-30, E-31 and E-36, normal ice debris was seen falling from the LH2 and LO2 ET/Orbiter umbilical disconnect areas at SSME ignition through liftoff. Several of these particles contacted the LH2 umbilical sill, but no damage was detected. No follow-up action is planned.

3. A flat rectangular piece of light colored debris was seen moving from the body flap hinge area and fall aft along the body flap after SSME ignition on camera E-17. The debris did not appear to strike the vehicle and no damage was noted. No follow-up action is planned.

4. On cameras OTV-163, OTV-170, OTV-171, E-2, E-3, E-4, E-5, E-15, E-16, E-18, E-19, E-20, E-30, E-36, E-41, E-52, E-62, E-76 and E-77, orange and green vapors (possibly free burning hydrogen) were seen below the body flap at SSME ignition. This vapor appears to be similar to the vapor noted on previous missions. It is not an issue and no follow-up action is planned.

5. Flashes were observed in the SSME #3 plume at SSME ignition (cameras E-3 and E76). Flashes in the SSME plumes have been seen on previous mission. No follow-up action is planned.

6. On cameras E-2 and E-19, several (8-10) small particles of debris were noted in the area between the right hand OMS pod and the vertical stabilizer falling aft after SSME ignition. The particles probably originated from the top surface of the OMS pod. No follow-up action is planned.

7. A piece of light colored debris was seen falling aft of the Orbiter and past the left SRB into the SRB plume at approximately 24 seconds MET on cameras KTV-4B, E-207 and E-222. This debris was probably umbilical purge barrier material (baggie). No follow-up action is planned.

8. On camera E-207, several pieces of SRB thermal curtain tape were partially detached from the SRB thermal curtains on both SRB's during ascent. No follow-up action is planned.

9. During the recovery of the SRB's it was noted that three of the BSM aero heat shield covers were missing on the left SRB frustum. Preliminary post flight analysis at KSC indicated that the covers had opened and latched properly and were probably lost after SRB separation, perhaps due to parachute riser entanglement or water impact. Additional analysis will be conducted at MSFC.

10. The following events have been reported on previous missions and observed on STS-61. These are not of major concern, but are documented here for information only:

    - Ice debris falling from the ET/Orbiter Umbilical disconnect area
    - Debris (Insta-foam, water trough) in the holddown post area and MLP
    - Charring of the ET aft dome
    - ET aft dome outgassing after liftoff
    - RCS Paper debris
    - Recirculation or expansion of burning gasses at the aft end of the SLV prior to SRB separation
    - Slight TPS erosion on the base heat shield during SSME start-up
    - Twang motion
    - Body flap motion during the maximum dynamic pressure (MAX-Q) region which appeared to have an amplitude and frequency similar to those of previous missions
    - Linear optical distortion, possibly caused by shock waves or ambient meteorological conditions near the vehicle, during ascent
    - Slag in SRB plume after separation
    - Vapor from the SRB stiffener rings after liftoff
    - Fore-and aft movement of the Orbiter base heat shield in the centerline area between the SSME cluster at engine start-up

11. Camera E33 and E41 - OMRSD File IX Vol. 5, Requirement No. DV08P.010 requires an analysis of launch pad film data to verify that the initial ascent clearance separation between the left SRB outer mold line and the falling ET umbilical structure does not violate the acceptable margin of safety.

    A qualitative assessment has been conducted and positive clearances between the left SRB and the ET vent umbilical have been verified. The films showed nominal launch pad hardware performance, and no anomalies were observed for the SRB body trajectory.

12. Cameras E7-16-OMRSD File IX Vol. 5, Requirement No. DV08P.020 requires and analysis of film data of SRM nozzle during liftoff to verify nozzle to holddown post drift clearance.

    A qualitative assessment of the launch films has been completed. No anomalies were observed for the SRM nozzle trajectory and positive clearances between the SRB nozzles and the holddown posts were verified.

13. The landing of STS-61 occurred on Runway 33 at the KSC Shuttle Landing Facility. Good video and film coverage were obtained and no anomalous events were observed. The flight marked the twelfth use of the orbiter drag chute. The drag parachute system performed as expected. All sequenced events occurred as expected and no hardware anomalies were observed.

Any questions concerning this report should be directed to the undersigned.

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13. ABSTRACT *(Maximum 200 words)*

A debris/ice/thermal protection system (TPS) assessment and integrated photographic analysis was conducted for Shuttle mission STS-61. 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/TPS conditions and integrated photographic analysis of Shuttle mission STS-61, and the resulting effect on the Space Shuttle Program.

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