NASA Technical Memorandum TM 109203

Debris/Ice/TPS Assessment and Integrated Photographic Analysis for Shuttle Mission STS-59

June 1994

National Aeronautics and
Space Administration

DEBRIS/ICE/TPS ASSESSMENT
AND
INTEGRATED PHOTOGRAPHIC ANALYSIS
OF
SHUTTLE MISSION STS-59

April 9, 1994

Prepared By:

J. Bradley Davis
NASA/Kennedy Space Center

Barry C. Bowen
NASA/Kennedy Space Center

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

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

Approved:

Gregory N. Katnik
Shuttle Ice/Debris Systems
NASA/Kennedy Space Center
TV-MSD-22

James G. Tatum
Chief, ET Mechanical Sys
NASA/Kennedy Space Center
TV-MSD-22

TABLE OF CONTENTS

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-59 was launched at 7:05 a.m. local 4/9/94

1.0 Summary

A pre-launch debris inspection of the pad and Shuttle vehicle was conducted on 7 April 1994. The detailed walkdown of Launch Pad 39A and MLP-2 also included the primary flight elements OV-105 Endeavour (6th flight), ET-63 (LWT 56), and BI-065 SRB's. There were no significant facility or vehicle anomalies.

The vehicle was cryoloaded on 7 April 1994. 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.

The launch was scrubbed at the end of the window while in an extended hold at T-5 minutes due to an RTLS crosswind violation at the SLF. A post drain walkdown revealed no flight hardware or facility anomalies.

The vehicle was cryoloaded a second time on 8 April 1994. 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 7:05 a.m. launch on 9 April 1994, a debris walkdown of Pad 39A was performed. No flight hardware or TPS materials were found. All of the north HDP doghouse blast covers were in the closed position. However, all four covers, which are sacrificial, sustained severe erosion with numerous areas of burn-through.

Post launch inspections revealed significant damage to the GOX Vent Arm at the axial adjustment attach point. Several welds were broken and the piston housing had collapsed. This damaged caused the hood to be skewed or twisted 1-2 inches from the centerline. Vibration/acoustic shock waves from the SRB plume and 16 knot winds from the east (105 degrees) at the time of launch are believed to be related to the failure. Some of the damage was attributed to improper welds (IFA STS-59-K-01).

A total of 117 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. The SSME #2 Mach diamond formed prior to SSME #3 during ignition, but MPS instrumentation showed no anomaly.

Differential deflection between inboard and outboard elevons during ascent was visible in numerous films. An ascent program/ schedule of elevon deflection for the purpose of load relief is I-loaded into the Orbiter computer prior to launch. Elevon actuator feedback based on aerodynamic pressure due to the actual flight conditions causes deflection deltas to the ascent schedule. These deflections are small in magnitude. The flight deltas to the STS-59 ascent schedule were normal.

On-orbit photography revealed no major vehicle damage or lost flight hardware that would have been a safety-of-flight concern. Six divots, ranging in size from 6 to 10 inches in diameter, occurred in the LH2 tank-to-intertank flange closeout in the +Y+Z quadrant (2 places outboard of the LO2 feedline), -Y+Z quadrant (3 places between the -Y bipod and the -Y thrust panel), and on the outboard bondline of the -Y bipod spindle housing closeout. A divot, 8 inches in diameter, occurred in the LH2 tank acreage just aft of the LH2 tank-to-intertank flange closeout near the -Y bipod. A dark area in the divot may be shadow or primer. Both bipod jack pad closeouts were intact and appeared to be in excellent condition.

The Solid Rocket Boosters were inspected at Hanger AF after retrieval. Both frustums had a combined total of 46 MSA-2 debonds over fasteners. A debris impact site was noted on the right IEA forward surface TPS at 145 degrees radial location (IFA STS-59-I-02). The impact cavity measured 2" x 1.5" x 1.75". The foam in the damage site was crushed and showed signs that heating had occurred inside the cavity possibly during ascent. No debris object or foreign substance was found. Post flight analysis at MSFC revealed no residual material in the cavity. The impact damage was most likely caused by a piece of ice from the ET LO2 feedline upper bellows.

K5NA had separated from Hypalon-covered BTA and primer-coated metal on the BSM support brackets (IFA STS-59-B-01). Current surface preparation procedures are inadequate for proper K5NA adhesion. The closeouts on STS-65 were reworked and changes to the procedure have been incorporated.

A post landing inspection of OV-105 was conducted on the runway at DFRF. The Orbiter TPS sustained a total of 77 hits, of which 19 had a major dimension of one inch or greater. The Orbiter lower surface had a total of 47 hits, of which 10 had a major dimension of one inch or greater. 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.

The crew hatch outer pane (window #11) sustained an apparent micrometeorite impact. The damage site measure 1/4-inch in diameter and was located at the 7 o'clock position of the window, one inch from the edge tiles.

ET/ORB separation devices EO-1 and EO-3 functioned properly though the EO-2 debris plunger had not seated. No debris was found on the runway beneath the ET/ORB umbilical cavities when the ET doors were opened, but a loose wave sprint was found resting against a Hi-Lock fastener on the LH2 umbilical door. The wave spring is part of the pyro separation device. All of the umbilical separation ordnance retention shutters were closed properly.

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

A total of ten Post Launch Anomalies, including three In-Flight Anomalies, were observed during the STS-59 mission assessment.

2.0 PRE-LAUNCH BRIEFING

The Ice/Debris/TPS/Photographic Analysis Team briefing for launch activities was conducted on 7 April 1994 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.

G. Katnik	NASA - KSC	Shuttle Ice/Debris Systems
B. Davis	NASA - KSC	Debris, IR, Photo Analysis
P. Rosado	NASA - KSC	Chief, ET Mechanical Systems
R. Speece	NASA - KSC	Lead, Thermal Protection Sys
B. Bowen	NASA - KSC	ET Processing/Ice/Debris/TPS
K. Tenbusch	NASA - KSC	ET Processing/Ice/Debris/TPS
J. Rivera	NASA - KSC	Lead, ET Structures
M. Bassignani	NASA - KSC	ET Processing, Ice/Debris
A. Oliu	NASA - KSC	ET Processing, Ice/Debris
J. Blue	LSOC - SPC	ET Processing
J. Kercsmar	LSOC - SPC	ET Processing
G. Fales	LSOC - SPC	ET Processing
M. Jaime	LSOC - SPC	ET Processing
Z. Byrns	NASA - KSC	Level II Integration
J. Stone	RI - DNY	Debris Assess, LVL II Integ
W. Atkinson	RI - LSS	GS Integration
S. Clark	RI - LSS	System Integration
J. Cook	MTI - LSS	SRM Processing
S. Otto	MMMSS- LSS	ET Processing
A. Howard	LSOC - SPC	Safety

3.0 SCRUB - RTLS CROSSWIND VIOLATION

The first launch attempt of STS-59 was scrubbed at the end of the window while in an extended hold at T-5 minutes due to an RTLS cross wind violation at the SLF.

3.1 PRE-LAUNCH SSV/PAD DEBRIS INSPECTION

A pre-launch debris inspection of the pad and Shuttle vehicle was conducted on 7 April 1994 from 0900-1030 hours. The detailed walkdown of Launch Pad 39A and MLP-2 also included the primary flight elements OV-105 Endeavour (6th flight), ET-63 (LWT 56), and BI-065 SRB's. There were no significant debris issues or vehicle anomalies.

3.2 ICE/FROST INSPECTION

The Ice/Frost Inspection of the cryoloaded vehicle was performed on 8 April 1994 from 0220 to 0400 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:	71.7 Degrees F
Relative Humidity:	70.5 Percent
Wind Speed:	15.5 Knots
Wind Direction:	026 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

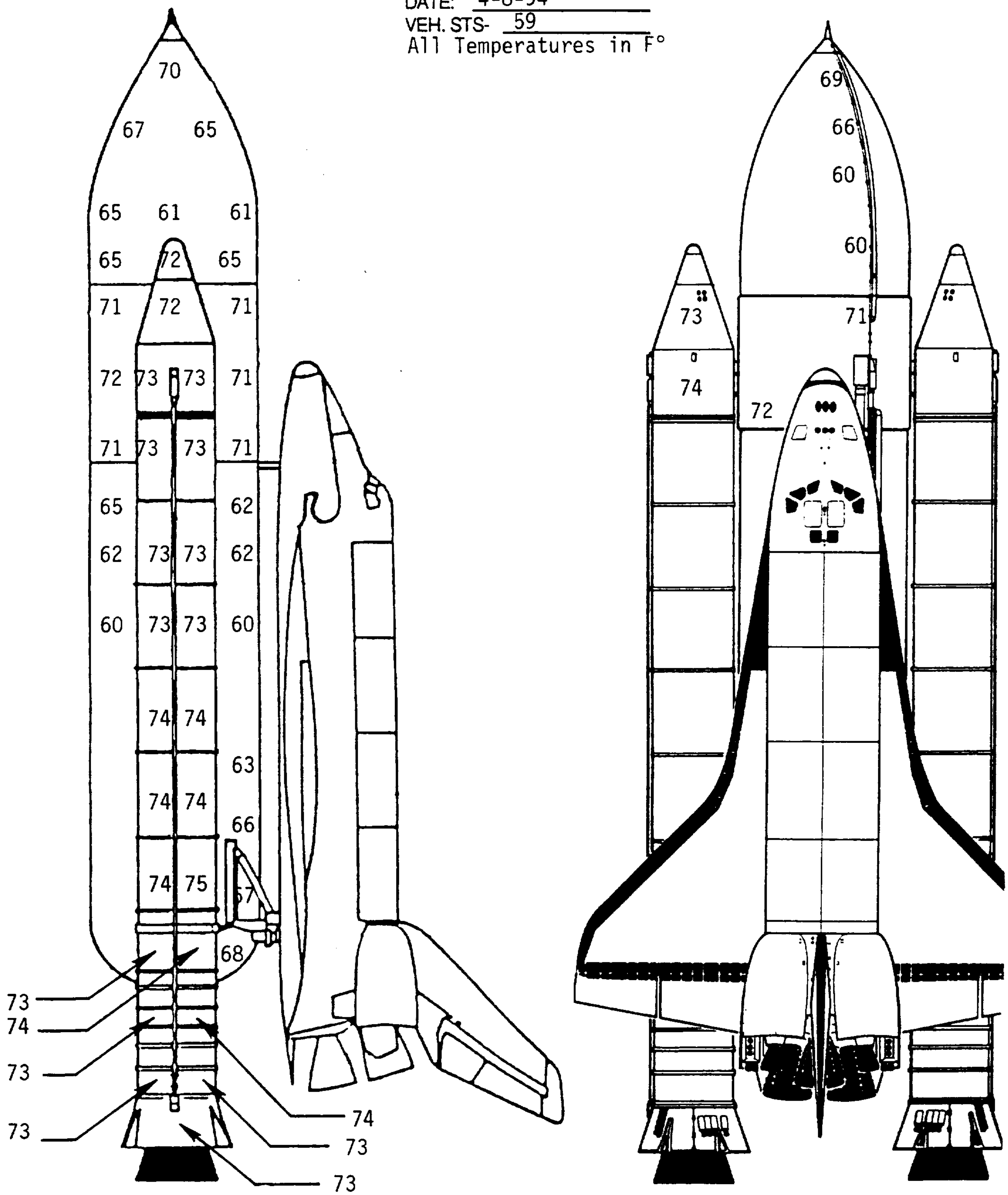
No Orbiter RCC panel or TPS anomalies were observed. All RCS thruster paper covers were intact though the cover on thruster L3D was wet. Typical ice and frost accumulations were present at the SSME heat shield-to-nozzle interfaces. The base heat shield tiles were dry. An infrared scan revealed readings in the low 30's on SSME #2 engine mounted heat shield. There were no unusual temperature gradients on the base heat shield or engine mounted heat shields.

3.4 SOLID ROCKET BOOSTERS

The STI portable infrared scanner recorded RH and LH SRB case temperatures of 72-75 degrees F. In comparison, temperatures measured by a hand-held Minolta Cyclops spot radiometer were 72-74 degrees F and the SRB Ground Environment Instrumentation (GEI) measured temperatures of 70-75 degrees F. All measured temperatures were above the 34 degrees F minimum requirement.

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

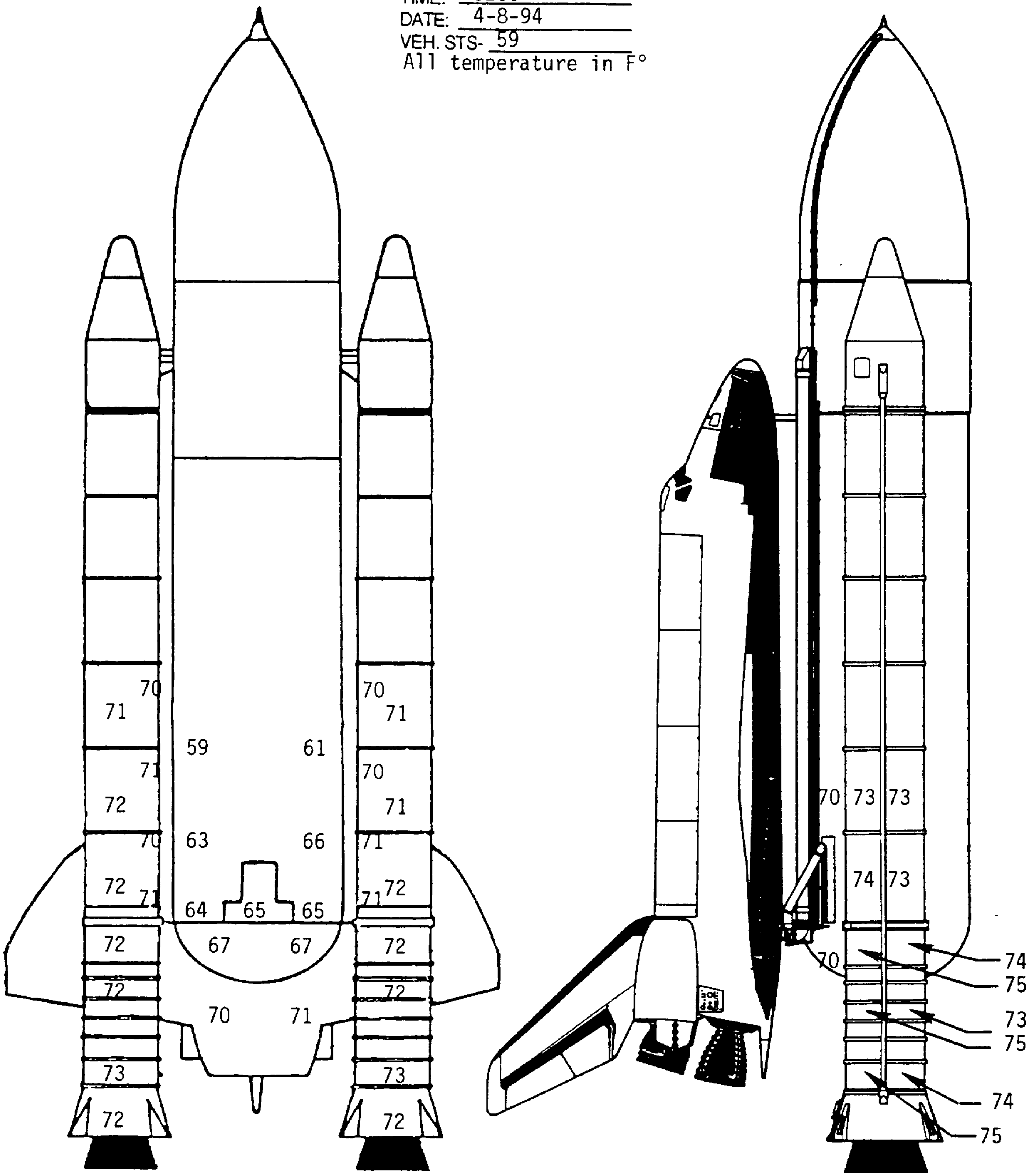
TIME: 0200 -0400
DATE: 4-8-94
VEH. STS- 59
All Temperatures in F°



EGG/V-3

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

TIME: 0200-0400
DATE: 4-8-94
VEH. STS- 59
All temperature in F°



EGG/V-343C

The predicted Propellant Mean Bulk Temperature (PMBT) supplied by MTI was 71 degrees F, which was within the required range of 44-86 degrees F. No access was available to view the TPS on the RH SRB ETA ring forward surface.

3.5 EXTERNAL TANK

The ice/frost prediction computer program 'SURFICE' was run from 2300 to 1030 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/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 63 degrees F on the barrel section. In comparison, the Cyclops radiometer measured temperatures that averaged 66 degrees F on the ogive and 64 degrees F on the barrel; SURFICE predicted temperatures of 62 degrees F on the ogive and 59 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 portable STI measured a surface temperature of 71 degrees F.

There were no LH2 tank TPS acreage anomalies. Very light condensate, but no ice/frost, was present on the acreage. The portable STI measured surface temperatures that averaged 62 degrees F on the upper LH2 tank and 65 degrees F on the lower LH2 tank. In comparison, the Cyclops radiometer measured temperatures that averaged 61 degrees F on the upper and 64 degrees F on the lower LH2 tank, respectively; SURFICE predicted temperatures of 59 degrees F on the upper LH2 tank and 60 degrees F on the lower LH2 tank.

There were no anomalies on the bipod jack pad closeouts. A crack, 8-inches long by 1/4-inch wide, was present in the -Y vertical strut cable tray forward surface TPS near the longeron closeout interface. The crack, which exhibited no offset and was not filled with ice or frost, was located approximately 4 inches farther in the +Z direction from the area where similar cracks had appeared on previous tanks.

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. There were light accumulations of ice/frost on the umbilical purge barrier. Ice/ frost fingers on the separation bolt pyrotechnic canister purge vents were typical.

STS- 59	TEST S0007 - RTLS Weather Scrub																DATE: 7 April 1994				T-0 TIME: DATE:			NASA KSC Ice/Frost/Debris Team	
ORBITER 105		ET 63	SRB BI-065	MLP 2	PAD B	LO2 CHILLDOWN TIME: 02:59 SLOW FILL TIME: 03:26 FAST FILL TIME: 03:38 REPLENISH TIME: 05:45										LH2 CHILLDOWN TIME: 02:52 SLOW FILL TIME: 03:02 FAST FILL TIME: 03:42 REPLENISH TIME: 05:22									
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				
(EDT)	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
2300	71.4	84.4	66.62	15	15	II	8.85	64.13	0.0023	-0.2917	II	8.85	61.48	0.0044	-0.2593	II	6.60	59.04	0.0047	-0.1877	II	14.85	63.49	0.0044	-0.4260
2345	71.0	91.0	68.34	13	14	II	7.67	64.68	0.0030	-0.2680	II	7.67	61.73	0.0051	-0.2357	II	5.72	59.01	0.0053	-0.1698	II	12.87	63.98	0.0056	-0.3870
0000	71.0	89.0	67.71	12	17	II	7.08	63.95	0.0028	-0.2452	II	7.08	60.77	0.0048	-0.2133	II	5.28	57.91	0.0050	-0.1528	II	11.88	63.16	0.0053	-0.3506
0015	71.0	87.0	67.07	15	16	II	8.85	64.29	0.0026	-0.2938	II	8.85	61.64	0.0047	-0.2613	II	6.60	59.19	0.0050	-0.1891	II	14.85	63.68	0.0048	-0.4294
0030	72.0	83.0	66.74	15	17	II	8.85	64.44	0.0021	-0.2953	II	8.85	61.80	0.0042	-0.2628	II	6.60	59.39	0.0046	-0.1906	II	14.85	63.79	0.0042	-0.4312
0045	72.0	84.0	67.08	13	16	II	7.67	64.19	0.0023	-0.2624	II	7.67	61.22	0.0044	-0.2304	II	5.72	58.55	0.0047	-0.1661	II	12.87	63.43	0.0045	-0.3779
0100	72.0	81.0	66.06	12	17	II	7.08	63.22	0.0021	-0.2375	II	7.08	60.02	0.0040	-0.2061	II	5.28	57.20	0.0044	-0.1475	II	11.88	62.36	0.0041	-0.3385
0115	72.0	80.0	65.71	15	17	II	8.85	63.74	0.0017	-0.2869	II	8.85	61.09	0.0038	-0.2547	II	6.60	58.67	0.0043	-0.1844	II	14.85	63.08	0.0036	-0.4183
0130	72.0	73.0	63.15	16	21	II	9.44	62.27	0.0008	-0.2832	II	9.44	59.72	0.0028	-0.2514	II	7.04	57.41	0.0035	-0.1817	II	15.84	61.62	0.0021	-0.4140
0145	72.0	72.0	62.76	14	27	II	8.26	61.62	0.0009	-0.2486	II	8.26	58.75	0.0029	-0.2173	II	9.80	59.18	0.0030	-0.2525	II	16.94	61.62	0.0016	-0.4377
0200	72.0	71.0	62.37	14	24	II	8.26	61.37	0.0008	-0.2459	II	8.26	58.49	0.0027	-0.2148	II	9.80	58.93	0.0029	-0.2496	II	16.94	61.37	0.0014	-0.4329
0215	72.0	73.0	63.15	14	24	II	8.26	[illegible]	0.0010	-0.2612	II	8.26	[illegible]	[illegible]	[illegible]	II	9.80	[illegible]	0.0031	[illegible]	II	16.94	[illegible]	[illegible]	[illegible]
0230	72.0	72.0	62.76	15	22	II	8.85	61.83	0.0008	-0.2644	II	8.85	59.13	0.0026	-0.2329	II	6.60	58.71	0.0034	-0.1677	II	14.85	[illegible]	[illegible]	[illegible]
0245	72.0	70.0	61.98	17	22	II	10.03	61.72	[illegible]	[illegible]	II	10.03	58.21	0.0023	[illegible]	II	[illegible]	[illegible]	0.0031	[illegible]	II	[illegible]	[illegible]	[illegible]	[illegible]
0300	72.0	72.0	62.76	15	26	II	8.85	61.83	0.0008	-0.2644	II	8.85	59.13	0.0026	-0.2329	II	10.50	[illegible]	0.0029	[illegible]	II	18.15	[illegible]	[illegible]	[illegible]
0315	72.0	70.0	61.98	16	26	II	9.44	61.54	0.0004	-0.2742	II	9.44	58.96	0.0024	-0.2427	II	11.20	59.37	0.0024	[illegible]	II	19.36	61.77	[illegible]	[illegible]
0330	71.0	70.0	61.00	17	27	II	10.03	[illegible]	[illegible]	-0.2774	II	10.03	58.24	0.0023	[illegible]	II	11.90	[illegible]	[illegible]	[illegible]	II	20.57	60.76	[illegible]	-0.4971
0345	71.0	70.0	61.00	13	30	II	7.67	59.87	0.0008	-0.2177	II	7.67	56.76	0.0027	-0.1872	II	9.10	57.22	0.0028	-0.2175	II	15.73	59.85	0.0015	-0.3802
0400	72.0	67.0	60.76	17	28	II	10.03	61.23	0.0000	-0.2802	II	10.03	58.50	0.0018	-0.2486	II	11.90	58.90	0.0018	[illegible]	II	20.57	61.33	0.0000	-0.5016
0415	72.0	66.0	60.34	16	32	II	9.44	60.79	0.0000	-0.2623	II	9.44	57.94	0.0018	-0.2312	II	11.20	58.35	0.0018	-0.2692	II	19.36	60.84	0.0000	-0.4667
0430	71.0	70.0	61.00	13	32	II	7.67	59.87	0.0008	-0.2177	II	7.67	56.76	0.0027	-0.1872	II	9.10	57.22	0.0028	-0.2175	II	15.73	59.85	0.0015	-0.3802
0445	71.0	68.0	60.19	14	30	II	8.26	59.63	0.0004	-0.2276	II	8.26	56.69	0.0023	-0.1970	II	9.80	57.14	0.0024	-0.2292	II	16.94	59.62	0.0008	-0.4001
0500	71.0	76.0	63.29	14	32	II	8.26	61.56	0.0013	-0.2481	II	8.26	58.67	0.0033	-0.2168	II	9.80	59.12	0.0035	-0.2520	II	16.94	61.59	0.0025	-0.4377
0515	71.6	68.2	60.86	14	35	II	8.26	60.28	0.0004	-0.2343	II	8.26	57.37	0.0024	-0.2035	II	9.80	57.81	0.0024	-0.2367	II	16.94	60.27	0.0008	-0.4119
0530	71.6	70.2	61.66	14	35	II	8.26	60.77	0.0007	-0.2395	II	8.26	57.87	0.0026	-0.2086	II	9.80	58.31	0.0027	-0.2425	II	16.94	60.77	0.0012	-0.4215
0545	71.0	77.0	63.65	15	31	II	8.85	62.02	0.0014	-0.2667	II	8.85	59.30	0.0034	-0.2351	II	10.50	59.73	0.0036	-0.2735	II	18.15	62.08	0.0025	-0.4738
0600	78.0	79.0	71.28	13	37	II	7.67	69.27	0.0019	-0.3190	II	7.67	66.53	0.0041	-0.2856	II	9.10	66.93	0.0044	-0.3302	II	15.73	69.23	0.0036	-0.5593
0615	72.0	80.0	65.71	14	32	II	8.26	63.52	0.0018	-0.2697	II	8.26	60.70	0.0039	-0.2378	II	9.80	61.15	0.0041	-0.2762	II	16.94	63.57	0.0033	-0.4765
0630	71.6	73.0	62.75	16	45	II	9.44	61.87	0.0008	-0.2783	II	9.44	59.30	0.0028	-0.2467	II	11.20	59.71	0.0029	-0.2871	II	19.36	61.92	0.0014	-0.4966
0645	71.4	71.4	61.94	16	41	II	9.44	61.28	0.0006	-0.2713	II	9.44	58.69	0.0026	-0.2398	II	11.20	59.11	0.0026	-0.2792	II	19.36	61.33	0.0010	-0.4838
0700	71.4	72.8	62.48	16	41	II	9.44	61.62	0.0007	-0.2754	II	9.44	59.04	0.0028	-0.2438	II	11.20	59.45	0.0029	-0.2838	II	19.36	61.67	0.0013	-0.4913
0715	71.4	73.2	62.63	15	44	II	8.85	61.52	0.0009	-0.2609	II	8.85	58.80	0.0029	-0.2295	II	10.50	59.22	0.0030	-0.2670	II	18.15	61.56	0.0017	-0.4628
0730	71.4	74.4	63.09	14	46	II	8.26	61.58	0.0012	-0.2483	II	8.26	58.71	0.0031	-0.2171	II	9.80	59.15	0.0033	-0.2523	II	16.94	61.61	0.0021	-0.4378
0745	71.4	75.8	63.61	13	43	II	7.67	61.67	0.0014	-0.2358	II	7.67	58.61	0.0034	-0.2047	II	9.10	59.07	0.0036	-0.2377	II	15.73	61.68	0.0026	-0.4128
0800	71.6	74.8	63.43	15	46	II	8.85	62.10	0.0011	-0.2676	II	8.85	59.40	0.0031	-0.2360	II	10.50	59.83	0.0033	-0.2745	II	18.15	62.15	0.0020	-0.4750
0815	72.0	73.6	63.38	16	46	II	9.44	62.42	0.0008	-0.2849	II	9.44	59.87	0.0029	-0.2531	II	11.20	60.27	0.0030	-0.2945	II	19.36	62.47	0.0015	-0.5085
0830	72.2	74.2	63.80	17	47	II	10.03	62.94	0.0008	-0.3054	II	10.03	60.53	0.0029	-0.2732	II	11.90	60.92	0.0030	-0.3181	II	20.57	63.00	0.0014	-0.5479
0845	72.4	73.0	63.54	14	51	II	8.26	62.26	0.0010	-0.2556	II	8.26	59.42	0.0030	-0.2242	II	9.80	59.85	0.0032	-0.2604	II	16.94	62.27	0.0019	-0.4503
0900	72.2	73.8	63.65	15	47	II	8.85	62.47	0.0010	-0.2718	II	8.85	59.79	0.0030	-0.2401	II	10.50	60.21	0.0032	-0.2791	II	18.15	62.51	0.0018	-0.4821
0915	72.4	74.6	64.15	13	53	II	7.67	62.41	0.0013	-0.2433	II	7.67	59.39	0.0033	-0.2120	II	9.10	59.84	0.0035	-0.2460	II	15.73	62.40	0.0024	-0.4257
0930	72.6	72.8	63.66	14	53	II	8.26	62.42	0.0010	-0.2573	II	8.26	59.58	0.0030	-0.2258	II	9.80	60.01	0.0031	-0.2622	II	16.94	62.42	0.0018	-0.4531
0945	73.2	72.8	64.25	13	49	II	7.67	62.79	0.0011	-0.2471	II	7.67	59.79	0.0031	-0.2158	II	9.10	60.24	0.0033	-0.2502	II	15.73	62.76	0.0021	-0.4320
1000	73.0	73.2	64.21	14	50	II	8.26	62.92	0.0010	-0.2628	II	8.26	60.10	0.0031	-0.2312	II	9.80	60.53	0.0032	-0.2684	II	16.94	62.92	0.0019	-0.4629
1015	73.2	75.0	65.08	12	46	II	7.08	63.05	0.0014	-0.2356	II	7.08	59.86	0.0034	-0.2043	II	8.40	60.33	0.0037	-0.2366	II	14.52	63.01	0.0028	-0.4088
1030	73.4	74.4	65.06	12	55	II	7.08	63.11	0.0014	-0.2362	II	7.08	59.93	0.0034	-0.2049	II	8.40	60.39	0.0036	-0.2372	II	14.52	63.06	0.0027	-0.4096
AVG.	71.8	75.0	63.64	14.63	49.00		8.63	62.26				8.63	59.48				9.21	59.09				16.83	62.09		

Period of Ice Team Inspection

FIGURE 3. "SURFICE" Computer Predictions

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

Typical amounts of ice/frost had accumulated on the LH2 ET/ORB umbilical top and outboard sides. Typical ice/frost fingers had formed on the pyro canister and plate gap purge vents. Two 2-inch diameter frost spots were present on the umbilical between the recirculation line and aft pyro canister closeout. There were no unusual vapors or cryogenic drips during tanking and stable replenish.

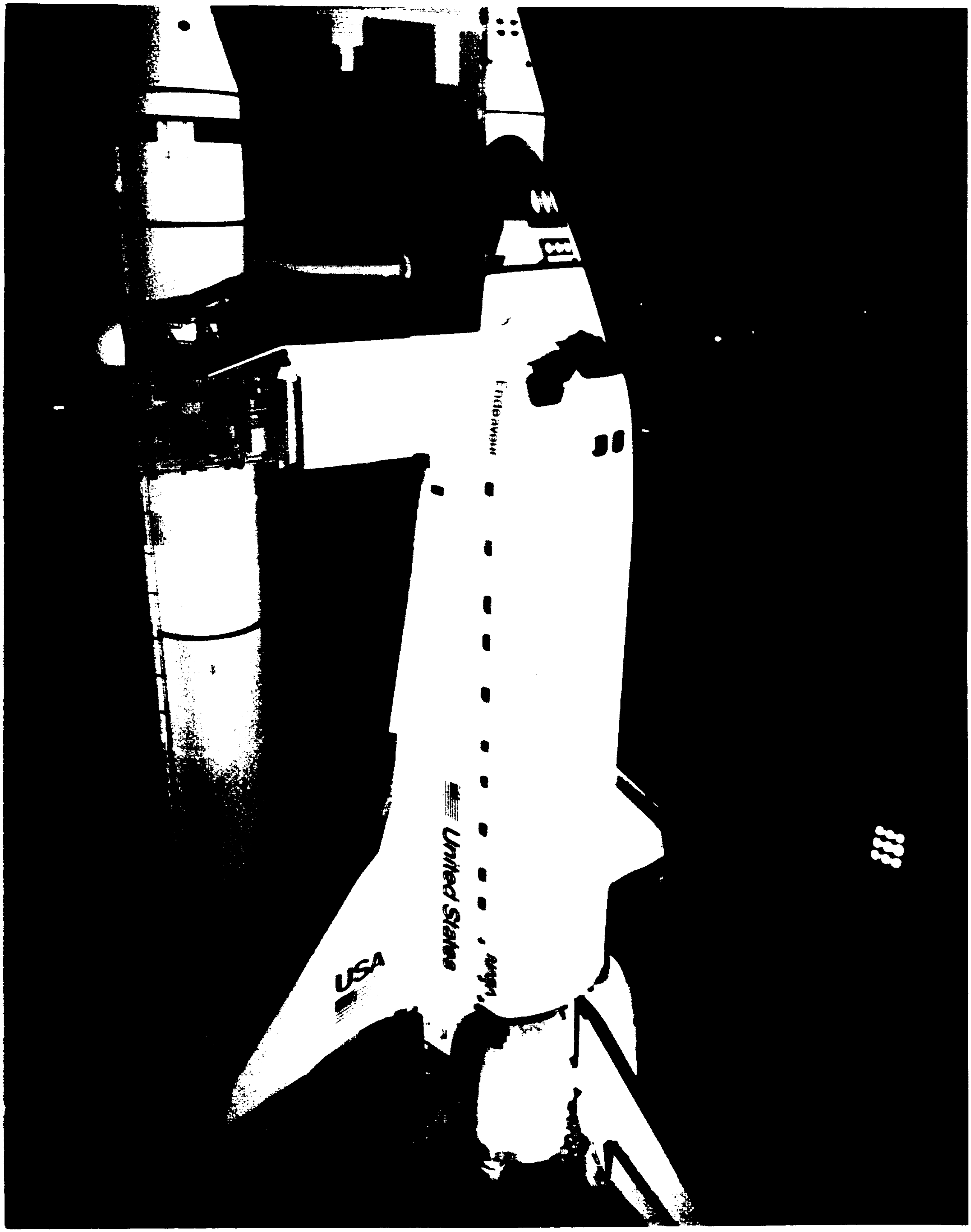
The summary of Ice/Frost Team observations/anomalies, which were acceptable for launch per the NSTS-08303 criteria, consisted of one OTV recorded item:

Anomaly 001 documented a crack, 8-inches long by 1/4-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.

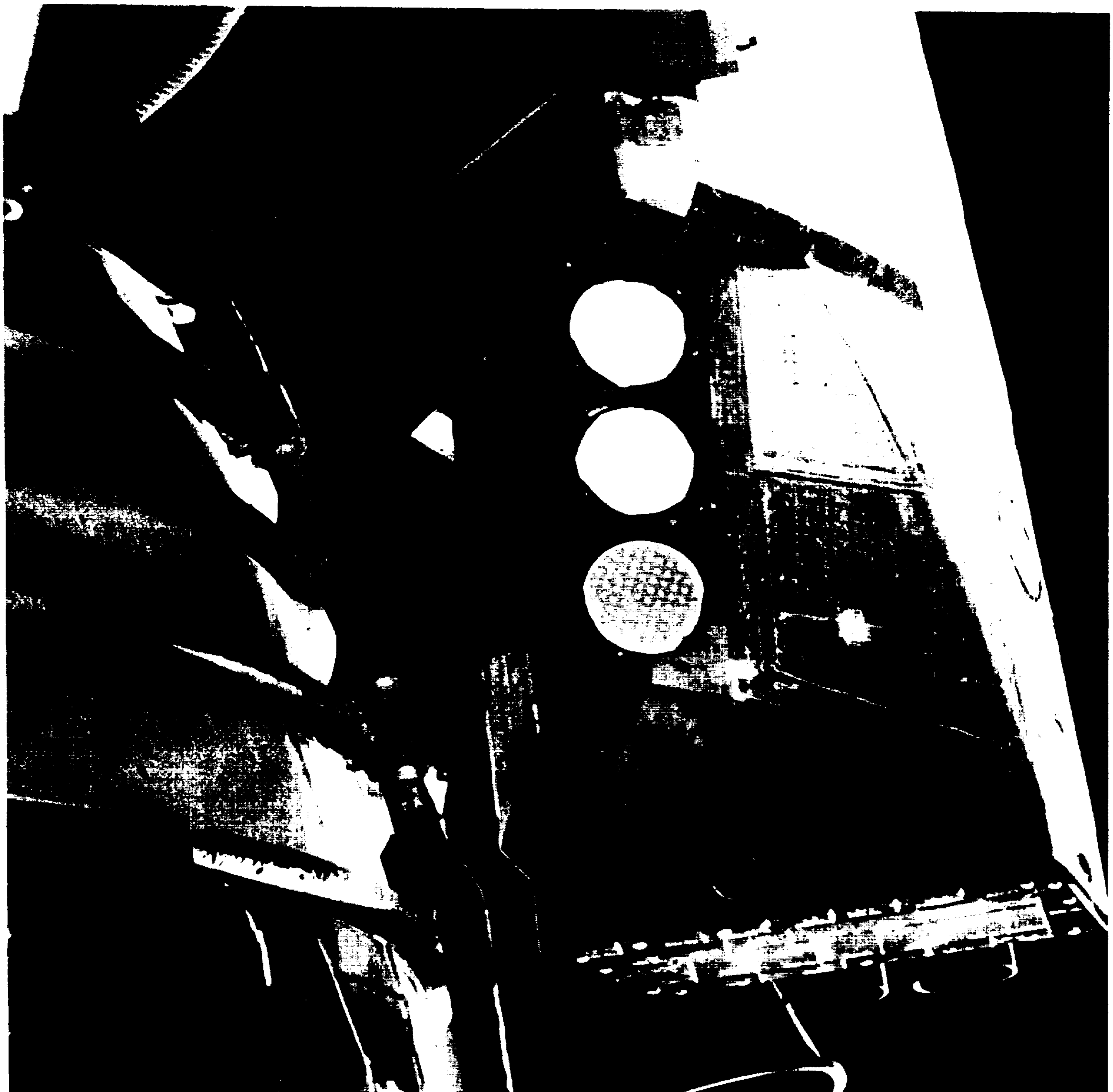
3.6 FACILITY

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 with the exception of a gray-painted 1" x 1/4" diameter bolt found on the MLP deck west of the LH SRB under the retraction path of the Orbiter Weather Protection (OWP). Similar bolts are used in the OWP sheet metal.

