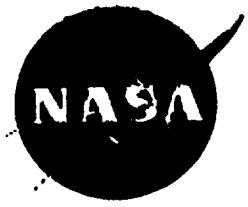
NASA Technical Memorandum TM 109189

Debris/Ice/TPS Assessment and Integrated Photographic Analysis for Shuttle Mission STS-51

October 1993



National Aeronautics and
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DEBRIS/ICE/TPS ASSESSMENT
AND
PHOTOGRAPHIC ANALYSIS
OF
SHUTTLE MISSION STS-51

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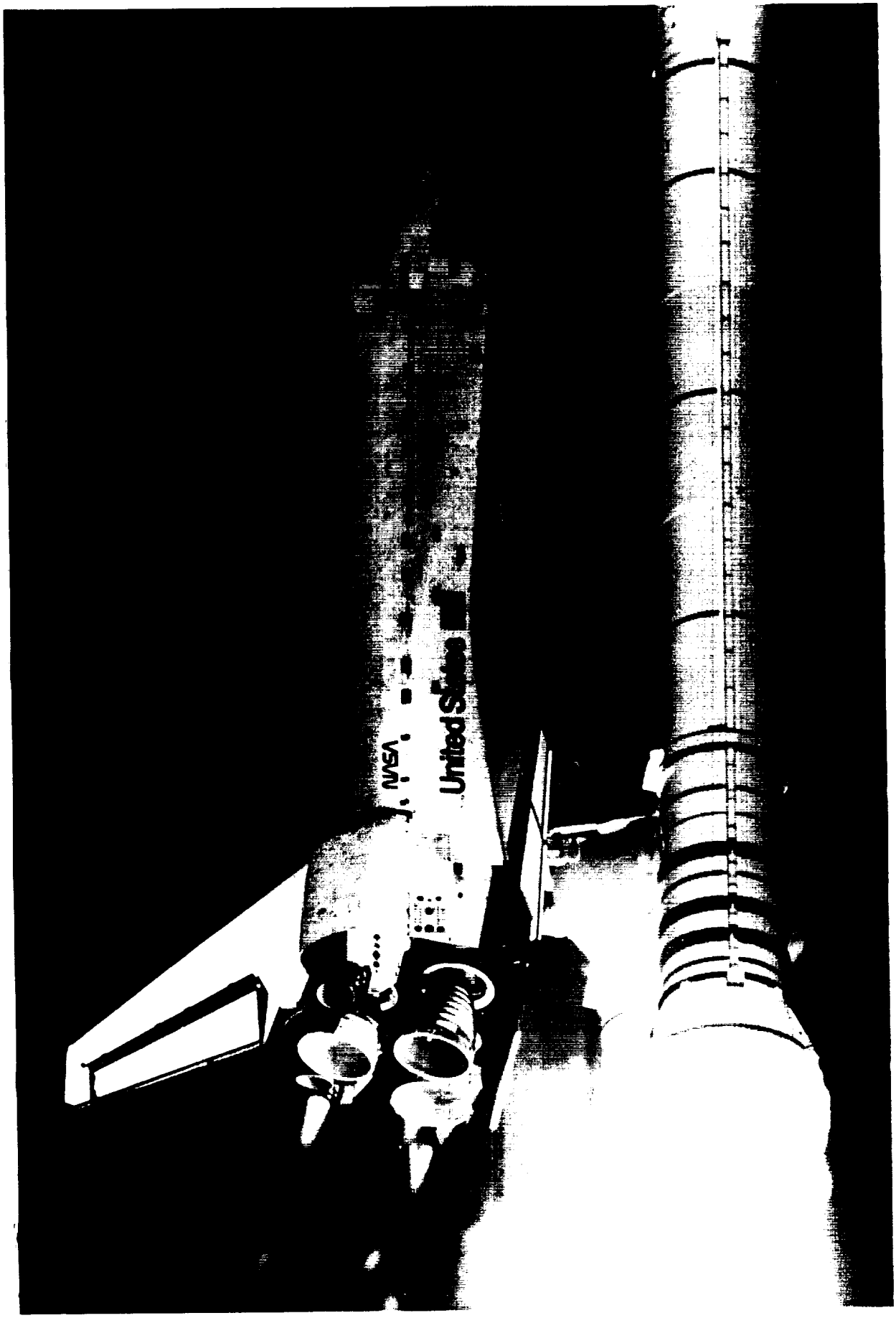
FOREWORD

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

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



Shuttle Mission STS-51 was launched at 7:45 a.m. local 9/12/93

1.0 Summary

A pre-launch debris inspection of the pad and Shuttle vehicle was conducted on 16 July 1993. The detailed walkdown of Launch Pad 39B and MLP-3 also included the primary flight elements OV-103 Discovery (17th flight), ET-59 (LWT 52), and BI-060 SRB's. There were no significant facility or vehicle anomalies.

The vehicle was cryoloaded on 17 July 1993. There were no Launch Commit Criteria (LCC), OMRS, or NSTS-08303 criteria violations. There were no ice/frost conditions outside of the established data base and no IPR's were taken.

The launch was scrubbed at T-20 minutes (and holding) when channel B ET vent arm system and SRB holddown post pyrotechnic initiator controllers armed without being commanded due to a HIM card failure. A post drain inspection of the vehicle revealed no significant anomalies.

The vehicle was cryoloaded a second time on 24 July 1993. There were no Launch Commit Criteria, OMRS, or NSTS-08303 criteria violations. There were no ice/frost conditions outside of the established data base and no IPR's were taken.

The launch was scrubbed at T-19 seconds when the RH SRB #2 HPU (tilt) turbine speed dropped below the specification lower limit. A post drain inspection of the vehicle revealed damaged foam on the inboard side of the LO2 feedline adjacent to the XT-1377 support bracket. The damaged area was repaired.

The vehicle was cryoloaded a third time on 11 August 1993. There were no Launch Commit Criteria, OMRS, or NSTS-08303 criteria violations. There were no ice/frost conditions outside of the established data base and no IPR's were taken.

The launch was aborted at T-3 seconds due to a problem with an SSME #2 fuel flow sensor. A post drain inspection of the vehicle revealed no significant anomalies as a result of the SSME shutdown and use of FIREX water.

Post abort film/video review showed FIREX water did not reach the ET/ORB LH2 umbilical and water coverage to the ET/ORB LO2 umbilical was inconsistent. A plan was created to increase the available water pressure by terminating the water flow on the FSS and MLP Side 1, which would not be needed for a main engine abort. A configuration change is being evaluated to move some FIREX nozzles to the top of the hydrogen dispersal system decreasing the distance from the water source to the ET/ORB umbilicals by 15 feet.

The vehicle was cryoloaded a fourth time on 11 September 1993. There were no Launch Commit Criteria, OMRS, or NSTS-08303 criteria violations. There were no ice/frost conditions outside of the established data base and no IPR's were taken.

Vapors (visible puffs of cold purge gas) simultaneously exited the External Tank intertank aero vents prior to SSME ignition. These vapors are routinely observed from the start of cryo load through terminal countdown. The visibility of the vapors is a function of ambient temperature, relative humidity, dew point, local winds conditions, lighting conditions (sunlight or Xenon light), and intertank gas temperature.

After the 7:45 a.m. launch on 12 September 1993, a debris inspection of Pad 39B was performed. No flight hardware or TPS materials were found. EPON shim material on the south holddown posts was intact. There was no visual indication of a stud hang-up on any of the south holddown posts. No frangible nut/ordnance fragments were found. Damage to the facility overall was minimal.

A total of 132 films and videos were analyzed as part of the post launch data review. No major vehicle damage or lost flight hardware was observed that would have affected the mission. No stud hang-ups occurred on any of the holddown posts. HDP #4 EPON sidewall shim material came loose during SRB lift off and fell into the SRB exhaust hole. All T-0 umbilicals operated properly.

On-orbit flight crew handheld photography revealed no major anomalies of the External Tank that would have been a safety of flight concern. One 8-inch divot was visible in the LH2 tank acreage just aft of the LH2 tank-to-intertank flange closeout between the bipods. One 8-inch divot occurred in the LH2 tank-to-intertank flange closeout adjacent to the outboard side of the -Y bipod spindle housing closeout. A divot, 10-12 inches in diameter, was present in the -Y (LH) longeron closeout.

The Solid Rocket Boosters were inspected at Hanger AF after retrieval. Both frustums had a combined total of 88 MSA-2 debonds over fasteners. All eight DCS plungers were seated. Hypalon paint was extensively blistered and/or missing from numerous areas of Booster Trowellable Ablator on the aft skirt (IFA STS-51-B-2). The Hypalon paint is used as a topcoat to prevent moisture intrusion prior to launch, but is not required for thermal protection during flight. The IFA was closed based on the rationale that blistering and/or loss of Hypalon in flight will not cause significant Orbiter tile damage due to the light mass/density of the topcoat. Practical application history has shown that blistering and loss of Hypalon occurs most frequently when multiple coats of the paint were applied during preflight processing. A change to the application procedure may specify only one, thin coat of Hypalon.

A post landing inspection of OV-103 was conducted after the landing at KSC. The Orbiter TPS sustained a total of 154 hits, of which 18 had a major dimension of one inch or greater. The Orbiter lower surface had a total of 100 hits, of which 18 had a major dimension of one inch or greater. Based on these

numbers and comparison to statistics from previous missions of similar configuration, the total number of debris hits was slightly greater than average while the number of hits one inch or larger was less than average. ET/Orbiter separation devices functioned properly.

Deployment of the ACTS/TOS payload and associated TOS Super*Zip Anomaly caused debris induced damage to the LH OMS pod leading edge, base of the vertical stabilizer, and payload bay areas aft of bay #11. Video review of the satellite deployment revealed at least 16 pieces of debris, most likely detached frangible doublers from the outer perimeter of the Super*Zip separation system, exiting the payload bay. A review of on-orbit imagery showed 6 damage sites on the vertical stabilizer base leading edge tiles. The LH OMS pod leading edge sustained a total of 18 tile damage sites. Seven hits were greater than one inch in length with depths ranging from 0.75 to 1.00 inch.

Post landing inspection of the payload bay revealed three penetrations in bay #12 cable tray covers, one penetration through the aft bulkhead near APU #3, scrapes on the bay #12 sill longeron, cuts/tears in thirteen TPS insulation blankets, and silicone/lead residues on fifteen aft bulkhead blankets. A 13-inch long segment of the frangible doubler was wedged between the port sill and the aft bulkhead.

During the ACTS/TOS deployment, the primary and secondary separation detonation cords in the airborne support equipment Super*Zip device fired simultaneously. This caused the ordnance containment tube to rupture and release debris into the orbiter payload bay. Only the primary detonation cord should have fired

Auxiliary Power Unit (APU) exhaust at the base of the vertical stabilizer, left side, appeared to be 2 - 3 feet in height and more noticeable than previous night landings. Infrared imagery during approach/rollout, cockpit instrumentation, and telemetry indicated the APU exhaust plume was typical and similar to APU operation for launch. APU #3 exhaust plume on the right side of the vertical stabilizer was present but barely visible.

Orbiter post landing microchemical sample results revealed a variety of residuals in the Orbiter lower surface tile samples from the Orbiter TPS, and paints/primers from various sources. A noteworthy finding was a trace of lead metallic in one of the forward OMS pod samples. The lead could have originated from the TOS Super*Zip anomaly. These residual sampling data do not indicate a single source of damaging debris as all of the materials have been documented previously in post-landing sample reports. The residual sample data also showed no debris trends when compared to previous mission data.

A total of 9 Post Launch Anomalies, including one In-Flight Anomaly, were observed during the STS-51 mission assessment.

2.0 PRE-LAUNCH BRIEFING

The Ice/Debris/TPS/Photographic Analysis Team briefing for launch activities was conducted on 10 September 1993 at 0830 hours with the following key personnel present:

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
A. Oliu	NASA - KSC	ET Processing, Ice/Debris
J. Cawby	LSOC - SPC	Supervisor, ET Processing
J. Blue	LSOC - SPC	ET Processing
J. Kercsmar	LSOC - SPC	ET Processing
M. Wollam	LSOC - SPC	ET Processing
M. Dean	LSOC - SPC	ET Processing
W. Richards	LSOC - SPC	ET Processing
J. Church	LSOC - SPC	ET Processing
Z. Byrns	NASA - KSC	Level II Integration
J. Stone	RI - DNY	Debris Assess, LVL II Integ
W. Atkinson	RI - LSS	Vehicle Integration
R. Kretz	MTI - LSS	SRM Processing
S. Otto	MMMSS- LSS	ET Processing

These personnel participated in various team activities, assisted in the collection and evaluation of data, and contributed to reports contained in this document.

2.1 PRE-LAUNCH SSV/PAD DEBRIS INSPECTION

A pre-launch debris inspection of the pad and Shuttle vehicle was conducted on 16 July 1993 from 0925-1030 hours. The detailed walkdown of Launch Pad 39B and MLP-3 also included the primary flight elements OV-103 Discovery (17th flight), ET-59 (LWT 52), and BI-060 SRB's. Documentary photographs were taken of facility anomalies, potential sources of vehicle damaging debris, and vehicle configuration changes.

There were no significant vehicle anomalies or debris issues.

Four each composite material samples were U-bolted to the hand rails on the FSS 135, 175, 215, and 255 foot levels (east side). The Debris Team evaluated each installation and found no debris concerns.

Four items were entered in S0007, Appendix K: 1) a loose bolt in an MLP deck access plate west of the LH SRB exhaust hole; 2) loose bolts under the MLP zero level raised decks around the SRB exhaust holes; 3) deck scale and dirt particles on the MLP deck; and 4) K5NA/TPS trimmings in the HDP #5 haunch area.

The MLP deck and areas under the raised deck were swept/vacuumed again prior to launch to remove small debris items, such as sand, rust flakes, and paint chips.

3.0 SCRUB - SRB PIC FAILURE

The first launch attempt of STS-51 was scrubbed at T-20 minutes and holding when channel B ET vent arm system and SRB HDP pyrotechnic initiator controllers armed without being commanded due to a HIM card failure.

3.1 ICE/FROST INSPECTION

The Ice/Frost Inspection of the cryoloaded vehicle was performed on 17 July 1993 from 0340 to 0505 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:	76.5 Degrees F
Relative Humidity:	80.1 Percent
Wind Speed:	6.0 Knots
Wind Direction:	201 Degrees

A hand-held Minolta/Land Cyclops spot radiometer was used to obtain vehicle surface temperature measurements for a thermal assessment of the vehicle.

3.2 ORBITER

No Orbiter RCC panel or TPS anomalies were observed. All RCS thruster paper covers were intact. Less than usual ice/frost accumulations were present at the SSME heat shield-to-nozzle interfaces. The base heat shield tiles were dry. An infrared scan revealed no unusual temperature gradients on the base heat shield or engine mounted heat shields. No unusual vapors originated from inside the SSME nozzles.

3.3 SOLID ROCKET BOOSTERS

No SRB anomalies or loose ablator/cork were observed. SRB case temperatures measured by the spot radiometer ranged from 76 to 80 degrees F and the SRB Ground Environment Instrumentation (GEI) measured a temperature of 80 degrees F. All measured temperatures were above the 34 degrees F minimum requirement. The predicted Propellant Mean Bulk Temperature (PMBT) supplied by MTI was 82 degrees F, which was within the required range of 44-86 degrees F.

3.4 EXTERNAL TANK

The ice/frost prediction computer program 'SURFICE' was run from 0030 to 0830 hours and the results tabulated in Figure 1. 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 barrel. There were no TPS anomalies. The tumble valve cover was intact. The Cyclops radiometer measured temperatures that averaged 71 degrees F on the ogive and 70 degrees F on the barrel; SURFICE predicted temperatures of 65 degrees F on the ogive and 60 degrees F on the barrel.

The intertank acreage TPS was dry. No frost spots appeared in the stringer valleys at the LH2 and LO2 tank-to-intertank flanges. Typical ice/frost accumulations and no unusual vapors were present on the ET umbilical carrier plate. The Cyclops radiometer measured an average surface temperature of 76 degrees F on the intertank.

There were no LH2 tank TPS acreage anomalies. Light condensate, but no ice or frost, was present on the acreage and aft dome. The Cyclops radiometer measured temperatures that averaged 64-70 degrees F on the upper LH2 tank and 63-68 degrees F on the lower LH2 tank; SURFICE predicted temperatures of 54 degrees F on the upper LH2 tank and 53 degrees F on the lower LH2 tank.

There were no anomalies on the bipod jack pad closeouts. Two cracks, 6-inches long by 3/8-inch wide and 4-inches long by 1/4-inch wide, were present in the -Y vertical strut cable tray forward surface TPS near the longeron closeout interface. These cracks exhibited no offset and were not filled with ice or frost. This condition was expected due to the elimination of the stress relief gap at the factory. A small ice/frost spot appeared on the aft side of both the +Y and -Y vertical strut-to ET interface bondlines.

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. The purge barrier (baggie) was configured properly and was holding positive purge pressure. There were no accumulations of ice/frost on the acreage areas of the umbilical. Formation of ice/frost on the separation bolt pyrotechnic canister purge vents was typical. Some ice/frost had formed on the bondline of the aft pyro canister. Normal venting of nitrogen purge gas had occurred during tanking and stable replenish.

STS- 51	TEST S0007 Scrub - PIC Failure															DATE: 17 July 1993					T-0 TIME: DATE:				NASA KSC Ice/Frost/Debris Team
ORBITER 103	ET 59	SRB BI-060	MLP 3	PAD B	LO2 CHILLDOWN TIME: 00:18 SLOW FILL TIME: 00:57				FAST FILL TIME: 01:09 REPLENISH TIME: 03:15				LH2 CHILLDOWN TIME: 00:21 SLOW FILL TIME: 00:29				FAST FILL TIME: 01:15 REPLENISH TIME: 03:05									
TIME (EDT)	CONDITIONS					LO2 TANK STA 370 TO 540					LO2 TANK STA 550 TO 852					LH2 TANK STA 1130 TO 1380					LH2 TANK STA 1380 TO 2058				
	TEMP F	REL HUM %	DEW PT F	WIND VEL KNTS	WIND DIR DEG	REG	LOCAL VEL KNTS	SOFI TEMP	COND RATE IN/HR	ICE RATE IN/HR	REG	LOCAL VEL KNTS	SOFI TEMP	COND RATE IN/HR	ICE RATE IN/HR	REG	LOCAL VEL KNTS	SOFI TEMP	COND RATE IN/HR	ICE RATE IN/HR	REG	LOCAL VEL KNTS	SOFI TEMP	COND RATE IN/HR	ICE RATE IN/HR
0030	79.40	72.4	70.19	6	219	II	3.54	66.14	0.0018	-0.1662	II	3.54	61.06	0.0036	-0.1358	II	1.92	53.81	0.0034	-0.0834	II	8.16	66.09	0.0037	-0.2936
0045	79.20	72.4	69.99	7	194	II	4.13	66.61	0.0017	-0.1866	II	4.13	62.06	0.0036	-0.1557	II	2.94	58.10	0.0038	-0.1069	II	2.66	57.09	0.0037	-0.0966
0100	79.20	72.8	70.15	8	193	II	4.72	67.25	0.0017	-0.2089	II	4.72	63.17	0.0037	-0.1776	II	3.36	59.46	0.0039	-0.1229	II	3.04	58.53	0.0039	-0.1112
0115	79.20	72.8	70.15	8	193	II	4.72	67.25	0.0017	-0.2089	II	4.72	63.17	0.0037	-0.1776	II	3.36	59.46	0.0039	-0.1229	II	3.04	58.53	0.0039	-0.1112
0130	79.00	73.0	70.03	8	188	II	4.72	67.10	0.0017	-0.2077	II	4.72	63.00	0.0037	-0.1764	II	3.36	59.28	0.0039	-0.1219	II	3.04	58.35	0.0039	-0.1102
0145	78.80	74.2	70.29	8	193	II	4.72	67.19	0.0018	-0.2085	II	4.72	63.10	0.0038	-0.1771	II	3.36	59.36	0.0040	-0.1224	II	3.04	58.43	0.0040	-0.1107
0200	78.40	75.2	70.28	8	195	II	4.72	67.02	0.0019	-0.2072	II	4.72	62.92	0.0039	-0.1759	II	3.36	59.16	0.0041	-0.1213	II	3.04	58.22	0.0040	-0.1096
0215	77.80	75.6	69.84	8	207	II	4.72	66.49	0.0019	-0.2031	II	4.72	62.35	0.0039	-0.1718	II	2.56	55.83	0.0038	-0.0892	II	10.88	66.69	0.0037	-0.3757
0230	77.80	76.4	70.14	7	191	II	4.13	66.12	0.0020	-0.1833	II	4.13	61.54	0.0039	-0.1525	II	2.94	57.48	0.0040	-0.1040	II	2.66	56.44	0.0039	-0.0938
0245	77.60	76.8	70.09	7	194	II	4.13	66.00	0.0021	-0.1825	II	4.13	61.42	0.0039	-0.1517	II	2.94	57.34	0.0040	-0.1034	II	2.66	56.31	0.0040	-0.0931
0300	77.60	77.6	70.38	7	190	II	4.13	66.20	0.0021	-0.1840	II	4.13	61.63	0.0040	-0.1531	II	2.94	57.55	0.0041	-0.1044	II	2.66	56.51	0.0040	-0.0941
0315	77.40	78.4	70.47	7	194	II	4.13	66.18	0.0022	-0.1839	II	4.13	61.60	0.0041	-0.1529	II	2.94	57.48	0.0042	-0.1042	II	2.66	56.47	0.0041	-0.0939
0330	77.00	79.0	70.29	8	204	II	3.54	65.17	0.0022	-0.1604	II	3.54	60.01	0.0040	-0.1300	II	1.92	52.46	0.0037	-0.0767	II	8.16	65.27	0.0045	-0.2848
0345	76.80	79.2	70.17	8	196	II	3.54	65.00	0.0023	-0.1593	II	3.54	59.82	0.0040	-0.1289	II	2.52	55.35	0.0040	-0.0884	II	2.28	54.24	0.0039	-0.0776
0400	76.80	79.6	70.31	6	197	II	3.54	65.10	0.0023	-0.1598	II	3.54	59.92	0.0040	-0.1295	II	2.52	55.45	0.0040	-0.0888	II	2.28	54.34	0.0039	-0.0780
0415	76.60	80.2	70.52	7	206	II	4.13	65.75	0.0023	-0.1809	II	4.13	61.14	0.0042	-0.1500	II	2.24	54.04	0.0039	-0.0761	II	9.52	65.97	0.0045	-0.3294
0430	76.40	80.0	70.06	5	200	II	2.95	63.82	0.0023	-0.1362	II	2.95	57.90	0.0039	-0.1064	II	2.10	52.99	0.0038	-0.0742	II	1.90	51.82	0.0037	-0.0742
0445	76.00	80.8	69.94	6	199	II	3.54	64.50	0.0024	-0.1563	II	3.54	59.28	0.0041	-0.1259	II	2.52	54.77	0.0041	-0.0839	II	2.28	53.64	0.0039	-0.0752
0500	76.20	81.8	70.49	6	203	II	3.54	64.96	0.0024	-0.1591	II	3.54	59.78	0.0042	-0.1287	II	1.92	52.12	0.0038	-0.0748	II	8.16	65.11	0.0048	-0.2832
0515	76.00	82.2	70.43	6	208	II	3.54	64.83	0.0025	-0.1583	II	3.54	59.64	0.0042	-0.1279	II	1.92	51.96	0.0038	-0.0741	II	8.16	64.99	0.0048	-0.2819
0530	75.80	82.4	70.30	5	217	II	2.95	63.70	0.0024	-0.1357	II	2.95	57.77	0.0040	-0.1058	II	1.60	50.77	0.0037	-0.0732	II	6.80	63.69	0.0049	-0.2340
0545	75.40	83.2	70.17	5	218	II	2.95	63.44	0.0025	-0.1343	II	2.95	57.48	0.0041	-0.1044	II	1.60	50.43	0.0037	-0.0717	II	6.80	63.44	0.0049	-0.2317
0600	76.00	83.2	70.77	4	203	II	2.36	62.85	0.0024	-0.1157	II	2.36	55.99	0.0039	-0.0862	II	1.28	51.17	0.0037	-0.0751	II	5.44	62.54	0.0049	-0.1909
0615	76.00	84.0	71.04	4	209	II	2.36	63.03	0.0024	-0.1165	II	2.36	56.17	0.0039	-0.0871	II	1.28	51.33	0.0038	-0.0758	II	5.44	62.74	0.0050	-0.1925
0630	76.00	85.2	71.44	5	218	II	2.95	64.57	0.0026	-0.1405	II	2.95	58.69	0.0043	-0.1104	II	1.60	51.56	0.0038	-0.0770	II	6.80	64.61	0.0052	-0.2430
0645	76.00	86.0	71.71	4	215	II	2.36	63.48	0.0026	-0.1187	II	2.36	56.65	0.0040	-0.0891	II	1.28	51.71	0.0039	-0.0777	II	5.44	63.23	0.0052	-0.1965
0700	76.00	86.4	71.84	5	224	II	2.95	64.86	0.0027	-0.1421	II	2.95	58.97	0.0043	-0.1119	II	1.60	51.79	0.0039	-0.0781	II	6.80	64.90	0.0053	-0.2459
0715	76.40	85.8	72.04	4	230	II	2.36	63.90	0.0026	-0.1207	II	2.36	57.10	0.0041	-0.0910	II	1.28	52.17	0.0039	-0.0799	II	5.44	63.64	0.0052	-0.1998
0730	76.40	85.6	71.97	3	247	II	1.77	62.08	0.0024	-0.1102	II	1.77	53.96	0.0037	-0.0855	II	0.96	52.13	0.0039	-0.0797	II	4.08	61.23	0.0050	-0.1497
0745	77.40	84.4	72.56	5	248	II	2.95	65.98	0.0026	-0.1483	II	2.95	60.19	0.0043	-0.1179	II	2.15	55.59	0.0042	-0.0844	II	6.05	65.20	0.0052	-0.2288
0800	78.40	81.2	72.45	5	257	II	2.95	66.35	0.0024	-0.1503	II	2.95	60.60	0.0041	-0.1199	II	2.15	56.08	0.0041	-0.0870	II	6.05	65.51	0.0049	-0.2315
0815	80.40	78.6	73.51	6	259	II	3.54	68.81	0.0023	-0.1838	II	3.54	63.87	0.0042	-0.1526	II	2.58	59.87	0.0043	-0.1079	II	7.26	68.19	0.0047	-0.2922
0830	79.80	78.0	72.70	7	264	II	4.13	68.68	0.0022	-0.2019	II	4.13	64.25	0.0042	-0.1704	II	3.01	60.51	0.0043	-0.1208	II	8.47	68.23	0.0045	-0.3283
AVG.	77.04	80.75	70.93	5.79	SE		3.41	65.22				3.41	59.78				2.18	54.59				5.40	61.49		

Period of Ice Team Inspection

FIGURE 1. "SURFICE" Computer Predictions

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

Less than usual amounts of ice/frost had accumulated on the top, aft, and outboard sides of the LH2 ET/ORB umbilical purge barrier. Typical ice/frost fingers had formed on the pyro canister and plate gap purge vents. Ice/frost was present on the forward bondline of the aft pyrotechnic canister closeout indicating a thermal short. No unusual vapors or cryogenic drips had appeared during tanking and stable replenish.

The ET/ORB hydrogen detection sensor tygon tubing was in proper position prior to removal. The tubing was removed from the vehicle without contacting Orbiter tiles, though there was a premature release of the third attach point on the ET/SRB upper strut fairing due to inadequate velcro surface area.

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

Anomaly 001 documented two cracks, 6-inches long by 3/8-inch wide and 4-inches long by 1/4-inch wide, in the -Y vertical strut cable tray forward surface near the longeron closeout interface. The cracks exhibited no offset and were not filled with ice or frost.

Anomaly 002 documented ice/frost formations on the -Z manhole cover: 1) +Y side at the plug pull location, 2) +Z side of the cover. The ice/frost formations eventually melted.

Anomaly 003 documented an ice/frost formation on the forward bondline of the aft pyro canister closeout.

Anomaly 004 (documentation only) recorded ice/frost formation below the -Y ET/SRB cable tray at the aft edge of the -Y longeron closeout.

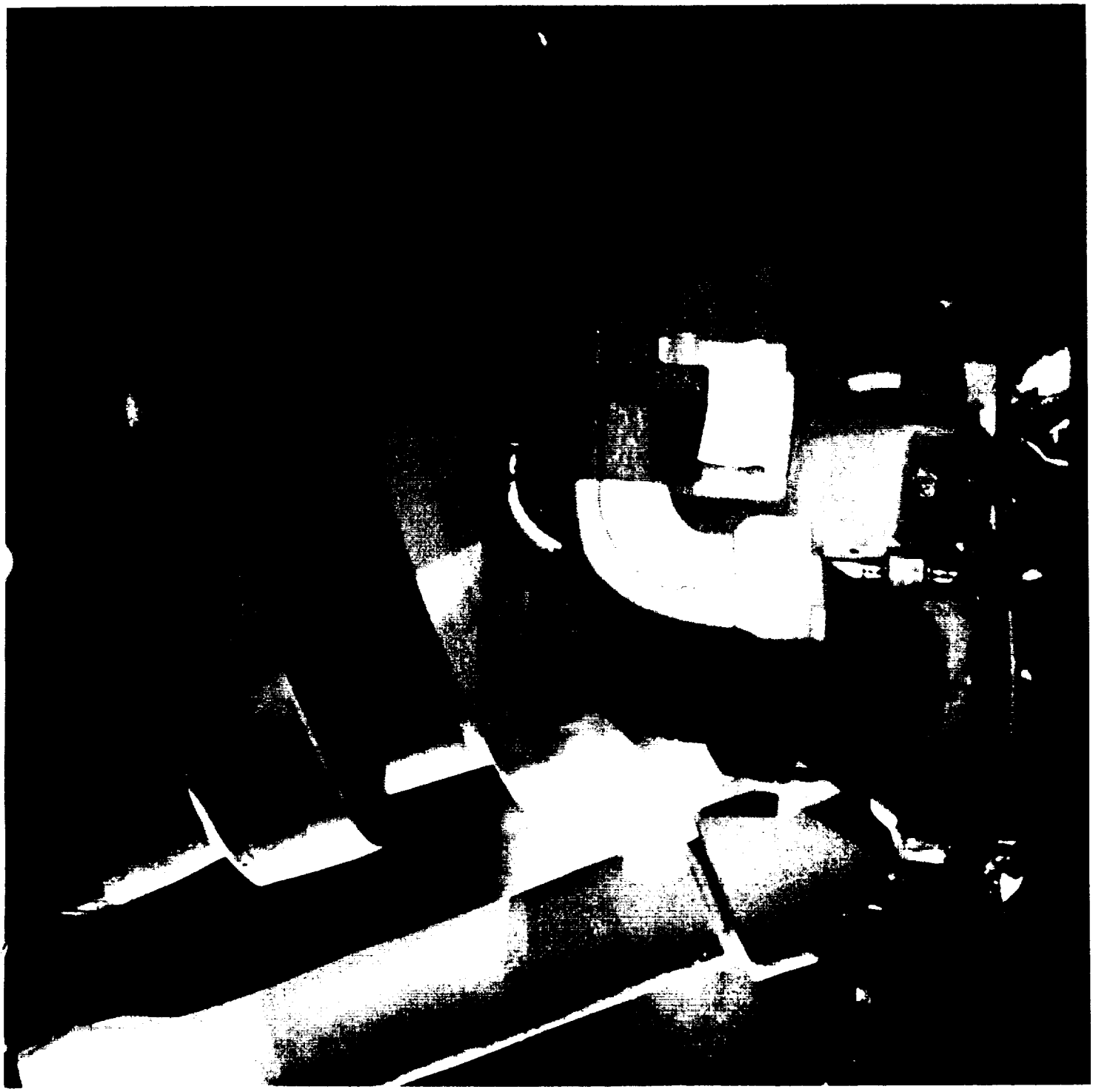
3.5 FACILITY

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

No leaks were observed on either the LO2 or LH2 Orbiter T-0 umbilicals. Typical accumulations of ice/frost were present on the cryogenic lines and purge shrouds.

There was no apparent hydrogen leakage anywhere on the GH2 vent line or GUCP. Some ice and frost, which was expected, had accumulated on the GUCP legs and on the uninsulated parts of the umbilical carrier plate.

Visual and infrared observations of the GOX seals confirmed no leakage.



Less than usual amounts of ice/frost had accumulated on the LH2 ET/ORB umbilical. No unusual vapors or cryogenic drips appeared during tanking and stable replenish.

3.6 POST DRAIN VEHICLE INSPECTION

The first launch attempt was scrubbed at T-20 minutes due to a problem with SRB HDP and ET VAS PIC voltages. A post drain inspection of the vehicle was performed at Pad-39B from 1400 to 1500 hours on July 17, 1993.

The tumble valve cover on the External Tank was intact. All other areas of the nosecone were obscured by the GOX vent hood/seal.

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

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

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

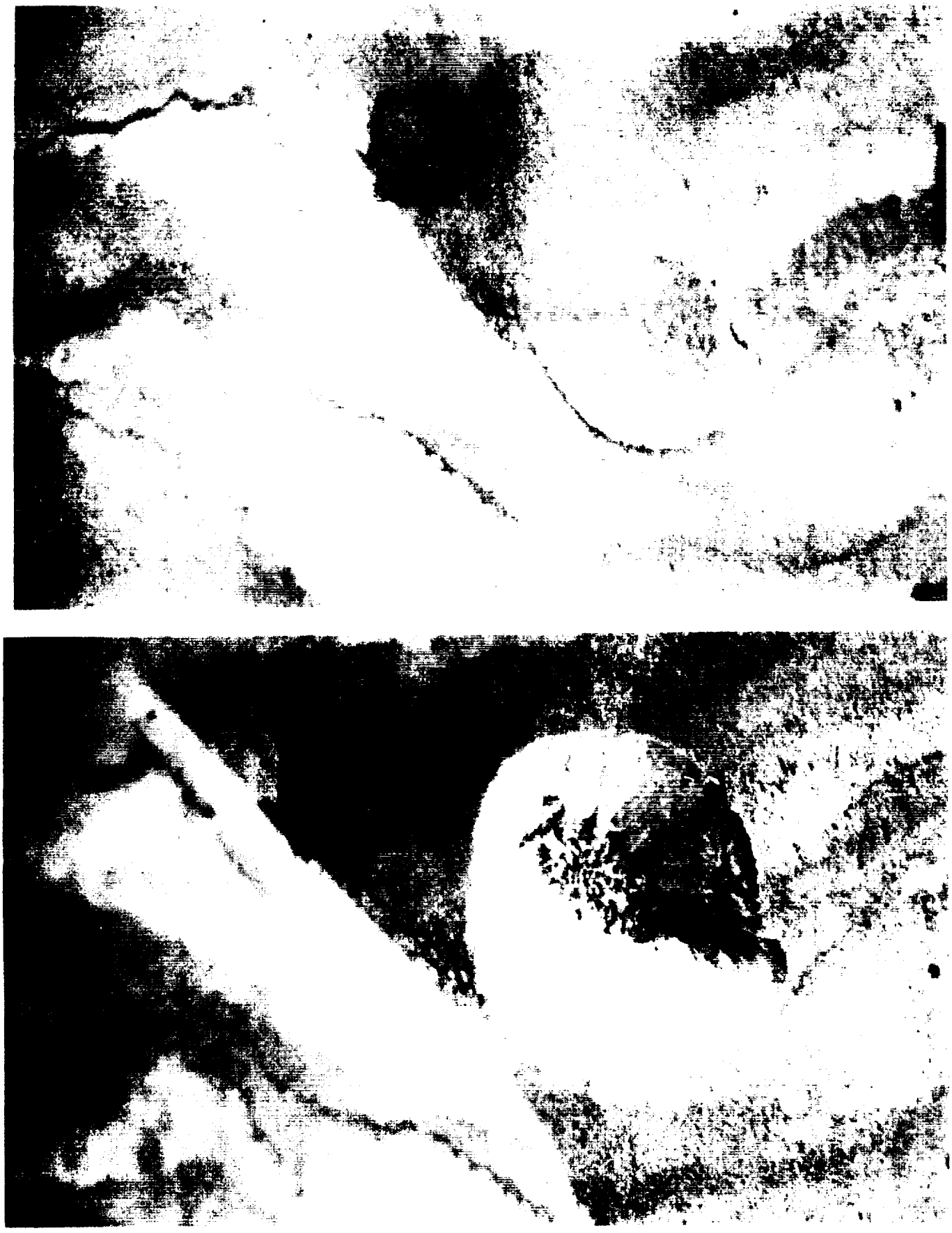
A 3-inch diameter defect appeared on the +Y longeron BX-250 closeout adjacent to the thrust strut knuckle. The loose piece of foam exhibited a 1/4-inch offset. The divot was trimmed and the area repaired by PDL foam injection. An MRB was required since the repair area was greater than 10 square inches.

The 6-inch and 4-inch cracks in the -Y ET/SRB vertical strut cable tray forward surface TPS (reported during the Ice Team Inspection) were still visible.

A 2-inch long ice/frost spot with venting vapors was present on the aft dome +Z manhole cover BX-250 closeout.

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

No significant vehicle damage was discovered as a result of the post drain inspection. The +Y longeron BX-250 divot was repaired on a Problem Report (PR). There were no constraints for the next cryoload.



A 3-inch diameter defect appeared in the +Y longeron BX-250 closeout adjacent to the thrust strut knuckle. The loose piece of foam exhibited a 1/4 inch offset. The divot was trimmed and repaired with PDL foam injection.

The 6-inch and 4-inch cracks in the -Y ET/SRB vertical strut cable tray forward surface TPS (reported during the Ice Team inspection) were still visible after the External Tank was drained.

4.0 SCRUB - RH SRB HPU #2 FAILURE

A second pre-launch debris inspection of the SSV and MLP deck was conducted from 0800 - 0905 on 23 July 1993. Numerous K5NA trimmings, two of which measured 3 inches in length, lay in the HDP #1 and #2 haunch areas. Those trimmings, along with MLP deck debris particles, were removed prior to cryoloading.

The second launch attempt of STS-51 was scrubbed at T-19 seconds when the RH SRB #2 (Tilt) HPU turbine speed dropped below the specification lower limit.

4.1 ICE/FROST INSPECTION

The Ice/Frost Inspection of the cryoloaded vehicle was performed on 24 July 1993 from 0330 to 0440 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:	75.0 Degrees F
Relative Humidity:	85.7 Percent
Wind Speed:	4 Knots
Wind Direction:	206 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 2 and 3.

4.2 ORBITER

No Orbiter RCC panel or TPS anomalies were observed. Some ice/frost accumulated at the SSME #1 heat shield-to-nozzle interface 6:00 o'clock position. Some frost was present on the SSME #1 and #3 drain lines. The SSME #2 and #3 engine mounted heat shields and tiles on the base heat shield were wet from condensate. An infrared scan revealed no unusual temperature gradients on the base heat shield or engine mounted heat shields. No unusual vapors originated from inside the SSME nozzles.

4.3 SOLID ROCKET BOOSTERS

No SRB anomalies or loose ablator/cork were observed. The STI portable infrared scanner recorded RH and LH SRB case temperatures between 78 to 80 degrees F. In comparison, temperatures measured by a hand-held Minolta/Land Cyclops spot radiometer ranged from 76 to 80 degrees F and the SRB Ground Environment Instrumentation (GEI) measured temperatures of 79-83 degrees F.

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

TIME: 0325-0440
DATE: 7-24-93
VEH. STS- 51 Scrub #2

All temperatures are in degrees Fahrenheit.

Emissivity was set to 1.0

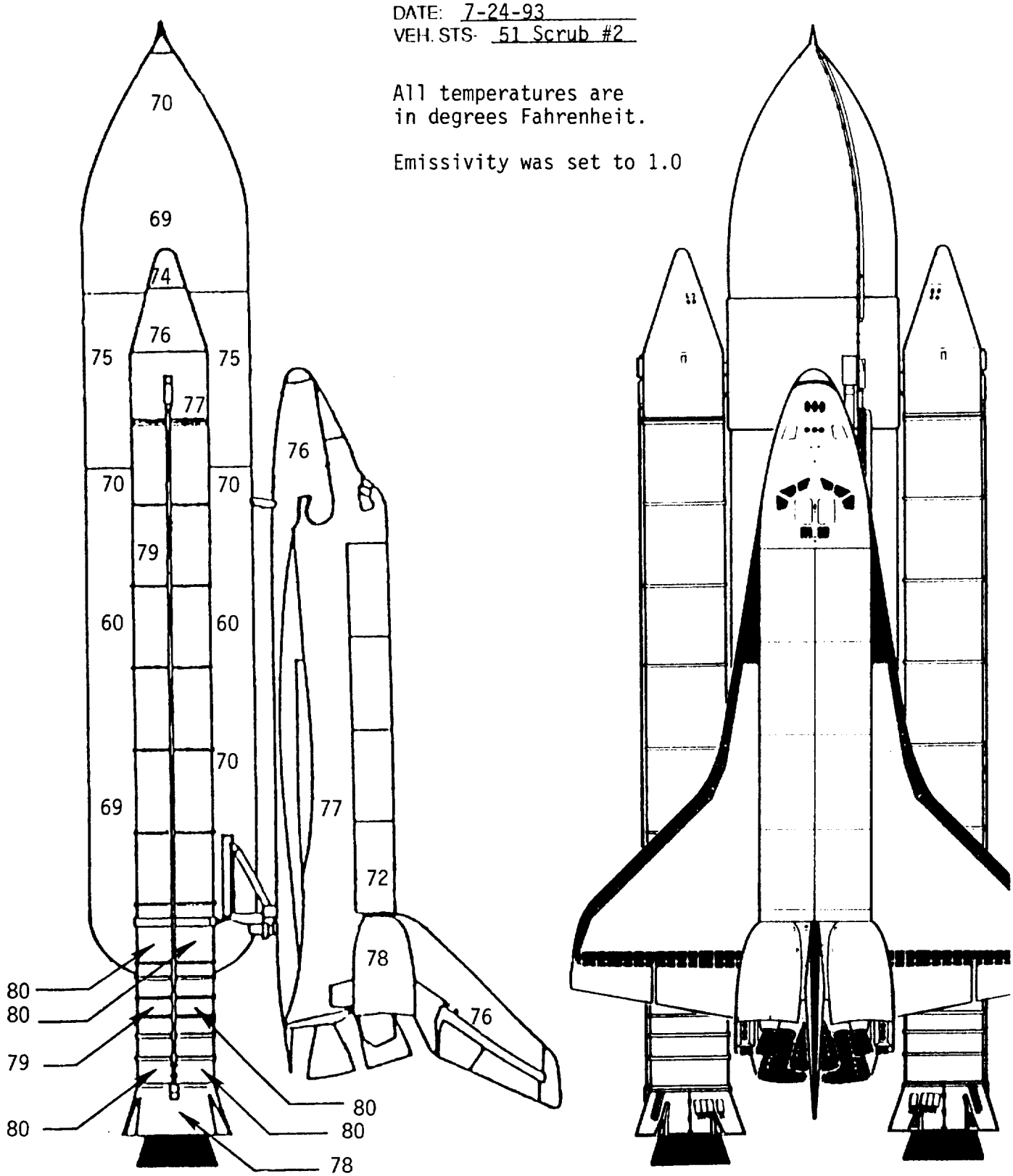
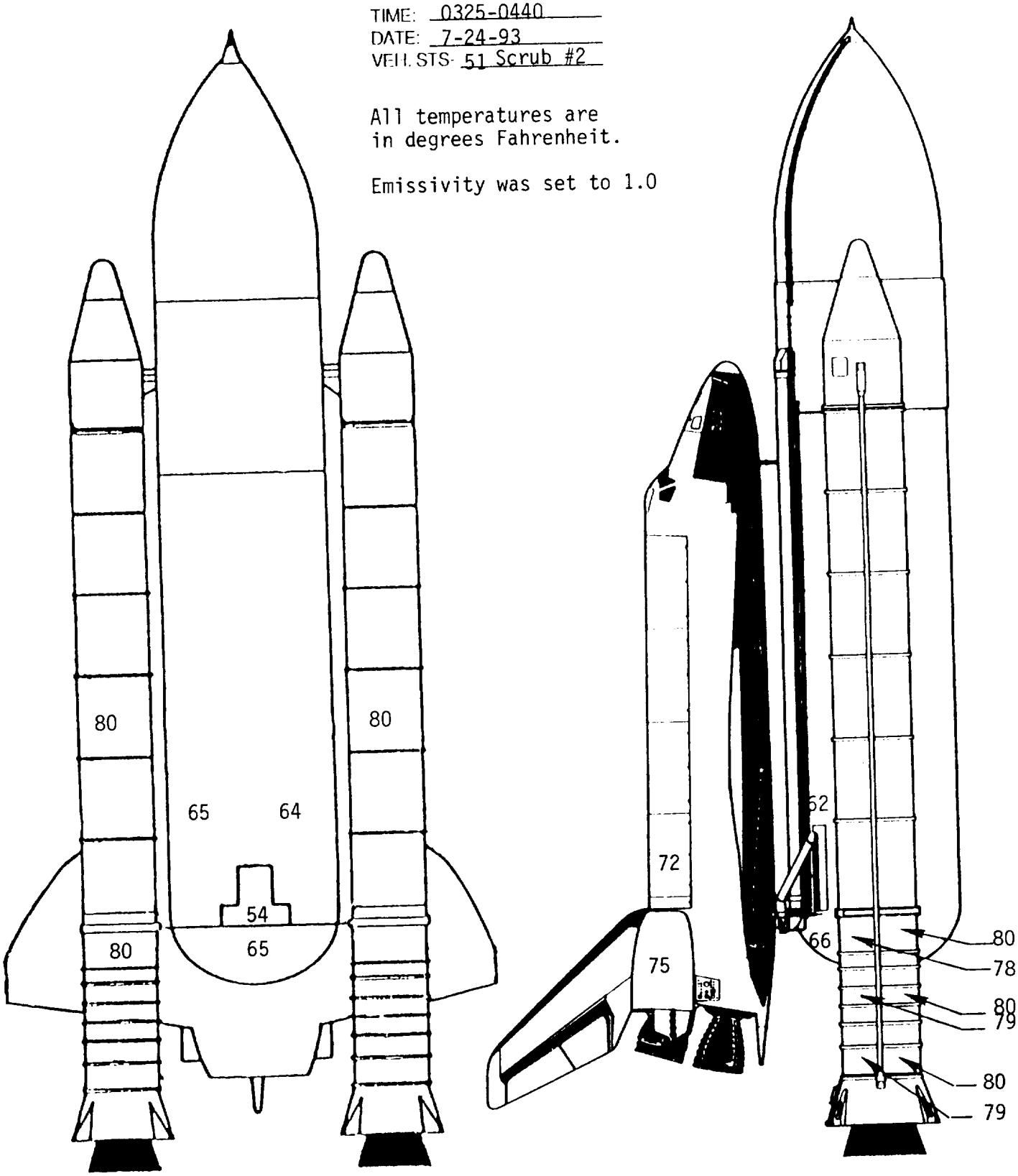


FIGURE 3. **SSV INFRARED SCANNER SURFACE TEMPERATURE SUMMARY DATA**

TIME: 0325-0440
DATE: 7-24-93
VEH. STS- 51 Scrub #2

All temperatures are in degrees Fahrenheit.

