NASA Technical Memorandum TM 109194

Debris/Ice/TPS Assessment and Integrated Photographic Analysis for Shuttle Mission STS-58

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National Aeronautics and
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DEBRIS/ICE/TPS ASSESSMENT
AND
INTEGRATED PHOTOGRAPHIC ANALYSIS
OF
SHUTTLE MISSION STS-58

October 18, 1993

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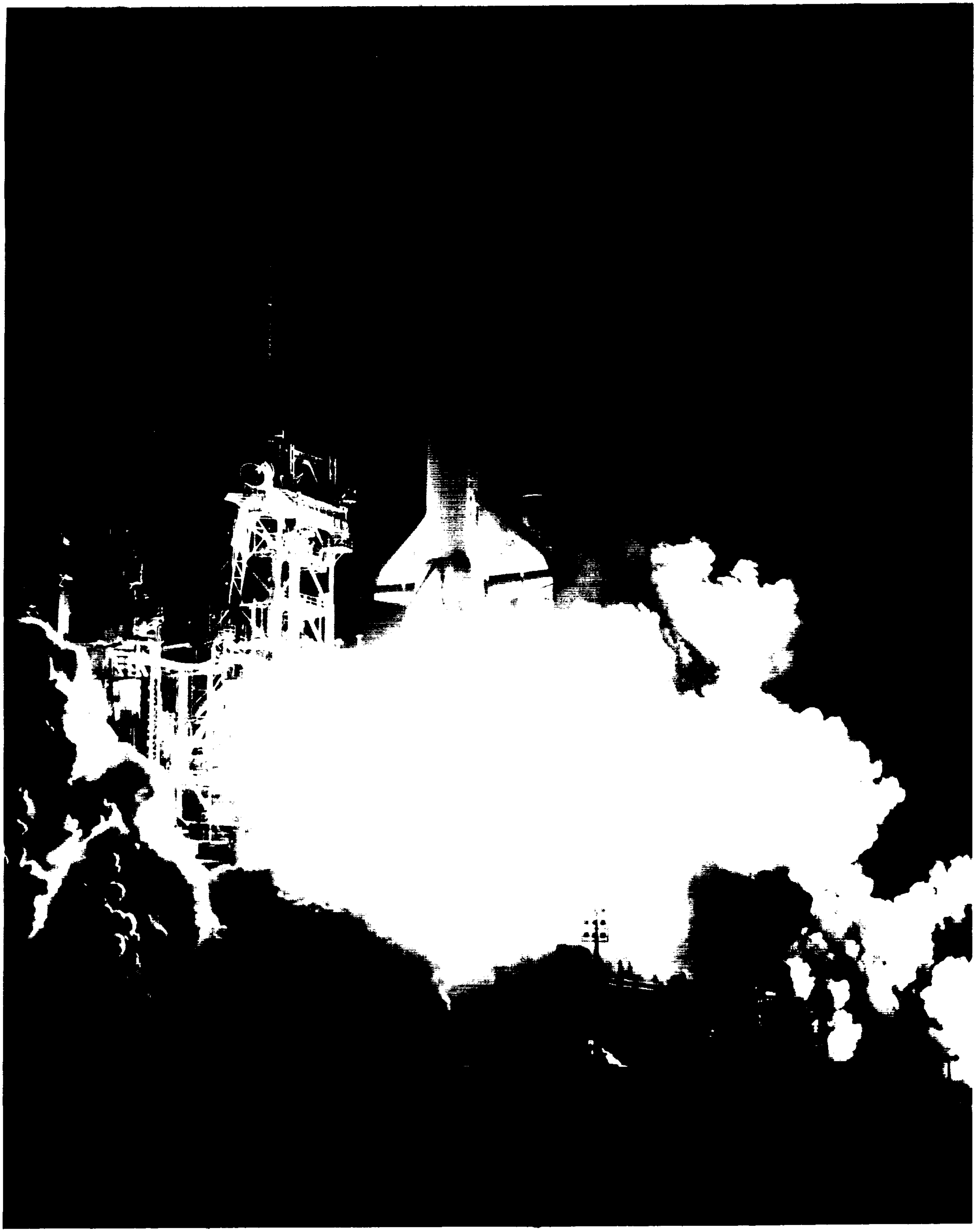


Shuttle Mission STS-58 was launched at 10:53 am local 10/18/93

1.0 Summary

A pre-launch debris inspection of the pad and Shuttle vehicle was conducted on 13 October 1993. The detailed walkdown of Launch Pad 39B and MLP-1 also included the primary flight elements OV-102 Columbia (15th flight), ET-57 (LWT 50), and BI-061 SRB's. There were no significant facility or vehicle anomalies.

The vehicle was cryoloaded on 14 October 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. One IPR was taken against two cracks on the -Y ET/SRB cable tray forward surface TPS. The condition was assessed and found acceptable for flight.

The launch was scrubbed at T-31 seconds and holding due to the loss of an Air Force range safety ground computer. A post drain inspection of the vehicle revealed no significant anomalies.

The vehicle was cryoloaded a second time on 15 October 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 during the T-9 minute hold due to an Orbiter S-band transponder failure. A post drain inspection of the vehicle revealed no anomalies.

The vehicle was cryoloaded a third time on 18 October 1993. There were no Launch Commit Criteria, OMRS, or NSTS-08303 criteria violations. There were no ice/frost conditions outside of the established data base and no IPR's were taken.

After the 10:53 a.m. launch on 18 October 1993, a debris walk down of Pad 39B was performed. No flight hardware or TPS materials were found. There was no visual indication of a stud hang-up on any of the south holddown posts. Two debris particles fell out of a cavity in the HDP #3 doghouse blast cover during liftoff. Damage to the facility and pad overall was minimal.

An IPR was taken on the GH2 vent line based on film review findings that the line moved approximately 6 inches back toward the vehicle before latching. Post launch troubleshooting showed the latch spring tension was within specification, but at the low end of the limit. The spring tension will be adjusted prior to the next launch. The deceleration shock absorber load cell data was reviewed and showed nominal performance.

A total of 117 films and videos were analyzed as part of the post launch data review. No major vehicle damage or lost flight hardware was observed that would have affected the mission.

One Dome Mounted Heat Shield (DMHS) closeout blanket MR patch (covering) was missing from the SSME #3 9:00 o'clock position (IFA STS58-V-0009) and was most likely the white object observed in the film review falling aft of the vehicle at 45 seconds MET. The underlying batting material was torn/frayed. The DMHS MR patch on SSME #2 3:00 o'clock position was detached on three sides.

The DMHS closeout blanket/MR patch protects the SSME support structure, inner flexseal, and pressure seal. The DMHS blanket MR patches on OV-102 and OV-104 are an old design consisting of "S" Glass material tack-stitched on 3-inch centers. Fraying and ripping of the patches in flight is common. Standard repair procedures are performed on a PR. A new design with AB312 (Nextel) material uses continuous stitching through the blanket on a 1-inch grid pattern. The new material is thicker, has a higher temperature resistance, is more durable, and is currently installed on OV-103 and OV-105. Until the new design blanket can be installed on OV-102 and OV-104, the current blanket repair procedure will be reviewed and the condition of any repaired blankets will be evaluated.

Orbiter post landing microchemical sample results revealed a variety of residuals in the Orbiter window samples from the window protective covers, SRB BSM exhaust, Orbiter TPS, RCS thruster paper covers, and paints/primers from various sources. Blue paint particulate with zinc alloy on one side was added as a new finding. The source of this material has not yet been determined. These residual sampling data do not indicate a single source of damaging debris as all of the other materials have previously been documented in post-landing sample reports. The residual sample data showed no debris trends when compared to previous mission data.

A total of 11 Post Launch Anomalies, including four In-Flight Anomaly, were observed during the STS-58 mission assessment.

3.0 SCRUB - RANGE SAFETY COMPUTER

The first launch attempt of STS-58 was scrubbed at T-31 seconds and holding due to the loss of an Air Force range safety (SRO) redundant ground computer.

3.1 PRE-LAUNCH SSV/PAD DEBRIS INSPECTION

A pre-launch debris inspection of the pad and Shuttle vehicle was conducted on 13 October 1993 from 0915-1015 hours. The detailed walkdown of Launch Pad 39B and MLP-1 also included the primary flight elements OV-102 Columbia (15th flight), ET-57 (LWT 50), and BI-061 SRB's. There were no significant debris issues or vehicle anomalies.

3.2 ICE/FROST INSPECTION

The Ice/Frost Inspection of the cryoloaded vehicle was performed on 14 October 1993 from 0425 to 0720 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. One IPR was taken against a two crack condition on the -Y ET/SRB cable tray forward surface TPS. Ambient weather conditions at the time of the inspection were:

Temperature:	72.6 Degrees F
Relative Humidity:	89.3 Percent
Wind Speed:	4 Knots
Wind Direction:	274 Degrees

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

3.3 ORBITER

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

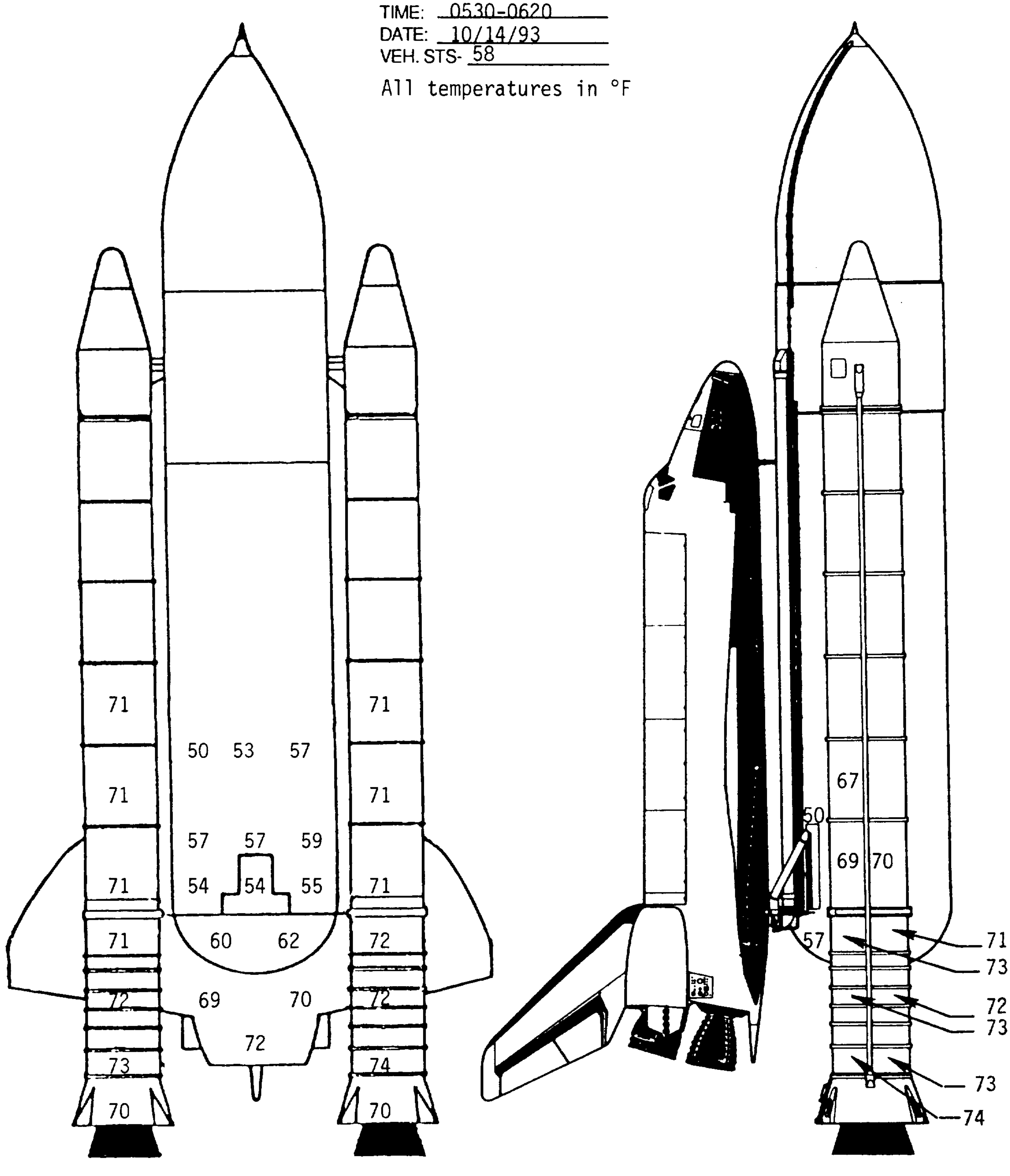
3.4 SOLID ROCKET BOOSTERS

The STI portable infrared scanner recorded RH and LH SRB case temperatures of 71-72 degrees F. In comparison, temperatures measured by a hand-held Minolta/Land Cyclops spot radiometer ranged from 72 to 75 degrees F and the SRB Ground Environment Instrumentation (GEI) measured temperatures of 76-77 degrees F. All measured temperatures were above the 34 degrees F minimum requirement. The predicted Propellant Mean Bulk Temperature (PMBT) supplied by MTI was 79 degrees F, which was within the required range of 44-86 degrees F.

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

TIME: 0530-0620
DATE: 10/14/93
VEH. STS- 58

All temperatures in °F



STS- 58 | TEST S0007 Scrub - ETR Computer | DATE: 14 October 1993 | T-0 TIME: DATE: | NASA KSC Ice/Frost/Debris Team

ORBITER 102 | ET 57 | SRB BI-061 | MLP 1 | PAD B

LO2 — CHILLDOWN TIME: 02:15; SLOW FILL TIME: 02:54; FAST FILL TIME: 03:07; REPLENISH TIME: 05:09

LH2 — CHILLDOWN TIME: 02:15; SLOW FILL TIME: 02:25; FAST FILL TIME: 03:10; REPLENISH TIME: 05:05

TIME	CONDITIONS					LO2 TANK STA 370 TO 540					LO2 TANK STA 550 TO 852					LH2 TANK STA 1130 TO 1380					LH2 TANK STA 1380 TO 2058				
(EDT)	TEMP F	REL HUM %	DEW PT F	WIND VEL KNTS	WIND DIR DEG	REG	LOCAL VEL KNTS	SOFI TEMP	COND RATE IN/HR	ICE RATE IN/HR	REG	LOCAL VEL KNTS	SOFI TEMP	COND RATE IN/HR	ICE RATE IN/HR	REG	LOCAL VEL KNTS	SOFI TEMP	COND RATE IN/HR	ICE RATE IN/HR	REG	LOCAL VEL KNTS	SOFI TEMP	COND RATE IN/HR	ICE RATE IN/HR
0230	75.00	79.2	68.39	3	164	=	1.77	59.02	0.0020	-0.0960	=	1.77	50.70	0.0032	-0.0714	=	1.26	49.16	0.0035	-0.0657	=	1.14	49.16	0.0035	-0.0657
0245	74.40	79.6	67.94	3	170	=	1.77	58.40	0.0020	-0.0931	=	1.77	50.04	0.0032	-0.0685	=	1.26	48.50	0.0034	-0.0629	=	1.14	48.50	0.0034	-0.0629
0300	74.40	79.6	67.94	3	170	=	1.77	58.40	0.0020	-0.0931	=	1.77	50.04	0.0032	-0.0685	=	1.26	48.50	0.0034	-0.0629	=	1.14	48.50	0.0034	-0.0629
0315	75.20	80.6	69.08	5	167	=	2.95	62.61	0.0023	-0.1298	=	2.95	56.61	0.0039	-0.1002	=	2.10	51.63	0.0038	-0.0681	=	1.90	50.44	0.0036	-0.0681
0330	75.00	81.8	69.30	5	159	=	2.95	62.66	0.0024	-0.1301	=	2.95	56.66	0.0039	-0.1004	=	2.10	51.66	0.0038	-0.0681	=	1.90	50.46	0.0037	-0.0681
0345	74.60	82.2	69.04	5	165	=	2.95	62.30	0.0024	-0.1282	=	2.95	56.28	0.0039	-0.0986	=	2.10	51.25	0.0038	-0.0663	=	1.90	50.05	0.0037	-0.0663
0400	74.80	82.8	69.44	4	171	=	2.36	61.38	0.0023	-0.1089	=	2.36	54.43	0.0037	-0.0797	=	1.68	49.61	0.0036	-0.0679	=	1.52	49.61	0.0036	-0.0679
0415	74.20	83.2	68.99	3	170	=	1.77	58.96	0.0022	-0.0954	=	1.77	50.61	0.0034	-0.0707	=	1.26	48.94	0.0036	-0.0650	=	1.14	48.94	0.0036	-0.0650
0430	73.00	86.2	68.80	4	229	=	2.36	60.05	0.0025	-0.1029	=	2.36	52.99	0.0038	-0.0739	=	1.28	48.01	0.0037	-0.0610	=	5.44	59.82	0.0050	-0.1700
0445	73.20	87.2	69.32	4	235	=	2.36	60.49	0.0025	-0.1050	=	2.36	53.44	0.0039	-0.0758	=	1.28	48.45	0.0037	-0.0630	=	5.44	60.29	0.0051	-0.1736
0500	73.20	87.8	69.51	4	239	=	2.36	60.62	0.0026	-0.1056	=	2.36	53.57	0.0039	-0.0764	=	1.28	48.55	0.0038	-0.0635	=	5.44	60.43	0.0051	-0.1747
0530	72.80	88.8	69.44	6	286	=	3.54	62.75	0.0028	-0.1458	=	3.54	57.40	0.0045	-0.1157	=	2.58	52.88	0.0044	-0.0772	=	7.26	62.30	0.0054	-0.2320
0600	72.00	90.2	69.08	2	307	=	1.18	56.06	0.0022	-0.0894	=	1.18	48.97	0.0035	-0.0647	=	0.92	47.48	0.0038	-0.0589	=	2.46	51.66	0.0043	-0.0702
0630	72.20	91.0	69.53	4	296	=	2.36	60.14	0.0027	-0.1034	=	2.36	53.04	0.0040	-0.0743	=	1.84	48.51	0.0039	-0.0607	=	4.92	59.17	0.0053	-0.1546
0700	72.40	91.4	69.85	5	294	=	2.95	61.83	0.0029	-0.1259	=	2.95	55.73	0.0044	-0.0961	=	2.30	51.63	0.0043	-0.0678	=	6.15	61.28	0.0055	-0.1974
0730	72.00	92.0	69.64	3	303	=	1.77	58.17	0.0025	-0.0909	=	1.77	49.74	0.0037	-0.0661	=	1.38	47.80	0.0039	-0.0604	=	3.69	56.49	0.0050	-0.1137
0800	71.00	93.0	68.95	1	316	=	0.59	55.33	0.0023	-0.0862	=	0.59	48.21	0.0036	-0.0615	=	0.46	46.71	0.0038	-0.0557	=	1.23	46.71	0.0038	-0.0557
0830	71.00	92.2	68.71	4	335	=	2.36	58.98	0.0027	-0.0983	=	2.36	51.79	0.0040	-0.0693	=	1.84	47.20	0.0039	-0.0551	=	4.92	58.03	0.0053	-0.1467
0900	73.20	91.0	70.53	6	343	=	3.54	63.68	0.0030	-0.1515	=	3.54	58.38	0.0046	-0.1211	=	2.64	54.15	0.0046	-0.0836	=	5.94	61.85	0.0055	-0.1974
0930	76.40	87.2	72.50	7	5	=	4.13	67.19	0.0029	-0.1913	=	4.13	62.64	0.0048	-0.1599	=	3.08	58.92	0.0048	-0.1144	=	6.93	65.67	0.0055	-0.2570
1000	77.00	80.8	70.93	2	39	=	1.18	60.26	0.0020	-0.1089	=	1.18	53.34	0.0034	-0.0842	=	1.40	51.93	0.0037	-0.0784	=	2.42	55.55	0.0041	-0.0855
1030	77.40	81.4	71.54	2	74	=	1.18	60.84	0.0021	-0.1118	=	1.18	53.95	0.0035	-0.0871	=	1.10	52.55	0.0037	-0.0814	=	2.44	56.29	0.0042	-0.0890
1100	77.40	80.8	71.33	3	22	=	1.77	62.18	0.0022	-0.1112	=	1.77	54.09	0.0035	-0.0865	=	1.32	52.43	0.0037	-0.0808	=	2.97	58.20	0.0044	-0.1084
1130	77.6	78.6	70.74	3	20	=	1.77	61.91	0.0021	-0.11	=	1.77	53.81	0.0034	-0.0854	=	1.32	52.23	0.0036	-0.0797	=	2.97	57.88	0.0042	-0.1067
1200	77.80	77.8	70.65	5	20	=	2.95	64.86	0.0022	-0.1419	=	2.95	59.01	0.0038	-0.1119	=	2.20	54.73	0.0038	-0.0800	=	4.95	62.49	0.0045	-0.1786
1230	78.00	75.8	70.11	7	16	=	4.13	66.19	0.0020	-0.1838	=	4.13	61.62	0.0039	-0.1529	=	3.08	58.01	0.0040	-0.1095	=	6.93	64.54	0.0042	-0.2451
AVG.	71.67	84.70	69.66	3.96	S-N-NNE		2.34	60.97				2.34	54.12				1.70	50.82				3.63	55.94		

Period of Ice Team Inspection

FIGURE 3. "SURFICE" Computer Predictions

3.6 FACILITY

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

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

3.7 POST DRAIN VEHICLE INSPECTION

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

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.