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

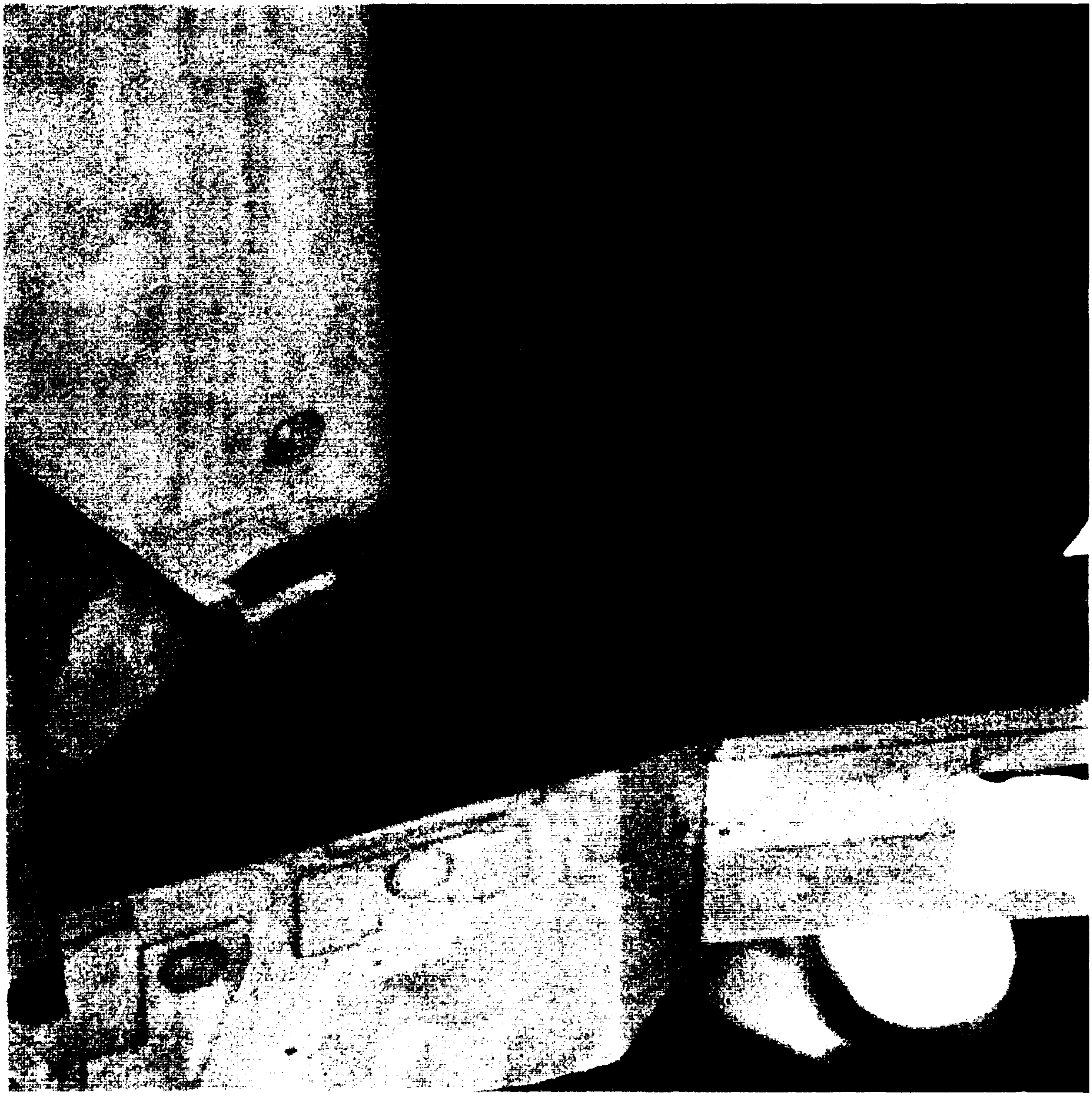


Overall view of OV-105 (6th flight), ET 63 (LWT 56), and BIO-65



All RCS thruster paper covers were intact though the cover on the L3D thruster was wet from an internal vapor leak

Pre-launch view of bipod jack pad closeouts



A crack 8 inches long by 1/4 inch wide appeared in the forward surface of the -Y ET/SRB cable tray after cryoload. The crack was not filled with ice or frost and exhibited no offset. The condition was acceptable for flight per the NSTS-08303 criteria

3.7 POST DRAIN VEHICLE INSPECTION

A post drain inspection was performed from 1600 to 1700 hours on 8 April 1994. This inspection also satisfied the requirement for a pre-launch SSV/pad debris walkdown approximately 24 hours prior to launch.

The tumble valve cover on the External Tank was intact. No defects were noted on the nosecone TPS -Y side.

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

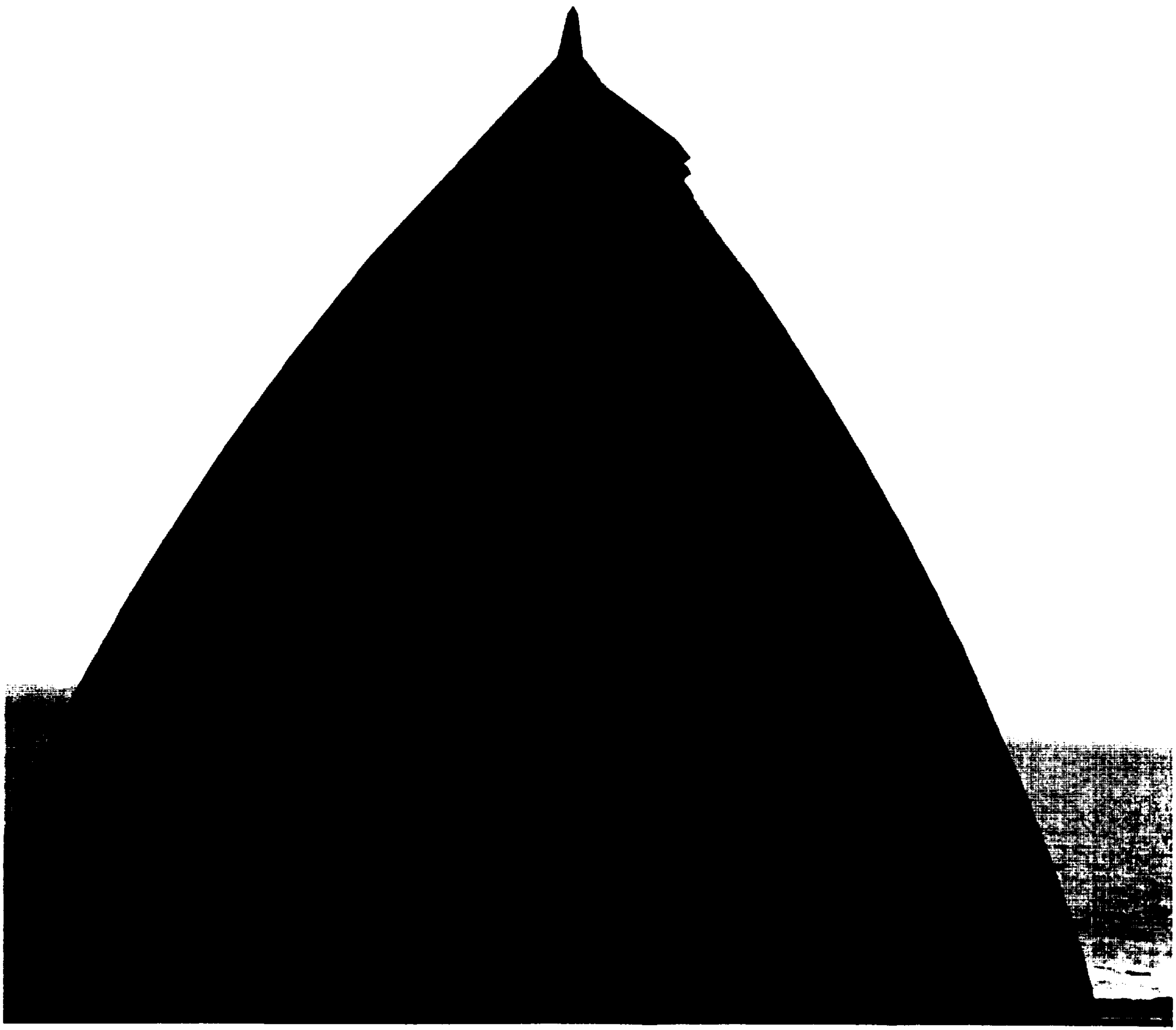
Ice remained in the LO2 feedline support brackets, but no loose foam or TPS damage was visible.

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

The 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 access was available to view the TPS on the RH SRB ETA ring forward surface.

No problems or corrective actions requiring resolution prior to the next cryoload were identified as a result of the post drain inspection.



Post drain inspection revealed no problems requiring corrective action prior to the next cryoload. The tumble valve cover was intact. No defects were observed on the nose cone TPS.

4.0 LAUNCH

STS-59 was launched at 94:099:11:05:00.020 GMT (7:05 am local) on 9 April 1994.

4.1 PRE-LAUNCH SSV/PAD DEBRIS INSPECTION

A post drain walkdown was performed after the scrub on 8 April 1994. This inspection also satisfied the requirement for a pre-launch SSV/pad debris walkdown approximately 24 hours prior to launch.

4.2 ICE/FROST INSPECTION

The Ice/Frost Inspection of the cryoloaded vehicle was performed on 9 April 1994 from 0200 to 0315 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:	71.6 Degrees F
Relative Humidity:	85.1 Percent
Wind Speed:	11.7 Knots
Wind Direction:	012 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

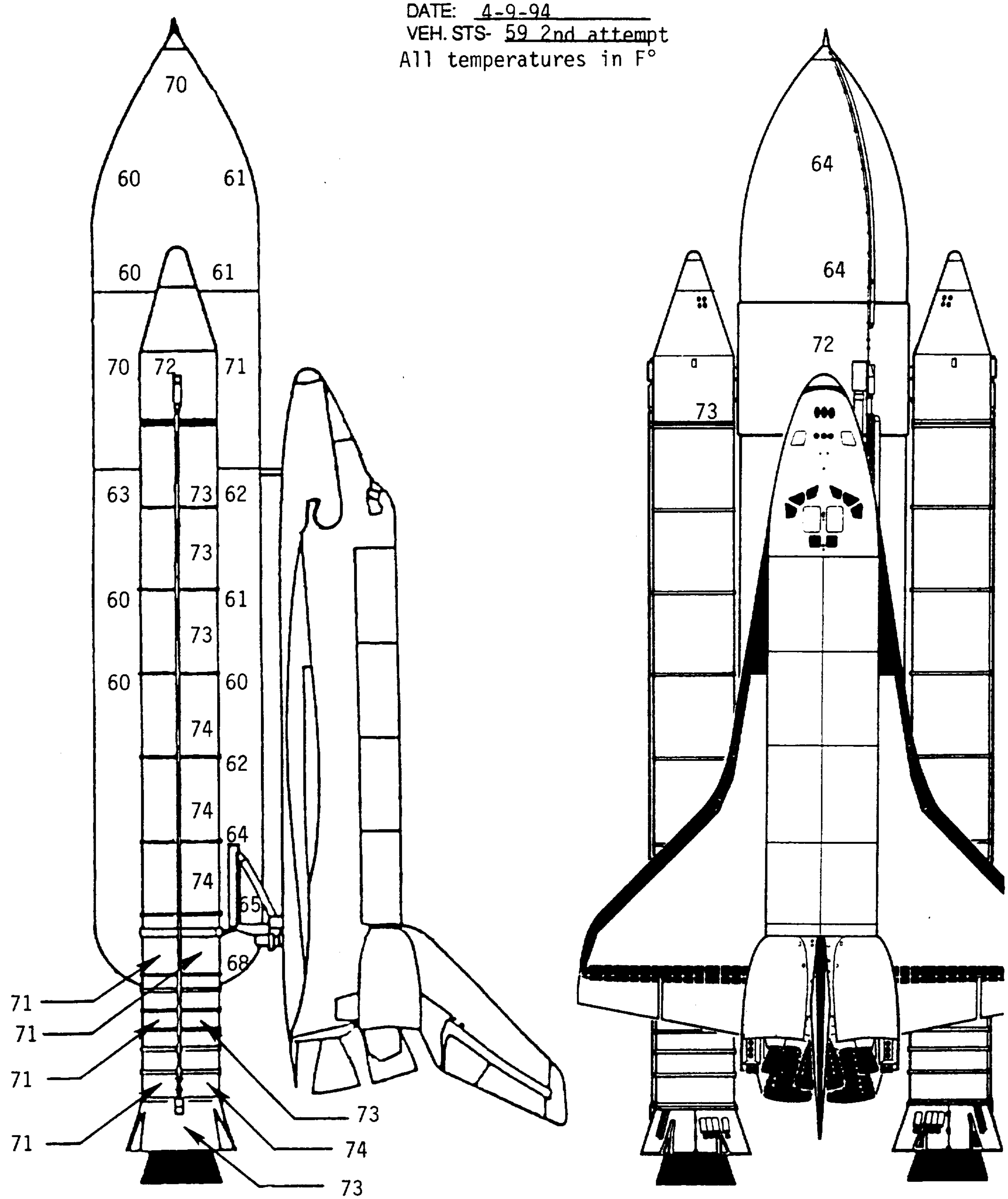
No Orbiter tile or RCC panel anomalies were observed. All RCS thruster paper covers, including the wet covers on the L3D and L4L nozzles, were intact. Typical ice/frost accumulations were present at the SSME #1 and #2 heat shield-to-nozzle interfaces. An infrared scan revealed no unusual temperature gradients on the base heat shield or engine mounted heat shields.

4.4 SOLID ROCKET BOOSTERS

SRB case temperatures measured by the PSTI ranged from 70 to 74 degrees F. The Minolta spot radiometer was not used for this launch attempt. The SRB Ground Environment Instrumentation (GEI) measured temperatures between 70-77 degrees F. All measured temperatures were above the 34 degrees F minimum requirement. The predicted Propellant Mean Bulk Temperature (PMBT) supplied by MTI was 71 degrees F, which was within the required range of 44-86 degrees F. No access was available to view the TPS on the RH SRB ETA ring forward surface.

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

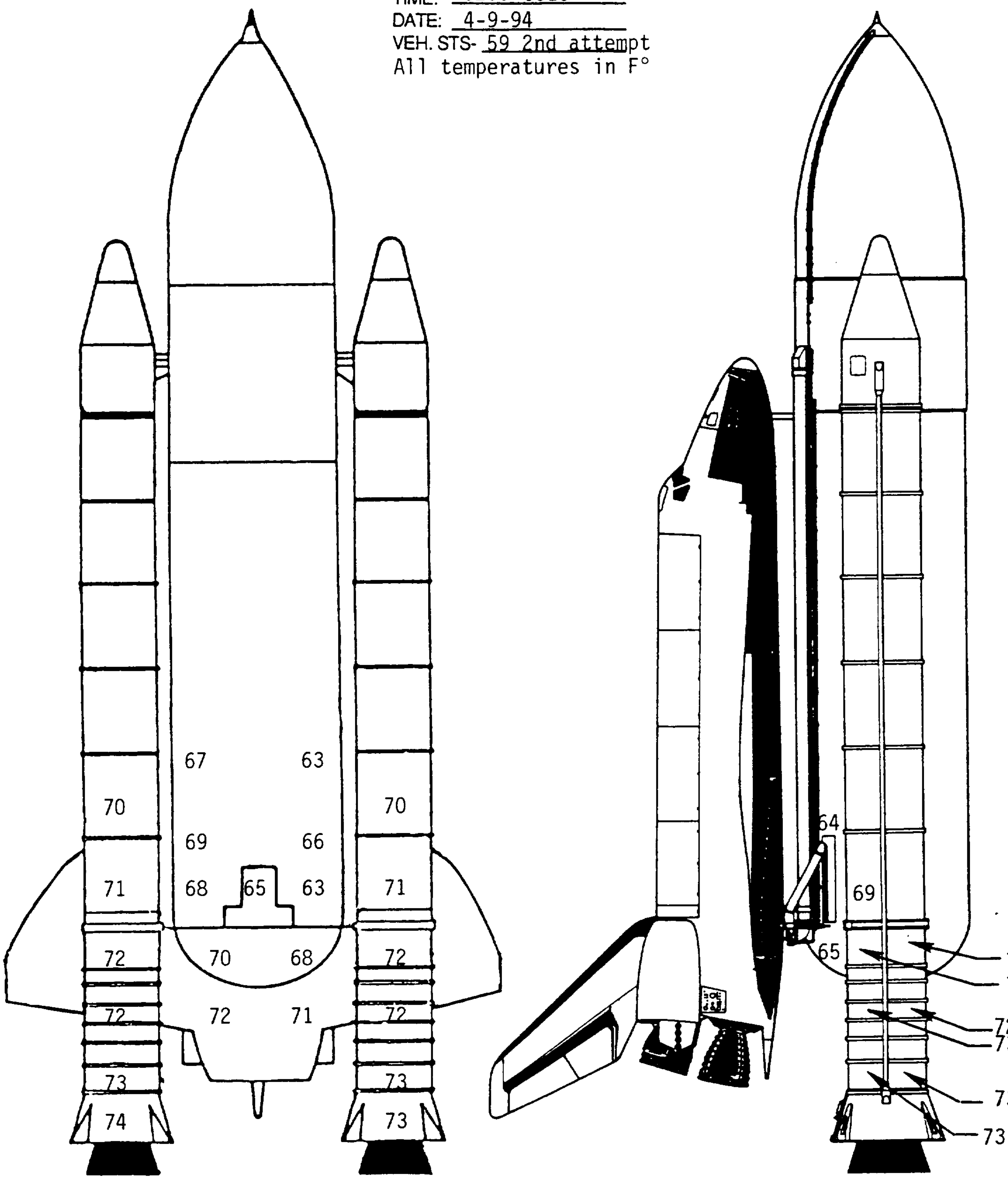
TIME: 0200 -0310
DATE: 4-9-94
VEH. STS- 59 2nd attempt
All temperatures in F°



EGG/V-3

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

TIME: 0200-0310
DATE: 4-9-94
VEH. STS- 59 2nd attempt
All temperatures in F°



EGG/V-343C

4.5 EXTERNAL TANK

The ice/frost prediction computer program 'SURFICE' was run from 2300 to 0705 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. The portable STI measured surface temperatures that averaged 63 degrees F on the ogive and 60 degrees F on the barrel section. The Minolta Cyclops radiometer was not used for this launch attempt. SURFICE predicted temperatures of 63 degrees F on the ogive and 60 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 portable STI measured an average surface temperature of 71 degrees F on the intertank.

There were no LH2 tank TPS acreage anomalies. Condensate, but no ice or frost, was present on the acreage. The portable STI measured surface temperatures that averaged 61 degrees F on the upper LH2 tank and 64 degrees F on the lower LH2 tank. SURFICE predicted temperatures of 58 degrees F on the upper LH2 tank and 62 degrees F on the lower LH2 tank.

There were no anomalies on the bipod jack pad closeouts.

The 8" x 1/4" crack in the -Y ET/SRB cable tray TPS, previously reported during the first cryoload, had not changed. The presence of the crack was acceptable for flight.

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 and frost in the LH2 recirculation line bellows and on both burst disks was typical. The LH2 feedline bellows were wet with condensate.

Typical amounts of ice/frost had accumulated on the LH2 ET/ORB umbilical purge barrier top and outboard sides. Typical ice/frost fingers had formed on the pyro canister and plate gap purge vents. Two 3-inch diameter frost spots were present on the umbilical between the recirculation line and aft pyro canister closeout. 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.

STS- 59	TEST S0007 LAUNCH				DATE: 8 April 1994	T-0 TIME: 07:05:00 DATE: 4/9/94	NASA KSC Ice/Frost/Debris Team
ORBITER 105	ET 63	SRB BI-065	MLP 2	PAD B	LO2 CHILLDOWN TIME: 02:59 FAST FILL TIME: 03:38 SLOW FILL TIME: 03:26 REPLENISH TIME: 05:45	LH2 CHILLDOWN TIME: 02:52 FAST FILL TIME: 03:42 SLOW FILL TIME: 03:02 REPLENISH TIME: 05:22	

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				
(EDT)	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
2300	69.6	83.0	64.36	10	360	II	5.90	60.41	0.0023	-0.1849	II	5.90	56.59	0.0041	-0.1545	II	4.40	53.29	0.0043	-0.1074	II	9.90	59.33	0.0044	-0.2569
2330	69.60	84.8	64.96	11	1	II	6.49	61.20	0.0024	-0.2049	II	6.49	57.68	0.0043	-0.1740	II	4.84	54.57	0.0045	-0.1223	II	10.89	60.25	0.0046	-0.2886
0000	70.00	86.1	65.79	10	357	II	5.90	61.52	0.0026	-0.1941	II	5.90	57.74	0.0044	-0.1634	II	4.40	54.46	0.0045	-0.1144	II	9.90	60.47	0.0048	-0.2706
0030	70.00	87.1	66.11	9	9	II	5.31	61.27	0.0027	-0.1785	II	5.31	57.18	0.0044	-0.1481	II	3.96	53.68	0.0045	-0.1028	II	8.91	60.09	0.0050	-0.2455
0100	70.70	87.3	66.87	8	6	II	4.72	61.53	0.0027	-0.1667	II	4.72	57.09	0.0044	-0.1364	II	3.52	53.36	0.0045	-0.0942	II	7.92	60.17	0.0051	-0.2256
0130	71.00	85.0	66.42	11	14	II	6.49	62.74	0.0025	-0.2187	II	6.49	59.29	0.0044	-0.1875	II	4.84	56.25	0.0046	-0.1331	II	10.89	61.81	0.0047	-0.3089
0200	71.70	[illegible]	[illegible]	[illegible]	13	II	[illegible]	[illegible]	0.0024	[illegible]	II	6.49	[illegible]	[illegible]	[illegible]	II	4.84	[illegible]	[illegible]	[illegible]	II	[illegible]	[illegible]	0.0047	-0.3173
0230	71.60	84.8	66.95	12	11	II	7.08	63.67	0.0024	-0.2421	II	7.08	60.45	0.0044	-0.2104	II	5.28	57.64	0.0047	-0.1509	II	11.88	62.63	0.0047	-0.3456
0300	71.60	86.0	67.34	12	12	II	7.08	63.93	0.0026	-0.2448	II	7.08	60.76	0.0046	-0.2130	II	5.28	57.92	0.0048	-0.1528	II	11.88	63.11	0.0049	-0.3498
0330	71.00	84.6	66.29	14	14	II	8.26	63.53	0.0023	-0.2700	II	8.26	60.70	0.0044	-0.2380	II	6.16	58.13	0.0047	-0.1714	II	13.86	62.84	0.0045	-0.3916
0400	71.20	82.8	65.88	14	19	II	8.26	63.33	0.0021	-0.2678	II	8.26	60.50	0.0041	-0.2358	II	6.16	57.93	0.0045	-0.1698	II	13.86	62.63	0.0042	-0.3880
0430	71.70	77.4	64.49	14	18	II	8.26	62.61	0.0015	-0.2595	II	8.26	59.76	0.0035	-0.2279	II	6.16	57.21	0.0040	-0.1638	II	13.86	61.87	0.0032	-0.3751
0500	71.90	75.2	63.88	13	15	II	7.67	62.04	0.0014	-0.2396	II	7.67	59.00	0.0033	-0.2083	II	5.72	56.33	0.0038	-0.1491	II	12.87	61.22	0.0030	-0.3432
0530	72.00	74.1	63.56	14	21	II	8.26	62.12	0.0011	-0.2541	II	8.26	59.27	0.0031	-0.2227	II	6.16	56.73	0.0037	-0.1600	II	13.86	61.37	0.0027	-0.3668
0600	72.00	71.1	62.41	15	25	II	8.85	61.62	0.0006	-0.2619	II	8.85	58.90	0.0027	-0.2305	II	10.50	59.32	0.0027	-0.2681	II	18.15	61.63	0.0012	-0.4641
0630	72.00	72.4	62.92	15	22	II	8.85	61.93	0.0008	-0.2655	II	8.85	59.23	0.0028	-0.2340	II	6.60	56.81	0.0035	-0.1685	II	14.85	61.23	0.0022	-0.3857
0700	71.90	70.4	62.04	16	24	II	9.44	61.54	0.0004	-0.2742	II	9.44	58.96	0.0025	-0.2427	II	11.20	59.37	0.0025	-0.2826	II	19.36	61.57	0.0008	-0.4888
T-0	71.90	71.3	62.39	14	25	II	8.26	61.34	0.0008	-0.2456	II	8.26	58.46	0.0028	-0.2145	II	9.80	58.90	0.0029	-0.2493	II	16.94	61.35	0.0015	-0.4324
AVG.	67.44	80.44	64.98	12.39			7.31	62.21				7.31	58.97				6.10	56.60				12.82	61.46		

Period of Ice Team Inspection

FIGURE 6. "SURFICE" Computer Predictions

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 ice/frost formations on the LO2 and LH2 ET/ORB umbilicals, pyro canister purge vents, and cable tray vent holes.

Anomaly 002 documented ice/frost accumulations on the LO2 feed line support brackets and bellows.

Anomaly 003 documented ice/frost formations in the LH2 feedline bellows and the LH2 recirculation line bellows and burst disks.

Anomaly 004 documented a crack, 8-inches long by 1/4-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.

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.

A crack 8 inches long by 1/4 inch wide in the forward surface of the -Y ET/SRB cable tray had not changed since the previous cryoload. The condition was acceptable for flight per the NSTS-08303 criteria.

Typical amounts of ice/frost had accumulated on the ET/ORB LH2 umbilical including ice/frost fingers on the plate gap and pyro can purge vents. No unusual vapors or cryogenic drips appeared during tanking, stable replenish, and launch.

5.0 POST LAUNCH PAD DEBRIS INSPECTION

The post launch inspection of the MLP, FSS, and RSS was conducted on 9 April 1994 from Launch + 2 to 3.5 hours.

No flight hardware or TPS materials were found.

South SRB HDP erosion was typical. All south HDP shoe EPON shim material was intact. A small portion of sidewall shim material was debonded from HDP #2. 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 had closed properly. However, all four covers, which are sacrificial, sustained severe erosion with numerous areas of burn-through. 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. However, an ELSA box container in the White Room detached from the wall spilling the individual ELSA units on the floor.

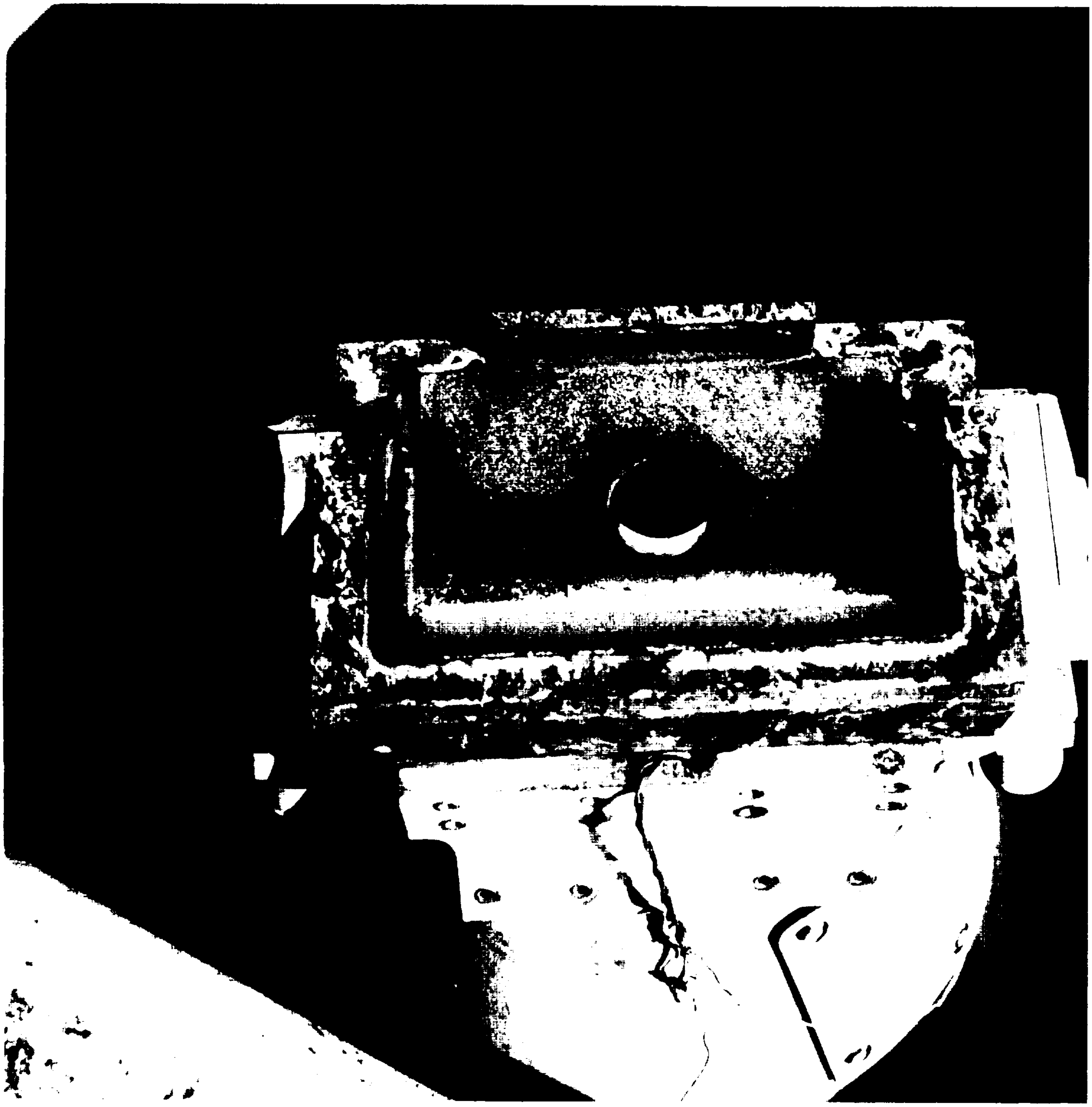
The GH2 vent line was latched on the eighth tooth of the latching mechanism, had no loose cables (static retract lanyard) and appeared to have latched properly with no rebound. The crossbeam between the two GUCP legs showed signs of contact with the lanyard.

Damage to the facility included four shattered lenses and one loose box inspection cover on the MLP deck cameras. A retaining pin, 8 inches long by 1.5 inches in diameter, came out from the northwest MLP crossover and fell to the stairs below. An aluminum rod, 20 inches long by 3/4 inches in diameter, was found on the FSS 135 foot level.

Post launch debris inspections of the pad acreage, beach, and areas outside the pad perimeter were performed. No flight hardware or TPS material was found.

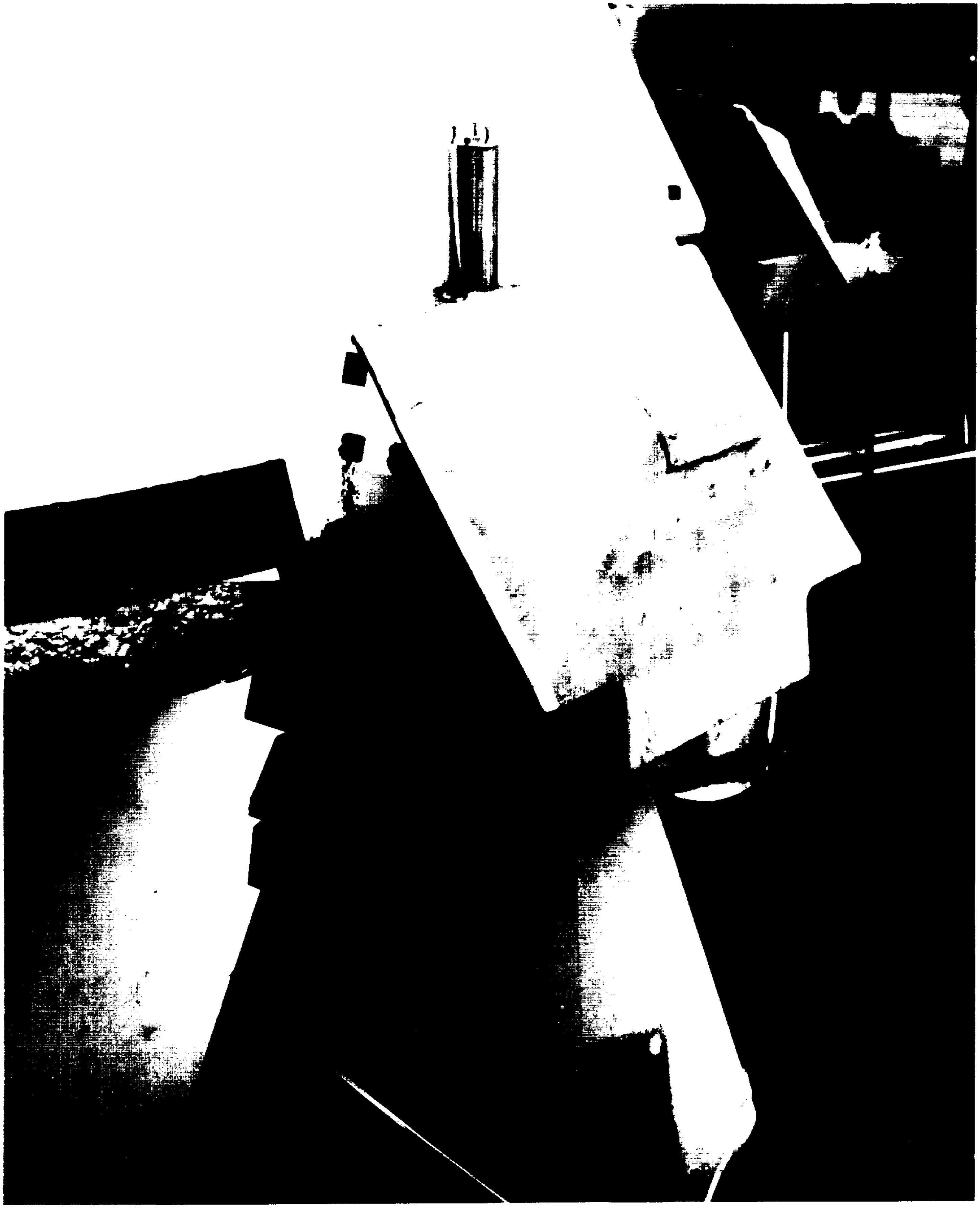
Subsequent inspections at the pad revealed significant damage to the GOX Vent Arm at the axial adjustment attach point. Several welds were broken and the piston housing had collapsed. This damaged caused the hood to be skewed or twisted approximately 1-2 inches from centerline (IFA STS-59-K-01). Vibration/acoustic shock waves from the SRB plume and 16 knot winds from the east (105 degrees) at the time of launch are believed to be related to the failure. Some of the damage was attributed to improper welds.

Post launch pad inspection anomalies are listed in Section 10.



South SRB holddown post erosion was typical. All south HDP shoe EPON shim material was intact.

All of the north holddown post doghouse blast covers had closed properly. However, all four covers, which are sacrificial, sustained severe erosion with numerous areas of burn-through.



Typical pre-launch configuration of north SRB holddown post doghouse blast cover

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 IPR's or 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 96 films and videos, which included forty-one 16mm films, twenty-one 35mm films, four 70mm films, and thirty videos, were reviewed starting on launch day.

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

Sparks from the hydrogen igniters contacted the LH2 TSM and the upper surface of the Orbiter inboard elevon (E-31).

SSME gimbal profile appeared normal (OTV 051, 070, 071). The SSME #1 and #2 Mach diamonds formed prior to SSME #3, which should have been first. MPS instrumentation showed no anomaly during ignition and flight (E-76). Free burning hydrogen drifted to the top of the LH2 TSM. A large piece of ice fell from the LO2 TSM T-0 umbilical cryogenic lines and contacted SSME #3 near the nozzle exit plane. No damage was visible (E-15, 19).

Two streaks occurred in the SSME plume during engine startup.

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 of the ice impacted the umbilical cavity sill and were deflected outward, but no tile damage was visible (OTV 009, 063).

A puff of vapor exited the L3D (aft down firing RCS thruster on the left side) after the nozzle paper cover tore during SSME startup. This cover had been wetted from the inside prior to launch - a condition indicative of an internal vapor leak (E-18).

Surface coating material was lost from base heat shield tiles outboard of SSME #3 (27 places), on the base heat shield between SSME #1 and #2 (3 places), near SSME #2 (1 place), on the RH ACPS pod aft surface (3 places), and on the LH ACPS pod aft surface (1 place). Erosion of the tile surface coating was more than usual (E-17, 18, 19, 20).

A small piece of ice or foam broke away from the +Y vertical strut-to-acreage interface during main engine ignition (OTV 054).

Residual gaseous oxygen exited the ET louvers. The louvers were covered by frost, but no ice was visible. Some frost fell away from the louvers after SSME ignition. There was no visible damage to the nosecone, fairing, louver, or footprint (OTV 013, 061, 063).

The Orbiter LH2 and LO2 T-0 umbilicals disconnected and retracted properly (OTV 049, 050).

GUCP disconnect from the External Tank was nominal. The GH2 vent line appeared to latch properly. Some slack in the static retract lanyard caused the cable to contact the GUCP leg/crossbeam. Post launch inspection found the GH2 vent line latched on the eighth tooth of the latching mechanism (E-33, 41, 42, 50, OTV 040).

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.

At approximately 7 seconds MET (after tower clear but prior to the vehicle roll program), vibration/acoustic shock waves from the SRB exhaust plume caused significant up/down movement of the GOX vent arm and twisting of the GOX vent hood. Component failure on the hood occurred at 8.16 seconds MET (IFA STS-59-K-01). The time of visible movement corresponded to maximum strains recorded by GVA strain gages during previous launches. Amplitude and frequency of the movement was significantly different when compared to previous launches with similar easterly winds. Vibration/acoustic shock waves from the SRB plume and a strong wind from the east (16 knots at 105 degrees) at the time of launch are believed to be the major contributor to the hood failure.

A box of emergency breathing units was observed falling to the floor of the Orbiter Access Arm White Room in this same time frame. All of the units remained within the confines of the white room and were not a threat to the vehicle (E-62).

Facility debris was blown westward beneath the RSS by the SRB exhaust plume (E-63).

A large piece of ice from the outboard side of LH2 ET/ORB umbilical fell aft and broke into smaller pieces without contacting the vehicle at 11:05:07 GMT (E-54, 59).

Six pieces of ET/ORB umbilical purge barrier (baggie) material fell aft of the vehicle just after the roll maneuver starting at 11:05:17 GMT (E-54, 59, 207, 212, 213, 220, 222, TV-4A).

Two pieces of aft skirt thermal curtain tape were loose on the RH SRB (E-207).