Emissivity was set to 1.0



EGG/V 343C

All measured temperatures were above the 34 degrees F minimum requirement. The predicted Propellant Mean Bulk Temperature (PMBT) supplied by MTI was 84 degrees F, which was within the required range of 44-86 degrees F.

4.4 EXTERNAL TANK

The ice/frost prediction computer program 'SURFICE' was run from 0030 to 0915 hours and the results tabulated in Figure 4. 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 barrel. There were no TPS anomalies. The tumble valve cover was intact. The portable STI measured surface temperatures that averaged 70 degrees F on the ogive and 69 degrees F on the barrel section. In comparison, the Cyclops radiometer measured temperatures that averaged 70 degrees F on the ogive and 69 degrees F on the barrel; SURFICE predicted temperatures of 62 degrees F on the ogive and 58 degrees F on the barrel.

The intertank acreage TPS was dry. No frost spots appeared in the stringer valleys at the LH2 and LO2 tank-to-intertank flanges. Less than usual ice/frost accumulations and no unusual vapors were present on the ET umbilical carrier plate. The portable STI measured an average surface temperature of 76 degrees F on the intertank.

There were no LH2 tank TPS acreage anomalies. Light condensate, but no ice or frost, was present on the acreage and aft dome. The portable STI measured surface temperatures that averaged 69 degrees F on the upper LH2 tank and 64 degrees F on the lower LH2 tank. In comparison, the Cyclops radiometer measured temperatures that averaged 67 degrees F on the upper and 65 degrees F on the lower LH2 tank, respectively; SURFICE predicted temperatures of 53 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. Two cracks, 8-inches long by 3/8-inch wide and 4-inches long by 1/4-inch wide, were present in the -Y vertical strut cable tray forward surface TPS near the longeron closeout interface. These cracks exhibited no offset and were not filled with ice or frost. This condition was expected due to the elimination of the stress relief gap at the factory.

An ice/frost ball had formed on the aft edge of the XT-1270.2 pressurization line ramp. An ice/frost formation appeared on the aft edge of the +Y vertical strut closeout.

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

STS- 51	TEST S0007 Scrub - RH SRB Tilt HPU (#2) Failure														DATE: 24 July 1993					T-0 TIME: DATE:				NASA KSC Ice/Frost/Debris Team
ORBITER 103	ET 59	SRB BI-060	MLP 3	PAD B	LO2 CHILLDOWN TIME: 00:33 SLOW FILL TIME: 00:58					FAST FILL TIME: 01:10 REPLENISH TIME: 03:11					LH2 CHILLDOWN TIME: 00:22 SLOW FILL TIME: 00:30					FAST FILL TIME: 01:15 REPLENISH TIME: 02:31				
TIME (EDT)	CONDITIONS					LO2 TANK STA 370 TO 540					LO2 TANK STA 550 TO 852					LH2 TANK STA 1130 TO 1380					LH2 TANK STA 1380 TO 2058				
	TEMP F	REL HUM. %	DEW PT F	WIND VEL KNTS	WIND DIR DEG	REG	LOCAL VEL KNTS	SOFI TEMP	COND RATE IN/HR	ICE RATE IN/HR	REG	LOCAL VEL KNTS	SOFI TEMP	COND RATE IN/HR	ICE RATE IN/HR	REG	LOCAL VEL KNTS	SOFI TEMP	COND RATE IN/HR	ICE RATE IN/HR	REG	LOCAL VEL KNTS	SOFI TEMP	COND RATE IN/HR	ICE RATE IN/HR
0030	78.80	83.4	73.61	4	184	II	2.36	66.12	0.0025	-0.1313	II	2.36	59.49	0.0041	-0.1013	II	1.68	54.68	0.0040	-0.0918	II	1.52	54.68	0.0040	-0.0918
0045	78.40	85.0	73.75	3	203	II	1.77	64.31	0.0024	-0.1217	II	1.77	56.37	0.0038	-0.0969	II	0.96	54.50	0.0040	-0.0910	II	4.08	63.45	0.0051	-0.1641
0100	77.80	85.2	73.23	3	241	II	1.77	63.65	0.0024	-0.1182	II	1.77	55.65	0.0037	-0.0934	II	0.96	53.80	0.0040	-0.0876	II	4.08	62.79	0.0051	-0.1597
0115	77.60	86.4	73.43	4	202	II	2.36	65.43	0.0026	-0.1280	II	2.36	58.73	0.0042	-0.0981	II	1.68	53.78	0.0040	-0.0876	II	1.52	53.78	0.0040	-0.0876
0130	77.60	85.8	73.23	5	217	II	3.54	67.47	0.0028	-0.1752	II	3.54	62.42	0.0046	-0.1441	II	1.92	54.86	0.0041	-0.0870	II	8.16	67.84	0.0054	-0.3128
0145	77.00	85.2	72.43	5	207	II	3.54	66.65	0.0027	-0.1699	II	3.54	61.56	0.0045	-0.1390	II	1.92	53.94	0.0041	-0.0828	II	8.16	66.83	0.0053	-0.3032
0200	77.20	84.4	72.36	5	216	II	2.95	65.75	0.0026	-0.1470	II	2.95	59.95	0.0043	-0.1167	II	1.60	52.99	0.0039	-0.0832	II	6.80	65.75	0.0052	-0.2542
0215	77.40	82.4	71.88	4	200	II	2.36	64.28	0.0024	-0.1224	II	2.36	57.51	0.0039	-0.0927	II	1.68	52.75	0.0038	-0.0824	II	1.52	52.75	0.0038	-0.0824
0230	77.00	81.8	71.28	5	194	II	2.95	64.92	0.0024	-0.1423	II	2.95	59.07	0.0041	-0.1122	II	2.10	54.19	0.0040	-0.0794	II	1.90	53.01	0.0038	-0.0794
0245	76.60	81.2	70.67	6	187	II	3.54	65.26	0.0024	-0.1610	II	3.54	60.10	0.0042	-0.1305	II	2.52	55.60	0.0041	-0.0875	II	2.28	54.48	0.0040	-0.0786
0300	75.80	82.2	70.23	5	201	II	2.95	63.66	0.0024	-0.1354	II	2.95	57.72	0.0040	-0.1056	II	2.10	52.76	0.0039	-0.0730	II	1.90	51.58	0.0038	-0.0730
0315	75.40	83.4	70.24	5	202	II	2.95	63.48	0.0025	-0.1345	II	2.95	57.53	0.0041	-0.1047	II	2.10	52.55	0.0039	-0.0718	II	1.90	51.35	0.0038	-0.0718
0330	75.00	84.8	70.32	4	227	II	2.36	62.06	0.0025	-0.1120	II	2.36	55.12	0.0039	-0.0827	II	1.28	50.24	0.0037	-0.0709	II	5.44	61.79	0.0050	-0.1850
0345	75.20	85.6	70.78	5	193	II	2.95	63.76	0.0026	-0.1361	II	2.95	57.81	0.0042	-0.1061	II	2.10	52.81	0.0041	-0.0727	II	1.90	51.60	0.0039	-0.0727
0400	74.60	86.4	70.45	4	225	II	2.36	61.95	0.0025	-0.1115	II	2.36	55.00	0.0040	-0.0822	II	1.28	50.04	0.0036	-0.0701	II	5.44	61.72	0.0051	-0.1845
0415	75.00	85.2	70.45	4	226	II	2.36	62.15	0.0025	-0.1124	II	2.36	55.21	0.0039	-0.0831	II	1.28	50.31	0.0036	-0.0712	II	5.44	61.89	0.0050	-0.1858
0430	75.00	85.8	70.65	3	168	II	1.77	60.46	0.0023	-0.1023	II	1.77	52.22	0.0036	-0.0775	II	1.26	50.43	0.0036	-0.0718	II	1.14	50.43	0.0038	-0.0718
0445	75.00	86.2	70.78	4	197	II	2.36	62.37	0.0025	-0.1135	II	2.36	55.45	0.0040	-0.0841	II	1.68	50.50	0.0036	-0.0722	II	1.52	50.50	0.0038	-0.0722
0500	74.60	86.0	70.32	3	197	II	1.77	60.03	0.0023	-0.1002	II	1.77	51.75	0.0035	-0.0755	II	1.26	49.97	0.0038	-0.0697	II	1.14	49.97	0.0038	-0.0697
0515	74.60	86.8	70.58	4	222	II	2.36	62.04	0.0026	-0.1120	II	2.36	55.09	0.0040	-0.0826	II	1.28	50.12	0.0038	-0.0704	II	5.44	61.81	0.0052	-0.1853
0530	76.60	87.6	72.83	4	222	II	2.36	64.54	0.0027	-0.1237	II	2.36	57.77	0.0042	-0.0939	II	1.28	52.76	0.0040	-0.0828	II	5.44	64.31	0.0054	-0.2054
0545	74.60	88.2	71.03	3	200	II	1.77	60.50	0.0024	-0.1022	II	1.77	52.26	0.0037	-0.0775	II	1.26	50.38	0.0039	-0.0717	II	1.14	50.38	0.0039	-0.0717
0600	75.00	88.4	71.49	4	173	II	2.36	62.85	0.0027	-0.1158	II	2.36	55.96	0.0041	-0.0862	II	1.68	50.91	0.0039	-0.0742	II	1.52	50.91	0.0039	-0.0742
0615	74.60	88.6	71.16	4	170	II	2.36	62.43	0.0027	-0.1138	II	2.36	55.50	0.0041	-0.0843	II	1.68	50.45	0.0039	-0.0720	II	1.52	50.45	0.0039	-0.0720
0630	75.20	88.6	71.76	6	180	II	3.54	65.41	0.0029	-0.1621	II	3.54	60.23	0.0046	-0.1314	II	2.52	55.60	0.0045	-0.0877	II	2.28	54.47	0.0044	-0.0786
0645	75.20	88.4	71.69	5	188	II	2.95	64.39	0.0028	-0.1396	II	2.95	58.48	0.0044	-0.1094	II	2.10	53.45	0.0042	-0.0753	II	1.90	52.24	0.0041	-0.0753
0700	75.40	89.0	72.09	5	212	II	2.95	64.76	0.0028	-0.1416	II	2.95	58.87	0.0045	-0.1114	II	1.60	51.53	0.0040	-0.0771	II	6.80	64.86	0.0056	-0.2456
0715	75.80	89.4	72.61	4	221	II	2.36	64.00	0.0027	-0.1212	II	2.36	57.20	0.0042	-0.0915	II	1.28	52.11	0.0040	-0.0798	II	5.44	63.82	0.0055	-0.2014
0730	76.20	88.8	72.81	4	219	II	2.36	64.34	0.0027	-0.1228	II	2.36	57.56	0.0042	-0.0930	II	1.28	52.50	0.0040	-0.0816	II	5.44	64.14	0.0055	-0.2040
0745	76.40	89.0	73.08	4	218	II	2.36	64.62	0.0027	-0.1242	II	2.36	57.85	0.0043	-0.0943	II	1.28	52.78	0.0041	-0.0829	II	5.44	64.42	0.0055	-0.2063
0800	76.60	86.0	72.30	3	199	II	1.77	62.40	0.0024	-0.1118	II	1.77	54.31	0.0037	-0.0870	II	1.26	52.46	0.0039	-0.0812	II	1.14	52.46	0.0039	-0.0812
0815	78.20	81.4	72.33	6	200	II	3.54	67.08	0.0025	-0.1725	II	3.54	62.03	0.0043	-0.1417	II	2.52	57.63	0.0043	-0.0964	II	2.28	56.53	0.0042	-0.0870
0830	78.80	79.4	72.21	5	212	II	2.95	66.36	0.0023	-0.1503	II	2.95	60.62	0.0040	-0.1200	II	1.60	53.86	0.0037	-0.0875	II	6.80	66.25	0.0047	-0.2588
0845	79.40	77.2	72.01	5	212	II	2.95	66.49	0.0022	-0.1510	II	2.95	60.75	0.0039	-0.1207	II	1.60	54.14	0.0037	-0.0887	II	6.80	66.33	0.0045	-0.2594
0900	80.80	74.2	72.26	5	200	II	2.95	67.28	0.0020	-0.1554	II	2.95	61.62	0.0038	-0.1250	II	2.10	57.01	0.0038	-0.0936	II	1.90	55.90	0.0036	-0.0936
0915	81.60	70.4	71.56	7	198	II	4.13	68.63	0.0016	-0.2011	II	4.13	64.21	0.0036	-0.1598	II	2.94	60.29	0.0038	-0.1153	II	2.66	59.41	0.0037	-0.1073
AVG.	76.56	84.66	71.77	4.47	SSE		2.64	64.22				2.64	57.75				1.68	53.02				3.61	57.31		

Period of Ice Team Inspection

FIGURE 4. "SURFICE" Computer Predictions

There were no TPS anomalies on the LO2 ET/ORB umbilical. The purge barrier (baggie) was configured properly and was holding positive purge pressure. Some ice/frost had accumulated on the aft and inboard sides of the umbilical. Formation of ice/frost on the separation bolt pyrotechnic canister purge vents was typical. Ice/frost had formed on the bondline of the aft pyro canister closeout. Normal venting of nitrogen purge gas had occurred during tanking and stable replenish.

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

Less than usual amounts of ice/frost had accumulated on the top and outboard sides of the LH2 ET/ORB umbilical purge barrier. Ice/frost on the aft side was typical. Ice/frost fingers had formed on the pyro canister and plate gap purge vents. Ice/frost was present on the LH2 feedline support bracket near the forward outboard pyro canister and on the aft pyrotechnic canister closeout bondlines indicating thermal shorts. No unusual vapors or cryogenic drips had appeared during tanking and stable replenish.

The ET/ORB hydrogen detection sensor tygon tubing was in proper position prior to removal. The tubing was successfully removed from the vehicle without contacting Orbiter tiles.

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

Anomaly 001 documented two areas of ice/frost with venting vapors on the -Z manhole cover closeout. The ice/frost had melted prior to the T-3 hour hold.

Anomaly 002 documented two cracks in the -Y ET/SRB cable tray forward surface BX-250 between the vertical strut cable tray and the vertical strut attachment fitting fairing.

Anomaly 003 documented ice/frost formation with venting vapors on the +Z manhole cover closeout. The ice/frost had melted by the T-3 hour hold.

Anomaly 004 documented an ice/frost accumulation below the -Y ET/SRB cable tray at the lower edge of the longeron closeout.

Anomaly 005 documented an ice/frost accumulation at the aft edge of the +Y ET/SRB cable tray-to-acreage interface.

Anomaly 006 documented ice/frost on the aft side of the XT-1270 pressurization line ramp.

Anomaly 007 documented ice/frost at the LH2 feedline outboard support bracket-to-acreage interface near the forward outboard pyro canister.

Anomaly 008 documented an ice/frost formation on the -Y bipod ramp outboard side at the intertank splice closeout.

Anomaly 009 documented ice/frost on the aft side of the ET/ORB LH2 umbilical upper outboard pyro canister closeout.

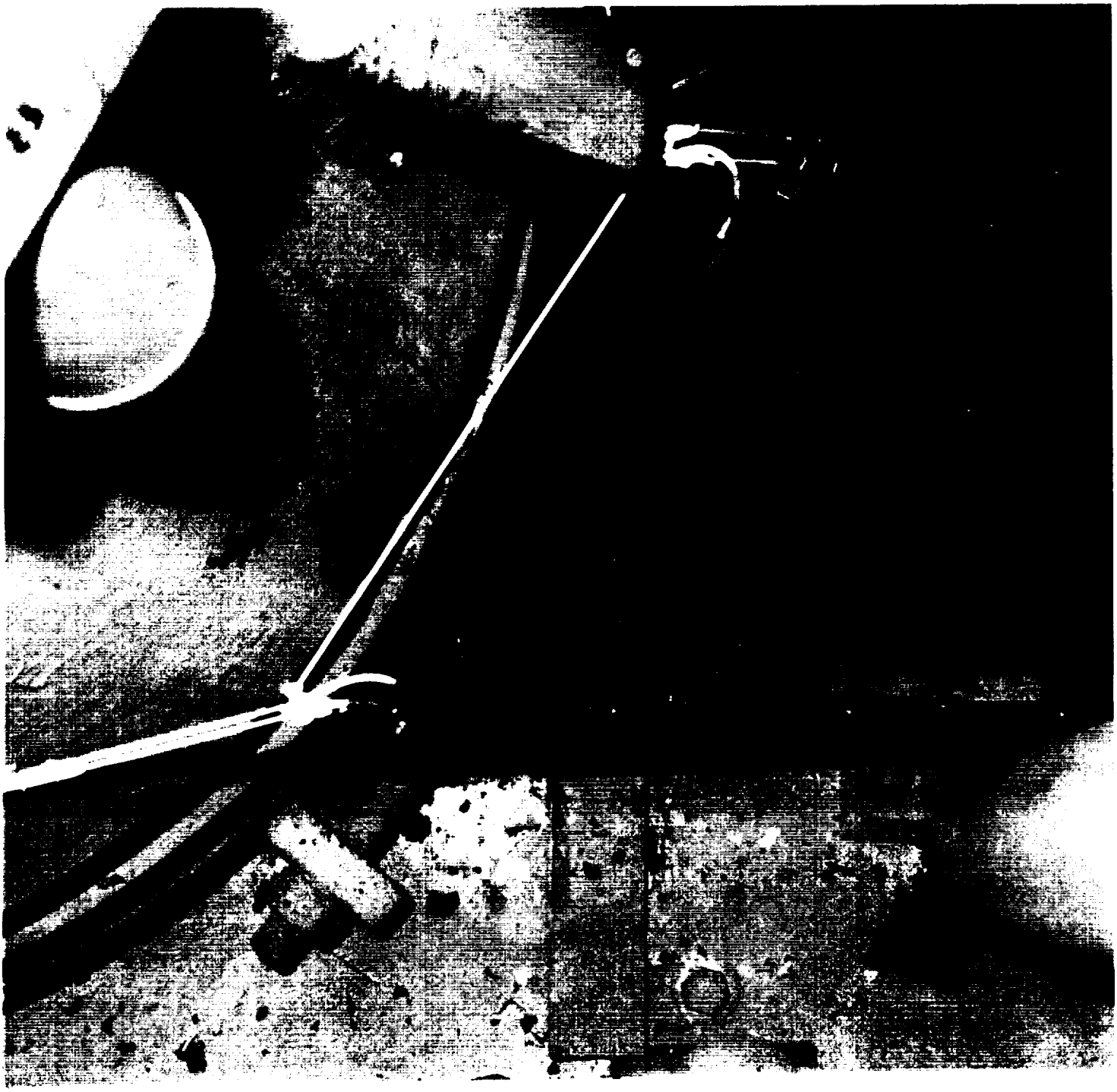
4.5 FACILITY

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

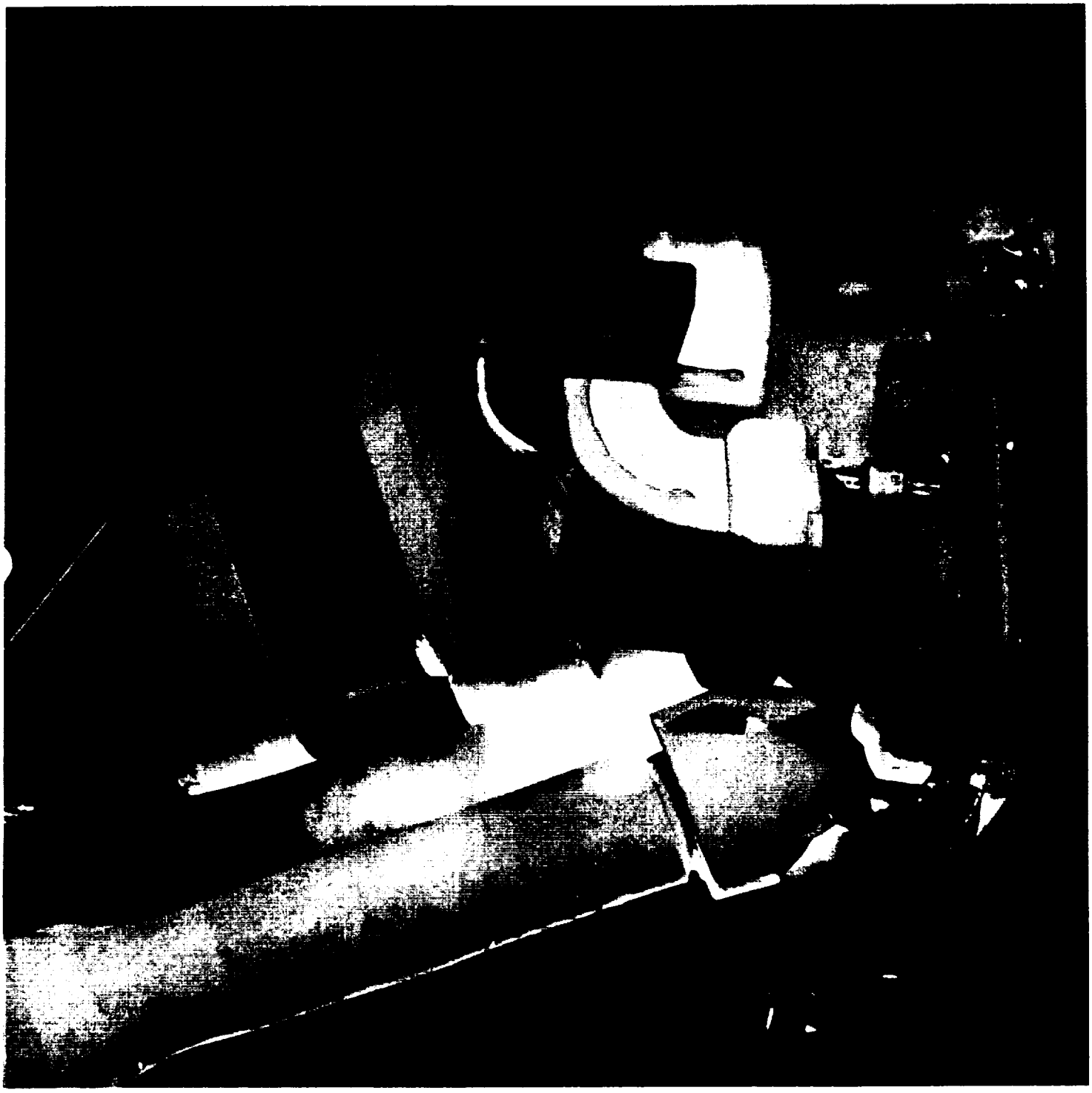
No leaks were observed on either the LO2 or LH2 Orbiter T-0 umbilicals. Typical accumulations of ice/frost were present on the cryogenic lines and purge shrouds.

There was no apparent hydrogen leakage anywhere on the GH2 vent line or GUCP. Some ice and frost, which was expected, had accumulated on the GUCP legs and on the uninsulated parts of the umbilical carrier plate.

Visual and infrared observations of the GOX seals confirmed no leakage. No ET nosecone/footprint damage was visible after the GOX vent hood was retracted.



Numerous K5NA trimmings, two of which measured 3 inches in length, lay in the HDP #1 and #2 haunch areas. Those trimmings, along with MLP deck debris particles, were removed prior to cryoloading.



Less than usual amounts of ice/frost had accumulated on the LH2 ET/ORB umbilical. No unusual vapors or cryogenic drips appeared during tanking and stable replenish.

4.6 POST DRAIN VEHICLE INSPECTION

The second launch attempt was scrubbed at T-19 seconds due to a problem with the RH SRB HPU #2 (Tilt). A post drain inspection of the vehicle was performed at Pad-39B from 1500 to 1530 hours on July 24, 1993.

The tumble valve cover on the External Tank was intact. All other areas of the nosecone were obscured by the GOX vent hood/seal.

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

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

Ice remained in the LO2 feedline support brackets, but no loose foam or TPS damage was visible during the preliminary post drain inspection. Subsequent hands-on inspection revealed damaged foam (11" x 4.5" in size) on the inboard side of the feedline adjacent to the XT-1377 support bracket. The area was repaired with PDL foam.

Two additional areas of damaged foam were found on the LO2 feedline support bracket and on the adjacent LH2 tank barrel CPR. The areas were evaluated and accepted by MRB to use-as-is.

The TPS defect on the +Y longeron BX-250 closeout, which was repaired prior to the second cryoload, was intact and showed no evidence of thermal short.

The 6-inch and 4-inch cracks in the -Y ET/SRB vertical strut cable tray forward surface TPS (reported during the Ice Team Inspection) were still visible. Ice/frost was observed in the 4-inch crack, a condition which must be assessed per the requirements in the NSTS 08303 criteria. Subsequent inspection revealed no debonds from substrate, so the condition was acceptable for flight.

Three ice/frost spots were present on the LH2 tank aft dome +Z manhole cover BX-250 closeout. One ice/frost spot occurred on the -Z manhole cover BX-250 closeout bondline.

No significant anomalies were observed on the Orbiter. All RCS thruster paper covers were intact, though the R2U and R3R covers appeared to be wetted by vapors inside the thruster.

There were no anomalies on the Solid Rocket Boosters or MLP.

No significant vehicle damage was observed during the post drain inspection. The LO2 feedline TPS damage was repaired on a PR. There were no constraints for the next cryoload.

5.0 ABORT - SSME #2 SENSOR FAILURE

A third pre-launch debris inspection of the SSV and MLP deck was conducted from 0915-1015 hours on 11 August 1993. Numerous bolts in MLP deck access covers near the RH SRB were loose. MLP deck debris particles were removed prior to cryoloading.

The third launch attempt of STS-51 was aborted at T-3 seconds due to a problem with an SSME #2 fuel flow sensor.

5.1 ICE/FROST INSPECTION

The Ice/Frost Inspection of the cryoloaded vehicle was performed on 11 August 1993 from 0340 to 0450 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:	77.4 Degrees F
Relative Humidity:	92.0 Percent
Wind Speed:	3.8 Knots
Wind Direction:	341 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 5 and 6.

5.2 ORBITER

No Orbiter RCC panel or TPS anomalies were observed. All RCS thruster paper covers were intact, though the R2U, R3R, and L2L thruster covers had been wetted by internal vapors. Less than usual ice/frost had formed on the SSME heat shield-to-nozzle interfaces. Some frost was present on the SSME #1 and #3 drain lines. The SSME engine mounted heat shields were wet from condensate. Tiles on the base heat shield were dry. An infrared scan revealed no unusual temperature gradients on the base heat shield or engine mounted heat shields. No unusual vapors originated from inside the SSME nozzles.

5.3 SOLID ROCKET BOOSTERS

No SRB anomalies or loose ablator/cork were observed. The STI portable infrared scanner recorded RH and LH SRB case temperatures between 77 to 81 degrees Fahrenheit (F). In comparison, temperatures measured by a hand-held Minolta/Land Cyclops spot radiometer ranged from 78 to 81 degrees F and the SRB Ground Environment Instrumentation (GEI) measured temperatures of 78-82 degrees F.

FIGURE 5. SSV INFRARED SCANNER SURFACE TEMPERATURE SUMMARY DATA

TIME: 0340-0450
DATE: 8-12-93
VEHICLE: 51

All temperatures are in degrees Fahrenheit

Emissivity was set to 1.0

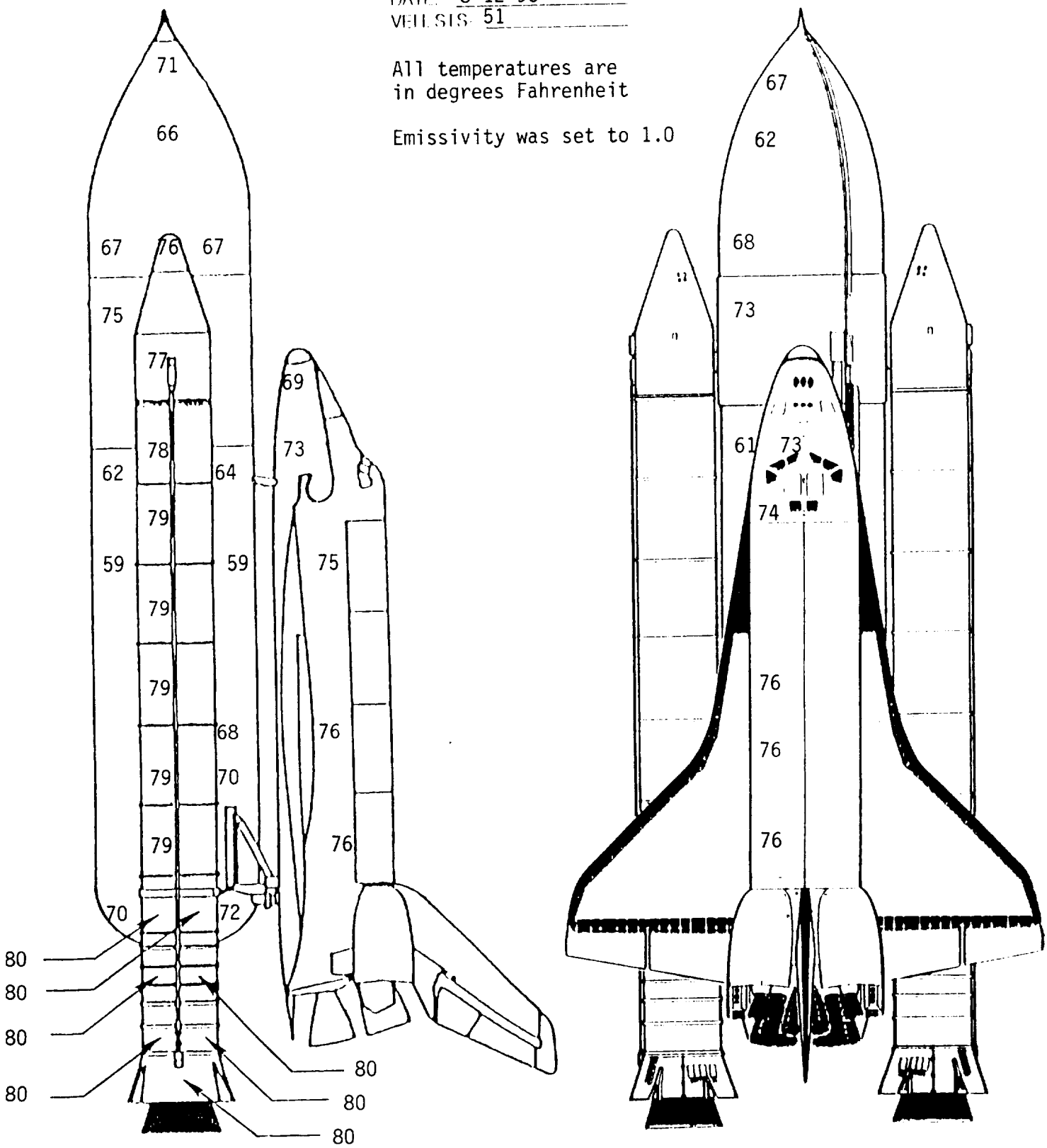
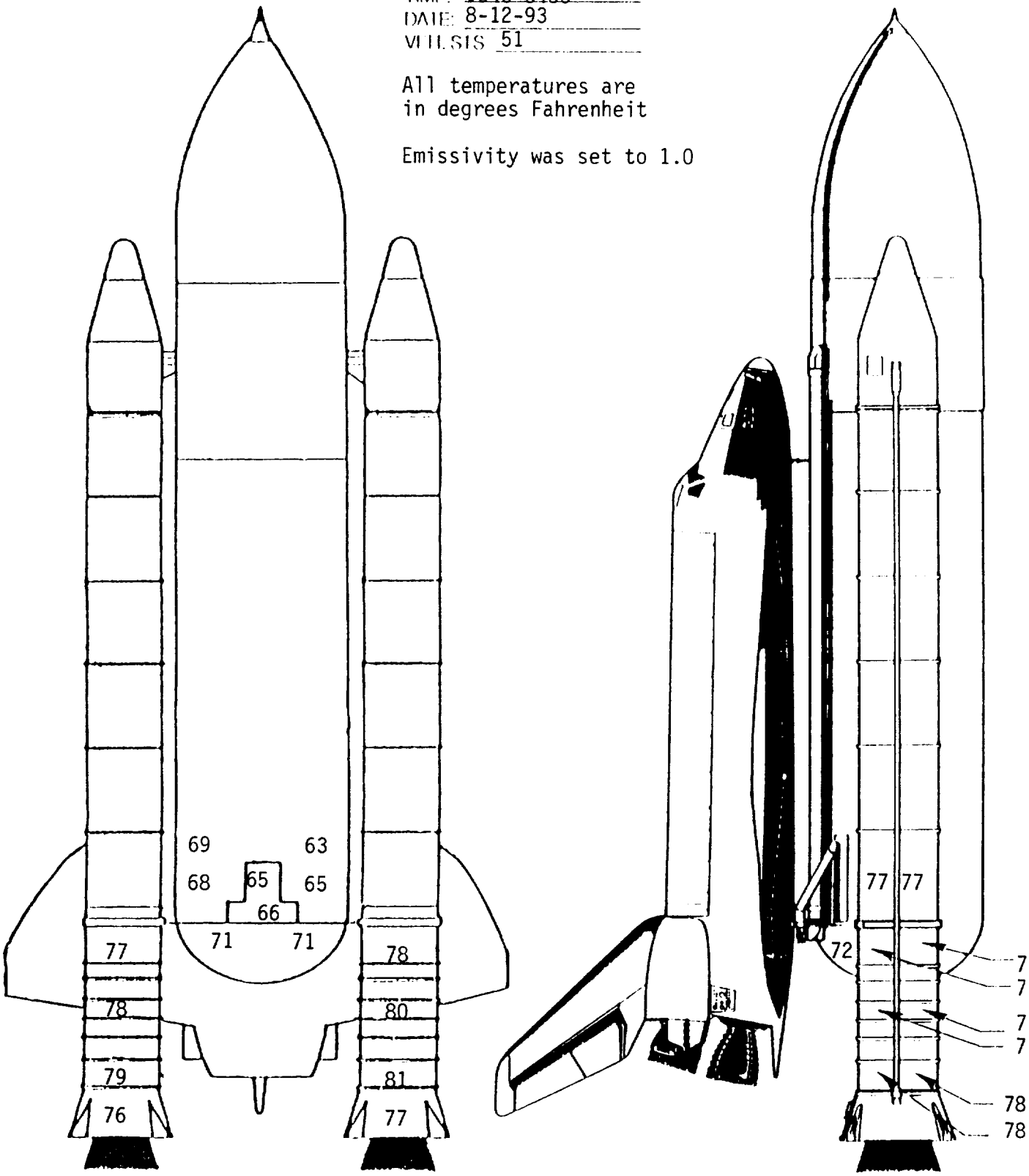


FIGURE 6. **SSV INFRARED SCANNER SURFACE TEMPERATURE SUMMARY DATA**

TIME: 0340-0450
DATE: 8-12-93
VEHICLE: 51

All temperatures are in degrees Fahrenheit

Emissivity was set to 1.0



All measured temperatures were above the 34 degrees F minimum requirement. The predicted Propellant Mean Bulk Temperature (PMBT) supplied by MTI was 85 degrees F, which was within the required range of 44-86 degrees F.

5.4 EXTERNAL TANK

The ice/frost prediction computer program 'SURFICE' was run from 0030 to 0830 hours and the results tabulated in Figure 7. 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 barrel. There were no TPS anomalies. The tumble valve cover was intact. The portable STI measured surface temperatures that averaged 71 degrees F on the ogive and 67 degrees F on the barrel section. In comparison, the Cyclops radiometer measured temperatures that averaged 73 degrees F on the ogive and 69 degrees F on the barrel; SURFICE predicted temperatures of 65 degrees F on the ogive and 57 degrees F on the barrel.

The intertank acreage TPS was dry. No frost spots appeared in the stringer valleys at the LH2 and LO2 tank-to-intertank flanges. Typical ice/frost accumulations and no unusual vapors were present on the ET umbilical carrier plate. The portable STI measured an average surface temperature of 75 degrees F on the intertank.

There were no LH2 tank TPS acreage anomalies. Light condensate, but no ice or frost, was present on the acreage and aft dome. The portable STI measured surface temperatures that averaged 60 degrees F on the upper LH2 tank and 68 degrees F on the lower LH2 tank. In comparison, the Cyclops radiometer measured temperatures that averaged 61 degrees F on the upper and 67 degrees F on the lower LH2 tank, respectively; SURFICE predicted temperatures of 55 degrees F on the upper LH2 tank and 61 degrees F on the lower LH2 tank.

There were no anomalies on the bipod jack pad closeouts. A frost spot appeared on a repair in the LH2 tank-to-intertank flange closeout near the -Y ET/SRB attach fitting. Three frost spots had formed on the -Y bipod ramp to acreage bondlines. Two cracks, 8-inches long by 3/8-inch wide and 4-inches long by 1/4-inch wide, were again present in the -Y vertical strut cable tray forward surface TPS. These cracks exhibited no offset and were not filled with ice or frost. This condition was expected due to the elimination of the stress relief gap at the factory.

Ice/frost had formed on the pressurization line ramp aft edges-to-acreage bondlines at stations XT-1334, 1399, 1464, 1528, and 1593.

STS- 51	TEST S0007 Abort - SSME #2 Fuel Flow Sensor																DATE: 12 August 1993					T-0 TIME: DATE:				NASA KSC Ice/Frost/Debris Team
ORBITER 103	ET 59	SRB BI-060	MLP 3	PAD B	LO2 CHILLDOWN TIME: 00:16 SLOW FILL TIME: 01:04						FAST FILL TIME: 01:17 REPLENISH TIME: 03:23					LH2 CHILLDOWN TIME: 00:16 SLOW FILL TIME: 00:36					FAST FILL TIME: 01:22 REPLENISH TIME: 03:14					
TIME (EDT)	CONDITIONS					LO2 TANK STA 370 TO 540					LO2 TANK STA 550 TO 852					LH2 TANK STA 1130 TO 1380					LH2 TANK STA 1380 TO 2058				
	TEMP F	REL HUM. %	DEW PT F	WIND VEL KNTS	WIND DIR DEG	REG	LOCAL VEL KNTS	SOFI TEMP	COND RATE IN/HR	ICE RATE IN/HR	REG	LOCAL VEL KNTS	SOFI TEMP	COND RATE IN/HR	ICE RATE IN/HR	REG	LOCAL VEL KNTS	SOFI TEMP	COND RATE IN/HR	ICE RATE IN/HR	REG	LOCAL VEL KNTS	SOFI TEMP	COND RATE IN/HR	ICE RATE IN/HR
0030	79.20	85.6	74.75	4	20	II	2.36	67.09	0.0027	-0.1363	II	2.36	60.52	0.0043	-0.1060	II	1.76	55.84	0.0041	-0.0966	II	3.96	64.29	0.0052	-0.1665
0045	79.00	86.0	74.68	4	33	II	2.36	66.95	0.0027	-0.1356	II	2.36	60.38	0.0043	-0.1054	II	2.80	60.86	0.0048	-0.1180	II	4.84	65.80	0.0054	-0.2012
0100	79.20	86.0	74.88	4	24	II	2.36	67.18	0.0027	-0.1367	II	2.36	60.63	0.0043	-0.1065	II	2.80	61.11	0.0048	-0.1192	II	4.84	66.04	0.0054	-0.2030
0115	79.20	85.8	74.81	3	26	II	1.77	65.43	0.0025	-0.1276	II	1.77	57.58	0.0039	-0.1027	II	2.10	57.96	0.0044	-0.0968	II	3.63	63.57	0.0051	-0.1534
0130	78.60	86.9	74.58	1	35	II	0.59	63.27	0.0023	-0.1250	II	0.59	56.52	0.0038	-0.1001	II	0.70	55.13	0.0041	-0.0943	II	1.21	55.13	0.0041	-0.0943
0145	78.40	86.4	74.22	1	339	II	0.59	62.94	0.0023	-0.1232	II	0.59	56.17	0.0038	-0.0984	II	0.44	54.79	0.0041	-0.0925	II	0.99	54.79	0.0041	-0.0925
0200	78.20	87.2	74.28	2	29	II	1.18	62.85	0.0023	-0.1228	II	1.18	56.08	0.0038	-0.0980	II	1.40	54.69	0.0041	-0.0921	II	2.42	58.60	0.0046	-0.0989
0215	78.40	88.2	74.81	3	45	II	1.77	65.02	0.0026	-0.1251	II	1.77	57.12	0.0040	-0.1003	II	2.10	57.51	0.0045	-0.0944	II	3.63	63.21	0.0053	-0.1512
0230	78.60	87.2	74.68	3	20	II	1.77	65.04	0.0026	-0.1253	II	1.77	57.14	0.0039	-0.1005	II	1.32	55.19	0.0041	-0.0946	II	2.97	61.26	0.0049	-0.1241
0245	78.00	88.6	74.54	3	316	II	1.77	64.64	0.0026	-0.1231	II	1.77	56.70	0.0040	-0.0982	II	1.38	54.71	0.0042	-0.0923	II	3.69	62.97	0.0053	-0.1513
0300	77.90	89.3	74.66	3	332	II	1.77	64.67	0.0026	-0.1232	II	1.77	56.74	0.0040	-0.0983	II	1.38	54.72	0.0042	-0.0924	II	3.69	63.02	0.0053	-0.1517
0315	77.80	90.0	74.79	3	336	II	1.77	64.71	0.0027	-0.1233	II	1.77	56.78	0.0040	-0.0984	II	1.38	54.73	0.0042	-0.0925	II	3.69	63.07	0.0054	-0.1520
0330	77.70	90.2	74.75	4	355	II	2.36	66.41	0.0029	-0.1329	II	2.36	59.76	0.0045	-0.1027	II	1.76	54.98	0.0043	-0.0921	II	3.96	63.64	0.0055	-0.1624
0345	77.90	89.7	74.79	4	358	II	2.36	66.53	0.0028	-0.1335	II	2.36	59.90	0.0044	-0.1033	II	1.76	55.12	0.0043	-0.0926	II	3.96	63.76	0.0054	-0.1632
0400	77.50	90.0	74.49	4	341	II	2.36	66.13	0.0028	-0.1315	II	2.36	59.47	0.0044	-0.1014	II	1.76	54.67	0.0042	-0.0906	II	3.96	63.35	0.0054	-0.1606
0415	77.00	91.0	74.31	3	354	II	1.77	63.97	0.0027	-0.1193	II	1.77	56.97	0.0040	-0.0944	II	1.32	53.91	0.0042	-0.0885	II	2.97	60.20	0.0061	-0.1187
0430	77.80	92.0	75.41	3	340	II	1.77	65.14	0.0028	-0.1254	II	1.77	57.23	0.0041	-0.1006	II	1.32	55.10	0.0043	-0.0945	II	2.97	61.44	0.0062	-0.1251
0445	77.00	94.4	75.35	3	329	II	1.77	64.69	0.0028	-0.1228	II	1.77	56.74	0.0042	-0.0978	II	1.38	54.54	0.0044	-0.0913	II	3.69	63.15	0.0057	-0.1526
0500	77.00	95.0	75.53	6	322	II	3.54	68.88	0.0034	-0.1949	II	3.54	63.91	0.0053	-0.1533	II	2.76	60.37	0.0053	-0.1148	II	7.38	68.61	0.0065	-0.3016
0515	76.00	94.1	74.26	3	306	II	1.77	63.42	0.0028	-0.1162	II	1.77	55.37	0.0041	-0.0913	II	1.38	53.22	0.0043	-0.0854	II	3.69	61.86	0.0055	-0.1447
0530	76.50	94.4	74.85	1	321	II	0.59	62.11	0.0026	-0.1196	II	0.59	55.32	0.0040	-0.0947	II	0.46	53.91	0.0043	-0.0888	II	1.23	53.91	0.0043	-0.0888
0545	74.80	95.6	73.52	2	255	II	1.18	60.28	0.0025	-0.1103	II	1.18	53.40	0.0040	-0.0854	II	0.86	51.97	0.0043	-0.0795	II	2.42	56.23	0.0049	-0.0887
0600	76.20	96.4	75.15	1	300	II	0.59	62.09	0.0026	-0.1197	II	0.59	55.31	0.0041	-0.0948	II	0.46	53.89	0.0044	-0.0888	II	1.23	53.89	0.0044	-0.0888
0615	76.20	96.8	75.27	3	265	II	1.77	64.24	0.0029	-0.1201	II	1.77	56.21	0.0043	-0.0952	II	1.29	53.96	0.0044	-0.0892	II	3.63	62.58	0.0057	-0.1477
0630	74.80	97.8	74.17	3	238	II	1.77	62.74	0.0029	-0.1124	II	1.77	54.62	0.0042	-0.0874	II	0.96	52.35	0.0044	-0.0815	II	4.08	62.18	0.0059	-0.1562
0645	74.30	98.0	73.72	6	257	II	3.54	66.44	0.0035	-0.1689	II	3.54	61.3	0.0053	-0.1378	II	2.58	56.86	0.0051	-0.0946	II	7.26	66.12	0.0065	-0.2712
0700	76.00	98.9	75.68	6	290	II	3.54	68.59	0.0036	-0.1830	II	3.54	63.58	0.0055	-0.1514	II	2.58	59.24	0.0053	-0.1055	II	7.26	68.27	0.0068	-0.2944
0715	77.00	99.1	76.74	4	296	II	2.36	67.52	0.0033	-0.1387	II	2.36	60.93	0.0050	-0.1081	II	1.84	56.61	0.0048	-0.0965	II	4.92	66.74	0.0065	-0.2114
0730	76.80	99.2	76.57	4	296	II	2.36	67.31	0.0033	-0.1376	II	2.36	60.70	0.0049	-0.1071	II	1.84	56.37	0.0048	-0.0953	II	4.92	66.52	0.0064	-0.2096
0745	76.40	98.4	75.94	4	298	II	2.36	66.66	0.0033	-0.1344	II	2.36	60.01	0.0049	-0.1039	II	1.84	55.66	0.0047	-0.0920	II	4.92	65.86	0.0063	-0.2044
0800	76.60	97.8	75.96	3	289	II	1.77	64.93	0.0030	-0.1237	II	1.77	56.95	0.0044	-0.0987	II	1.29	54.64	0.0045	-0.0927	II	3.63	63.30	0.0059	-0.1521
0815	76.20	96.4	75.15	4	300	II	2.36	66.00	0.0031	-0.1310	II	2.36	59.30	0.0047	-0.1008	II	1.84	54.96	0.0046	-0.0888	II	4.92	65.16	0.0061	-0.1988
0830	77.20	94.8	75.67	4	287	II	2.36	66.84	0.0031	-0.1352	II	2.36	60.20	0.0047	-0.1048	II	1.72	55.08	0.0045	-0.0935	II	4.84	65.84	0.0061	-0.2018
0845	78.40	90.2	75.45	6	315	II	3.54	69.39	0.0031	-0.1881	II	3.54	64.45	0.0050	-0.1565	II	2.76	60.99	0.0051	-0.1178	II	7.38	69.04	0.0060	-0.3061
0900	78.40	87.2	74.48	9	320	II	5.31	70.44	0.0029	-0.2554	II	5.31	66.82	0.0051	-0.2226	II	4.14	64.13	0.0053	-0.1702	II	11.07	70.37	0.0056	-0.4388
AVG.	77.32	92.13	74.94	3.54	W-NNE		2.09	65.44				2.09	58.57				1.70	55.99				4.17	62.96		

Period of Ice Team Inspection

FIGURE 7. "SURFICE" Computer Predictions

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. The purge barrier (baggie) was configured properly and was holding positive purge pressure. Some ice/frost had accumulated on the aft and inboard sides of the umbilical. Formation of ice/frost on the separation bolt pyrotechnic canister purge vents was typical. Normal venting of nitrogen purge gas had occurred during tanking and stable replenish.