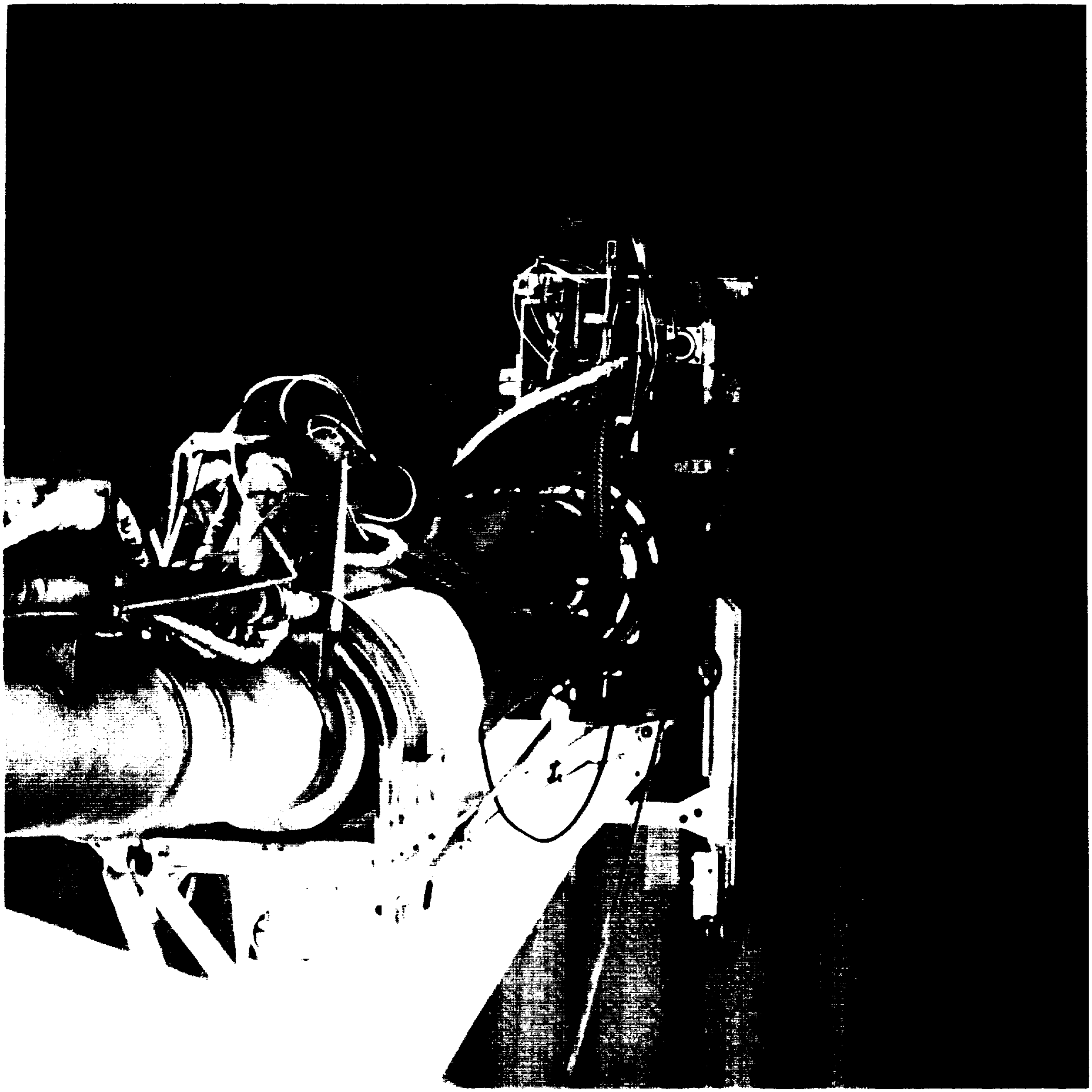
Bipod jack pad closeouts were intact and flush with adjacent LH2 tank-to-intertank flange closeout foam.

One of the two cracks in the -Y ET/SRB vertical strut cable tray forward surface TPS (reported during the Ice Team Inspection) was still visible.

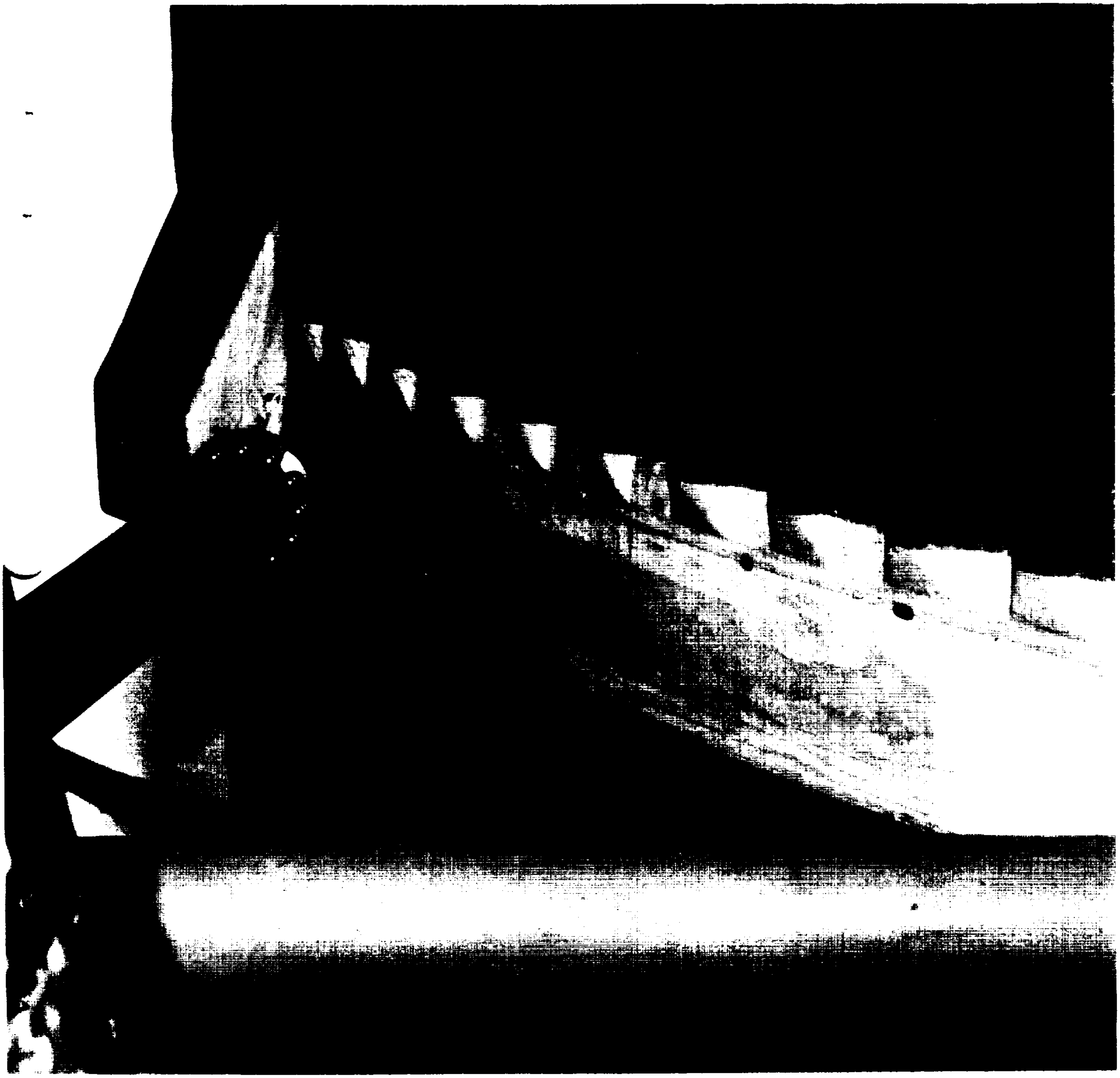
Some froth was present on the aft dome +Z manhole cover BX-250 closeout.

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.



Pre-launch configuration of ET intertank and GUCP



Pre-launch configuration of bipod jack pad closeouts

Stream of liquid (water) from LO2 feedline elbow was caused by condensate run-off. Ice/frost finger of the umbilical aft pyro can closeout was typical.

Typical amounts of ice/frost had accumulated on the LH2 ET/ORB umbilical outboard side, aft plate gap purge vent, aft pyro can purge vent, and cable tray drain hole. No unusual vapors or cryogenic drips appeared during tanking and stable replenish.

4.0 SCRUB - ORBITER S-BAND TRANSPONDER

The second launch attempt of STS-58 was scrubbed during the T-9 minute hold due to an Orbiter S-Band Transponder #2 anomaly.

4.1 PRE-LAUNCH SSV/PAD DEBRIS INSPECTION

A pre-launch debris inspection of the SSV and MLP deck was not performed due to the 24 hour scrub-turnaround.

4.2 ICE/FROST INSPECTION

The Ice/Frost Inspection of the cryoloaded vehicle was performed on 15 October 1993 from 0540 to 0710 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:	76.0 Degrees F
Relative Humidity:	84.7 Percent
Wind Speed:	4.1 Knots
Wind Direction:	146 Degrees

A portable Shuttle Thermal Imager (STI) infrared scanning radiometer was utilized to obtain vehicle surface temperature measurements for an overall thermal assessment of the vehicle, as shown in Figures 4 and 5.

4.3 ORBITER

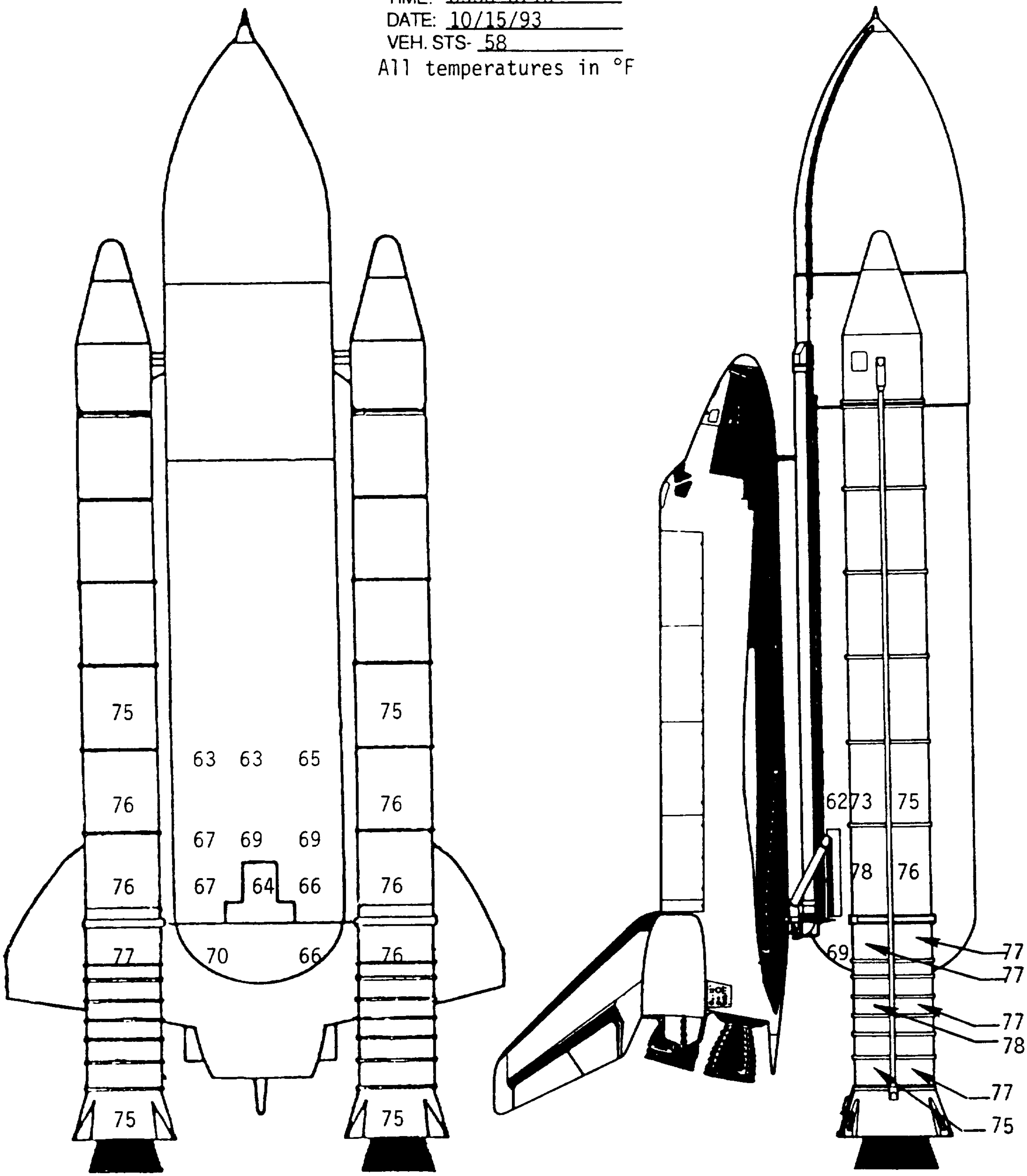
No Orbiter RCC panel or TPS anomalies were observed. The F2U and F4D RCS thruster paper covers had been wetted by internal vapors. Typical ice/frost accumulated at the SSME heat shield-to-nozzle interfaces. Some frost was present on the SSME #1 drain line. The SSME engine mounted heat shields were wet from condensate. An infrared scan revealed no unusual temperature gradients on the base heat shield or engine mounted heat shields.

4.4 SOLID ROCKET BOOSTERS

The STI portable infrared scanner recorded RH and LH SRB case temperatures of 75-78 degrees F. In comparison, temperatures measured by a hand-held Minolta/Land Cyclops spot radiometer averaged 78 degrees F and the SRB Ground Environment Instrumentation (GEI) measured temperatures of 79 degrees F. All measured temperatures were above the 34 degrees F minimum requirement. The predicted Propellant Mean Bulk Temperature (PMBT) supplied by MTI was 79 degrees F, which was within the required range of 44-86 degrees F.

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

TIME: 0530-0710
DATE: 10/15/93
VEH. STS- 58
All temperatures in °F



STS- 58 | TEST S0007 Scrub - Orbiter Transponder #2 | DATE: 15 October 1993 | T-0 TIME: DATE: | NASA KSC Ice/Frost/Debris Team

ORBITER 102 | ET 57 | SRB BI-061 | MLP 1 | PAD B

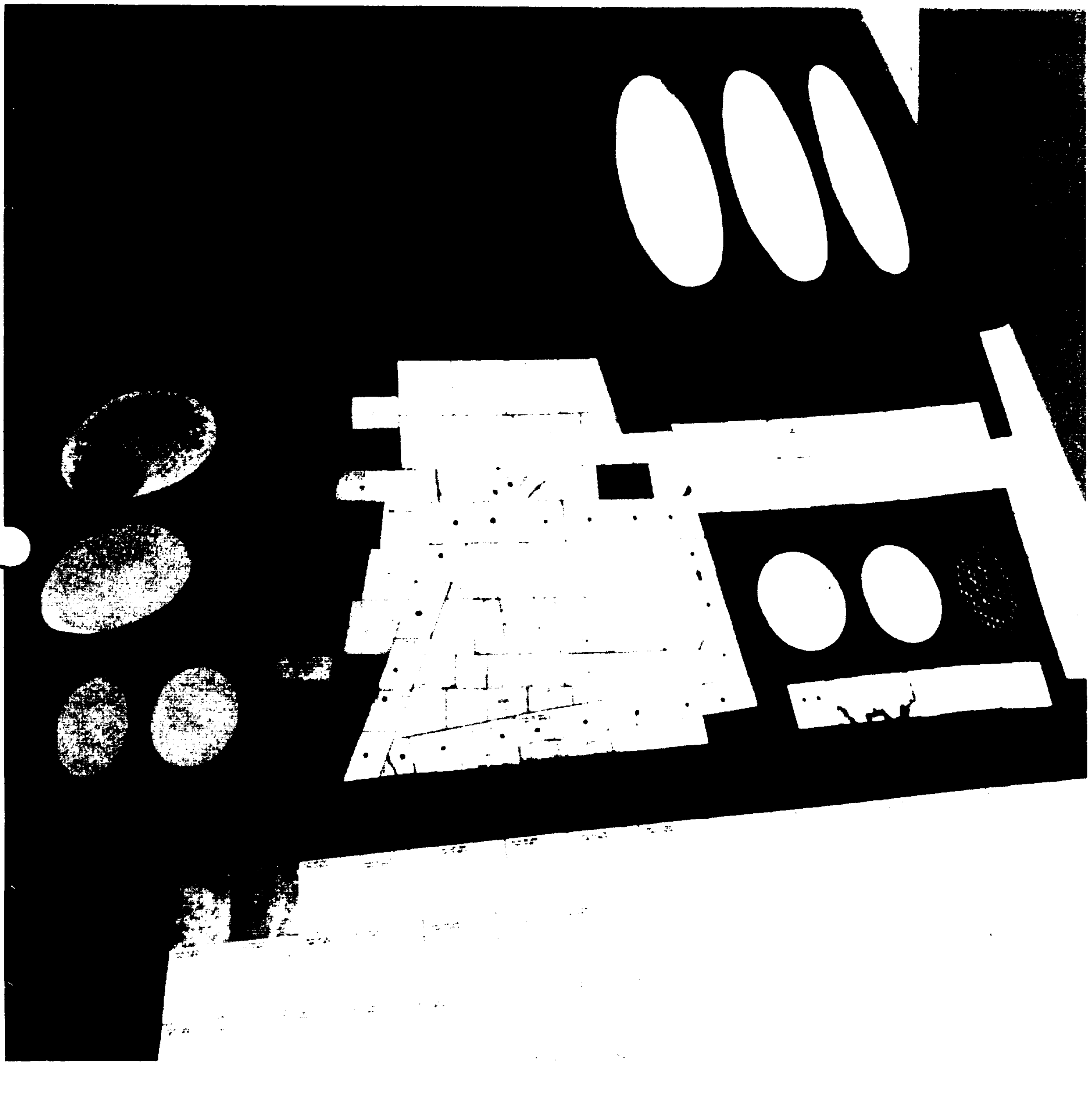
LO2 — CHILLDOWN TIME: 02:23 FAST FILL TIME: 03:12 SLOW FILL TIME: 02:58 REPLENISH TIME: 05:20

LH2 — CHILLDOWN TIME: 02:18 FAST FILL TIME: 03:12 SLOW FILL TIME: 02:29 REPLENISH TIME: 05:04

TIME	CONDITIONS					LO2 TANK STA 370 TO 540					LO2 TANK STA 550 TO 852					LH2 TANK STA 1130 TO 1380					LH2 TANK STA 1380 TO 2058				
(EDT)	TEMP F	REL. HUM. %	DEW PT F	WIND VEL KNTS	WIND DIR DEG	REG	LOCAL VEL KNTS	SOFI TEMP	COND RATE IN/HR	ICE RATE IN/HR	REG	LOCAL VEL KNTS	SOFI TEMP	COND RATE IN/HR	ICE RATE IN/HR	REG	LOCAL VEL KNTS	SOFI TEMP	COND RATE IN/HR	ICE RATE IN/HR	REG	LOCAL VEL KNTS	SOFI TEMP	COND RATE IN/HR	ICE RATE IN/HR
0245	77.00	82.2	71.42	7	137	II	4.13	66.66	0.0025	-0.1874	II	4.13	62.11	0.0044	-0.1563	II	2.24	55.03	0.0041	-0.0801	II	9.73	67.02	0.0048	-0.3491
0300	76.60	82.2	71.02	7	138	II	4.13	66.23	0.0025	-0.1843	II	4.13	61.64	0.0043	-0.1533	II	2.24	54.52	0.0041	-0.0781	II	9.73	66.59	0.0048	-0.3433
0315	76.80	81.6	71.01	7	136	II	4.13	66.30	0.0024	-0.1848	II	4.13	61.72	0.0043	-0.1538	II	2.24	54.63	0.0040	-0.0785	II	9.73	66.65	0.0047	-0.3441
0330	76.80	81.3	71.08	7	141	II	4.13	66.35	0.0024	-0.1852	II	4.13	61.77	0.0043	-0.1541	II	2.24	54.68	0.0040	-0.0787	II	9.73	66.70	0.0047	-0.3448
0345	76.80	81.3	71.08	6	138	II	3.54	65.62	0.0024	-0.1633	II	3.54	60.48	0.0042	-0.1327	II	1.32	52.88	0.0038	-0.0783	II	8.34	65.88	0.0048	-0.2969
0400	76.60	82.6	71.16	5	146	II	2.95	64.65	0.0025	-0.1409	II	2.95	58.78	0.0041	-0.1108	II	1.60	51.30	0.0037	-0.0779	II	6.95	64.77	0.0049	-0.2433
0415	76.80	82.3	71.42	7	137	II	4.13	66.59	0.0025	-0.1869	II	4.13	62.02	0.0044	-0.1558	II	2.24	54.92	0.0041	-0.0797	II	9.73	66.95	0.0049	-0.3483
0430	76.60	82.2	71.02	4	136	II	2.36	63.31	0.0024	-0.1178	II	2.36	56.50	0.0038	-0.0883	II	1.28	51.72	0.0037	-0.0775	II	5.56	63.14	0.0049	-0.1985
0445	76.80	82.6	71.36	6	135	II	3.54	65.81	0.0025	-0.1645	II	3.54	60.68	0.0043	-0.1339	II	1.32	53.07	0.0039	-0.0791	II	8.34	66.08	0.0049	-0.2993
0500	76.80	81.4	70.94	7	133	II	4.13	66.25	0.0024	-0.1845	II	4.13	61.67	0.0043	-0.1535	II	2.24	54.58	0.0040	-0.0783	II	9.73	66.60	0.0047	-0.3435
0515	77.40	80.4	71.18	5	114	II	2.95	65.03	0.0023	-0.1429	II	2.95	59.20	0.0040	-0.1128	II	1.50	52.35	0.0037	-0.0803	II	6.95	65.10	0.0047	-0.2514
0530	77.20	76.6	69.62	6	137	II	3.54	64.81	0.0021	-0.1580	II	3.54	59.63	0.0038	-0.1277	II	1.92	52.13	0.0035	-0.0754	II	8.34	64.98	0.0041	-0.2861
0545	77.00	80.4	70.79	6	135	II	3.54	65.51	0.0024	-0.1625	II	3.54	60.36	0.0041	-0.1320	II	1.92	52.80	0.0038	-0.0780	II	8.34	65.75	0.0046	-0.2952
0600	77.20	81.0	71.20	6	143	II	3.54	65.88	0.0024	-0.1648	II	3.54	60.76	0.0042	-0.1342	II	1.92	53.20	0.0038	-0.0798	II	8.34	66.12	0.0047	-0.2995
0615	77.00	82.2	71.42	4	144	II	2.36	63.77	0.0024	-0.1200	II	2.36	56.99	0.0039	-0.0904	II	1.28	52.21	0.0038	-0.0798	II	5.56	63.59	0.0049	-0.2023
0630	76.80	82.8	71.42	6	149	II	3.54	65.86	0.0025	-0.1648	II	3.54	60.73	0.0043	-0.1342	II	1.92	53.12	0.0039	-0.0793	II	8.34	66.14	0.0049	-0.2999
0645	74.00	87.4	70.18	6	187	II	3.54	63.79	0.0027	-0.1521	II	3.54	58.51	0.0044	-0.1218	II	2.52	53.84	0.0043	-0.0801	II	2.28	52.67	0.0042	-0.0715
0700	75.60	89.6	72.47	3	118	II	1.77	61.39	0.0026	-0.1094	II	1.77	53.85	0.0038	-0.0846	II	0.96	51.89	0.0040	-0.0788	II	4.17	61.44	0.0053	-0.1533
0715	74.50	89.6	71.38	2	149	II	1.18	58.92	0.0023	-0.1030	II	1.18	51.96	0.0037	-0.0782	II	0.64	50.51	0.0039	-0.0724	II	2.78	56.05	0.0047	-0.0945
0730	76.20	89.2	72.94	3	117	II	1.77	62.62	0.0026	-0.1126	II	1.77	54.53	0.0038	-0.0878	II	0.96	52.57	0.0041	-0.0819	II	4.17	62.06	0.0053	-0.1573
0745	76.60	90.0	73.59	4	118	II	2.36	65.08	0.0028	-0.1264	II	2.36	58.34	0.0043	-0.0964	II	1.28	53.22	0.0041	-0.0851	II	5.56	65.06	0.0057	-0.2148
0800	77.20	89.4	74.00	6	107	II	3.54	67.85	0.0030	-0.1778	II	3.54	62.92	0.0049	-0.1466	II	3.30	61.13	0.0051	-0.1312	II	7.32	67.45	0.0058	-0.2866
0815	78.00	88.0	74.35	6	93	II	3.54	68.43	0.0029	-0.1816	II	3.54	63.44	0.0048	-0.1502	II	3.30	61.77	0.0051	-0.1347	II	7.32	68.00	0.0057	-0.2925
0830	78.20	87.6	74.41	6	96	II	3.54	68.56	0.0029	-0.1824	II	3.54	63.58	0.0048	-0.1511	II	3.30	61.92	0.0051	-0.1355	II	7.32	68.12	0.0057	-0.2939
0845	78.80	84.6	74.02	5	80	II	2.95	67.61	0.0027	-0.1576	II	2.95	61.93	0.0044	-0.1269	II	2.75	60.07	0.0047	-0.1129	II	6.10	66.89	0.0053	-0.2457
0900	79.60	82.6	74.13	5	118	II	2.95	68.03	0.0026	-0.1601	II	2.95	62.39	0.0043	-0.1293	II	1.60	55.51	0.0040	-0.0958	II	6.95	68.10	0.0052	-0.2824
0915	79.60	81.6	72.79	7	117	II	4.13	68.27	0.0025	-0.1990	II	4.13	63.81	0.0044	-0.1675	II	2.24	56.88	0.0042	-0.0887	II	9.73	68.58	0.0048	-0.3704
0930	79.00	81.4	73.12	7	121	II	4.13	68.66	0.0025	-0.2019	II	4.13	64.22	0.0044	-0.1703	II	2.24	57.33	0.0042	-0.0909	II	9.73	68.96	0.0048	-0.3756
0945	79.20	80.8	73.11	8	117	II	4.72	69.28	0.0024	-0.2257	II	4.72	65.29	0.0045	-0.1936	II	2.56	58.88	0.0043	-0.1029	II	11.12	69.62	0.0046	-0.4277
1000	78.80	81.2	72.85	6	126	II	3.54	67.69	0.0025	-0.1765	II	3.54	62.69	0.0043	-0.1455	II	1.92	55.28	0.0040	-0.0894	II	8.34	67.91	0.0049	-0.3208
1015	75.40	83.0	70.11	11	147	II	6.49	66.97	0.0024	-0.2588	II	6.49	63.72	0.0045	-0.2265	II	3.52	58.02	0.0045	-0.1186	II	15.29	67.45	0.0043	-0.5110
1030	72.00	85.8	67.67	12	198	II	7.08	64.32	0.0026	-0.2486	II	7.08	61.15	0.0046	-0.2167	II	5.04	57.95	0.0048	-0.1483	II	4.56	57.08	0.0047	-0.1333
1045	75.20	86.4	71.04	2	315	II	1.18	59.18	0.0022	-0.1040	II	1.18	52.23	0.0036	-0.0792	II	0.92	50.79	0.0038	-0.0735	II	2.46	54.84	0.0043	-0.0833
1100	76.00	85.0	71.37	3	43	II	1.77	61.47	0.0023	-0.1073	II	1.77	53.32	0.0036	-0.0825	II	2.10	53.69	0.0041	-0.0768	II	3.63	59.52	0.0048	-0.1294
AVG.	74.66	83.76	71.78	5.82	ESE		3.44	65.51				3.44	60.08				2.11	54.85				7.42	64.76		