All SSME Dome Mounted Heat Shield closeout blankets appeared to be intact and missing no material (E-207).

Very clear views of Orbiter body flap movement showed amplitude and frequency similar to previous flights (E-207, 212, 213).

Differential deflection between inboard and outboard elevons during ascent was visible in numerous films (E-207, 212). An ascent program/schedule of elevon deflection for the purpose of load relief is I-loaded into the Orbiter computer prior to launch. Elevon actuator feedback based on aerodynamic pressure due to the actual flight conditions causes deflection deltas to the ascent schedule. These deflections are small in magnitude. The flight deltas to the STS-59 ascent schedule were normal.

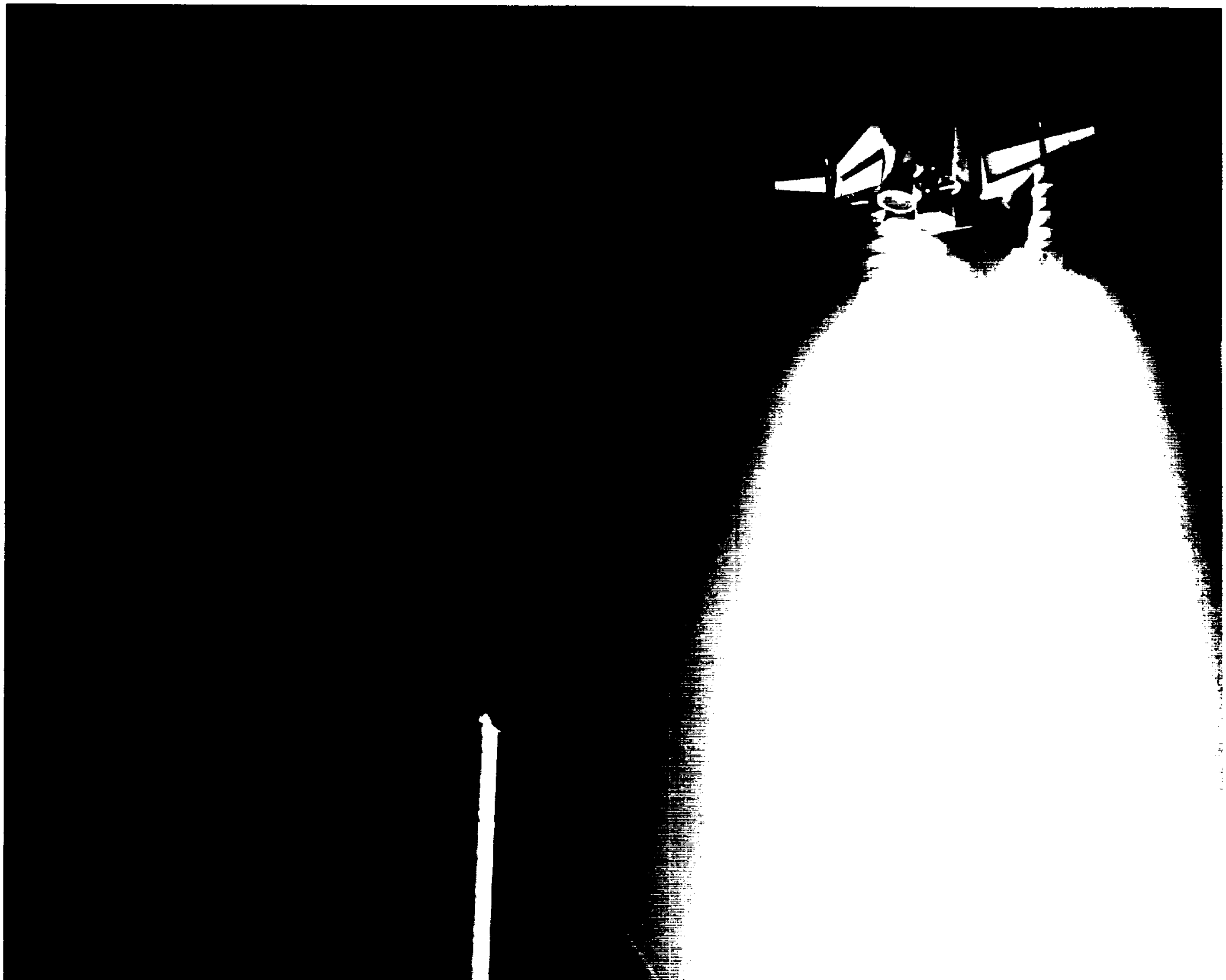
Numerous (at least 35) SRB propellant particles fell from the exhaust plume during ascent at GMT 11:06:05.967, 11:06:07.035, and 11:06:17.079 (E-208, 220, TV-4A).

Exhaust plume recirculation, ET aft dome charring, and SRB separation appeared nominal. Numerous pieces of slag dropped out of the SRB plume before, during, and after separation.

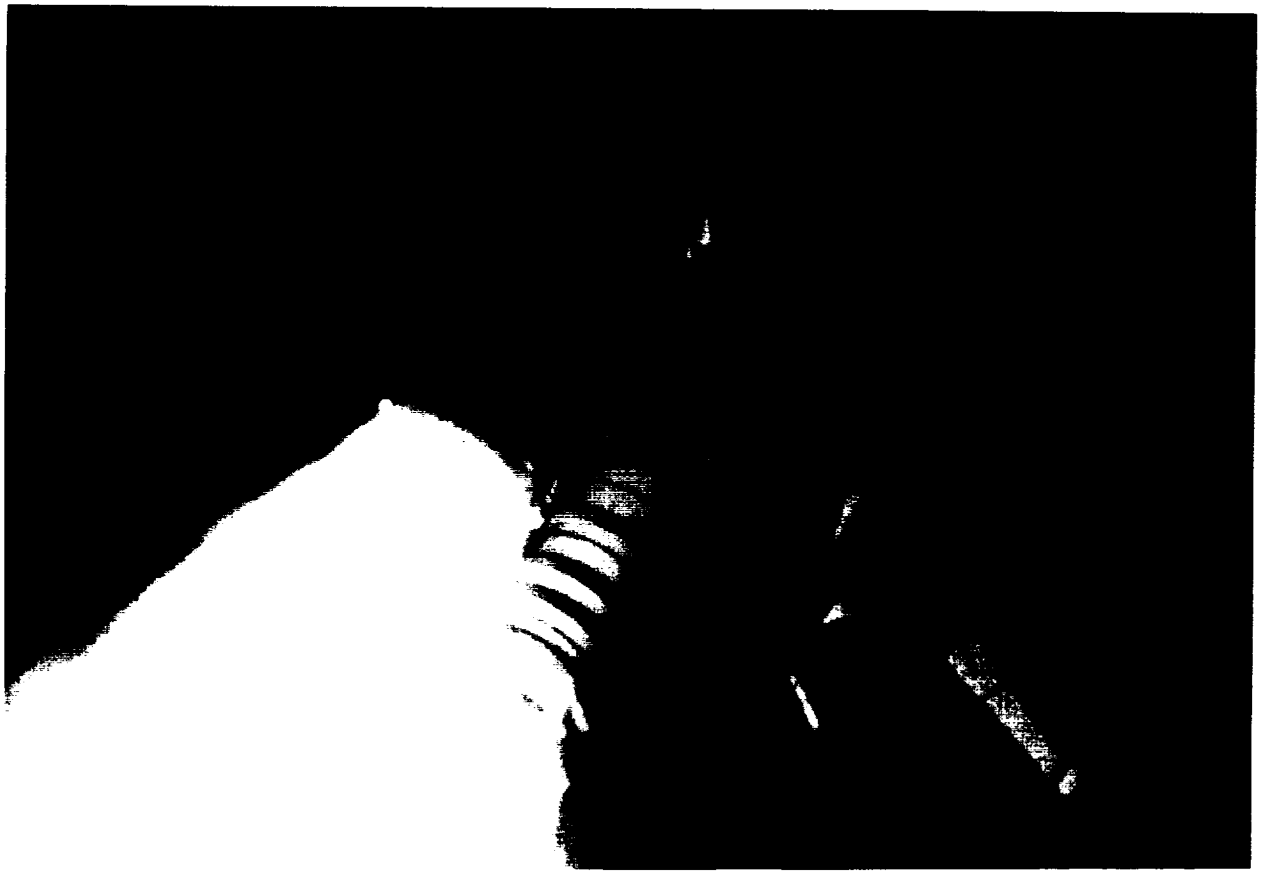
Frustum separation from the forward skirts and parachute deployment appeared normal. One parachute was late in opening but reached full reef position before nozzle severance (E-301). Water splashdown was not visible.

The SSME #1 and #2 Mach diamonds formed prior to SSME #3, which should have been first. MPS instrumentation showed no anomalies during ignition and flight.

Surface coating material was lost from 27 places on base heat shield tiles near SSME #3. Erosion of the tile surface coating was more than usual.



A strong easterly wind and vibration/acoustics from the SRB exhaust plume caused damage to the ET Gaseous Oxygen Vent Hood and a box of emergency breathing units in the White Room.



Differential deflection between inboard and outboard elevons during ascent was visible in numerous films. The deflections, programmed for flight load relief, were found to be normal.

6.2 ON-ORBIT FILM AND VIDEO SUMMARY

DTO-0312 was performed by the flight crew. Thirty-six hand-held still images were obtained of the ET after separation from the Orbiter. OV-105 was equipped to carry two umbilical cameras: 16mm motion picture with 10mm lens and 35mm still views.

No major vehicle damage or lost flight hardware was observed that would have been a safety of flight concern. Review of the on-orbit photography resulted in no IFA candidates.

Six divots, ranging in size from 6 to 10 inches in diameter, occurred in the LH2 tank-to-intertank flange closeout in the +Y+Z quadrant (2 places outboard of the LO2 feedline), -Y+Z quadrant (3 places between the -Y bipod and the -Y thrust panel), and on the outboard bondline of the -Y bipod spindle housing closeout.

A less than usual number of shallow "popcorn" type divots were visible on the +Z side of the intertank acreage in the vicinity of the bipods. There were no divots on any of the intertank stringer heads.

A divot, 8 inches in diameter, occurred in the LH2 tank acreage just aft of the LH2 tank-to-intertank flange closeout near the -Y bipod. A dark area in the divot may be shadow or primer.

Both bipod jack pad closeouts were intact and appeared to be in excellent condition.

Four divots, ranging in size from 6 to 12 inches in diameter, occurred in the LH2 tank-to-intertank flange closeout -Z side in an area between the -Z RSS antenna and the flight door.

A 6-inch diameter divot appeared in the LH2 tank acreage just below the flange closeout aft of the -Y EB fitting.

The LH2 ET/ORB umbilical TPS appeared to be in good condition with minimal damage. The red purge seal was intact. Blistering of the fire barrier coating was typical. Small pieces of foam were missing or eroded from the horizontal section of the cable tray and the vertical section of the LH2 feedline support. Frozen hydrogen adhered to the 17-inch flapper valve.

The LO2 ET/ORB umbilical appeared to be in good condition overall. Numerous divots and eroded areas were visible on the horizontal and vertical sections of the cable tray. The red purge seal was intact. All lightning contact strips on the umbilical appeared to be present and intact.

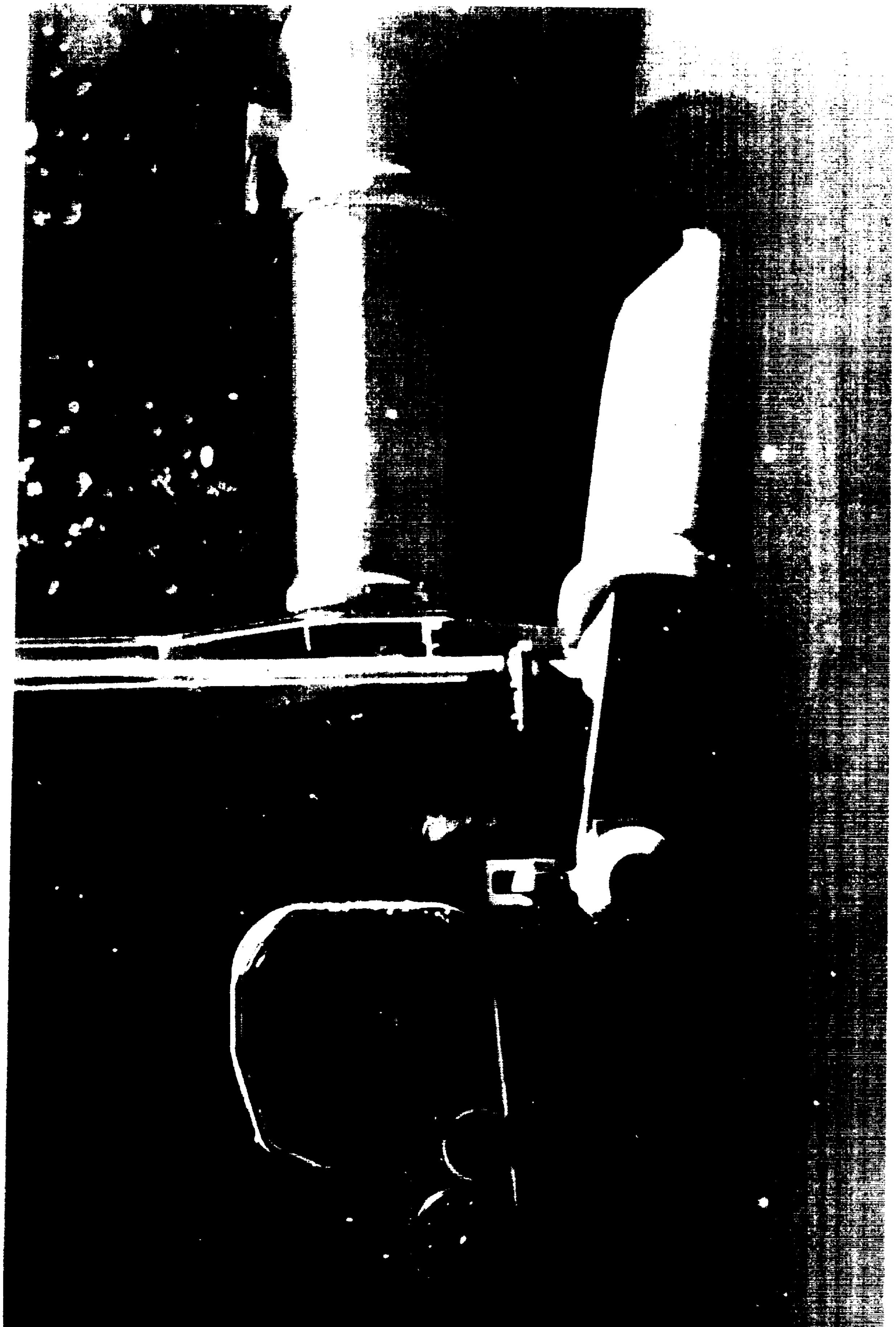
A greater than usual number of small shallow "popcorn" type divots occurred on the LH2 tank acreage forward of the crossbeam.

SRB separation from the ET and External Tank separation from the Orbiter were nominal.

The BSM burn scars on the LO2 tank barrel were typical. Somewhat more than usual charring from ascent aeroheating occurred on the nosecone and LO2 tank ogive. No anomalies were observed on the nosecone, LO2 tank acreage, PAL ramps, RSS antennae, flight door, bipod ramps, LO2 feedline, and aft hard point. Typical charring from plume recirculation, but no divots, were visible on the aft dome acreage. Erosion of the manhole cover closeouts and aft dome apex was also typical.

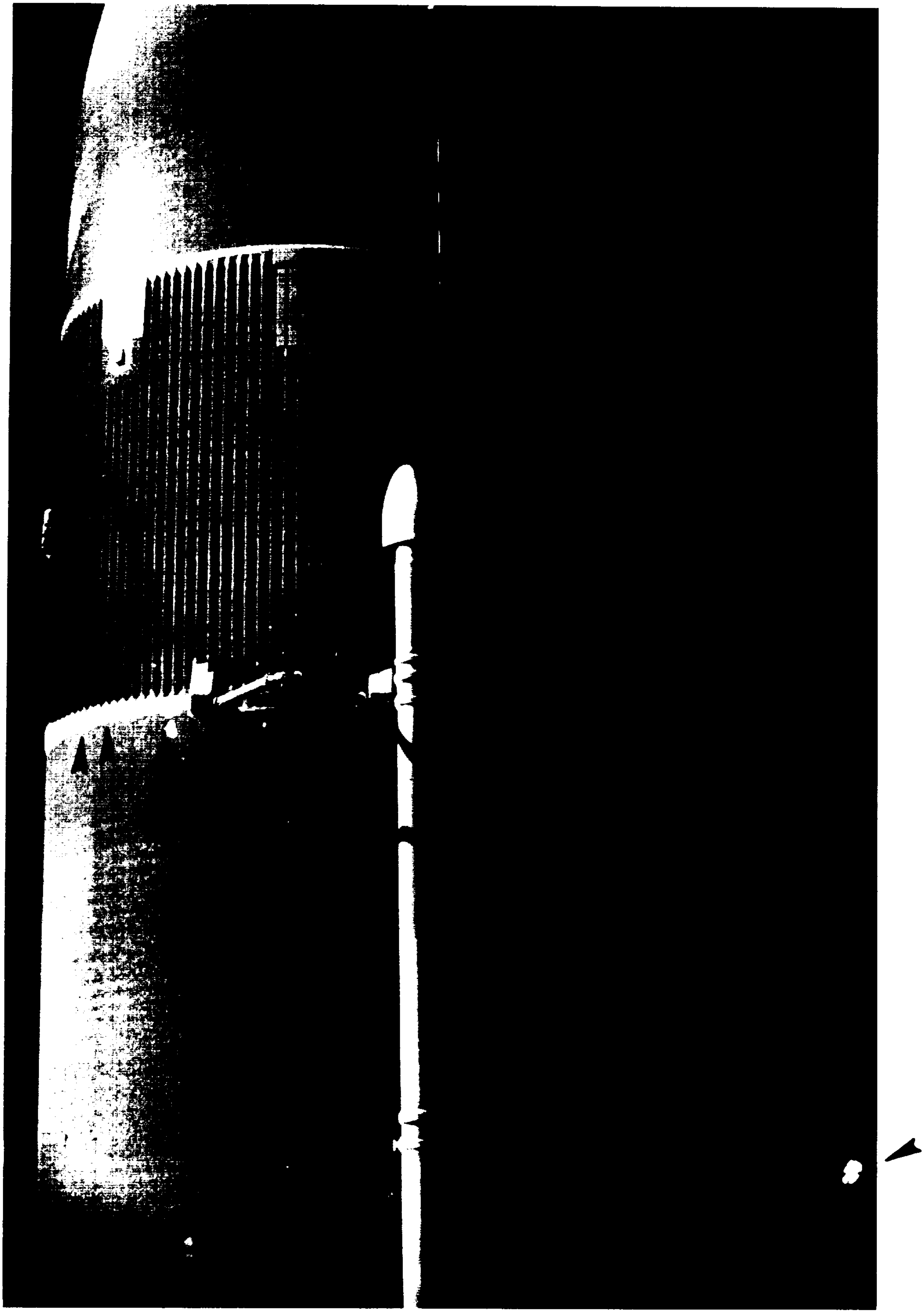
SRB separation appeared normal. Erosion of TPS from the aft surfaces of the left vertical strut and the LH2 cable tray was typical.

Separation of the External Tank from the Orbiter appeared normal. Small pieces of foam were missing or eroded from the horizontal section of the cable tray and the vertical section of the LH2 feedline support. The red purge seal appeared to be intact. Frozen hydrogen adhering to the 17-inch flapper valve was typical.

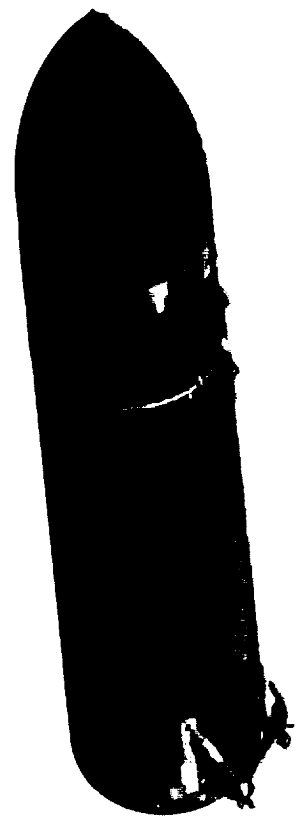


The LO2 ET/ORB umbilical appeared to be in good condition. A greater than usual number of shallow "popcorn" type divots occurred on the LH2 tank acreage forward of the crossbeam.

ORIGINAL PAGE
COLOR PHOTOGRAPH



The bipod jack pad closeouts were intact. An 8-inch diameter divot with exposed primer occurred in the LH2 tank acreage near the left bipod. Six divots were visible in the intertank-to-LH2 tank flange closeout. Note unusual shaped ice in lower corner.



No anomalies were observed on the nose cone or acreage areas of the LO2 tank, intertank, and LH2 tank (-Y and -Z sides). Nine divots occurred in the intertank-to-LH2 tank flange closeout between the left bipod and the -Z RSS antenna.

6.3 LANDING FILM AND VIDEO SUMMARY

A total of 18 landing films and videos, including eleven 16mm high speed films, two 35mm large format films, and five videos, 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 virtually simultaneous.

The drag chute was deployed after breakover, but before the nose gear contacted the runway. Drag chute deployment appeared nominal.

Touchdown of the nose landing gear was smooth. There were no anomalies during rollout and wheel stop.

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 11 April 1994 from 1130 to 1330 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 23 MSA-2 debonds over fasteners (Figure 7). There was virtually no blistering of the Hypalon paint with the exception of minor localized blistering along the 395 ring. All BSM aero heat shield covers had locked in the fully opened position though the upper right cover attach ring 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, though the +Z antenna base plate had delaminated. PR-1422 adhesive was missing from one RSS antenna bolt head. 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 generally in good condition. Trailing edge damage to the FJPS and the GEI cork runs were attributed to debris resulting from severance of the nozzle extension.

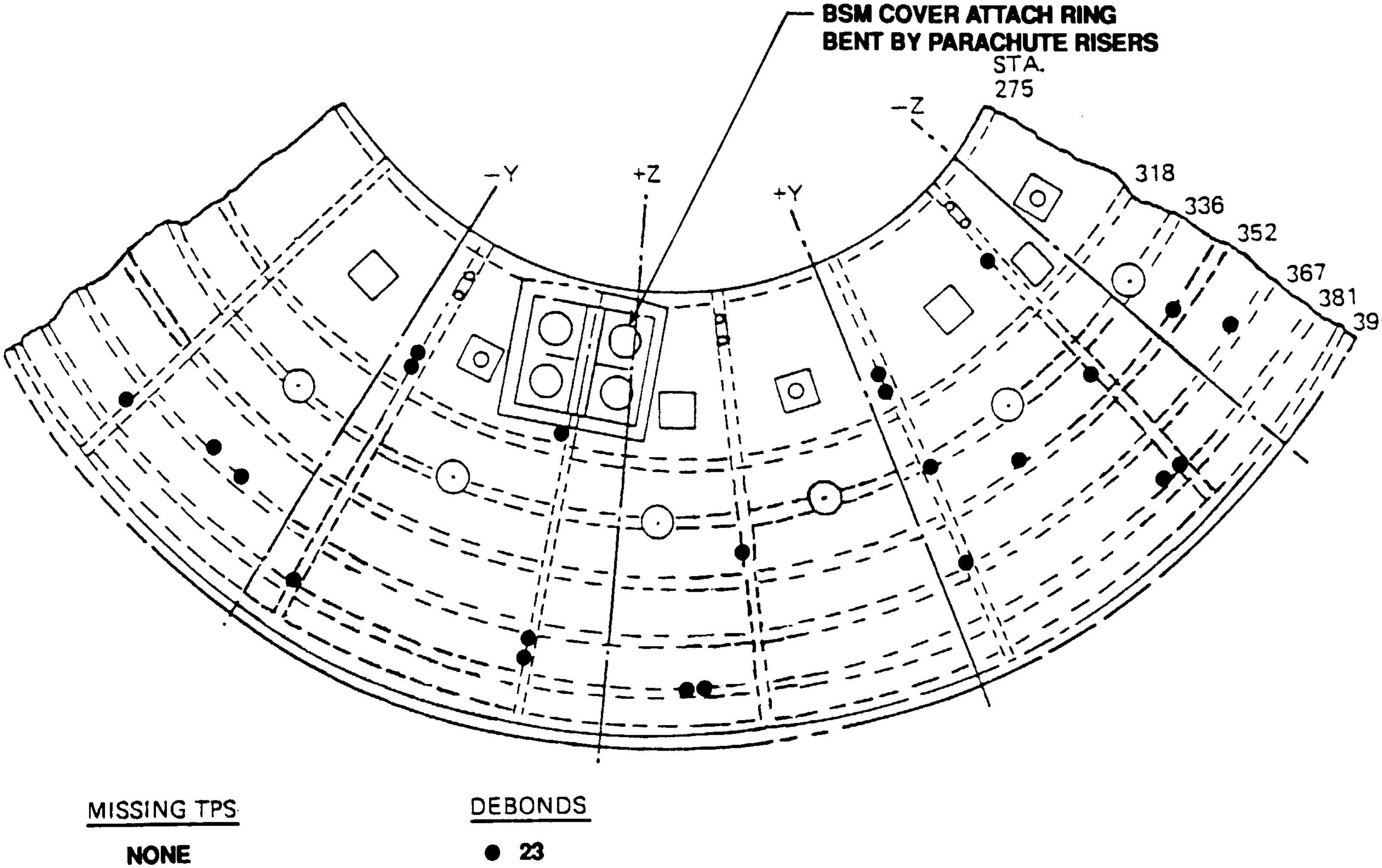
Separation of the aft ET/SRB struts appeared normal. The ET/SRB aft struts, ETA ring, IEA, and IEA covers appeared undamaged. A debris impact site was noted on the IEA forward surface TPS at 145 degrees radial location (IFA STS-59-I-02). The impact cavity measured 2" x 1.5" x 1.75". The foam in the damage site was crushed and showed signs that heating had occurred inside the cavity possibly during ascent. No debris object or foreign substance was found. Post flight analysis at MSFC revealed no residual material in the cavity. The impact damage was most likely caused by a piece of ice from the ET LO2 feedline upper bellows. 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. K5NA had separated from Hypalon-covered BTA and primer-coated metal on the BSM support brackets (IFA STS-59-B-01). Current surface preparation procedures are inadequate for proper K5NA adhesion. The closeouts on STS-65 were reworked and the procedure changed

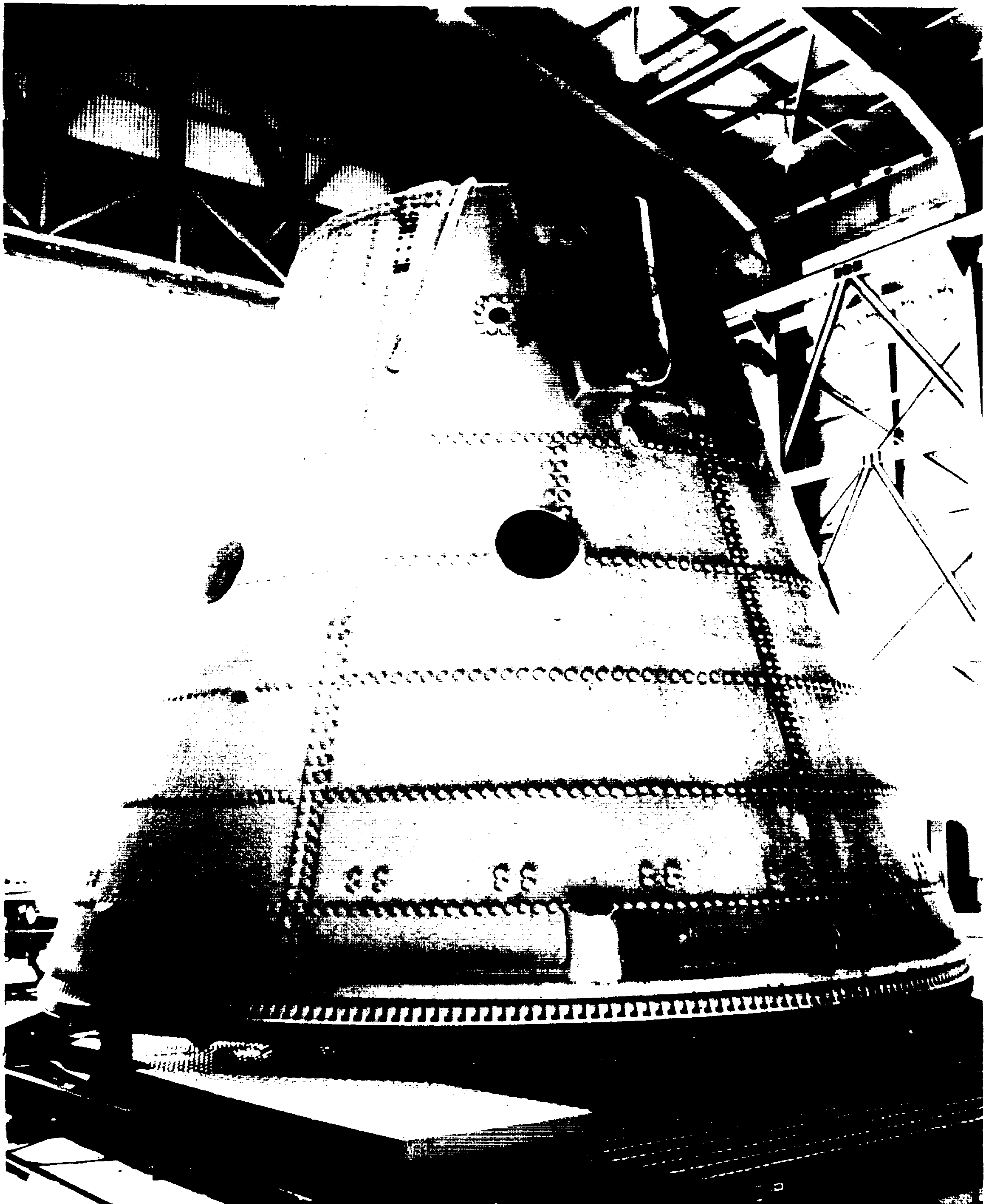
The HDP Debris Containment System (DCS) plungers were seated and appeared to have functioned properly. EPON shim material is no longer bonded to the HDP #3 and #4 aft skirt structure.

STS-59

FIGURE 7. **RIGHT SRB FRUSTUM**



EGG/V-326



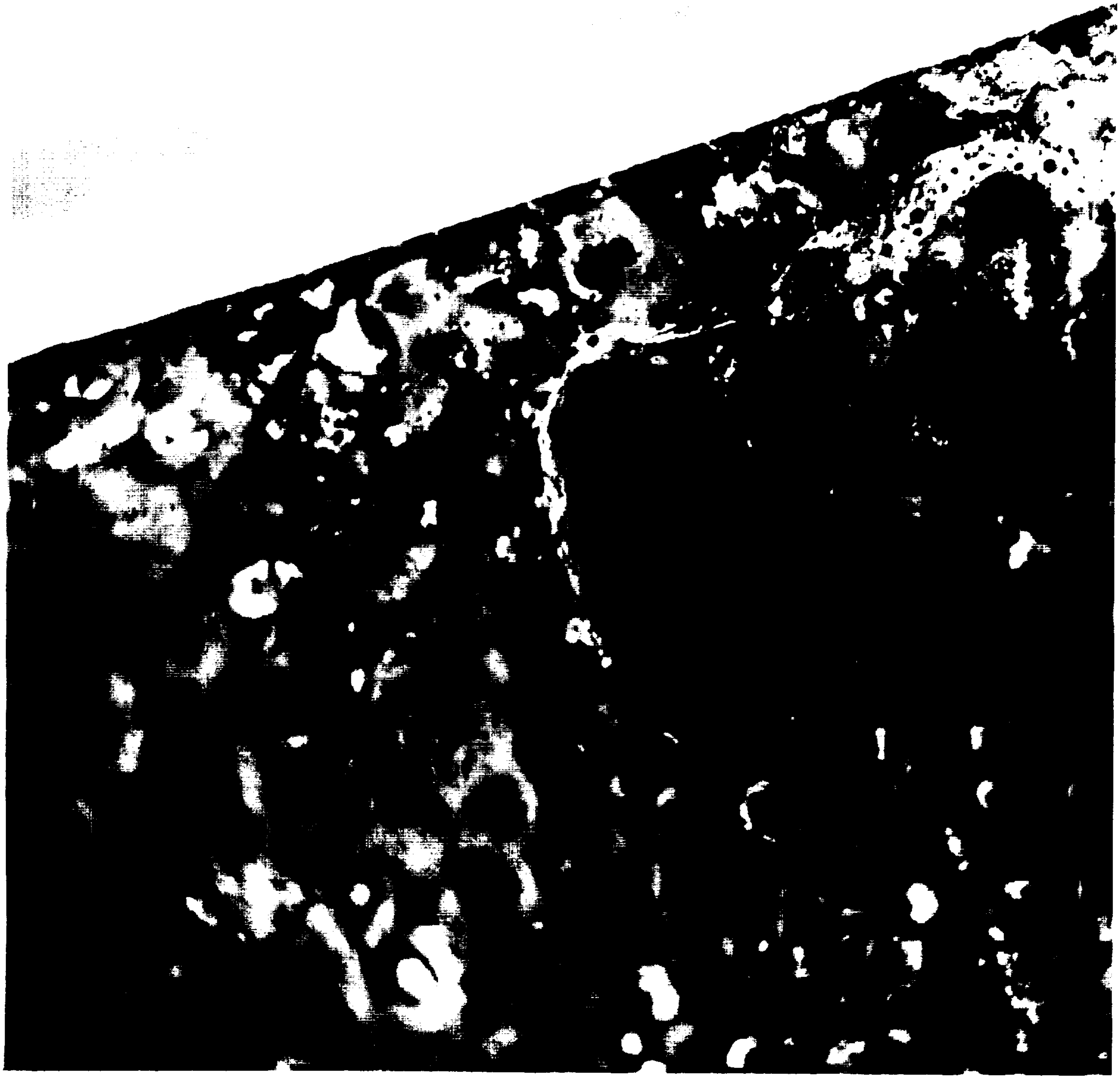
The RH frustum was missing no TPS but had 23 MSA-2 debonds over fasteners. Blistering of the Hypalon paint was minimal. The BSM aero heat shield covers had locked in the fully opened position

ORIGINAL PAGE
COLOR PHOTOGRAPH

RH forward skirt acreage exhibited no debonds or missing TPS. Blistering of the Hypalon paint was minimal.

Both RSS antennae covers/phenolic base plates were intact, though the +Z antenna base plate had delaminated.

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.



A debris impact site was noted on the right IEA forward surface TPS at 145 degrees radial location. The foam in the damage site was crushed and showed signs that heating had occurred inside the cavity. No debris object or foreign residue was found.

7.2 LH SOLID ROCKET BOOSTER DEBRIS INSPECTION

The LH frustum was missing no TPS but had 17 MSA-2 debonds over fasteners and 6 debonds over acreage (Figure 8). Significant amounts of BTA had been applied to closeouts on this frustum. Hypalon paint was blistered/missing over the areas where the BTA had been applied. The underlying BTA was not sooted. All BSM aero heat shield covers had locked in the fully opened position.

The LH forward skirt acreage exhibited no missing TPS though two debonded areas occurred between the flight door and the ET/SRB attach point. 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, IEA covers, and stiffener rings 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 (Figure 9). Two by two inch pieces of MSA-2 were missing from fasteners near the hydrazine servicing ports (3 places) and on the 1860 ring frame near the +Y axis (1 place). Hypalon paint was blistered over areas where BTA had been applied. The underlying BTA was generally not sooted.

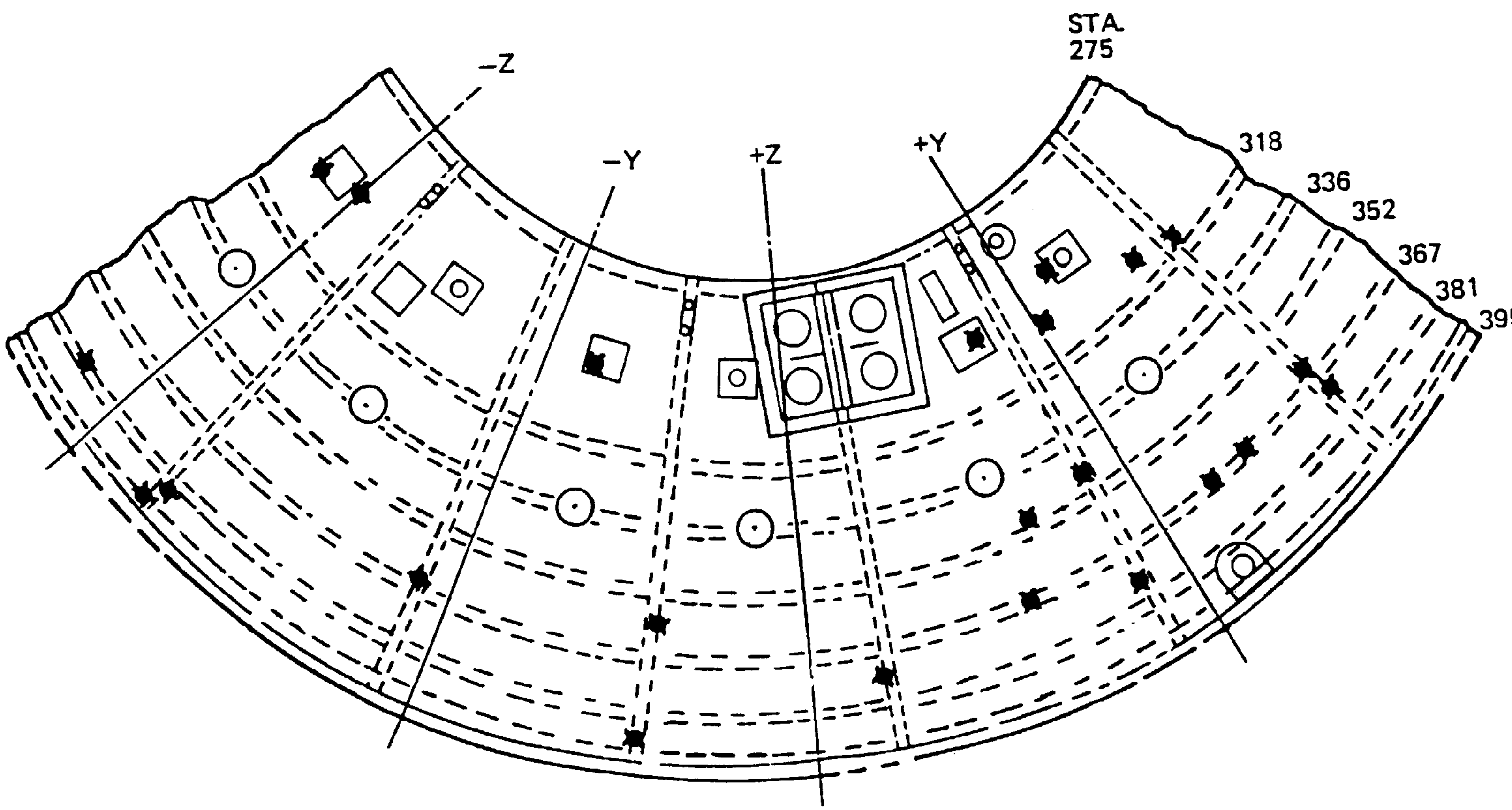
K5NA had separated from Hypalon-covered BTA and primer-coated metal on the BSM support brackets (IFA STS-59-B-01). Current surface preparation procedures are inadequate for proper K5NA adhesion. The closeouts on STS-65 were reworked and changes to the procedure were incorporated.