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

Less than usual amounts of ice/frost had accumulated on the top and outboard sides of the LH2 ET/ORB umbilical purge barrier. Ice/frost on the aft side was typical. Ice/frost fingers had formed on the pyro canister and plate gap purge vents. Ice/frost was present on the LH2 feedline support bracket near the forward outboard pyro canister and on the aft pyrotechnic canister closeout bondlines indicating thermal shorts. No unusual vapors or cryogenic drips had appeared during tanking and stable replenish.

The ET/ORB hydrogen detection sensor tygon tubing was in proper position prior to removal. The tubing was successfully removed from the vehicle without contacting Orbiter tiles.

The summary of Ice/Frost Team observations/anomalies, which were acceptable for launch per the NSTS-08303 criteria, consisted of 11 OTV recorded items:

Anomaly 001 documented an ice/frost formation at the interface of the LH2 feedline and outboard support bracket.

Anomaly 002 documented an ice/frost formation with venting vapor on the +Y side of the -Z manhole cover closeout. The ice and frost had melted by T-3 hours.

Anomaly 003 documented ice/frost formation on the -Y longeron closeout approximately 2 inches forward of the ET/SRB cable tray.

Anomaly 004 documented two cracks in the -Y ET/SRB cable tray forward surface BX-250 near the longeron closeout.

Anomaly 005 documented an ice/frost formation with venting vapor on the +Y side of the +Z manhole cover closeout. The ice and frost had melted by T-3 hours.

Anomaly 006 documented ice/frost accumulations on the aft side of the GH2/GO2 pressurization line ramps at stations XT-1205, 1270, 1334, 1464, and 1722.

Anomaly 007 documented 3 frost formations along the outboard and aft edge of the -Y bipod ramp to acreage interface.

Anomaly 008 documented a frost formation on the +Y longeron closeout approximately 2 feet aft of the thrust strut knuckle-to-longeron interface.

Anomaly 009 documented an ice/frost formation on a factory repair located in the LH2 tank-to-intertank flange closeout (-Y+Z quadrant).

Anomaly 010 documented an ice/frost accumulation with venting vapors on the +Y side of the LH2 recirculation line during drain.

Anomaly 011 documented a crack (knitline separation) on the forward side of the +Y vertical strut electrical feed-through box closeout. The crack, detected during the post drain walk down, was located on the bevel +Z side of the closeout.

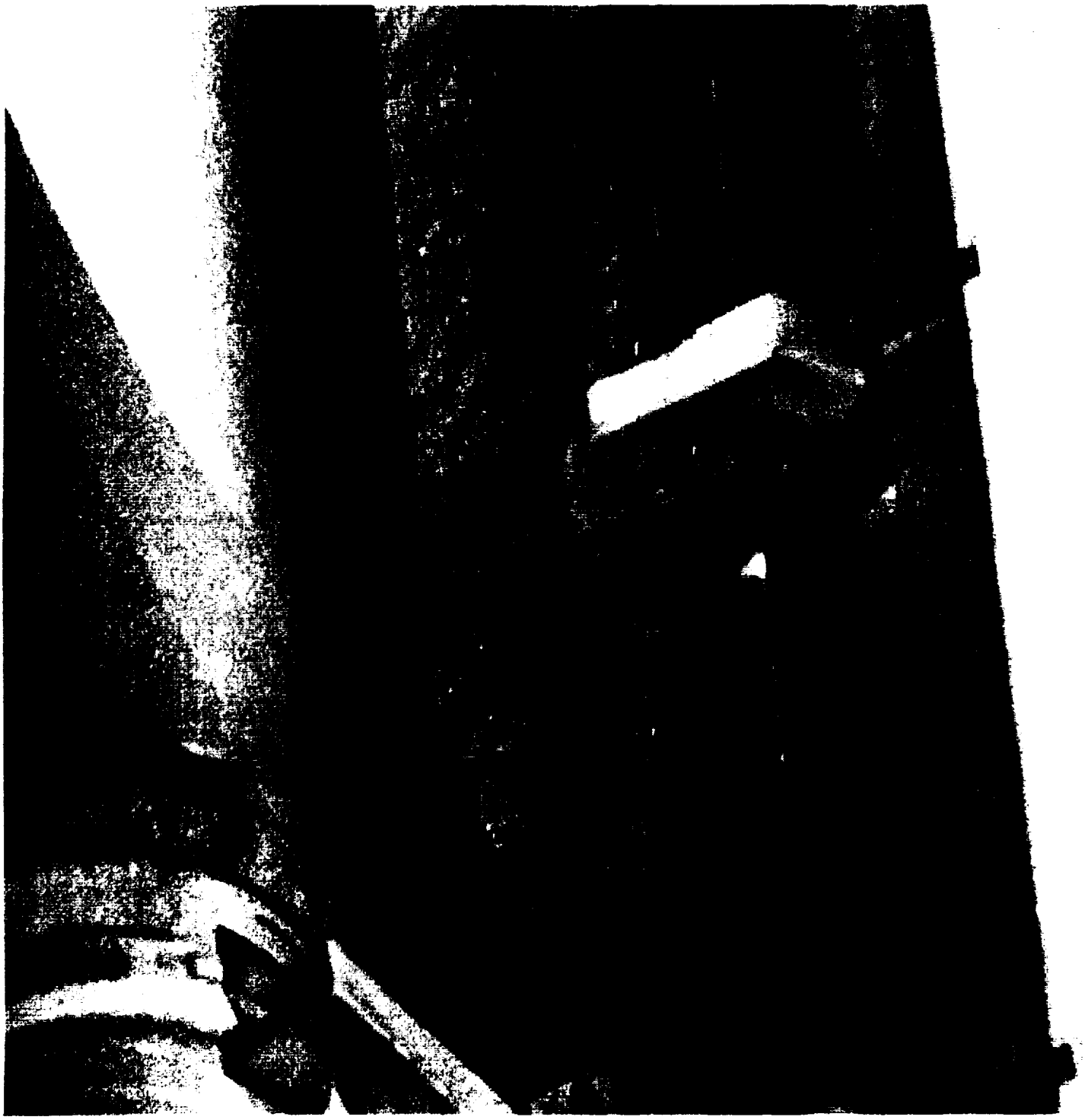
5.5 FACILITY

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

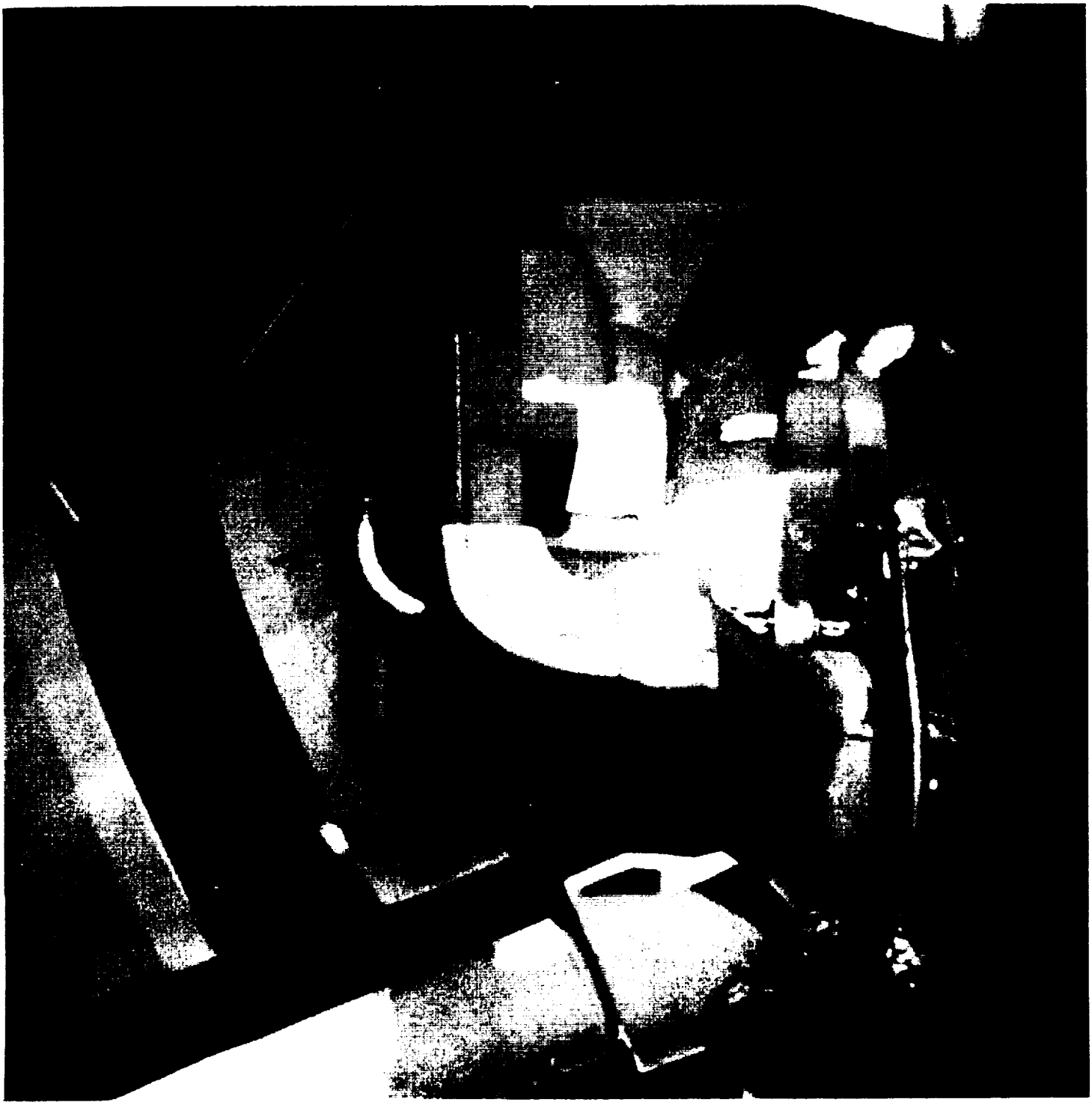
No leaks were observed on either the LO2 or LH2 Orbiter T-0 umbilicals. Typical accumulations of ice/frost were present on the cryogenic lines and purge shrouds.

There was no apparent hydrogen leakage anywhere on the GH2 vent line or GUCP. Some ice and frost, which was expected, had accumulated on the GUCP legs and on the uninsulated parts of the umbilical carrier plate.

Visual and infrared observations of the GOX seals confirmed no leakage. No ET nosecone/footprint damage was visible after the GOX vent hood was retracted.



Ice and frost had formed on the pressurization line ramp aft edges-to-acreage bondlines at stations XT-1334, 1399, 1464, 1528, and 1593.



Less than usual amounts of ice/frost had formed on the ET/ORB LH2 umbilical. Some ice/frost was present on the LH2 feedline support bracket near the forward outboard pyro canister bondline indicating a thermal short. No cryogenic drips or unusual vapors appeared during tanking and stable replenish.

5.6 POST DRAIN VEHICLE INSPECTION

The launch of STS-51 was aborted at T-3 seconds due to a problem with an SSME #2 fuel flow sensor. A post drain inspection of the vehicle was performed at Pad-39B from 1520 to 1615 hours on 12 August 1993.

The tumble valve cover on the External Tank was intact. There were seven shallow scratches in the nosecone footprint area topcoat. There appeared to be two scratches on the -Y side of the nosecone possibly exposing the SLA.

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

Some ice remained in the LO2 feedline support brackets, but no loose foam or TPS cracks were visible.

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

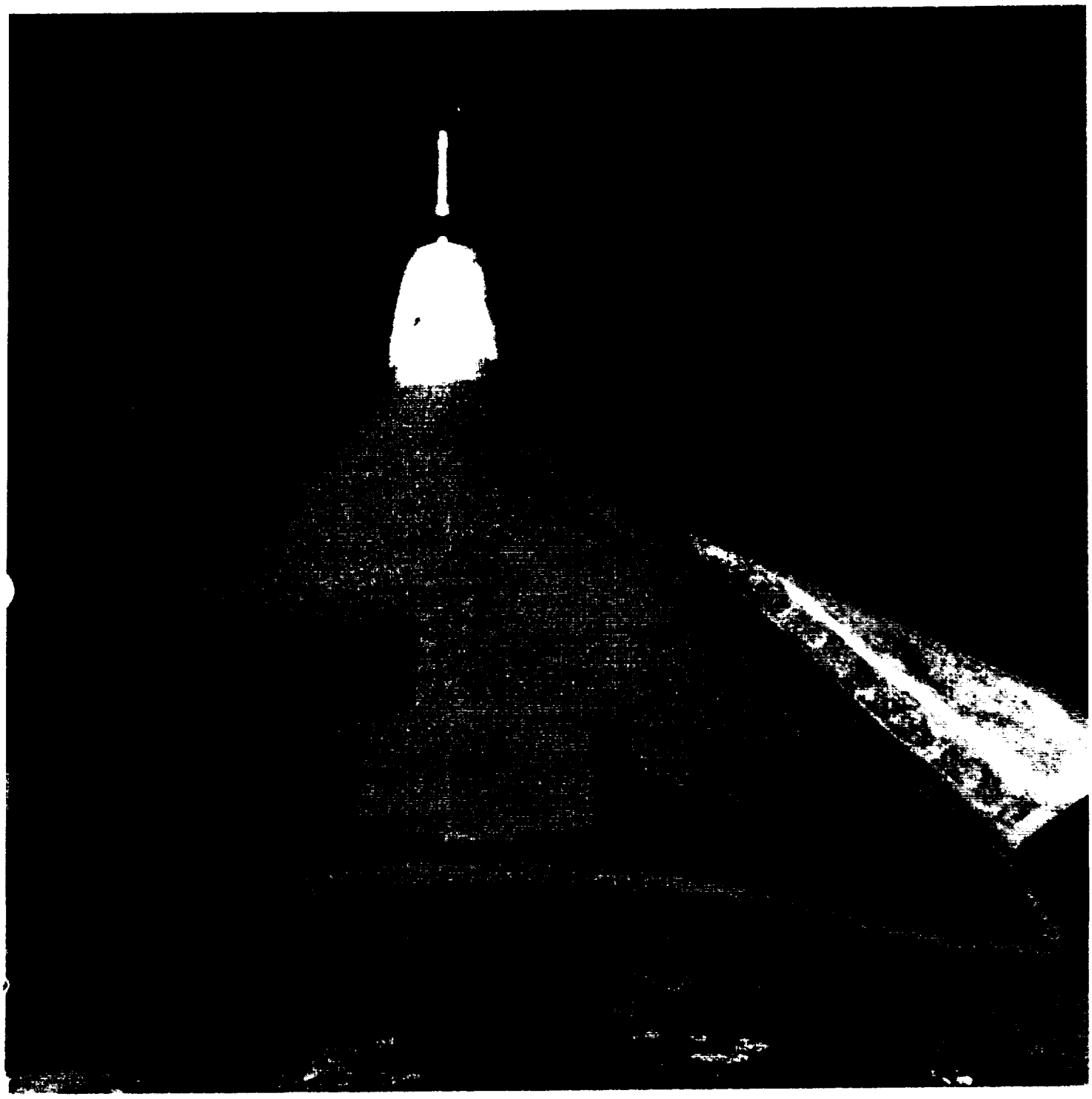
The 6-inch and 4-inch cracks in the -Y ET/SRB vertical strut cable tray forward surface TPS (observed during the two previous cryogenic loadings) were still visible but had not changed.

No obvious TPS damage was visible on the LH2 recirculation line, the -Y thrust strut-to-longeron interface, or the -Y bipod ramp closeout aft edge where small areas of ice/frost had formed during drain.

The SSME abort, and resulting free burning hydrogen fire, as well as the use of FIREX water caused no significant TPS damage on the Orbiter. Numerous 1/4 - 1/2 inch diameter damage sites were visible on the base heat shield tiles. Some of the AFRSI blankets on the -Z side of the aft RCS stingers appeared to be discolored. The ET/ORB LH2 and LO2 umbilical purge barrier baggies were torn in several locations. A small piece of foil-like insulation was loose on SSME #1.

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

No significant vehicle damage was observed during the preliminary external post drain inspection. No IPR's were generated as a result of this inspection.



Post drain inspection revealed seven shallow scratches in the nosecone footprint area topcoat. There appeared to be two scratches on the -Y side of the nosecone possibly exposing the SLA.

5.7 ABORT FILM/VIDEO REVIEW

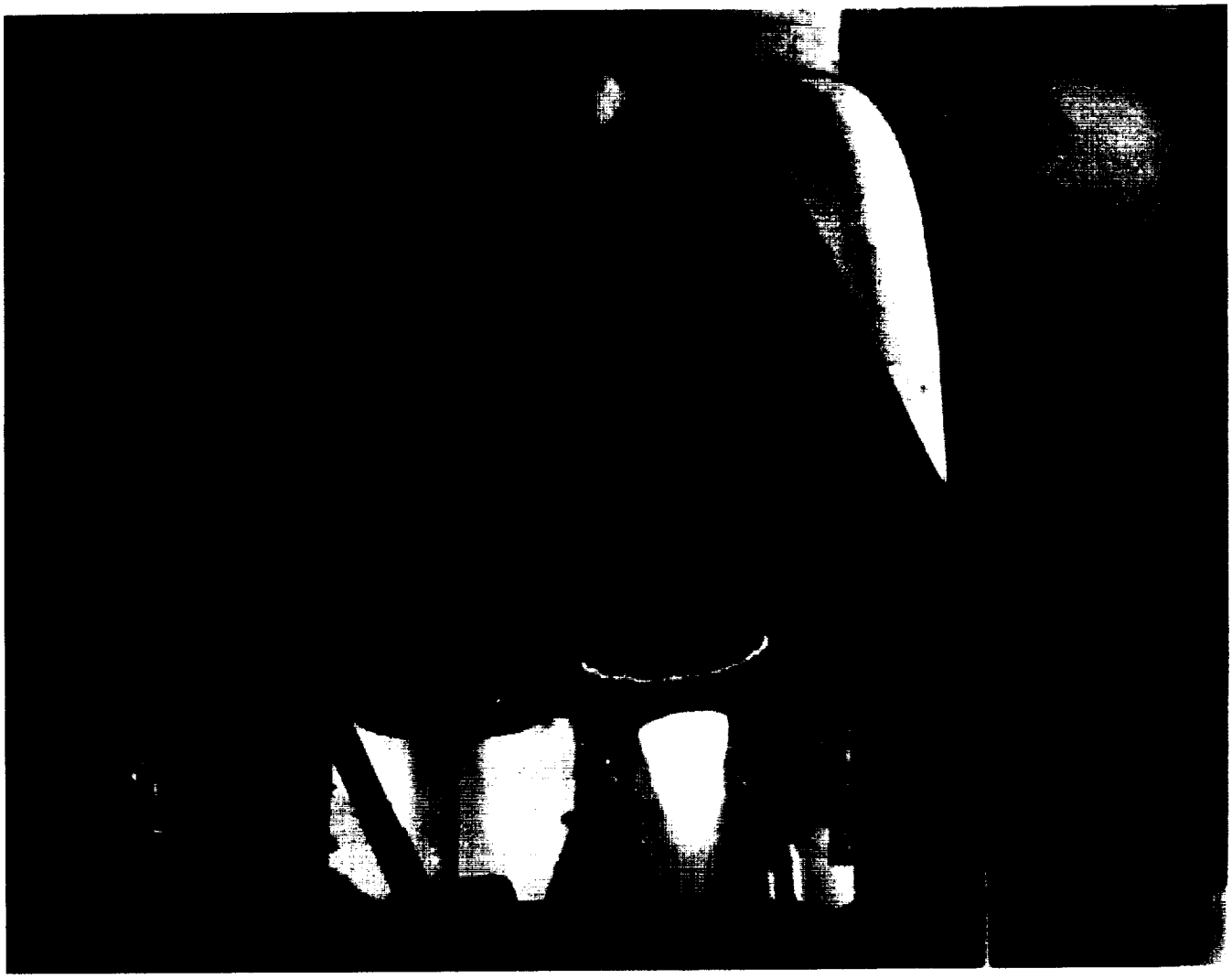
Eighteen videos, sixteen 16mm high speed films, and seven 35mm large format films were reviewed on 20 August 1993.

There was no significant external damage to the vehicle as a result of the SSME abort.

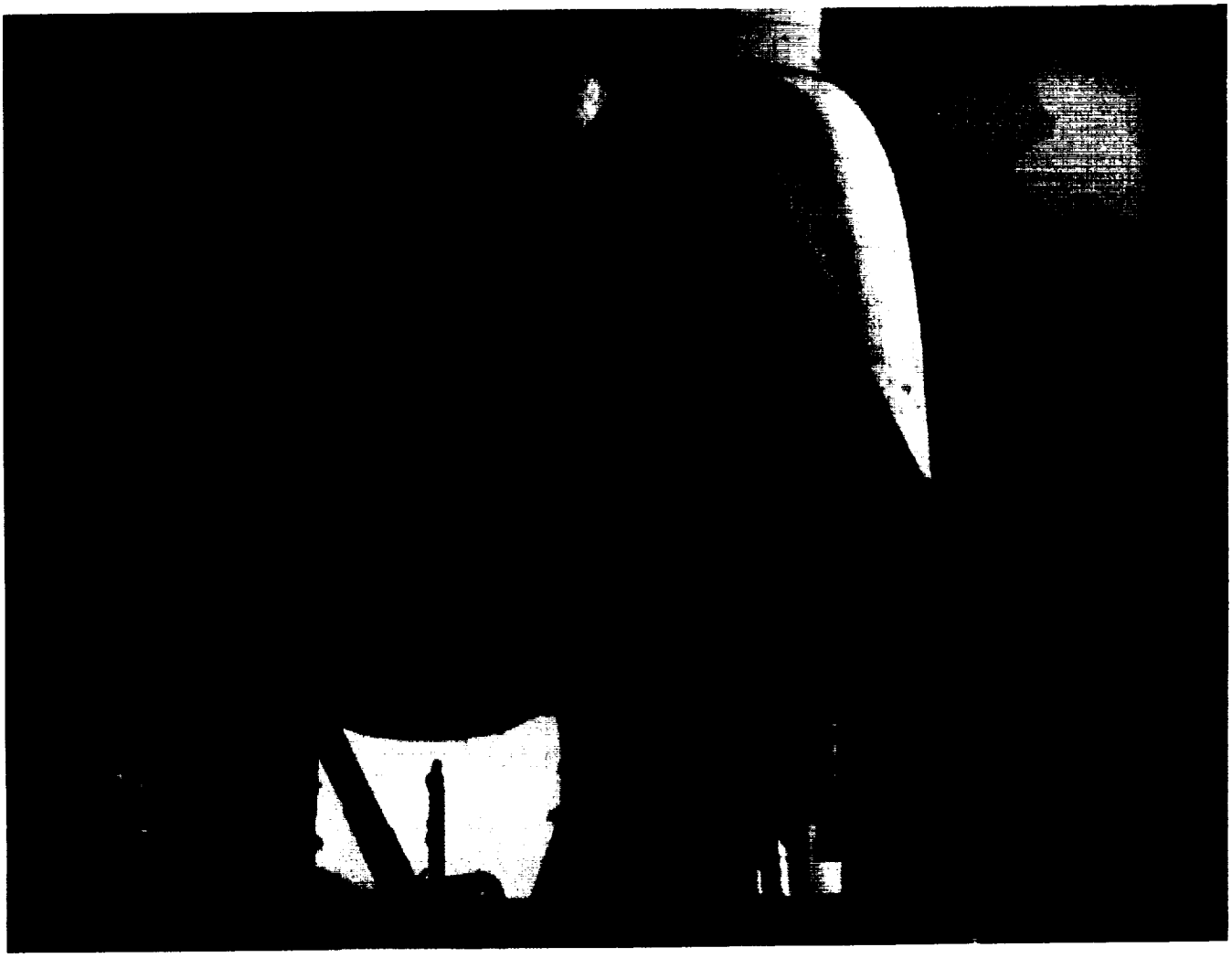
Only SSME #1 had a run time long enough to form a Mach diamond before receiving the shutdown command. Post shutdown appearance of hydrogen and cold helium purge gas exiting the SSME nozzles was similar to previous SSME aborts.

Free burning hydrogen drifted upward to the base heat shield and OMS pods, burned the aft RCS thruster paper covers, and appeared to dissipate quickly (E-76, 77, OTV 170, 171). Insulation and small amounts of surface contamination on the LH2 T-0 umbilical freon supply lines burned/flared briefly (E-18, 20, 63, 77, OTV 171). Subsequent inspection of the freon supply lines revealed only minor charring of the insulation.

FIREX water coverage of the SSME's and base heat shield area was adequate. Firex water to the OMS pods and Orbiter T-0 umbilicals was not activated since no fire or leak detectors had been tripped. Firex water streams directed at the center of the Orbiter vertical stabilizer did not appear to help the safing process and may be changed. Firex water did not reach the ET/ORB LH2 umbilical and water coverage to the ET/ORB LO2 umbilical was inconsistent. Firex systems engineers and Design Engineering recommended increasing the available water pressure by terminating the water flow on the FSS and MLP Side 1, which would not be needed for a main engine abort. A configuration change is being evaluated to move some FIREX nozzles to the top of the hydrogen dispersal system decreasing the distance from the water source to the ET/ORB umbilicals by 15 feet.



Only SSME #1 had a run time long enough to form a Mach diamond before receiving the shutdown command. Post shutdown appearance of hydrogen and cold helium purge gas exiting the SSME nozzles was similar to previous SSME aborts. There was no significant external damage to the vehicle as a result of the abort.



Free burning hydrogen drifted upward to the base heat shield and OMS pods, burned the aft RCS thruster paper covers, and appeared to dissipate quickly. Insulation and small amounts of surface contamination on the LH2 T-0 umbilical freon supply lines burned/flared briefly. Subsequent inspection of the freon supply lines revealed only minor charring of the insulation.

6.0 LAUNCH

STS-51 was launched at 12:11:45:00.007 GMT (7:45 a.m. local) on 12 September 1993.

6.1 ICE/FROST INSPECTION

A pre-launch SSV/pad debris inspection was performed from 0845 to 1000 hours on 11 September 1993. No anomalies on the facility or the flight hardware were detected. The only item entered in OMI S0007, Appendix K, listed cleaning/vacuuming deck scale and sand from the MLP deck zero level.

The Ice/Frost Inspection of the cryoloaded vehicle was performed on 12 September 1993 from 0210 to 0340 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:	72.9 Degrees F
Relative Humidity:	100. Percent
Wind Speed:	4.1 Knots
Wind Direction:	284 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 8 and 9.

6.2 ORBITER

No Orbiter tile or RCC panel anomalies were observed. All RCS thruster paper covers, including the wet covers on the F3U, F4R, L2L, L3L, R2U, and R3R nozzles, were intact. Typical ice and frost accumulations were present at the SSME #1 and #2 heat shield-to-nozzle interfaces. Some condensate was present on the SSME engine mounted heat shields and the base heat shield tiles. An infrared scan revealed no unusual temperature gradients on the base heat shield or engine mounted heat shields. No unusual vapors originated from inside the SSME nozzles.

6.3 SOLID ROCKET BOOSTERS

No SRB anomalies or loose ablator/cork were observed. SRB case temperatures measured by the PSTI averaged 76-77 degrees F; the spot radiometer ranged from 76 to 79 degrees F; and the SRB Ground Environment Instrumentation (GEI) measured temperatures from 77 to 81 degrees F. All measured temperatures were above the 34 degrees F minimum requirement. The predicted Propellant Mean Bulk Temperature (PMBT) supplied by MTI was 81 degrees F, which was within the required range of 44-86 degrees F.

FIGURE 8. **SSV INFRARED SCANNER SURFACE TEMPERATURE SUMMARY DATA**

TIME: 0210-0345
DATE: 09/12/93
VEH. STS- 51
Temperatures in F°

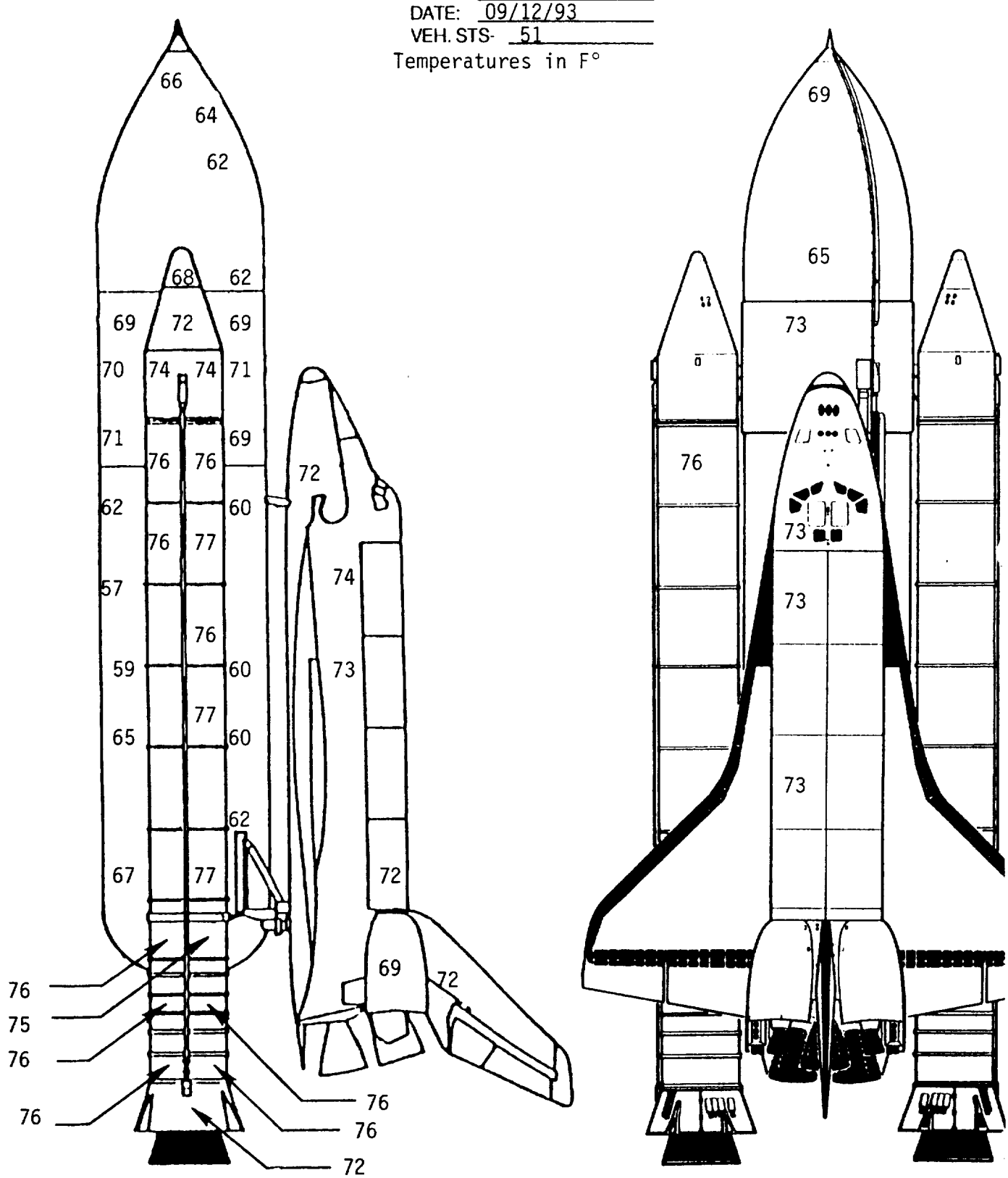
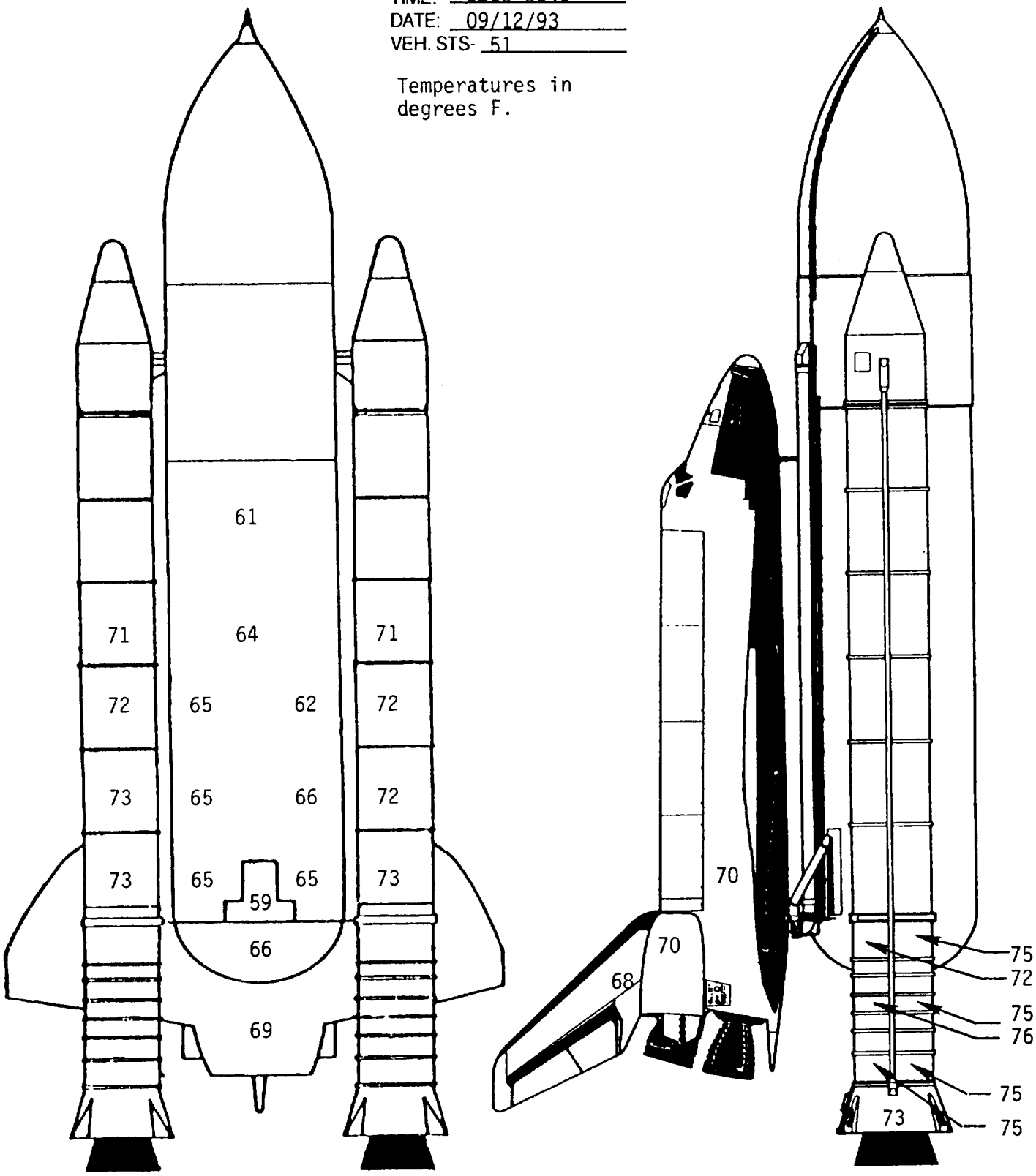


FIGURE 9. **SSV INFRARED SCANNER SURFACE TEMPERATURE SUMMARY DATA**

TIME: 0210-0345
DATE: 09/12/93
VEH. STS- 51

Temperatures in degrees F.



6.4 EXTERNAL TANK

The ice/frost prediction computer program 'SURFICE' was run from 0030 to 0745 hours and the results tabulated in Figure 10. 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 tumble valve cover was intact. The portable STI measured surface temperatures that averaged 69 degrees F on the ogive and 65 degrees F on the barrel section. In comparison, the Cyclops radiometer measured temperatures that averaged 68 degrees F on the ogive and 65 degrees F on the barrel; SURFICE predicted temperatures of 64 degrees F on the ogive and 58 degrees F on the barrel.

The intertank acreage TPS was dry. No frost spots appeared in the stringer valleys at the LH2 and LO2 tank-to-intertank flanges. 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. The spot radiometer measured a surface temperature of 72 degrees F.

Vapors (visible puffs of cold purge gas) simultaneously exited the intertank +Z and -Z aero vents numerous times during the walkdown at T-3 hours. The vapors were also observed just before SSME ignition. This is a common and expected event.

There were no LH2 tank TPS acreage anomalies. Condensate, but no ice or frost, was present on the acreage and aft dome. The portable STI measured surface temperatures that averaged 59 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 60 degrees F on the upper and 64 degrees F on the lower LH2 tank, respectively; SURFICE predicted temperatures of 53 degrees F on the upper LH2 tank and 64 degrees F on the lower LH2 tank.

There were no anomalies on the bipod jack pad closeouts. A frost spot appeared on a repair in the LH2 tank-to-intertank flange closeout near the -Y ET/SRB attach fitting. Three frost spots had formed on the -Y bipod ramp to acreage bondlines. Ice/frost had formed on the pressurization line ramp aft edges-to-acreage bondlines at stations XT-1851.60, 1787.00, 1334.80, 1205.60, and 1270.20. Three small frost spots had formed on the -Y longeron closeout; 5 small frost spots had formed on the +Y longeron closeout.

Two cracks, 9-inches long by 3/8-inch wide and 4-inches long by 1/4-inch wide, were again present in the -Y ET/SRB cable tray forward surface TPS. These cracks exhibited no offset and were

STS- 51	TEST S0007 LAUNCH															DATE: 12 September 1993					T-0 TIME: 07:45:00.007 DATE: 9/12/93				NASA KSC Ice/Frost/Debris Team
ORBITER 103	ET 59	SRB BI-080	MLP 3	PAD B	LO2 CHILLDOWN TIME: 22:50 SLOW FILL TIME: 23:29				FAST FILL TIME: 23:41 REPLENISH TIME: 01:43				LH2 CHILLDOWN TIME: 22:50 SLOW FILL TIME: 22:58			FAST FILL TIME: 23:43 REPLENISH TIME: 01:35									
TIME (EDT)	CONDITIONS					LO2 TANK STA 370 TO 540					LO2 TANK STA 550 TO 852					LH2 TANK STA 1130 TO 1380					LH2 TANK STA 1380 TO 2058				
	TEMP F	REL HUM %	DEW PT F	WIND VEL KNTS	WIND DIR DEG	REG	LOCAL VEL KNTS	SOFI TEMP	COND RATE IN/HR	ICE RATE IN/HR	REG	LOCAL VEL KNTS	SOFI TEMP	COND RATE IN/HR	ICE RATE IN/HR	REG	LOCAL VEL KNTS	SOFI TEMP	COND RATE IN/HR	ICE RATE IN/HR	REG	LOCAL VEL KNTS	SOFI TEMP	COND RATE IN/HR	ICE RATE IN/HR
0030	74.20	100.0	74.20	2	237	II	1.18	60.28	0.0027	-0.1107	II	1.18	53.42	0.0041	-0.0858	II	0.64	51.97	0.0044	-0.0798	II	2.72	57.78	0.0053	-0.1016
0045	74.80	98.6	74.40	3	238	II	1.77	62.91	0.0029	-0.1131	II	1.77	54.79	0.0042	-0.0882	II	0.96	52.49	0.0044	-0.0822	II	4.08	62.36	0.0059	-0.1574
0100	74.60	97.6	73.91	3	249	II	1.77	62.46	0.0029	-0.1110	II	1.77	54.31	0.0042	-0.0860	II	1.29	52.06	0.0043	-0.0801	II	3.63	60.78	0.0057	-0.1370
0115	74.60	98.0	74.02	4	257	II	2.36	64.44	0.0032	-0.1234	II	2.36	57.61	0.0047	-0.0934	II	1.72	52.32	0.0044	-0.0805	II	4.84	63.48	0.0061	-0.1840
0130	74.20	99.2	73.97	4	249	II	2.36	64.21	0.0032	-0.1224	II	2.36	57.37	0.0047	-0.0924	II	1.72	52.04	0.0044	-0.0791	II	4.84	63.27	0.0062	-0.1825
0145	72.20	99.2	71.97	6	260	II	3.54	64.27	0.0034	-0.1553	II	3.54	58.98	0.0052	-0.1247	II	2.58	54.42	0.0050	-0.0838	II	7.26	63.98	0.0065	-0.2491
0200	72.40	100.0	72.40	3	253	II	1.77	60.26	0.0029	-0.0999	II	1.77	51.93	0.0041	-0.0750	II	1.29	49.67	0.0043	-0.0691	II	3.63	58.59	0.0056	-0.1244
0215	73.00	100.0	73.00	5	253	II	2.95	64.32	0.0034	-0.1394	II	2.95	58.37	0.0050	-0.1091	II	2.15	53.42	0.0048	-0.0726	II	6.05	63.79	0.0064	-0.2170
0230	73.00	100.0	73.00	5	275	II	2.95	64.32	0.0034	-0.1394	II	2.95	58.37	0.0050	-0.1091	II	2.15	53.42	0.0048	-0.0726	II	6.05	63.79	0.0064	-0.2170
0245	72.80	100.0	72.80	5	261	II	2.95	64.09	0.0034	-0.1382	II	2.95	58.12	0.0050	-0.1079	II	2.15	53.16	0.0047	-0.0715	II	6.05	63.56	0.0064	-0.2150
0300	72.80	100.0	72.80	5	291	II	2.95	64.09	0.0034	-0.1382	II	2.95	58.12	0.0050	-0.1079	II	2.15	53.16	0.0047	-0.0715	II	6.05	63.56	0.0064	-0.2150
0315	72.60	100.0	72.60	3	319	II	1.77	60.50	0.0029	-0.1011	II	1.77	52.19	0.0041	-0.0762	II	1.38	49.93	0.0043	-0.0703	II	3.89	59.00	0.0057	-0.1280
0330	73.00	100.0	73.00	2	298	II	1.18	58.94	0.0026	-0.1035	II	1.18	51.91	0.0040	-0.0785	II	0.92	50.44	0.0043	-0.0726	II	2.46	55.06	0.0050	-0.0845
0345	73.00	100.0	73.00	4	294	II	2.36	62.94	0.0032	-0.1164	II	2.36	56.00	0.0046	-0.0866	II	1.84	51.47	0.0045	-0.0726	II	4.92	62.15	0.0061	-0.1761
0400	73.20	100.0	73.20	3	292	II	1.77	61.23	0.0029	-0.1047	II	1.77	52.99	0.0042	-0.0797	II	1.29	50.69	0.0043	-0.0738	II	3.63	59.58	0.0057	-0.1301
0415	73.00	100.0	73.00	2	288	II	1.18	58.84	0.0026	-0.1035	II	1.18	51.91	0.0040	-0.0785	II	0.86	50.44	0.0043	-0.0726	II	2.42	54.87	0.0050	-0.0830
0430	72.80	100.0	72.80	4	286	II	2.36	62.70	0.0032	-0.1153	II	2.36	55.74	0.0046	-0.0855	II	1.72	50.33	0.0043	-0.0714	II	4.84	61.77	0.0061	-0.1715
0445	72.80	100.0	72.80	3	284	II	1.77	60.75	0.0029	-0.1023	II	1.77	52.45	0.0041	-0.0774	II	1.29	50.18	0.0043	-0.0714	II	3.63	59.09	0.0056	-0.1272
0500	73.00	100.0	73.00	4	286	II	2.36	62.94	0.0032	-0.1164	II	2.36	56.00	0.0046	-0.0866	II	1.72	50.60	0.0043	-0.0726	II	4.84	62.01	0.0061	-0.1732
0515	72.80	100.0	72.80	4	292	II	2.36	62.70	0.0032	-0.1153	II	2.36	55.74	0.0046	-0.0855	II	1.72	50.33	0.0043	-0.0714	II	4.84	61.77	0.0061	-0.1715
0530	73.40	100.0	73.40	4	288	II	2.36	63.42	0.0032	-0.1186	II	2.36	56.52	0.0047	-0.0888	II	1.72	51.14	0.0044	-0.0750	II	4.84	62.49	0.0062	-0.1767
0545	73.60	100.0	73.60	1	298	II	0.59	59.56	0.0026	-0.1071	II	0.59	52.66	0.0041	-0.0821	II	0.46	51.20	0.0044	-0.0762	II	1.23	51.20	0.0044	-0.0762
0600	74.00	100.0	74.00	2	280	II	1.18	60.04	0.0027	-0.1095	II	1.18	53.16	0.0041	-0.0845	II	0.86	51.71	0.0044	-0.0786	II	2.42	56.16	0.0051	-0.0885
0615	74.20	100.0	74.20	4	287	II	2.36	64.37	0.0032	-0.1232	II	2.36	57.55	0.0047	-0.0931	II	1.72	52.21	0.0044	-0.0798	II	4.84	63.45	0.0062	-0.1838
0630	73.60	100.0	73.60	3	268	II	1.77	61.72	0.0029	-0.1071	II	1.77	53.50	0.0042	-0.0821	II	1.29	51.20	0.0044	-0.0762	II	3.63	60.08	0.0057	-0.1330
0645	73.40	100.0	73.40	3	292	II	1.77	61.48	0.0029	-0.1059	II	1.77	53.24	0.0042	-0.0809	II	1.29	50.95	0.0043	-0.0750	II	3.63	59.83	0.0057	-0.1315
0700	73.80	100.0	73.80	1	286	II	0.59	59.80	0.0027	-0.1083	II	0.59	52.91	0.0041	-0.0833	II	0.43	51.46	0.0044	-0.0774	II	1.21	51.46	0.0044	-0.0774
0715	74.00	100.0	74.00	3	287	II	1.77	62.21	0.0030	-0.1095	II	1.77	54.01	0.0042	-0.0845	II	1.29	51.71	0.0044	-0.0786	II	3.63	60.58	0.0058	-0.1359
0730	74.80	100.0	74.80	4	289	II	2.36	65.09	0.0033	-0.1266	II	2.36	58.32	0.0048	-0.0965	II	1.72	53.01	0.0045	-0.0835	II	4.84	64.17	0.0063	-0.1892
T-0	74.80	100.0	74.80	1	286	II	0.59	61.00	0.0027	-0.1144	II	0.59	54.17	0.0042	-0.0894	II	0.43	52.73	0.0045	-0.0835	II	1.21	52.73	0.0045	-0.0835
AVG.	71.11	99.75	73.41	3.33	W		1.97	62.19				1.97	55.08				1.43	51.66				4.07	60.08		

Period of Ice Team Inspection

FIGURE 10. "SURFICE" Computer Predictions

not filled with ice or frost. The one crack, previously 6 inches in length, was now 9 inches in length. A three-inch diameter ice/frost accumulation had formed on the +Y vertical strut aft surface-to-acreage bondline

These conditions were acceptable for flight per the NSTS-08303 criteria.