Period of Ice Team Inspection

FIGURE 6. "SURFICE" Computer Predictions



The F2U and F4D RCS thruster paper covers had been wetted by internal vapors.

5.0 LAUNCH

STS-58 was launched at 93:291:14:53:10.009 GMT (10:53 am local) on 18 October 1993.

5.1 PRE-LAUNCH SSV/PAD DEBRIS INSPECTION

A pre-launch SSV/pad debris inspection was performed from 0900 to 1000 hours on 17 October 1993. No anomalies on the facility or the flight hardware were detected.

5.2 ICE/FROST INSPECTION

The Ice/Frost Inspection of the cryoloaded vehicle was performed on 18 October 1993 from 0525 to 0655 hours during the two hour built-in-hold at T-3 hours in the countdown. There were no Launch Commit Criteria, OMRS, or NSTS-08303 criteria violations. There were no conditions outside of the established data base and no IPR's were taken. Ambient weather conditions at the time of the inspection were:

Temperature:	71.2 Degrees F
Relative Humidity:	95.0 Percent
Wind Speed:	6.7 Knots
Wind Direction:	295 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 7 and 8.

5.3 ORBITER

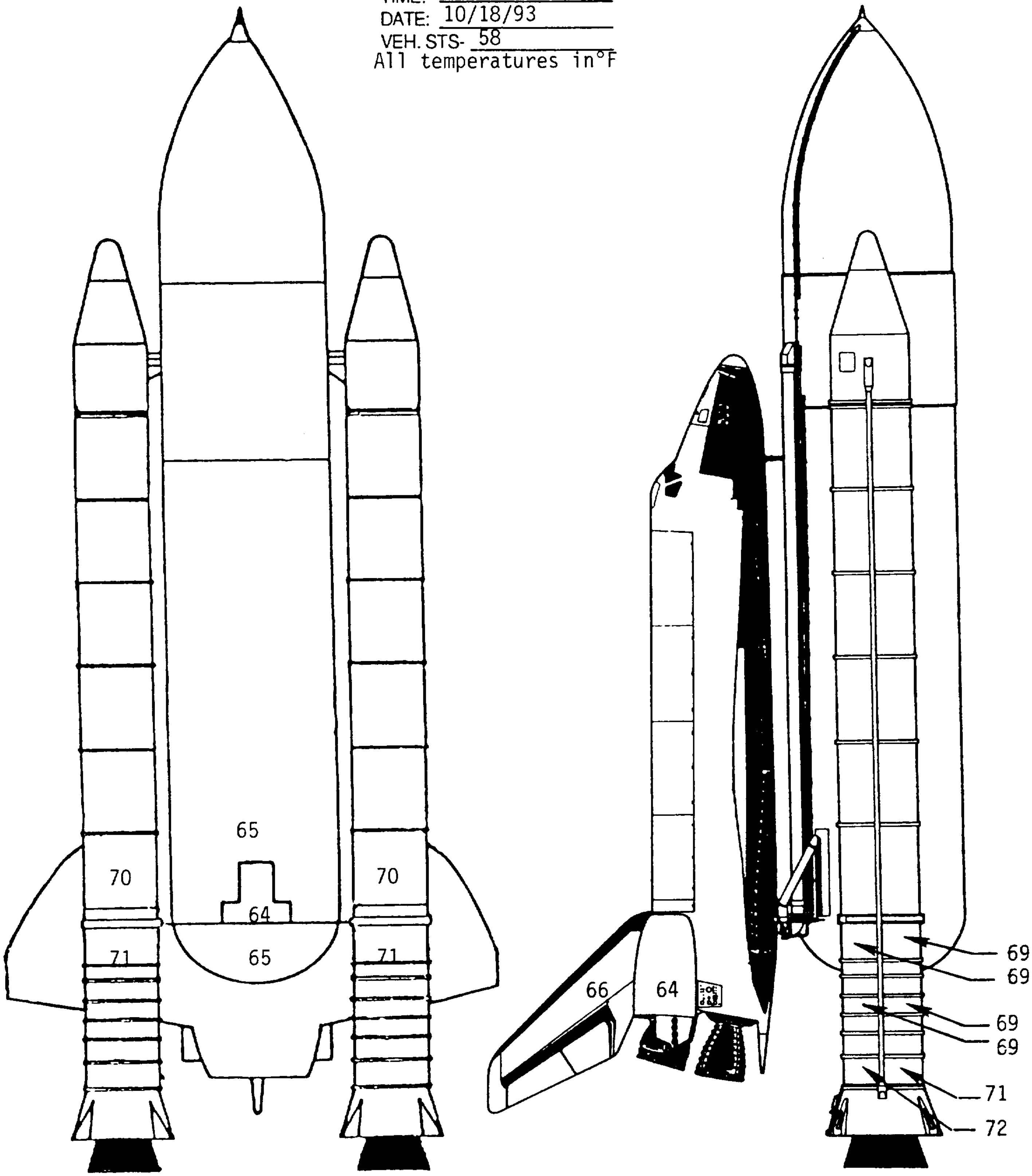
No Orbiter tile or RCC panel anomalies were observed. All RCS thruster paper covers, including the wet cover on the R4D nozzle, were intact. Typical ice and frost accumulations were present at the SSME #1 and #2 heat shield-to-nozzle interfaces. Some frost was present on the SSME #1 and #3 drain lines. An infrared scan revealed no unusual temperature gradients on the base heat shield or engine mounted heat shields.

5.4 SOLID ROCKET BOOSTERS

SRB case temperatures measured by the PSTI averaged 70-74 degrees F; the spot radiometer ranged from 72 to 74 degrees F; and the SRB Ground Environment Instrumentation (GEI) measured temperatures at 75 degrees F. All measured temperatures were above the 34 degrees F minimum requirement. The predicted Propellant Mean Bulk Temperature (PMBT) supplied by MTI was 79 degrees F, which was within the required range of 44-86 degrees Fahrenheit.

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

TIME: 0535-0655
DATE: 10/18/93
VEH. STS- 58
All temperatures in°F



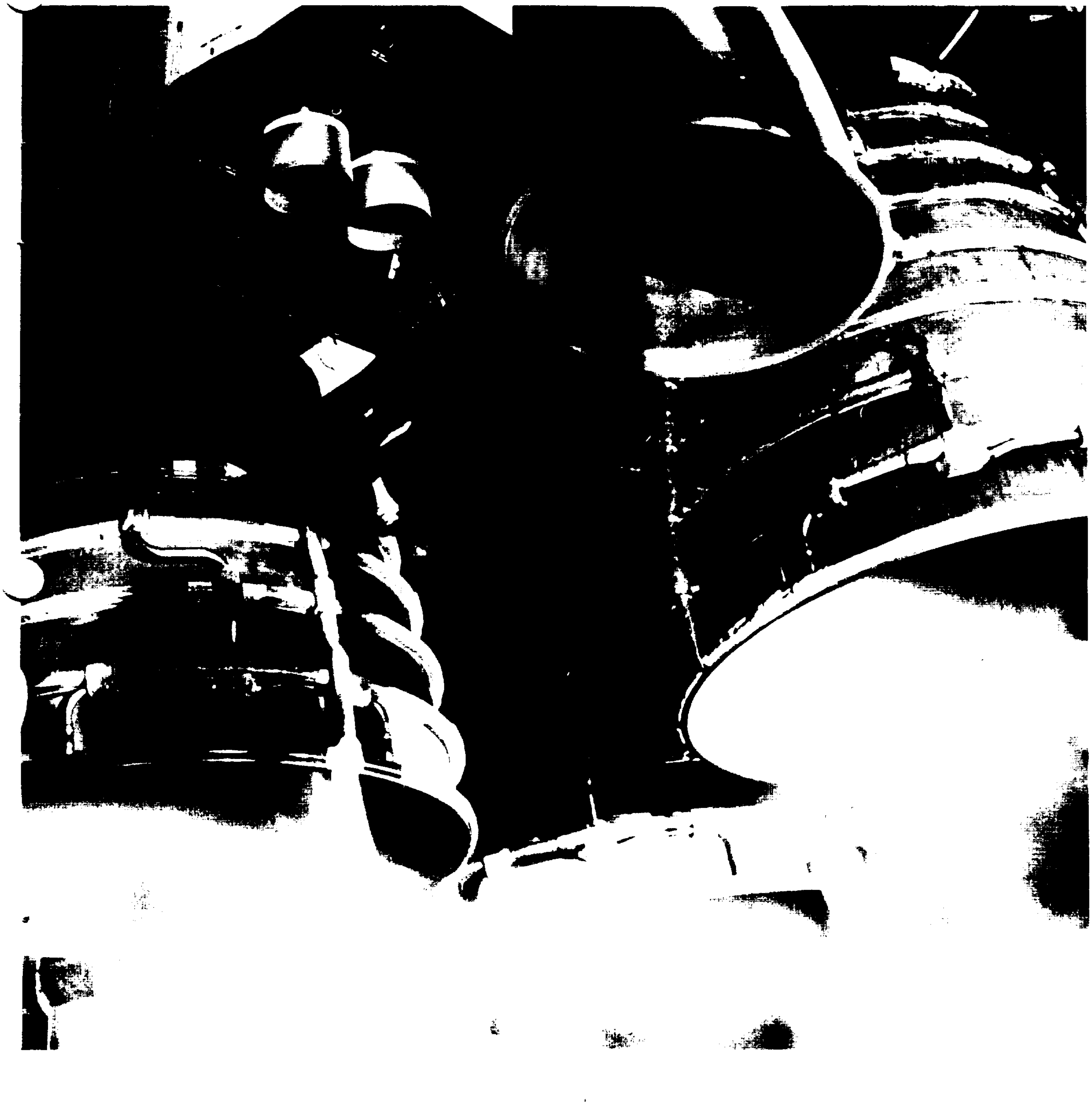
EGG/V-343C

STS- 58	TEST S0007 LAUNCH				DATE: 18 October 1993	T-0 TIME: 10:53:10.009 DATE: 10/18/93	NASA KSC
ORBITER 102	ET 57	SRB 31-061	MLP 1	PAD B	LO2 CHILLDOWN TIME: 02:16 SLOW FILL TIME: 02:54 FAST FILL TIME: 03:07 REPLENISH TIME: 05:03	LH2 CHILLDOWN TIME: 02:16 SLOW FILL TIME: 02:25 FAST FILL TIME: 03:10 REPLENISH TIME: 05:03	Ice/Frost/Debris Team

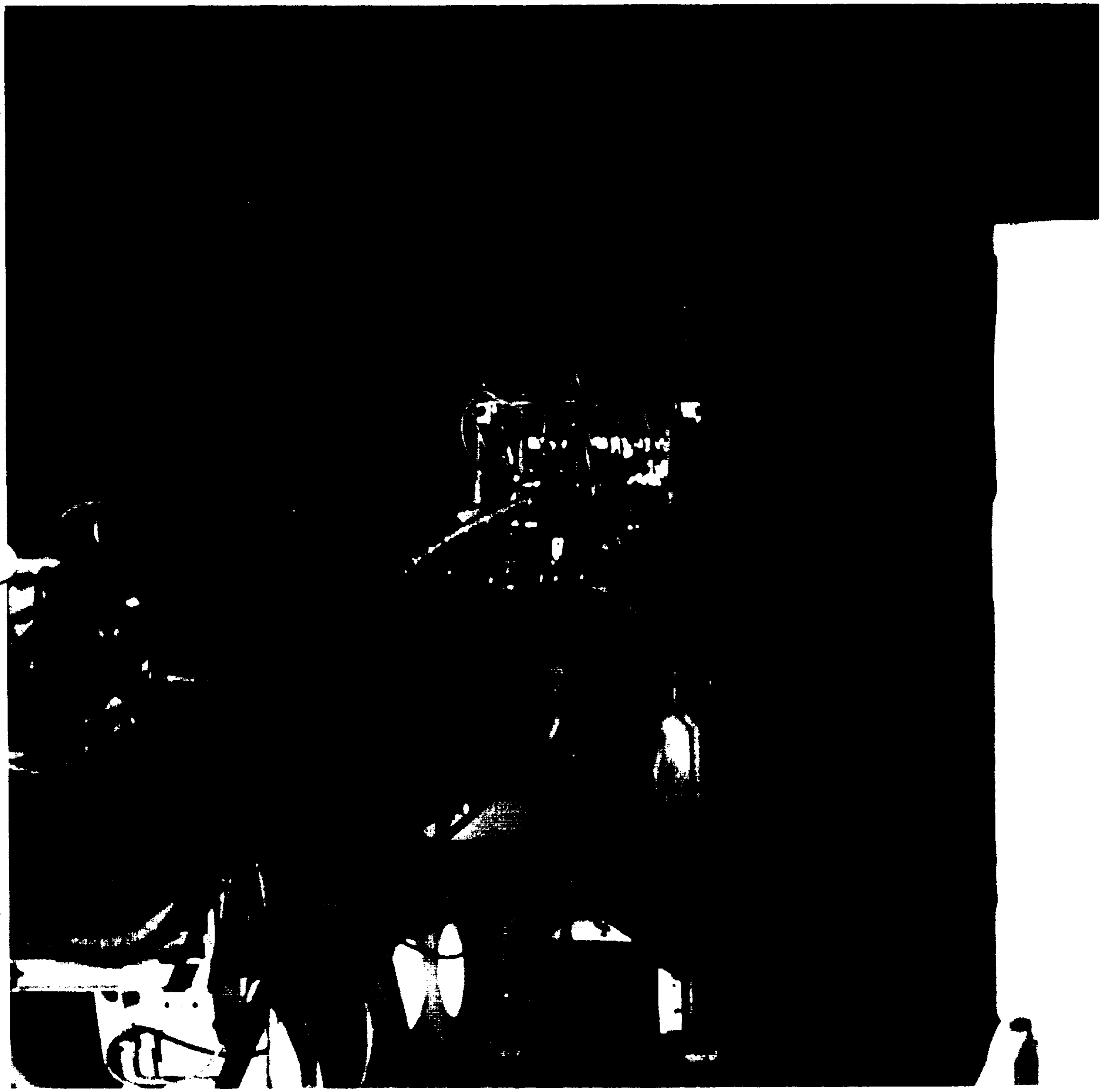
TIME	CONDITIONS					LO2 TANK STA 370 TO 540					LO2 TANK STA 550 TO 852					LH2 TANK STA 1130 TO 1380					LH2 TANK STA 1380 TO 2058				
(EDT)	TEMP F	REL. HUM. %	DEW PT F	WIND VEL KNTS	WIND DIR DEG	REG	LOCAL VEL KNTS	SOFI TEMP	COND RATE IN/HR	ICE RATE IN/HR	REG	LOCAL VEL KNTS	SOFI TEMP	COND RATE IN/HR	ICE RATE IN/HR	REG	LOCAL VEL KNTS	SOFI TEMP	COND RATE IN/HR	ICE RATE IN/HR	REG	LOCAL VEL KNTS	SOFI TEMP	COND RATE IN/HR	ICE RATE IN/HR
0230	71.30	93.6	69.93	6	293	II	3.54	62.64	0.0031	-0.1453	II	3.54	57.27	0.0047	-0.1151	II	2.76	53.47	0.0047	-0.0826	II	7.38	62.37	0.0058	-0.2358
0245	70.00	93.4	68.07	3	303	II	1.77	56.04	0.0025	-0.0812	II	1.77	47.45	0.0036	-0.0564	II	1.38	45.52	0.0038	-0.0507	II	3.69	54.35	0.0049	-0.1022
0300	72.60	93.2	70.60	6	293	II	3.54	63.47	0.0031	-0.1503	II	3.54	58.15	0.0048	-0.1199	II	2.76	54.40	0.0047	-0.0867	II	7.38	63.19	0.0059	-0.2439
0315	72.40	91.4	69.85	6	296	II	3.54	62.36	0.0029	-0.1465	II	3.54	57.50	0.0046	-0.1163	II	2.76	53.75	0.0046	-0.0838	II	7.38	62.56	0.0056	-0.2375
0330	72.00	94.0	70.25	6	297	II	3.54	62.95	0.0031	-0.1472	II	3.54	57.60	0.0048	-0.1169	II	2.76	53.31	0.0047	-0.0842	II	7.38	62.69	0.0059	-0.2390
0345	71.40	94.4	69.77	6	281	II	3.54	62.35	0.0031	-0.1436	II	3.54	56.95	0.0047	-0.1134	II	2.58	52.35	0.0046	-0.0750	II	7.26	61.99	0.0059	-0.2292
0400	69.40	94.6	67.34	6	283	II	3.54	60.10	0.0030	-0.1305	II	3.54	54.57	0.0046	-0.1008	II	2.58	49.85	0.0044	-0.0647	II	7.26	59.76	0.0057	-0.2080
0415	71.40	94.3	69.89	7	293	II	4.13	63.26	0.0032	-0.1643	II	4.13	58.45	0.0050	-0.1337	II	3.22	54.95	0.0049	-0.0973	II	8.61	63.17	0.0060	-0.2734
0430	71.20	95.0	69.75	7	289	II	4.13	63.07	0.0032	-0.1630	II	4.13	58.26	0.0050	-0.1325	II	3.01	54.00	0.0048	-0.0892	II	8.47	62.89	0.0060	-0.2669
0445	68.20	95.2	66.82	8	298	II	4.72	60.41	0.0032	-0.1590	II	4.72	55.88	0.0049	-0.1288	II	3.68	52.50	0.0049	-0.0923	II	9.84	60.46	0.0059	-0.2697
0500	70.80	95.4	69.47	8	294	II	4.72	63.37	0.0033	-0.1802	II	4.72	59.01	0.0051	-0.1493	II	3.68	55.74	0.0051	-0.1095	II	9.84	63.40	0.0061	-0.3057
0515	71.00	95.2	69.61	3	296	II	4.72	63.55	0.0033	-0.1816	II	4.72	59.20	0.0051	-0.1506	II	3.68	55.95	0.0051	-0.1106	II	9.84	63.58	0.0061	-0.3080
0530	71.40	95.2	70.01	7	295	II	4.13	63.34	0.0032	-0.1649	II	4.13	58.54	0.0050	-0.1342	II	3.22	56.04	0.0050	-0.0977	II	8.61	63.26	0.0061	-0.2744
0545	71.60	95.0	70.15	3	296	II	4.72	64.18	0.0033	-0.1882	II	4.72	59.87	0.0051	-0.1552	II	3.88	56.64	0.0052	-0.1144	II	9.84	64.20	0.0062	-0.3159
0600	72.00	96.0	70.55	6	296	II	3.54	63.18	0.0032	-0.1485	II	3.54	57.32	0.0048	-0.1181	II	2.76	54.03	0.0048	-0.0852	II	7.38	62.92	0.0060	-0.2412
0615	71.40	94.3	69.89	7	294	II	4.13	63.26	0.0032	-0.1643	II	4.13	58.45	0.0050	-0.1337	II	3.22	54.95	0.0049	-0.0973	II	8.61	63.17	0.0060	-0.2734
0630	70.00	94.6	68.43	7	285	II	4.13	61.63	0.0031	-0.1535	II	4.13	56.73	0.0048	-0.1233	II	3.01	52.41	0.0047	-0.0818	II	8.47	61.45	0.0059	-0.2511
0645	70.40	94.8	68.09	3	298	II	3.54	61.29	0.0031	-0.1373	II	3.54	55.83	0.0047	-0.1074	II	2.76	51.96	0.0046	-0.0761	II	7.38	61.05	0.0058	-0.2229
0700	71.80	94.3	70.29	3	305	II	3.54	62.89	0.0031	-0.1468	II	3.54	57.53	0.0048	-0.1166	II	2.76	53.74	0.0047	-0.0838	II	7.38	62.64	0.0060	-0.2385
0715	71.20	94.4	69.57	5	306	II	2.95	61.07	0.0030	-0.1220	II	2.95	54.91	0.0045	-0.0923	II	2.30	50.75	0.0044	-0.0643	II	6.15	60.57	0.0057	-0.1915
0730	71.60	94.4	69.97	6	298	II	3.54	62.58	0.0031	-0.1449	II	3.54	57.20	0.0048	-0.1147	II	2.76	53.40	0.0047	-0.0823	II	7.38	62.33	0.0059	-0.2353
0745	67.50	94.4	65.98	2	214	II	1.18	51.51	0.0022	-0.0694	II	1.18	44.21	0.0034	-0.0447	II	0.64	42.67	0.0036	-0.0390	II	2.72	48.16	0.0043	-0.0596
0800	69.20	94.4	67.58	1	177	II	0.59	53.41	0.0023	-0.0777	II	0.59	46.21	0.0035	-0.0530	II	0.42	44.68	0.0037	-0.0472	II	0.38	44.68	0.0037	-0.0472
0815	70.60	94.4	68.97	6	297	II	3.54	61.43	0.0031	-0.1382	II	3.54	55.98	0.0047	-0.1082	II	2.76	52.13	0.0046	-0.0768	II	7.38	61.19	0.0058	-0.2242
0830	71.00	94.0	69.25	6	294	II	3.54	61.81	0.0031	-0.1404	II	3.54	56.38	0.0047	-0.1103	II	2.76	52.55	0.0046	-0.0786	II	7.38	61.55	0.0058	-0.2277
0845	71.40	93.4	69.47	6	298	II	3.54	62.14	0.0030	-0.1423	II	3.54	56.74	0.0047	-0.1122	II	2.76	52.93	0.0046	-0.0802	II	7.38	61.88	0.0058	-0.2309
0900	72.20	91.0	69.53	4	301	II	2.36	60.14	0.0027	-0.1034	II	2.36	53.04	0.0040	-0.0743	II	1.34	48.51	0.0039	-0.0607	II	4.92	59.17	0.0053	-0.1546
0915	72.40	89.4	69.23	4	314	II	2.36	60.03	0.0026	-0.1029	II	2.36	52.93	0.0040	-0.0738	II	1.34	48.43	0.0038	-0.0604	II	4.92	59.04	0.0051	-0.1536
0930	72.80	86.2	68.60	4	314	II	2.36	59.81	0.0025	-0.1019	II	2.36	52.74	0.0038	-0.0729	II	1.34	48.25	0.0037	-0.0600	II	4.92	58.77	0.0049	-0.1516
0945	74.00	82.4	68.52	4	319	II	2.36	60.37	0.0023	-0.1043	II	2.36	53.35	0.0037	-0.0753	II	1.84	48.94	0.0036	-0.0632	II	4.92	59.25	0.0046	-0.1548
1000	76.80	73.8	70.02	6	323	II	3.54	64.91	0.0022	-0.1587	II	3.54	59.72	0.0040	-0.1283	II	2.76	56.22	0.0041	-0.0947	II	7.38	64.40	0.0045	-0.2554
1015	75.00	76.4	67.38	7	336	II	4.13	63.10	0.0020	-0.1627	II	4.13	58.33	0.0037	-0.1325	II	3.22	55.02	0.0039	-0.0973	II	8.61	62.75	0.0039	-0.2575
1030	75.40	75.0	67.25	6	325	II	3.54	62.46	0.0019	-0.1437	II	3.54	57.13	0.0036	-0.1139	II	2.76	53.58	0.0037	-0.0827	II	7.38	61.90	0.0039	-0.2301
1045	76.20	72.4	67.04	6	322	II	3.54	62.69	0.0017	-0.1450	II	3.54	57.38	0.0034	-0.1153	II	2.76	53.88	0.0036	-0.0840	II	7.38	62.09	0.0036	-0.2318
T-0	76.60	72.2	67.36	6	330	II	3.54	63.07	0.0017	-0.1473	II	3.54	57.79	0.0034	-0.1175	II	2.76	54.31	0.0036	-0.0859	II	7.38	62.46	0.0036	-0.2355
AVG.	69.86	90.79	69.02	5.30	WNW		3.42	61.55				3.42	55.97				2.84	52.32				7.10	60.84		