Three of four Debris Containment System (DCS) plungers were seated and appeared to have functioned properly. The HDP #6 DCS plunger was obstructed by frangible nut debris. Disassembly of the DCS revealed a retention of 96 percent. 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-59

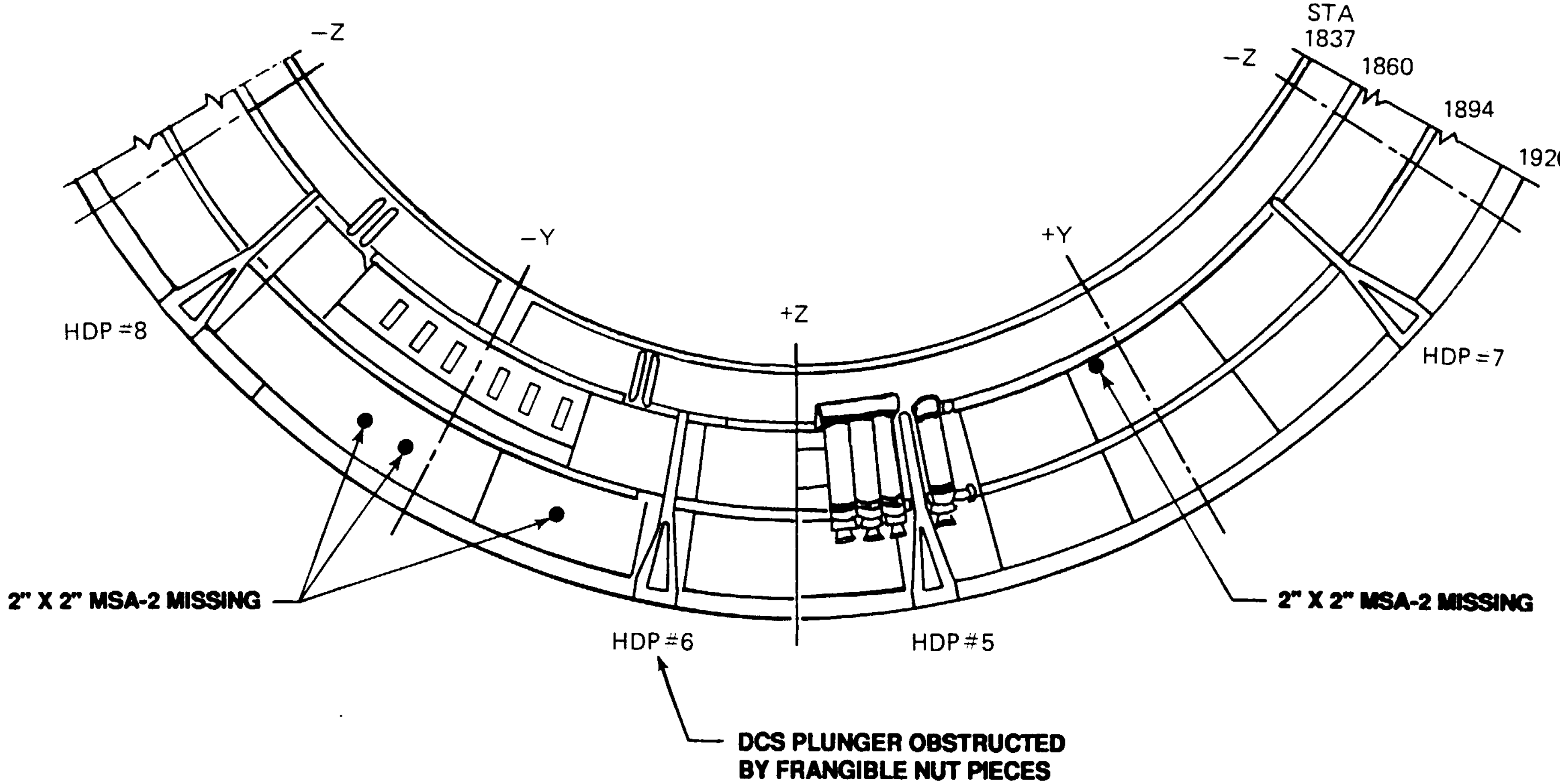
FIGURE 8. **LEFT SRB FRUSTUM**

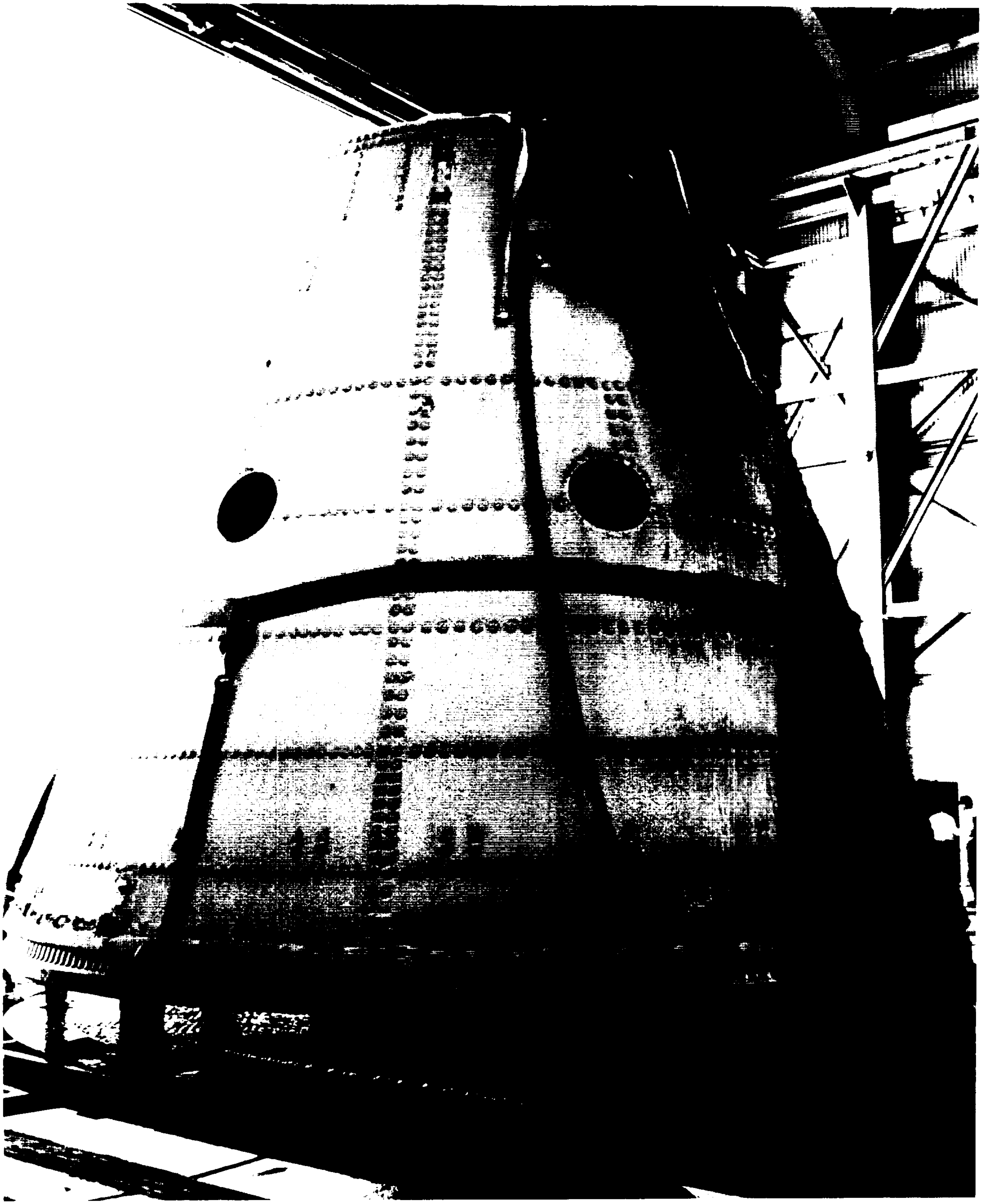


MISSING TPS
NONE

DEBONDS
● **23**

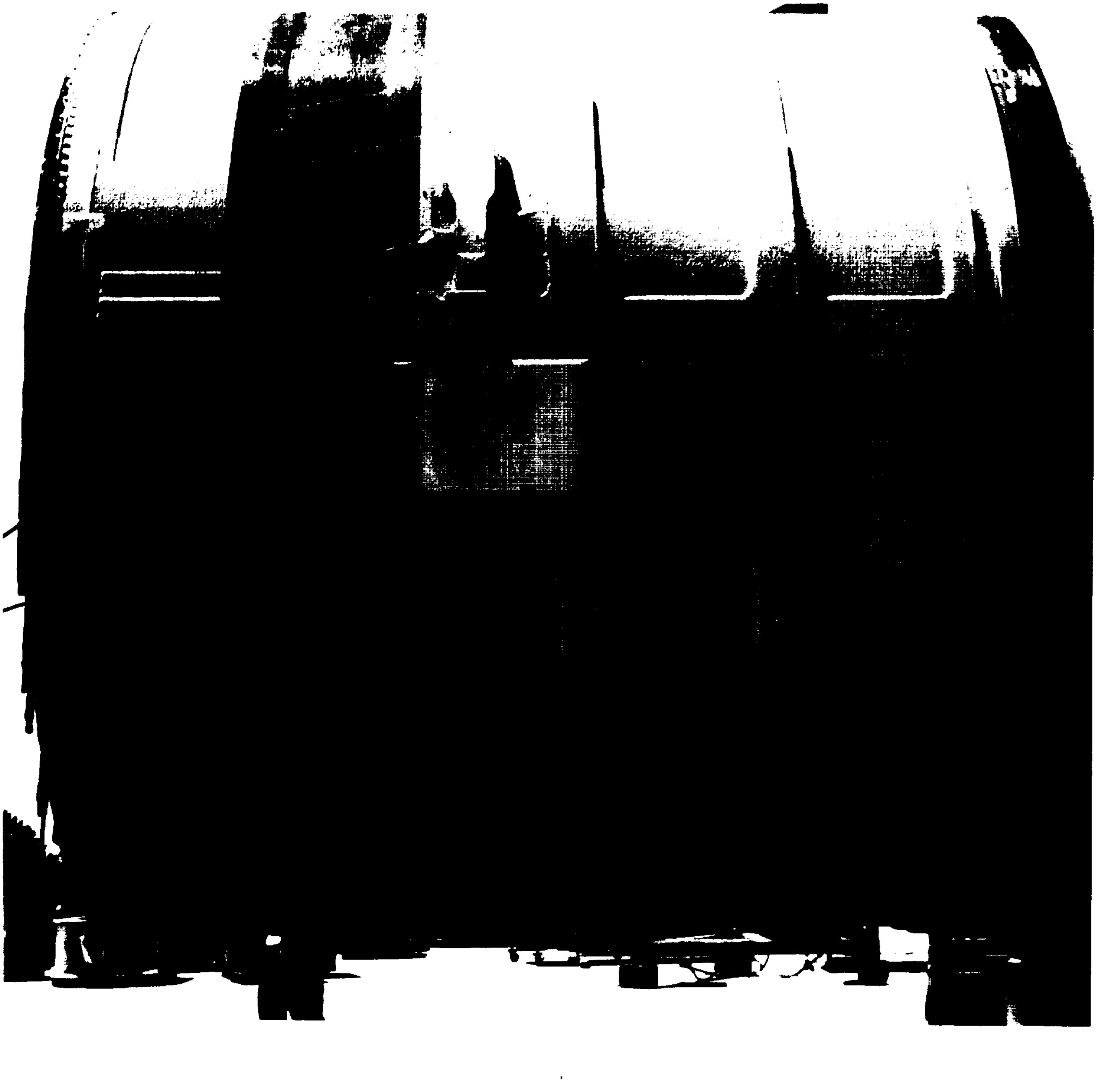
STS-59
FIGURE 9. **LEFT SRB AFT SKIRT EXTERIOR TPS**



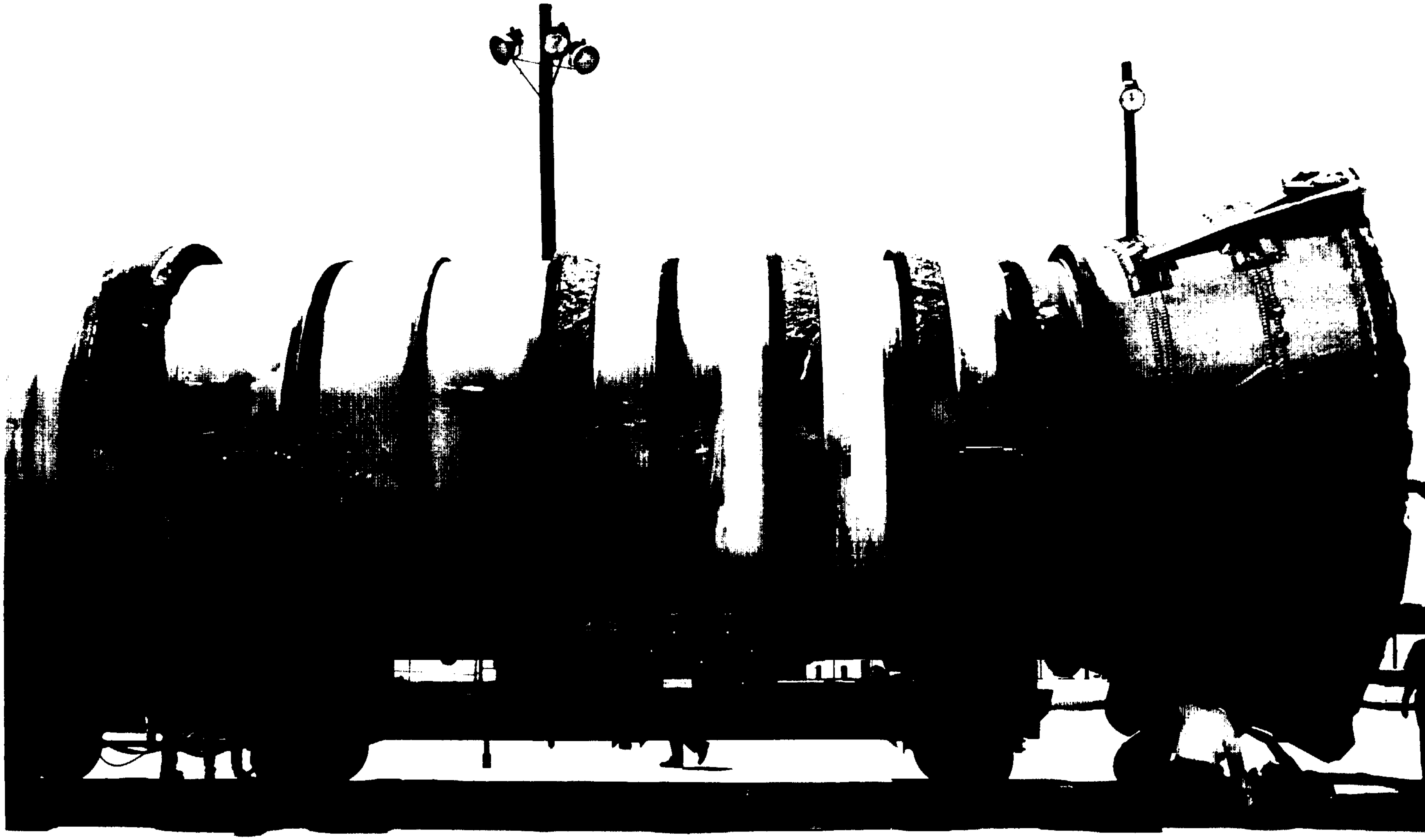


The LH frustum had a total of 17 MSA-2 debonds over fasteners and 6 acreage debonds. Significant amounts of BTA had been applied as a closeout material on this frustum.

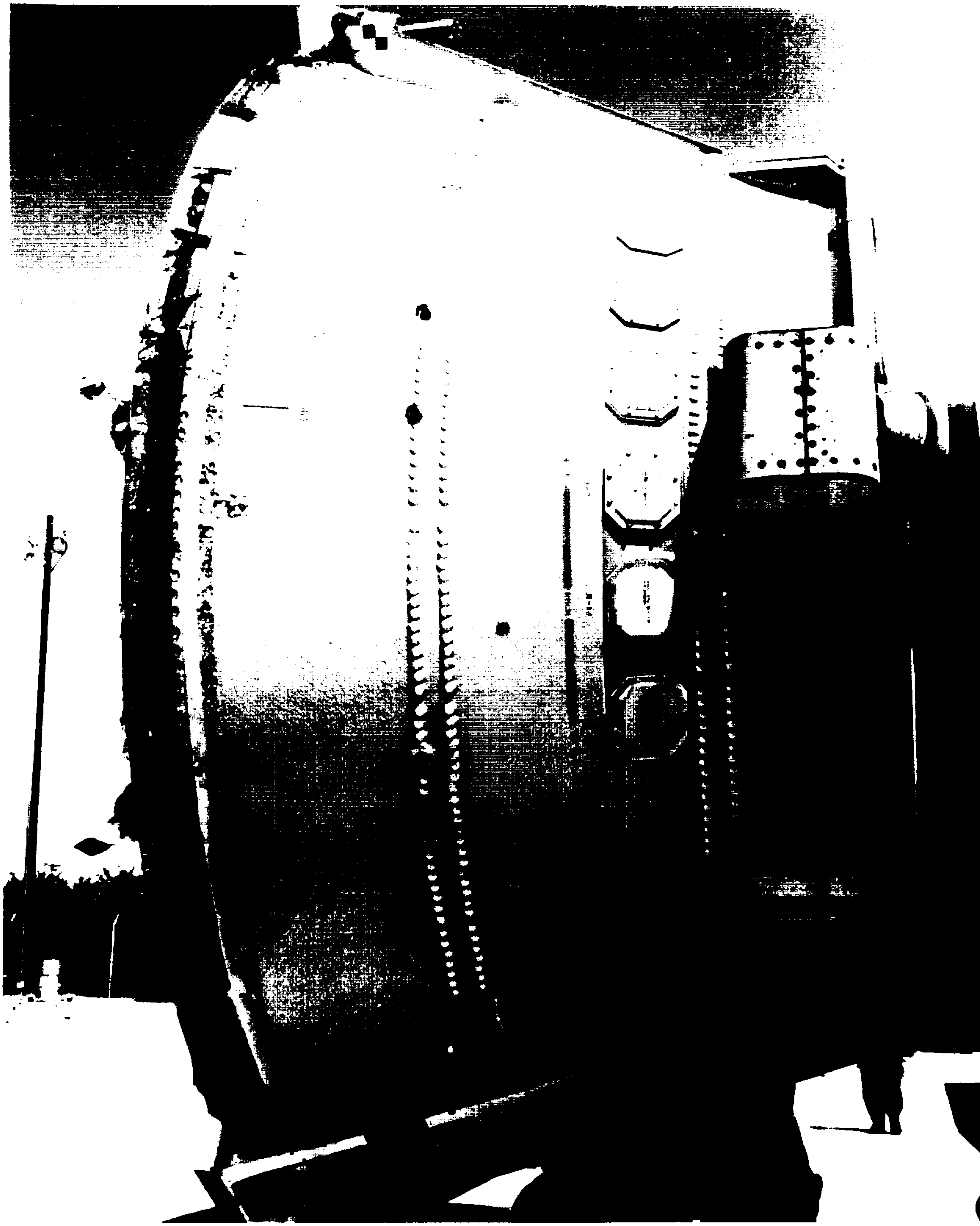
Hypalon paint was blistered and/or missing from areas where BTA had been applied. The underlying BTA was not sooted.



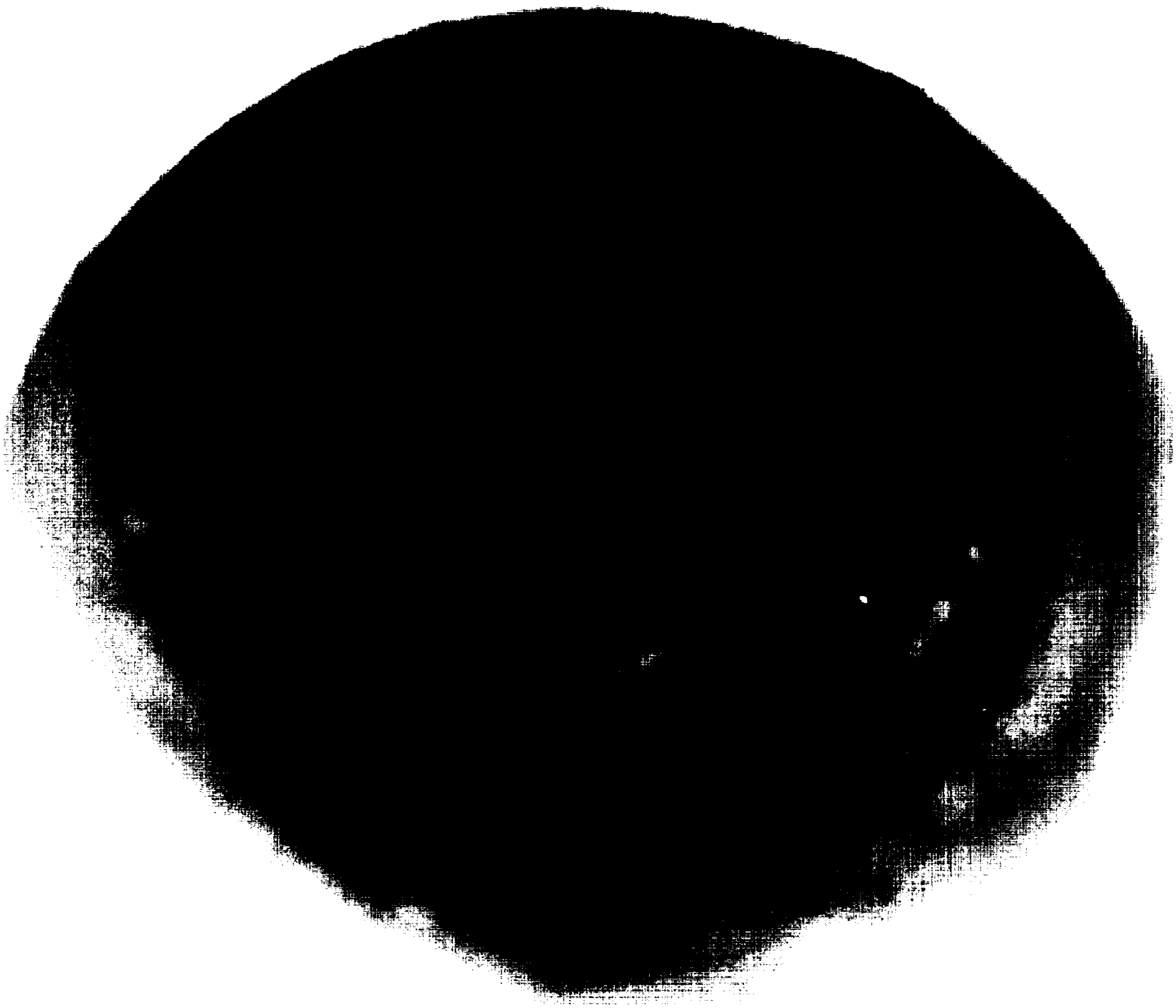
The LH forward skirt acreage MSA-2 exhibited no missing TPS though two debonded areas occurred between the flight door and the ET/SRB attach point. Both RSS antenna covers/phenolic base plates were intact.



Post flight condition of the LH aft booster and aft skirt. The ET/SRB aft struts, ETA ring, IEA, IEA covers, and stiffener rings appeared undamaged. The stiffener ring splice plate closeouts were intact and no K5NA material was missing.



Two by two inch pieces of MSA-2 were missing from fasteners near the hydrazine service ports. Hypalon paint was blistered/ missing from BTA closeout areas.



HDP #6 DCS plunger was obstructed by frangible nut debris

8.0 ORBITER POST LANDING DEBRIS ASSESSMENT

A post landing debris inspection of OV-105 (Endeavour) was conducted 20-21 April 1994 at the Dryden Flight Research Center (DFRF) on runway 22 and in the Mate/Demate Device (MDD). This inspection was performed to identify debris impact damage and, if possible, debris sources. The Orbiter TPS sustained a total of 77 hits, of which 19 had a major dimension of one inch or larger. This total does not include the numerous hits on the base heat shield attributed to SSME vibration/acoustics and exhaust plume recirculation. A comparison of these numbers to statistics from 46 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 (Figures 10-13).

The following table breaks down the STS-59 Orbiter debris damage by area:

	HITS > 1"	TOTAL HITS
Lower surface	10	47
Upper surface	8	18
Right side	0	2
Left side	0	0
Right OMS Pod	1	9
Left OMS Pod	0	1
TOTALS	19	77

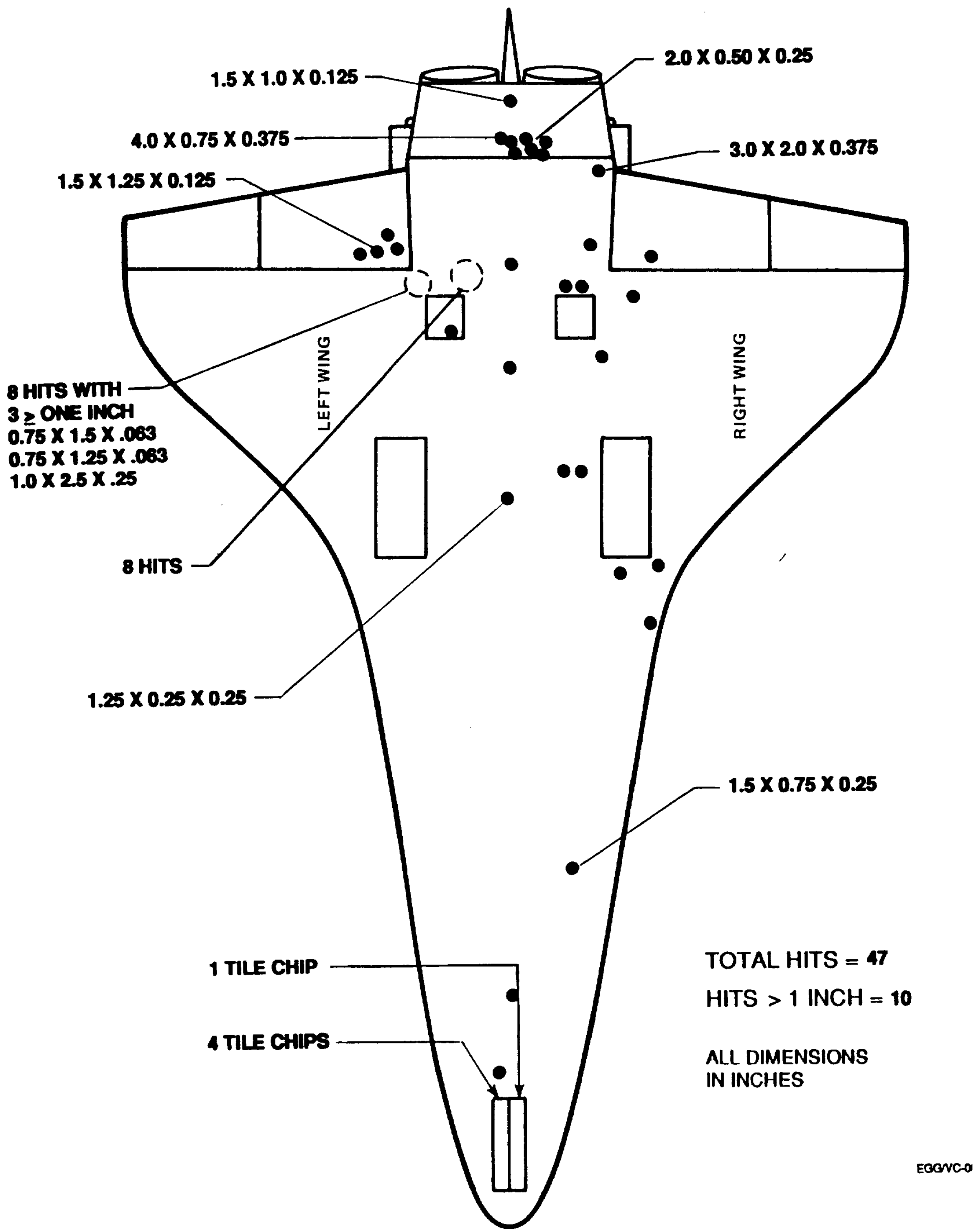
The Orbiter lower surface sustained a total of 47 hits, of which 10 had a major dimension of 1-inch or larger. A total of 16 hits, in two clusters of eight hits, occurred just aft of the LH2 ET/ORB umbilical. Three of these damage sites had a major dimension larger than 1-inch. Clusters of hits around the LO2 and LH2 ET/ORB umbilicals are believed to be impacts from umbilical ice.

The inboard tires on both the left and right main landing gear sustained significant wear-type damage on the inboard portions. Numerous pieces of tread were found on the runway following landing. Although none of the tire tread debris was found in the tile damage sites, some of the lower surface debris damage aft of the main landing gear may be attributable to the tire debris.

The crew hatch outer pane (window #11) sustained an apparent micrometeorite impact. The damage site measure 1/4-inch in diameter and was located at the 7 o'clock position of the window, one inch from the edge tiles.

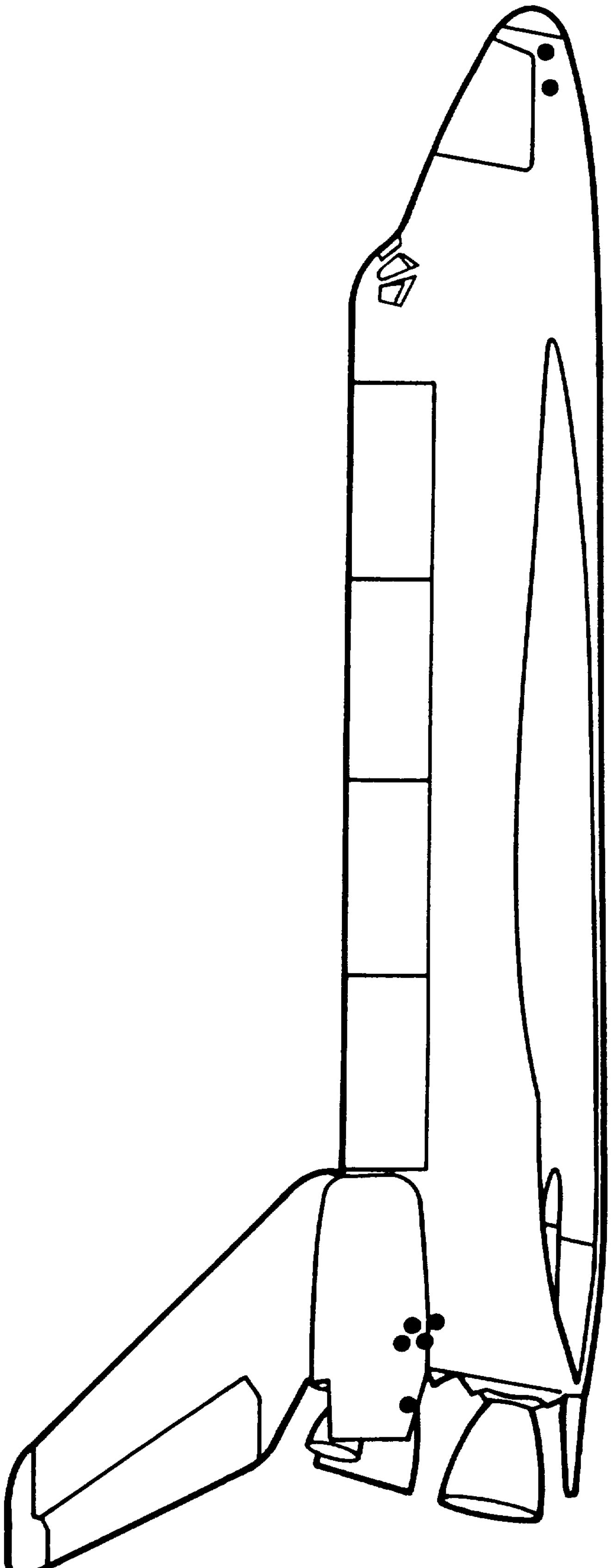
STS-59

FIGURE 10. **DEBRIS DAMAGE LOCATIONS**



STS-59

FIGURE 11. DEBRIS DAMAGE LOCATIONS



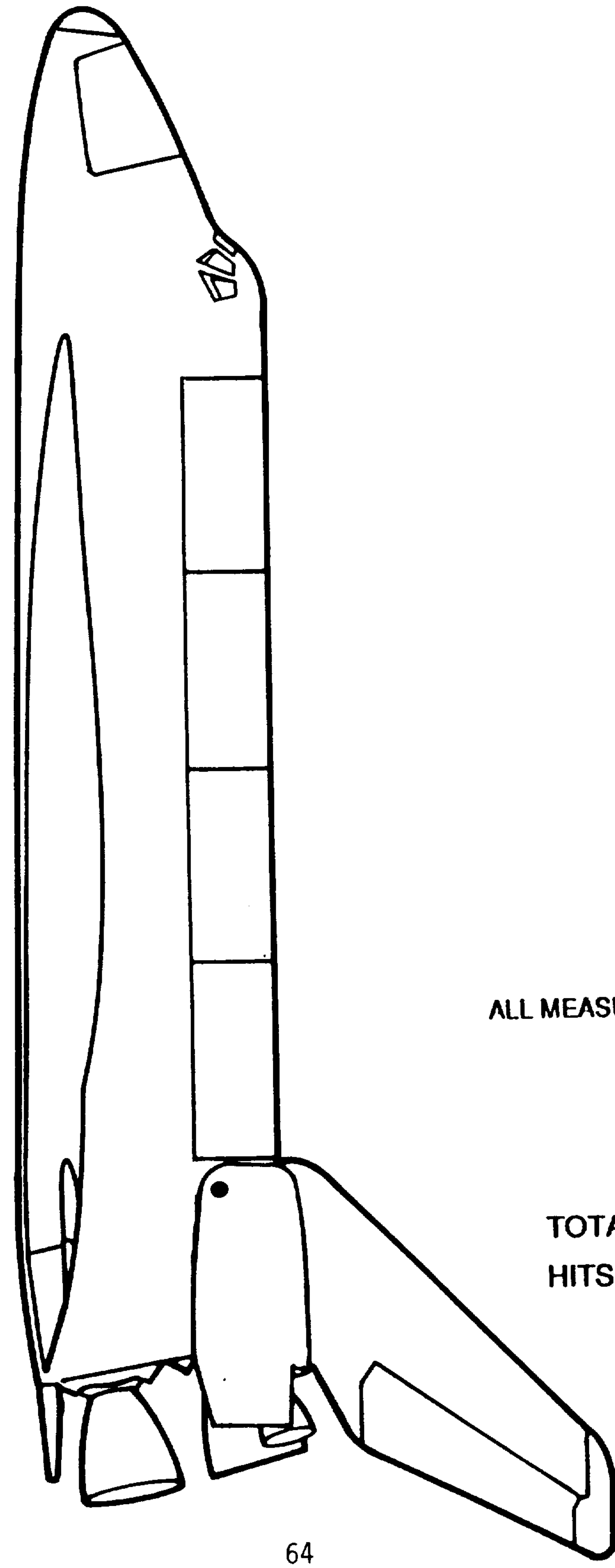
TOTAL HITS = 7

HITS > 1 INCH = 0

EGG/VC-088A

STS-59

FIGURE 12. DEBRIS DAMAGE LOCATIONS



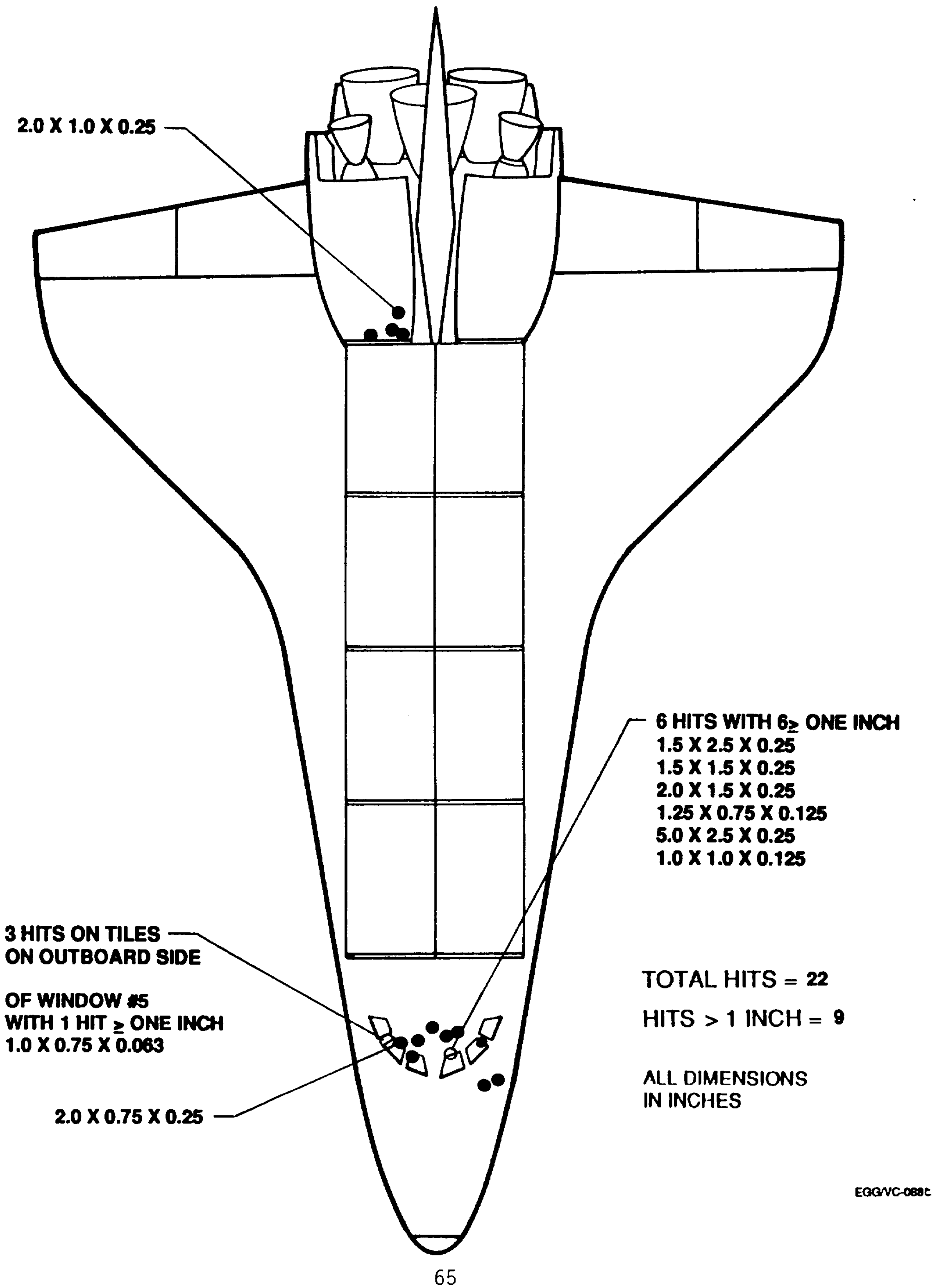
ALL MEASUREMENTS IN INCHES

TOTAL HITS = 1

HITS > 1 INCH = 0

EGG/VC-088

STS-59
FIGURE 13. **DEBRIS DAMAGE LOCATIONS**



Orbiter windows #3 and #4 exhibited typical hazing. Only a very light haze was present on the other windows. Surface wipes were taken from all windows for laboratory analysis. No other sites on the Orbiter were identified for chemical analysis. A total of 12 hits with eight larger than 1-inch in size were noted on the perimeter tiles around windows #3 and #5. These hits may have been caused by impacts from RTV used to bond paper covers to the FRCS nozzles.