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. The purge barrier (baggie) was configured properly and was holding positive purge pressure. Some accumulations of ice/frost were present on the acreage areas of the umbilical along the purge barrier. Formation of ice/frost fingers on the separation bolt pyro canister purge vents was typical. Normal venting of nitrogen purge gas had occurred during tanking, stable replenish, and launch.

Ice/frost in the LH2 recirculation line bellows and on both burst disks was typical. The LH2 feedline bellows were wet with condensate and some frost was beginning to form.

Less than usual amounts of ice/frost had accumulated on the top, aft, and outboard sides of the LH2 ET/ORB umbilical purge barrier. Typical ice/frost fingers had formed on the pyro canister and plate gap purge vents. Ice/frost was present on the LH2 feedline-to-support bracket closeout bondline and on both the aft and forward outboard pyrotechnic canister closeout bondlines indicating thermal shorts. The 17-inch flapper valve actuator access port foam plug was properly closed out. Some ice/frost had formed around the cable tray vent hole. No unusual vapors or cryogenic drips had appeared during tanking, stable replenish, and launch.

The ET/ORB hydrogen detection sensor tygon tubing was in proper position prior to removal. The tubing was removed from the vehicle without contacting Orbiter tiles.

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

Anomaly 001 documented an ice/frost formation with venting vapor on the +Y side of the -Z manhole cover closeout. The ice and frost had melted by T-2 hours.

Anomaly 002 documented an ice/frost formation at the interface of the LH2 feedline and outboard support bracket.

Anomaly 003 documented ice/frost formation on the -Y longeron closeout approximately 2 inches forward of the ET/SRB cable tray.

Anomaly 004 documented two cracks in the -Y ET/SRB cable tray forward surface BX-250 near the longeron closeout.

Anomaly 005 documented ice/frost accumulations on the aft side of the GH2/GO2 pressurization line ramps at stations XT-1851.60, 1787.00, 1334.80, 1270.20, and 1205.60.

Anomaly 006 documented an ice/frost formation with venting vapor on the +Y side of the +Z manhole cover closeout. The ice and frost had melted by T-2 hours.

Anomaly 007 documented a frost formation with venting on the +Y longeron closeout approximately 3-4 feet aft of the forward edge and 8-inches from the +Y edge. There were 4 other frost spots on the longeron closeout TPS.

Anomaly 008 documented a 3-inch long by 1.5-inch wide ice/frost formation with venting along the outboard and aft edges of the -Y bipod ramp to acreage interface.

Anomaly 009 documented a 4-inch long by 1.5-inch wide ice/frost area with venting aft of the +Y ET/SRB cable tray on the BX-250 closeout.

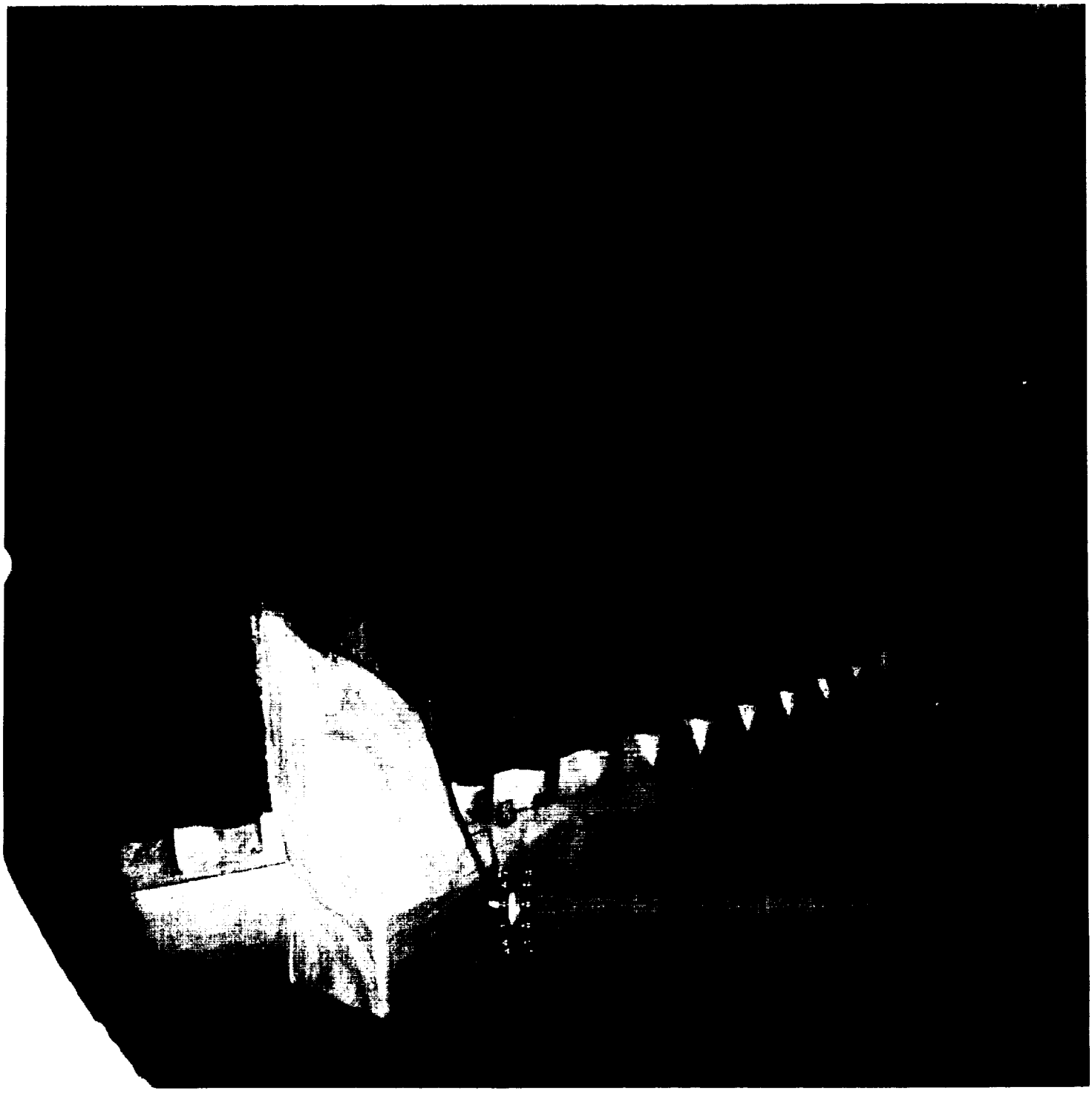
6.5 FACILITY

All SRB sound suppression water troughs were filled and properly configured for launch. There was no debris on the MLP deck or in the SRB holddown post areas. An electrical outlet cover was loose and dangling from a tether on the west side of the LH2 TSM.

No leaks were observed on either the LO2 or LH2 Orbiter T-0 umbilicals. Typical accumulations of ice/frost were present on the cryogenic lines and purge shrouds.

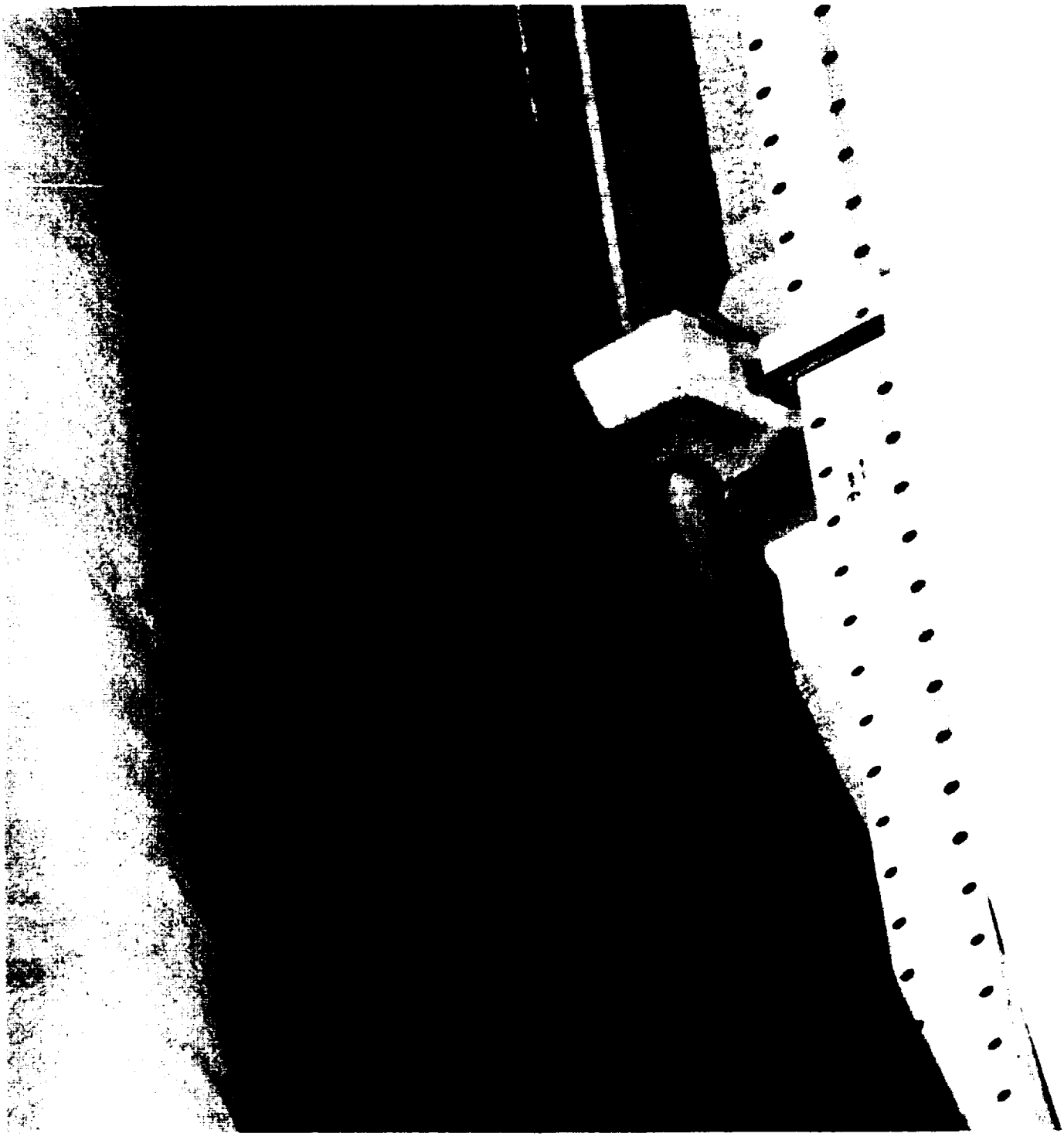
There was no apparent hydrogen leakage anywhere on the GH2 vent line or GUCP. Some ice and frost, which was expected, had accumulated on the GUCP legs and on the uninsulated parts of the umbilical carrier plate. Liquid air dripped from the GH2 vent line on the FSS 115 foot level to the FSS 195 foot level in front of the closeout crew tool locker. No hydrogen registered on a hand-held hydrogen meter. Post launch inspection of the area revealed two saw cuts in the drip pan beneath the GH2 vent line elbow. The cuts will be tack welded closed.

The GOX seals were in nominal configuration. No ET nosecone/footprint damage was visible after the GOX vent hood was retracted. No icicles were present on the GOX vent ducts at the time of launch.



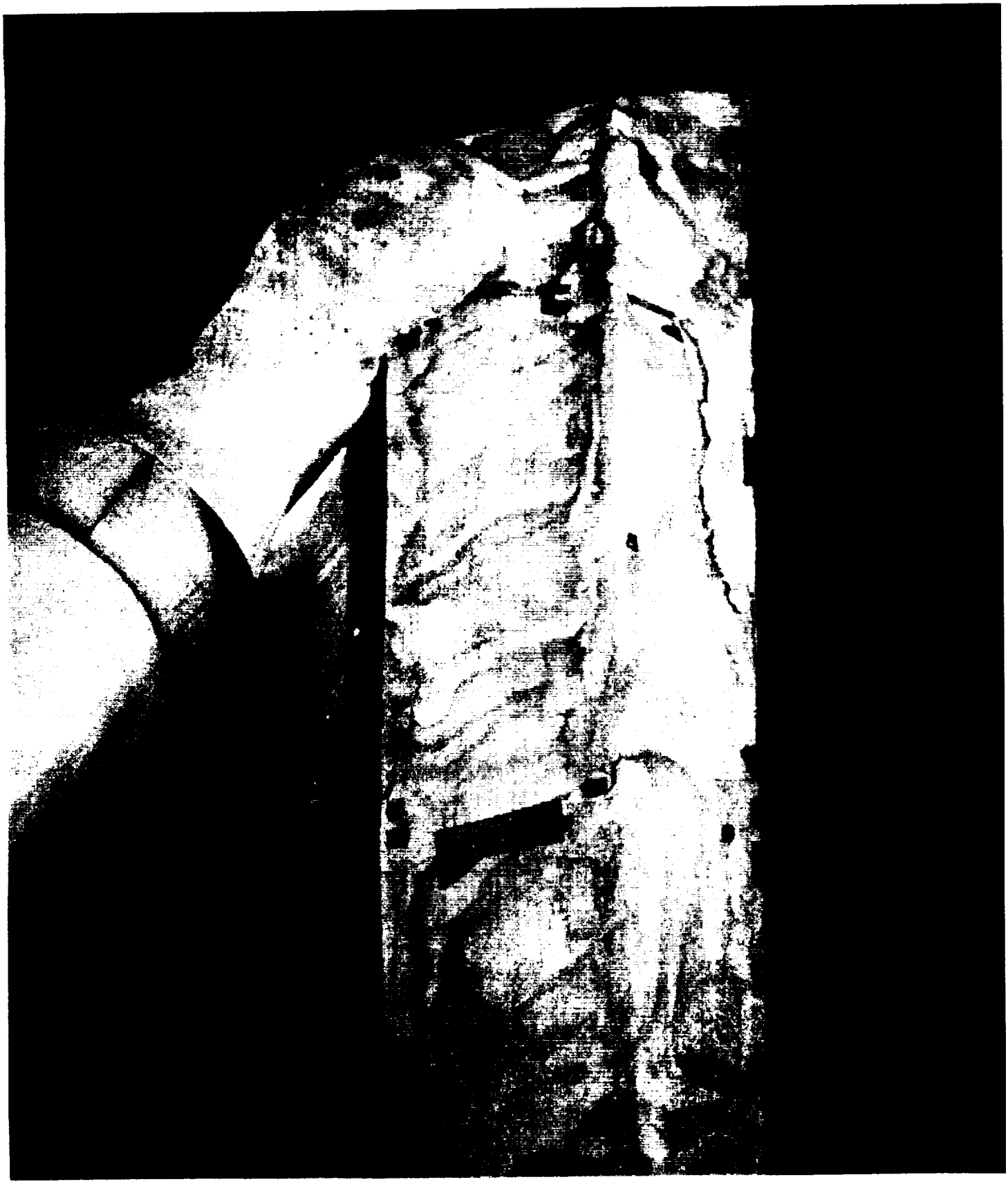
Pre-launch configuration of the bipods, jack pad closeouts, and intertank acreage TPS prior to cryoloading

Ice/frost formed on the -Y (left) bipod spindle housing closeout-to-ET interface bondline.



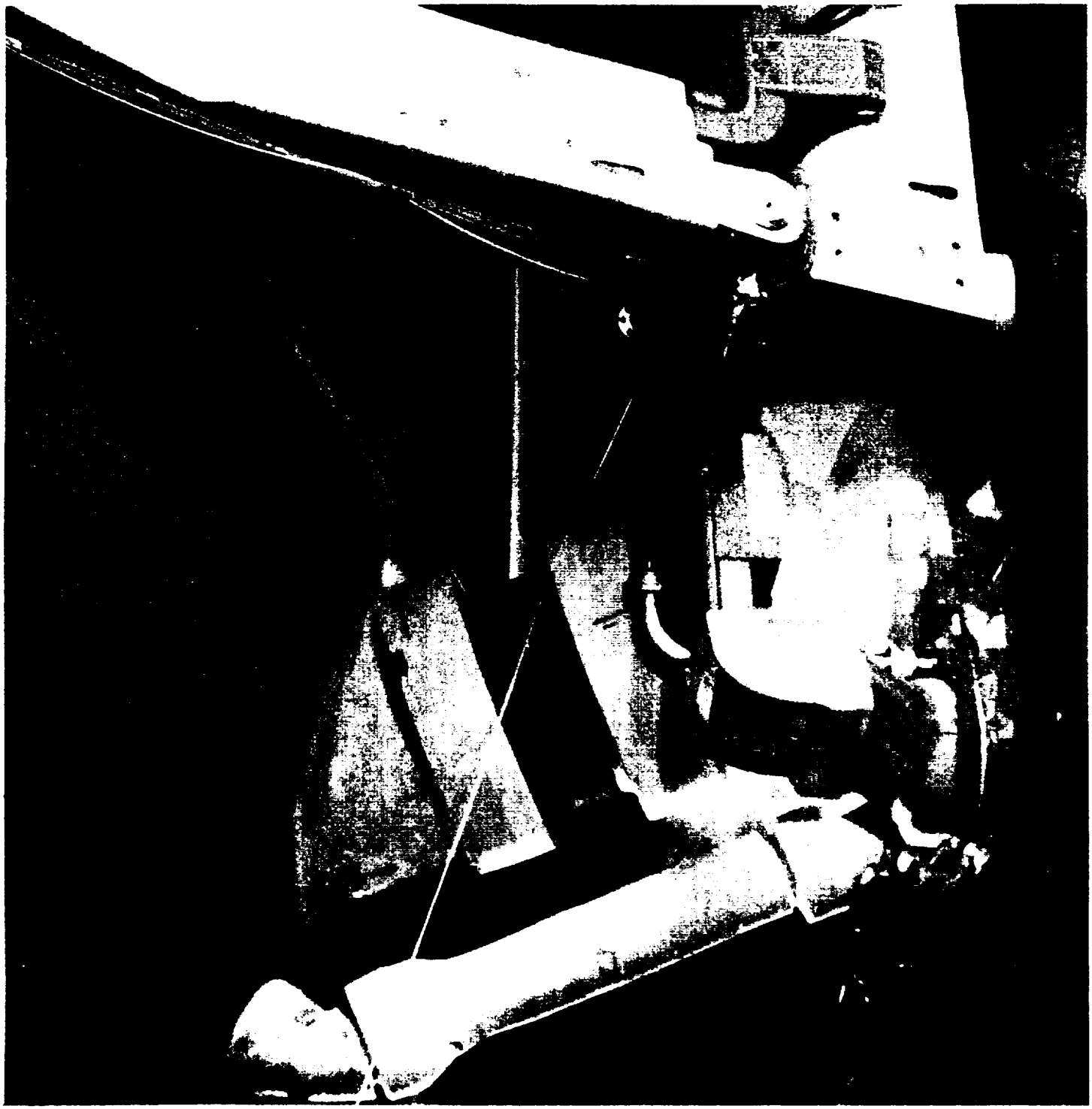
Ice/frost had formed on the pressurization line ramp aft edges-to-acreage bondlines at stations XT-1851.60, 1787.00, 1334.80, 1205.60, and 1270.20.

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



5 small ice/frost spots had formed on the +Y longeron closeout

Two cracks, 9-inches long by 3/8-inch wide and 4-inches long by 1/4-inch wide, were present in the -Y ET/SRB cable tray forward surface TPS. The cracks exhibited no offset and were not filled with ice or frost.



Less than usual amounts of ice/frost had formed on the ET/ORB LH2 umbilical. Some ice/frost was present on the LH2 feedline support bracket near the forward outboard pyro canister bondline indicating a thermal short. No cryogenic drips or unusual vapors appeared during tanking, stable replenish, and launch.

7.0 POST LAUNCH PAD DEBRIS INSPECTION

The post launch inspection of the MLP, FSS, and RSS was conducted on 12 September 1993 from Launch + 1-1/2 to 3 hours.

The only flight hardware found was a small piece of Orbiter FRSI plug material on the MLP deck.

South SRB HDP erosion was typical. All south HDP EPON shoe shim material was intact. There was no visual indication of a stud hang-up on any of the south holddown posts. All of the north HDP doghouse blast covers were in the closed position. The SRB aft skirt purge lines were in place, but slightly damaged. The SRB T-0 umbilicals exhibited typical damage with several connectors protruding above the interface plane.

The Tail Service Masts (TSM), Orbiter Access Arm (OAA), and GOX vent arm showed only minor damage. The GH2 vent line was latched on the fourth tooth of the latching mechanism and had no loose cables (static retract lanyard). The GH2 vent line appeared to have retracted nominally and showed typical signs of SRB plume impingement. The ET intertank access structure also sustained typical plume heating effects.

Typical damage to the facility included:

1. Film camera E-1 (located on NE corner of MLP deck) housing lens was shattered.

2. The door to the phone box on the FSS 115 foot level had been blown open but remained attached.

3. A 7 foot by 4 inch by 1/4-inch thick piece of sheet metal was located on the elevator south side FSS 175 foot level. An electrical box cover (TTC 20) was blown off and was found on the north side of the elevator.

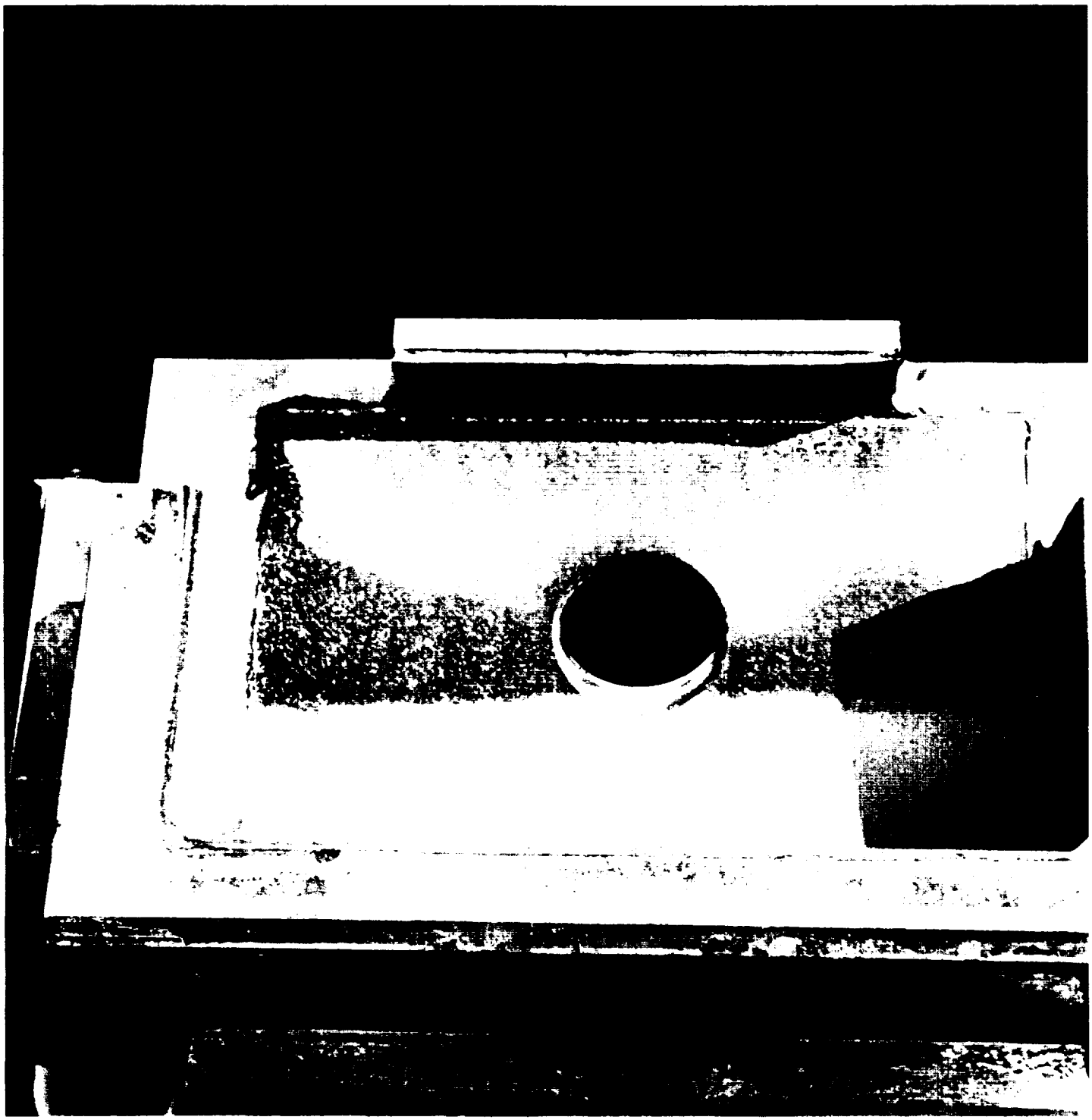
4. A section of a "Caution" sign was found on the retracted portion of the intertank access arm on the FSS 215' level.

5. The 255 foot elevation sign was detached from the east side of the level.

6. A large light fixture 2 feet by 1.5 foot diameter was found near the entrance to the PTCR on the pad apron.

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

Post launch inspections on 13 September 1993 included a walkdown of the pad acreage, north flame trench and beach, and a helicopter overflight of the pad/water areas. No flight hardware or TPS material was found. Post launch pad inspection anomalies are listed in Section 12.



South SRB HDP erosion was typical. All south HDP EPON shim material was intact. There were no stud hang-ups on any of the holddown posts.

A 7-foot by 4-inch by 1/4-inch thick piece of sheet metal was found on the elevator south side FSS 175 foot level

8.0 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 IFA candidates were proposed as a result of the film review.

8.1 LAUNCH FILM AND VIDEO SUMMARY

A total of 105 films and videos, which included forty-one 16mm films, twenty-one 35mm films, four 70mm films, and thirty-nine videos, were reviewed starting on launch day.

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

Vapors (visible puffs of cold purge gas) simultaneously exited the intertank +Z and -Z aero vents prior to SSME ignition (E-34). These vapors are routinely observed from the start of cryo load through terminal countdown. The visibility of the vapors is a function of ambient temperature, relative humidity, dew point, local winds conditions, lighting conditions (sunlight or Xenon light), and intertank gas temperature.

Prior to ignition, free burning hydrogen drifted under the body flap. SSME ignition, Mach diamond formation, and gimbal profile appeared normal (C/S-2 STI, OTV 151, 163, 170, 171).

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

SSME ignition caused numerous pieces of ice to fall from the ET/Orbiter umbilicals. There were no unusual vapors or cryogenic drips from the ET/ORB umbilicals during tanking, stable replenish, ignition, liftoff, or tower clear (OTV 109, 150, 154, 163, 164).

Three small pieces of tile surface coating material were lost from base heat shield tiles outboard of SSME #3 during ignition (E-17).

A small debris particle fell out of the LH OMS nozzle during SSME ignition (E-20).

Deflection of the External Tank nosecone during SSME ignition was approximately 33 inches (E-79).

The Orbiter LH2 and LO2 T-0 umbilicals disconnected and retracted properly (OTV 149, 150, 163). GUCP disconnect and retraction from the External Tank was nominal. The GH2 vent line latched normally with no rebound (E-33, 34, OTV 160).

Several white objects appeared near the top of the GH2 vent line elbow and are believed to be pieces of ice (E-41, 42, 48, 50).

A dark object falling from the LH wing RCC panels near the wing tip was identified as a moth (OTV 163).

No stud hang-ups occurred on any of the holddown posts. The HDP #4 EPON sidewall shim material came loose during SRB lift off and fell into the SRB exhaust hole (E-7). The north holddown post blast covers closed normally.

The protective lens in the E-1 camera cover was shattered by the SRB ignition shock wave.

Two cloth parts tags from the SRB sound suppression water troughs were ejected upward out of the RH SRB exhaust hole after T-0 (E-5).

Film item E-60 confirmed that water flowed properly from all MLP rainbirds.

Pad debris, most likely pieces of SRB throat plug material, was visible to the north over the SRB flame trench. Two light colored objects believed to be birds near the camera, appeared in the field of view during ascent (TV-4B).

A flash occurred in the SSME #1 plume as the vehicle cleared the tower (E-40).

Condensate/vapors trailed from the split in the rudder speed brake. White flashes occurred in the SSME plume during the roll maneuver (E-52, 57).

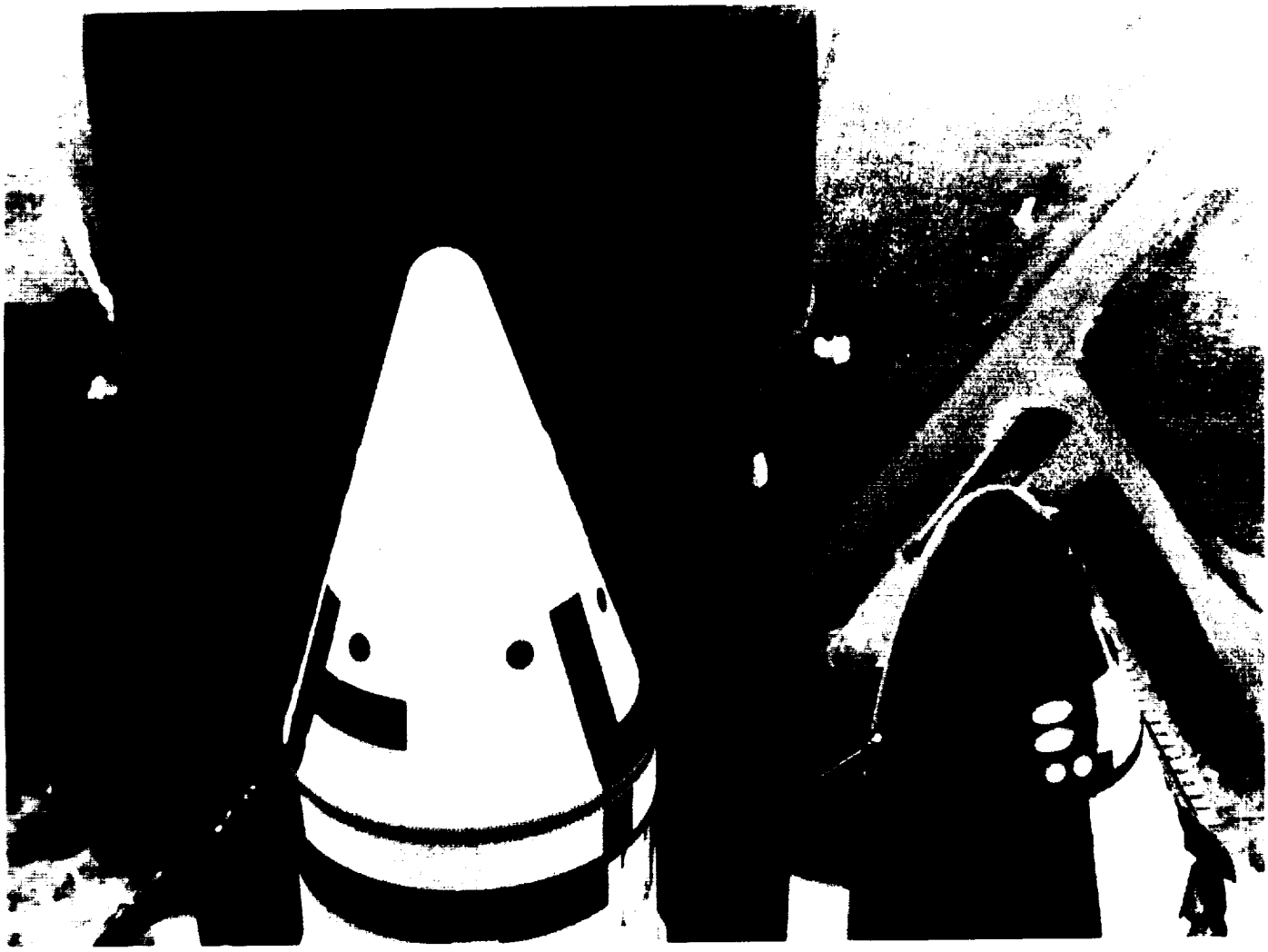
Pieces of RCS paper covers were visible passing over the Orbiter wings (E-59, 212, 222).

Movement of the body flap was very pronounced with frequencies similar to previous flights (E-207, 212, 220, 222).

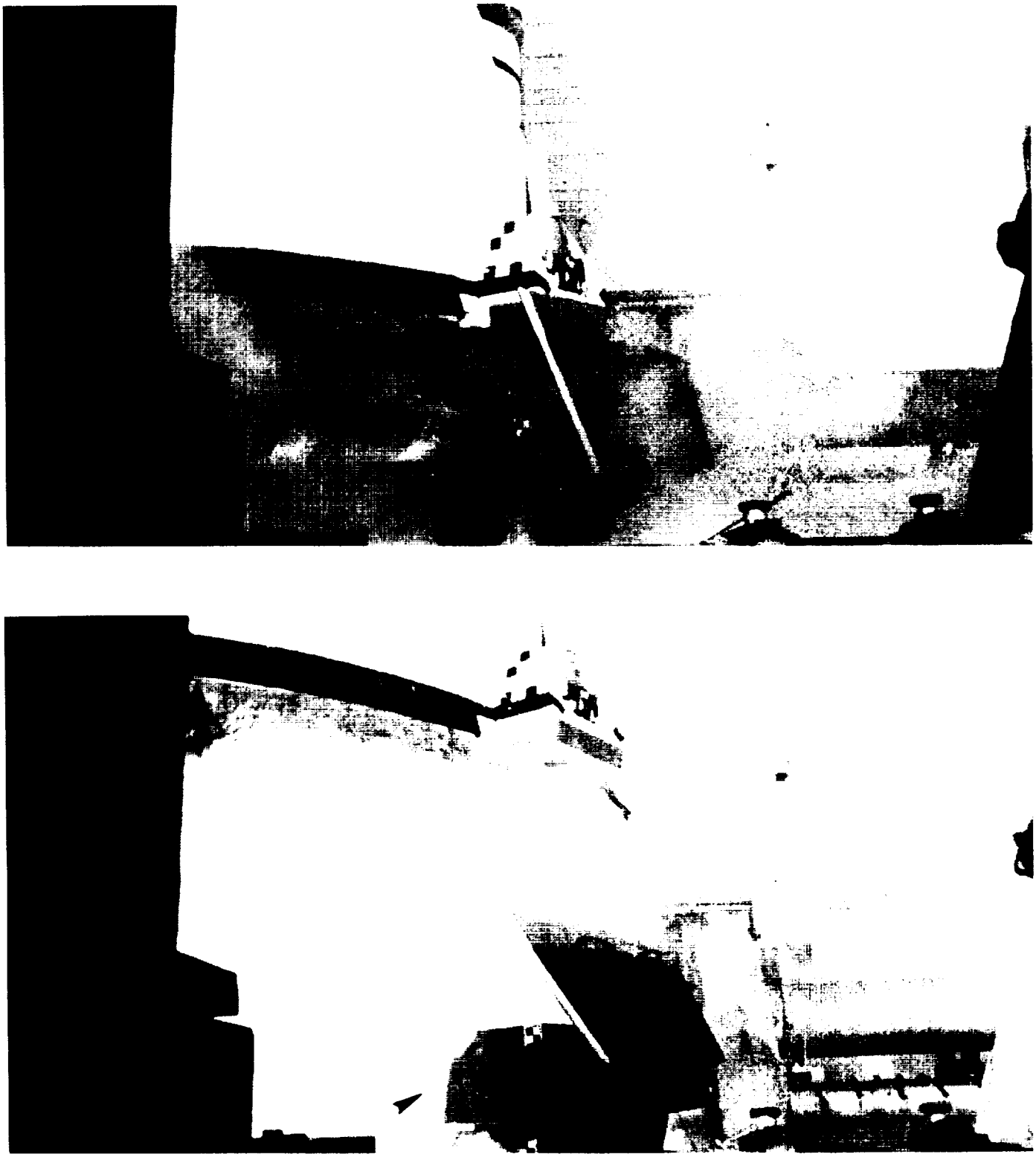
Local flow condensation on the vehicle was typical (E-207, 220).

Exhaust plume recirculation, SRB plume tailoff, and separation appeared nominal (E-207, 208, 212, TV-4B).

Frustum separation from the forward skirts appeared normal. Main parachute deployment, reefing, inflation, and jettison at splash down was nominal. Nozzle severance debris was typical (E-301, 302).



Vapors (visible puffs of cold purge gas) simultaneously exited the intertank +Z and -Z aero vents prior to SSME ignition. The vapors are routinely observed from the start of cryoload through terminal countdown. The visibility of the vapors is a function of ambient weather conditions, lighting, and intertank gas temperature.



The HDP #4 EPON sidewall shim material came loose during SRB liftoff and fell into the SRB exhaust hole

COLOR PHOTOGRAPH

8.2 ON-ORBIT FILM AND VIDEO SUMMARY

ORBITER

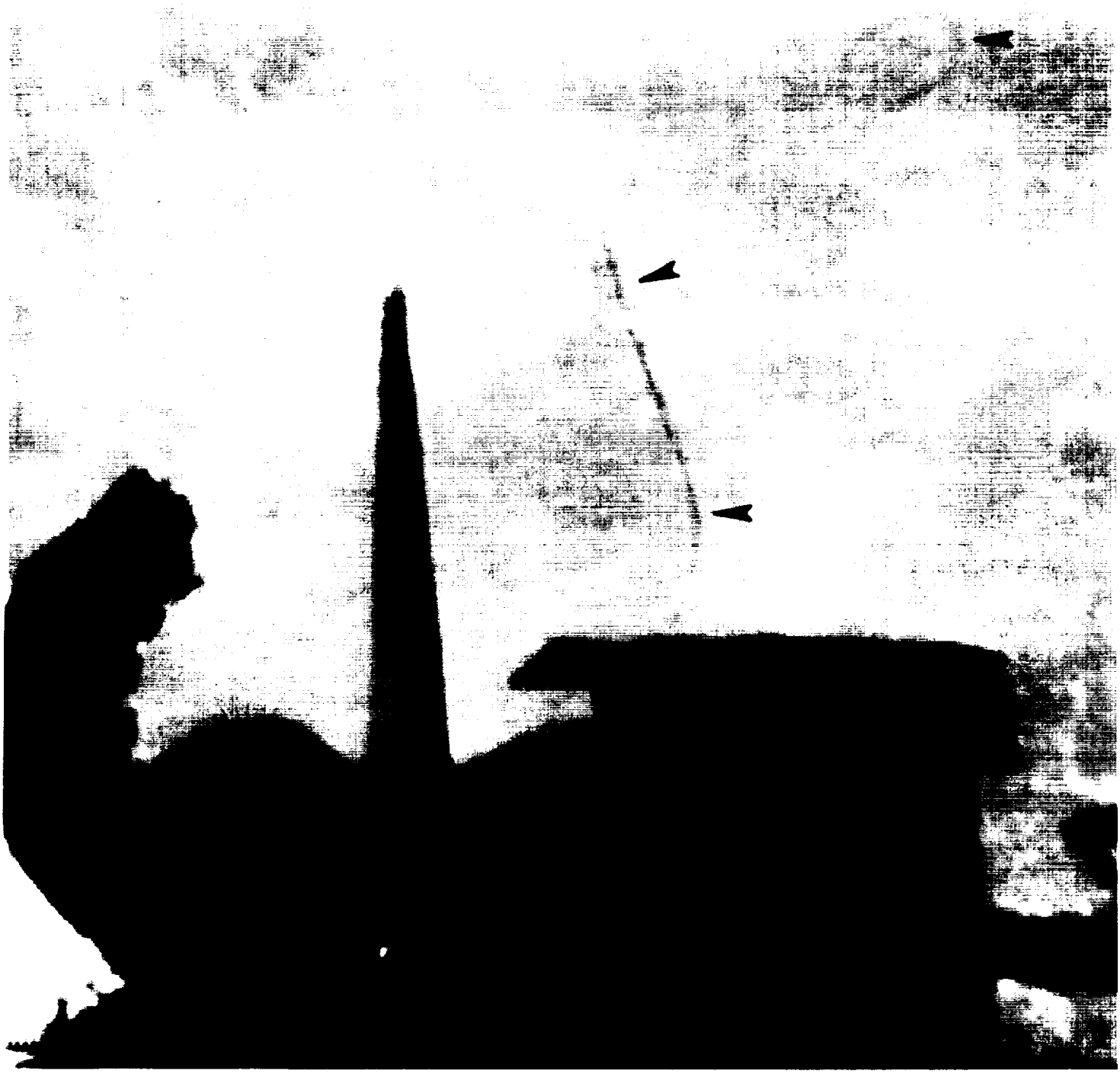
Deployment of the ACTS/TOS payload and associated TOS Super*Zip Anomaly (reference IPR 60V-0007 and Post Flight Anomaly Investigation by S. J. Payne/TP-POD-2/19 October 1993) caused debris induced damage to the LH OMS pod leading edge, base of the vertical stabilizer, and payload bay areas aft of bay #11.

Video review of the satellite deployment revealed at least 16 pieces of debris, most likely detached frangible doublers from the outer perimeter of the Super*Zip separation system, exiting the payload bay.

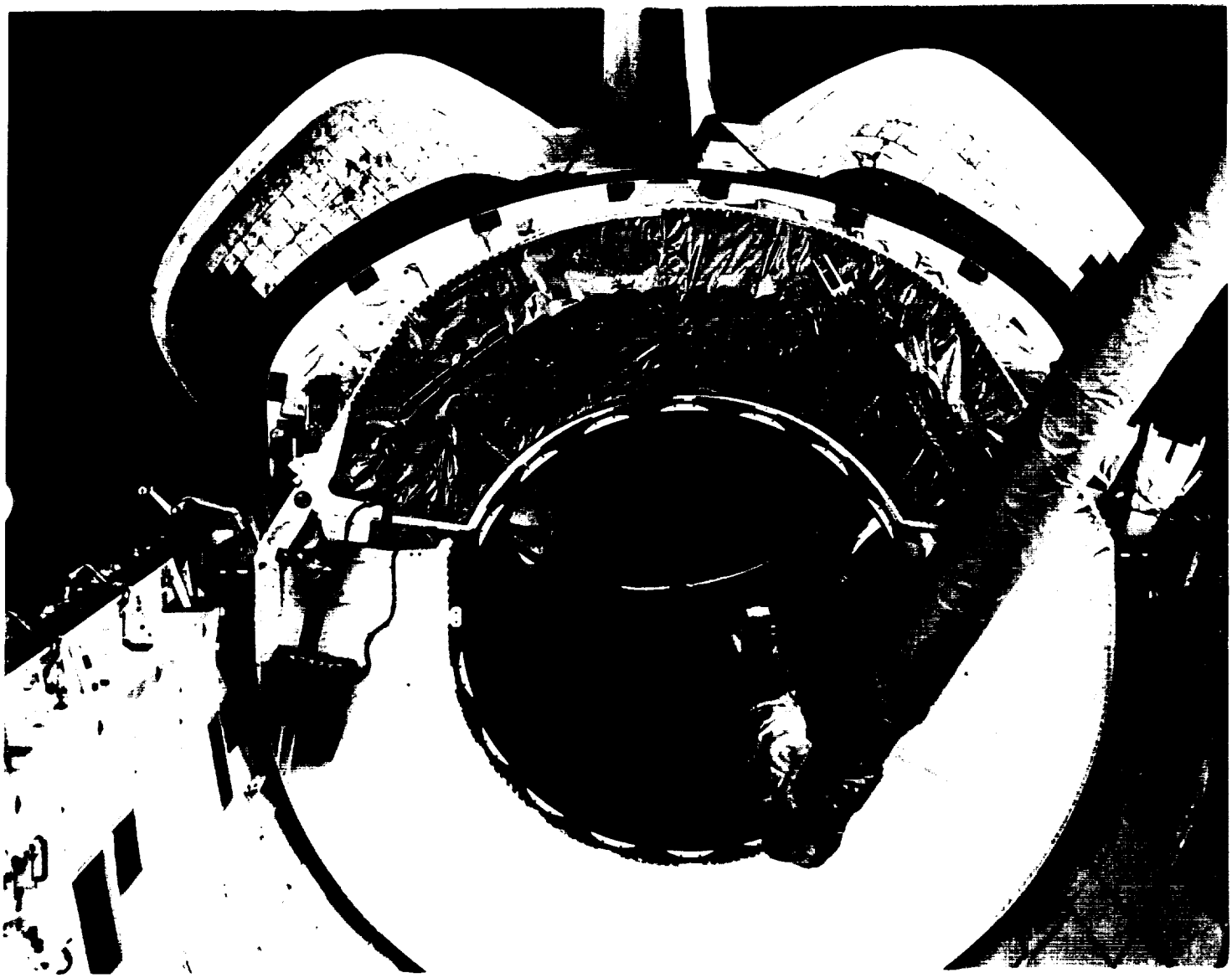
A review of on-orbit photographs from the crew handheld still cameras showed 6 damage sites on the vertical stabilizer base leading edge tiles. The LH OMS pod leading edge sustained a total of 18 tile damage sites. Seven hits were greater than one inch in length with depths ranging from 0.75 to 1.00 inches.

Post landing inspection of the payload bay revealed three penetrations (3-1/2" x 1/8", 3/4" x 1/8", 1-3/4" x 1/8") in bay #12 cable tray covers, one penetration (1/2" x 1/8") through the aft bulkhead near APU #3, scrapes on the bay #12 sill longeron, cuts/tears in thirteen TPS insulation blankets, and silicone/ lead residues on fifteen aft bulkhead blankets. A 13-inch long segment of the frangible doubler was wedged between the port sill and the aft bulkhead.

During the ACTS/TOS deployment, the primary and secondary separation detonation cords in the airborne support equipment Super*Zip device fired simultaneously. This caused the ordnance containment tube to rupture and release debris into the orbiter payload bay. Only the primary detonation cord should have fired.



On-orbit camera view revealed at least 16 pieces of debris, most likely detached frangible doublers from the outer perimeter of the Super*Zip separation system, exiting the payload bay after satellite deployment.



Debris from the Super*Zip anomaly caused 6 damage sites on the vertical stabilizer leading edge tiles. The LH OMS pod leading edge sustained a total of 18 tile damage sites.

COLOR PHOTOGRAPH

EXTERNAL TANK

Thirty-seven handheld still images (DTO-0312) and video were obtained of the External Tank after separation from the Orbiter by the flight crew. OV-103 was not equipped to carry umbilical cameras.

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

One 8-inch divot was visible in the LH2 tank acreage just aft of the LH2 tank-to-intertank flange closeout between the bipods. Both +Y and -Y bipod ramps and jack pad closeouts appeared to be intact.

One 8-inch divot occurred in the LH2 tank-to-intertank flange closeout adjacent to the outboard side of the -Y bipod spindle housing closeout.