Period of Ice Team inspection

FIGURE 9. "SURFICE" Computer Predictions

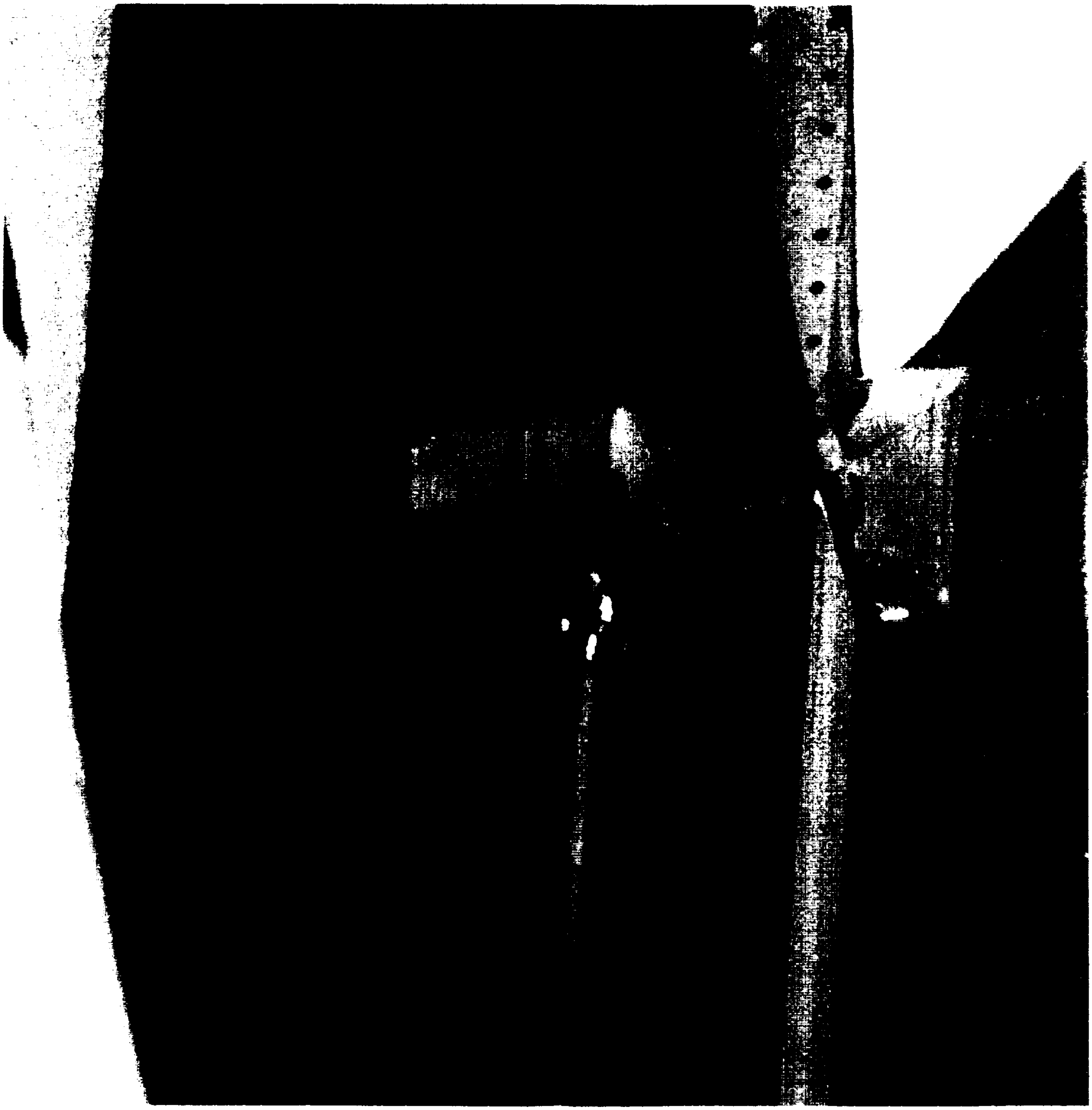


Typical ice and frost accumulations were present on the SSME #1 and #2 heat shield-to-nozzle interfaces and on the SSME #1 and #3 drain lines.



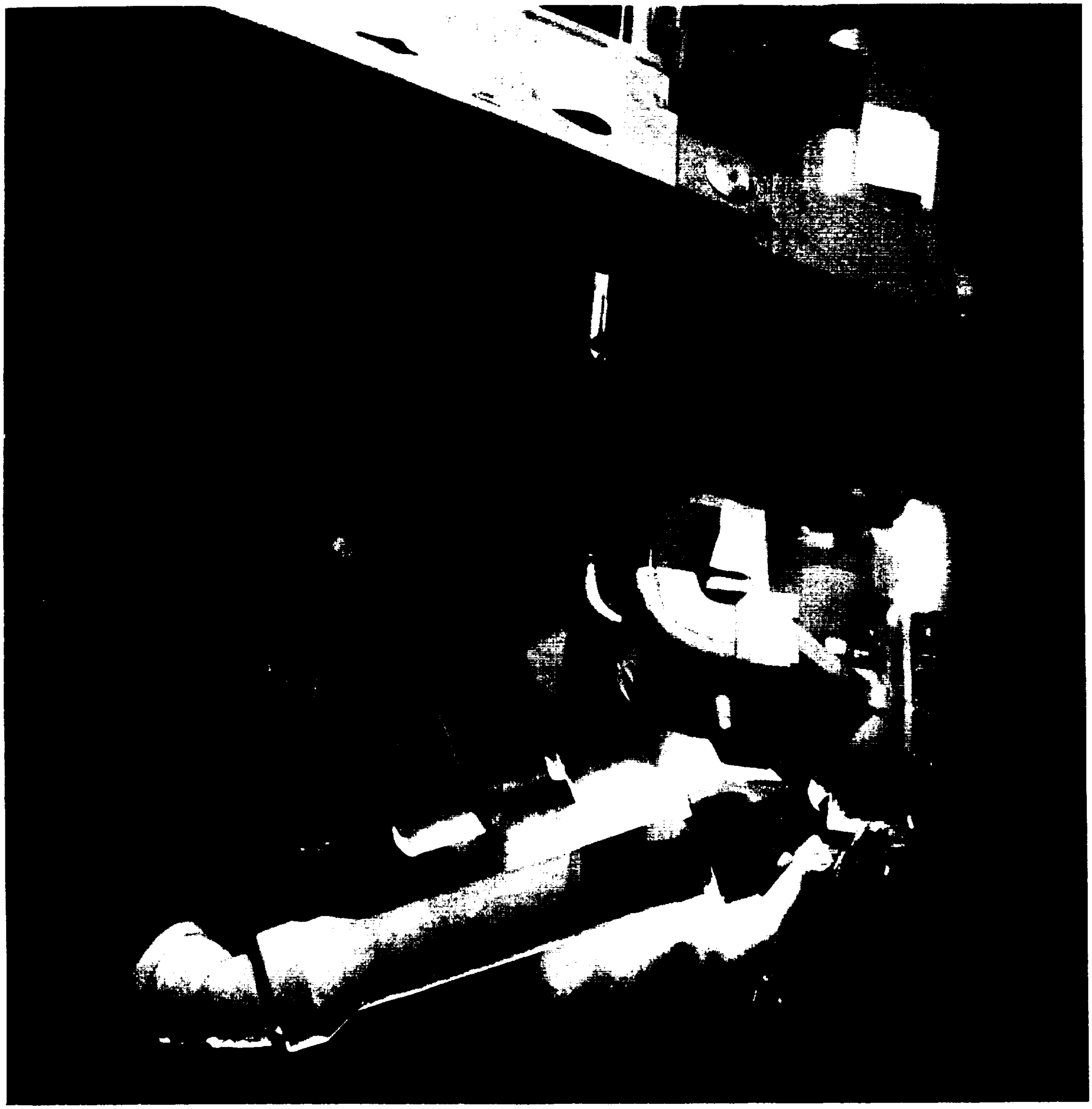
Pre-launch configuration of the intertank and GUCP after cryo load. Ice formation on the GUCP legs and uninsulated areas was typical. No unusual vapors were present around the GUCP.

Ice/frost with venting vapors appeared at the aft outboard corner of the +Y bipod spindle housing closeout. There were no anomalies visible on the bipod jack pad closeouts. Ice/frost in the LO2 feedline upper bellows was typical.



Ice/frost had formed on the pressurization line support closeout aft edges-to-acreage bondlines and cable tray ramp aft edges

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



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

6.0 POST LAUNCH PAD DEBRIS INSPECTION

The post launch inspection of the MLP, FSS, and RSS was conducted on 18 October 1993 from Launch + 1 to 2.5 hours.

No flight hardware or TPS materials were found.

South SRB HDP erosion was typical. All south HDP EPON shoe shim material was intact though some of the HDP #5 and #6 sidewall material was debonded. There was no visual indication of a stud hang-up on any of the south holddown posts. The SRB T-0 umbilicals exhibited typical damage with several connector savers 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 second of eight teeth of the latching mechanism and had no loose cables (static retract lanyard). The GH2 vent line showed typical signs of SRB plume impingement.

An IPR was taken on the GH2 vent line based on film review findings that the line moved approximately 6 inches back toward the vehicle before latching. Post launch troubleshooting showed the latch spring tension was within specification, but at the low end of the limit. The spring tension will be adjusted prior to the next launch. The deceleration shock absorber load cell data was reviewed and showed nominal performance.

Typical damage to the facility included:

1. OTV camera 156 (located on north side of the MLP deck) sustained a broken purge tube.

2. A cable tray elbow cover was detached on the RSS 207 foot level.

3. 2 large pieces of masonry lay in the SSME flame trench.

4. Sheet metal, 36" x 24" in size, was found on the pad apron near the southwest MLP pedestal.

5. A piece of black foam rubber, 48" x 18" x 0.5" in size, lay on the platform near the GH2 vent line latch.

Post launch inspections on 19 October 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 11.

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.

The GH2 vent line was latched on the second of eight teeth of the latching mechanism. Normally the line latches on the 6th or 7th tooth. An IPR was taken based on film review findings that the line moved approximately 6 inches before reaching the final latch position.

7.0 FILM REVIEW AND PROBLEM REPORTS

Anomalies observed in the Film Review were presented to the Mission Management Team, Shuttle managers, and vehicle systems engineers. Three In-Flight Anomalies and one IPR were generated as a result of the film review. Post flight anomalies are listed in Section 11.

7.1 LAUNCH FILM AND VIDEO SUMMARY

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

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

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. At least five pieces of ice contacted the umbilical cavity sill and were deflected outward, but no tile damage was visible (OTV 109). One white object, most likely ice from the LO2 feedline fell aft from a position forward of the LH2 ET/ORB umbilical (OTV 163).

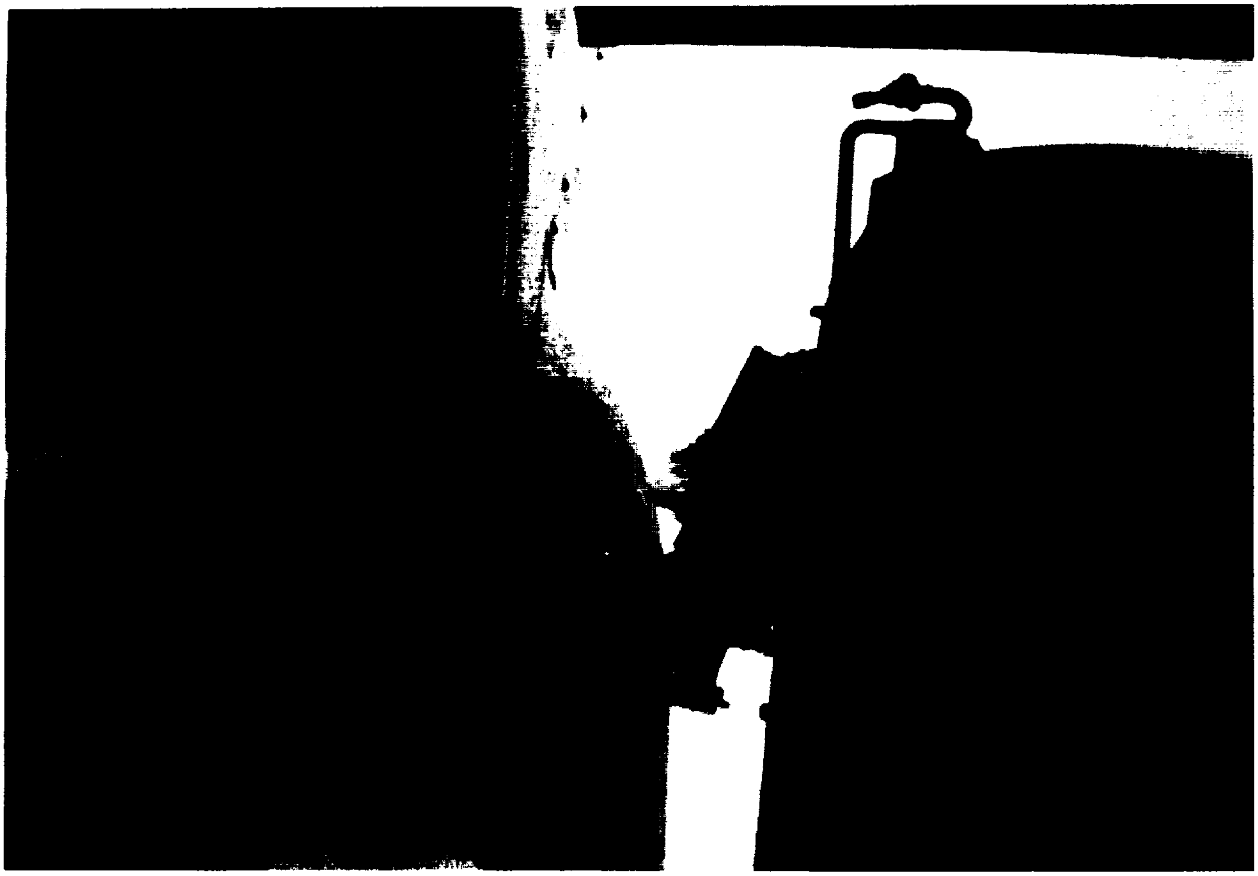
There were no unusual vapors or cryogenic drips from the ET/ORB umbilicals during tanking, stable replenish, ignition, liftoff, and tower clear (OTV 109, 150, 154, 163, 164).

Six pieces of ice fell from the LO2 feedline upper bellows, but did not contact Orbiter tiles. Two dark particles, one forward of the bipods and the second appearing in an area between the intertank and the feedline bellows, also did not contact the vehicle (E-65 frame 1200).

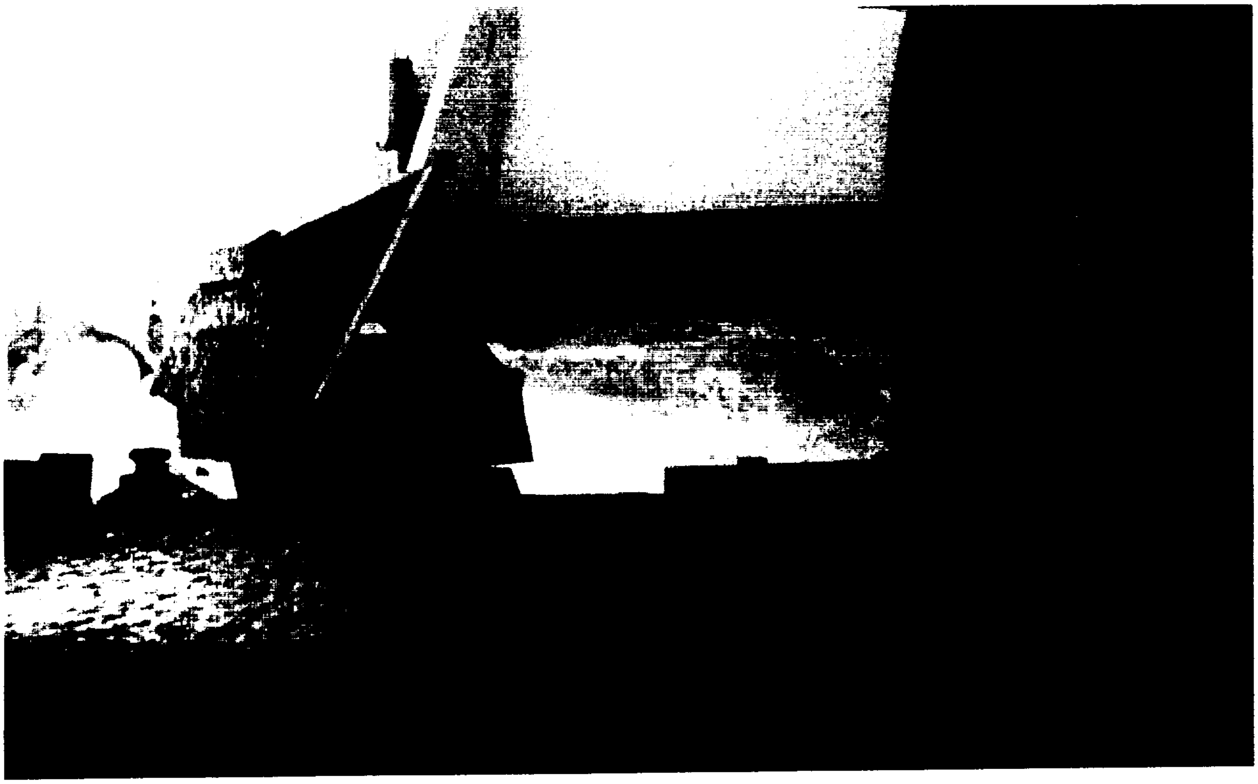
A black particle, most likely facility debris, first appeared forward of the Orbiter and fell aft along the -Y side of the vehicle prior to T-0 (E-34, frame 2510; E-35, frame 1859). This may be the same particle entering the field of view and passing near the outboard elevon (E-31). A second thin, white particle, entered the field of view forward of the LH2 ET/ORB umbilical and fell aft after T-0 (E-31, frame 1202).