ET/ORB separation devices EO-1 and EO-3 functioned properly though the EO-2 debris plunger had not seated. No debris was found on the runway beneath the ET/ORB umbilical cavities when the ET doors were opened, but a loose wave spring was found resting against a Hi-Lock fastener on the LH2 umbilical door. The wave spring is part of the pyro separation device. All of the umbilical separation ordnance retention shutters were closed properly. No significant amounts of foam or red purge seal adhered to the LH2 ET/ORB umbilical near the 4-inch flapper valve.

Tile damage on the base heat shield was typical with the majority of hits occurring in the areas between SSME #1/2 and #1/3. Six TUFI tiles located on the triangular carrier panel between and below SSME #2 and #3 sustained no damage. This was the first flight of TUFI tiles. The Dome Mounted Heat Shield (DMHS) closeout blankets on all three SSME's were in excellent condition and no material was missing.

Three tile damage sites on the vertical stabilizer "stinger" were attributed to contact with the Orbiter drag chute risers during deployment.

Runway 22 had been swept/inspected by Air Force personnel prior to landing and all potentially damaging debris was removed. The post landing walkdown of Runway 22 was performed immediately after landing. No Shuttle flight hardware was found on the runway except for the previously mentioned landing gear tire debris. All drag chute hardware was recovered and showed no signs of abnormal operation. No organic (bird) debris was found on the runway.

A Minolta/Land Cyclops infrared spot radiometer was used to measure the surface temperatures of several areas on the vehicle (per OMRSD V09AJ0.095). Twenty minutes after landing, the Orbiter nosecap RCC was 284 degrees F. Twenty-two minutes after landing, the RH wing leading edge RCC panel #9 was 127 degrees F and panel #17 was 137 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 (Figures 15-16). The type of TPS damage is typical and not attributable to any single debris source. Orbiter Post Launch Debris Anomalies are listed in Section 10.

FIGURE 14. **STS-59 RCC TEMPERATURE MEASUREMENTS AS RECORDED BY THE SHUTTLE THERMAL IMAGER**

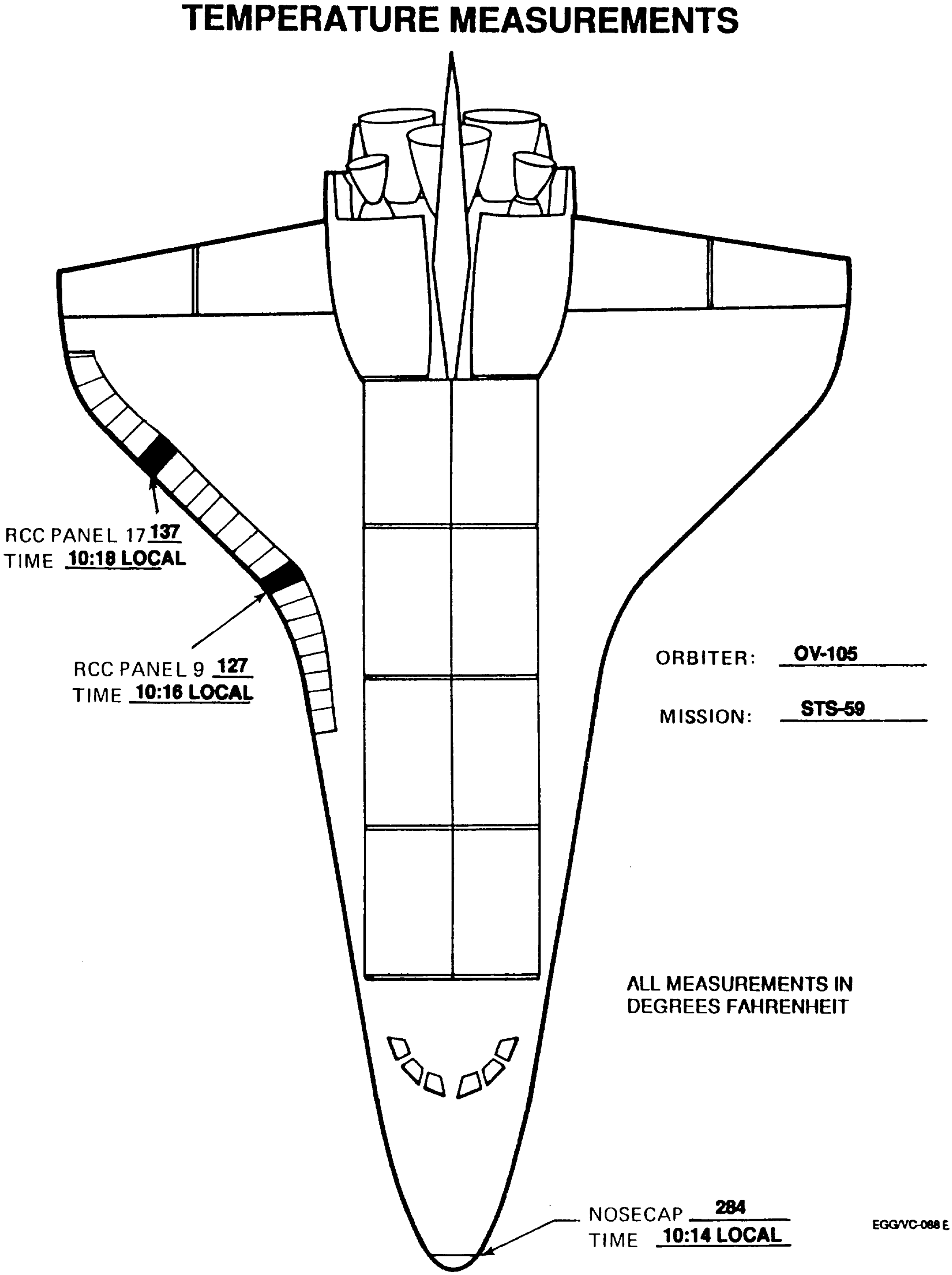
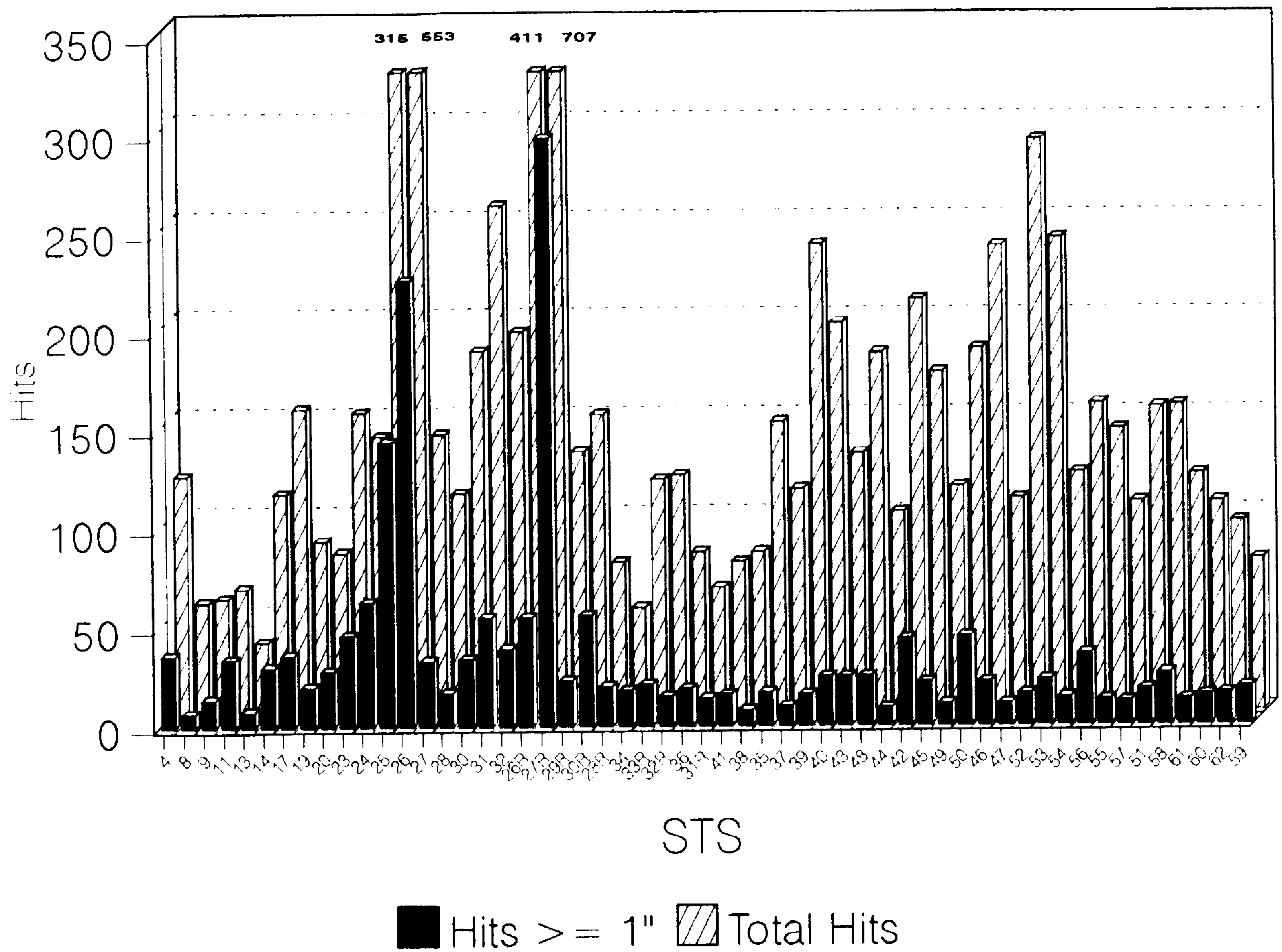


FIGURE 15 ORBITER POST FLIGHT DEBRIS DAMAGE SUMMARY

	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
STS-61	7	59	13	120
STS-60	4	48	15	106
STS-62	7	36	16	97
AVERAGE	14.0	90.4	21.4	132.0
SIGMA	7.4	44.3	10.4	57.6
STS-69	10	47	19	77

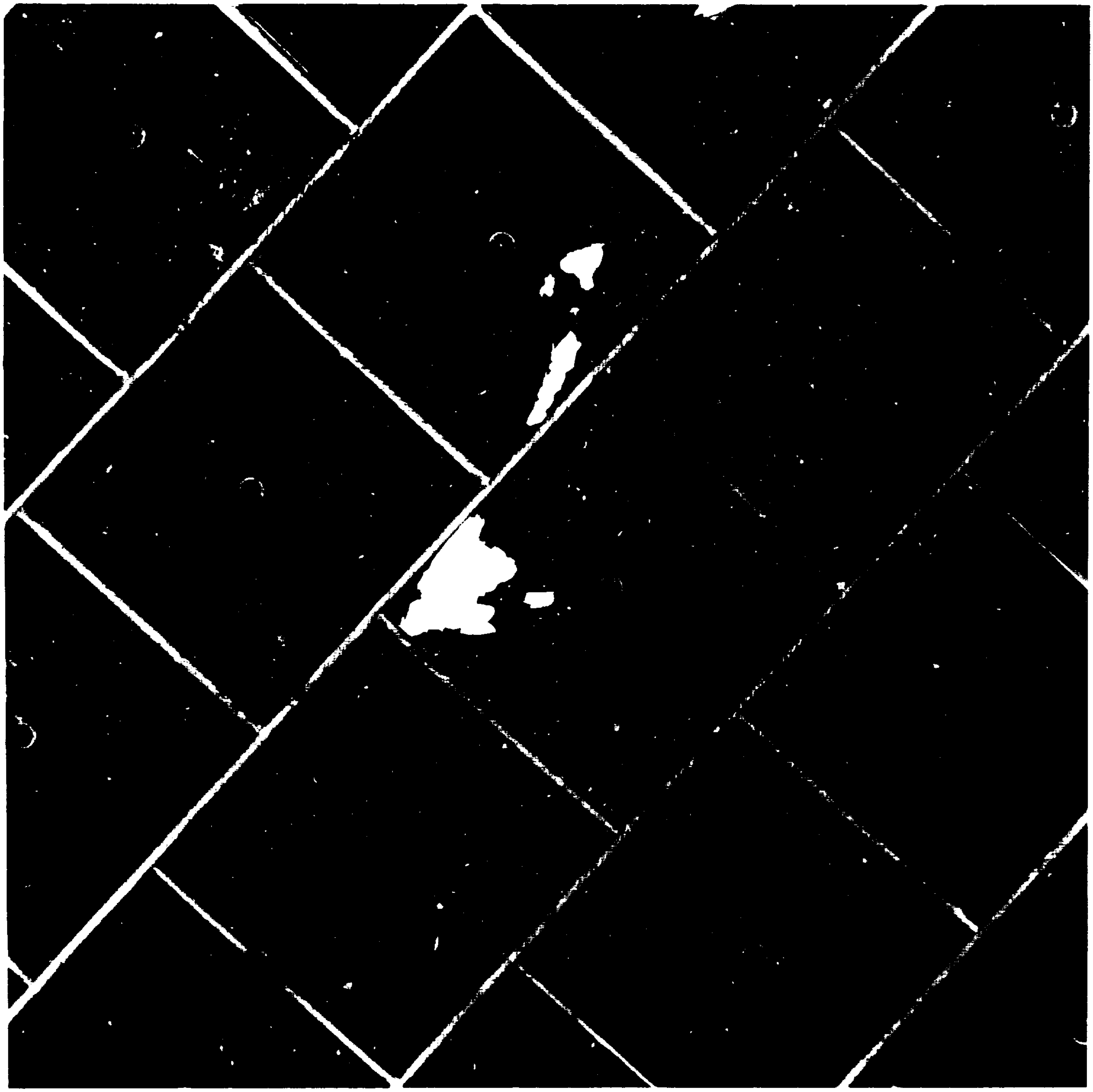
MISSIONS STS-23, 24, 25, 26, 26R, 27R, 30R, AND 42 ARE NOT INCLUDED IN THIS ANALYSIS SINCE THESE MISSIONS HAD SIGNIFICANT DAMAGE CAUSED BY KNOWN DEBRIS SOURCE

FIGURE 16. **COMPARISON TABLE**

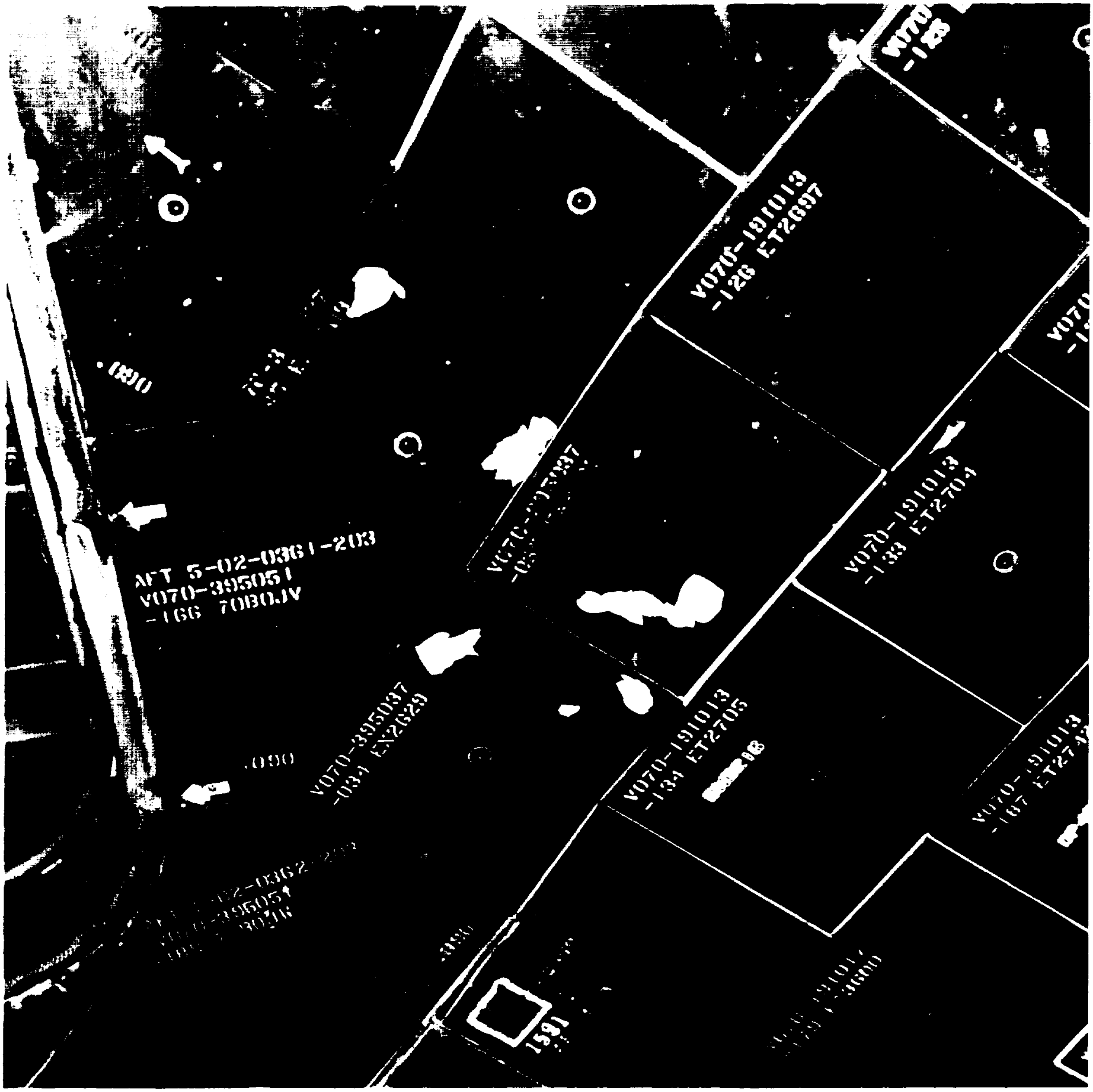


OV-105 Endeavour landed on EAFB runway 22 on 20 April 1994

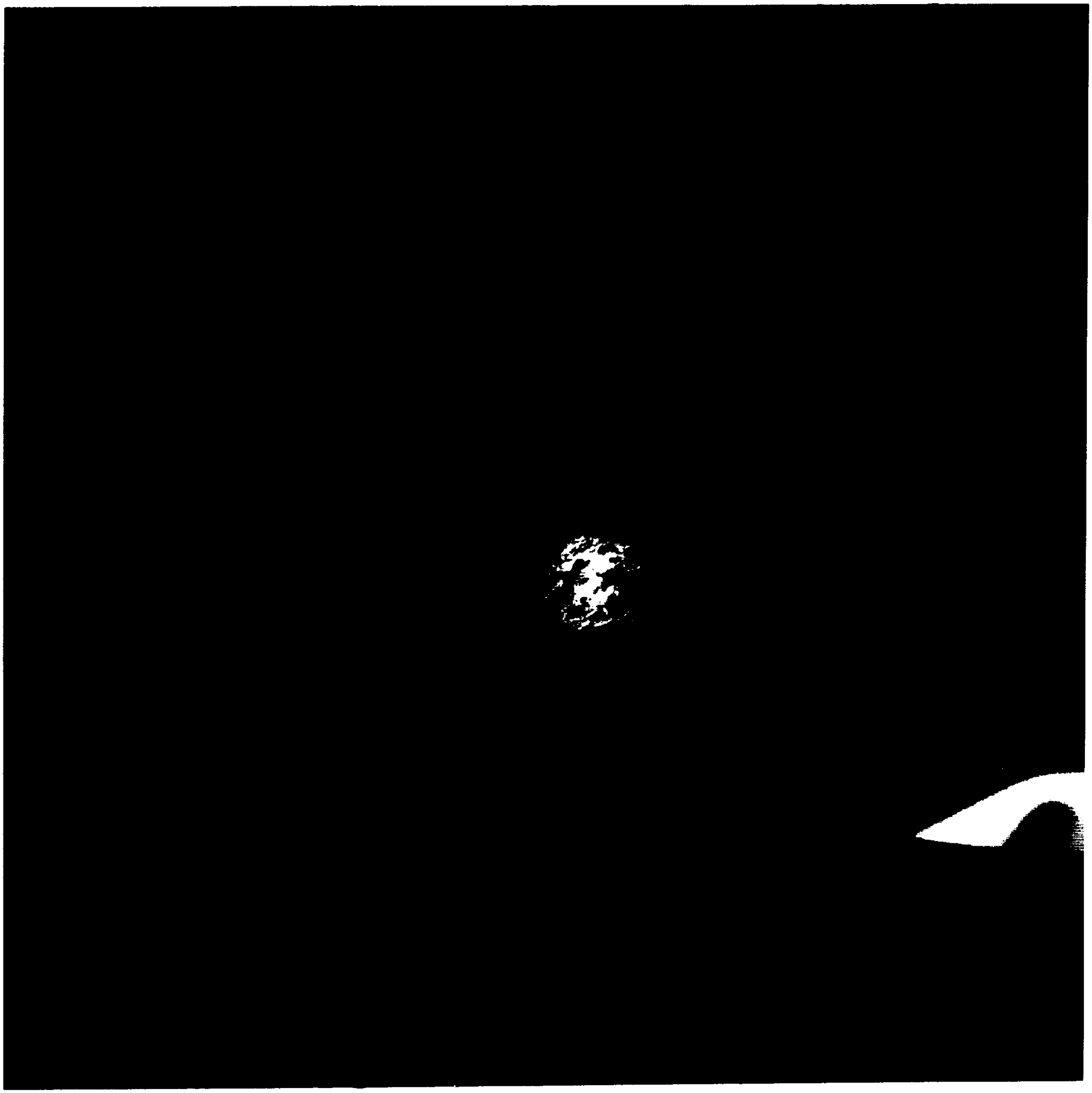
Overall view of the Orbiter left side



The Orbiter lower surface tiles sustained a total of 47 hits, of which 10 had a major dimension of 1-inch or greater. The largest tile damage sites were located on the lower surface of the body flap and aft of the ET/ORB umbilicals.

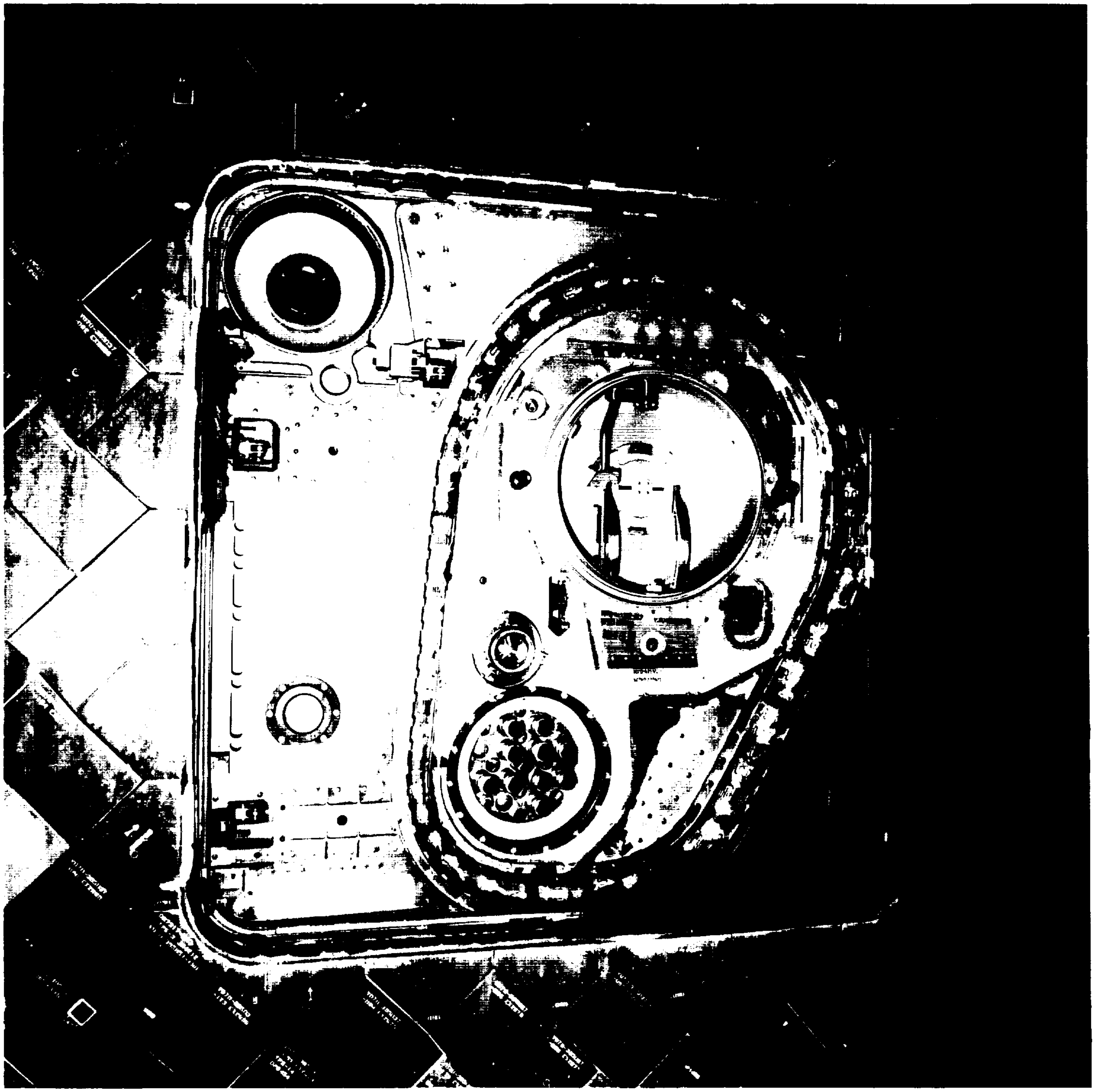


A total of 16 hits, in two clusters of 8 hits, occurred near the LH2 ET/ORB umbilical. Hits around the ET/ORB umbilicals are believed to be impacts from umbilical ice.

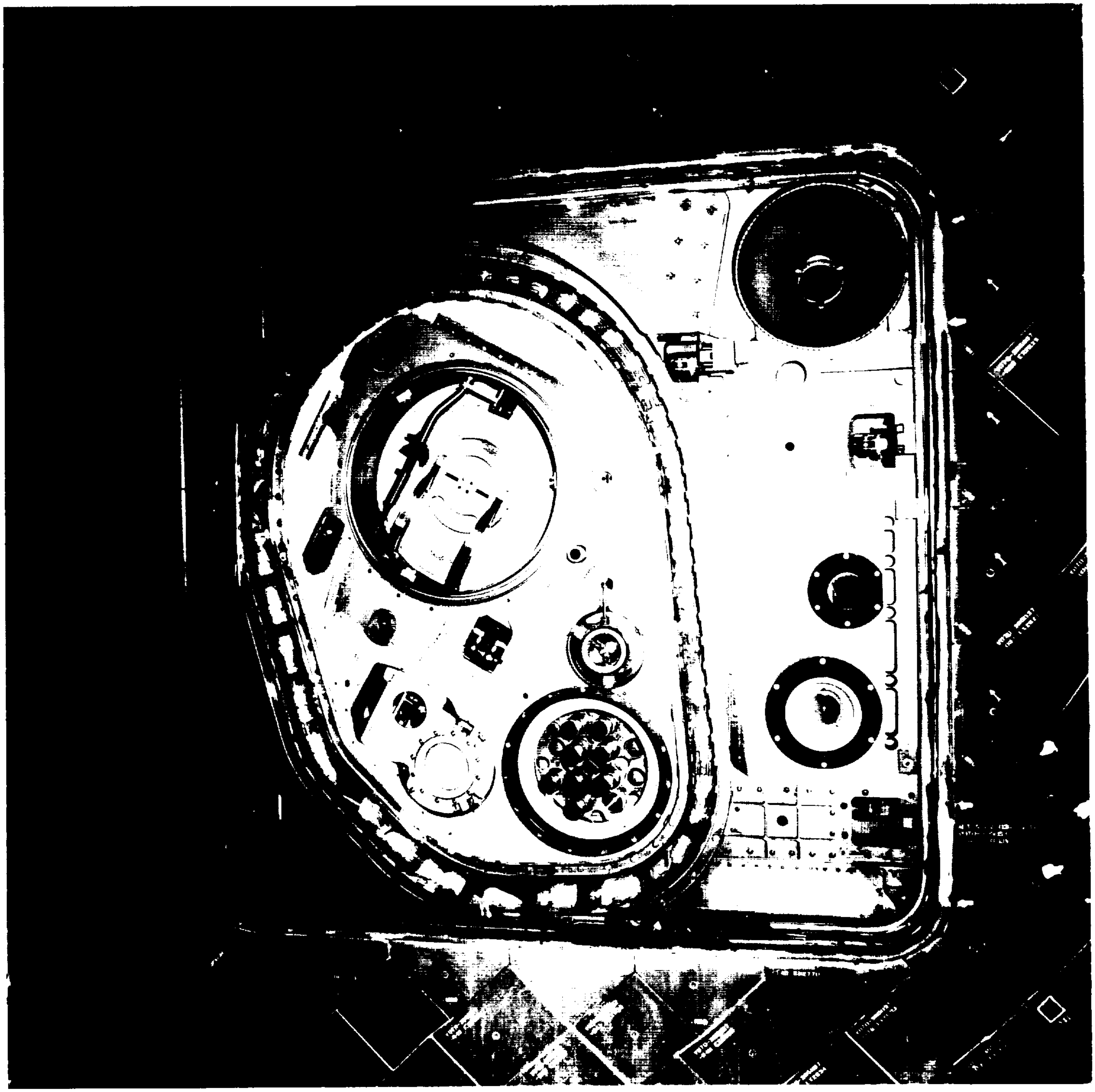


The crew hatch outer pane (window #11) sustained an apparent micrometeorite impact. The damage site measured 1/4-inch in diameter and was located at the 7 o'clock position of the window, one inch from the edge tiles.

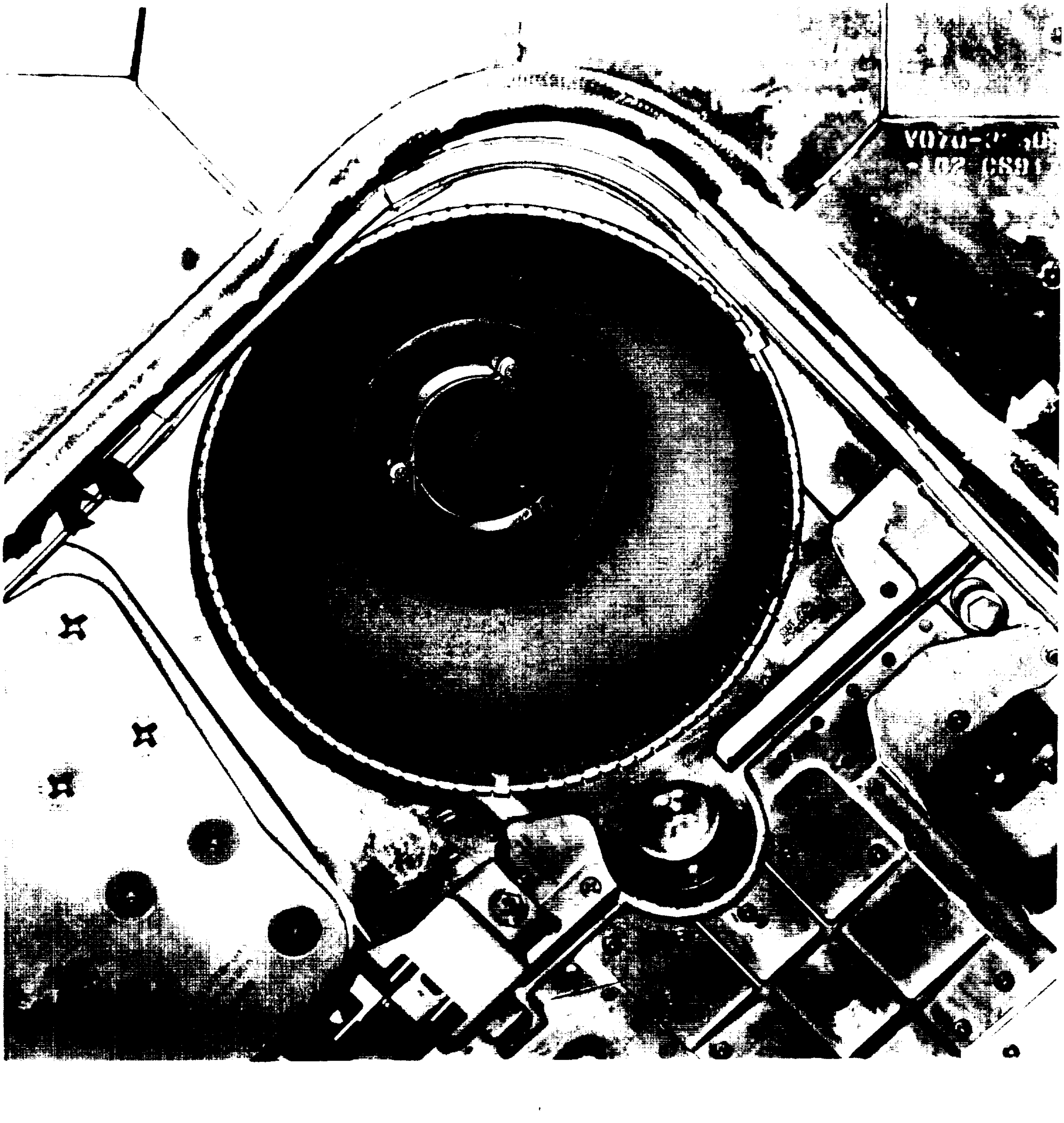
Forward-facing Orbiter windows #3 and #4 exhibited typical hazing. A very light haze was present on the other windows. Twelve hits with 8 larger than 1-inch in size were noted on the perimeter tiles around windows #3 and #5.



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.