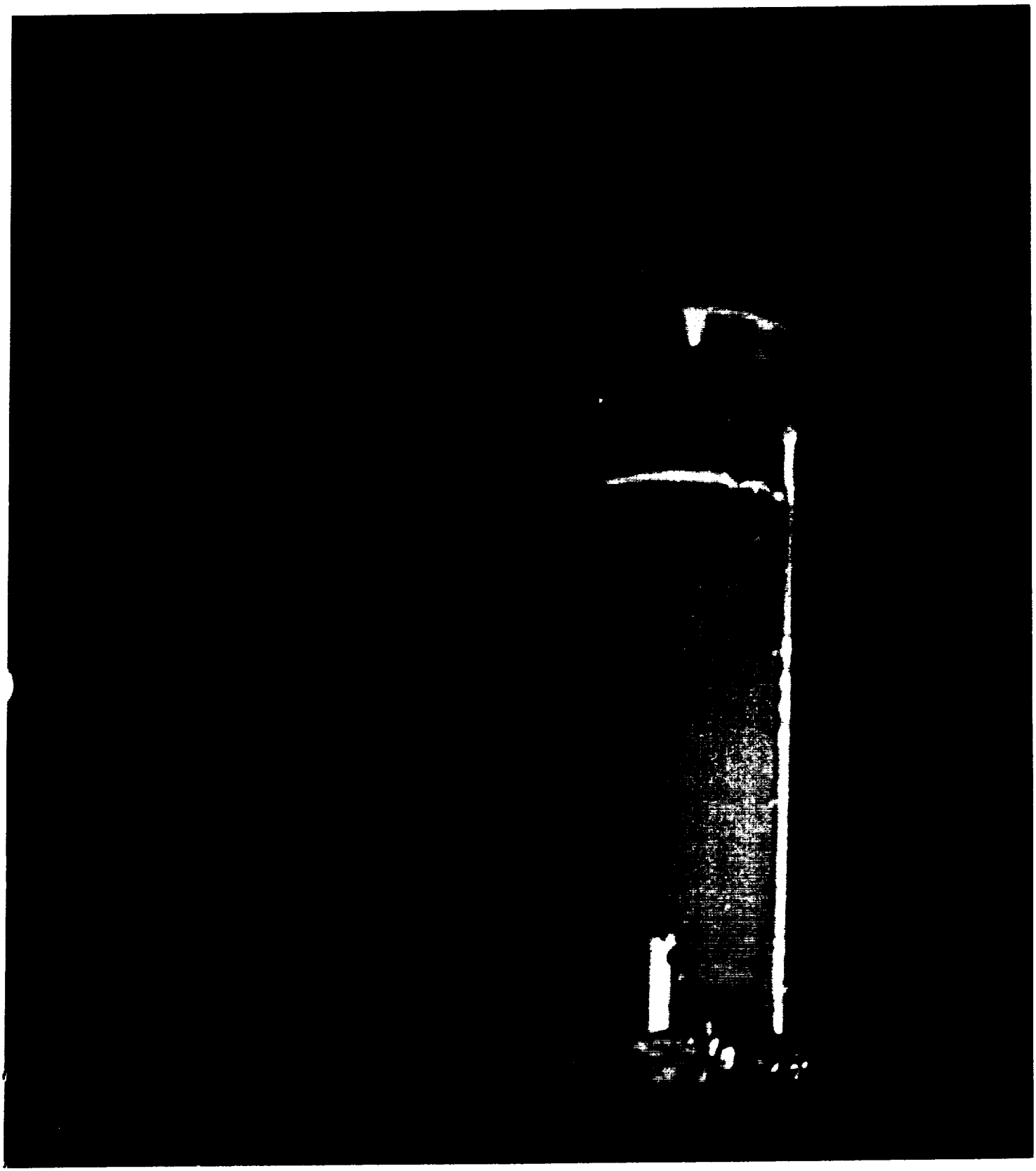
Three 8-inch diameter divots were present on or near the -Z LH2 tank-to-intertank flange closeout.

A divot, 10-12 inches in diameter, was present in the -Y (LH) longeron closeout.

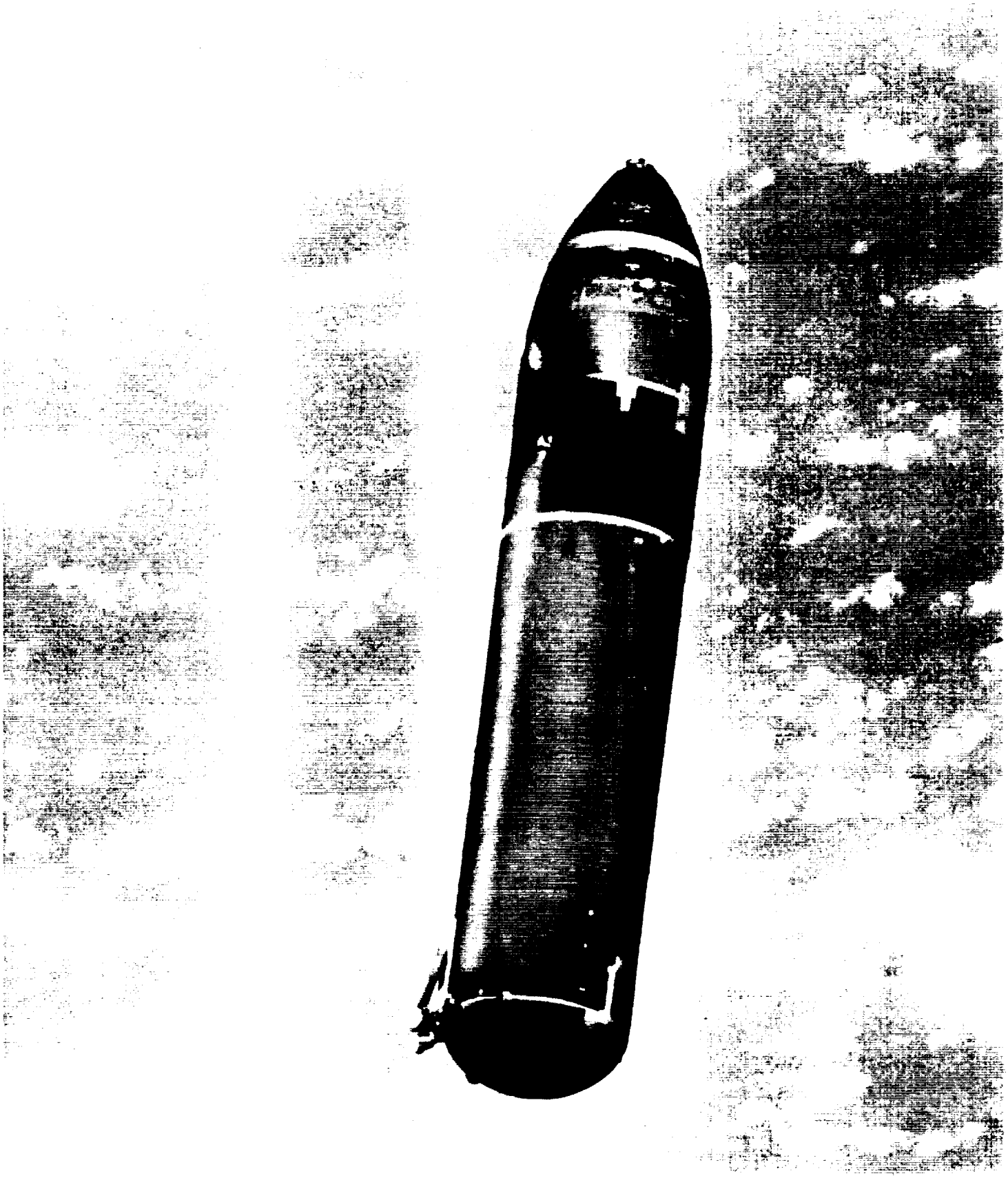
Foam was missing from the +Y thrust strut flange closeout and "new" foam was exposed.

The BSM burn scars on the LO2 tank were typical. No anomalies were observed on the nosecone, LO2 tank acreage, PAL ramps, RSS antennae, flight door, flight umbilical carrier plate, EB fittings, bipod ramps, LO2 feedline, aft hard point, and LH2 tank aft dome acreage. Typical ablation had occurred on the two aft dome manhole cover closeouts. Frozen hydrogen was visible on the LH2 ET/ORB umbilical 17-inch flapper valve.

No major damage or lost flight hardware was observed that would have been a safety of flight concern. A rare, detailed view of the nosecone showed charring, but no signs of TPS loss. No anomalies were visible on the tank acreage, RSS antenna, flight door, flight umbilical carrier plate, and EB fittings. The light band on the LO2 tank ogive was an area sanded smooth prior to launch.



One 8-inch divot occurred in the LH2 tank-to-intertank flange closeout adjacent to the outboard side of the -Y bipod spindle housing closeout; one 8-inch divot was present in the LH2 tank acreage just aft of the flange closeout between the bipods; and one divot, 10-12 inches in diameter, was visible in the left (-Y) longeron closeout (arrows).



Three divots are visible in the LH2 tank-to-intertank flange closeout (arrows). The BSM burn scar on the LO2 tank and aft dome charring are typical. Scorch marks running the length of the ET from the EB fitting were caused by shock waves/air flow. There were no TPS anomalies on the LH2 and LO2 tank acreage.

8.3 LANDING FILM AND VIDEO SUMMARY

A total of twenty-three landing items, including eight 35mm large format films, four 16mm high speed films, and 11 videos, were reviewed.

Due to the dark conditions of a night landing, most detail of the approach, touchdown, and rollout were obtained from infrared (3-5 and 8-12 micron) imagery.

Orbiter performance in the Heading Alignment Circle (HAC) and final approach appeared normal. There were no anomalies when the landing gear was extended. Touchdown of the left and right main gear was nominal and almost simultaneous.

The Xenon lights at the runway threshold provided good definition of the Orbiter wing tip vortices.

The drag chute was deployed just after breakover, but before the nose gear contacted the runway. Drag chute deployment appeared nominal. The drag chute door appeared to get caught in an aerodynamic vortex and made a harder-than-usual impact with the runway. The mortar cover was propelled upward/aft when the pyrotechnic charge fired and followed a trajectory to clear the grass along the edge of the runway. The cover was not recovered and most likely landed in a canal.

Touchdown of the nose landing gear was smooth. The Orbiter drifted slightly east of the runway centerline before being corrected with nose wheel steering.

Auxiliary Power Unit (APU) exhaust at the base of the vertical stabilizer, left side, appeared to be 2 - 3 feet in height and more noticeable than previous night landings. Infrared imagery during approach/rollout, cockpit instrumentation, and telemetry indicated the APU exhaust plume was typical and similar to APU operation for launch. APU #3 exhaust plume on the right side of the vertical stabilizer was present but barely visible.

9.0 SRB POST FLIGHT/RETRIEVAL DEBRIS ASSESSMENT

Both Solid Rocket Boosters were inspected for debris damage and debris sources at CCAFS Hangar AF on 14 September 1993 from 0830 to 1100 hours. From a debris standpoint, both SRB's were in good condition.

9.1 RH SOLID ROCKET BOOSTER DEBRIS INSPECTION

The RH frustum had 47 MSA-2 debonds over fasteners. Minor blistering of the Hypalon paint had occurred in localized areas (Figure 11). All BSM aero heatshield covers were locked in the fully opened position.

The RH forward skirt acreage had two small MSA-2 divots as a result of handling. There were no MSA-2 debonds. The -Z RSS antenna cover/phenolic base plate was intact. The +Z RSS antenna cover was damaged and the phenolic base plate was missing. The substrate was not sooted and the damage most likely was the result of nozzle severance debris impact. Minor blistering of the Hypalon paint occurred on the systems tunnel cover and around the ET/SRB attach point (Figure 12). No pins were missing from the frustum severance ring. The forward separation bolt appeared to have separated cleanly.

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. Paint was missing from several areas on the forward segment.

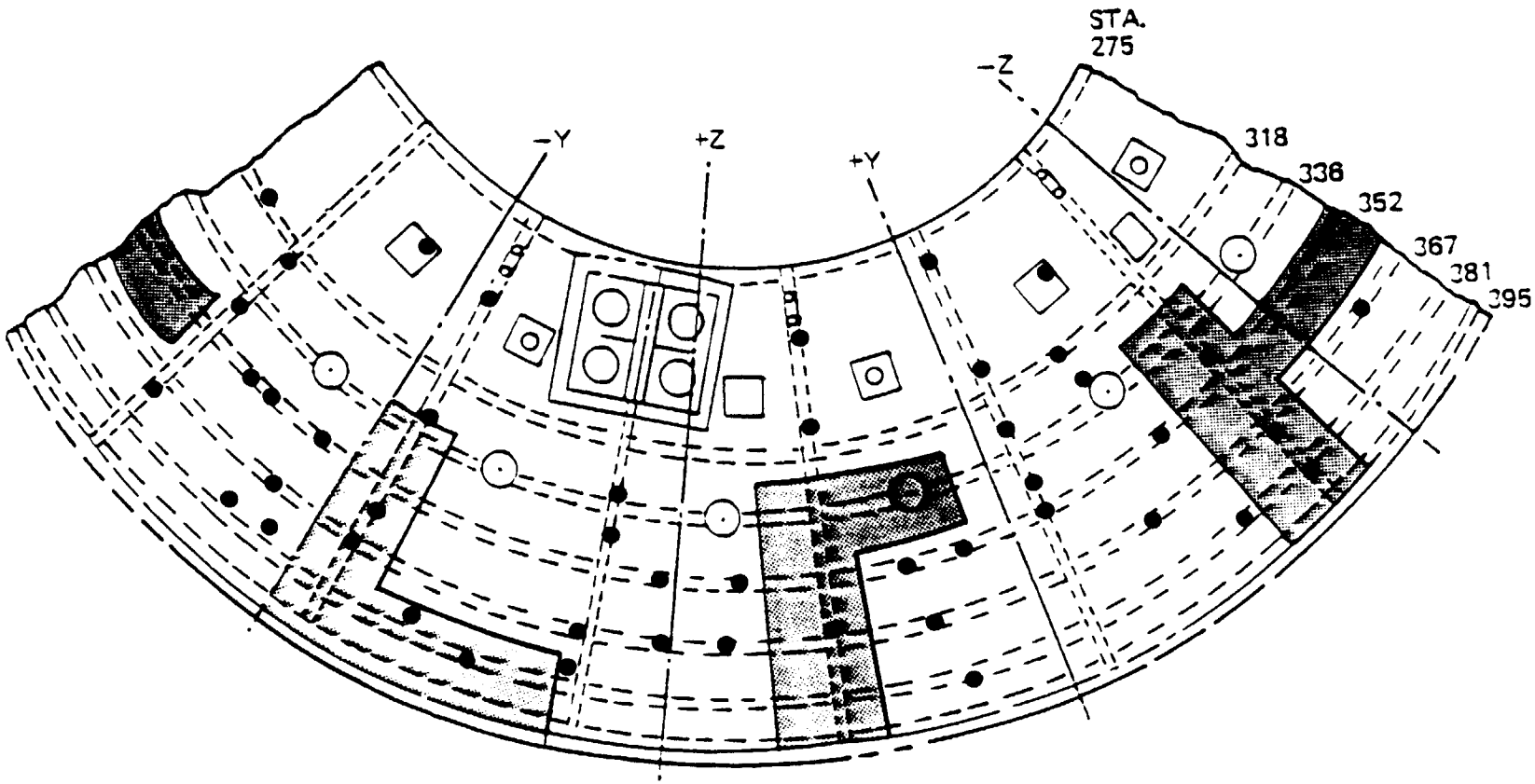
Separation of the aft ET/SRB struts appeared normal. The ET/SRB aft struts, ETA ring, IEA, and IEA covers appeared undamaged. The K5NA closeout material on the upper strut fairing was intact. All three aft booster stiffener rings sustained damage from water impact. The aft booster stiffener ring splice plate closeouts were intact and no K5NA material was missing.

The phenolic material on the kick ring was delaminated. The K5NA closeouts (protective domes) on the kick ring forward and aft fasteners are no longer used. RTV-133 has replaced the K5NA over the forward fasteners.

The aft skirt acreage TPS was generally in good condition. However, a separation line was detected between the Booster Trowellable Ablator (BTA) and the adjacent cork (Squawk 51-011, PV-6-252520). BTA was developed by USBI as a more economic alternative to the K5NA closeout material and was applied for the first time as closeout TPS to general acreage areas.

All four Debris Containment System (DCS) plungers were seated and appeared to have functioned correctly. The EPON shim material was intact during liftoff and flight (Figure 13).

FIGURE 11. **RIGHT SRB FRUSTUM**



MISSING TPS

NONE

DEBONDS

- 47 DEBONDS OVER FASTENERS

FIGURE 12. **RIGHT SRB FWD SKIRT**

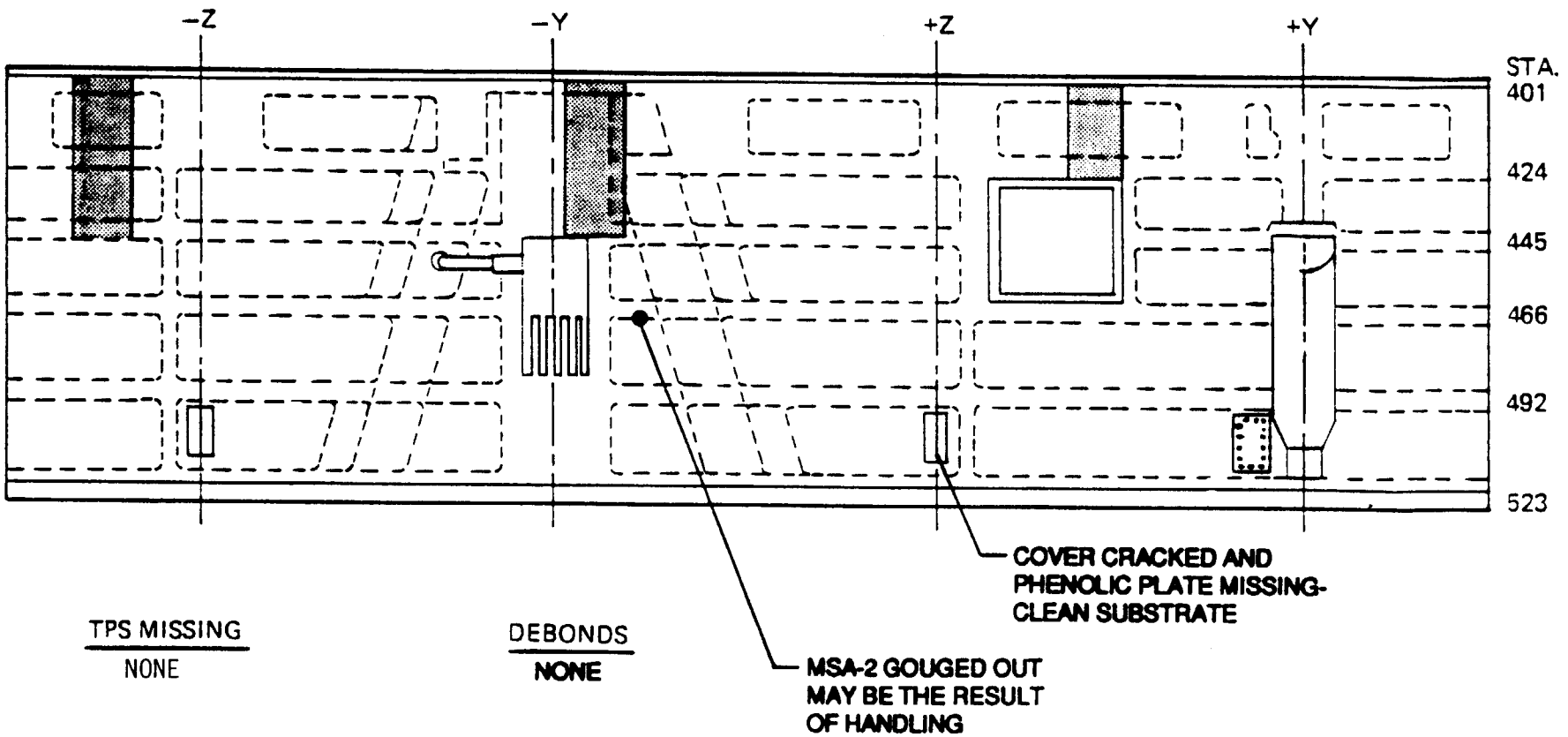
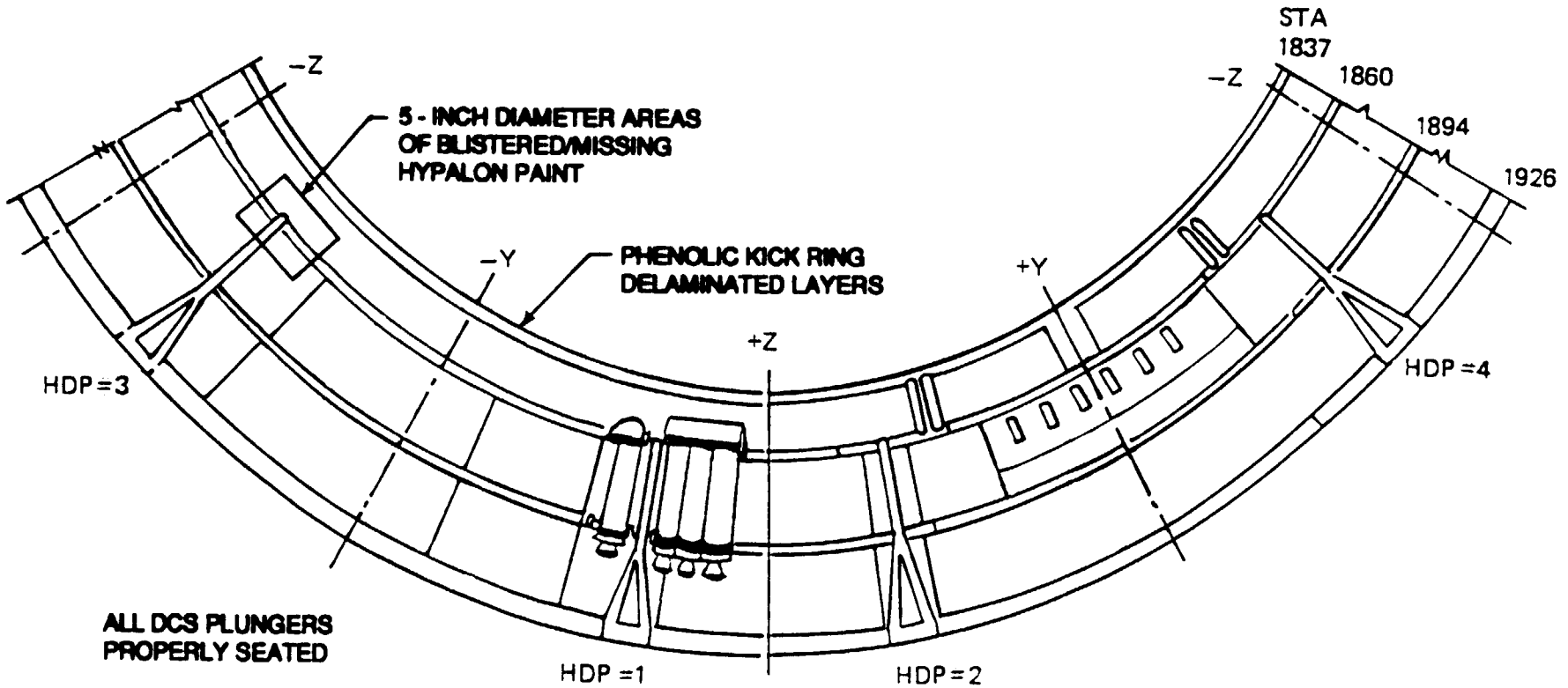
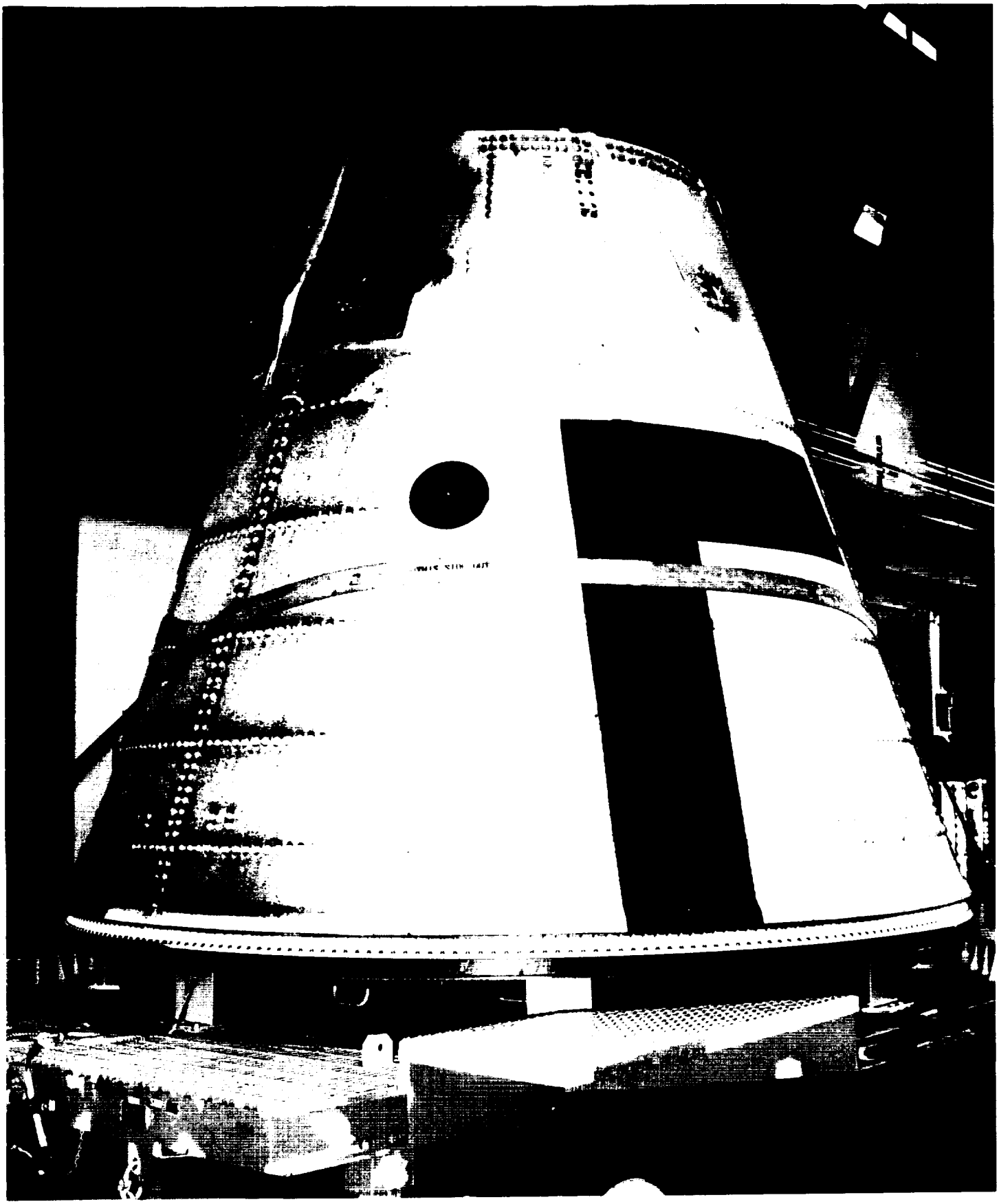


FIGURE 13. **RIGHT SRB AFT SKIRT EXTERIOR TPS**

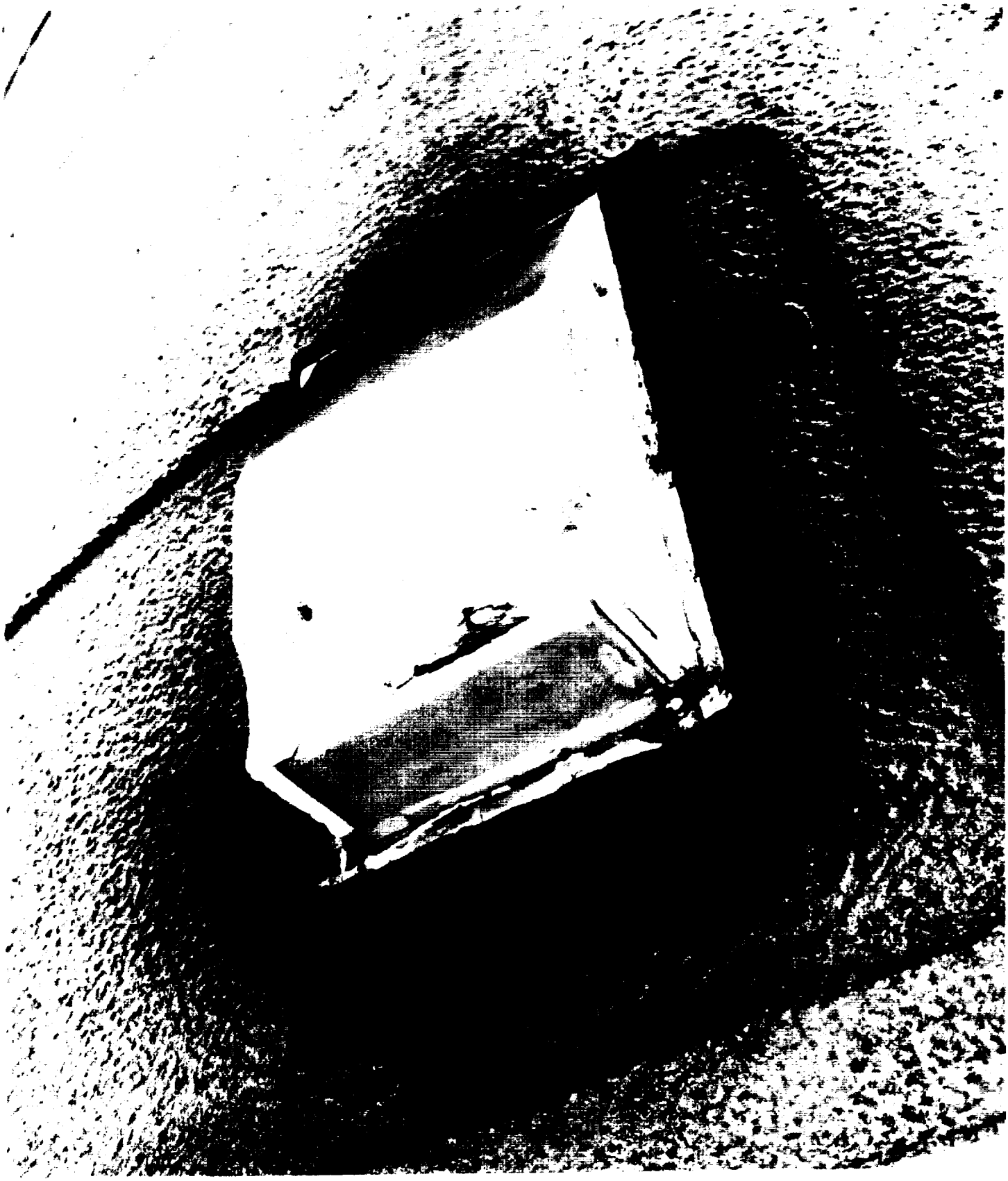


EGG-V 326C

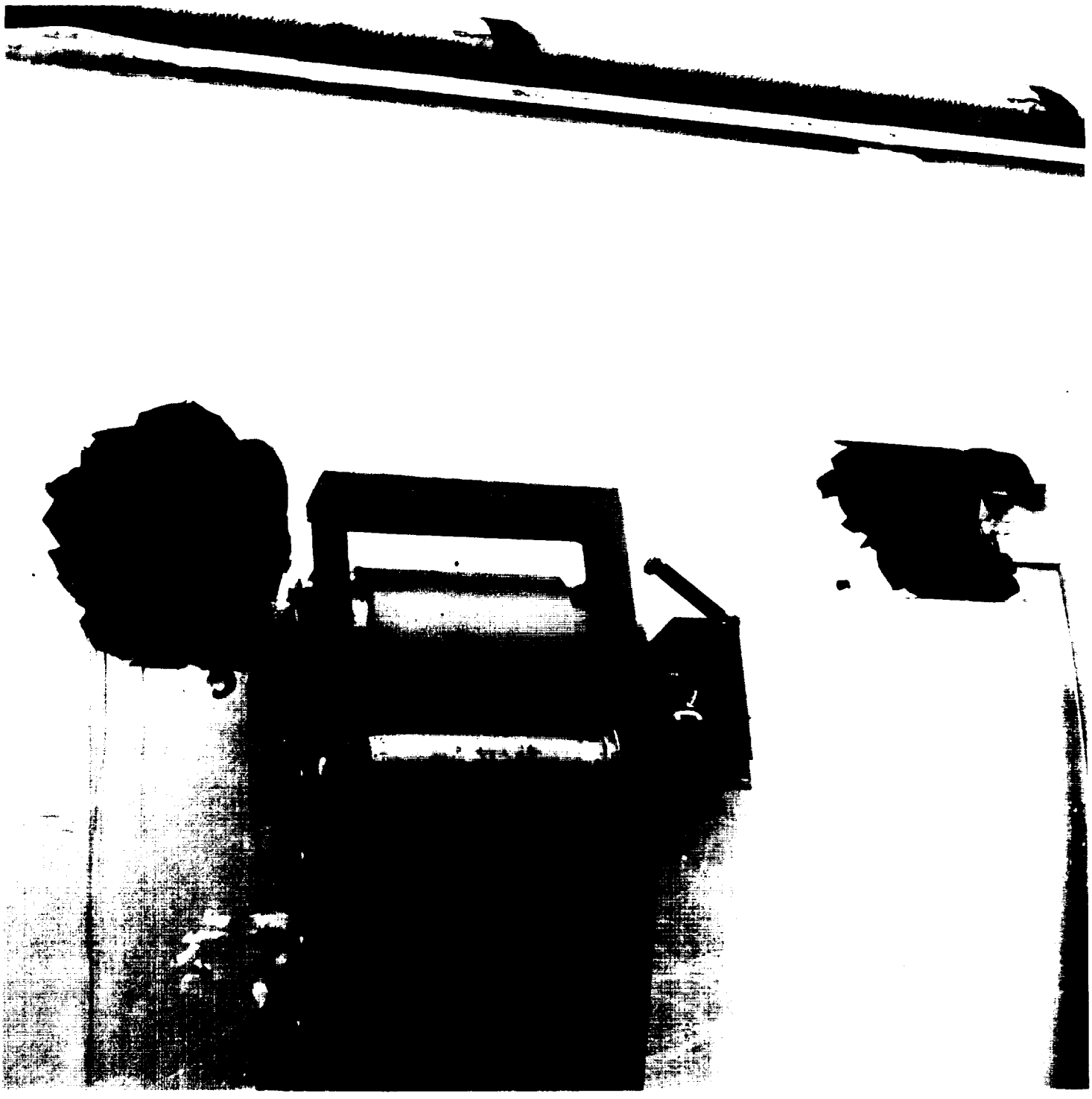


The RH frustum had 47 MSA-2 debonds over fasteners, but no missing TPS. All BSM aero heatshield covers were locked in the fully opened position.

The RH forward skirt acreage MSA-2 had no debonds. Two small areas of missing MSA-2 were the result of handling. The -Z RSS antenna cover/phenolic base plate was intact.



The +Z RSS antenna cover was damaged and the phenolic base plate was missing. The substrate was not sooted and the damage most likely was the result of nozzle severance debris impact.



Paint was missing from several areas on the forward segment

Post flight condition of the aft booster/aft skirt. A separation line was detected between the Booster Trowellable Ablator and the adjacent cork on the aft skirt. BTA, which is intended to replace K5NA closeouts, was applied for the first time as closeout TPS to general acreage areas.

9.2 LH SOLID ROCKET BOOSTER DEBRIS INSPECTION

The LH frustum was missing no TPS, but had 41 MSA-2 debonds over fasteners. Minor localized blistering of the Hypalon paint had occurred in localized areas (Figure 14). The BSM aero heat shield covers were locked in the fully opened position.

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

The Field Joint Protection System (FJPS) closeouts were in good condition. In general, minor trailing edge damage to the FJPS and the GEI cork runs were attributed to debris resulting from severance of the nozzle extension.

Separation of the aft ET/SRB struts appeared normal. The ET/SRB aft struts, ETA ring, IEA, and IEA covers appeared undamaged. The K5NA closeout material on the upper strut fairing was intact. Two aft booster stiffener rings were damaged by water impact. The stiffener ring splice plate closeouts were intact and no K5NA material was missing.

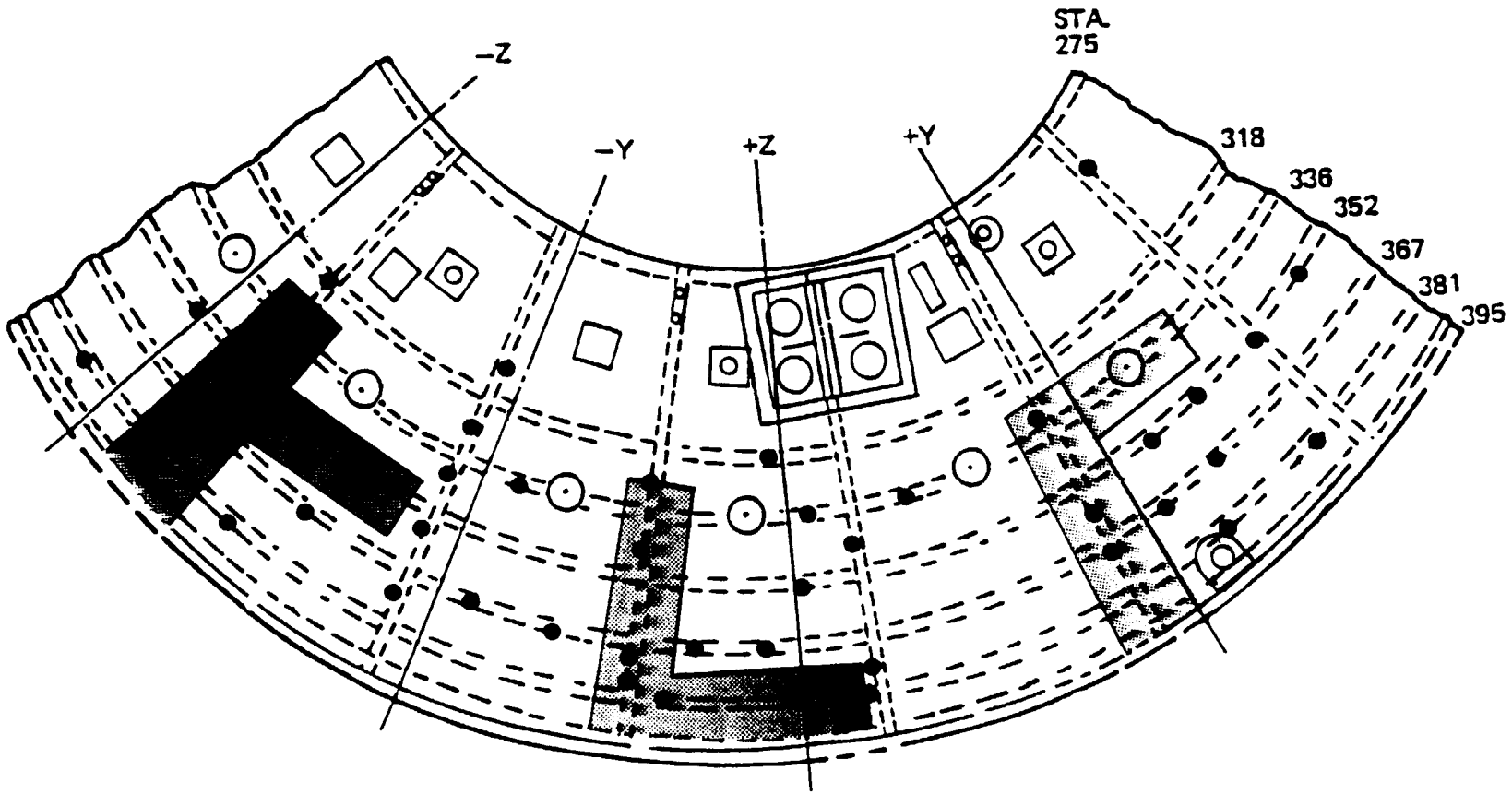
The phenolic material on the kick ring was delaminated. A 3-inch diameter piece of MSA-2 was missing from aft skirt fasteners near the +Y side of the BSM's. Four MSA-2 debonds over fasteners also occurred in this same general area. A separation line was detected between the BTA and adjacent cork (Squawk 51-010, PV-6-252523).

Hypalon paint was extensively blistered and/or missing from numerous areas of Booster Trowellable Ablator on the aft skirt - IFA STS-51-B-2 (Figure 15). The Hypalon paint is used as a topcoat to prevent moisture intrusion prior to launch, but is not required for thermal protection during flight. The IFA was closed based on the rationale that blistering and/or loss of Hypalon in flight will not cause significant Orbiter tile damage due to the light mass/density of the topcoat. Practical application history has shown that blistering and loss of Hypalon occurs most frequently when multiple coats of the paint were applied during preflight processing. A change to the application procedure may specify only one, thin coat of Hypalon.

All four Debris Containment System (DCS) plungers were seated and appeared to have functioned properly. Approximately ten percent of the EPON shim material on HDP #7 aft skirt support structure was missing prior to splashdown. The substrate was sooted.

SRB Post Launch Anomalies are listed in Section 12.