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

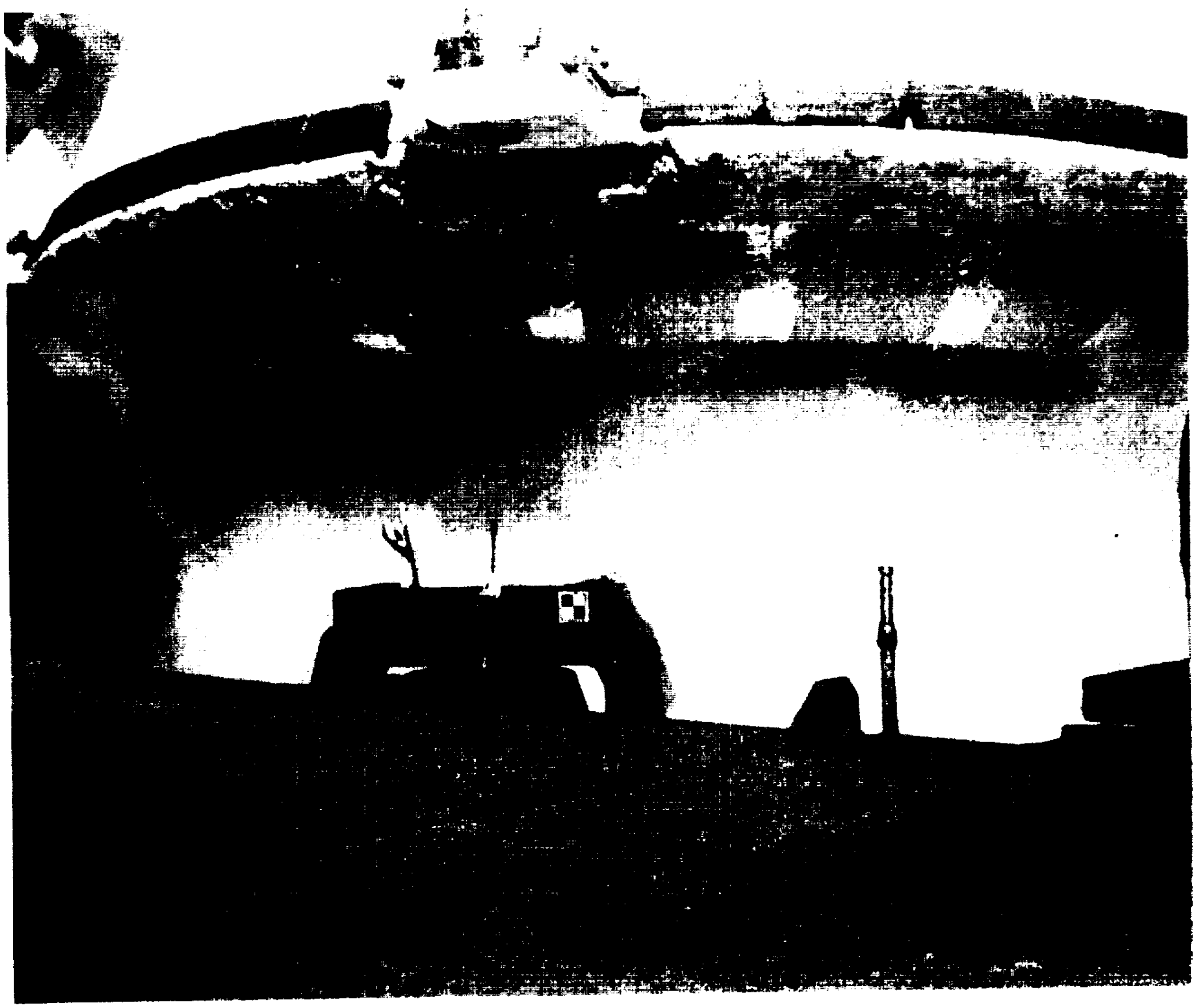
Frustum separation from the forward skirts, parachute deployment appeared normal. One parachute was late in opening but reached full reef position before nozzle severance (E-301). Water splashdown was not visible (E-301, 302).



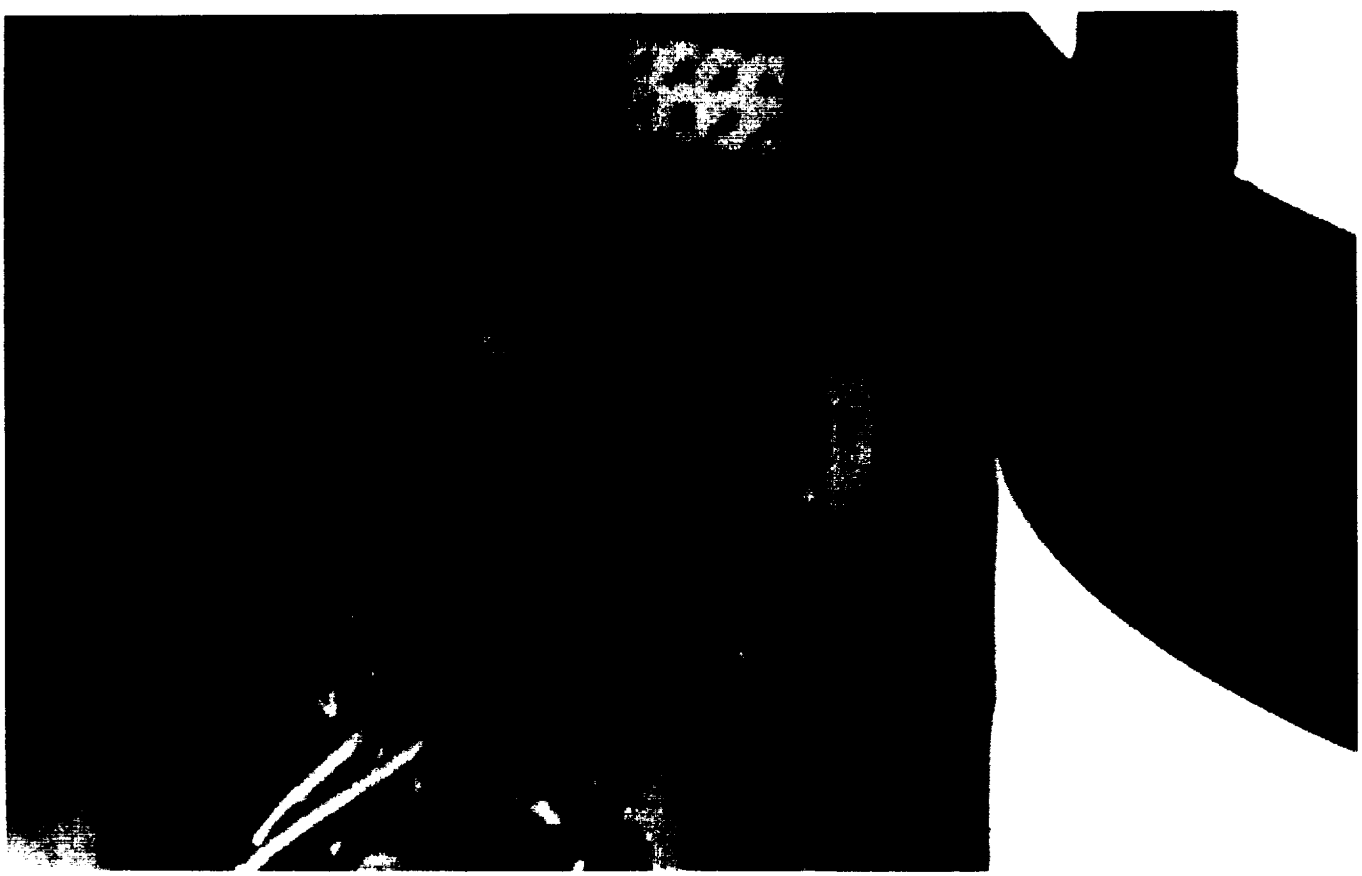
Two small silhouetted objects between the Orbiter and the LH2 T-0 umbilical carrier plate shortly after liftoff appear to be pieces of aft RCS thruster paper covers (arrows).



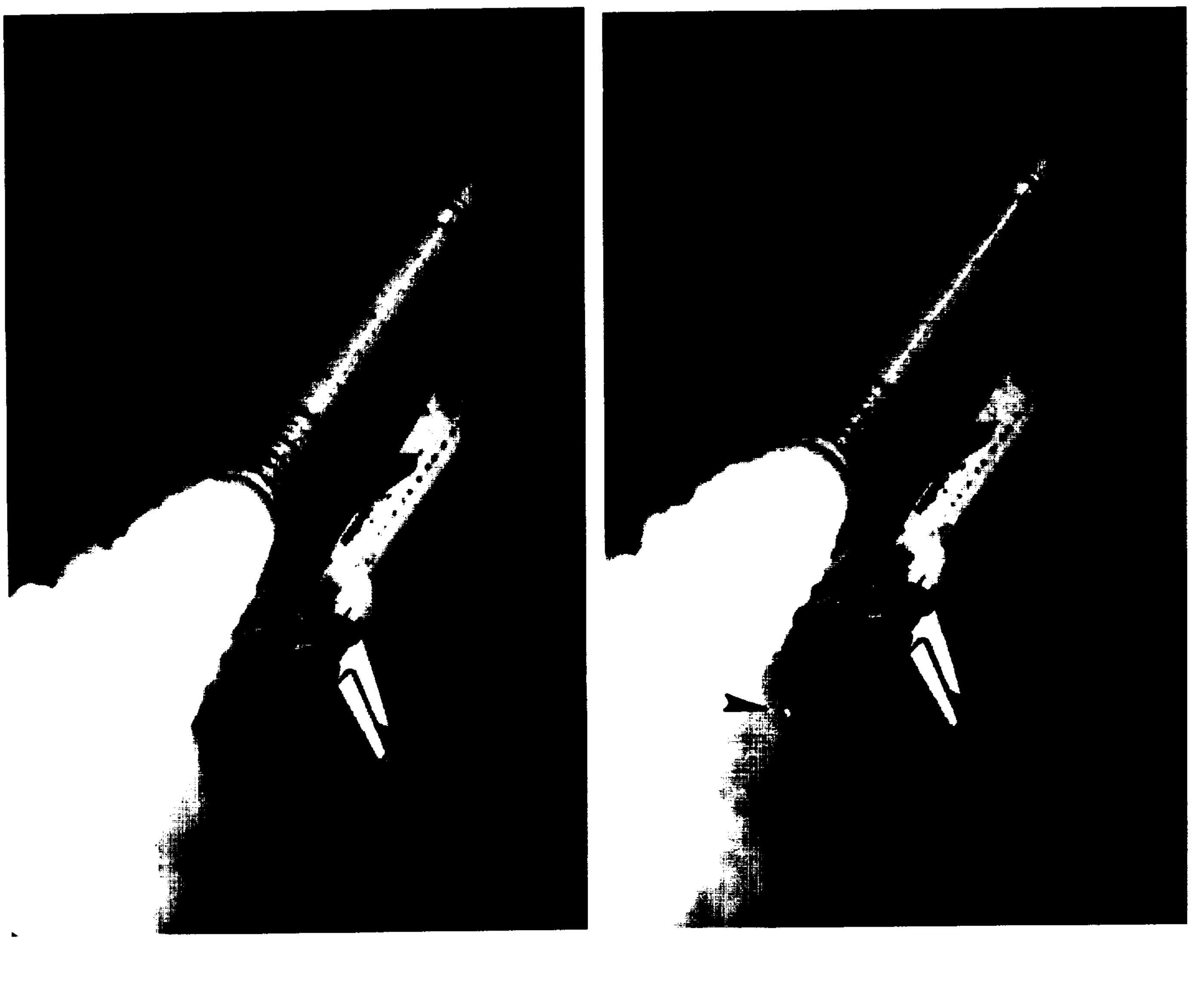
Two debris particles fell out of a cavity in the HDP #3 doghouse blast cover during liftoff (arrows)



No stud hang-ups occurred. Two ordnance fragments fell from the HDP #2 DCS/stud hole shortly after liftoff.



Ice on the GUCP legs caused two pieces of intertank CPR foam (10" x 2" and 3" x 2") to pull loose from adjacent stringer heads and expose primer/substrate.



A white object, believed to be a Dome Mounted Heat Shield closeout blanket MR patch, fell aft of the vehicle 45 seconds MET. The object originated between SSME #2 and #3, got caught in plume recirculation near the base heat shield, and passed the exit plane of SSME #1 before falling away from the vehicle.

7.2 ON-ORBIT FILM AND VIDEO SUMMARY

DTO-0312 was performed by the flight crew. Thirty-eight hand held still images were obtained of the ET after separation from the Orbiter. OV-102 was equipped to carry umbilical cameras: 16mm motion picture with 5 mm lens; 16mm motion picture with 10mm lens; sixty 35mm still views. Data was obtained from all three films.

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

CPR foam, 28 inches long by 3 inches wide, was missing from an intertank stringer head forward of the bipods and aft of the +Z aero vent (XT-990). At least 18 inches of primed substrate was exposed. The loss of this foam may have contributed to the tile damage along the Orbiter lower surface centerline (IFA STS-58-T-1). The divot appears to be a different type than the spray gun "rollover" induced divots observed on previous vehicles. An investigation team confirmed all acceptance requirements were met and there were no processing anomalies. The team is currently reviewing certification history, material processing development, and requirements.

One divot, 12 inches long by 8 inches wide, occurred in the LH2 tank-to-intertank flange closeout in the -Y+Z quadrant between the -Y bipod and the thrust panel. A second divot, 4-6 inches in diameter, occurred in the +Y+Z quadrant flange closeout.

Both bipod jack pad closeouts were missing. Primer was visible in 25 percent of the +Y jack pad cavity and 50 percent of the -Y jack pad cavity (IFA STS-58-T-1). The loss of this foam may have contributed to the centerline tile damage on the Orbiter lower surface. A rough-edged object drifting aft along the +Z side of the tank was light colored on one side (new foam) and dark on the other side (rind or topcoat). This object may have been a piece of ET foam.

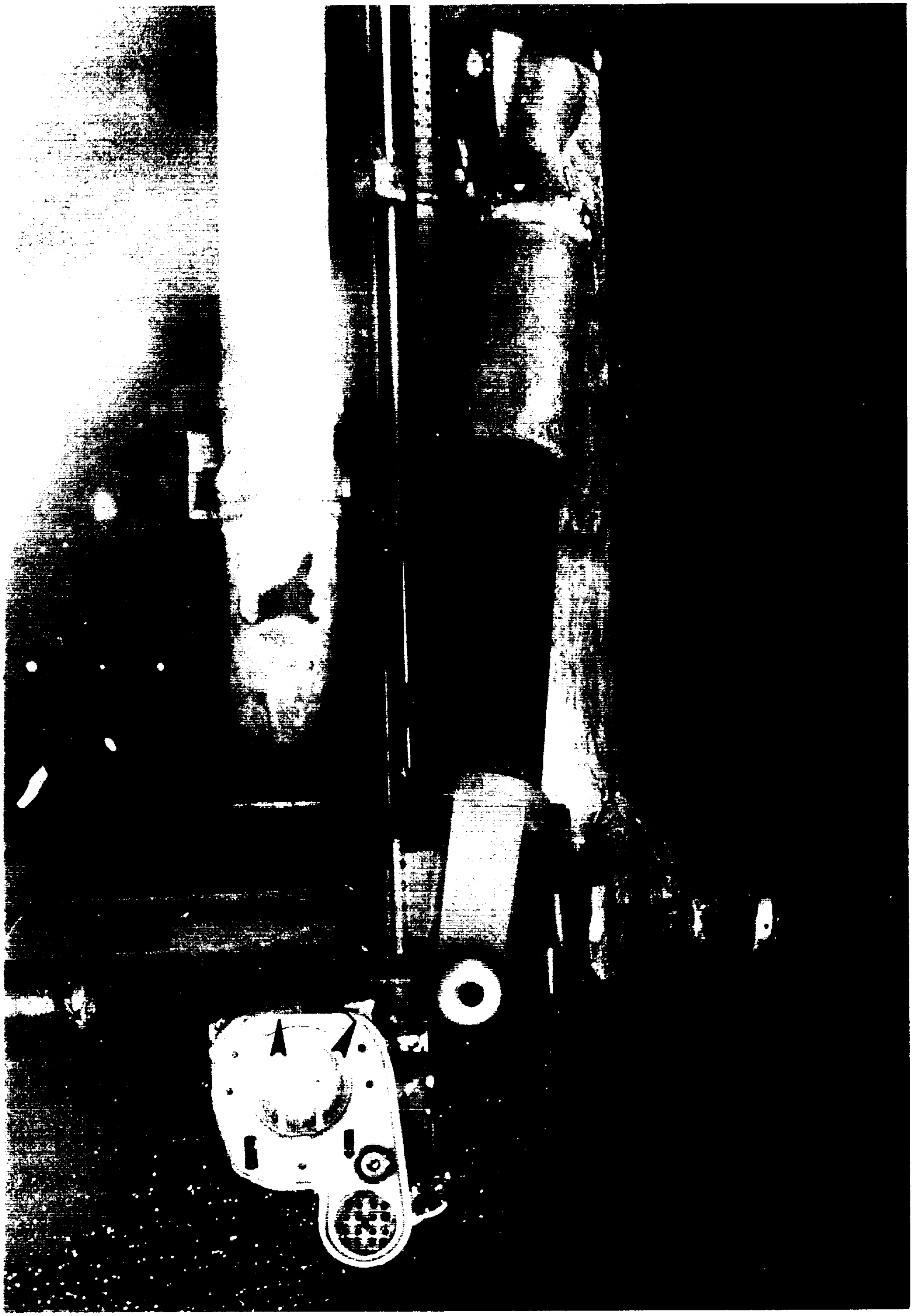
Historically, jack pad closeouts have lost material during ascent on numerous flights. Corrective actions already implemented include expanding the cleaning and priming requirements, beveling the forward edge of the cavity to reduce entrapped air/voids, performing a two step closeout (filling the insert holes with PDL), and specialized training techniques to minimize process anomalies. An investigation team confirmed there were no processing anomalies and that all acceptance requirements were met. The team is currently reviewing material processing development, the certification history, and all requirements.

Three divots, 3-5 inches in diameter, occurred in intertank acreage TPS forward of the bipods.

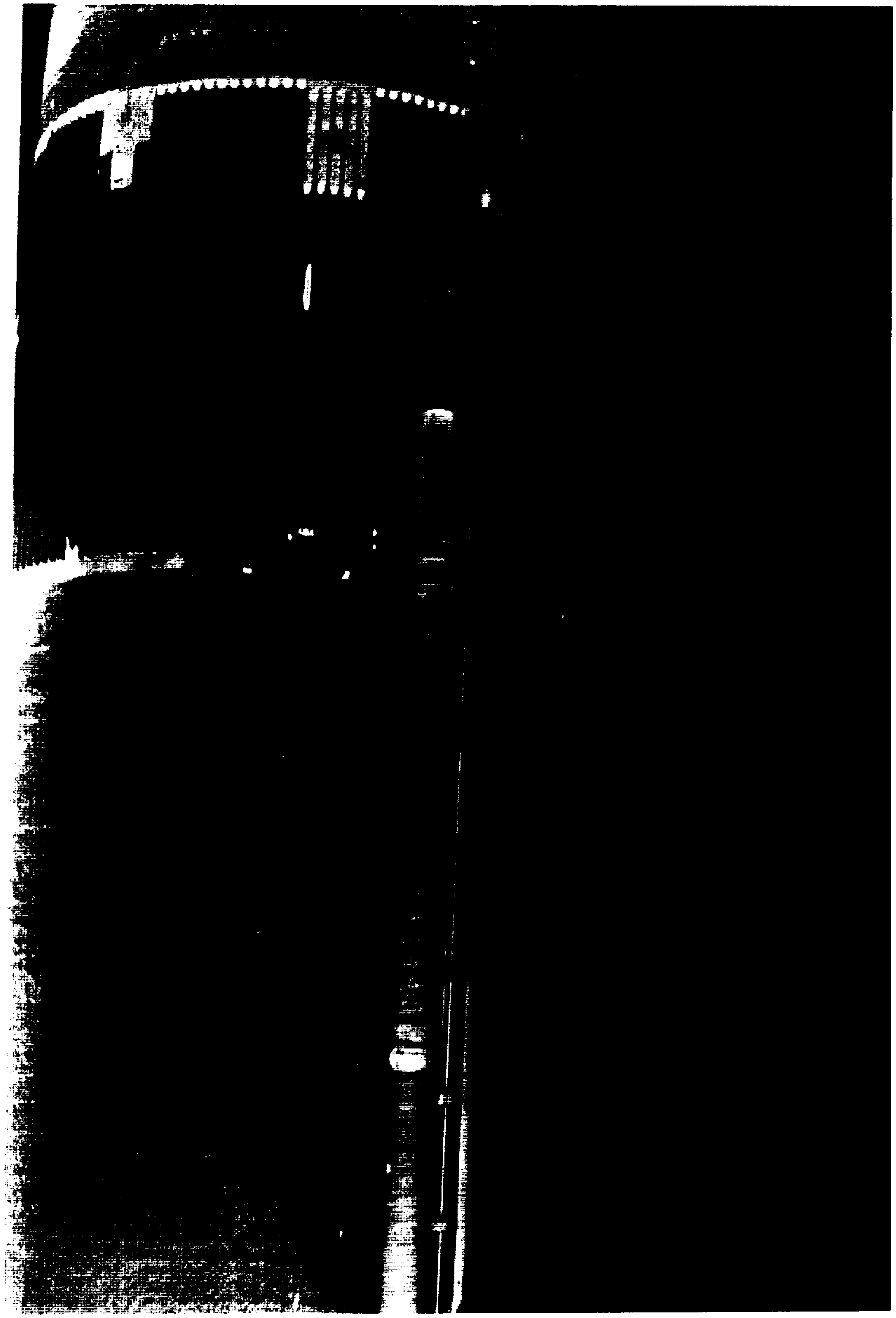
SRB separation from the ET was nominal. Ablation/charring of -Y ET/SRb vertical strut was typical. Note erosion of foam from the LH2 umbilical cable tray and blistering of fire barrier coating on outboard side of the umbilical.