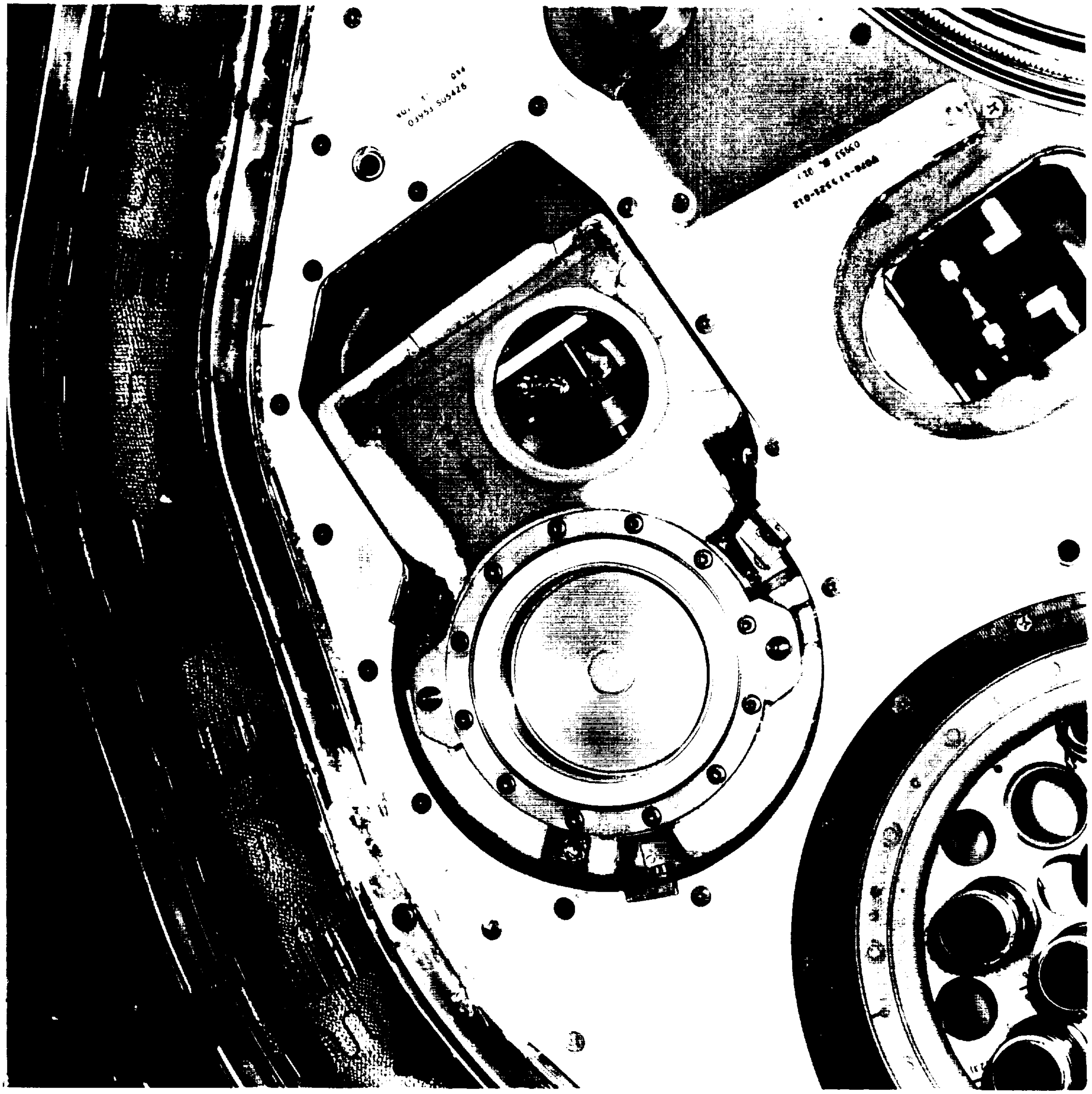


Overall view of the LH2 ET/ORB umbilical. All three umbilical separation ordnance devices functioned properly.



The EO-2 plunger was not seated. No flight hardware was found on the runway below the umbilical when the ET door was opened, but a loose wave spring from the pyro separation device was found resting against a fastener on the ET door

The EO-2 debris plunger was obstructed by ordnance debris



A small amount of white RTV and ET foam, but no red purge seal, adhered to the LH2 ET/ORB umbilical plate near the 4-inch line.

9.0 DEBRIS SAMPLE LAB REPORTS

A total of eight samples were obtained from OV-105 Endeavour during the STS-59 post landing debris assessment at Dryden Flight Research Center, California. The samples consisted of 16 wipes (1 IPA, 1 dry for each window) 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 the placing and the correlating of particles and residues with respect to composition, thermal (mission) effects, and availability. Debris sample results/analyses are listed by Orbiter location in the following summaries.

9.1 ORBITER WINDOWS

Samples from the Orbiter windows indicated exposure to SRB BSM exhaust (metallic particulate), landing site materials (earth minerals), Orbiter Thermal Protection System (tile, tile repair materials and glass insulation), paints and primer from various sources. Building insulation fibers and carbon steel spheres 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.

9.2 ORGANIC ANALYSIS

The results of the organic analysis revealed an exposure to a variety of materials. Identified component items included those associated with window covers (plastic polymers), RTV from Orbiter TPS and OMS/FRCS thruster nozzle cover adhesive, and paint from various sources. All of these materials have been noted in previous debris sample analyses and did not appear to be associated with any vehicle damage.

9.3 NEW FINDINGS

This set of post-flight debris residual samples exhibited no new findings. No debris sample trends are apparent when compared to previous mission data (Figure 17).

STS	Sample Location				
	Windows	Wing RCC	Lower Tile Surface	Umbilical	Other
59	Metallics - BSM Residue (SRB) RTV, Tile, Tile filler (ORB TPS) Insulation Glass (ORB TPS) Fiber- Building insulation, wipe cloth Earth minerals (Landing site) Organics- Plastic polymer, sealant RTV-RCS thruster nozzle cover (SRB) Paint and primer				
62	Metallics - BSM Residue (SRB) RTV, Tile, Tile filler (ORB TPS) Insulation Glass (ORB TPS) Fiber- Building insulation, wipe cloth Earth minerals (Landing site) Organics- Plastic polymer, sealant RTV-RCS thruster nozzle cover (SRB) Paint and primer				
60	Metallics - BSM Residue (SRB) RTV, Tile, Tile filler (ORB TPS) Insulation Glass (ORB TPS) Fiber - Building insulation, textile Earth minerals - (Landing site) Organics- Plastic polymers, sealant RTV-RCS nozzle thruster cover(SRB) Paint and primer				
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				
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				

	Windows	Wing RCC	Lower Tile Surface	Umbilical	Other
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.				
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 -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)		

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 TPS) 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	

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	

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)		

STS	Sample Location				
	Windows	Wing RCC	Lower Tile Surface	Umbilical	Other
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')
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 material.
Metallics - includes mostly Aluminum and Carbon Steel alloys

10.0 POST LAUNCH ANOMALIES

Based on the debris walkdowns and film/video review, ten post launch anomalies, including three In-Flight Anomalies, were observed on the STS-59 mission.

10.1 LAUNCH PAD/SHUTTLE LANDING FACILITY

1. An ELSA box container detached from the OAA White Room wall during launch spilling the individual ELSA units on the floor.

2. Post launch inspection revealed the GOX Vent Arm sustained damage at the axial adjustment attach point. Several welds were broken and the piston housing had collapsed. This damaged caused the hood to be skewed or twisted approximately 1-2 inches from centerline. Some of the GOX vent arm damage was attributed to improper welds (IFA STS-59-K-01).

10.2 EXTERNAL TANK

1. A divot, 8 inches in diameter, occurred in the LH2 tank acreage just aft of the LH2 tank-to-intertank flange closeout near the -Y bipod.

2. Six divots, ranging in size from 6 to 10 inches in diameter, occurred in the LH2 tank-to-intertank flange closeout in the +Y+Z quadrant (2 places outboard of the LO2 feedline), -Y+Z quadrant (3 places between the -Y bipod and the -Y thrust panel), and on the outboard bondline of the -Y bipod spindle housing closeout.

10.3 SOLID ROCKET BOOSTERS

1. K5NA had separated from Hypalon-covered BTA and primer-coated metal on the BSM support brackets (IFA STS-59-B-01). Current surface preparation procedures are inadequate for proper K5NA adhesion.

2. A debris impact site was noted on the IEA forward surface TPS at 145 degrees radial location (IFA STS-59-I-02). The impact cavity measured 2" x 1.5" x 1.75". The foam in the damage site was crushed and shows signs that heating had occurred inside the cavity - possibly during ascent.

3. Both frustums had a combined total of 46 MSA-2 debonds.

4. Significant amounts of BTA had been applied to closeouts on the LH frustum, forward skirt, and aft skirt. Hypalon paint was blistered/missing where the BTA had been applied.

10.4 ORBITER

1. During SSME ignition, surface coating material was lost from base heat shield tiles outboard of SSME #3 (27 places), on the base heat shield between SSME #1 and #2 (3 places), near SSME #2 (1 place), on the RH ACPS pod aft surface (3 places), and on the LH ACPS pod aft surface (1 place).

2. The EO-2 debris plunger had not seated. No debris was found on the runway beneath the ET/ORB umbilical cavities when the ET doors were opened, but a loose wave spring was found resting against a Hi-Lock fastener on the LH2 umbilical door. The wave spring is part of the pyro separation device.

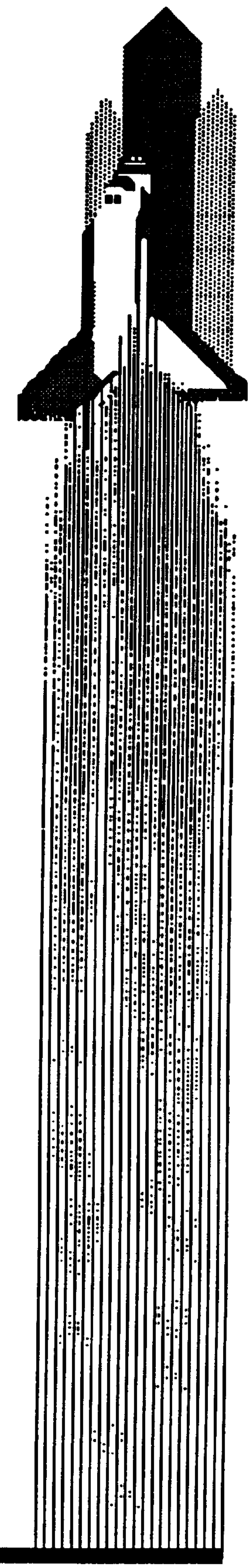
Appendix A. JSC Photographic Analysis Summary

Space Shuttle

Photographic and Television Analysis Project

STS-59 Summary of Significant Events

May 27, 1994



National Aeronautics and
Space Administration

Lyndon B. Johnson Space Center
Houston, Texas 77058

Space Shuttle Photographic and Television Analysis Project

STS-59 Summary of Significant Events

Project Work Order - SN-AFV

Approved By

Lockheed

Christine L. Dailey 5/27/94

C. L. Dailey, Project Specialist
Photo/TV Analysis Project

Robert W. Payne

R. W. Payne, Supervisor
Flight Sciences Support Section

Jess G. Carnes

Jess G. Carnes, Manager
Solar System Exploration Department

NASA

Michael T Gaunce

Mike Gaunce, Lead
Photo/TV Analysis Project
Flight Science Branch

Prepared By

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

National Aeronautics and
Space Administration

Lyndon B. Johnson Space Center
Houston, Texas 77058

C-2.

Table of Contents

List of Figures

1.0 STS-59 OV-105 Film/Video Screening and Timing Summary

1.1 Screening Activities

1.1.1 Launch

Endeavour (OV-105) launched on mission STS-59 from pad A at 11:05:00.032 Coordinated Universal Time (UTC) on April 9, 1994 (day 99) as seen on camera E-12. Solid Rocket Booster (SRB) separation occurred at 11:07:04.128 UTC as seen on camera E-211.

On launch day, 24 videos were screened. Following launch day, 55 films were reviewed.

A post landing inspection of the Fixed Service Structure by KSC personnel identified damage to the GOX vent arm. A review of the launch camera footage showed that both the GOX vent arm and the Orbiter Access Arm oscillated during the launch. A discussion of the analysis conducted may be found in Section 2.2.6, Damage to GOX Vent Arm (Task #13) and Section 2.2.7, Orbiter Access Arm Motion. The damage to the GOX vent arm during the launch of STS-59 has been declared an In-Flight Anomaly (IFA# STS-59-K-01, Pad A GOX Vent Arm Damage during Launch).

Detailed test objective (DTO)-0312 (photography of the external tank after separation) was performed this mission using the umbilical well cameras and a handheld Nikon camera with a 300 mm lens and 2X extender. Thirty-six handheld frames of the External Tank (ET) were acquired by the astronauts. The tank appeared to be in good condition on the handheld film with the exception of four possible divots on the LH2 intertank interface on the -Z side of the ET, a probable divot on the -Y axis of the ET at the LH2 intertank interface below the LSRB forward attach, and a divot on the LH2 tank aft of the left leg of the forward bipod. Video of the external tank was downlinked by the astronauts. All sides of the external tank were imaged. Several of the divots seen on the films were also noted on the video views. Two rolls of umbilical well film were received: the 35 mm film from the LO2 umbilical and a 16 mm film (5 mm lens) from the LH2 umbilical. Several divots were noted on the umbilical well film including two divots on the LH2 tank TPS and six divots on the LH2 intertank interface flange. Divots in the ET TPS were noted on the aft LO2 feed line support bracket. Multiple erosion marks were noted on the LH2 tank TPS in the -Y direction from the aft LO2 feed line and support bracket. Numerous pieces of insulation and frozen hydrogen debris were seen during the SRB and external tank separations. See Section 2.4.1, Onboard Handheld Camera ET Analysis (Task #6) and Section 2.4.2, Umbilical Well Camera Analysis (Task #5) for analysis.

1.1.2 On-Orbit

No on orbit anomalies were identified.

1.1.3 Landing

Endeavour landed on runway 22 at Edwards Air Force Base (EAFB) on April 20, 1994. Four videos of the Orbiter approach and landing were received. NASA Select TV, which is a real-time composite of the other videos, was also received. Right main gear touchdown was at 110:16:54:29.212 UTC and left main gear touchdown occurred at 110:16:54:29.346 UTC as seen on camera DTV-3. Nose wheel touchdown occurred at

110:16:54:45.310 UTC and wheel stop was at 110:16:55:22.848 UTC as seen on camera DTV-1.

Fifteen landing films were expected from DFRC. Thirteen films were received and screened. Films E-1020 and E-1021 were not received. The importance of these films to the drag chute analysis task was identified to Dryden personnel, who will rectify the situation for future Dryden landings.

The following items were noted during the post-landing walk around: apparent damage to the tread on the inboard tires of both main landing gears; TPS erosion on the forward portion of the port OMS pod; and slight TPS erosion distributed across the base heat shield.

1.2 Timing Activities

All launch videos had timing and film cameras E-1, E-2, E-3, E-4, E-5, E-6, E-7, E-8, E-9, E-10, 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, E-211, E-222, E-223 and E-224 had in-frame alphanumeric timing. These videos and films were used to time specific mission events during the initial screening. Film camera E-57 had in-frame alphanumeric timing, but the timing was incorrect. Film from launch cameras E-62, E-205, E-207 and E-223 were used to time events using encoded film edge timing marks (IRIG-B).

All landing videos had timing. Film from landing cameras E-1005 and E-1008 were used to time events using encoded film edge timing marks (IRIG-B).

2.0 Summary of Significant Events Analysis

2.1 DEBRIS

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

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

(Cameras E-5, E-17, E-18, E-19, E-20, OTV-49, OTV-50, OTV-51, OTV-70, OTV-71)

Normal white (ice) debris was noted falling from the LH2 and LO2 TSM T-0 umbilical disconnect areas at SSME ignition through liftoff.

One piece of debris fell from the LO2 TSM disconnect area at T-1.6 seconds and struck the SSME #3 bell near the rim at the 3 o'clock position. The debris then fell aft into the SSME plume. No damage was detected to the vehicle. No follow-up action was requested.

Figure 2.1.1.1 White Debris (Ice) from the LO2 TSM Disconnect Area Strikes SSME #3 Bell Rim at T-1.6 Seconds
(Camera E-19, Frame 3240)

2.1.1.2 LH2 and LO2 ET/Orbiter Umbilical Debris

(Cameras E-4, E-5, E-6, E-15, E-16, E-18, E-19, E-25, E-26, E-31, E-34, E-40, OTV-9, OTV-54, OTV-60, OTV-61, OTV-63)

Normal white (ice) debris was noted falling from the LH2 and LO2 ET/Orbiter umbilical disconnect areas and aft along the body flap at SSME ignition through liftoff. A large piece of white debris broke away from the LH2 umbilical area and contacted the lower edge of the LH2 umbilical door sill at T-2.3 seconds on the camera OTV-9 view. No damage to the vehicle was detected. No follow-up action was requested.

Figure 2.1.1.2 White Debris from LH2 Umbilical Area Contacts the Lower Edge of the LH2 Umbilical Door Sill at T-2.3 Seconds
(Camera OTV-109)

2.1.1.3 Flash in SSME plume at SSME Ignition

(Cameras E-2, E-3, E-19)

Two orange flashes were noted in the SSME plume near the time of SSME ignition. A flash was noted in the SSME #1 plume at T-2.2 seconds and in the SSME #3 plume at T+0.9 seconds. No follow-up action was requested.

2.1.2 Debris during the Time of SRB Ignition

2.1.2.1 SRB Flame Duct Debris (Task #7)
(Cameras E-7, E-9, E-10, E-13, E-14, E-16, E-26)

As on previous missions, several pieces of debris originated from the SRB flame duct area after SRB ignition. No debris was noted during the screening process which warranted velocity measurement. No follow-up action was requested.

2.1.2.2 Flame Trench Debris at Liftoff
(Cameras E-57, E-63)

A single piece of white debris (possibly from the RSRB flame trench) traveled north at liftoff on camera E-57. Numerous pieces of light colored debris moved westward from the Rotating Service Structure (RSS) after liftoff from camera E-63. None of the debris was seen to strike the vehicle. No follow-up action was requested.

2.1.2.3 Debris near SRB Holddown Posts (HDP)
(Cameras E-7, E-8, E-9, E-10, E-11, E-12, E-13, E-14)

A dark piece of debris was seen near the LSRB holddown post M-8 on film camera E-14 just after Pyrotechnic Ignitiator Controller (PIC) firing. Several pieces of light colored MLP debris were noted around all of the holddown posts. No ordnance or frangible nut debris were seen near any of the holddown post DCS stud holes. No follow-up action was requested.

2.1.3 Debris after Liftoff

2.1.3.1 Frost and Debris from the GOX Vent Louvers
(Camera E-79, OTV-61)

Frost was noted on both GOX vent louvers on the ogive of the ET. Two small pieces of frost fell from the port side vent louver at T-2.1 and T+0.8 seconds as seen on camera OTV-61. The debris did not appear to strike the vehicle.

2.1.3.2 Debris along Body Flap after Liftoff
(Cameras E-41, E-52, E-57, E-59, E-65, E-211, E-224)

Several pieces of light colored debris fell along the body flap into the SRB plume after liftoff through the roll maneuver. Most of the debris sightings were probably ice from the ET/Orbiter umbilicals. One distinctly large piece of white debris was first seen near the LH2 ET/Orbiter umbilicals and fell aft along the body flap into the SSME plume at 7.7 seconds MET on cameras E-52 and E-59. None of the debris objects were observed to strike the vehicle.

2.1.3.3 Debris near ET during Roll Maneuver
(Cameras E-52, E-54, E-59, E-211, E-212, E-213, E-218, E-220, E-223, E-224, KTV-4A)

Several small orange-colored pieces of debris fell from the region aft of the ET into the SRB plumes during roll maneuver. This debris was probably umbilical purge barrier material. No follow-up action was requested.

2.1.3.4 Debris falling along SRB Plume during Ascent
(Cameras E-204, E-208, E-212, E-218, E-220, E-222, E-223, KTV-4A)

Numerous pieces of light colored debris fell aft along the SRB plume during ascent from 60 to 80 seconds MET. The same event was seen just before SRB separation. Similar debris has been noted on previous missions. No follow-up action was requested.

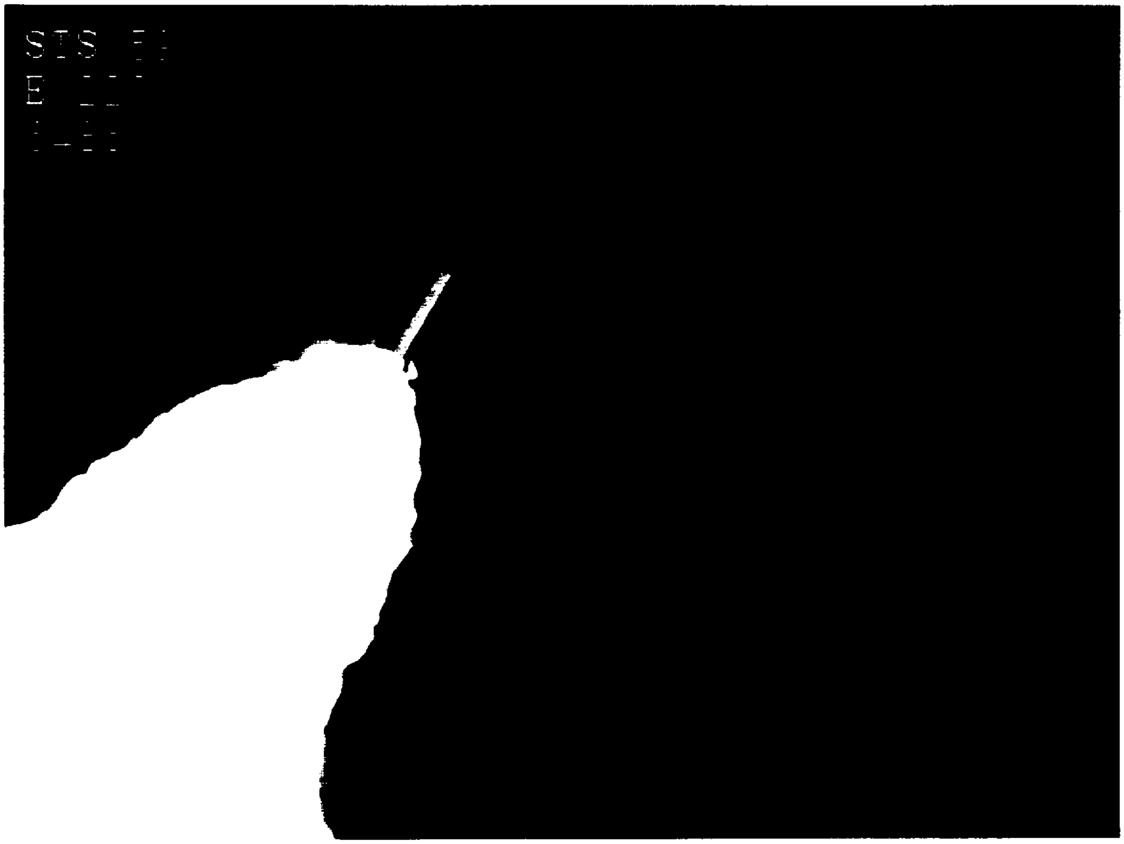


Figure 2.1.3.4 **Light Colored Debris Falls Aft Along the SRB Plume During Ascent from 60 to 80 Seconds MET**
(Camera E-220, Frame 6486)

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

The following is a written transcript of the crew debris report provided by STS-59 Commander to the Mission Control Center Capcom on April 9, 1994.

Capcom:
Endeavour, Houston, for Sid and Chilton. We would like to get the window debris report from you.

Endeavour - Sid Gutierrez:
Ok, Jay says to tell you we got camcorder of the ET and we did not note significant debris. There were a few smudges on the front window screen, but nothing out of the ordinary.

Capcom:
Roger, we copy no significant debris other than a couple of smudges on the front window screen.

Endeavour - Sid Gutierrez:
That is right. The typical stuff you see after a flight. I got about 3-4 splotches on my windshield, for example.

Capcom:
Roger, I copy that.

2.2 MLP EVENTS

2.2.1 Orange Vapor (Possibly Free-burning Hydrogen)

(Cameras E-1, E-2, E-3, E-5, E-16, E-17, E-18, E-19, E-20, E-36, E-52, E-57, E-63, E-76, E-77, E-222, OTV-70, OTV-71)

An orange vapor (possibly free-burning hydrogen) was seen beneath the SSME bells prior to SSME ignition. The vapor appeared to extend forward of the aft edge of the left OMS pod on the view available from camera E-77. No follow-up action was requested.

2.2.2 Flares in Hydrogen Burn Ignitor Nozzles

(Cameras E-1, E-3, E-20, E-30, E-57, E-77)

Flares were noted in the northwest and southwest hydrogen burn ignitor nozzles at SSME ignition.

2.2.3 Variation in Order of SSME Mach Diamond Formation

(Cameras E-19, E-20, E-76, OTV-51)

The SSME Mach diamonds were noted to form in a different order compared to previous mission films and videos. The order of formation was SSME #2 (at 11:04::56.841 UTC), SSME #1 (at 11:04:56.903 UTC) and SSME #3 (at 11:04:56.910 UTC) as seen on camera E-19. No follow-up action was requested.

2.2.4 Base Heat Shield TPS Erosion

(Cameras E-5, E-6, E-17, E-18, E-19, E-20,. E-25)

Numerous occurrences of TPS erosion were noted on the base heat shield and both of the RCS stingers after SSME startup. Erosion of the base heat shield TPS has been seen on previous missions. No follow up action was requested.

2.2.5 Vapor from LH2 T-0 Umbilical Disconnect lines

(Camera E-18)

A white vapor was noted coming from one of the LH2 lines between the LH2 TSM and the LH2 T-0 carrier plate. No follow-up action was requested.

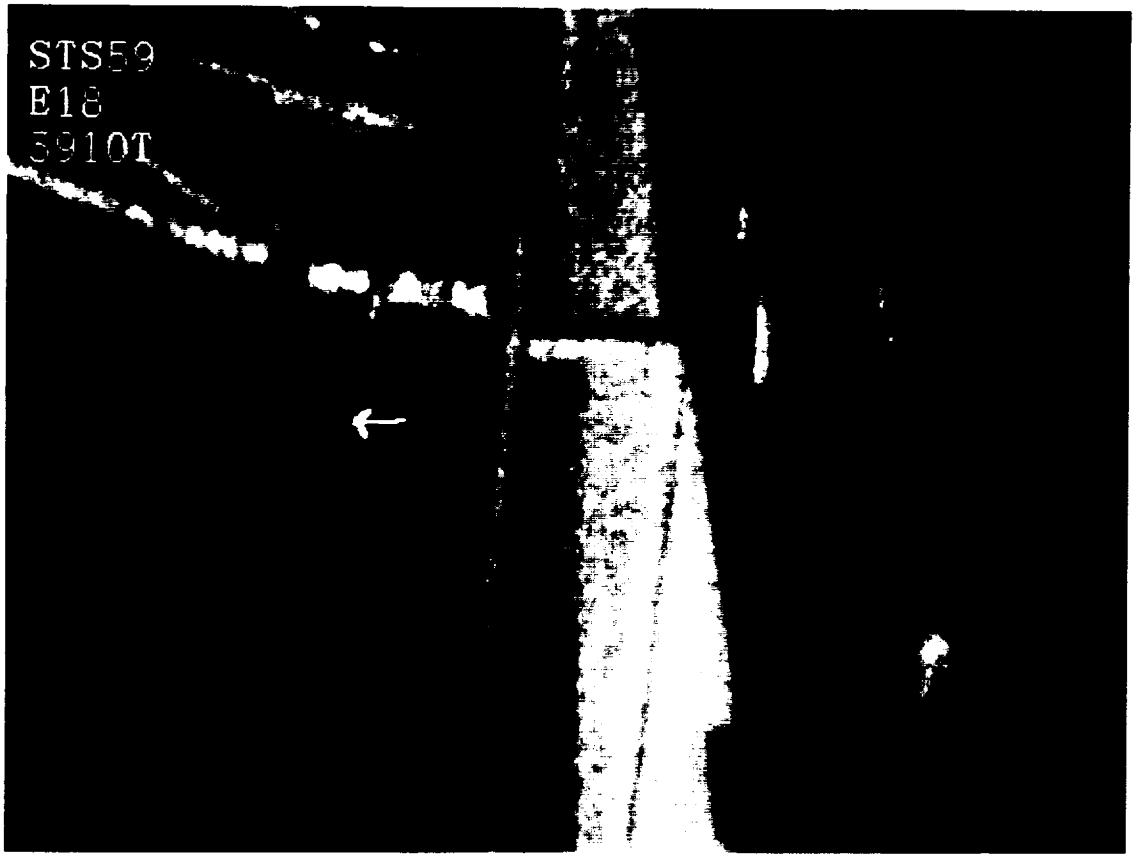


Figure 2.2.5 **Vapor from the LH2 TSM Umbilical Lines Prior to Liftoff**
(Camera E-18, Frame 3910)

2.2.6 Damage to GOX Vent Arm *(Task #13)*
(Camera E-62)

KSC reported that damage occurred to the gaseous oxygen vent arm during the STS-59 liftoff. Films from STS-59, STS-38 and STS-60 were reviewed to determine the relative motion of the GOX vent arm. This analysis was performed on the JSC 35-mm Film Motion Analyzer (FMA). Movement of the GOX vent arm was determined with respect a fixed position on the Fixed Service Structure (FSS) to reduce camera and projector motion noise. The positive Y direction was measured from the bottom to the top of the field-of-view and are referenced in arbitrary image units. The motion from STS-60 could not be distinguished from camera motion. Identical points on the FSS and the GOX vent hood were used for both STS-59 and STS-38. On STS-38 motion was visible; however, specific peaks were lower in magnitude than STS-59 and difficult to distinguish. The STS-59 GOX vent arm frequency was determined to be 3.1 Hz and the STS-38 GOX vent arm frequency was determined to be 3.2 Hz.

2.2.7 Orbiter Access Arm Motion
(Camera E-62)

The Orbiter access arm was seen to oscillate after the vehicle had cleared the tower on camera E-62. A white object on the floor of the "white room" traversed across the floor during the oscillation. No follow-up action was requested.

2.3 ASCENT EVENTS

2.3.1 Body Flap Motion *(Task #4)*
(Cameras E-5, E-17, E-18, E-207, E-213, E-223)

Body flap motion was observed on views from three different ascent film cameras. While the motion did not appear to be substantial in comparison to earlier missions, the clarity of this event on E-207 warranted further analysis.

The time of apparent maximum deflection (between 32 and 35 seconds MET) was visually chosen from camera E-207. The motion of the aft port and aft starboard edges were plotted as a function of time. One of two control points on the fuselage was used as a measure of the noise. Note that some of the apparent deflection exceeded the noise component. A frequency domain analysis revealed identifiable modes of vibration.

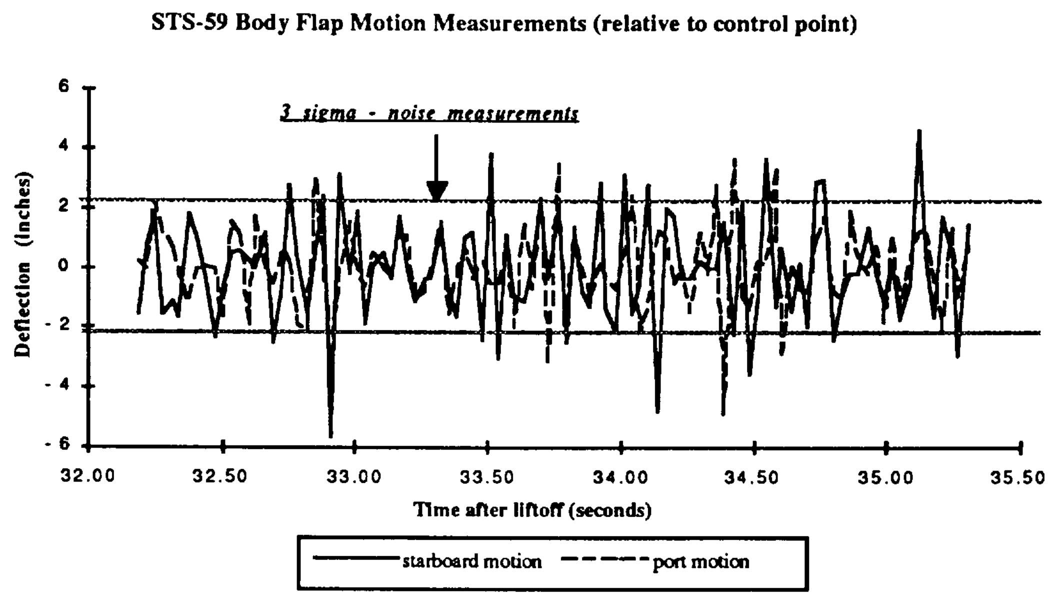


Figure 2.3.1 **Body Flap Motion Versus Time between 32.0 and 35.5 Seconds MET**

2.3.2 Flares in SSME plume
(Cameras E-211, E-212, E-220, E-223, E-224)

At least 6 flares were noted in the SSME plumes from 23.0 to 55.5 seconds MET. Flares in the SSME plume after liftoff have been observed on previous missions. No follow-up action was requested.

A white flare (opposed to the typical orange flare) was noted in the SSME #1 plume during ascent at 52.6 seconds MET on camera E-223.

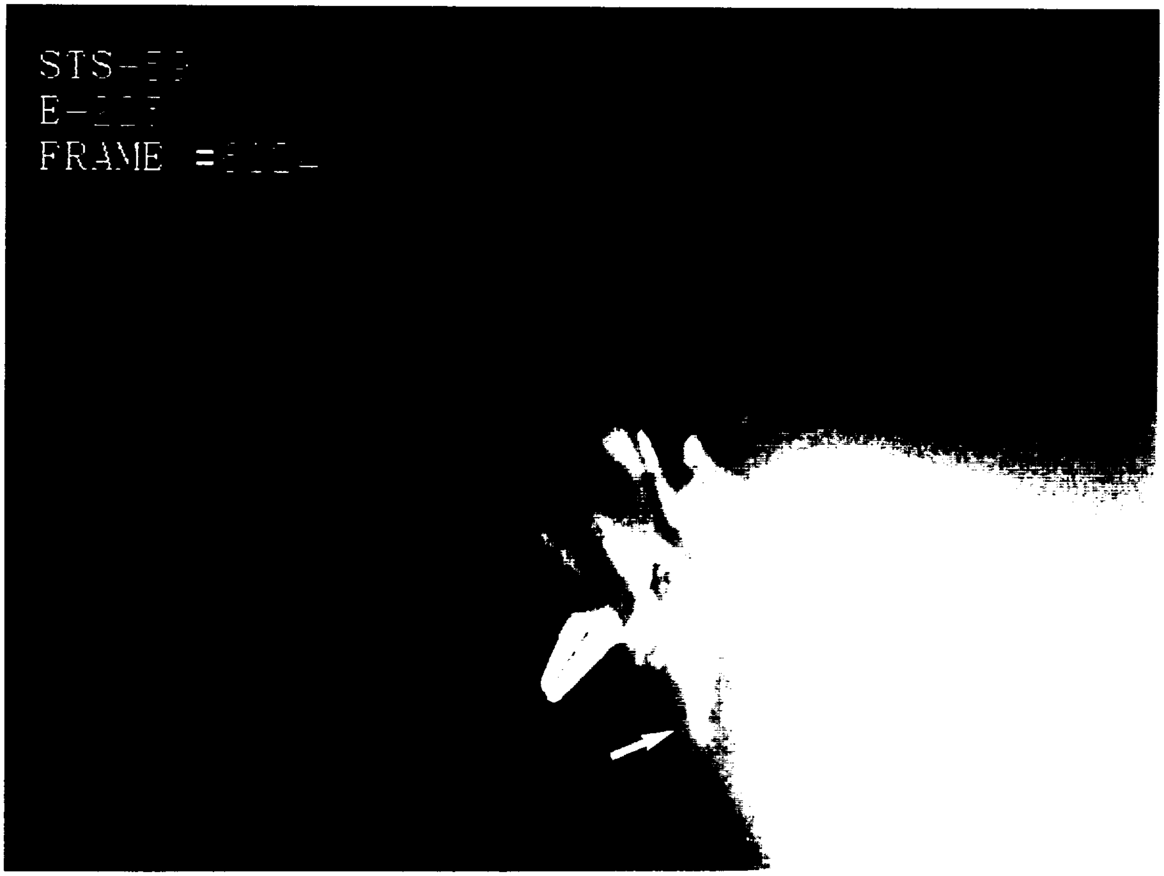


Figure 2.3.2 **White Flare in SRB plume at 52.6 seconds MET**
(Camera E-223, Frame 6124)

2.3.3 Questionable Landing Gear Door Sensor Indication After Liftoff
(Task #11)

The MER reported that at approximately one minute after launch, near the point of maximum aerodynamic pressure (max q), the left main gear (LMG) door uplock proximity sensor indicated off (i.e., door not uplocked). Approximately 10 seconds later, the sensor transferred back to on (i.e., door uplocked). No further problems were noted with this sensor. The MER requested that the long range tracking videos be screened for anything unusual at 60 to 70 seconds MET. No unusual events were noted during the visual analysis other than debris sightings that are typically seen during this time period. A listing of the debris sightings near the time of the questionable gear sensor reading was forwarded to the MER on launch day. A similar event occurred for 12 seconds on STS-9 and was attributed to vibration at max q and the close tolerance on the rigging of the proximity switch. The MER concluded that the questionable sensor indication was not an issue based on the STS-9 data and no further visual analysis support was required.

2.3.4 Linear Optical Effect
(Cameras E-204, E-207, E-208, ET-207, ET-208)

Linear optical effects were seen between 75.4 and 87.9 seconds MET, and again at approximately 122 seconds MET (just prior to SRB separation). Linear optical effects have been seen on previous missions. No follow-up action was requested.

2.3.5 Loose Thermal Curtain Tape on RSRB during Ascent
(Camera E-207)

Loose thermal curtain tapes were noted on the RSRB aft skirt during ascent. No follow-up action was requested.

2.3.6 Recirculation *(Task #1)*
(Cameras E-205, E-207, E-223, ET-207)

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-59, recirculation was observed between 91 and 109 seconds MET on camera E-207.

<u>Cameras on which recirculation was observed for STS-59</u>

CAMERA	START (seconds MET)	STOP (seconds MET)
ET-207	94	102
E-205*	91	109
E-207	91	104
E-223	---	---

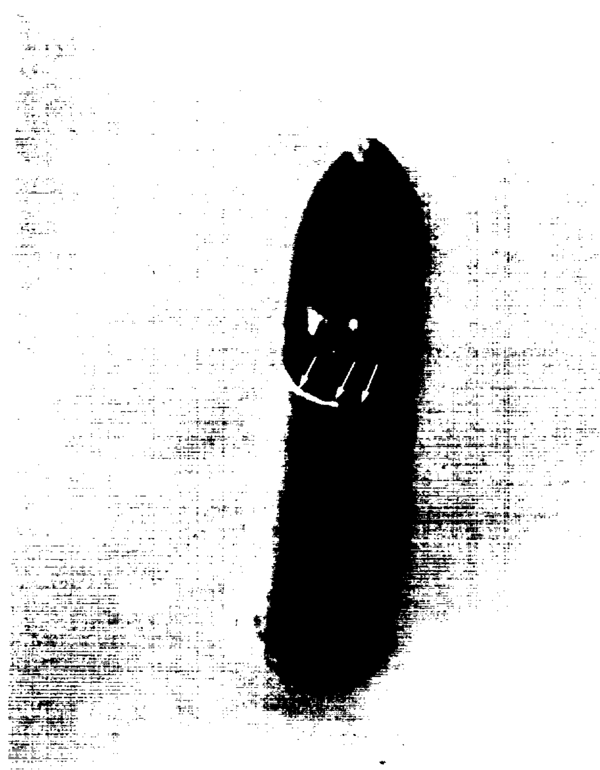
* BEST VIEW OF RECIRCULATION

2.4 DTO 312 ANALYSIS

2.4.1 Onboard Handheld Camera ET Analysis *(Task #6)*
(STS-59-315-01 through 36 and L1 Camcorder Video)

Thirty-six exposures from a 35 millimeter Nikon F4 camera were taken with Ektar 3101 film and a 300 millimeter lens coupled with a 2x multiplier. The photographs were taken by Linda Godwin. The entire ET was photographed. No timing data was on the film. The ET was approximately 1587 meters from the Orbiter at the time of the third photograph.