FIGURE 14. **LEFT SRB FRUSTUM**



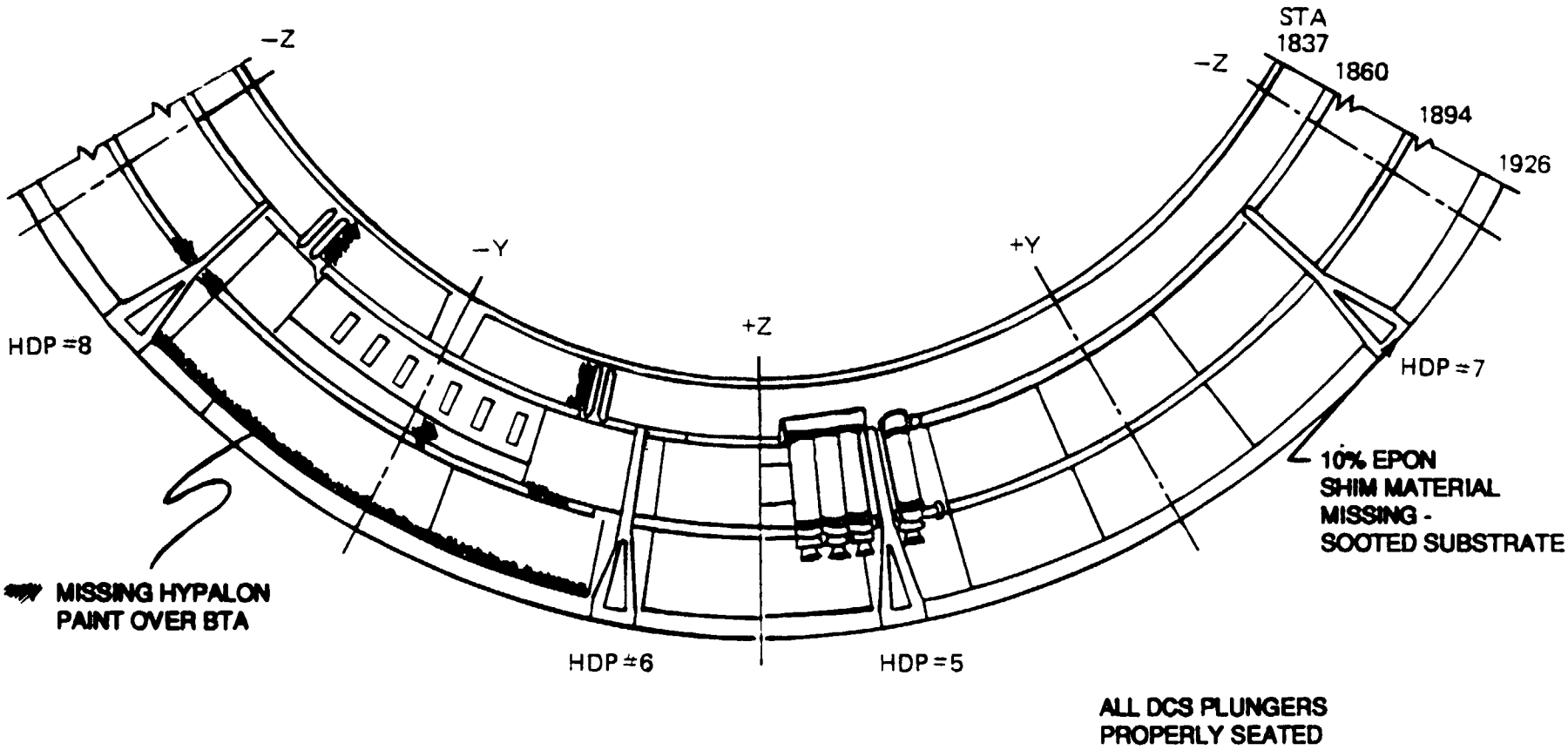
MISSING TPS

NONE

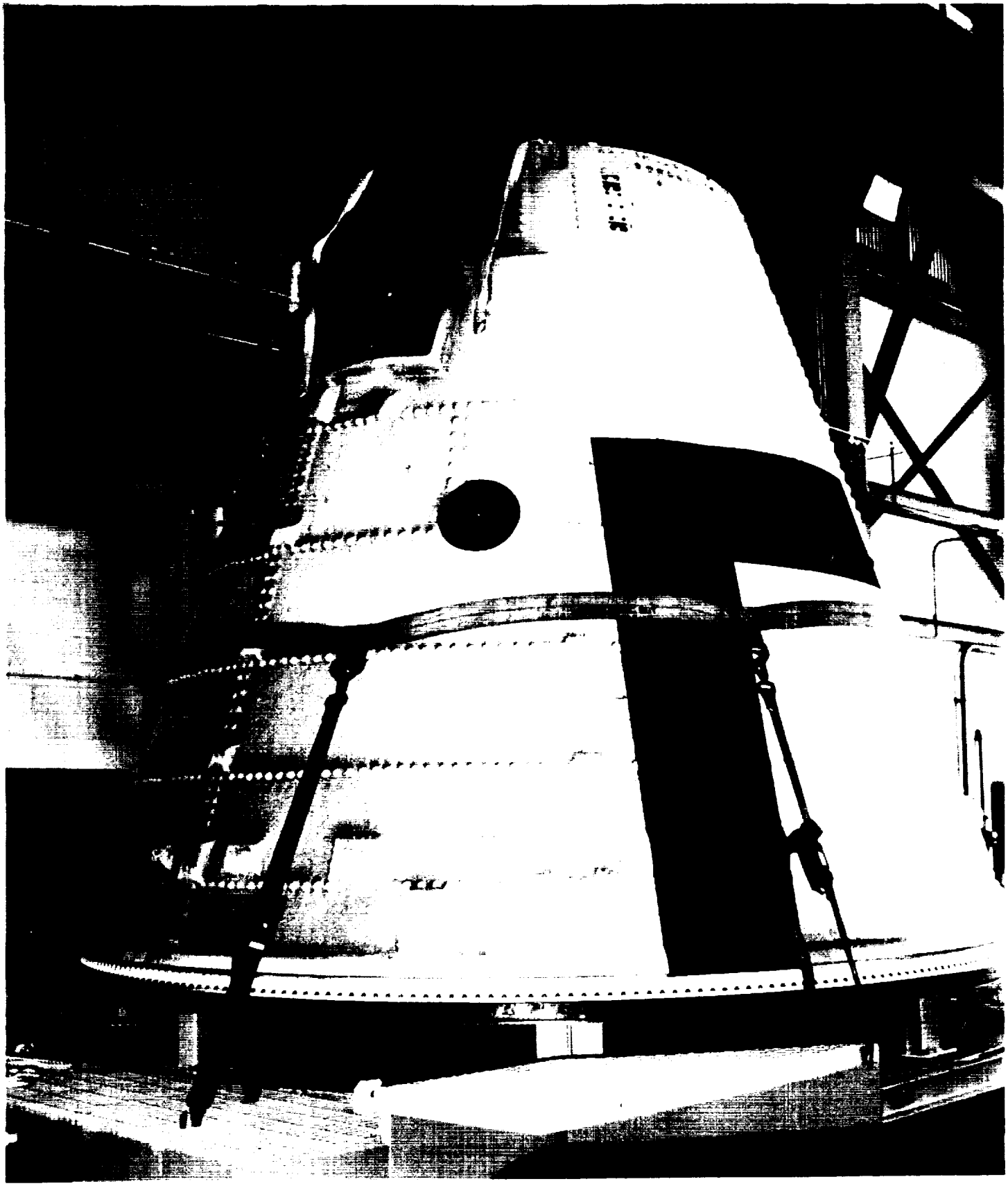
DEBONDS

● 41

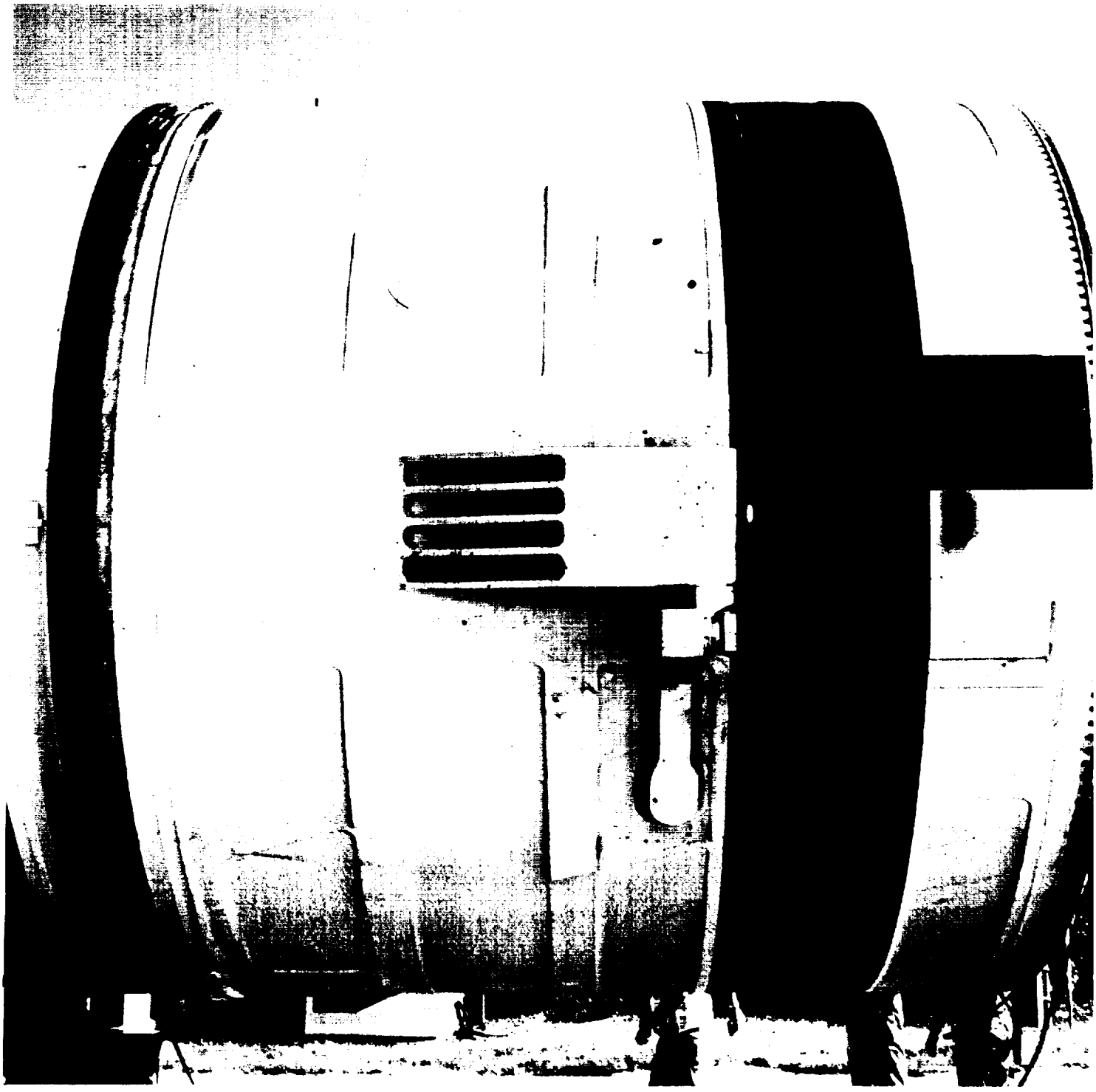
FIGURE 15. **LEFT SRB AFT SKIRT EXTERIOR TPS**



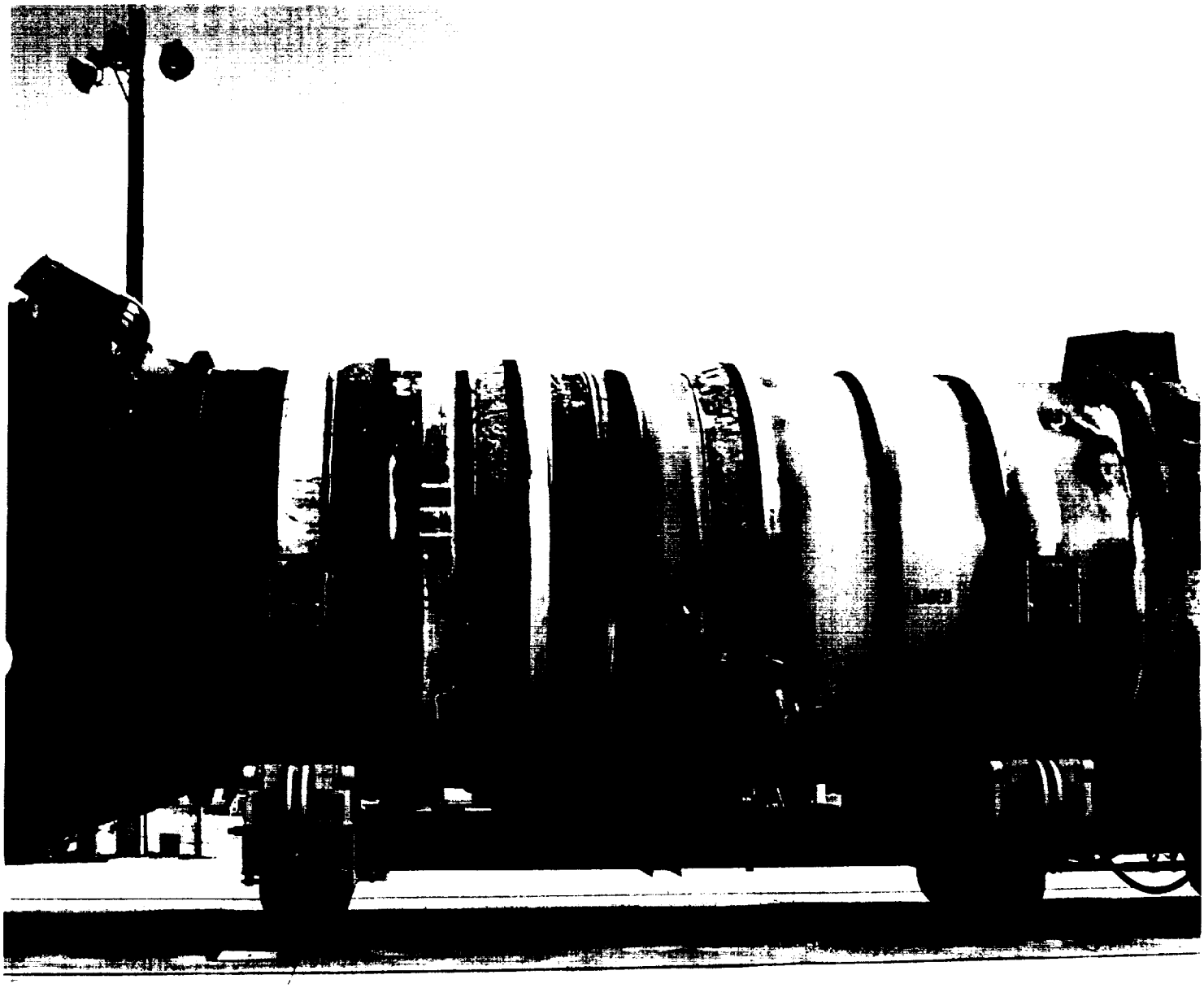
EGG/V-326F



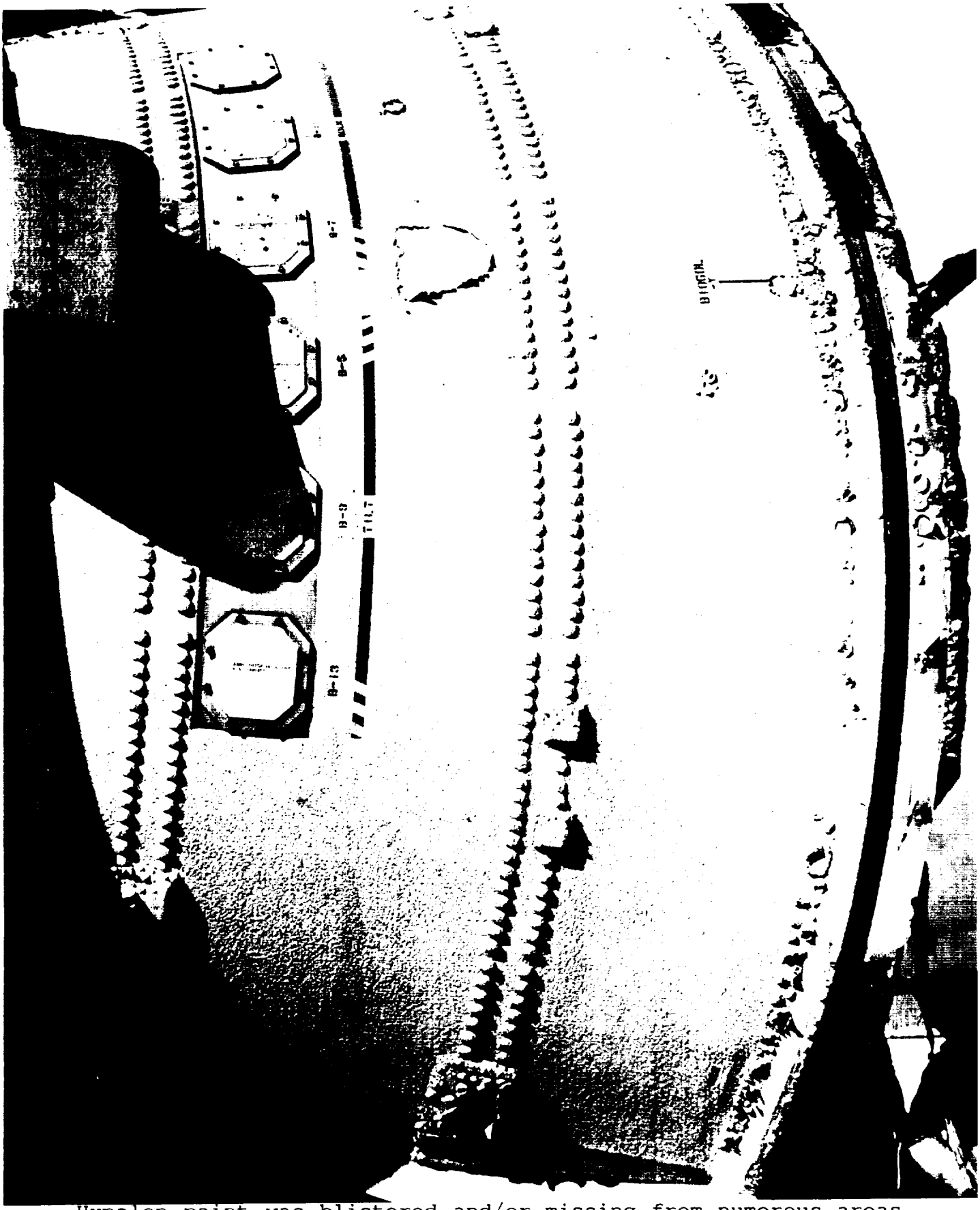
The LH frustum was missing no TPS, but had a total of 41 MSA-2 debonds over fasteners. The BSM aero heatshield covers were locked in the fully opened position.



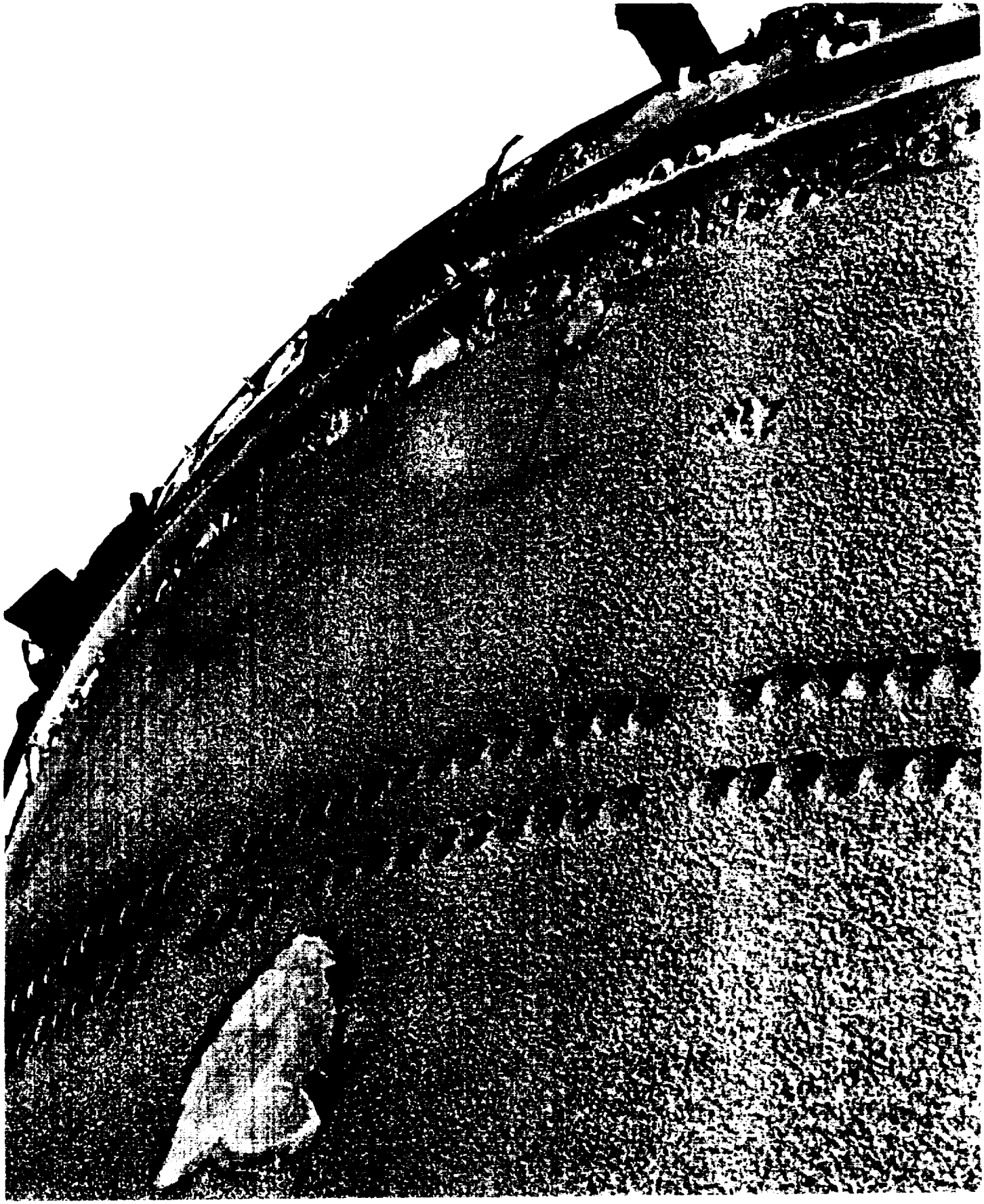
The LH forward skirt acreage MSA-2 exhibited no debonds or missing TPS. Both RSS antenna covers/phenolic base plates were intact.



Post flight condition of the aft booster/aft skirt. A 3-inch diameter divot and 4 debonds occurred over aft skirt fasteners near the BSM's. A separation line was detected between the BTA and the adjacent cork.



Hypalon paint was blistered and/or missing from numerous areas of Booster Trowellable Ablator on the aft skirt. The Hypalon paint is used as a topcoat to prevent moisture intrusion prior to launch, but is not required for thermal protection during flight. BTA, which is intended to replace K5NA closeouts, was applied for the first time as closeout TPS to general acreage areas.



Blistering and loss of Hypalon paint occurs most frequently when multiple coats of the paint are applied during pre-flight processing. A change to the application procedure could specify only one, thin coat of Hypalon.

10.0 ORBITER POST LANDING DEBRIS ASSESSMENT

A post landing debris inspection of OV-103 (Discovery) was conducted 22-23 September 1993 at the Kennedy Space Center on Shuttle Landing Facility (SLF) runway 15 and in the Orbiter Processing Facility bay #3. This inspection was performed to identify debris impact damage and, if possible, debris sources. The Orbiter TPS sustained a total of 154 hits, of which 18 had a major dimension of one inch or greater. This total does not include the numerous hits on the base heat shield attributed to SSME vibration/acoustics and exhaust plume recirculation. A comparison of these numbers to statistics from 41 previous missions of similar configuration (excluding missions STS-23, 25, 26, 26R, 27R, 30R, and 42, which had damage from known debris sources), indicates that the total number of hits was slightly greater than average while the number of hits one inch or larger was less than average (reference Figures 16-19).

The Orbiter lower surface sustained a total of 100 hits, of which 18 had a major dimension of one inch or greater. The distribution of hits on the lower surface does not suggest a single source of ascent debris, but indicates a shedding of ice and Thermal Protection System (TPS) debris from random sources.

The following table breaks down the STS-51 Orbiter debris damage by area:

	HITS > 1"	TOTAL HITS
Lower surface	8	100
Upper surface	1	22
Right side	1	2
Left side	0	4
Right OMS Pod	1	8
Left OMS Pod	7	18
TOTALS	18	154

The largest tile damage site on the lower surface (RH inboard elevon) measured 3.75" x 0.50" x 0.25".

Twenty-nine hits just aft of the LH2 ET/ORB umbilical may be indicative of impacts from higher density materials, such as ice.

No anomalies were noted on the RCC nosecap. LH RCC panel #9 coating had degraded. RH RCC panels #9 and #12 were streaked or marked.

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

FIGURE 16. **DEBRIS DAMAGE LOCATIONS**

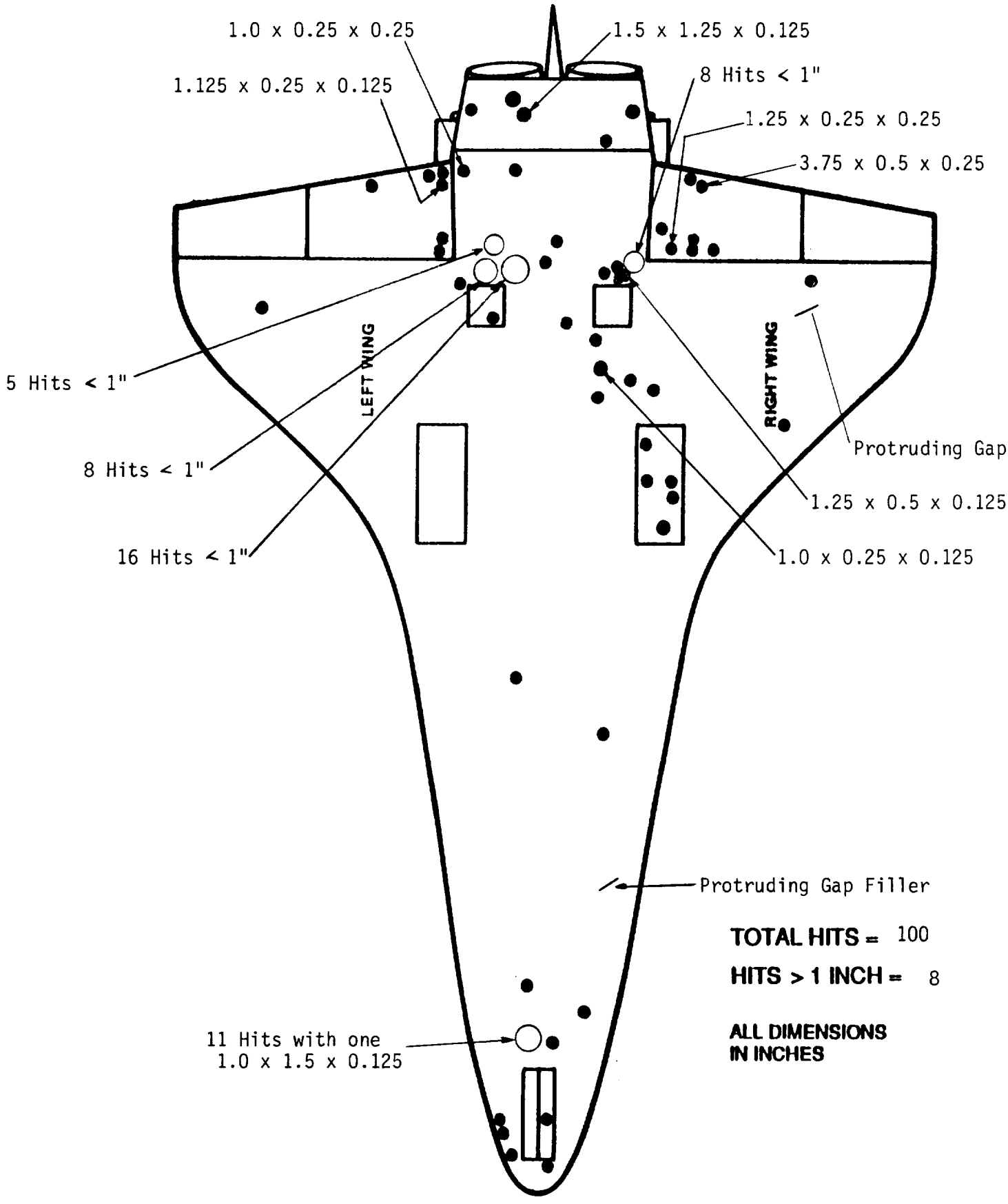
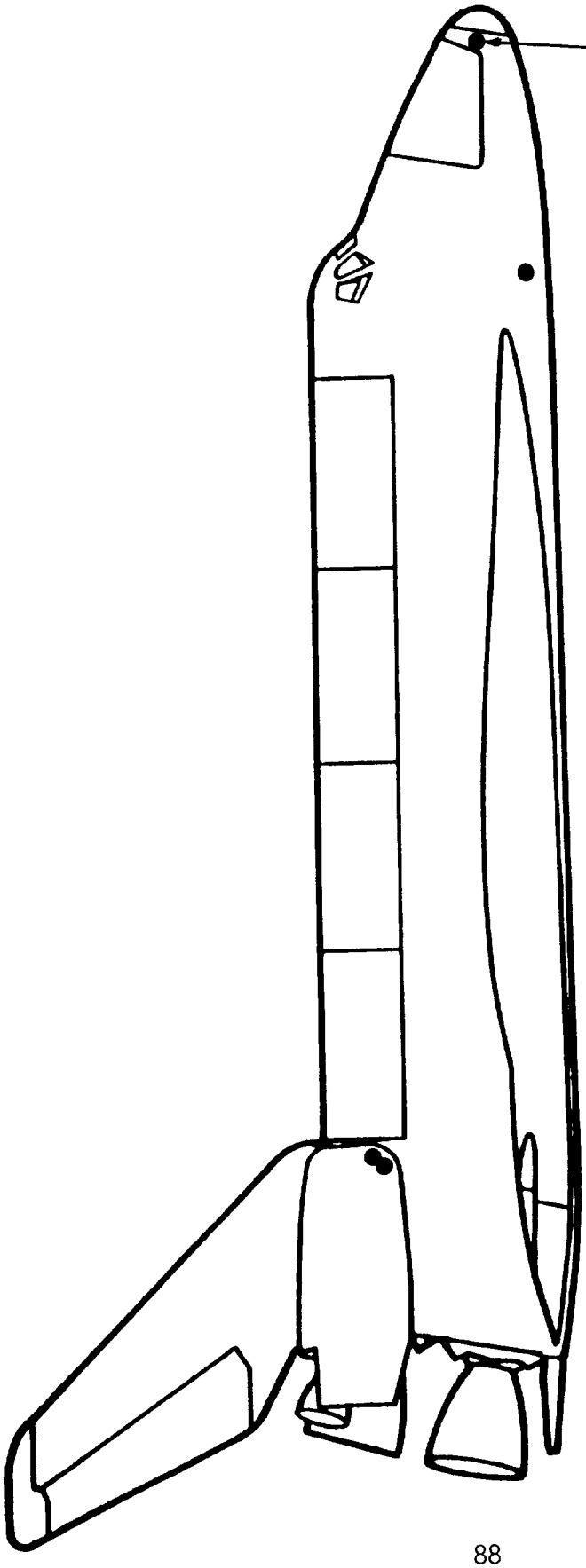


FIGURE 17. **DEBRIS DAMAGE LOCATIONS**

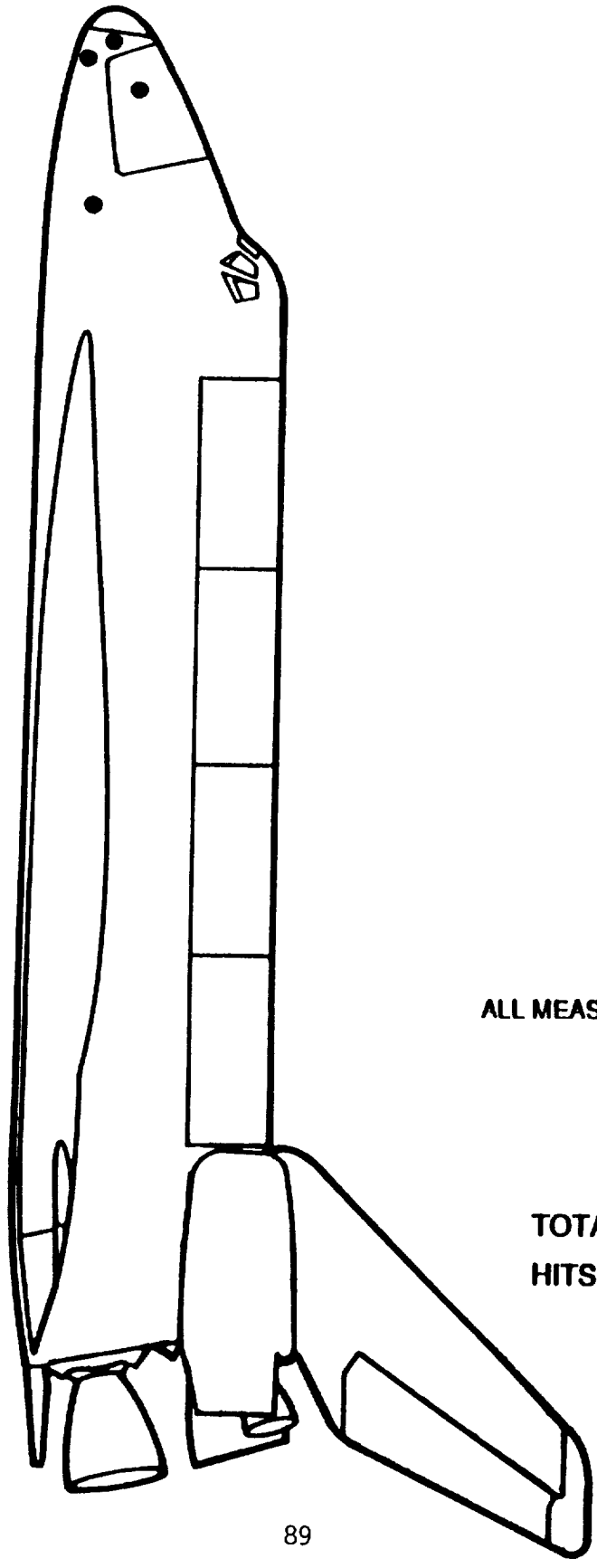


TOTAL HITS = 4

HITS > 1 INCH = 1

STS-51

FIGURE 18. **DEBRIS DAMAGE LOCATIONS**

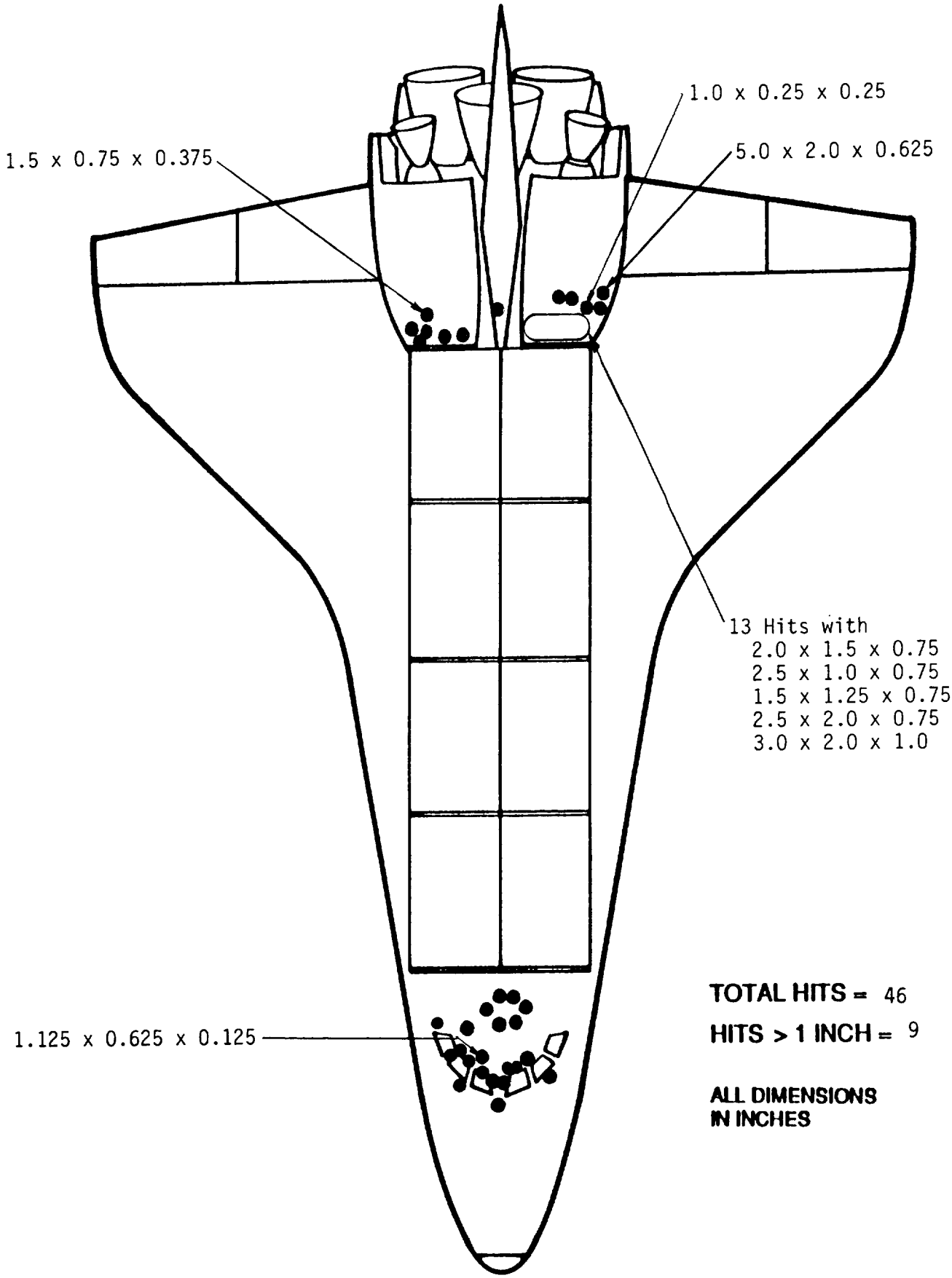


ALL MEASUREMENTS IN INCHES

TOTAL HITS = 4

HITS > 1 INCH = 0

FIGURE 19. **DEBRIS DAMAGE LOCATIONS**



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

Orbiter windows #3 and #4 were moderately hazed; windows #2 and #5 exhibited light hazing. Streaks were present on windows #2, #3 and #4. Surface wipes were taken from all windows for laboratory analysis.

Tile damage on the base heat shield was less than average though one tile between SSME #2 and #3 exhibited a large damage site. One Dome Mounted Heat Shield (DMHS) closeout blanket MR patch on SSME #2 9:00 o'clock position was torn/frayed, but no material was missing. The other DMHS blankets were in excellent condition. Tiles on the vertical stabilizer "stinger" and around the drag chute door were intact and undamaged.

The LH OMS pod leading edge sustained a total of 18 tile damage sites. Seven hits were greater than an inch in length with depths ranging from 0.75 to 1.00 inch. The damage was caused by debris from the TOS Super*Zip anomaly.

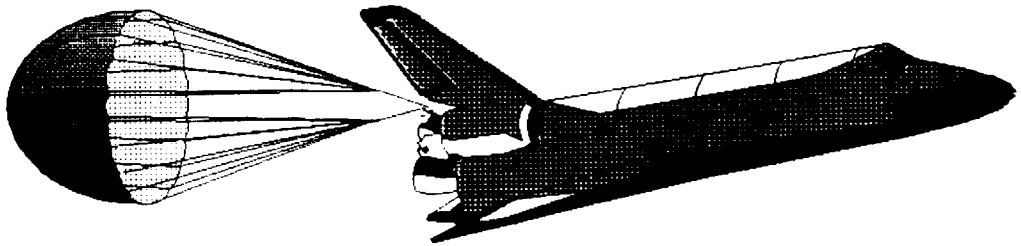
Due to the very prominent APU exhaust visible during the night landing, an inspection of the area around the APU exhaust ports and at the base of the vertical stabilizer was made. There were no anomalies, such as TPS damage, loss of material, signs of burning or melting, scorch marks, etc. The appearance of the visible exhaust was considered to be a result of normal APU operation.

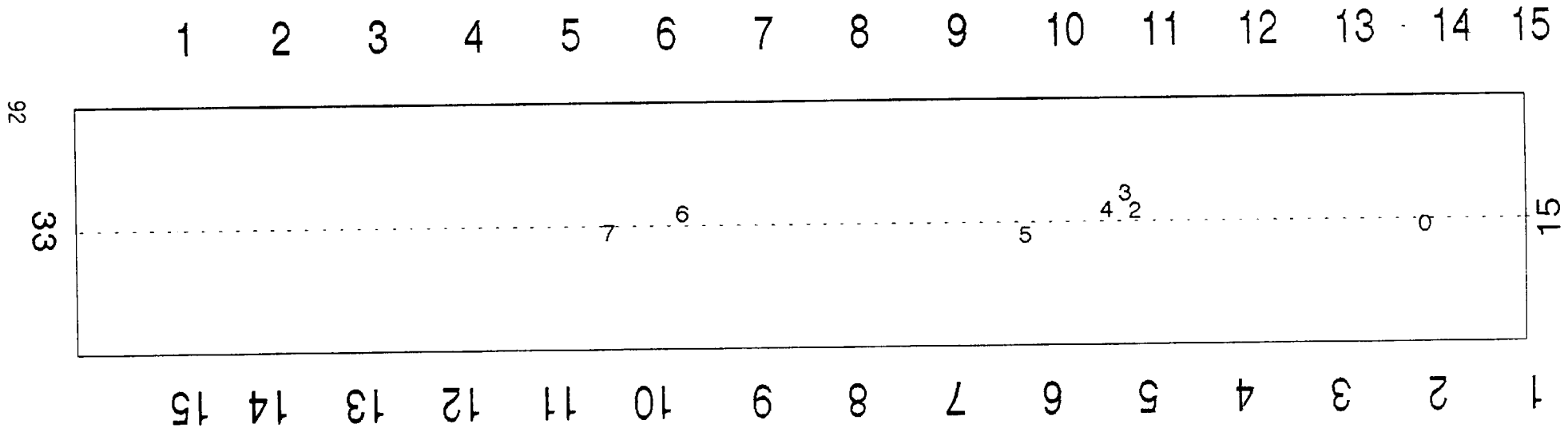
Runway 15 had been swept/inspected by SLF operations personnel prior to landing and all potentially damaging debris was removed.

The post landing walkdown of Runway 15 was performed immediately after landing. All Orbiter drag chute hardware, with the exception of the mortar cover, was recovered and showed no signs of abnormal operation (tenth use of the Orbiter drag chute in the Shuttle program). The cover was not found during a more detailed daylight search. No organic (bird) debris was found on the runway. Four Q-felt plugs, most likely from the base heat shield area, were recovered in the vicinity of the drag chute door (Figure 20).

The Shuttle Thermal Imager (STI) was used to measure the surface temperatures of several areas on the vehicle (per OMRSD V09AJ0.095). Nine minutes after landing, the Orbiter nosecap RCC was 206 degrees F. Forty-two minutes after landing, the RH wing leading edge RCC panel #9 was 108 degrees F and panel #17 was 107 degrees F (Figure 21).

FIGURE 20. RECOVERY LOCATIONS OF DRAG CHUTE COMPONENTS





0 (MLG TOUCHDOWN): 2100'
1 (MORTAR COVER): NOT FOUND
2 (SABOT): 5350', 25' R OF C/L
3 (DOOR): 5360',50' R OF C/L
4 (PILOT CHUTE): 5400', 15' R OF C/L
5 (NLG TOUCHDOWN): 6540'
6 (MAIN CHUTE): 9950', 15' R OF C/L
7 (WHEEL STOP): 10370'

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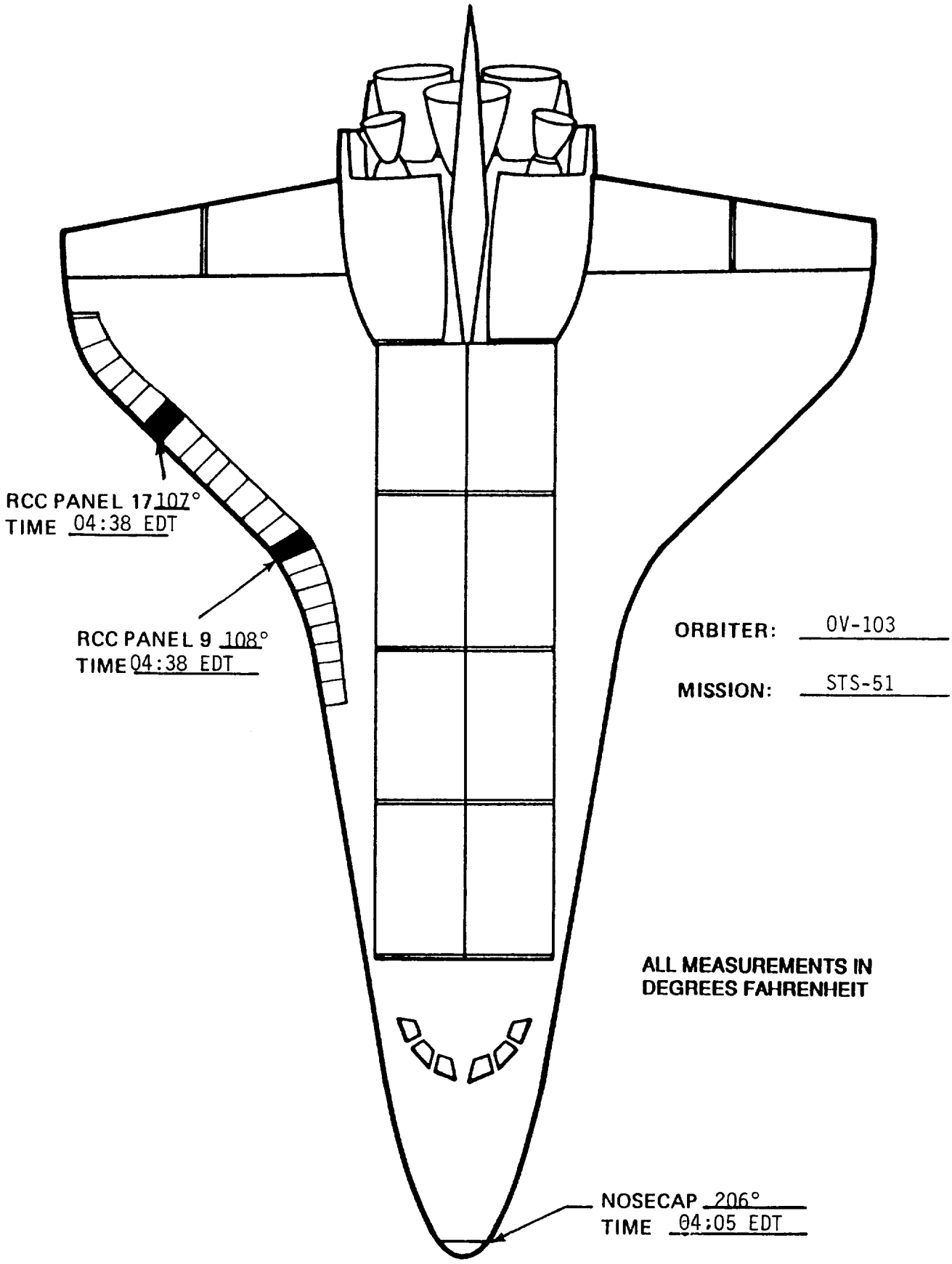
FIGURE 21. **STS-51 RCC TEMPERATURE MEASUREMENTS AS RECORDED BY THE SHUTTLE THERMAL IMAGER**



In summary, the total number of Orbiter TPS debris hits was slightly above average while the number of hits one inch or larger was less than average when compared to previous missions (reference Figures 22 and 23).

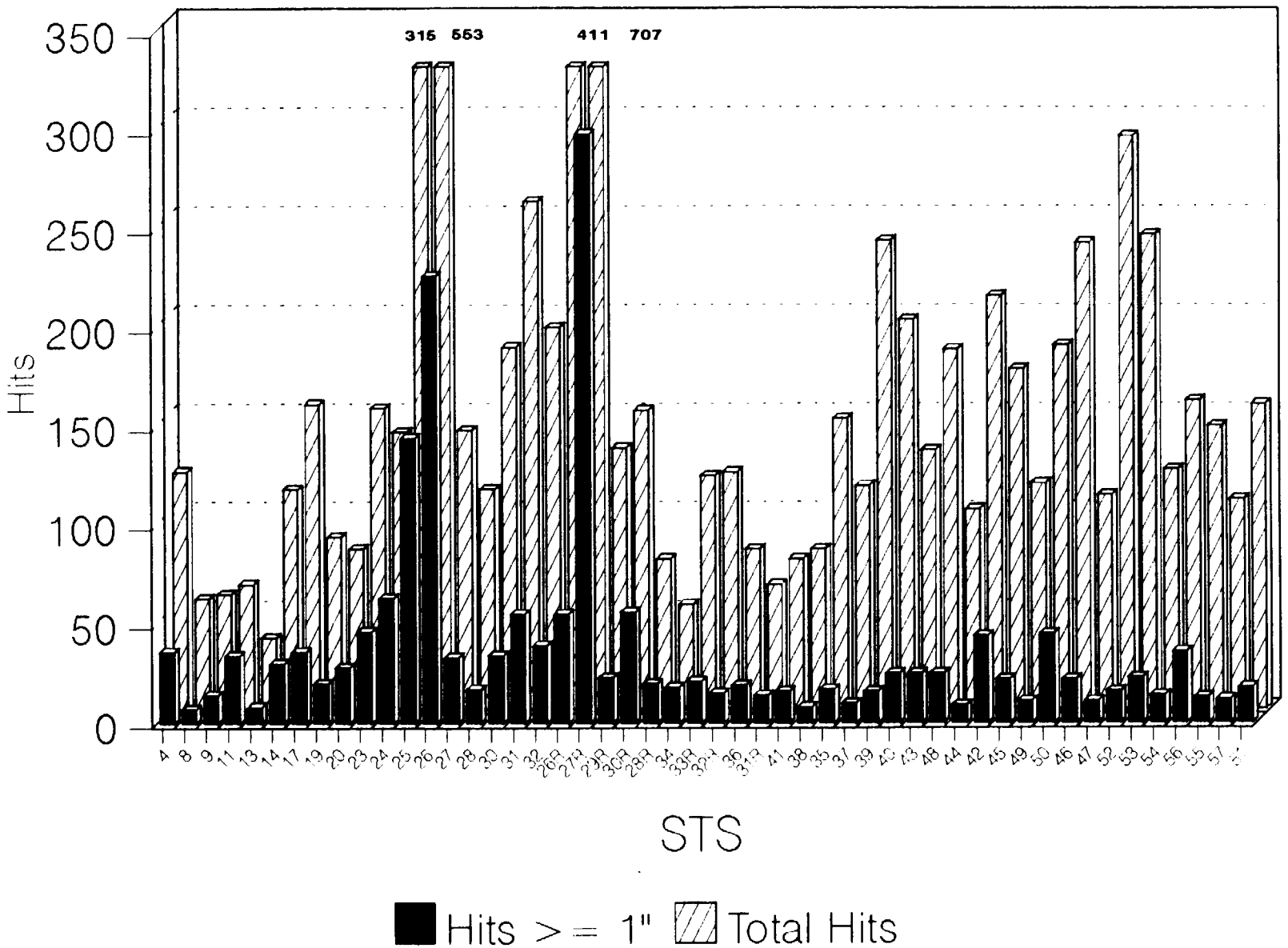
Orbiter Post Launch Debris Anomalies are listed in Section 12.0.