A 10-inch by 5-inch piece of foam was missing from the outboard surface of the -Y ET/SRB cable tray. The LH2 ET/ORB umbilical appeared to be in good condition with the exception of foam peeled back on the forward surface near the forward inboard pyro can closeout. The red purge seal was intact.

Frozen hydrogen adhered to a portion of the LH2 17-inch flapper valve. A large chunk of frozen hydrogen from the remaining flapper valve surface area drifted by the camera.



Foam on the forward surface of the LO2 ET/ORB umbilical was peeled back (2 places). The lightning contact strip across the forward section of the umbilical had detached completely and is visible in this view just above the crossbeam.



Foam, 28" x 3", was missing from a stringer head aft of the +X aero vent (XT-990). At least 18 inches of primed substrate was exposed. Portions of both bipod jack pad closeouts were missing revealing primed substrate.

7.3 LANDING FILM AND VIDEO SUMMARY

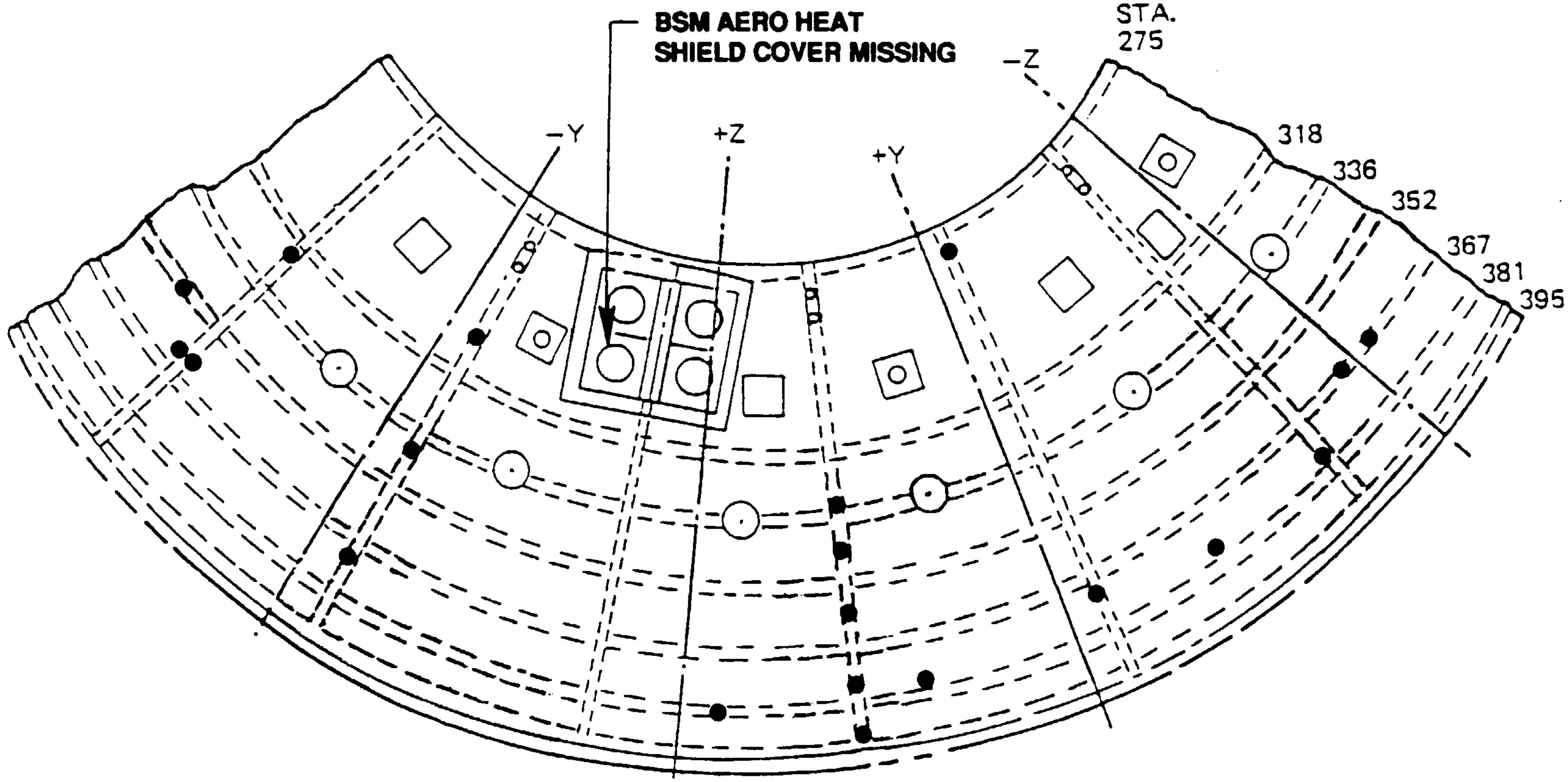
A total of twelve 16mm landing films were reviewed.

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

The drag chute was deployed after breakover, but before the nose gear contacted the runway. Drag chute deployment appeared nominal. The drag chute door and sabot cover appeared to get caught in an aerodynamic vortex and made a harder-than-usual impact with the runway.

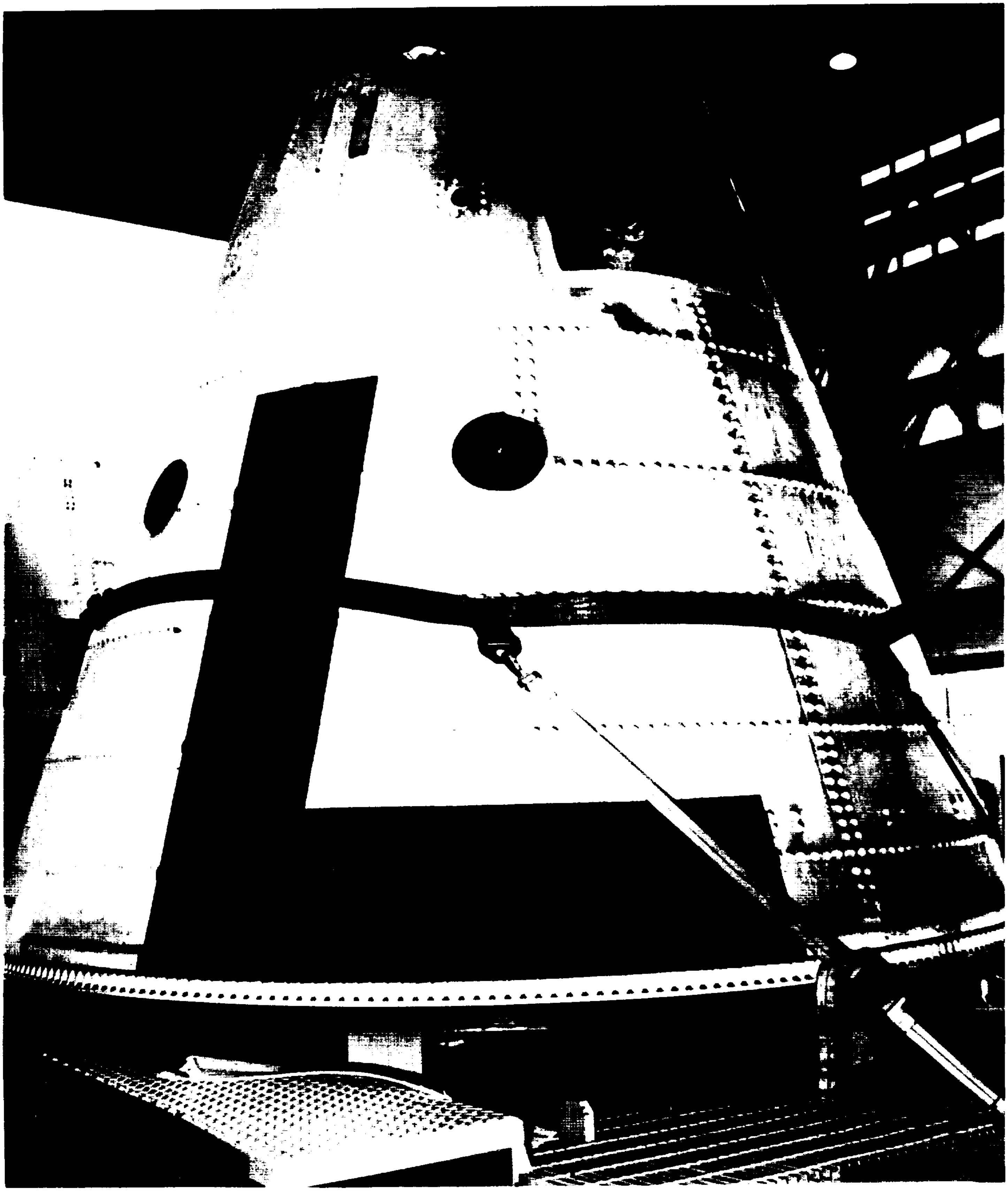
Touchdown of the nose landing gear was smooth.

FIGURE 10. **RIGHT SRB FRUSTUM**

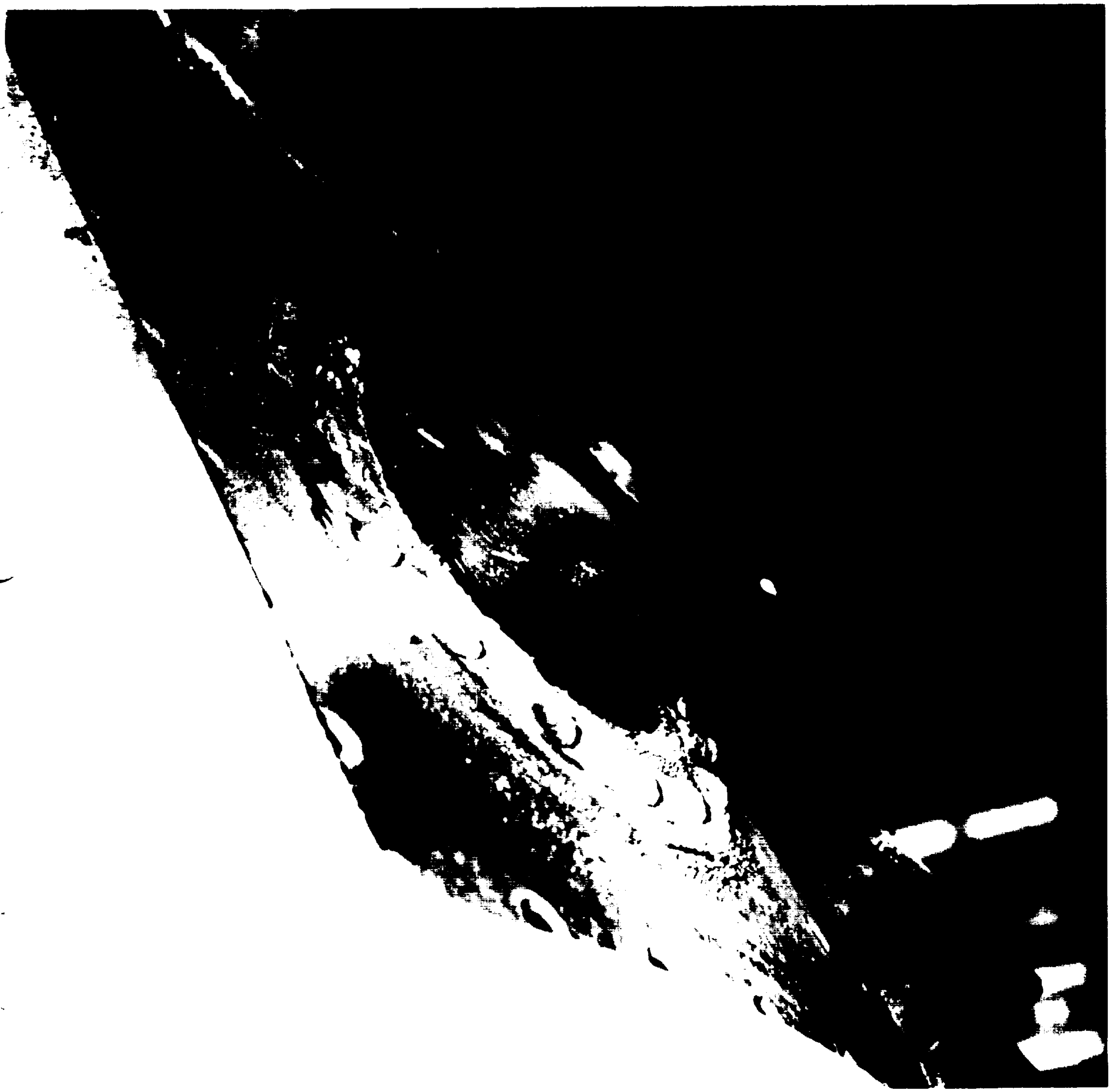


MISSING TPS
NONE

DEBONDS
20 ●

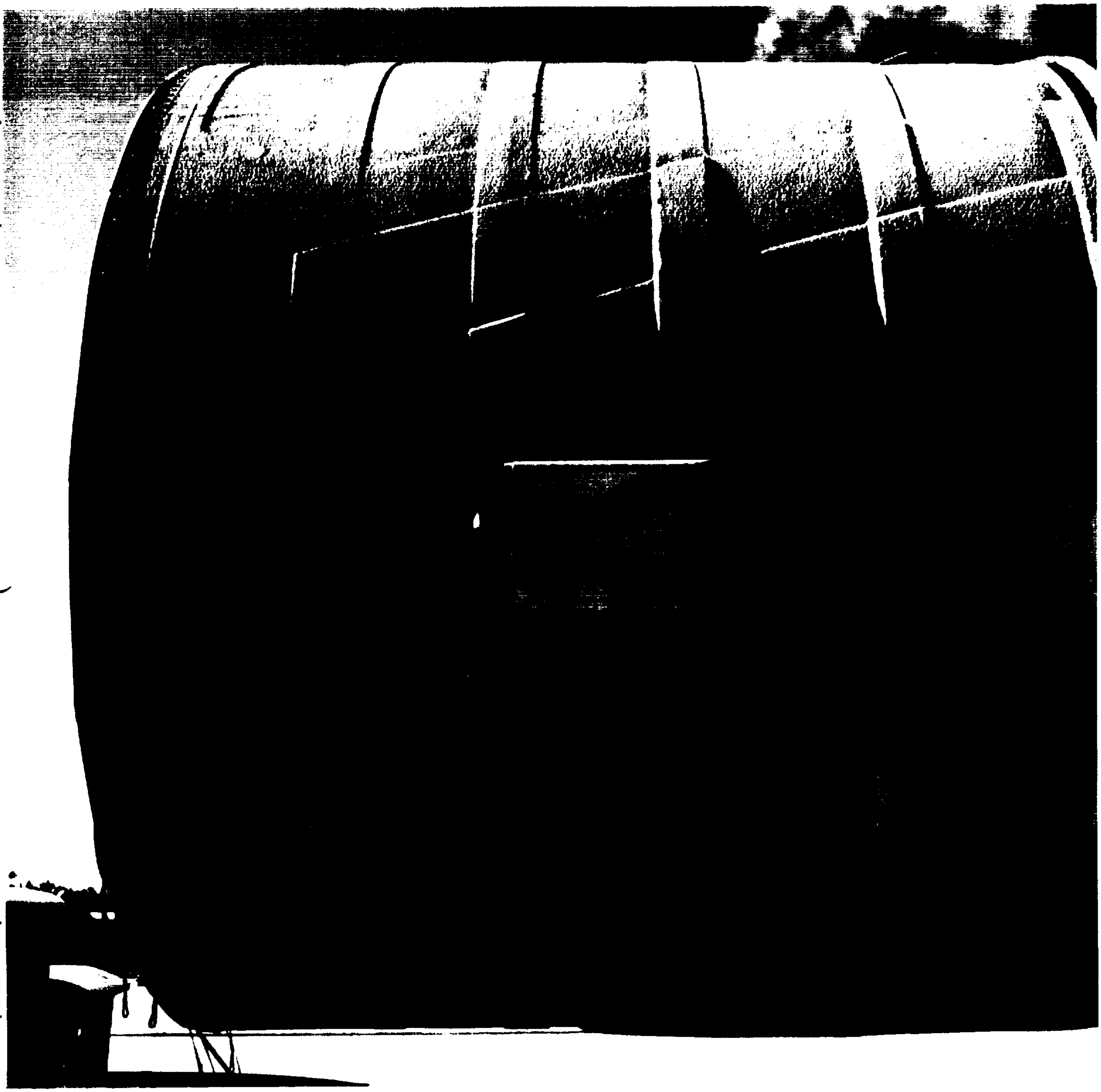


The RH frustum was missing no TPS, but had 20 MSA-2 debonds over fasteners. Minor blistering of the Hypalon paint occurred in localized areas.



Three BSM aero heatshield covers were locked in the fully opened position. The lower left cover was missing. Note bent/fractured cover attach ring at nozzle exit plane.

Post flight assessment determined the cover was lost during re-entry/water impact. BSM covers have been lost on eight previous flights.



The RH forward skirt exhibited no debonds or missing TPS

Post flight condition of the RH aft booster and aft skirt. The ET/SRB aft struts, ETA ring, IEA, and IEA covers appeared undamaged though foam was missing from the aft side of the ETA ring. Charring of adjacent material indicated the foam was lost in flight rather than at water impact.

The HDP #3 DCS plunger was obstructed by a frangible nut web, firing cable, and NSI cartridge. Post flight disassembly of the DCS container revealed a 78% retention of ordnance fragments.

8.2 LH SOLID ROCKET BOOSTER DEBRIS INSPECTION

The LH frustum was missing no TPS, but had 34 MSA-2 debonds over fasteners (Figure 12). Minor blistering of the Hypalon paint had occurred in localized areas. 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.

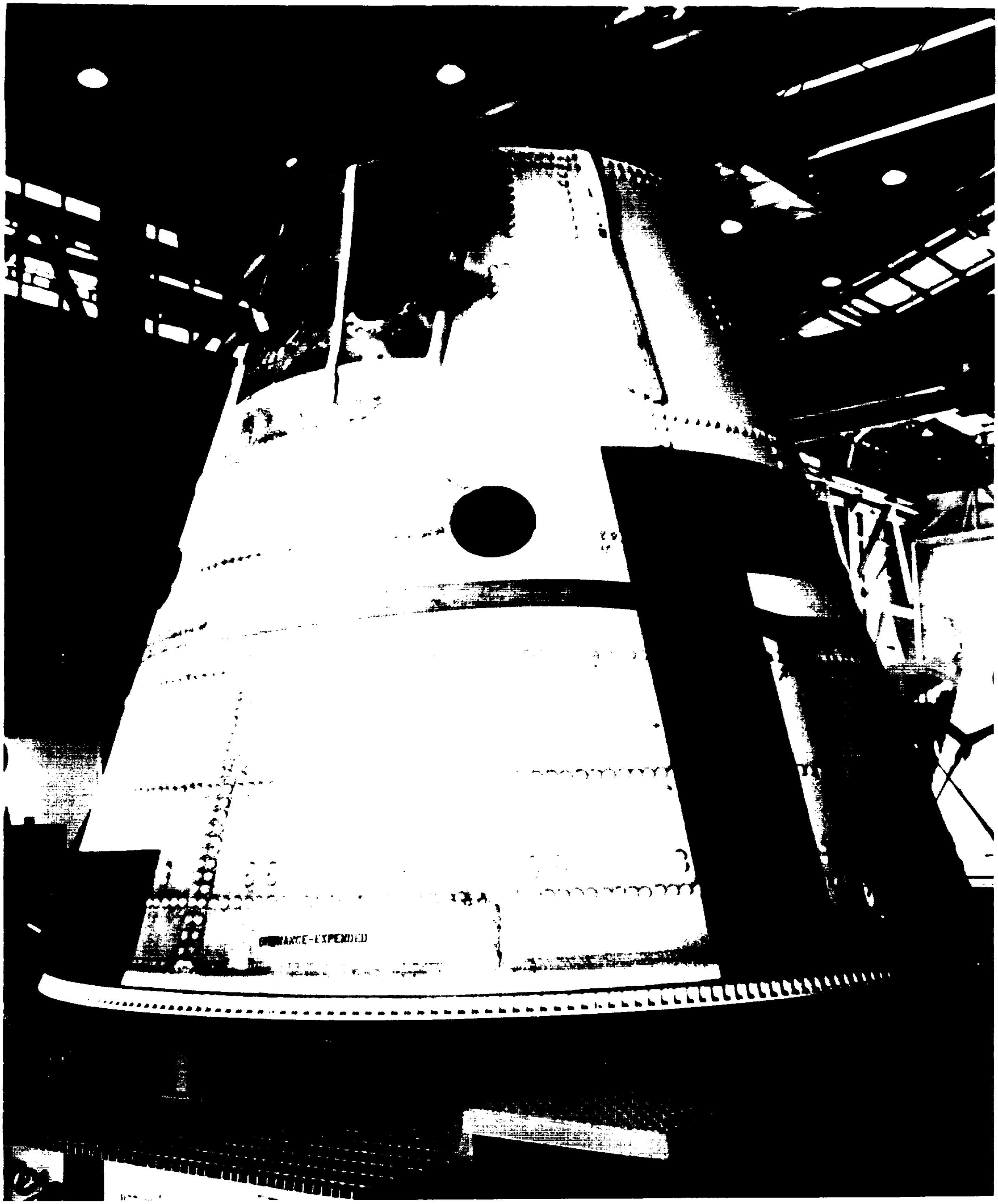
The Field Joint Protection System (FJPS) closeouts were in good condition.

Separation of the aft ET/SRB struts appeared normal. The ET/SRB aft struts, ETA ring, IEA, and IEA covers appeared undamaged.