35 mm Nikon Camera
(STS-59-315-012)



L1 Camcorder View

Figure 2.4.1a Handheld Views of -Z Axis of External Tank

Three of four (probable) divots noted on the LH2/intertank interface on the -Z side of the ET are shown on the views above. Excellent quality video of the STS-62 external tank after separation was down linked by the astronauts. A camcorder with a 2X extender and a 10 to 1 zoom lens (100 to 10 mm focal length) was used to image the external tank. The ET was tracked over nearly 7 minutes of video. Several of the divots seen on the films were also noted on the video views. The average tumble rate of the external tank was calculated to be 0.97 degrees/second from the video. This rotation is similar to previous missions.

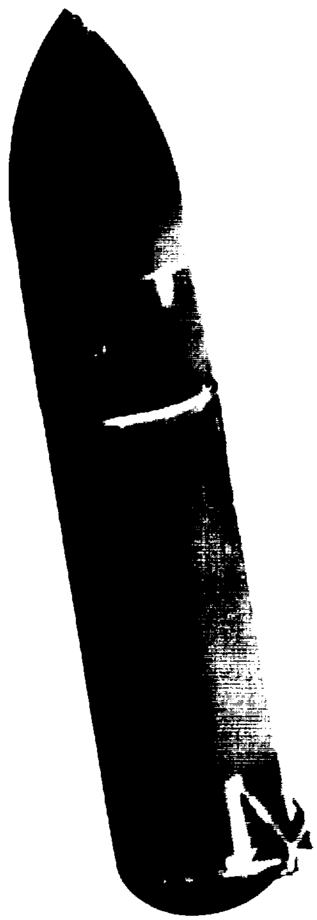


Figure 2.4.1b **Handheld Camera View of +Y Axis of External Tank**
(Camera STS-59-315-003)

A probable divot was seen on the -Y axis of the ET at the LH2 tank/intertank interface below the LSRB forward attach (1) and a divot was noted on the LH2 tank TPS aft of the left leg of the forward bipod (2).

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 high quality, well focused 16 mm motion picture film was acquired from the Orbiter LH2 umbilical camera. The LSRB separation and the external tank separation appeared normal. The 16 mm umbilical film sequence of ET separation had variable exposure. Timing data was present on the 16 mm film.

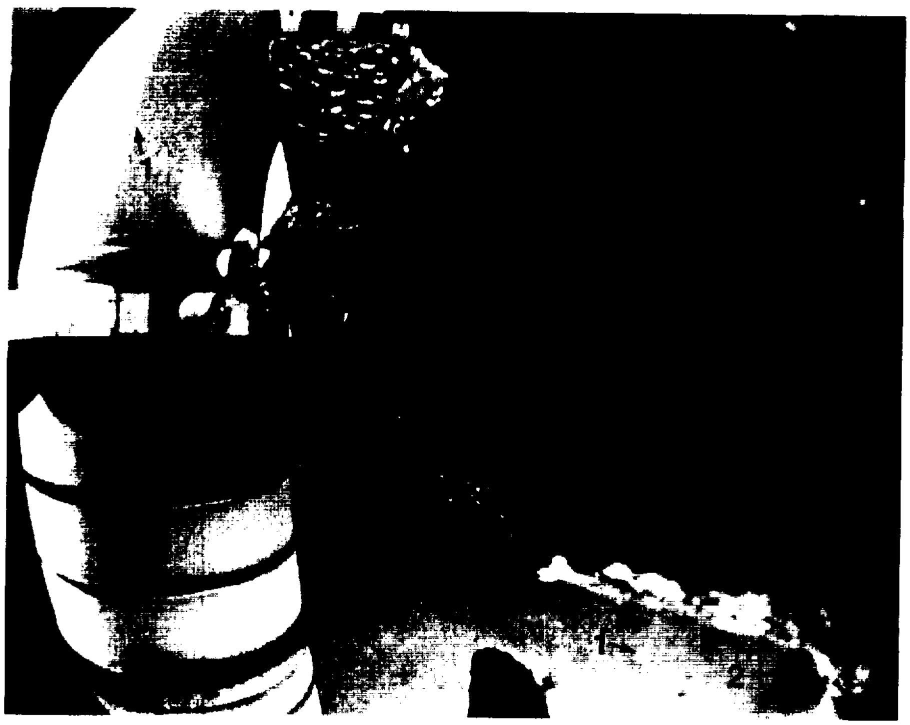


Figure 2.4.2.1a LSRB at Separation
(Frame STS-59-G-267-1077, Mag 1011)

Numerous light colored pieces of debris (probably insulation) are in view throughout the SRB film sequence (1). Typical chipping and erosion of the side and base on the -Y electric cable tray are visible (2). Erosion and scarring of the ET/Orbiter aft attach strut are visible (3). A piece of TPS debris was seen to strike the horizontal section of the LH2 electric cable tray (frame 611). This debris did not appear to cause damage. A loose piece of TPS was seen on the base of the electric cable tray (frame 694). A light colored piece of TPS detached from the base of the LH2 electric cable tray prior to SRB separation (frame 819). A piece of debris was seen aft of the LH2 electric cable tray that appeared light colored on one side and dark on the other side (frame 1292). This debris appeared orange in color on some frames. The debris had a thin profile when viewed from the side and may have been a piece of ablated top coat material.

Figure 2.4.2.1b **LH2 Umbilical After ET Separation**
(Frame STS-59-G-267-5412)

An unidentified copper colored piece of debris drifted from right to left in front of the electric monoball attach on the LH2 umbilical (1) (frames 5393 through 5618). This debris may have been a piece of TPS. Frozen hydrogen is visible in the LH2 17-inch line connection (2). Blistering of the fire barrier coating on the outboard side of the LH2 umbilical was apparent (3). A piece of frozen hydrogen debris struck the top of the horizontal portion of the electric cable tray prior to ET separation (frame 3235). A small piece of frozen hydrogen debris was seen striking the LH2 tank TPS prior to ET separation (frame 4980). No visible damage to the ET was detected from the two debris hits. A fast moving gray colored piece of debris was seen in front of the LH2 electric cable tray prior to ET separation (frame 4432). TPS erosion was noted across the base of the LH2 tank forward of the cross beam (frame 6369).

2.4.2.2 35 mm Umbilical Well Camera Views of ET Separation

Sixty exposures of the external tank were taken with the 35 mm umbilical well camera. The 35 mm film had good exposure and focus on the sunlit portions of the external tank (the LO2 umbilical and the +Y side of the ET is in shadow). Timing data was not present nor expected on the 35 mm film.

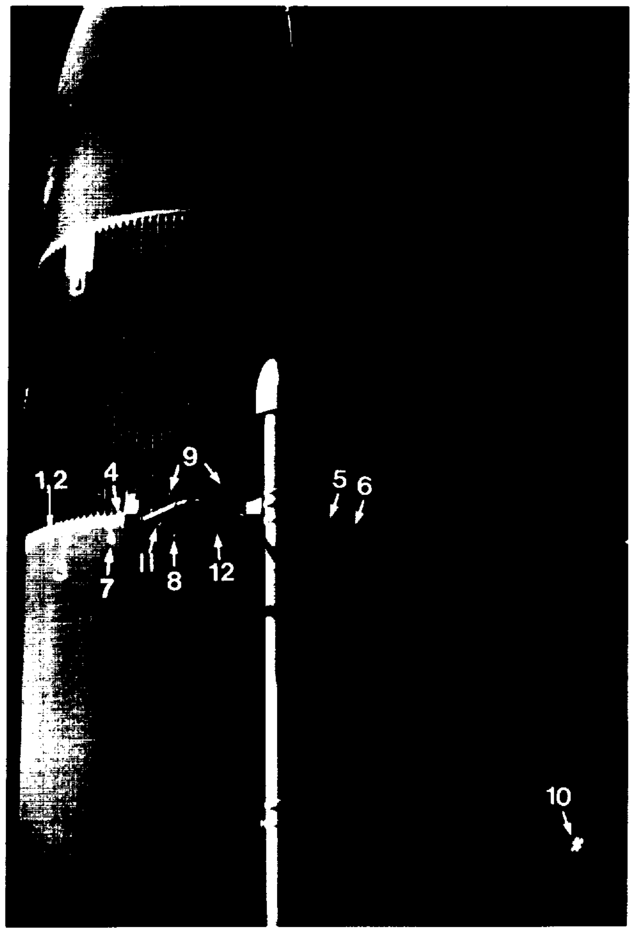


Figure 2.4.2.2a **Divots Near LH2 Intertank Interface**
(Camera STS-59-63-50)

Four white marks (divots) are visible on the LH2 intertank interface in the -Y direction from the ET/Orbiter forward attach bipod (1 through 4). Two white marks (divots) are visible on the LH2 tank/intertank close-out flange in the +Y direction to the right of the LO2 feed line (5 and 6). Two white marks (divots) are visible on the LH2 tank acreage (7 and 8). A dark shadowed area is visible at the center of mark # 7. This divot measured six inches along its longest dimension. Approximately twenty-one small white erosion or "pop corn" marks were seen on the intertank TPS in the vicinity of the forward ET/Orbiter attach bipod (9). A piece of debris with a "clover leaf" shape is visible to the right of the ET (10). This debris has a thick appearance when viewed from the side. Small white debris objects are visible throughout the 35 mm umbilical film sequence. Many of these white debris objects appear to be frozen hydrogen. Both jack pad close-outs appeared intact (11 and 12).

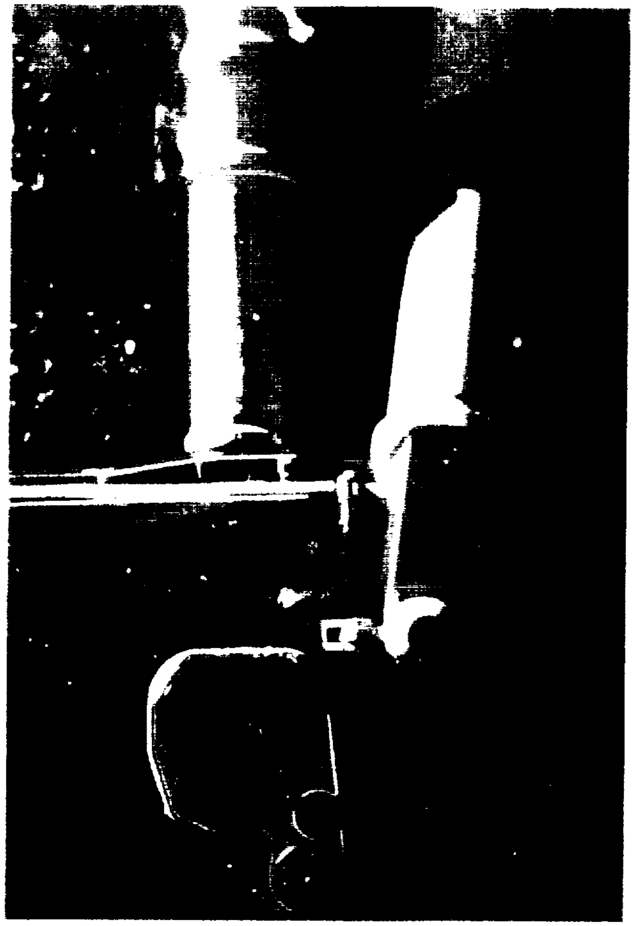


Figure 2.4.2.2b **TPS Erosion and Voids on Aft ET**
(Camera STS-59-63-10)

TPS erosion and voids are visible on the aft LO2 feed line bellows and support bracket (1). Multiple TPS erosion marks and voids are visible on the LH2 tank TPS forward of the cross beam (2). The red seal around the EO-3 fitting appears intact (3). The presence of the LO2 lightning contact strips was not verified due to the shadow across the LO2 umbilical.

2.5 ON ORBIT EVENTS

2.5.1 Debris Seen After Payload Bay Door Opening *(Task #12)*

A D2 tape titled "STS-59 Downlink Earth Views" (JL5 reference number 606402) was screened for debris after payload bay door opening (the duration of the tape is 2 minutes and 10 seconds). Three prominent white pieces of debris were noted along with several smaller pieces of white debris. The larger pieces of debris appeared to go from white to dark as they tumbled out of view. The dark view could be the "thin" side of the object. All of the debris appeared to originate aft of the vehicle rather than from the payload bay. The debris could have been frozen oxygen which has been seen on previous missions. Debris seen near the payload bay on previous missions include:

2.0 Summary of Significant Events Analysis

STS-41 - Crescent shaped debris seen during Ulysses' deploy. This event was declared an IFA.

STS-43 - Crescent shaped debris seen at TDRS deploy. The debris tumbled changing from black to white. Engineers believed this debris was solidified oxygen which had formed on the SSME bells during the oxygen dump just after MECO.
STS-54 - Numerous pieces of debris were seen on camera A after the TDRS deploy. None of the debris appeared to originate within the payload bay. The debris was believed to be ice from a water dump.

STS-56 - Debris was seen during the Spartan capture. The origin of debris was not determined. The size of the debris was 2 x 3 inches with a velocity of 1.15 feet per second.

The MER reported that they were no longer concerned about the STS-59 debris and that no further analysis was required.

2.6 LANDING EVENTS

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

2.6.1.1 Landing Sink Rate Analysis Using Film

Camera E-1008 was used to determine the sink rate of the main gear. Data was gathered for approximately 1 second prior to landing from film with a frame rate of 100 frames per second. Scale information was determined by using the main gear diameter (44 inches) as a reference. A point on the runway immediately beneath the wheel was taken as reference. The motion of each point was tracked for one full second. This height was then regressed with respect to time, and the slope of the trend line was defined as the sink rate. Measures of the sink rate were calculated over the full second prior to touchdown, the last half second, and the last quarter second. Over these three intervals, the corresponding main gear sink rates were determined to be 3.1 feet per second, 4.2 feet per second and 4.0 feet per second.

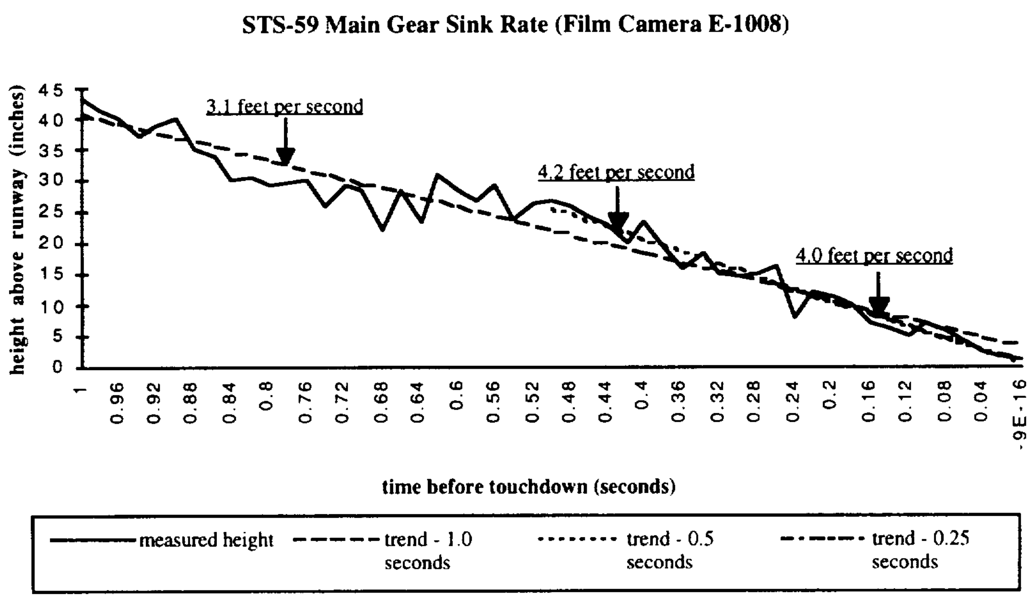


Figure 2.6.1.1a Main Gear Sink Rate Determination from Film

The same scale reference was used in the calculation of the nose gear sink rate. Data was gathered for approximately 1 second prior to touchdown from the E-1008 film. In addition to the top and bottom of the main gear, an additional scale check was obtained using the SSME bell diameters. These scaling factors appeared to agree closely with each other. The bottom of the left nose wheel was tracked for a full second. This height was then regressed with respect to time, and the slope of the trend line was defined as the sink rate. Measures of the sink rate were calculated over the full second prior to touchdown, the last half second, and the last quarter second. Over these three intervals, the corresponding nose gear sink rates were determined to be 3.2 feet per second, 3.7 feet per second and 3.9 feet per second.

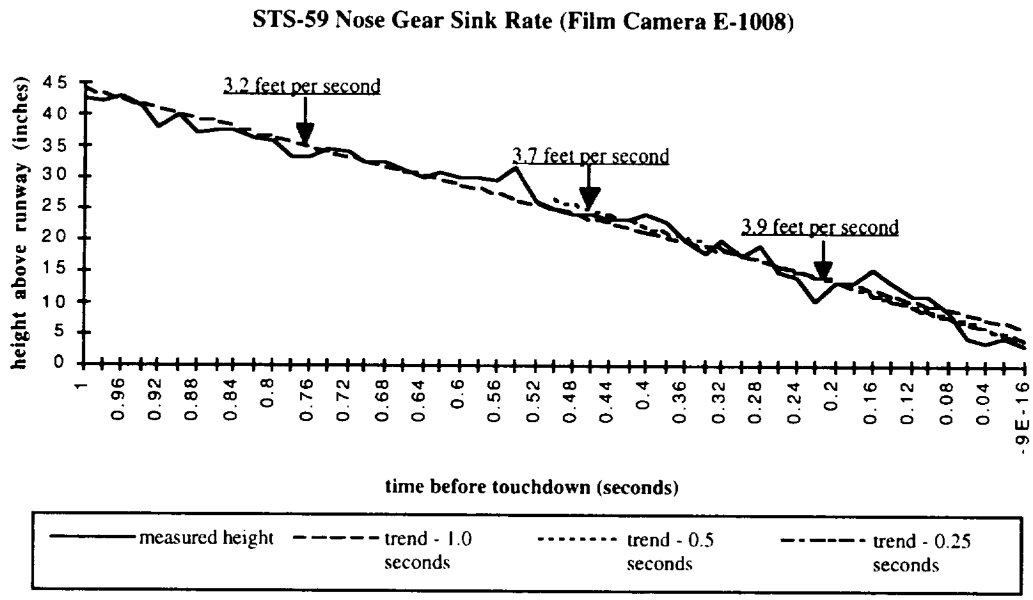


Figure 2.6.1.1b **Nose Gear Sink Rate Determination from Film**

2.6.1.2 Landing Sink Rate Analysis Using Video

Camera LRO was used to determine the sink rate of the main gear. Data was gathered for approximately 1 second prior to landing from the video (frame rate of 30 frames per second.) Scale information was determined by using the rudder speed brake (201 inches) as a reference. A point on the runway immediately beneath the wheel was taken as reference. The motion of each point was tracked for one full second. This height was then regressed with respect to time, and the slope of the trend line was defined as the sink rate. Measures of the sink rate were calculated over the full second prior to touchdown, the last half second, and the last quarter second. Over these three intervals, the corresponding main gear sink rates were determined to be 3.8 feet per second, 4.7 feet per second and 4.0 feet per second.

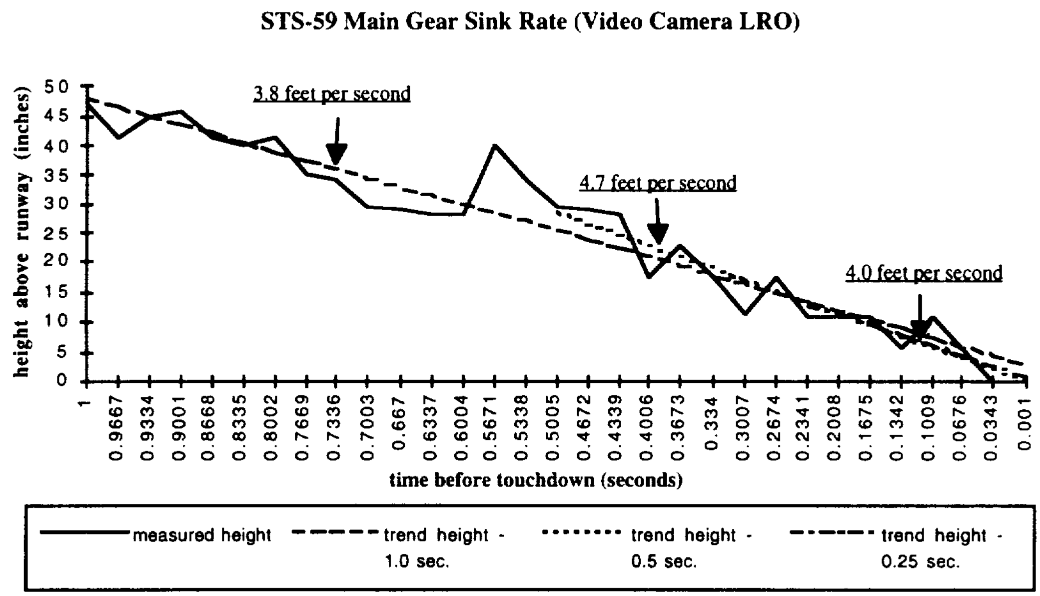


Figure 2.6.1.2a Main Gear Sink Rate Determination from Video

For the nose gear sink rate calculations, the main gear was used as a scale reference. Data was gathered for approximately 1 second prior to touchdown from camera DTV-3. The bottom of the left nose wheel was tracked for a full second. This height was then regressed with respect to time, and the slope of the trend line was defined as the sink rate. Measures of the sink rate were calculated over the full second prior to touchdown, the last half second, and the last quarter second. Over these three intervals, the corresponding nose gear sink rates were determined to be 3.5 feet per second, 3.9 feet per second and 4.0 feet per second.

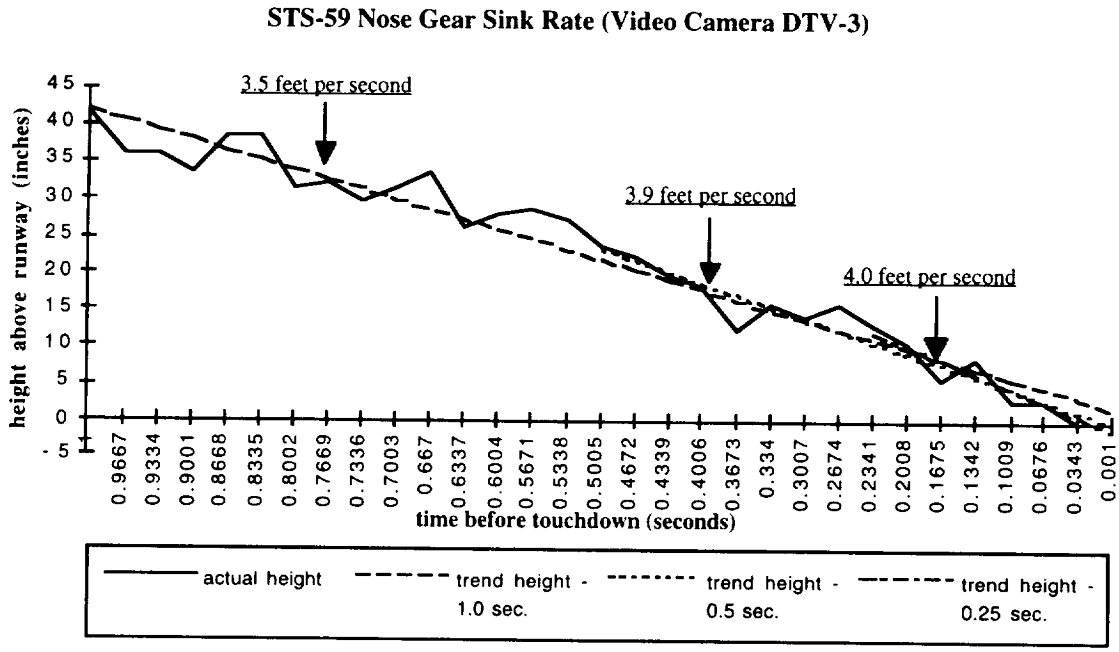


Figure 2.6.1.2b Nose Gear Sink Rate Determination from Video

Normally, sink rate is calculated from end-of-runway cameras which are thought to provide the best results. While the nose gear sink rates calculated from film and video agreed closely, the measured main gear sink rates differed between film and video by 0.7 feet per second. However, upon close examination of the graphs, one can see that the slope varies similarly as a function of time. The implication is that the scaling factor for one of the two sources may be off because of viewing angle discrepancies.

2.6.2 Drag Chute Performance *(Task #9)*

(Cameras E-1005, E1008)

The landing of Endeavour at the end of mission STS-59 marked the fourteenth deployment of the Orbiter drag chute. All components of the drag chute appeared to deploy as expected. Standard analysis of the drag chute angles as a function of time was performed using the views from the film cameras E-1005 and E-1008. This analysis is used to support the improvement of the aerodynamic math models currently in use. The measurements from the side of runway cameras have an expected bias on the order of one degree. The maximum measured horizontal chute deflection was approximately 6.9 degrees to the port side of the vehicle. Figure 2.6.2a presents the measured heading angle versus time. Figure 2.6.2b presents the measured riser angle versus time.

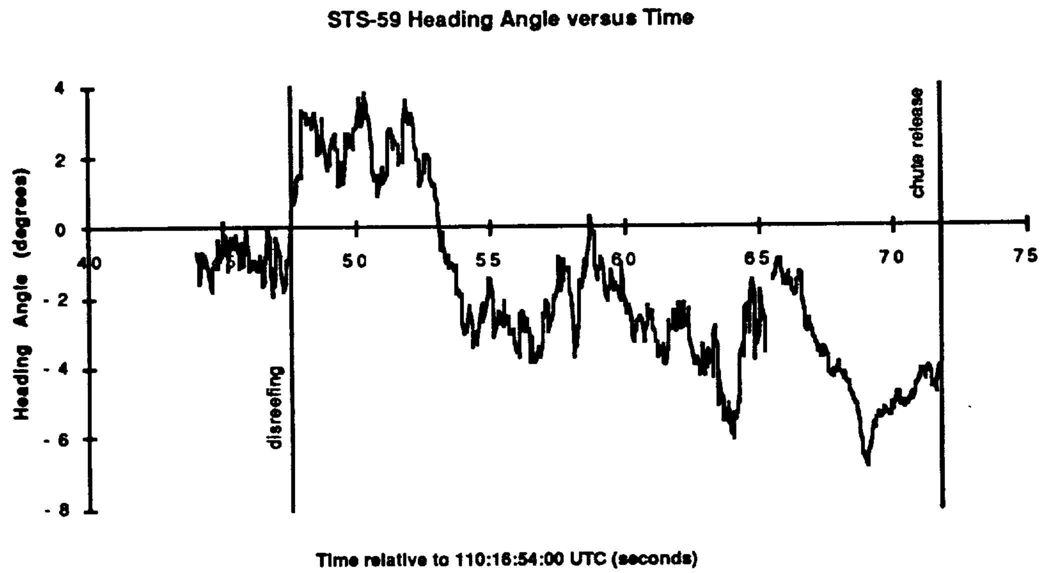


Figure 2.6.2a Heading Angle Versus Time

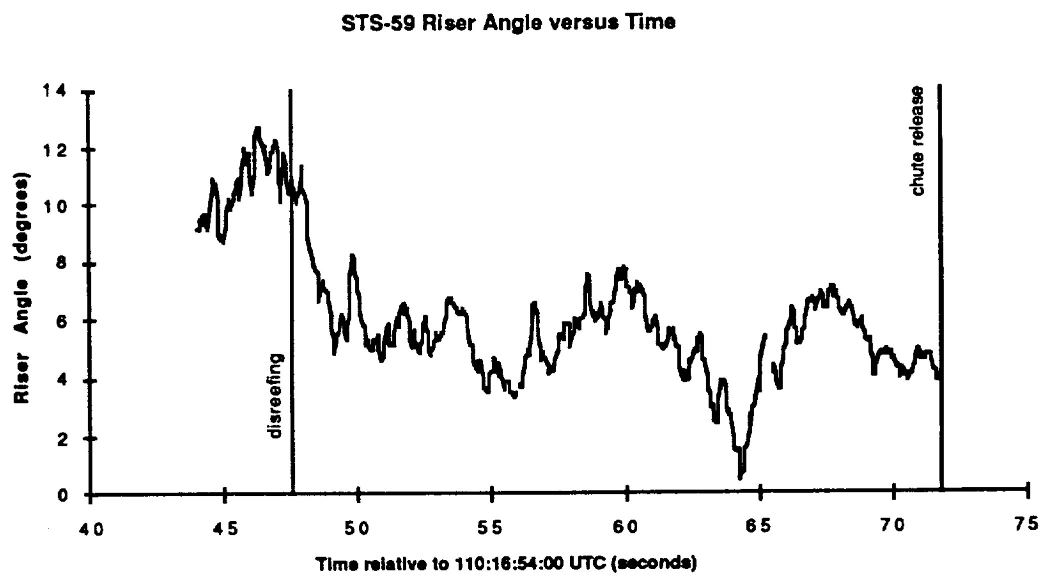


Figure 2.6.2b Riser Angle Versus Time.

Camera DTV-3 was used to determine the following drag chute event times.

EVENT	Coordinated Universal Time
Drag chute initiation	110:16:54:41.458
Pilot chute inflation	110:16:54:42.325
Drag chute bag release	110:16:54:43.059
Drag chute inflation, reefed configuration	110:16:54:44.027
Drag chute inflation, disreefed configuration	110:16:54:47.597
Drag chute release	110:16:55:11.788

2.7 OTHER NORMAL EVENTS

Other normal event observed include: ET twang, Dome Mounted Heat Shield (DMHS) vibration noted at SSME ignition, RCS paper debris after SSME ignition, ice and vapor from the TSM T-0 umbilical disconnect areas at liftoff, right and left inboard and outboard elevon motion visible after SSME ignition and at liftoff, ice and vapor from the Ground Umbilical Carrier Plate (GUCP) during SSME startup and ET GH2 vent arm retraction, debris in the exhaust cloud at the pad after liftoff, acoustic waves noted in the SRB exhaust cloud, ET aft dome outgassing, vapor from the SRB stiffener rings after liftoff, white flashes near the SRB plume, expansion waves, charring of the ET aft dome during ascent, dark puffs in SRB exhaust prior to SRB separation, SRB plume brightening, and slag debris in the SRB exhaust plume during and after SRB separation.

MLP events are: Fixed Service Structure (FSS) deluge water spray activation, Mobile Launch Platform (MLP) water dump activation, and a water leak from an MLP J-pipe.

Appendix B. MSFC Photographic Analysis Summary

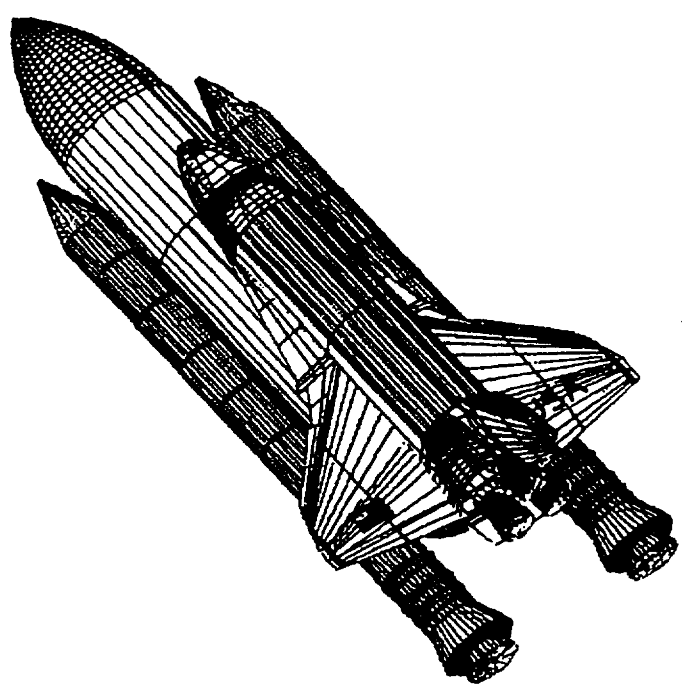
National Aeronautics and
Space Administration

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

SPACE SHUTTLE

ENGINEERING PHOTOGRAPHIC ANALYSIS REPORT

STS-59



ENGINEERING PHOTOGRAPHIC ANALYSIS REPORT

STS-59

FINAL

PREPARED BY:

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

SUBMITTED BY:

JIM ULM
SUPERVISOR, LAUNCH OPERATIONS/ROCKWELL/HSV

APPROVED BY:

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

STS-59 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.

May 9, 1994

I. INTRODUCTION

The launch of space shuttle mission STS-59, the sixth flight of the Orbiter Endeavour occurred on April 9, 1994, at approximately 6:05 A.M. Central Standard Time from Launch Complex 39A (LC-39A), Kennedy Space Center (KSC), Florida. Extensive photographic and video coverage exists and has been evaluated to determine proper operation of the ground and flight hardware. Cameras (video and cine) providing this coverage are located on the fixed service structure (FSS), mobile launch platform (MLP), LC-39B perimeter sites, onboard the vehicle, and uprange and downrange tracking sites.

II. ENGINEERING ANALYSIS OBJECTIVES:

The planned engineering photographic and video analysis objectives for STS-59 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

There was one special test objective for this mission:

1. DTO-0312, ET photography after separation.

III. CAMERA COVERAGE ASSESSMENT:

Film was received from fifty-seven of fifty-seven requested cameras as well as video from twenty-four of twenty-four requested cameras. The following table illustrates the camera data received at MSFC for STS-59.

Camera data received at MSFC for STS-59

	16mm	35mm	Video
MLP	22	0	3
FSS	7	0	3
Perimeter	3	3	6
Tracking	0	16	11
Onboard	4	2	1
Totals	36	21	24

Total number of films and videos received 81

An 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:

The FSS and MLP films of the STS-59 launch were generally dark. This is due to the inability to change the exposure settings after the scrub and due to the fact that the launch time was moved up an hour earlier.

b. Onboard Camera Assessment:

Each SRB forward skirt contained a camera to record the main parachute deployment. Both cameras operated properly. Neither camera recorded water impact. A 35mm hand-held camera was used to record film for evaluating the ET TPS integrity after ET separation. Thirty-six frames of the external tank were recorded. Additionally a hand-held camcorder recorded the external tank during the same time period and acquired approximately 8 minutes of good quality video. A 16mm motion picture camera and a 35mm still camera were flown in the orbiter's umbilical well to record the SRB and ET separation events. Both cameras operated properly.

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 north of MLP ejected from SRB blast holes, debris induced streaks in the SSME plume, ice falling from the 17 inch 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. GOX Vent Arm/Beanie Cap Motion

It was reported after launch that the GOX vent arm/beanie cap assembly was damaged during liftoff. Pad perimeter cameras were reviewed and showed no evidence of damage. Motion of this assembly was observed after the vehicle cleared the tower. This observed motion seems to be more severe than that observed on previous missions.

Measurements of the beanie cap motion were taken from camera E-62 located southeast on the perimeter which provides a near-normal view of the vent arm. This view orientation is shown in figure 1. Table 1 provides a summary of measured peak-to-peak and RMS values in both the cameras horizontal and vertical planes. These data represent previous mission from Pad A. Table 2 provides a similar summary for missions which had similar wind conditions at liftoff. None of these data are typical of the STS-59 data. Figure 2 is a plot of the measured STS-59 data compared to the STS-48 data. The STS-48 data are typical of the previous missions that were measured. A large displacement is noted on STS-59 at approximately T+8.0 seconds where the beanie cap moved down and towards the FSS. This type of motion was not observed on the previous missions.

An additional analysis was performed to determine the vehicle position relative to the FSS during liftoff. Tracking cameras E-220 and E-224 were used to plot the position of the ET tip relative to the FSS. Figures 3 and 4 provide the plan views for Cameras E-220 and E-224 respectively. Data were taken on STS-59 and STS-48 which had the same trajectory and photographic parameters. Data measured from each camera's horizontal and vertical planes were fitted and interpolated to provide data points at specific times(T+3.0 to T+6.0 seconds). These data were then transformed to provide position data relative to the MLP. Eastward motion (away from the FSS) is in the +Y direction and northward motion is +Z direction. These data for STS-48 and STS-59 are shown in figure 5. They show that the STS-48 vehicle was tracking closer to the FSS than the STS-59 vehicle prior to T+6 seconds. Data could not be obtained after this time since no FSS reference was in the camera views after T+6 seconds.

Measured Beanie Cap Motion

Pad A missions screened

Mission		Observations	Displacement P-P (in) Horz	Vert	Displacement RMS (in) Horz	Vert
STS-42		Slight movement	5	11	1	2
STS-44		Slight movement	Bad timing-Unable to read			
STS-45		Moderate movement	6	9	2	2
STS-48		Moderate movement	7	10	2	2
STS-50		Vent arm obscured	Unable to read			
STS-53		Vent arm obscured	Unable to read			
STS-55		Moderate movement	8	9	2	2
STS-60		Slight movement	Unable to read			

Table 1

Measured Beanie Cap Motion

Missions with similar winds

Mission	Pad	Wind Vel	Direction	Observations	Displacement P-P (in) Horz	Vert	Displacement RMS (in) Horz	Vert
STS-1	A	6 knots	120 degrees	Film unavailable				
STS-41D	A	2 knots	106 degrees	Slight movement				
STS-51F	A	9 knots	101 degrees	Slight movement				
STS-30	B	12 knots	106 degrees	Moderate movement	31	11	4	2
STS-41	B	24 knots	90 degrees	Slight movement	11	10	1	2
STS-57	B	6 knots	91 degrees	Slight movement	19	12	2	2
STS-59	A	16 knots	101 degrees	Severe movement	28	22	13	8

Table 2

b. Foam Indentation on Right SRB

It was reported that the forward face of the right hand ETA ring around the IEA area had suffered an indentation in the foam. The indentation was 2.5 inches by 1.5 inches by 1.5 inches deep and showed signs of heating effect.