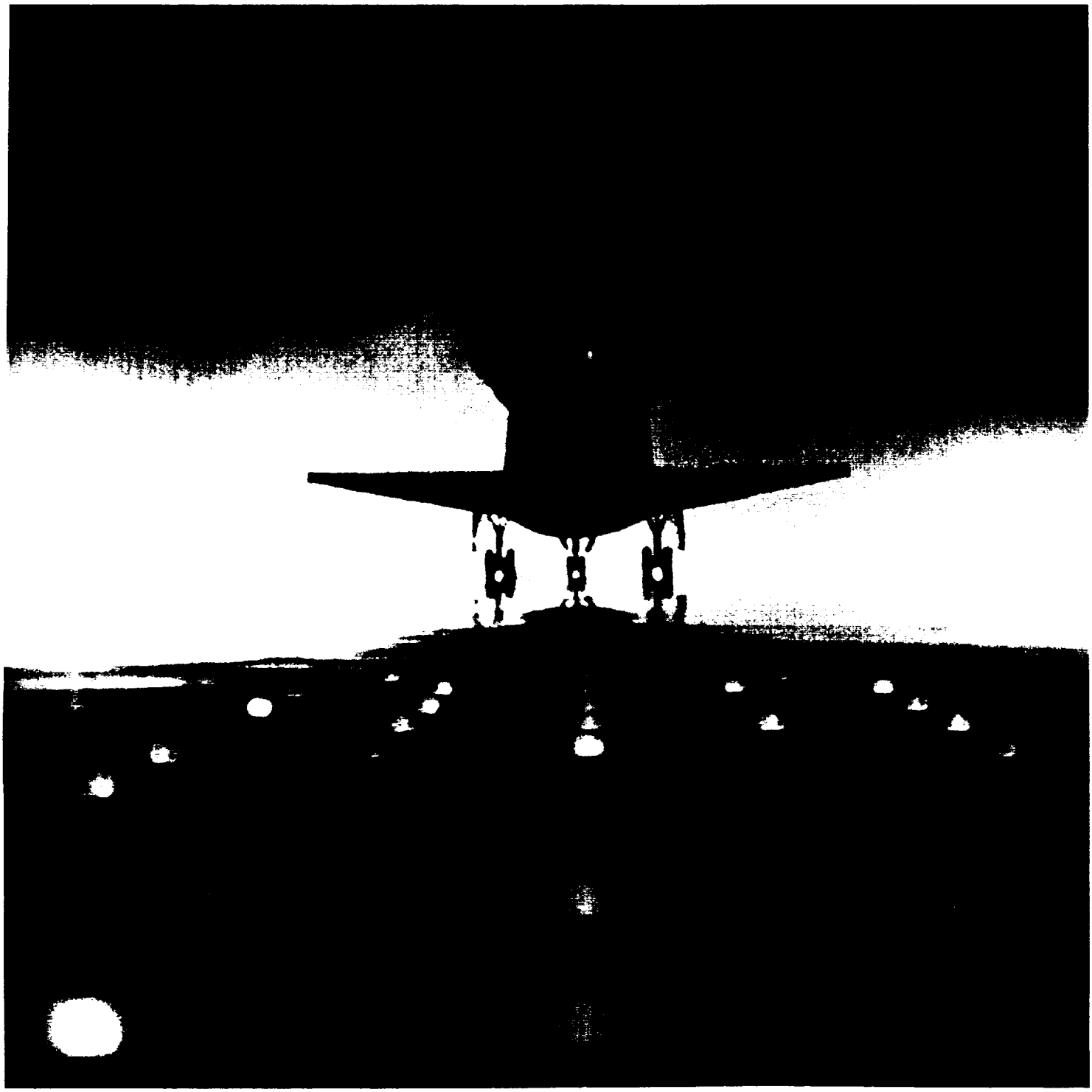
FIGURE 22 .ORBITER POST FLIGHT DEBRIS DAMAGE SUMMARY

	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
AVERAGE	14.5	93.6	21.9	132.7
SIGMA	7.3	45.3	10.8	60.4
STS-51	8	100	18	154

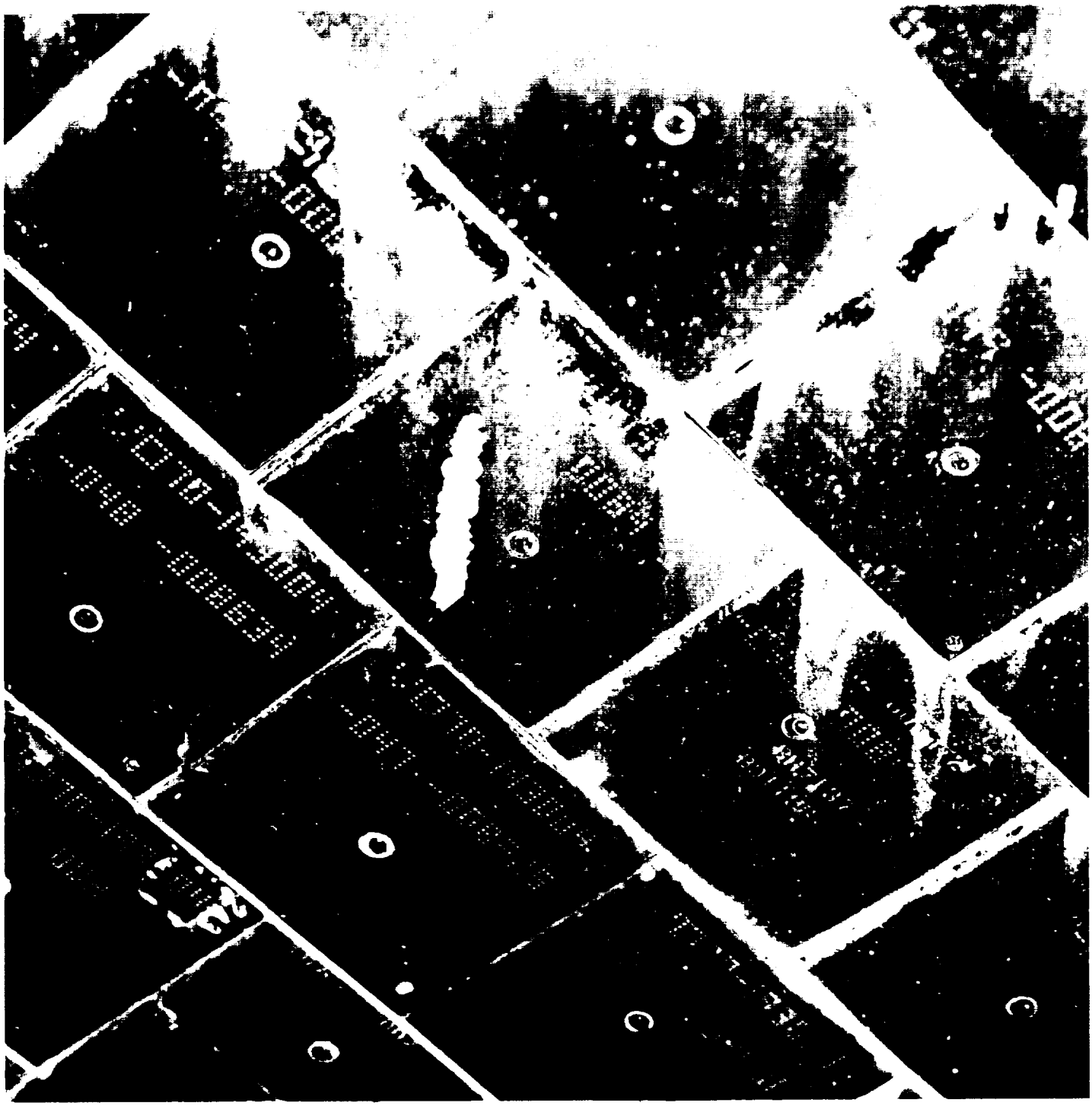
MISSIONS STS-23, 24, 25, 26, 26R, 27R, 30R, AND 42 ARE NOT INCLUDED IN THIS ANALYSIS SINCE THESE MISSIONS HAD SIGNIFICANT DAMAGE CAUSED BY KNOWN DEBRIS SOURCES

FIGURE 23. # COMPARISON TABLE



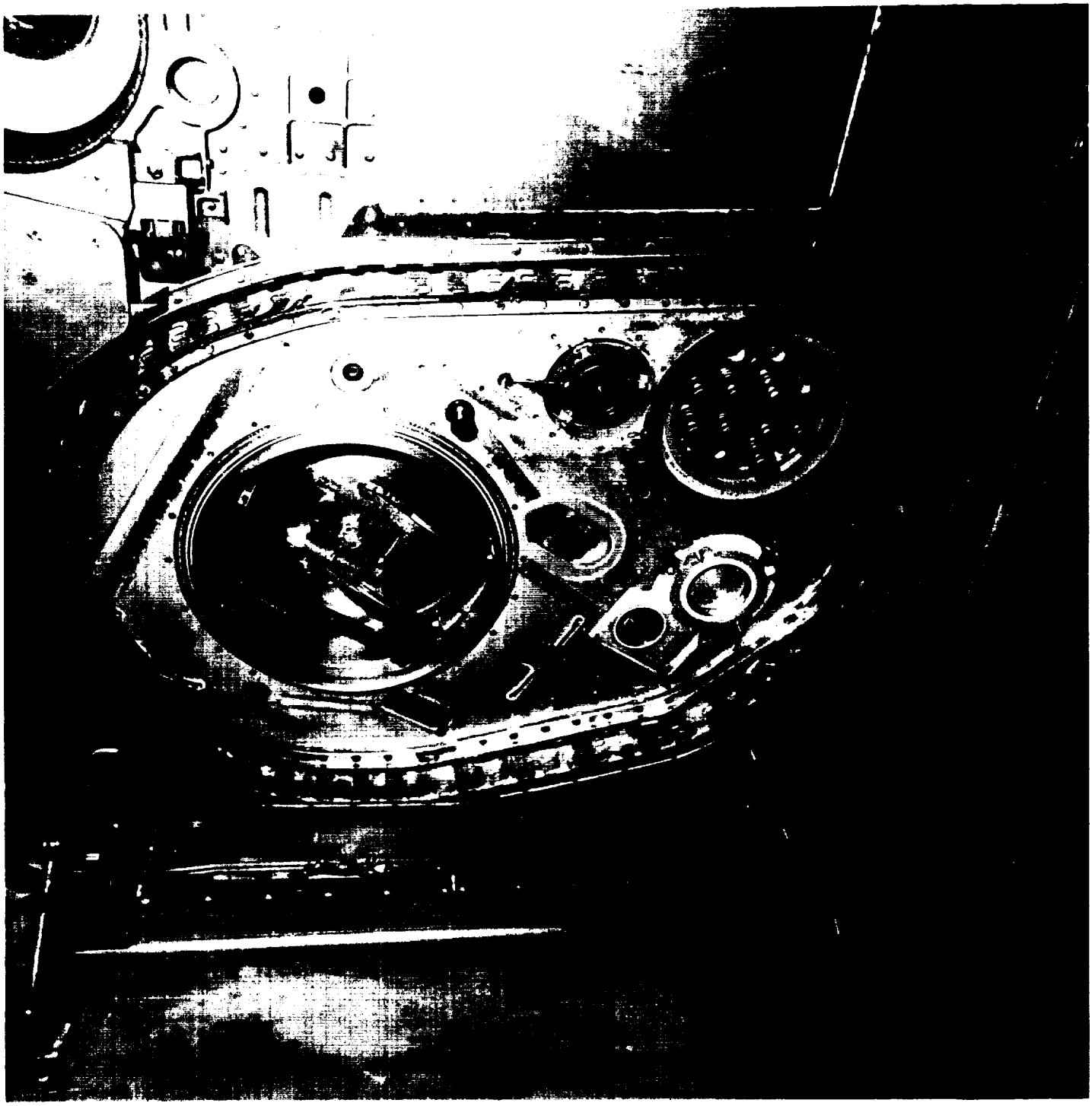


OV-103 Discovery made the first night landing on KSC runway 15 September 22, 1993. The new drag chute configuration is silhouetted in the Xenon lights. A very prominent, but normal, APU exhaust is visible at the base of the vertical stabilizer.



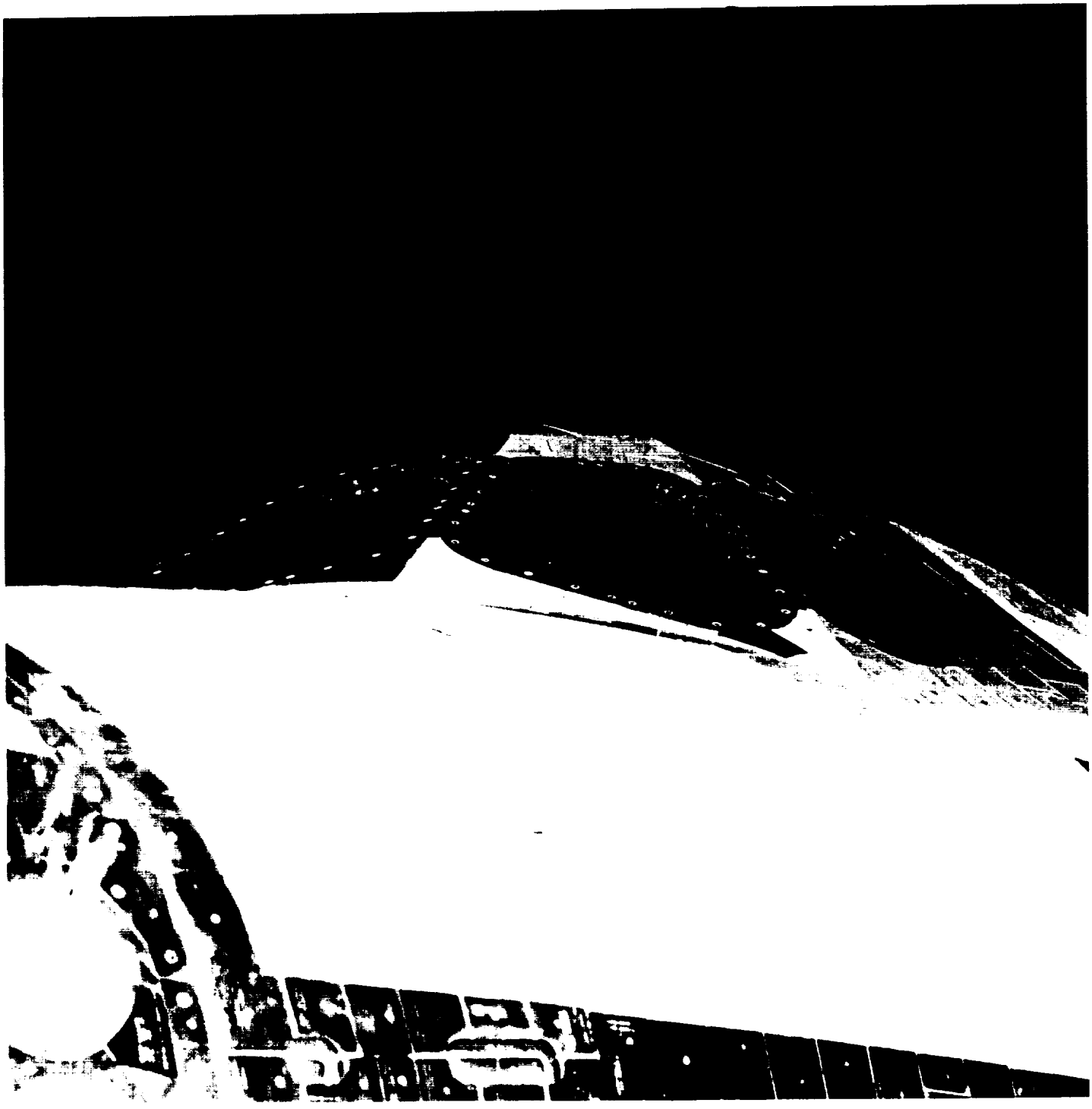
The largest tile damage site on the lower surface (RH inboard elevon) measured 3.75 inches long, 0.5 inches wide, and 0.25 inches deep.

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 separation ordnance devices functioned properly. No flight hardware was found on the runway below the umbilical when the ET door was opened.

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



Forward facing windows #3 and #4 were moderately hazed
Streaks were present on windows #2, #3, and #4

Tile damage on the base heat shield was less than average. The SSME Dome Mounted Heat Shield (DMHS) closeout blanket MR patches were intact and missing no material. Tiles on the vertical stabilizer "stinger" and around the drag chute door were undamaged.

The left OMS pod leading edge sustained 18 tile damage sites. Seven of the hits were greater than one inch in length with depths ranging from 0.75 to 1.00 inch. The damage was caused by debris from the payload deployment TOS Super*Zip anomaly.

11.0 DEBRIS SAMPLE LAB REPORTS

A total of sixteen samples were obtained from OV-103 Discovery during the STS-51 post landing debris assessment at Kennedy Space Center. The window samples were inadvertently discarded after sampling and no analysis was performed. The submitted samples consisted of 2 lower surface tile residue scrape/wipes from an area aft of the ET forward attach point and 6 scrape/wipe samples from the leading edge of the left OMS pod. 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 correlating of particles and residues with respect to composition, thermal (mission) effects, and availability. Debris sample results/analyses are listed by Orbiter location in the following summaries.

ORBITER LOWER SURFACE TILES

Samples from the Orbiter lower surface tiles indicated exposure to Orbiter Thermal Protection System (TPS), paints, and primer from various sources. There was no apparent vehicle damage related to these residuals.

ORBITER LEFT OMS POD

Samples from the left OMS pod indicated exposure to Orbiter TPS materials (tile, RTV, and silicon carbide) and metallics (aluminum, zinc, and lead alloys). Trace amounts of ground-type materials (salts, calcium and sulfur containing) and paints were detected. The presence of the lead alloy could have originated from the lead sheath in the pyrotechnic device of the TOS "Super*Zip."

STS-57 ORGANIC ANALYSIS

The final results of the STS-57 organic analysis are also shown in this report (ref Figure 24). Types of identified materials included those associated with window covers (plastic polymers, RTV,paint). No new findings were associated with this analysis.

NEW FINDINGS

This set of post-flight debris residual samples led to one new finding, which was obtained from the left OMS pod samples. Although not conclusive, it appeared to be related to the debris damage caused by the TOS Super*Zip anomaly. Of the six samples from the OMS pod damage sites, only one contained a trace amount of lead material believed to be attributed to the payload pyrotechnic device.

STS	Sample Location				
	Windows	Wing RCC	Lower Tile Surface	Umbilical	Other
51			Silica tile material Black and white paints		Left OMS pod- -tile,RTV,silicon carbide
57	Metallics-BSM Residue(SRB) RTV,Tile,Tile coating(ORB TPS) Insulation Glass(ORB TPS) Glass fiber-"E"-glass Calcite,Alpha-Quartz,Salt(Lndg.Site) Paint and Primer Organics-plastic polymer,RTV,paint				
55	Metallics - BSM Residue (SRB) RTV, Tile (ORB TPS) Insulation Glass (ORB TPS) Glass fiber - 'E-glass' Calcite,Muscovite,Salt(Landing Site) Anhydrite (Landing Site) Paint Organics-Plastic polymer,rubber,adh.				
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)

FIGURE 24. Orbiter Post Landing Microchemical Sample Results

STS	Sample Location				
	Windows	Wing RCC	Lower Tile Surface	Umbilical	Other
52	Metallics - BSM Residue (SRB) RTV, Tile (ORB TPS) Insulation Glass (ORB TPS) Calcite, Salt (Landing Site) Organics-Fibrous mat'l,red RTV Organics-filled rubber,plastic polymers Paint				HRSI Tile Damage Site- -Tile Mat'l and silicon carbide (ORB TPS) -Paints -Calcite,salts (Landing Site)
47	Metallics - BSM Residue (SRB) RTV, Tile (ORB TPS) Insulation Glass (ORB TPS) Calcite, Salt (Landing Site) Window Polish Residue (ORB) Organics-Fibrous mat'l,red RTV Organics-filled rubber,plastic polymers Paint		Silica-rich Tile (ORB TPS)		
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		

FIGURE 24. Orbiter Post Landing Microchemical Sample Results

STS	Sample Location				
	Windows	Wing RCC	Lower Tile Surface	Umbilical	Other
42	Metallics - BSM Residue (SRB) RTV, Tile (ORB TPS) Insulation Glass (ORB TPS) Calcite, Salt (Landing Site) Muscovite (Landing Site) Organics Paint		Metallics - BSM Residue (SRB) Tile, Tile Coating (ORB) Salt (Landing Site) Paint	Organics	RH Fuselage - Tile Coating (ORB)
44	Metallics - BSM Residue (SRB) RTV, Tile (ORB TPS) Insulation Glass (ORB TPS) Calcite, Salt (Landing Site) Muscovite (Landing Site) Organics Paint			Organics Silica-Magnesium Mat'l	
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		

STS	Sample Location				
	Windows	Wing RCC	Lower Tile Surface	Umbilical	Other
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)		
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	

FIGURE 24. Orbiter Post Landing Microchemical Sample Results

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

FIGURE 24. Orbiter Post Landing Microchemical Sample Results

12.0 POST LAUNCH ANOMALIES

Based on the debris walkdowns and film/video review, 9 post launch anomalies, including 1 In-Flight Anomaly, were observed on the STS-51 mission.

12.1 LAUNCH PAD/SHUTTLE LANDING FACILITY

1. Liquid air dripped from the GH2 vent line on the FSS 115 foot level to the FSS 195 foot level in front of the closeout crew tool locker. No hydrogen registered on a hand-held hydrogen meter. Post launch inspection of the area revealed two saw cuts in the drip pan beneath the GH2 vent line elbow. The cuts will be tack welded closed.

12.2 EXTERNAL TANK

1. One 8-inch divot was visible in the LH2 tank acreage just aft of the LH2 tank-to-intertank flange closeout between the bipods.

2. One 8-inch divot occurred in the LH2 tank-to-intertank flange closeout adjacent to the outboard side of the -Y bipod spindle housing closeout.

3. A divot, 10-12 inches in diameter, was present in the -Y (LH) longeron closeout.

12.3 SOLID ROCKET BOOSTERS

1. Hypalon paint was extensively blistered and/or missing from numerous areas of BTA on the LH aft skirt (IFA STS-51-B-2).

2. A separation line was detected between the BTA and the adjacent cork on the RH aft skirt (Squawk 51-011, PV-6-252520).

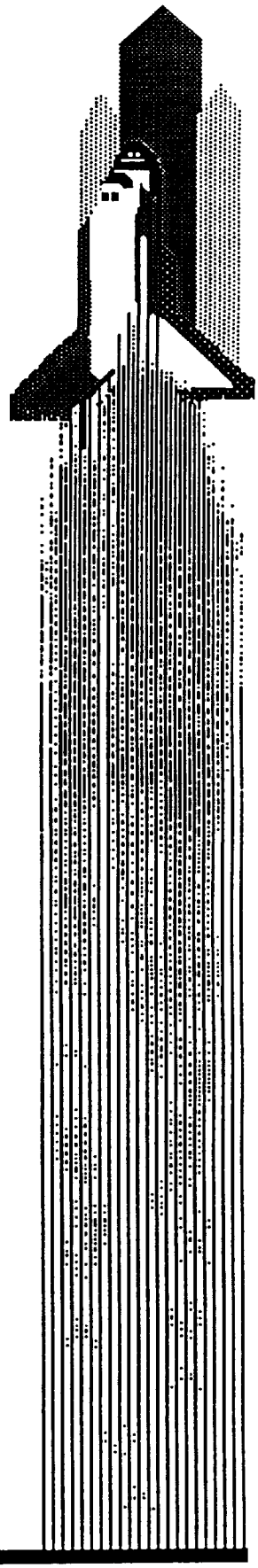
3. A separation line was detected between the BTA and the adjacent cork on the LH aft skirt (Squawk 51-010, PV-6-252523).

4. The HDP #4 EPON sidewall shim material came loose during SRB liftoff and fell into the SRB exhaust hole (film item E-7).

12.4 ORBITER

1. The LH OMS pod leading edge sustained a total of 18 tile damage sites. Seven hits were greater than an inch in length with depths ranging from 0.75 to 1.00 inches. The damage is believed to have been caused by debris from the TOS Super-Zip anomaly IPR 60V-0007.

Appendix A. JSC Photographic Analysis Summary



Space Shuttle

Photographic and Television Analysis Project

STS-51 Final Report

October 27, 1993

NASA
National Aeronautics and Space Administration

Lyndon B. Johnson Space Center
Houston, Texas 77058

Lockheed

ENGINEERING AND SCIENCE PROGRAM
2400 NASA Road 1, P. O Box 58561, Houston, Texas 77258 (713) 333-5411

October 27, 1993

Greg Katnik
MC/TV-MSD-22
OSB Room 5203R
KSC, Florida 32899

Dear Greg,

The following Summary of Significant Events report is from the Johnson Space Center NSTS Photographic and Television Analysis Project, STS-51 Final Report, and was completed October 27, 1993. Publication numbers are LESC-30924 and JSC-25994-51. The actual document can be obtained through the LESC library/333-6594 or Christine Dailey /483-5336 of the NSTS Photographic and Television Analysis Project.

Sincerely,

Christine Dailey, Staff Scientist
Photo/TV Analysis Project

cc: Job order file

2.0 Summary of Significant Events

2.1 Debris

2.1.1 Debris near the Time of SSME Ignition

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

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

2.1.1.1 Reflective Piece of Debris Below ET/Orbiter Umbilical Area *(Camera E-6)*

Figure 2.1.1.1 An Orange Rectangular Shaped Reflective Piece of Debris was seen Falling from the ET/Orbiter Umbilical Area at T-0.634 sec. MET.

An orange rectangular shaped reflective piece of debris was noted falling below the ET/Orbiter umbilical area at T-0.634 seconds prior to liftoff. KSC reported that they thought the reflective object was probably a thin piece of gold mylar tape used to attach parts of the umbilical purge barrier material. The object was definitely not metallic according to KSC.

2.1.1.2 SRB Flame Duct Debris

(Cameras E-2, E-5, E-7, E-8, E-9, E-10, E-11, E-13, E-15, E-16, E-26, and E-222)

2.1.1.2.1 Cloth-like Debris from SRB Flame Duct Area

As on previous missions, several pieces of debris were noted originating from the Solid Rocket Booster (SRB) flame duct area after SRB ignition. At 2.18 seconds MET, at least four pieces of debris were seen north of the MLP. The origin of the four pieces of debris was not determined but they were possibly from the SRB flame ducts.

Figure 2.1.1.2.1 Cloth-like Debris from SRB Flame Duct Area

Two white cloth-like debris objects approximately 2.5 inches wide were noted coming from the RSRB area at liftoff (0.387 seconds MET). The objects were not seen to contact the vehicle. KSC reported that the objects were two cloth parts tags from the SRB sound suppression water troughs that were ejected upward out of the RSRB exhaust hole after T-0.

2.1.1.2.2 Dark Debris from LSRB Holddown Post M-7 Shoe Area
(Camera E-11)

A small dark piece of debris was seen coming from the LSRB holddown post M-7 shoe area at liftoff (0.557 seconds MET). The debris object did not appear to strike the launch vehicle. A rope like piece of debris was seen to the right of the LSRB at SRB ignition on the same view.

2.1.1.2.3 Fast Moving Debris Near RSRB Holddown Post M-4*(Task #7)*
(Camera E-7)

A fast moving piece of debris was seen near the RSRB holddown post M-4 at 00.161 seconds MET. This debris did not appear to strike the launch vehicle. The 2D velocity of this debris was found to be approximately 88 ft/sec. and the length of the debris was approximately 1.8 inches. See Appendix D, Task 7 for more details.

2.1.2.3 Debris Near RSRB at Liftoff
(Camera E-25)

Numerous pieces of light colored debris fell along the RSRB at 0.581 seconds MET. The debris did not appear to contact the launch vehicle. The origin of this debris could not be determined.

2.1.2.4 Debris Forward of ET/Orbiter Umbilicals
(Cameras E-34 and E-79)

Two small pieces of debris seen forward of the ET/Orbiter umbilicals and aft of the forward attach bipod fell between the orbiter and the ET at liftoff. The source of this debris could not be determined.

2.1.3 Debris after Liftoff
(Cameras E-52, E-54, E-65, E-212, E-224, E-207, E-213 and E-222)

2.1.3.1 Linear White Object at Tower Clear
(Camera E-54)

A linear white object was seen on the right side of the camera field of view as the orbiter cleared the tower. The object did not appear to contact the vehicle.

2.1.3.2 Bright Objects Seen at 40 Seconds and 54 Seconds MET
(Camera E-222)

Two small bright objects were noted passing through the camera field of view at approximately 40 seconds MET and 54 seconds MET. Neither object appeared to originate from the vehicle and neither object was seen to strike the vehicle.

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

No anomalies were reported by the crew in the ascent debris report. A transcript of the ascent debris report is provided in Appendix D, Task #10.

2.2 MLP Events

2.2.1 Orange Vapor (Possibly Free-burning Hydrogen)
(Cameras E-15, E-17, E-19, E-30, E-36, OTV-163, and OTV-170)

Orange vapor (possibly free burning hydrogen) was seen under the body flap prior to SSME ignition. An orange vapor was also noted below the SSME bells and above the SSME #3 rim prior to SSME ignition.

2.2.2 Vapors from ET Intertank Purge Vents
(Camera E-34 and E-63)

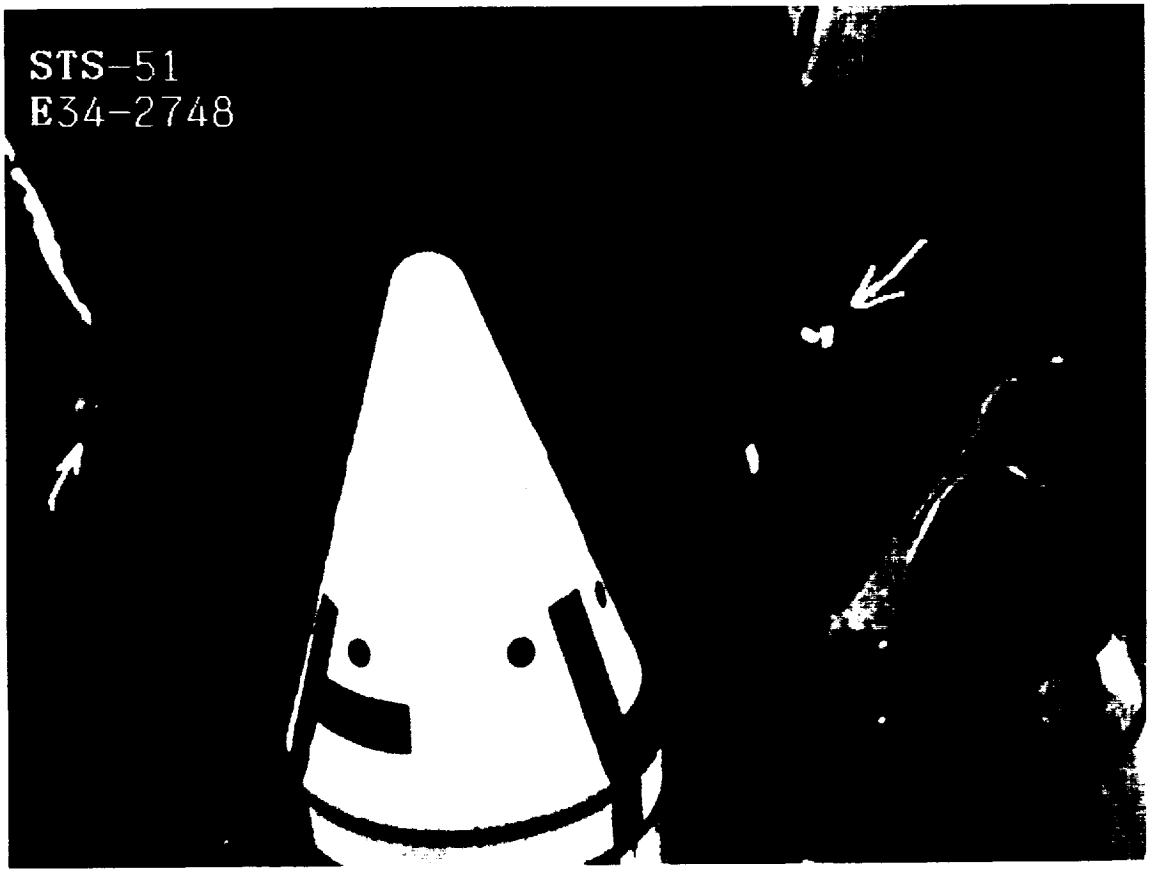


Figure 2.2.2 Vapors noted from ET Intertank Purge Vents

Vapor was noted coming from the external tank intertank +Z and -Z purge vents (approximately 180 degrees apart) at T-2.799 to T-1.363 seconds prior to liftoff. Venting from these purge vents has not been seen on previous mission launch films. This event was reviewed with KSC, Martin Marietta, and the MER. No follow-up action has been requested.

2.2.3 Discolored RCS (R3R) Paper Cover
(Camera E-19)

The R3R RCS port cover appeared discolored (prior to liftoff). Discolored RCS port covers have been seen on previous missions. No follow-up action has been requested.

2.3 Ascent Events

2.3.1 Orange Flashes in SSME #1 Exhaust Plume
(Camera E-2, E-19, E-40 and E-76)

Two orange flashes were noted in the SSME #1 exhaust plume at liftoff (0.765 and 0.873 seconds MET). Orange flashes in the SSME exhaust plume at liftoff have been seen on previous missions. No follow-up action has been requested.

2.3.2 White Puffs in SSME Exhaust Plumes after Liftoff
(Camera E-52, E-57, E-218, KTV-5, KTV-7B, OTV-141, and OTV-148)

White puffs were seen after liftoff in the SSME exhaust plumes at approximately 11 to 13 seconds MET. White puffs in the SSME exhaust plumes prior to the roll maneuver have been seen on previous mission films and videos. No follow-up action has been requested.

2.3.3 Flares in the SSME Exhaust Plumes After Liftoff
(Cameras E-52, E-204, E-212, E-218, and E-223)

Flares were seen in the SSME exhaust plumes after liftoff. A flare in the SSME #3 exhaust plume was seen at 12.93 seconds MET on camera E-52. Flares in the SSME exhaust plumes after liftoff have been seen on previous mission films and videos. No follow-up action has been requested.

2.3.4 Body Flap Motion *(Task #4)*

2.3.4.1 Body Flap Motion Seen on the Pad
(Cameras E-17,E-18)

Body flap motion was seen during the launch sequence. Analysis of this on-pad motion indicated frequency peaks at 2.5, 7, 9 and 12 hertz for the starboard side; and 3.5, 7, 9, 11.5, 13, 20 and 23 hertz for the port side. Of all these peaks, only global rotation (9 hertz) could be correlated with an identifiable mode and this occurred on both sides of the flap. The maximum peak-to-peak deflection on the starboard side was 0.9 inches on the starboard side and 0.7 inches on the port side.

2.3.4.2 Body Flap Motion Seen during Ascent
(Cameras E-207, E-212)

During ascent, body flap motion was noted from approximately 24.4 to 48.8 seconds MET. Films from the tracker cameras were reviewed for flap motion during ascent. Camera E-207 provided the best view of this event during the period of maximum dynamic pressure (~30-90 seconds MET). Due to camera defocus during the time of maximum motion (frames 2520-2620 or about 40-45 seconds MET), analysis of the data indicated that measurements lay within the noise.

2.3.5 Linear Optical Effect
(Cameras E-212, ET-208, KTV-13)

A linear optical distortion along the SLV was noted at approximately 58 seconds MET on the E-212 long range tracking view. Linear optical effects have been seen on previous mission long range tracking views. No follow up action is planned.

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

The recirculation or expansion of burning gases at the aft end of the SLV prior to SRB separation has been seen on nearly all previous missions. For STS-51 the start of recirculation was observed at 93 seconds MET and the end was noted at approximately 112 seconds MET on camera KTV-13.

Cameras on which recirculation was observed for STS-51

CAMERA	START (seconds MET)	STOP (seconds MET)
KTV-13	93	112
ET-204	93	110
ET-212	-	-
*E-204	88	109
E-208	93	111
E-212	92	106
E-218	-	-

* BEST VIEW OF RECIRCULATION

2.4 On Orbit

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

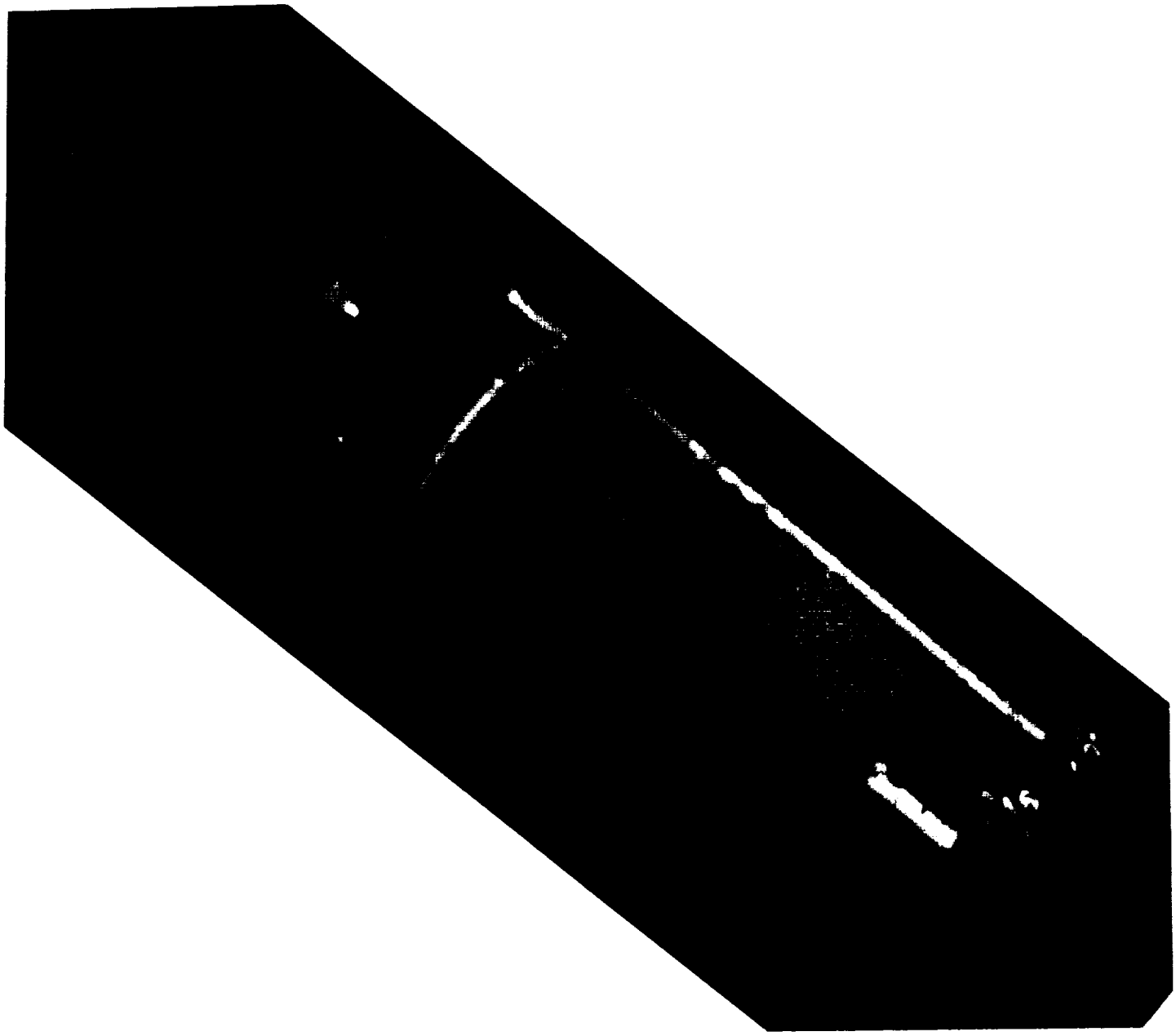


Figure 2.4.1a **ET Photographed after Separation Using 300 mm Lens with a 2x Extender on a Nikon Camera - Frame STS-51-22-019**

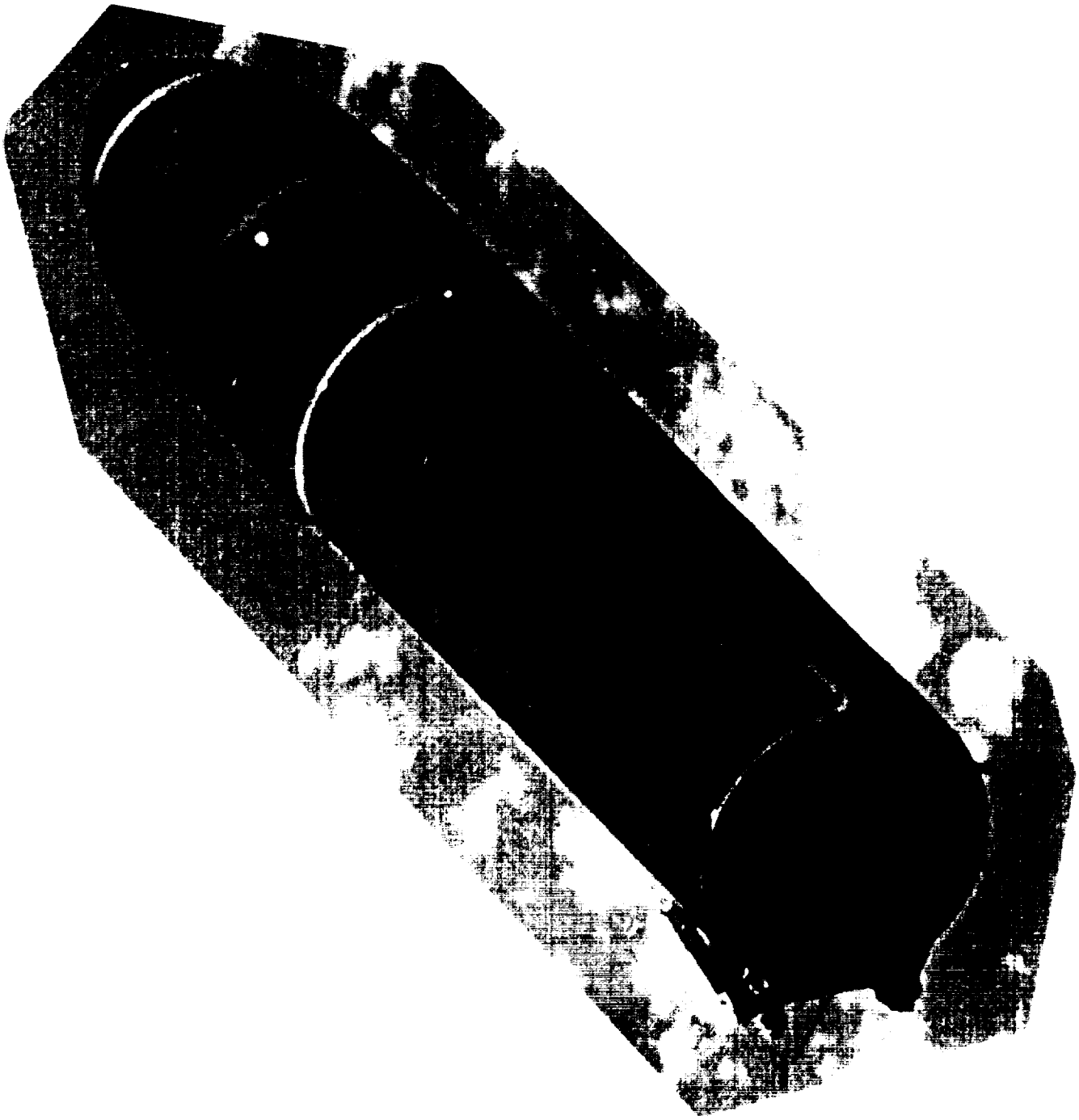


Figure 2.4.1b **ET Photographed after Separation Using 300 mm Lens with a 2x Extender on a Nikon Camera - Frame STS-51-22-011**

The following items were noted during the initial screening of the handheld photography of the external tank. (All measurements of divots were made along the longest axis.)

A divot (arrow 1, figure 2.4.1a), measuring approximately 13 inches, was observed on the ET-Y longeron above the LH2 umbilical. Three divots were observed near the forward

bipod : one to the left (-Y) of the left leg of the ET/Orbiter forward bipod on the LH2 tank-to-intertank flange closeout, measuring approximately 15 inches (arrow 2, figure 2.4.1a), one on the LH2 tank-to-intertank flange closeout between and just aft of the legs of the forward bipod, measuring approximately 11.5 inches (arrow 3, figure 2.4.1a) and a very small divot on or near the -Y leg of the forward ET/Orbiter attach bipod jackpad. A white mark on the face of the LH2 umbilical (probably frozen hydrogen) was also noted (arrow 4, figure 2.4.1a).

Several small light colored areas (possibly TPS ablation) were observed on the edges of the man hole covers on the aft dome (arrows 1 and 2, figure 2.4.1b). Other divot events that were observed included: a divot on the LH2 tank-to-intertank closeout on the -Z axis of the ET and a divot on the LH2 tank TPS (-Z) just aft of the LH2 tank-to-intertank closeout (arrows 3 and 4, figure 2.4.1b) measuring 8.5 and 11.2 inches, a small divot on the intertank acreage between the LO2 feedline and the right SRB forward attach point, and a small divot on the LH2 tank TPS acreage near the aft right SRB attach point (arrow 5, figure 2.4.1b).

Detailed notes for the handheld camera photographic screening of the external tank are located in Appendix D, Task #6.

2.4.2 Analysis of aft ACTS/TOS Payload Cradle

Figure 2.4.2 Views Showing Aft Cradle Support Mechanism Left view is from Payload Bay camera A; Right is from In-Cabin Video.

The down link videos covering the state of the aft cradle for the ACTS/TOS payload were carefully screened. There appeared to be possible damage to the forward edge of the aft cradle (arrow 2). The "super zipper" tube (arrow 1) was only attached to the cradle at the detonation boxes located at the 12 o'clock position. A dual-camera Cartesian phototheodolite technique was used to determine the distance of the super-zipper from the aft cradle to the base of the cradle. The distance between these two points was estimated

to be 8.1 inches. An analysis of the motion induced in the super-zipper after an RCS burn was performed. This analysis estimated the maximum induced motion to have a peak-to-peak magnitude of 4.4 inches with a frequency of motion estimated at 0.30 hertz.

Views of the ACTS/TOS deploy sequence were studied in an attempt to find the source of damage seen on the aft bulkhead. A review of the scene list from STS-51 indicated that the actual deploy was seen from payload bay cameras D (starboard forward) and B (port aft). However, while several pieces of debris were seen exiting the launch cradle area, neither view revealed damage to the aft bulkhead. A sequence of frames from the deploy sequence (taken at 5 second intervals from payload bay camera D) were saved to disk. These images were then enhanced using techniques to increase the contrast in the region of interest. However, the video quality (zoom factor and wide field-of-view) hampered detailed analysis. Analysis was also performed on the post debris damage assessment views: specifically, from the RMS wrist camera. Since this assessment was mostly concerned with damage to the cradle area, only a brief view of the port side of the aft bulkhead was shown (P). Enhancements of the area in question proved inconclusive.