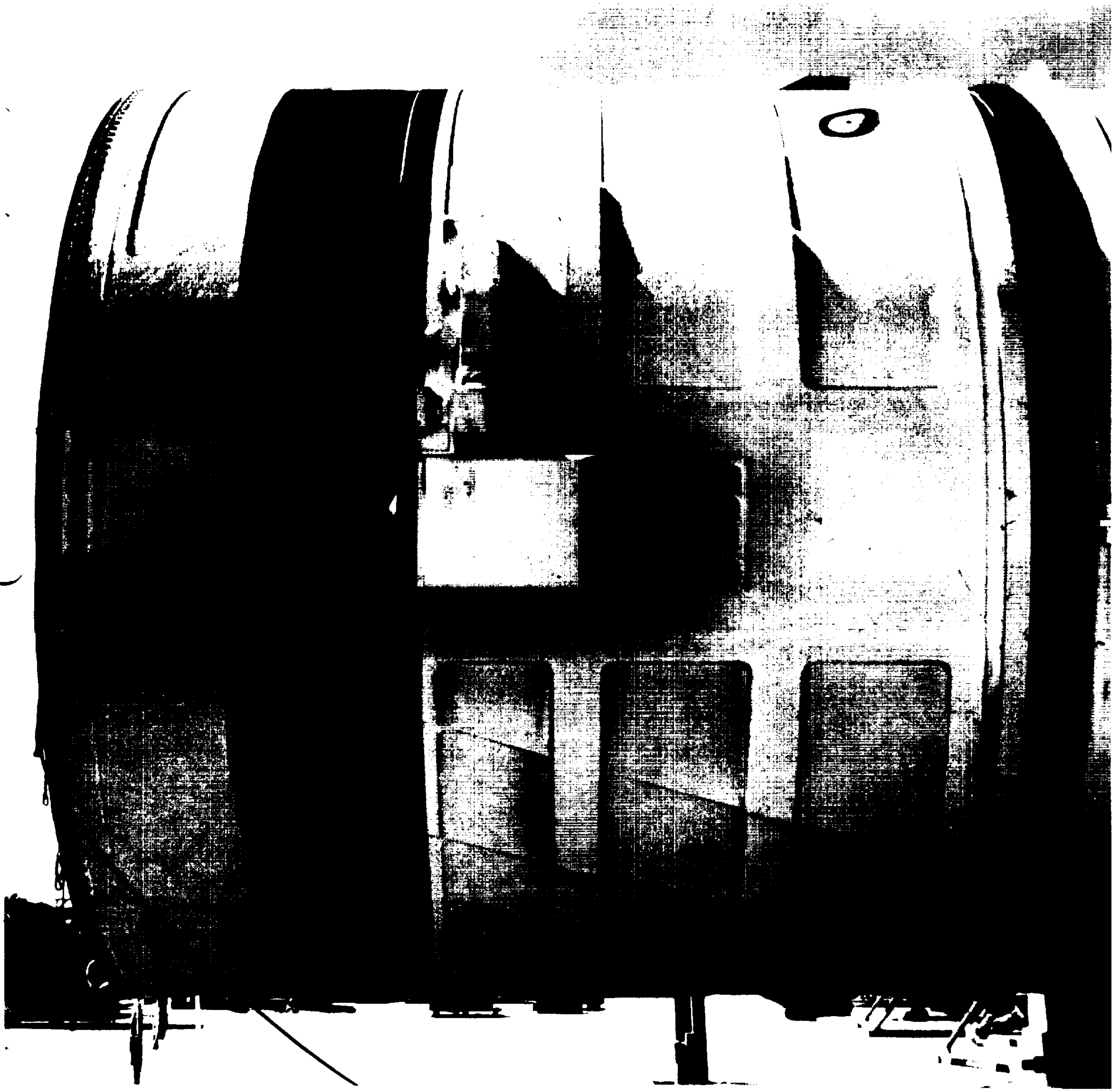
The phenolic material on the kick ring was delaminated. The aft skirt acreage MSA-2 TPS was generally in good condition. No significant amount of BTA was used on this aft skirt.

All four Debris Containment System (DCS) plungers were seated and appeared to have functioned properly. A post retrieval disassembly of the HDP #5 and #6 DCS containers revealed a retention of 99% and 94%, respectively. No EPON shim material was lost during flight.

SRB Post Launch Anomalies are listed in Section 11.



The LH frustum was missing no TPS, but had a total of 34 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. Acreage MSA-2 was generally in good condition. No significant amount of BTA was used on this aft skirt.

9.0 ORBITER POST LANDING DEBRIS ASSESSMENT

A post landing debris inspection of OV-102 (Columbia) was conducted 1-2 November 1993 at the Ames-Dryden Flight Research Center/Edwards Air Force Base on runway 22 and in the Mate/Demate Device. This inspection was performed to identify debris impact damage and, if possible, debris sources. The Orbiter TPS sustained a total of 155 hits, of which 26 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 42 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 both the total number of hits and the number of hits one inch or larger was greater than average (reference Figures 13-16).

The Orbiter lower surface sustained a total of 78 hits, of which 23 had a major dimension of one inch or greater. The appearance of 15 shallow tile damage sites greater than one inch in size from the nose landing gear door to the ET/ORB umbilicals along the Orbiter centerline indicates impacts from low density objects, such as foam from the ET intertank.

The following table breaks down the STS-58 Orbiter debris damage by area:

	HITS > 1"	TOTAL HITS
Lower surface	23	78
Upper surface	2	43
Right side	1	19
Left side	0	3
Right OMS Pod	0	3
Left OMS Pod	0	9
TOTALS	26	155

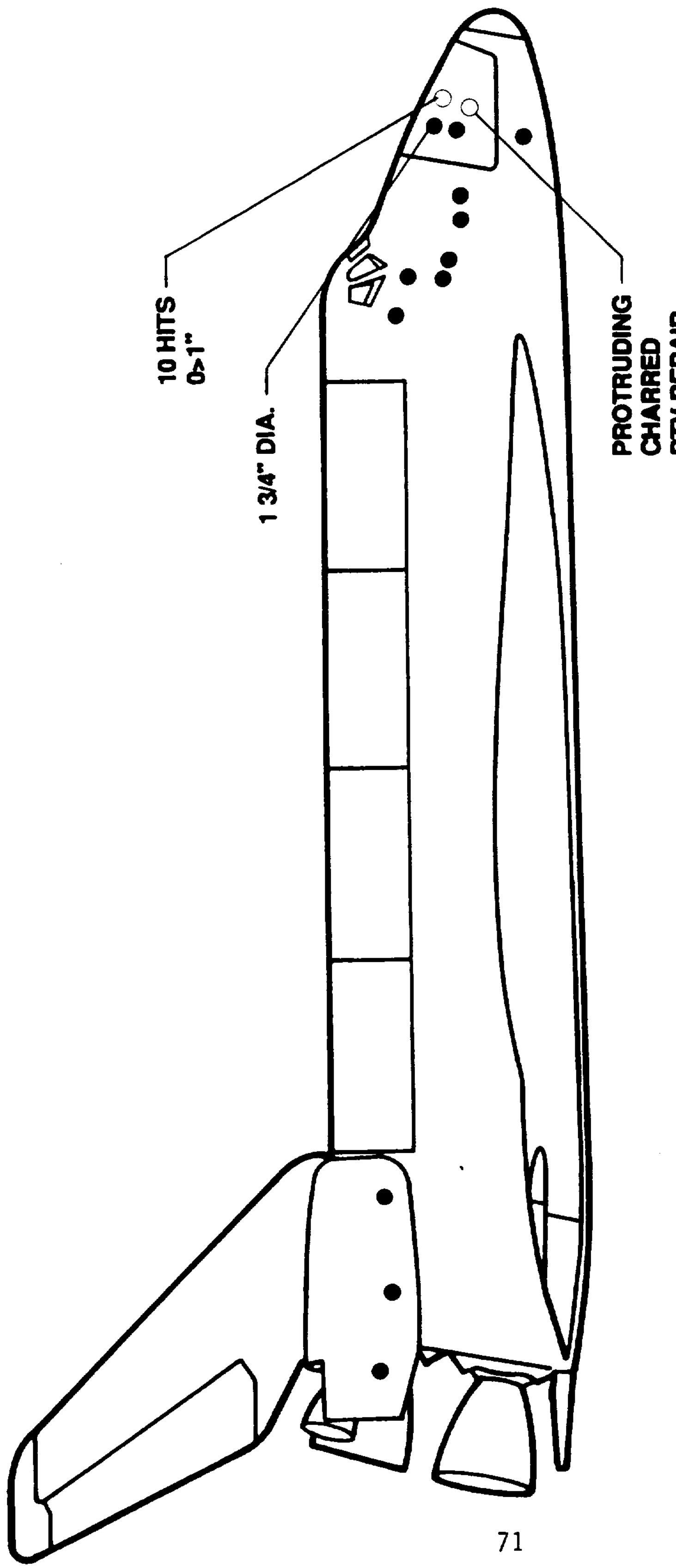
Numerous hits in the vicinity of the LH2 ET/ORB umbilical may be indicative of impacts from higher density materials, such as ice.

No TPS damage was attributed to material from the wheels, tires, or brakes. The main landing gear tires showed typical wear from landing on a concrete runway. The LH MLG outboard tire exhibited an undercut on the inner tread.

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 flight hardware was found on the runway below the ET/ORB umbilical cavities when the ET doors were opened.

STS-58

FIGURE 14. **DEBRIS DAMAGE LOCATIONS**



TOTAL HITS = 22

HITS > 1 INCH = 1

EGG/VC-088A

STS-58

FIGURE 16. **DEBRIS DAMAGE LOCATIONS**

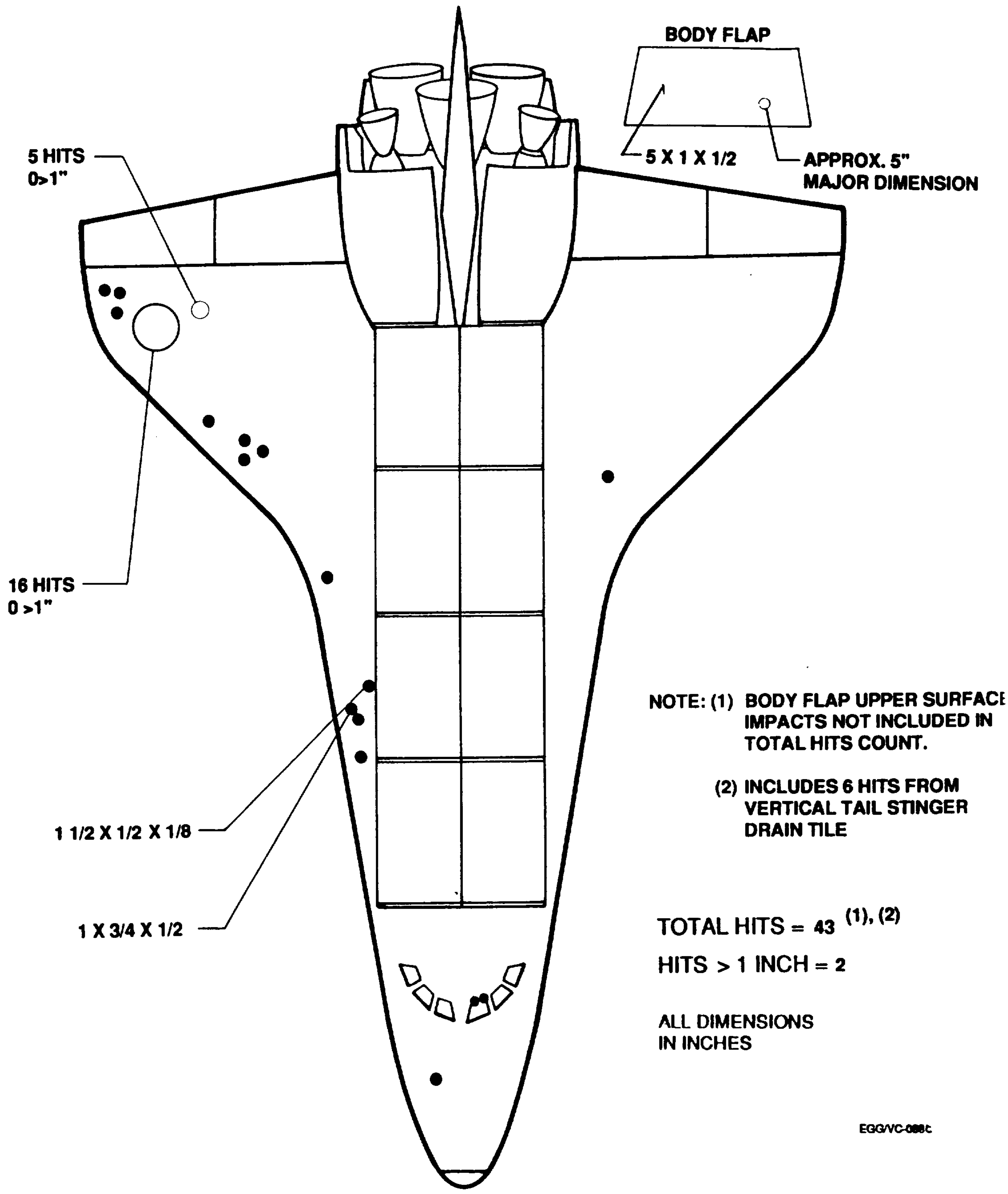


FIGURE 17. **STS-58 RCC TEMPERATURE MEASUREMENTS AS RECORDED BY THE SHUTTLE THERMAL IMAGER**

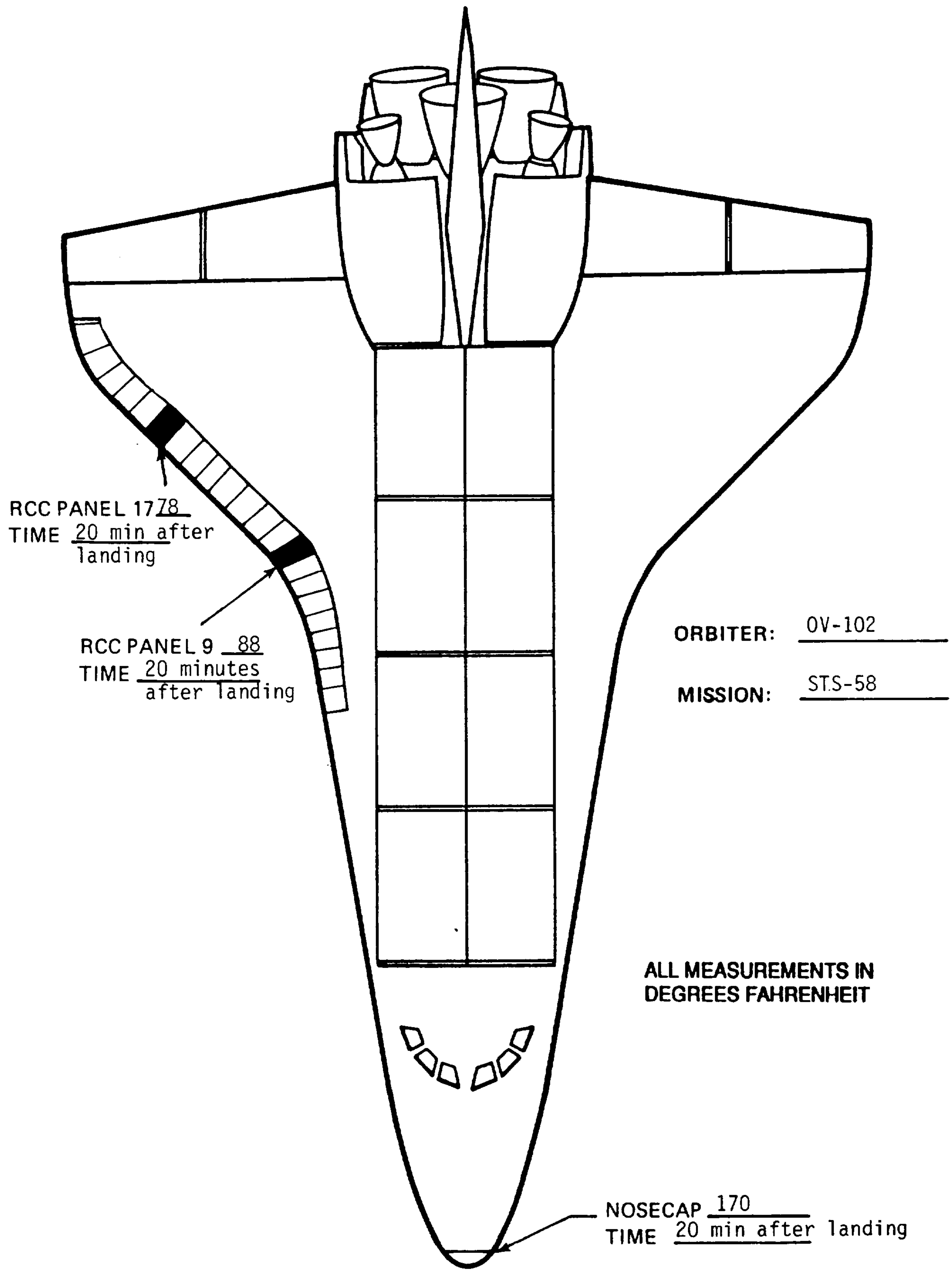
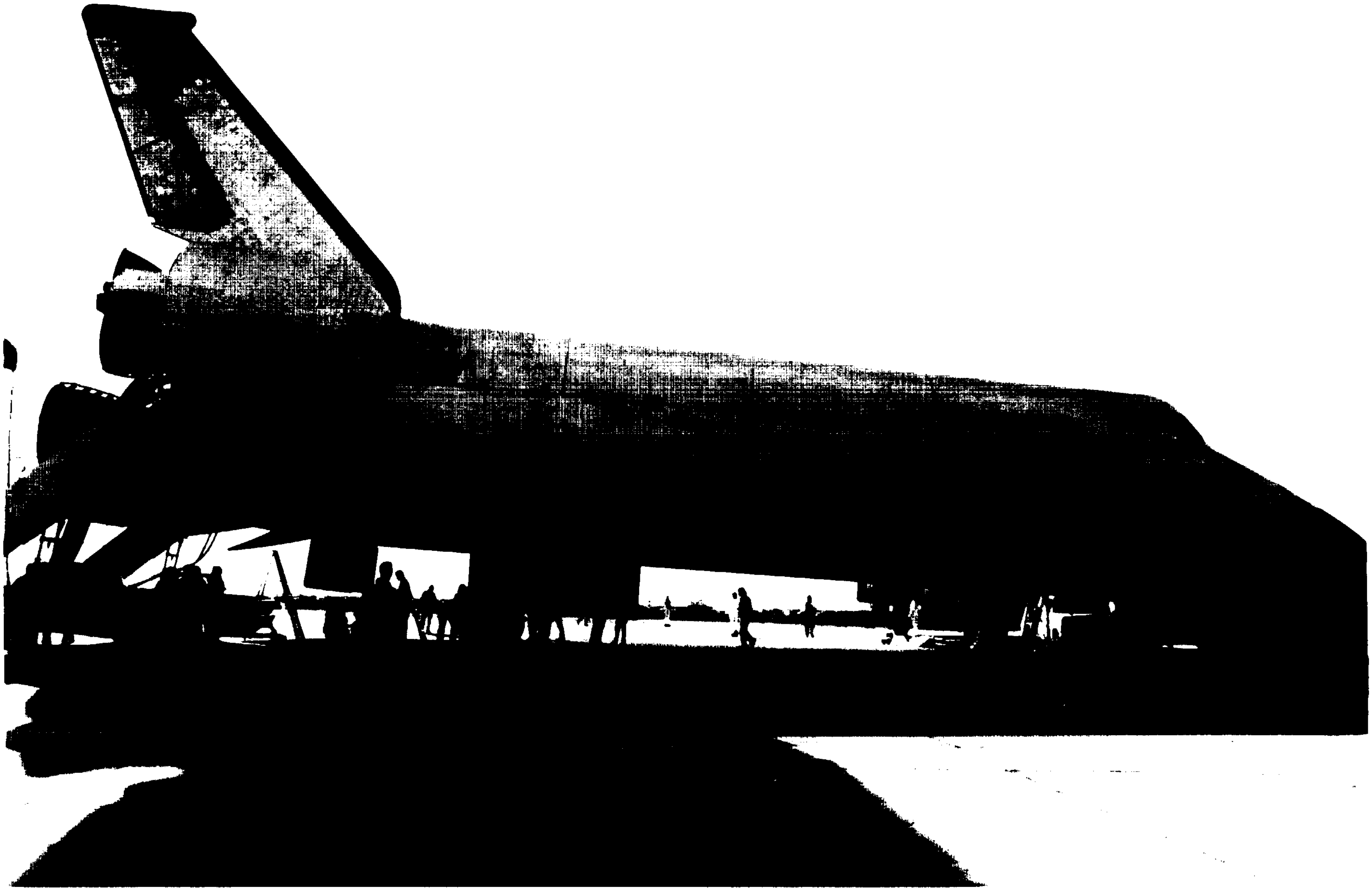


FIGURE 18. ORBITER DEBRIS DAMAGE ASSESSMENT SUMMARY

	LOWER SURFACE		ENTIRE VEHICLE	
	HITS > 1"	TOTAL HITS	HITS > 1"	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-23 (51-D)	43*	111*	46*	152*
STS-24 (51-B)	45*	110*	63*	140*
STS-25 (51-G)	109*	231*	144*	315*
STS-26 (51-F)	179*	482*	226*	553*
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-26R	47*	342*	55*	411*
STS-27R	272*	644*	298*	707*
STS-29	18	100	23	132
STS-30R	52*	134*	56*	151*
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-42	38*	159*	44*	209*
STS-45	18	122	22	172
STS-49	6	55	11	114
STS-50	28	141	45	184
STS-46	11	186	22	236
STS-47	3	48	11	108
STS-52	6	152	16	290
STS-53	11	145	23	240
STS-54	14	80	14	131
STS-56	18	94	36	156
STS-55	10	128	13	143
STS-57	10	75	12	106
STS-51	8	100	18	154
AVERAGE	14.3	93.8	21.8	133.2
STS-58	23	78	26	155