Five STS-59 films were reviewed that showed the aft IEA box of the right SRB, or a possible debris source that would impact the aft IEA box on the right SRB (E-25, 52, 62, 65, 207). The aft IEA box of the right SRB was visible from SSME ignition through most of the roll maneuver to approximately T+70 seconds. No evidence of an impact nor a debris source was noted that could have produced the indention in the ETA ring. Most of the films had dark exposures because to the early morning launch. As the vehicle ascended the image resolution further degraded to a point that a particle of less than six inches could not be detected.

c. ET TPS Divots

Several divots were noted on or near the LH2 tank/intertank scarf joint. Figure 6 shows these divots as recorded by the 35mm umbilical well camera.

V. ENGINEERING DATA RESULTS:

a. T-Zero Times:

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

POST	CAMERA POSITION	TIME (UTC)
M-1	E-9	99:11:05:00.029
M-2	E-8	99:11:05:00.030
M-5	E-12	99:11:05:00.029
M-6	E-13	99:11:05:00.029

b. ET Tip Deflection:

Maximum ET tip deflection for this mission was determined to be approximately 30 inches. Figure 7 is a data plot showing the measured motion of the ET tip in both the horizontal and vertical directions. A positive horizontal displacement represents motion in the -z direction. These data were derived from video camera OTV-061. Film camera E-79 was not used to measure ET tip deflection due to the low light levels at liftoff which provided a degraded image.

c. SRB Separation Time:

SRB separation time for STS-59 was determined to be 99:11:07:04.15 UTC as recorded camera E-207.

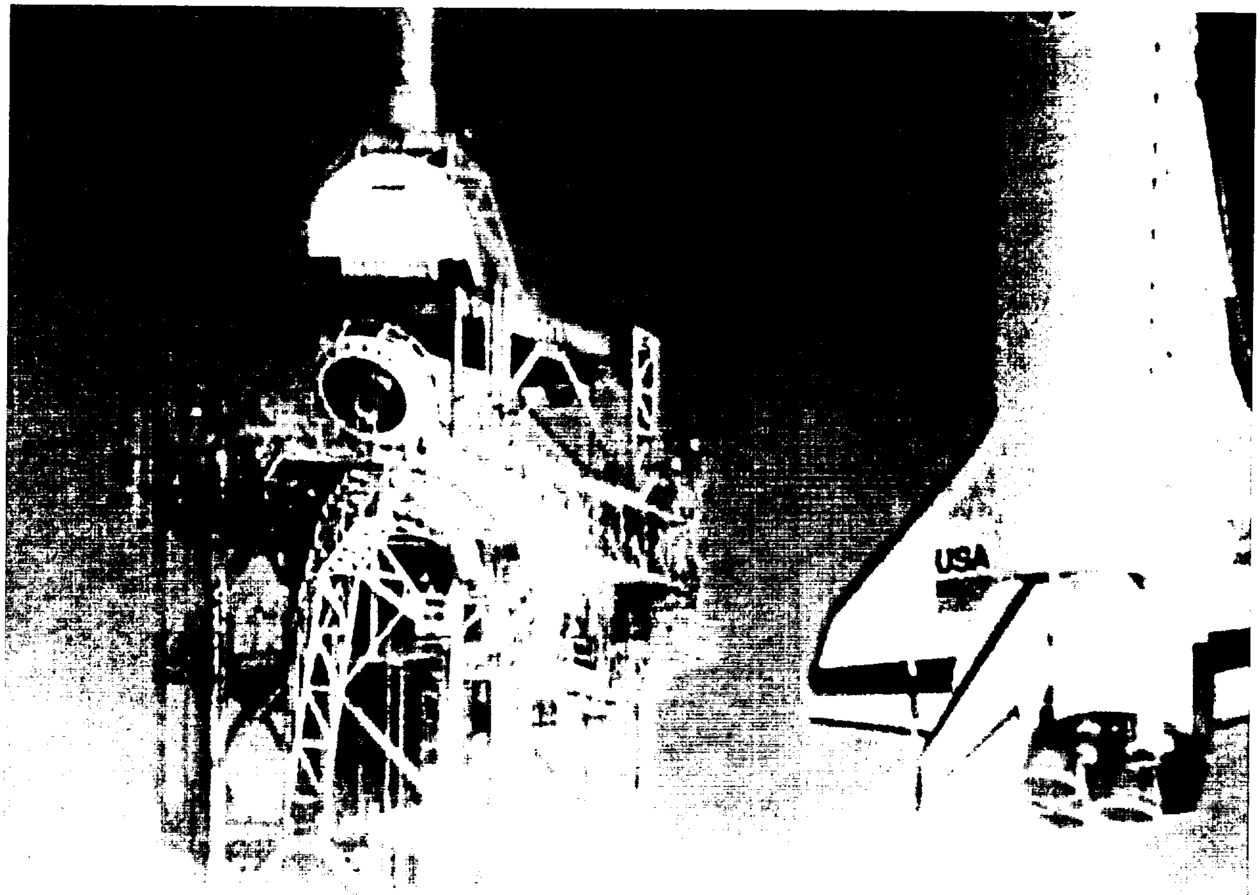
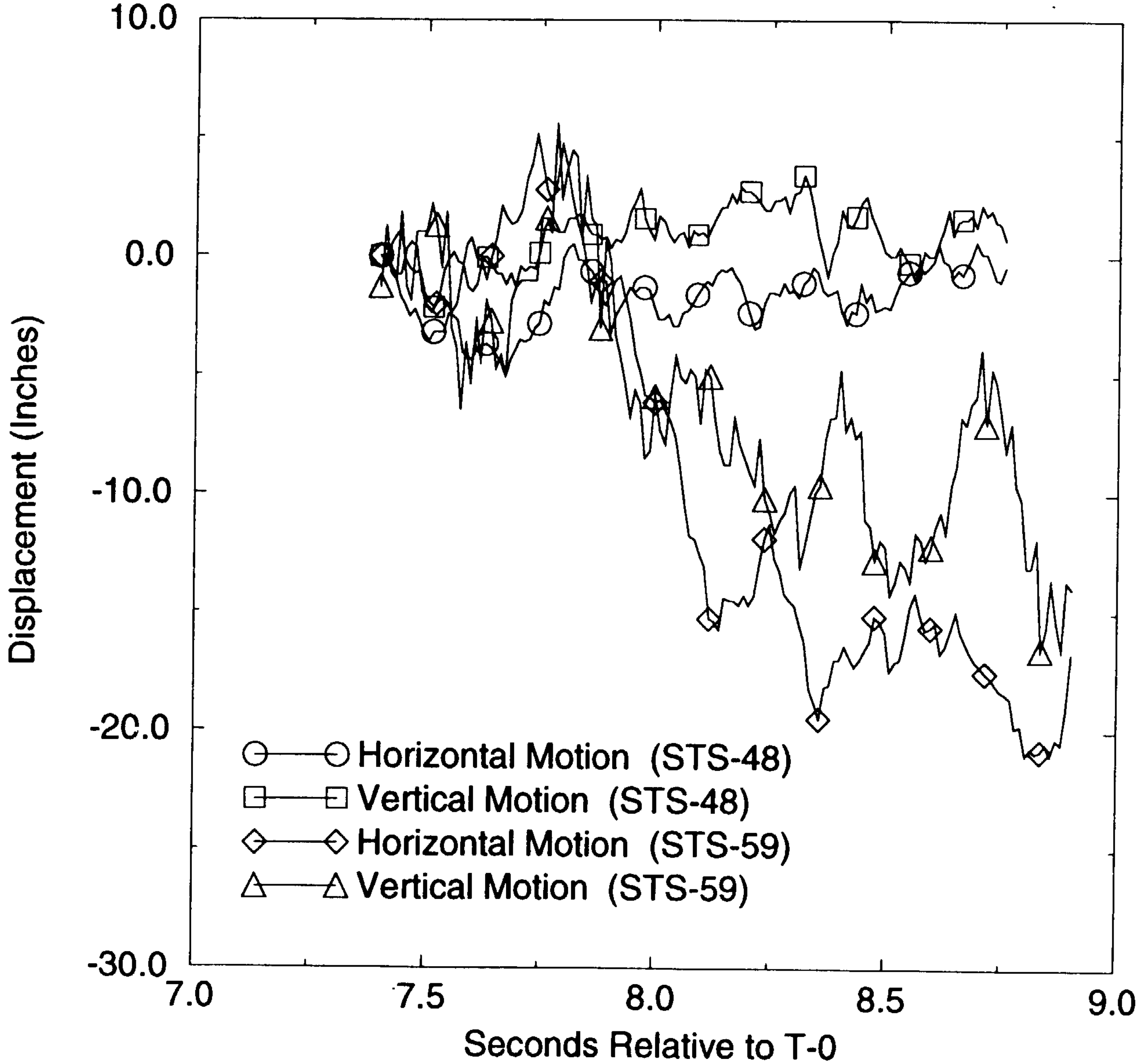


Figure 1: View From Camera E-62

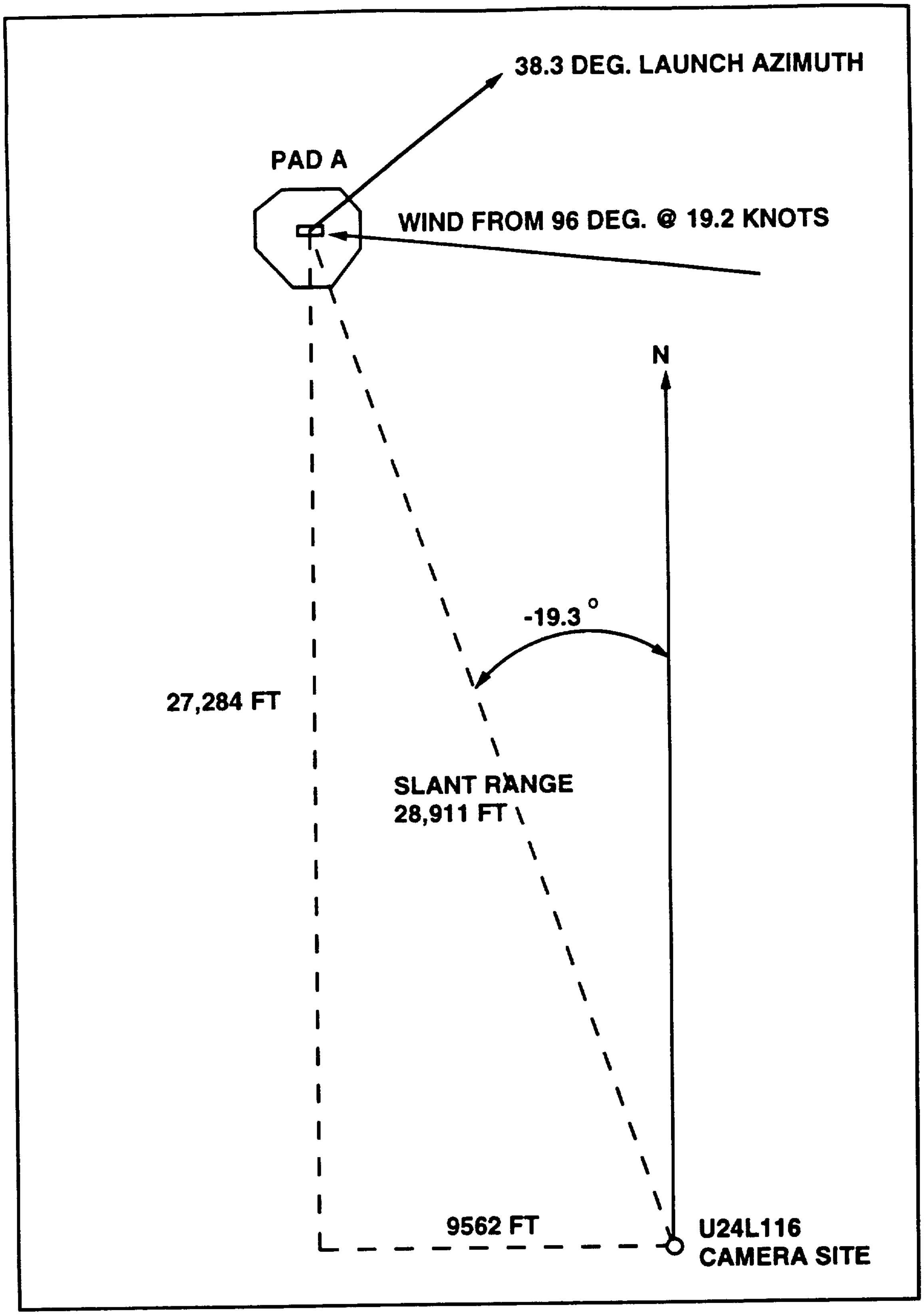
Comparison of STS-48 and STS-59

Measured Benie Cap Motion from Camera E-62



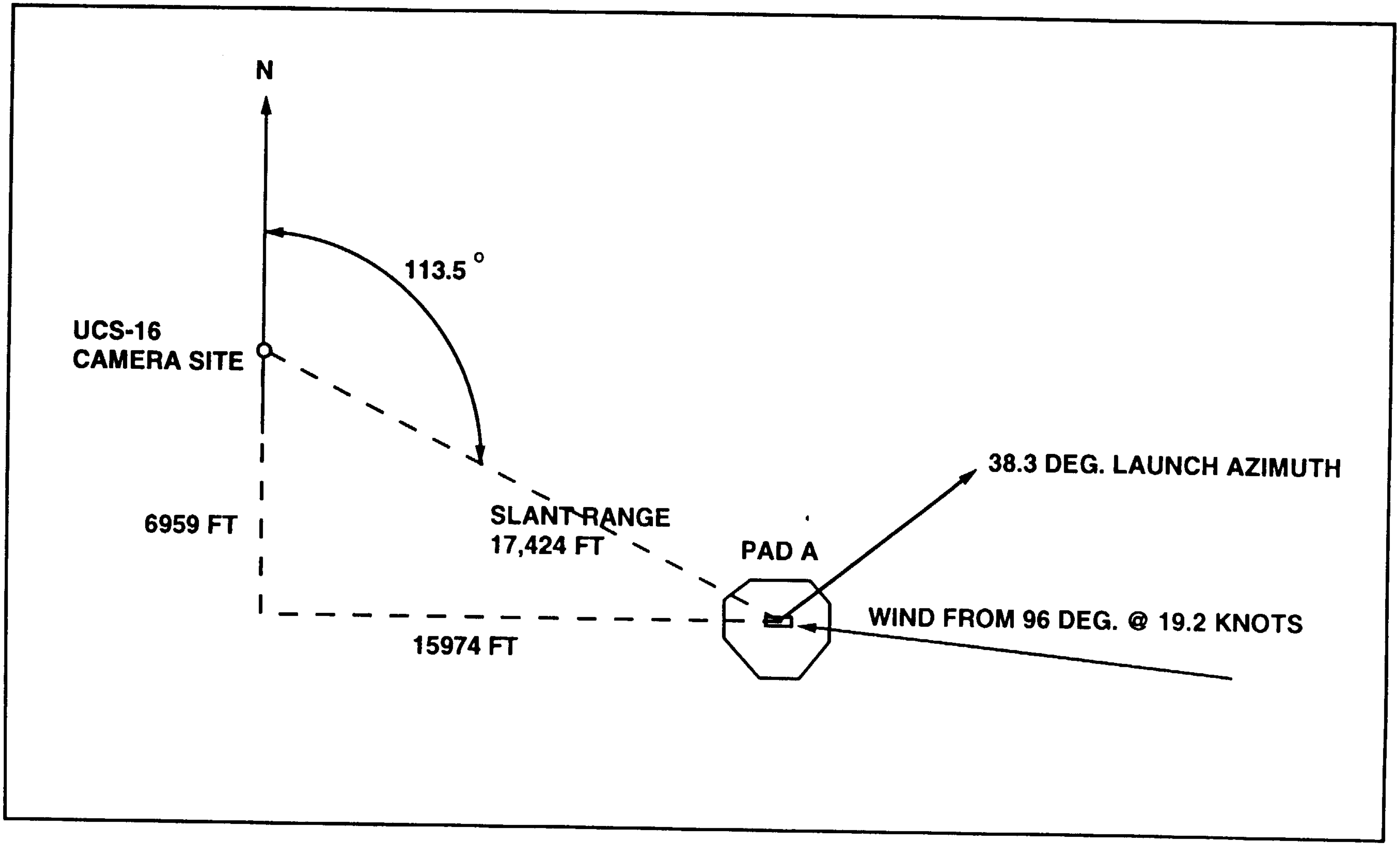
MSFC ENGINEERING PHOTOGRAPHIC ANALYSIS

Figure 2



Camera E-220 Plan View

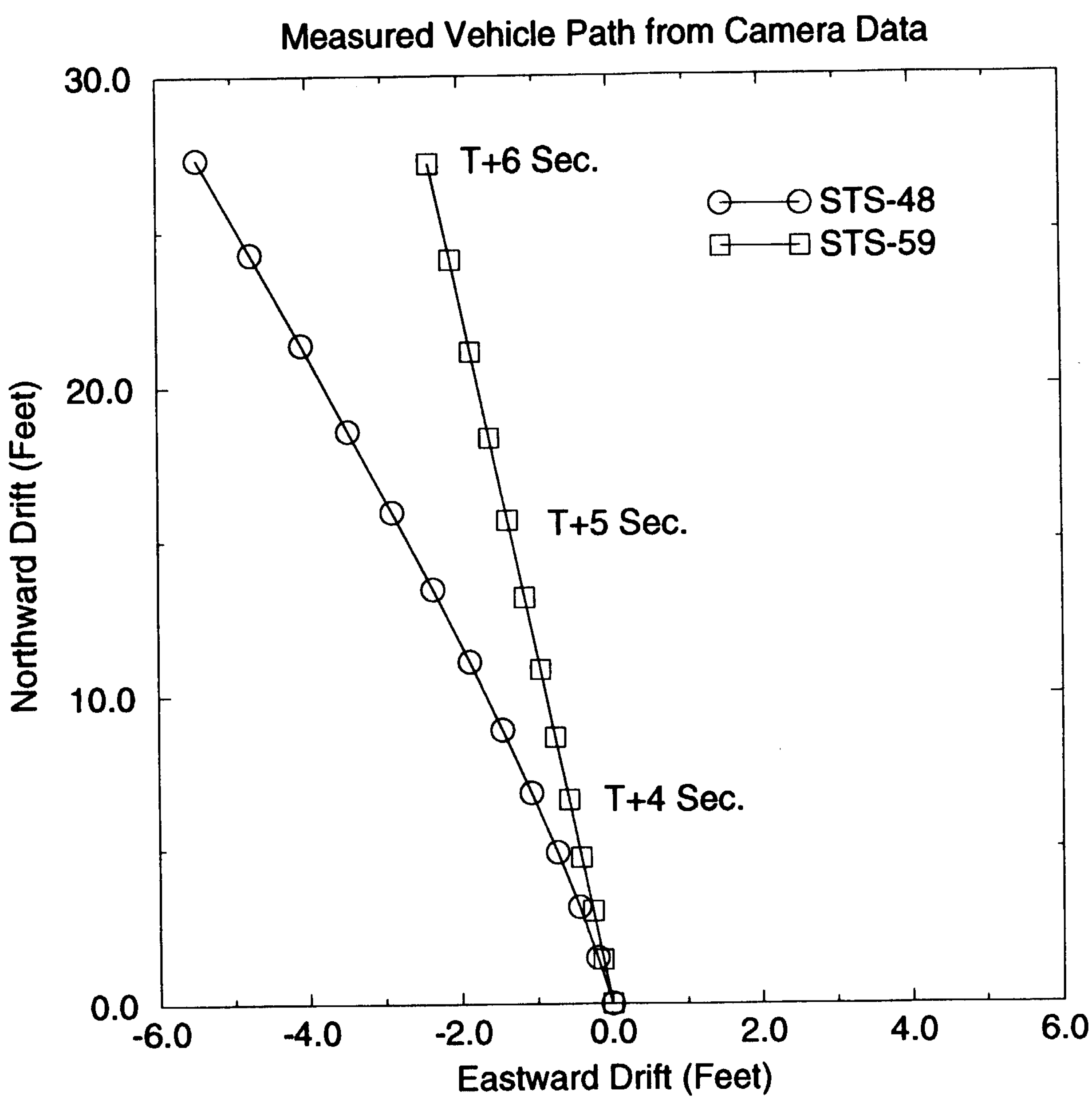
Figure 3



Camera E-224 Plan View

Figure 4

Comparison of STS-48 and STS-59 Liftoff



MSFC ENGINEERING PHOTOGRAPHIC ANALYSIS

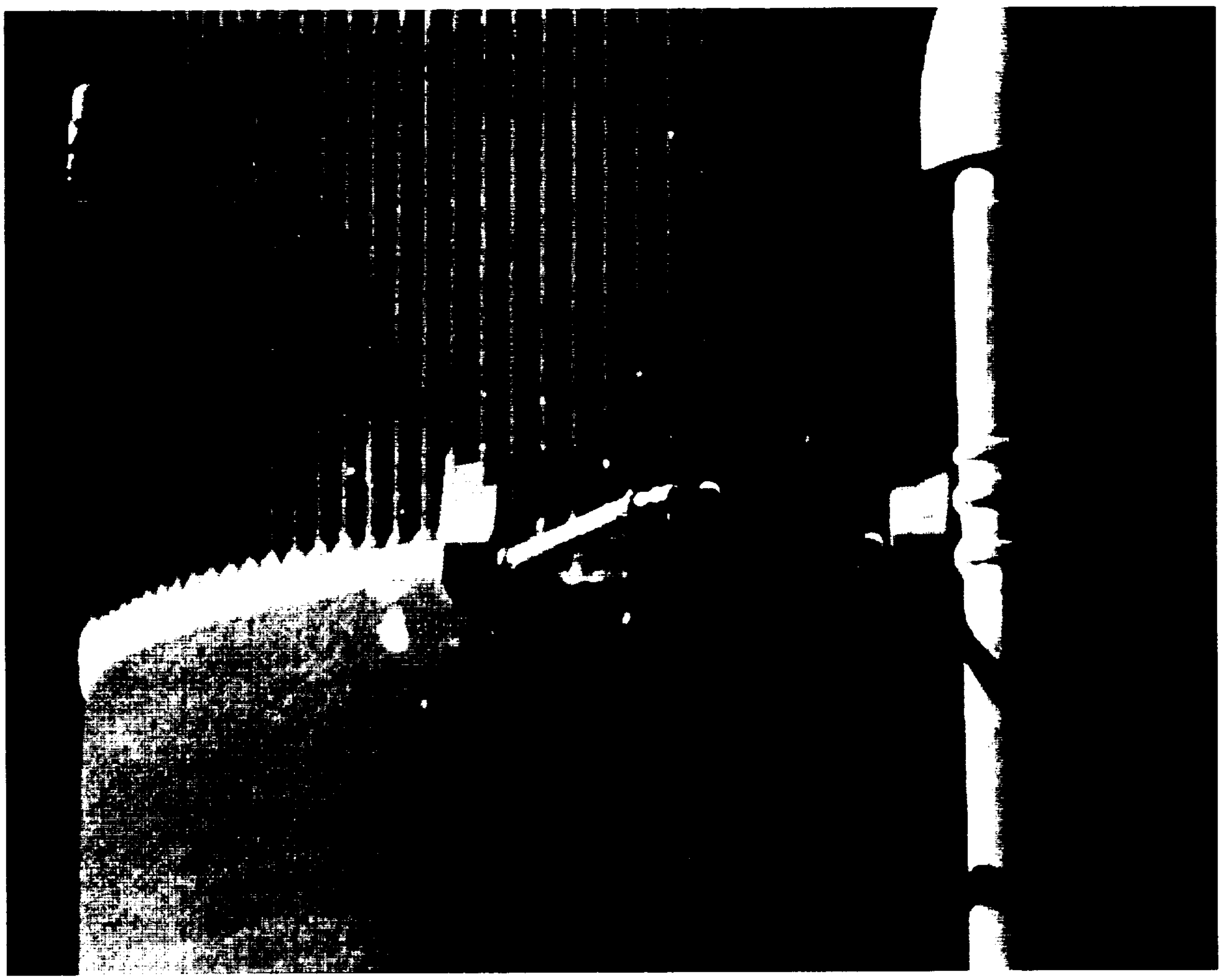


Figure 6: ET TPS Divots

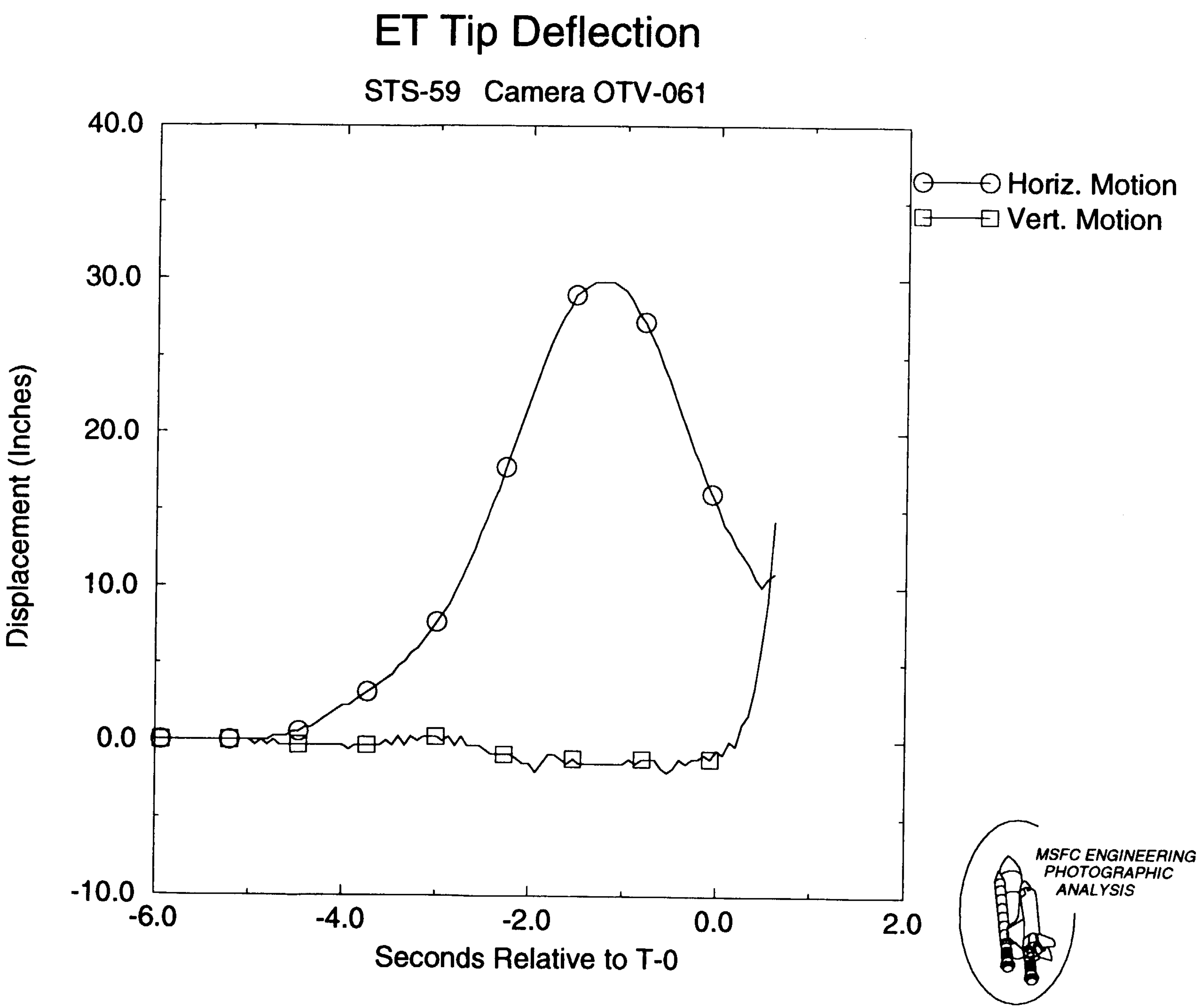

ET Tip Deflection
STS-59 Camera OTV-061
Horiz. Motion
Vert. Motion
40.0
30.0
20.0
10.0
0.0
-10.0
-6.0
-4.0
-2.0
0.0
2.0
Displacement (Inches)
Seconds Relative to T-0
MSFC ENGINEERING
PHOTOGRAPHIC
ANALYSIS

Figure 7

Appendix C. Rockwell Photographic Analysis Summary

ATTACHMENT I

IL NO.: 279-300-5518
5/18/94

ROCKWELL ENGINEERING PHOTOGRAPHIC ANALYSIS SUMMARY REPORT FOR STS-59

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 39A Fixed Service Structure (FSS), Mobile Launch Platform (MLP), various perimeter sites, and uprange and downrange tracking sites for the STS-59 launch conducted on April 9, 1994, at 4:05 a.m. PDT/GMT 099:11:05:00.020 from the Kennedy Space Center (KSC) and for the landing on April 20, 1994 at Edwards Air Force Base (EAFB) at 9:54 a.m. PDT/GMT 110:16:54:30. Rockwell received launch films from 82 cameras (58 cine, 24 video) and landing films from 11 cameras (5 cine, 6 video) to support the STS-59 photographic evaluation effort.

Overall, the films showed STS-59 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.

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.

Significant events that were observed or identified include the flares noted at the hydrogen burn-off ignitors prior to SSME ignition, the GOX vent arm damage found during the post-launch inspection of the FSS, and the apparent meteorite impact to the crew hatch outer window. These events and other events noted by the Rockwell film/video users during the review and analysis of the STS-59 photographic items are summarized in the following comments. These events are not considered to be a constraint to next flight.

COMMENTS

1. On Cameras E-1, E-3, E-20, E-30 and E-77, several flares (possibly excess hydrogen) were noted at the hydrogen burn-off ignitor nozzles just prior to SSME ignition (three on the northwest side and one on the southwest side). Flares have been observed on previous flights and no follow-on work is scheduled.

2.. On cameras OTV-070, OTV-071, E-1, E-2, E-3, E-5, E-16, E-17, E-18, E-19, E-20, E-76 and E-77, orange vapor (possibly free burning hydrogen) was noted to drift from beneath the SSME bells upward to the left OMS pod just prior to ignition. This vapor has been observed on previous flights and no follow-on work is scheduled

3. During the post-launch inspection of the FSS significant damage to the GOX vent arm was reported by KSC. Review of the Pad perimeter cameras showed no evidence of damage, however, at approximately 8 seconds MET (after tower clear but prior to the vehicle roll maneuver) an up/down motion of the GOX vent arm and twisting of the GOX vent hood was seen on camera E-62. Review of films from selected previous mission (STS-60, STS-38, STS-37, STS-52, STS-35 and STS-29) also showed the GOX vent arm oscillation. The video tape of the damage to the GOX vent arm at the arm-to-hood assembly (broken stud, separated welds) and films were reviewed by RI/DNY engineers. A copy of the video tape was provided by RI/DNY to the JSC debris/photo analysis team for their review. This event will most likely be classified as a KSC In-Flight Anomaly (IFA). KSC, MSFC and RI/DNY are currently working this issue to determine the cause of the damage.

4. Post-launch pad debris inspection identified four MLP cameras with shattered lenses. Films from cameras E-2, EX2, EX3 and E-14 were reviewed from camera start/stop to determine the cause of damage (debris impact, shock/pressure wave, etc.). No indication of lens damage is visible on the films and no further photographic support has been requested.

5. On cameras E-19, E-20 and E-76 the SSME #2 Mach diamond formed prior to SSME #3 compared to previous mission films and videos. No follow-up action is planned.

6. Two orange flashes were noted in the SSME plumes at SSME ignition (cameras E-2, E-3 and E-19). One flash was seen in the SSME #1 plume and the other in the SSME #3 plume. Flashes in the SSME plumes have been seen on previous missions. No follow-up action is planned.

7. On cameras OTV-070, OTV-071, E-5, E-17, E-18, E-19 and E-20 normal ice debris was seen falling from the LH2 and LO2 TSM T-0 umbilical disconnect area at SSME ignition through liftoff. One piece fell from the LO2 TSM disconnect area and impacted the SSME #3 nozzle near the rim. No damage to the vehicle was observed. No follow-up action is planned.

8. On Cameras OTV-009, OTV-054, OTV-063, E-5, E-6, E-15, E-18, E-25, E-26 and E-31, normal ice debris was seen falling from the LH2 and LO2 ET/Orbiter umbilical disconnect area at SSME ignition through liftoff. Several pieces contacted the LH2 umbilical door sill, but no damage was detected. No follow-up action is planned.

9. Several pieces of light colored debris were seen falling along the body flap into the SRB plume after liftoff through the roll maneuver on cameras E-52, E-59, E-211, E-222 and E-224. This debris was probably ice from the ET/Orbiter umbilicals and RCS paper covers. One large piece of white debris fell along the body flap into the SSME plume. None of the debris appeared to impact the vehicle. No follow-up action is planned.

10. On Cameras E-52, E-54, E-59, E-207, E-212, E-213, E-220, E-223 and E224, several pieces of orange-colored debris fell aft of the vehicle into the SRB plumes during the roll maneuver. This was probably umbilical purge barrier (baggie) material. No follow-up action is planned.

11. Two pieces of loose thermal curtain tape were noted on the aft skirt of the right SRB during ascent on camera E-207. Loose thermal curtain tape has been seen on previous missions and no follow-up action required.

12. Several flares were observed on the SSME plumes during ascent (23 to 50 seconds MET) on cameras E-205, E-211, E-212, E-220, E-223 and E-224. Flares have been noted on previous missions. No follow-up action is planned.

13. The following events have been reported on previous missions and observed on STS-59. 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
- Condensation on the Orbiter forward fuselage, ET nose and SRB frustums during ascent.
- Elevon deflection for load relief was visible during ascent.

14. 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.

15. Cameras E7-16-OMRSD File IX Vol. 5, Requirement No. DV08P.020 requires an 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.

16. The landing of STS-59 occurred on Runway 22 at the Edwards Air Force Base. Good video and film coverage were obtained. Main landing gear touchdown occurred at 110:16:54:30 GMT and nose landing gear touchdown occurred at 110:16:54:45 GMT with wheel stop occurring at 110:16:55:23 GMT. Prior to landing the crew reported that the egress hatch window had an impact crater in the lower left quadrant. The post-landing inspection revealed that the crew hatch outer window had sustained an apparent meteorite impact. The damage site measured 1/4" in diameter and is located in the left quadrant of the window. The window glass will be removed and sent to JSC for analysis.

    The post-landing inspection also identified damage to the inboard tires on both the left-hand and right-hand main landing gear. No follow-up action is planned.

    The flight marked the fifteenth 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.

IL NO.: 279-300-5518
5/18/94

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

Prepared by:	Approved by:
R. Ramon	
R.Ramon	N.L. Geiser, CAM
MISSION OPERATIONS	SHUTTLE INTEGRATION-DESIGN

cc:	D.H EMERO	AB08	M.G. FAGAN	AC15
	F.H. ENGEL	ZK88	N.L. GEISER	FB81
	R. RAMON	FA43	G.F. TAMAGNO	AC15
	R.E. GATTO	AE04	J.A. WOLFELT	AC15
	R.E. THOMAS	AB38	J.L. BENEDICT	FA43
	S.K. ALBRECHT	AC15		
	J.W. McCLYMONDS	AE21		
	L. JOHNSON	ZK90		
	L.E. LOHRLI-KIRK	FC94		

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY (Leave blank)

2. REPORT DATE
June 1994

3. REPORT TYPE AND DATES COVERED
Final 7-22 April 1994

4. TITLE AND SUBTITLE
Debris/Ice/TPS Assessment and Integrated Photographic Analysis for Shuttle Mission STS-59

5. FUNDING NUMBERS

6. AUTHOR(S)
Gregory N. Katnik
Barry C. Bowen
J. Bradley Davis

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
NASA
External Tank - Mechanical Systems
Mail Code: TV-MSD-22
Kennedy Space Center, Florida 32899

8. PERFORMING ORGANIZATION REPORT NUMBER
TM 109203

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Publicly Available
Unclassified - Unlimited

12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)

A debris/ice/thermal protection system assessment and integrated photographic analysis was conducted for Shuttle mission STS-59. 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 an on-pad visual inspection. High speed photography of the launch was analyzed to identify ice/debris sources and evaluate potential vehicle damage and/or in-flight anomalies. This report documents the ice/debris/thermal protection system conditions and integrated photographic analysis of Shuttle mission STS-59, and the resulting effect on the Space Shuttle Program.

14. SUBJECT TERMS
STS-59 Thermal Protection System (TPS)
Ice Debris Photographic Analysis

15. NUMBER OF PAGES

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	Unlimited

NSN 7540-01-280-5500

Standard Form 298 (Rev 2-89)
Prescribed by ANSI Std Z39-18
298-102

KSC DEBRIS/ICE/TPS ASSESSMENT AND INTEGRATED PHOTOGRAPHIC ANALYSIS REPORT DISTRIBUTION LIST 5/94

NASA - KSC

MK/L. J. Shriver
TE-CID-2/C. Brown
TV-PEO-2/P. Weber
TV-MSD-1/C. Stevenson
TV-MSD-22/G. Katnik (8)
RO-STS/P. Ramsey

GK-5/Z. H. Byrns
SK-LOS/J. Martin
BICO-1/R. B. Hoover
ZK-88/K. J. Mayer
LSO-321/H. L. Lamberth
LSO-437/J. J. Cawby
USBI-LSS/L. Clark
MMC-16/D. S. Otto

NASA - HQ

QSO/W. Comer

NASA - JSC

Johnson Space Center
Houston, Texas 77058

VA/D. Germany
VF2/W. Gaylor
EP2/B. Rosenbaum
ES3/J. Kowal
SN3/E. Christiansen
SN5/M. Gaunce

NASA - MSFC

Marshall Space Flight Center
Huntsville, AL 35812

ED31/D. Andrews
EE31/M. A. Pessin
EP24/T. J. Rieckhoff
SA32/J. G. Cavalaris

Rockwell - Downey

Rockwell International
12214 Lakewood Blvd
Downey, CA 90241

AE21/J. McClymonds
FA44/R. Ramon

Martin Marietta

13800 Old Gentilly Road
New Orleans, Louisiana 70129
P. O. Box 29304
New Orleans, Louisiana 70189

Dept. 3571/S. Copsey
Dept. 4200/P. Lewis