2.5 Landing Events

2.5.1 Venting of the Left Auxiliary Power Unit Exhaust Port(s)

(Cameras EL-18 (IR), KTV-5L, KTV-6L, KTV-11L, KTV-33L, SLF North, SLF South, and UCS-7 (AR))

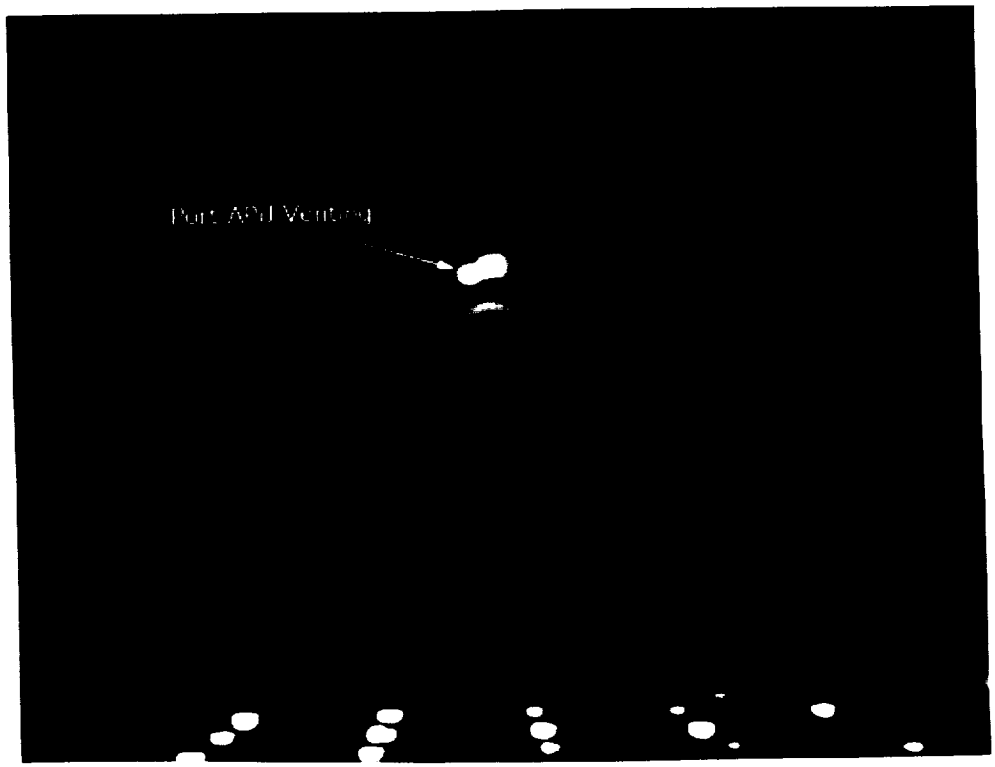


Figure 2.5.1 Venting noted from Left Auxiliary Power Unit Exhaust Port(s).

The MER requested a comparison of the STS-51 left auxiliary power unit (APU) venting which indicated that a fire may be present and the APU venting of previous landings. Videos from seven landings were reviewed (STS-32, STS-35 @ night; STS-33 @ dawn

and STS-31, STS-41, STS-55 and STS-57 during the day). Venting of the APUs was seen on the infrared views for the landings which had infrared cameras (STS-32, 33, 35); however, venting was not observed on any of the visible views except for STS-33. During a close-up view of the STS-33 APU area, venting was seen due to the presence of heat waves; however, no flames were observed. The review of these previous missions indicated that the venting during the STS-51 landing was the most prominent and persistent. The origin of the flame (exhaust port 1 or 2) could not be determined from the given views due to the resolution of the video. Normal venting was observed from the right APU exhaust port on the infrared views. Launch views of the left auxiliary power unit vent area have been reviewed. No unusual events were seen in the vicinity of the left APU exhaust port.

The MER requested that a composite video be prepared. The video contained views of STS 51 landing, STS 35 also a night landing, STS 9 a day landing with a known fire source, and approach and landing test (ALT) #1. Additionally, six composite films from ALT #1 and #2 and 25 films of the manned/captive ALT #1 and #2 were screened. No indication of a fire in the port APUs could be identified. However, none of these films showed a view of the port APU area immediately following wheel stop.

2.5.2 **Landing Sink Rate Analysis Using Film** (Task #3) *(Camera EL-7)*

Camera EL-7 was used to determine the sink rate of the main gear. Data were gathered approximately 1 second prior to landing through touchdown using film EL-7 that had a speed of 100.0 frames per second. Scalar information was determined by using the distance between the main landing gear struts. An assumption was made that the line of sight of the camera was perpendicular to the Orbiter's y-axis. The y distance between the main gear and the reference point was then multiplied by the scale to find the height of the main gear. These heights were then regressed with respect to time, and the slope of the regression line was equal to the sink rate. The main gear sink rate was determined to be 0.84 feet per second over the period from touchdown to one second before touchdown. For the last 0.5 seconds the sink rate was approximately 0.8 feet per second, for the last 0.25 seconds the sink rate was approximately 1.3 feet per second, and for the last 0.1 seconds before touchdown the sink rate was found to be approximately 3 feet per second. Note that the sink rate for the last 0.1 seconds is based on only five data points and may be greatly influenced by digitizing errors.

Graphs depicting the above data can be seen in Task #3 Appendix D.

No film camera views of the nose gear touchdown sequence were obtained that would allow for the measurement of the nose wheel sink rate.

2.5.3 **Landing Sink Rate Analysis Using Video** *(Camera SLF-North, KTV-33L)*

Camera SLF-North was used to determine the video sink rate of the main gear. Data was gathered approximately 1 second prior to landing through touchdown at a rate of 30 frames per second. The points digitized were left main gear, right main gear and a reference point. For main gear sink rate, the scale was found using the distance between the main landing gear struts. An assumption was made that the line of sight of the camera was perpendicular to the Orbiter's y-axis. The y distance between the average position of the main gear and the reference was then multiplied by the scale to find the height of the main gear. These heights were then regressed with respect to time. The

slope of the regression line was equal to the main gear sink rate. The analysis showed that the main gear sink rate was 0.89 feet per second.

Nose gear touchdown occurred approximately 15 seconds after main gear touchdown. Camera TV-33 was used to determine the sink rate of the nose gear. Scalar information was determined by a system of equations which took into account the orientation of the camera relative to the orbiter. Data was gathered approximately 1 second prior to landing through touchdown at a rate of 30 frames per second. The equations were solved for each observation which took into account the change in perspective as well as increase in size. The distance between the bottom of the nose gear and the main gear was computed and a linear regression was applied on this normalized vertical distance versus time data to find the actual sink rate. This rate was determined to be 3.57 feet per second.

Graphs depicting the above data can be seen in Task #3 Appendix D.

2.5.4 Drag Chute Performance *(Task #9)*

(Cameras EL-9, EL-17 (IR), EL-18 (IR), KTV-5L, KTV-6L, KTV-11L, KTV-15L, KTV-33L, SLF North, and SLF South)

Video coverage of the drag chute deploy was obtained. The deployment of the drag chute appeared as expected. All drag chute event times were obtained from camera KTV-33L. Drag chute initiation was noted at 265:07:56:15.560 UTC. Pilot chute inflation was noted at 265:07:56:16.494 UTC. Bag release was noted at 265:07:56:17.162 UTC. Drag chute inflation in the reefed configuration was noted at 265:07:56:18.363 UTC. Drag chute inflation in the disreefed configuration was noted at 265:07:56:21.433 UTC. Chute release was noted at 265:07:56:42.320 UTC.

The landing of Discovery at the end of mission STS-51 marked the tenth 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 EL-9. This analysis is used to support the improvement of the aerodynamic math models currently in use. The maximum horizontal chute deflection was approximately 5.22 degrees. Graphical representations of the results of this analysis may be found in Appendix D, Task #9.

2.6 Other Normal Events

Other normal events observed include: ice buildup on the SSME vent nozzles; ice debris falling from the LH2 and LO2 ET/Orbiter umbilical disconnects at SSME ignition through liftoff; ice debris falling from the LH2 and LO2 TSM disconnects at SSME ignition through liftoff; inboard and outboard elevon motion at SSME startup; slight vapor from the gaseous oxygen (GOX) vent on the ET and frost on the vent louvers, flashes in the SSME plume prior to liftoff; slight motion of the body flap between SSME ignition and liftoff; base heat shield erosion during SSME startup; ice and vapor from the GUCP during SSME startup and GH2 vent arm retraction; a slight slack in the GH2 vent line lanyard during latchback; debris in the exhaust cloud at the pad after liftoff; vapor from the drain on the aft edge of the rudder speed break at tower clear; multiple pieces of debris (RCS paper and ice) prior to and after liftoff; ET aft dome outgassing and vapor from the SRB stiffener rings after liftoff; charring of the ET aft dome during ascent; debris in the SSME exhaust plume from liftoff through the early ascent; slight overshoot on the roll maneuver; a rippling of the RSRB thermal curtain after the roll maneuver; expansion waves; condensation around the SLV during ascent; linear optical distortion; SRB plume brightening; dark puffs in the SRB plume during plume brightening; slag

debris in the SRB exhaust plume during and after SRB separation. Normal events related to the pad are FSS deluge water spray activation; and MLP water dump activation.

2.7 STS-51 Abort Analysis *(Task #11)*

The following events were noted during the screening of the August 12 abort film and videos: Orange vapors (probably free burning hydrogen) were noted beneath the SSMEs after the startup of the hydrogen ignitors. After the apparent shutdown of the SSMEs, orange vapors were noted beneath the SSMEs, near the base heat shield, and extending forward along the left OMS pod and forward of the vertical stabilizer. Orange flames were seen along the LH2 T-0 umbilical disconnect tubing. The paper covering the aft RCS ports were observed to ignite in flames.

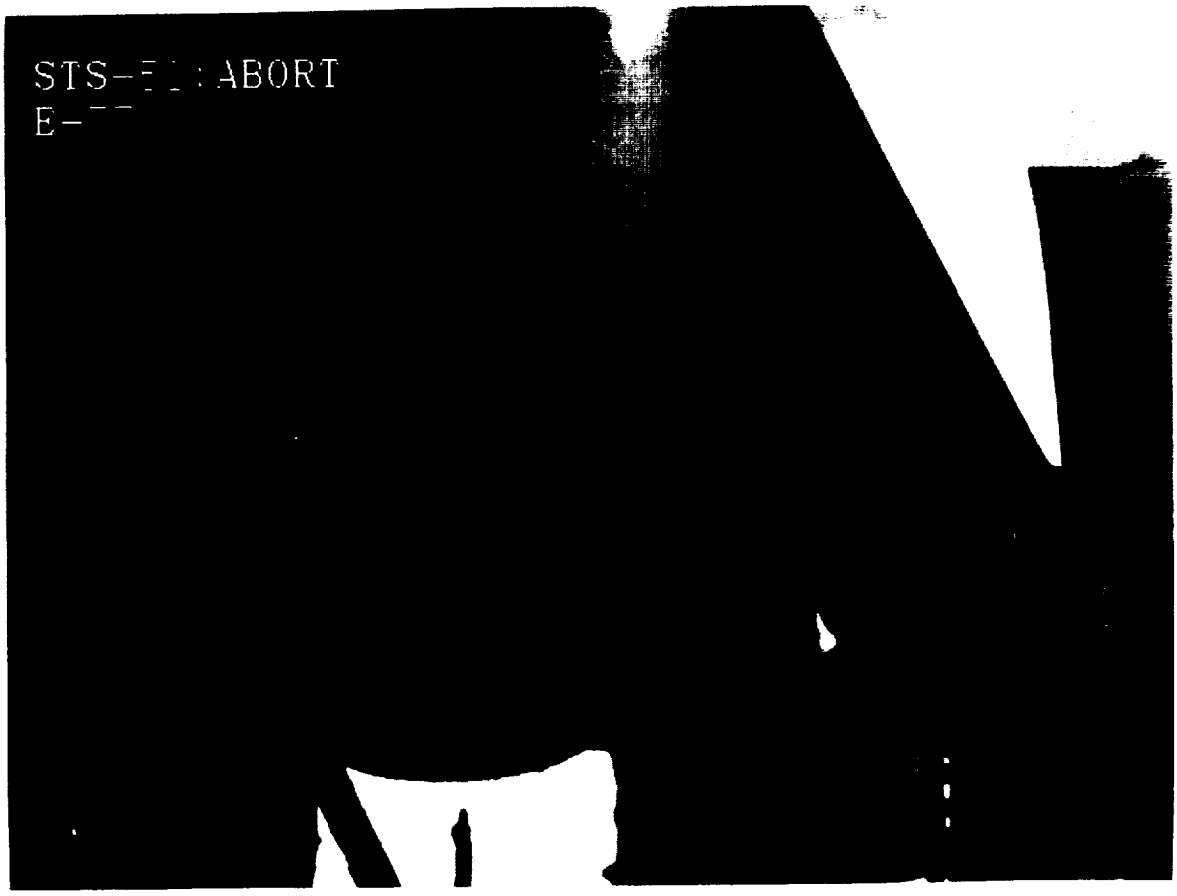


Figure 2.7 Flames along the LH2 T-0 Umbilical Disconnect Tubing

A detailed integrated timeline of the events noted during the abort film and video screening along with representative pictures were prepared for the MER manager. A detailed screening report and the integrated timeline is included in Appendix D, Task 11.

Appendix B. MSFC Photographic Analysis Summary

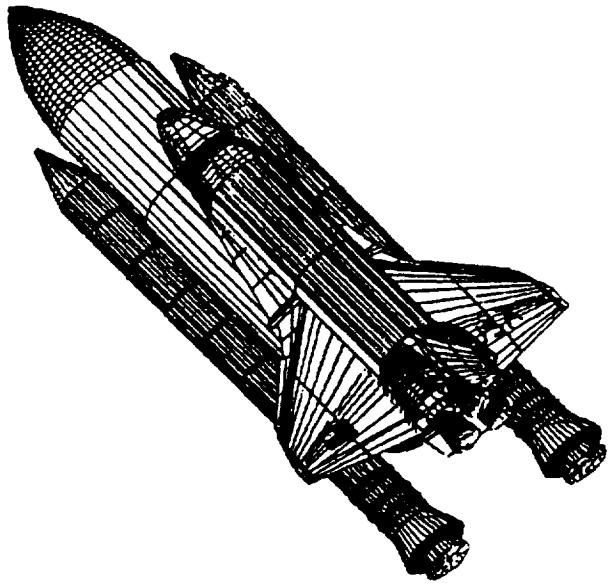
NASA
National Aeronautics and
Space Administration

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

SPACE SHUTTLE

ENGINEERING PHOTOGRAPHIC ANALYSIS REPORT

STS-51



MSFC - Form 454 (Rev. October 1976)

National Aeronautics and
Space Administration

George C. Marshall Space Flight Center
Marshall Space Flight Center, Alabama 35812
AC(205)544-2121

NASA

y to Attn of: EP24 (93-25)

TO: Distribution

FROM: EP24/Thomas J. Rieckhoff

SUBJECT: Engineering Photographic Analysis Report for STS-51

Enclosed is the Engineering Photographic Analysis Report for the Space Shuttle Mission STS-51. For additional copies, or for further information concerning this report, contact Tom Rieckhoff at 544-7677, or Jeff Hixson, Rockwell at 544-7121.

Tom Rieckhoff

Thomas J. Rieckhoff

Enclosure

ENGINEERING PHOTOGRAPHIC ANALYSIS REPORT

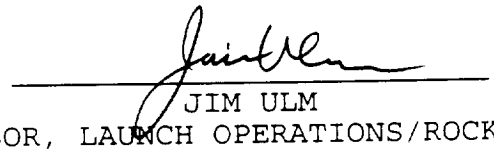
STS-51

FINAL

PREPARED BY:

B. EPPS, J. HIXSON, B. VIGER
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-51 ENGINEERING PHOTOGRAPHIC ANALYSIS REPORT

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

October , 1993

I. INTRODUCTION

Space Shuttle Mission STS-51, the seventeenth flight of the Orbiter Discovery was conducted September 12, 1993 at approximately 6:45 A.M. Central Daylight Time from Launch Complex 39B (LC-39B), Kennedy Space Center (KSC), Florida. Extensive photographic and video coverage was provided and has been evaluated to determine proper operation of the ground and flight hardware. Cameras (video and cine) providing this coverage are located on the fixed service structure (FSS), mobile launch platform (MLP), LC-39B perimeter sites, onboard, and uprange and downrange tracking sites.

II. ENGINEERING ANALYSIS OBJECTIVES:

The planned engineering photographic and video analysis objectives for STS-51 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:

a. DTO-0312, ET photography after separation

III. CAMERA COVERAGE ASSESSMENT:

Film was received from fifty-four of fifty-four requested cameras as well as video from all twenty-four requested cameras. The following table illustrates the camera data received at MSFC for STS-51.

CAMERA DATA RECEIVED FOR STS-51

	16mm	35mm	Video
MLP	22	0	4
FSS	7	0	3
Perimeter	3	3	6
Tracking	0	16	11
Onboard	2	1	1
Totals	34	20	25

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

a. Ground Camera Coverage:

Photographic coverage of STS-51 was considered excellent; however, cameras facing east were strongly backlit by the sun. There was a loss of data on camera E-57 due to a film jam. Camera E-8 provided invalid timing data.

b. Onboard Camera Assessment:

A camera was flown on each SRB forward skirt to record the main parachute deployment. Both cameras operated properly and recorded data through water impact. The astronauts carried a 35mm hand-held camera to record film for evaluating the ET TPS integrity after ET separation. Thirty-seven frames of data were recorded. Approximately seven minutes of camcorder video of the ET after separation was received and reviewed.

IV. ANOMALIES/OBSERVATIONS:

a. General Observations:

While viewing the film, several events were noted which occur on most missions. These included: pad debris rising and falling as the vehicle lifts off; debris induced streaks in the SSME plume; ice falling from the 17" disconnects and umbilicals; and debris particles falling aft of the vehicle during ascent, which consist of RCS motor covers, hydrogen fire detectors and purge barrier material. Body flap and inboard right elevon motions were noted during ascent.

b. ET Intertank Aero Venting:

Figure 1 is a frame of film taken from camera E-34 showing venting from the external tank. After correlating this view with views of the same event on cameras E-62 and E-63 it was determined that the most likely source of the venting was the ET intertank aero vent. Review of previous launch films show this type of venting occurs when atmospheric conditions are similar.

c. Debris Near RSRB Aft Skirt:

Figure 2 is a film frame from camera E-212 showing a dark debris object that was observed near the RSRB aft skirt at time 31.6 seconds. The origin of the debris is unknown. This debris was observed only from camera E-212.

d. Debris Exiting LSRB Plume:

Figure 3 is a film frame showing a debris object that was observed exiting the LSRB plume from camera E-222. The object appeared to exhibit a vapor trail as it exited the plume. This debris does not exhibit the behavior typical of slag particles that exit the plume. The debris was observed outside the plume at 67 seconds MET.

e. ET TPS Evaluation:

Thirty-seven frames of 35mm film of the ET after separation were received and reviewed. There were two divots on the LH2 tank/intertank scarf joint on the -Z axis. These divots are shown in figure 4. A divot was observed on the LH2 aft attach brace. There was a divot at the base of the forward bipod on the -Y side of the bipod. Also there was a divot located between the legs of the bipod. These divots are shown in figure 5.

V. ENGINEERING DATA RESULTS:

a. T-Zero Times:

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

POST	CAMERA POSITION	TIME (UTC)
M-1	E-9	255:11:45:00.017
M-2	E-8	invalid timing
M-5	E-12	255:11:45:00.016
M-6	E-13	255:11:45:00.015

b. ET Tip Deflection:

Maximum ET tip deflection for this mission was determined to be approximately 32 inches. Figure 6 is a data plot showing the measured motion of the ET tip in both the horizontal and vertical directions. These data were derived from camera E-79.

c. SRB Separation Time:

SRB separation time for STS-56 was determined to be 255:11:47:04.73 UTC as recorded by camera E-207.

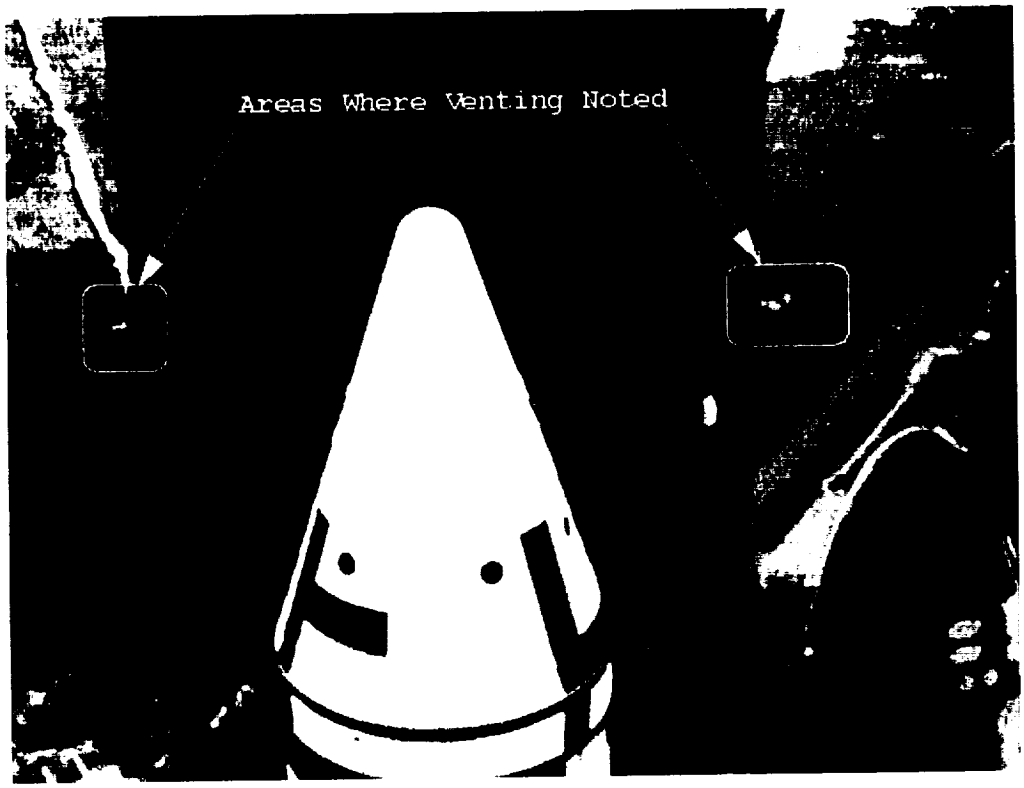

Figure 1.

Venting from ET Intertank Aero Vent

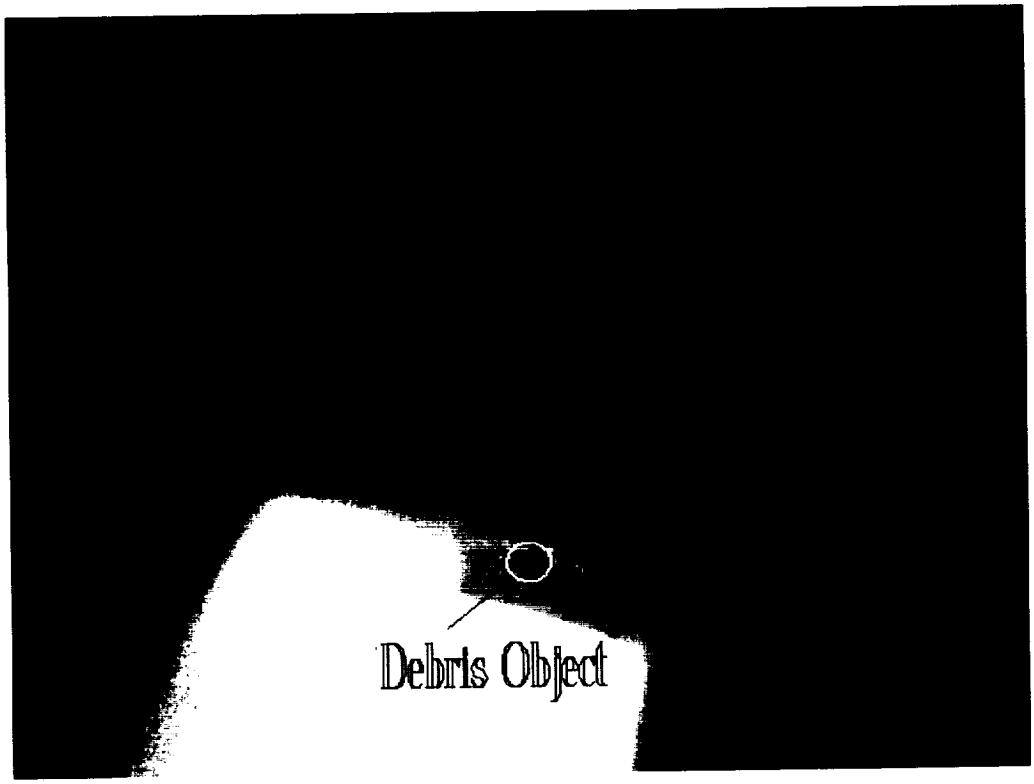

Figure 2.

Unknown Debris near RSRB Aft Skirt at 31.6 sec MET

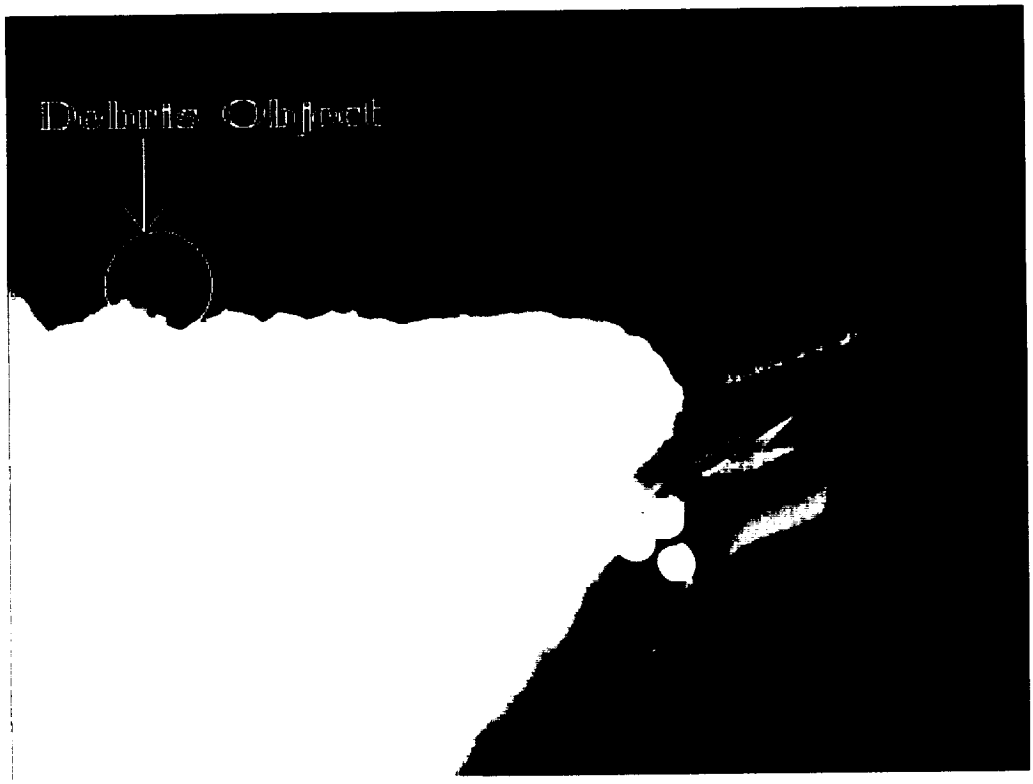

Figure 3.

Debris Object Exiting LSRB Plume at 67 sec MET

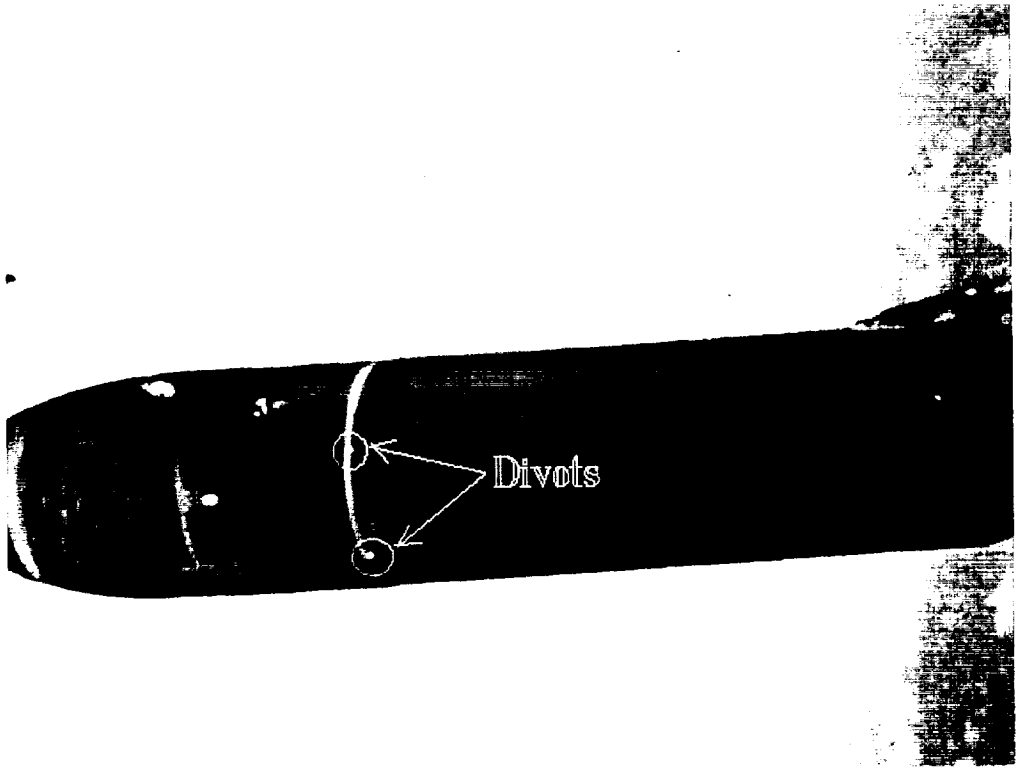

Figure 4.

ET TPS Divots at LH2 Tank/Intertank Scarf Joint

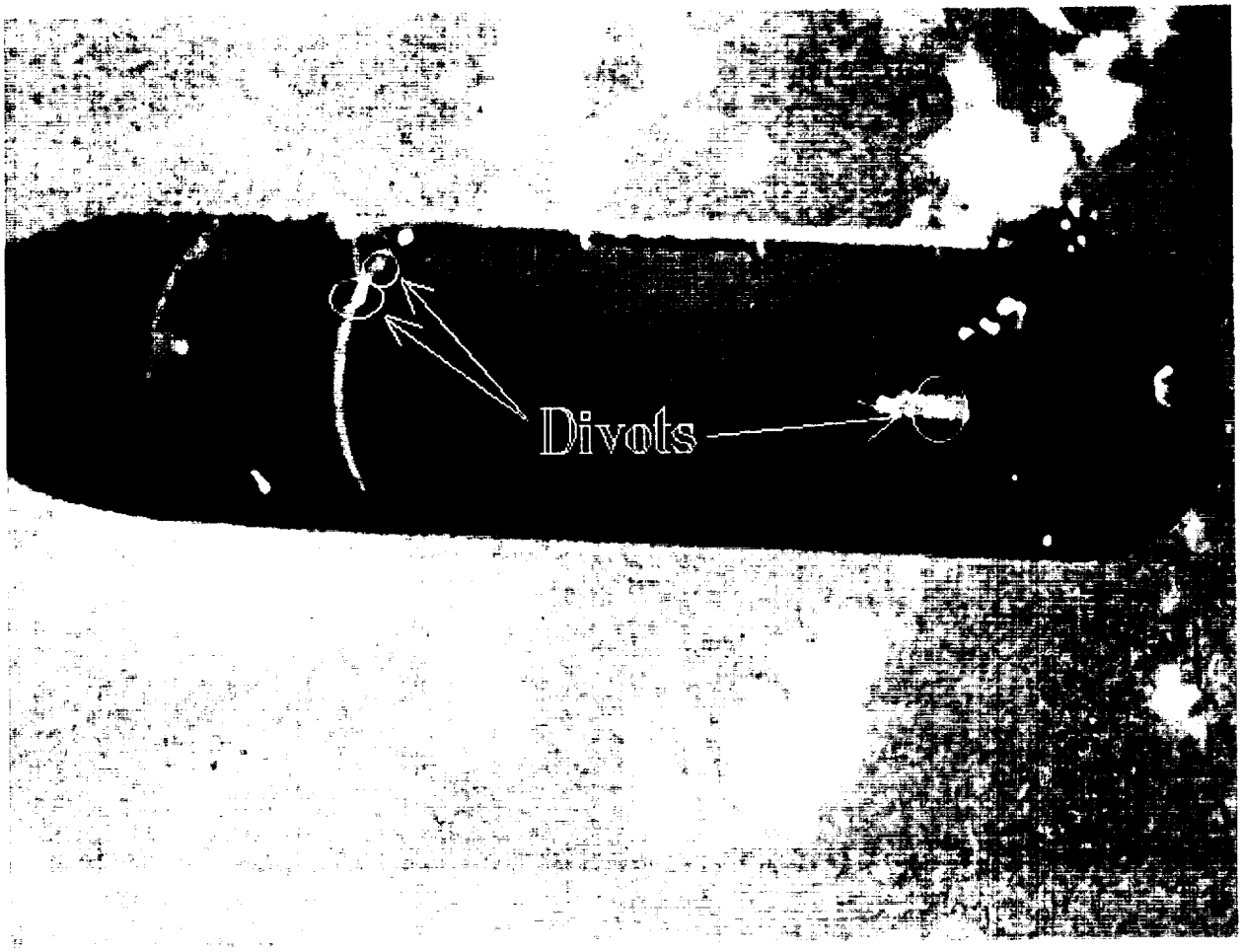

Figure 5.

ET TPS Divots at Attach Points

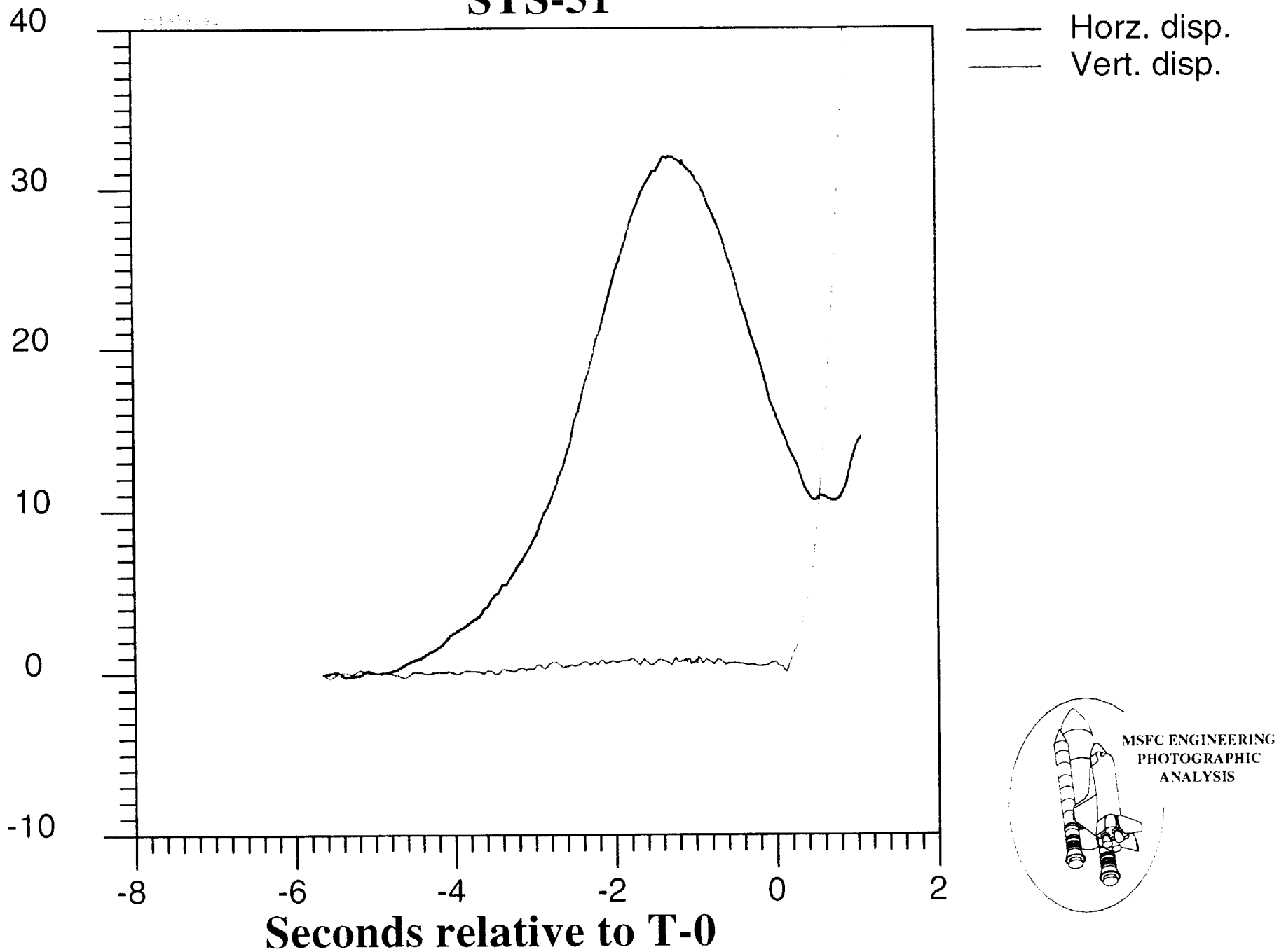
ET Tip Deflection
STS-51
Horz. disp.
Vert. disp.
Inches
40
30
20
10
0
-10
-8
-6
-4
-2
0
2
Seconds relative to T-0
MSFC ENGINEERING
PHOTOGRAPHIC
ANALYSIS

Figure 6

Appendix C. Rockwell Photographic Analysis Summary

Space Systems Division
Rockwell International Corporation
12214 Lakewood Boulevard
P.O. Box 7009
Downey, California 90241-7009

Rockwell International

October 21, 1993

In Reply Refer to 93MA3662

National Aeronautics and Space Administration
Lyndon B. Johnson Space Center
Houston, Texas 77058

Attention: L. G. Williams (WA)

Contract NAS9-18500, System Integration, Transmittal of the Rockwell Engineering Photographic Analysis Report for the STS-51 (Scrub 1, Scrub 2, Launch Abort) and STS-51 Mission

The System Integration Contractor hereby submits the Engineering Photographic Analysis Summary Report in accordance with the Space Shuttle Program Launch and Landing Photographic Engineering Evaluation Document (NSTS 08244).

The first launch attempt on July 17, 1993 of STS-51 flight was scrubbed (5:55 a.m. PST/GMT 198:12:55:00) because the system B External Tank vent arm system and SRB holddown post pyrotechnic initiator controller's (PIC's) were armed without being commanded due to a switch card failure. No films were received from this launch attempt.

The second attempt to launch STS-51 on July 24, 1993 was scrubbed at T-19 seconds (6:26:41 am PDT/GMT 205:13:26:41) due to the right SRB hydraulic power unit (HPU) turbine speed dropping below the specification lower limit. No films received from this launch attempt.

The third launch attempt of STS-51 on August 12, 1993 was aborted at T-3 seconds (6:12:32 a.m. PDT/GMT 224:13:12:32:545) due to SSME #2 fuel flow sensor A2 failure.

As a result of the launch abort several films were selected and processed by KSC to provide possible data in the evaluation of the STS-51 launch abort. Rockwell received 15 films for the photographic evaluation effort on August 18, 1993.

Review of films E-19 and E-20 did not identify any visual anomalies or other off-nominal occurrences on the external surfaces of the three SSME's. Orange vapors (possibly free burning hydrogen) were noted beneath the SSME's after the start-up of the hydrogen ignitors. After SSME shutdown, orange vapor was noted beneath the SSME's drifting upward to the base heat shield, along the left OMS pod, and the vertical stabilizer. Orange flames were seen along the LH2 T-O umbilical disconnect tubing and the paper covering the aft RCS ports were seen to ignite in flames.

(Packing Sheet No. DM93-18408)

Due to the excessive orange vapor noted, films from previous aborted launches (STS-55, 51F, and 41D) were screened for comparison and some orange vapor was noted on the film from the STS-55 aborted launch.

Orange vapors were also visible on films E-1, E-18, and E-77 and burning paper from the RCS ports was visible on films E-17, E-18 and E-77.

Other normal events reported on previous missions and observed for this aborted launch were ice debris from the ET/Orbiter umbilical, ice from LH2 TSM T-O disconnect, white debris (probably ice) from LO2 TSM umbilical lines and RCS paper debris, during SSME start-up.

The fourth launch attempt of the STS-51 mission was successful and occurred on September 12, 1993.

Extensive photographic and video coverage was provided and has been evaluated to determine ground and flight performance. Cameras (cine and video) providing this coverage are located on the Launch Complex 39B Fixed Service Structure (FSS), Mobile Launch Platform (MLP), various perimeter sites, and uprange and downrange tracking sites for the STS-51 launch conducted on September 12, 1993, at approximately 4:45 a.m. PDT (GMT 255:11:45:00.006) from the Kennedy Space Center (KSC) and for the landing on September 22, 1993 at KSC at 00:56 a.m. PDT (GMT 265:07:56:06).

Rockwell received launch films from 84 cameras (60 cine, 24 video) and landing films from 26 cameras (12 cine, 14 video) to support the STS-51 photographic evaluation effort.

Overall, the films showed STS-51 to be a clean flight. Several pieces of ice from the ET/ORB umbilicals 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. Vapor was observed in the vicinity of the rudder/speed brake at liftoff. 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 plum impingement. Both TSM umbilicals released and retracted as designed. The ET GH_2 vent line carrier dropped normally and latched securely with no rebound. No anomalies were identified with the ET/ORB LH_2 umbilical hydrogen dispersal system hardware.

STS-51 was the seventeenth flight with the optimized attach link in the SRB holddown support post Debris Containment Systems (DCS's). The link is designed to increase the plunger velocity and seating accuracy, while leaving the holddown bolt ejection velocity unchanged. This prevents frangible nut fragments and/or NSI cartridges from falling from the DCS, while not increasing the probability of a holddown bolt hang-up.

No major or significant events were observed or identified. Events noted by the Rockwell film/video users during the review and analysis of the STS-51 photographic items are summarized in the following comments. These events are not considered to be a constraint to next flight.

COMMENTS

1. Orange vapor (possibly free burning hydrogen) was seen below the SSME's and the body flap just prior to SSME ignition on cameras OTV-163, OTV-170, E-17, E-19, E-30, and E-36. This vapor appears to be similar to the vapor noted on previous missions. It is not an issue and no follow-up action is planned.

2. Vapors from the External Tank intertank purge vents was noted at SRB ignition on cameras E-34 and E-63. The two vent openings, each with an area of six square inches, are located at the forward end of the intertank for venting during preflight environmental conditioning and for equalization of internal/external pressures in flight. Although venting from the purge vents has not been seen on previous mission launch films, this event was reviewed by JSC with KSC, Martin Marietta, and the MER. This event is not considered anomalous and no follow-on work is scheduled for this issue.

3. On camera E-6, an orange rectangular shape reflective piece of debris was noted falling below the ET/Orbiter umbilical area at liftoff. KSC stated that the debris was probably a thin piece of gold mylar tape used to attach parts of the umbilical purge barrier material. No follow-up action is planned.

4. On cameras E-8 and E-9, two white cloth-like pieces of debris approximately 2.5 inches wide were noted originating from the right SRB flame duct area at liftoff. This debris did not appear to strike the vehicle. KSC reported that the objects were two cloth parts tags from the SRB sound suppression water troughs that were ejected upward out of the right SRB flame trench. No follow-up action is planned.

5. Two orange flashes were noted in the SSME #1 plume at liftoff on cameras E-19 and E-40. Flashes in the SSME plume have been observed on previous missions and are probably caused by small amounts of contaminants in the main engine. No follow-up action is planned.

6. White flashes were noted in the SSME plume during the roll maneuver on cameras E-52, E-57, and E-212. White flashes or puffs in the SSME plumes have been seen on previous mission films and videos. No follow-up action is planned.

7. During the film review at KSC (cameras E-207, E-212, E-220 and E-222) it was reported that body flap motion was very pronounced with frequencies similar to previous flights. Review of the films by JSC and Rockwell corroborated the KSC observation.

   Analysis is being conducted by JSC to measure the amount of deflection of the trailing edge of the body flap. Analysis results will be documented in the JSC report. No additional action(s) are currently planned.

8. The following events have been reported on previous missions and observed on STS-51. 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 areas and MLP.
   - Charring of the ET aft dome.
   - ET aft dome outgassing after liftoff.
   - Butcher paper falling from the RCS.
   - Recirculation or expansion of burning gases 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.
   - Condensation around the SLV during ascent.
   - 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.

9. 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.

10. Cameras E7-16 and E27-E28 - 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.

11. The landing of STS-51 occurred on runway 15 at the KSC Shuttle Landing Facility. During the final approach and through wheel stop, excessive venting of the left Auxiliary Power Unit (APU) exhaust port 1 or 2 was observed on cameras EL-17 (IR), EL-18 (IR), KTV-5, KTV-6, KTV-11 and KTV-33. Review of the videos to identify the origin of the venting (port 1 or port 2) could not be determined. Videos from previous night landings (STS-32, STS-35), dawn landing (STS-33), and day landing (STS-57) were reviewed to compare the STS-51 left APU venting with venting seen on those landings. Venting from the APU exhaust ports were only seen in the infrared views of the previous landings and the STS-51 venting was more predominant. No follow-up action is planned.

    Good video and film coverage of the drag chute deploy was obtained and no anomalous events were observed. The flight marked the tenth 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.

This letter is of particular interest to Messers W. J. Gaylor (VF2) and C. F. Martin (MK-SIO-2) at NASA/JSC and NASA/KSC respectively. The Integration Contractor contact is R. Ramon at (310) 922-3679.

ROCKWELL INTERNATIONAL
Space Systems Division

J. A. Wolfelt
Chief Engineer
System Integration

RR/cl

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13. ABSTRACT *(Maximum 200 words)*

A debris/ice/thermal protection system (TPS) assessment and integrated photographic analysis was conducted for Shuttle mission STS-51. Debris inspections of the flight elements and launch pad were performed before and after launch. Icing conditions on the External Tank were assessed by the use of computer programs, nomographs, and infrared scanner data during cryogenic loading of the vehicle followed by on-pad visual inspection. High speed photography was analyzed after launch to identify ice/debris sources and evaluate potential vehicle damage and/or in-flight anomalies. This report documents the debris/ice/TPS conditions and integrated photographic analysis of Shuttle mission STS-51, and the resulting effect on the Space Shuttle Program.

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Thermal Protection System (TPS) Photographic Analysis

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