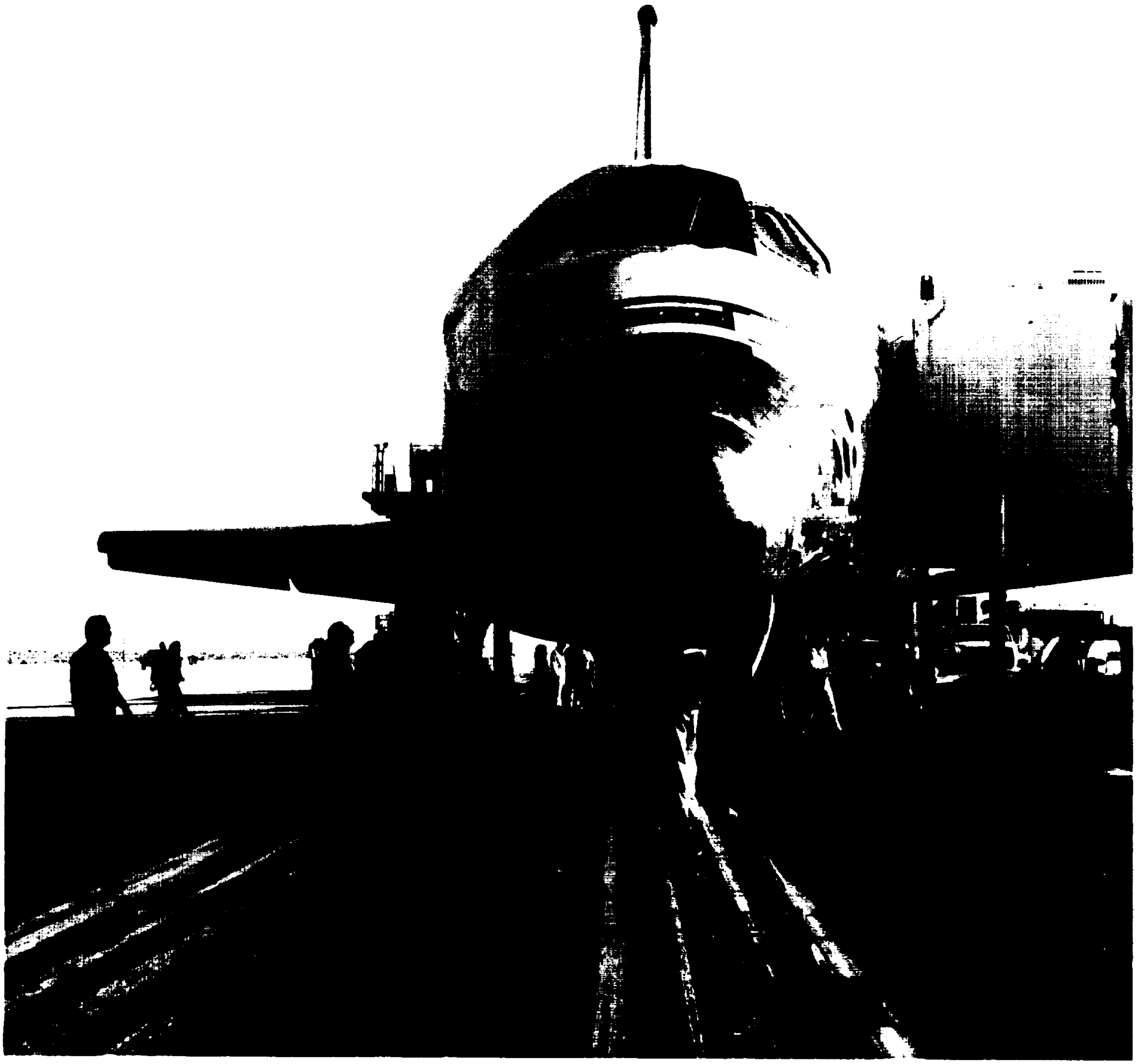
MISSIONS MARKED WITH (*) ARE NOT INCLUDED IN THE STATISTICAL ANALYSIS SINCE THESE HIT TOTALS WERE BIASED BY DAMAGE FROM KNOWN DEBRIS SOURCES.

Overall view of Orbiter left side

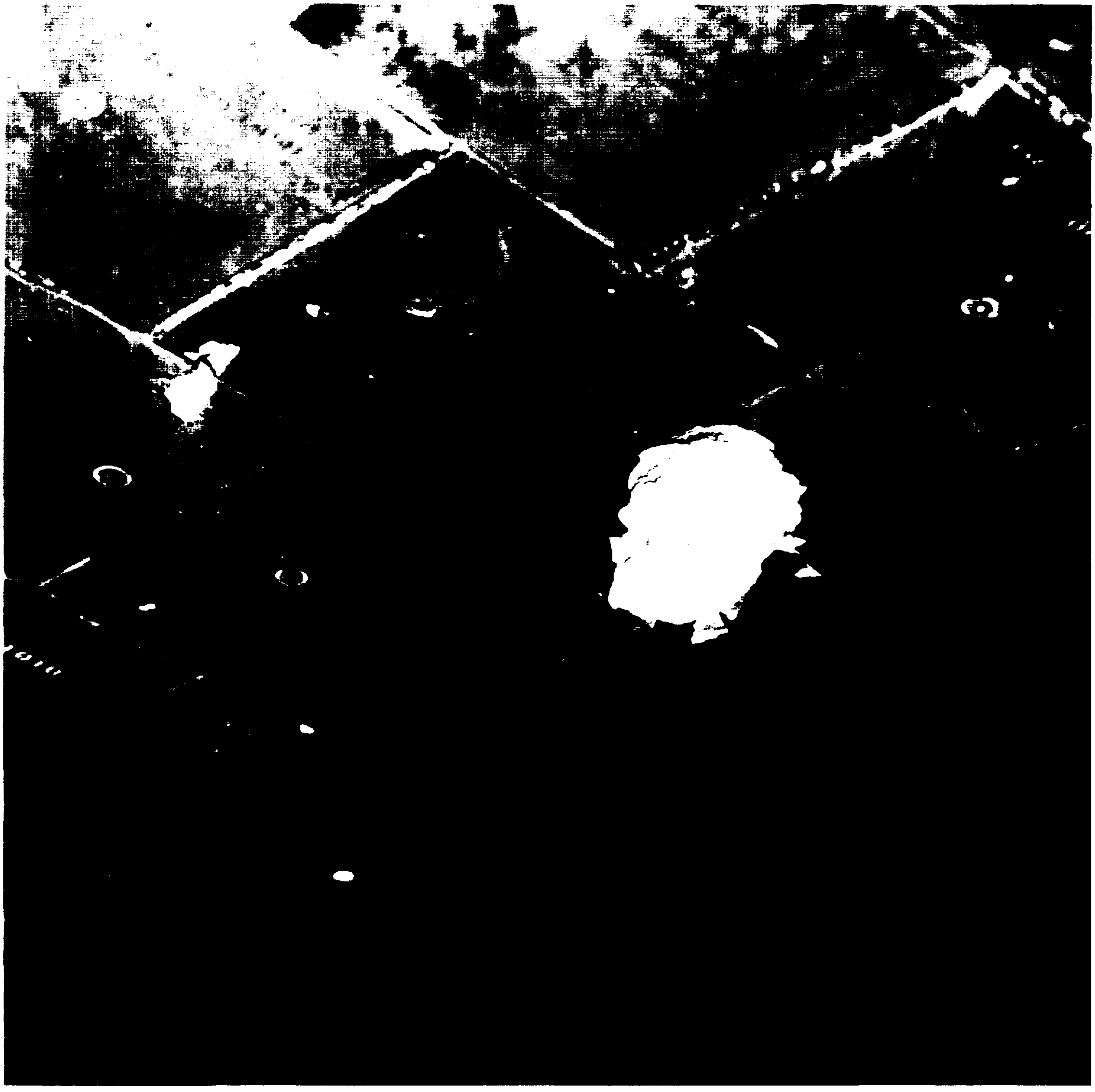


Overall view of Orbiter right side. Note: white spot on right main landing gear door is a film defect and not tile damage.

Overall view of base heat shield and SSME's. Tile damage on the base heat shield was less than usual. Note damage to SSME #2 and #3 Dome Mounted Heat Shield closeout blankets.



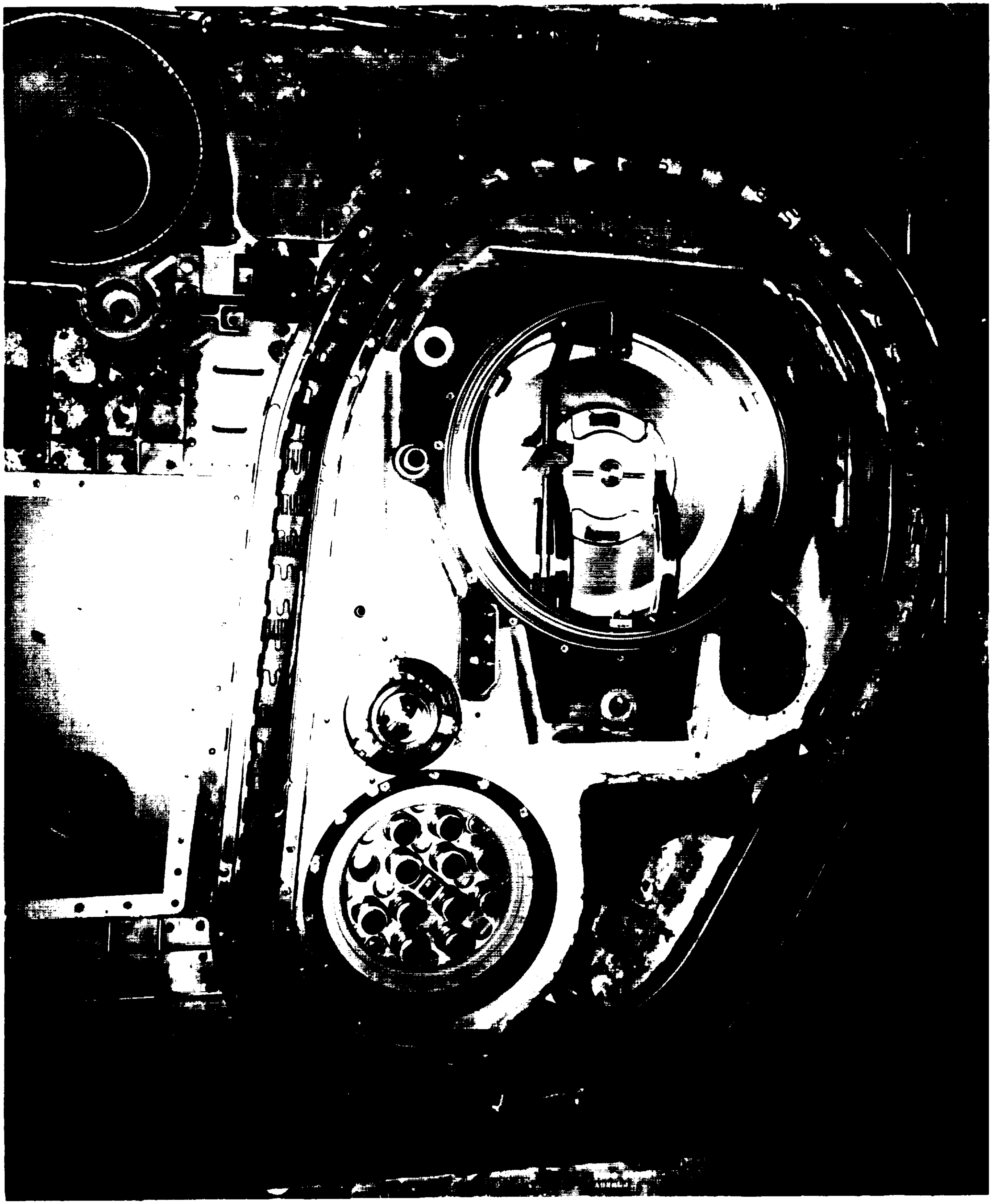
Overall view of Orbiter nose. Hazing on Orbiter forward facing windows was typical. Window #3 was hazed the most. Damage to window perimeter tiles was less than usual.



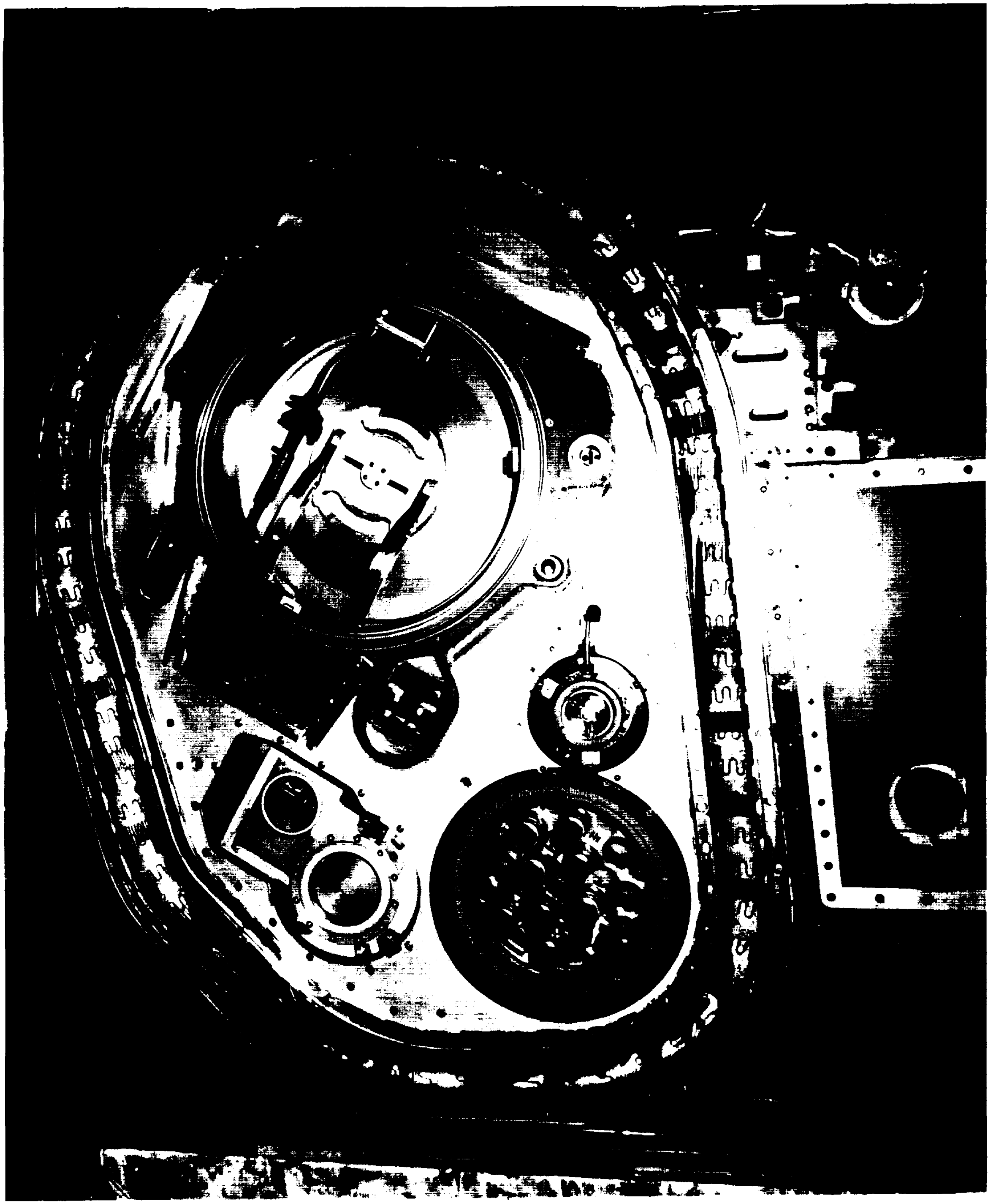
The Orbiter lower surface tiles sustained a total of 78 hits, of which 23 had a major dimension of 1-inch or larger

Damage to ET door edge tile

Close-in view of lower surface tile damage site shows effects of re-entry heating (glazing, slumping, discoloration)



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 significant amounts of ET foam or red purge seal adhered to the LH2 ET/ORB umbilical plate near the LH2 4-inch line flapper valve.

Dome Mounted Heat Shield closeout blanket covering was missing from the SSME #3 9:00 o'clock position and was most likely the white object observed in the post launch film review falling aft of the vehicle at 45 seconds MET.

10.0 DEBRIS SAMPLE LAB REPORTS

A total of eight samples were obtained from OV-102 Columbia during the STS-58 post landing debris assessment at Dryden Flight Research Facility, California. The submitted samples consisted of 8 wipes from Orbiter windows 1-8. The samples were analyzed by the NASA KSC Microchemical Analysis Branch (MAB) for material composition and comparison to known STS materials. Debris analysis involves both the placing and the correlating of particles and residues with respect to composition, thermal (mission) effects, and availability. Debris sample results/ analyses are listed by Orbiter location in the following summaries.

ORBITER WINDOWS

Samples from the Orbiter windows indicated exposure to SRB BSM exhaust (metallic particulate), landing site materials (earth minerals), Orbiter Thermal Protection System (tile, RTV and glass insulation), paints and primer from various sources. An interesting finding was the repeated occurrence of glass fiber from structural insulation (ref STS-50 vertical stabilizer sample). A blue paint/zinc alloy particulate combination was also noted and is discussed as a new finding. There was no apparent vehicle damage related to these residuals.

STS-58 ORGANIC ANALYSIS

The results of the STS-58 organic analysis are included in this report (ref Figure 20). Identified materials included those associated with window covers (plastic polymers), RTV from RCS thruster nozzle cover adhesive and paint from various sources. The analysis of the blue particulate revealed an alkyd base paint of unknown origin.

STS-51 ORGANIC ANALYSIS

The final results of the STS-51 organic analysis are also shown in this report (ref Figure 20). Identified materials included those associated with window covers (plastic polymers), RTV from RCS protective cover adhesive, and paint from various sources. 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 Orbiter window samples. Blue paint of an alkyd base with zinc alloy on one side of the particulate was discovered. Although the precise source has not yet been determined, the blue paint does not appear to be related to any debris damage.

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

FIGURE 20. Orbiter Post Landing Microchemical Sample Results

STS	Sample Location				
	Windows	Wing RCC	Lower Tile Surface	Umbilical	Other
39		Metallics - BSM Residue (SRB) RTV, Tile (ORB) Insulation Glass (ORB TPS) Ensolite Foam (RCC Prot. Covers) Organics Paint Hypalon Paint (SRB)	Tile (ORB TPS) Insulation Glass (ORB TPS)		
37	Metallics - BSM Residue (SRB) RTV, Tile (ORB TPS) Insulation Glass (ORB TPS) Calcite, Salt (Landing Site) Organics	Metallics - BSM Residue (SRB) RTV, Tile (ORB) Insulation Glass (ORB TPS) Calcite, Salt (Landing Site) Organics Paint	RTV, Tile ((ORB TPS) Insulation Glass (ORB TPS) Metallics - BSM Residue (SRB) Calcite, Salt (Landing Site) Organics		
35	Metallics - BSM Residue (SRB) RTV, Tile (ORB TPS) Insulation Glass (ORB TPS) Calcite, Salt (Landing Site) Window Polish Residue (ORB) Organics Paint	Metallics - BSM Residue (SRB) RTV, Tile (ORB) Organics	RTV, Tile (ORB TPS) Metallic - Rust, Aluminum Welding Slag (Facility)		
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	

FIGURE 20. Orbiter Post Landing Microchemical Sample Results

11.0 POST LAUNCH ANOMALIES

Based on the debris walkdowns and film/video review, 11 post launch anomalies, including four In-Flight Anomalies, were observed on the STS-58 mission.

11.1 LAUNCH PAD/SHUTTLE LANDING FACILITY

1. Two debris particles fell out of a cavity in the HDP #3 doghouse blast cover during liftoff.

2. The GH2 vent line did not immediately latch, but drifted back toward the vehicle approximately 12 inches before finally latching within the envelope of the intertank access structure. There was no excessive slack in the static retract lanyard. Post launch inspection found the GH2 vent line latched on the second tooth of the latching mechanism.

11.2 EXTERNAL TANK

1. Ice on the GUCP legs caused two pieces of intertank CPR foam to pull loose from adjacent stringer heads and expose primer/substrate. The two pieces of intertank foam (10"x2" on the +Z side; 3"x2" on the -Z side) adhered to the ice on the GUCP legs during disconnect and retraction. The large piece of foam eventually fell between the LH SRB and the External Tank.

2. Foam, 28 inches long by 3 inches wide, was missing from a stringer head forward of the bipods and aft of the +Z aero vent (XT-990). At least 18 inches of primer was exposed. The loss of this foam may have contributed to the centerline tile damage on the Orbiter lower surface (IFA STS-58-T-1).

3. Both bipod jack pad closeouts were missing. Primer was visible in 25 percent of the +Y jack pad cavity and 50 percent of the -Y jack pad cavity. The loss of this foam may have contributed to the centerline tile damage on the Orbiter lower surface (IFA STS-58-T-1).

4. The lightning contact strip across the forward section of the LO2 ET/ORB umbilical had detached completely and was later observed tumbling near the ET cross beam. It drifted aft slowly until lost from the field of view (IFA STS-58-V-0010).

Appendix A. JSC Photographic Analysis Summary

Lockheed
Engineering & Sciences Company

ENGINEERING AND SCIENCE PROGRAM
2400 NASA Road 1, P. O. Box 58561, Houston, Texas 77258-8561 (713) 333-5411

December 1, 1993

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

Dear Greg,

The following STS-58 Summary of Significant Events report is from the Johnson Space Center NSTS Photographic and Television Analysis Project, and was completed December 1, 1993. If you have any questions or comments please contact Christine Dailey /483-5336 of the NSTS Photographic and Television Analysis Project.

Sincerely,

Christine Dailey 12/1/93
Christine Dailey, Staff Scientist
Photo/TV Analysis Project

cc: Job order file

Table of Contents

1.0 Mission Summary

STS-58 was the longest duration shuttle mission since the inception of the program. The orbit inclination angle for this mission was 28.45 degrees and the initial orbit altitude was 153 nautical miles. The primary cargo in the payload bay was the Spacelab Life Sciences-2 (SLS-2) module. The primary middeck payload was the Shuttle Amateur Radio Experiment-II (SAREX-II). The crew on this mission consisted of: commander John Blaha, pilot Richard Searfoss, payload commander Rhea Seddon, payload specialist Martin Fettman and mission specialists Shannon Lucid, David Wolf and William McArthur.

1.1 Launch

The launch of Columbia (OV-102) for STS-58 occurred from Pad B at 14:53:10.019 UTC on October 18, 1993 (day 291) as seen on camera E-9. Solid rocket booster (SRB) separation occurred at 14:55:13.735 UTC as seen on camera E-204.

Two events seen on films were declared inflight anomalies (IFS's). The debris seen at 45 seconds MET is believed to have come from the dome mounted heat shield damage found after landing (IFA STS58-V-09). A missing lightning contact strip on the ET LO2 umbilical seen on the umbilical well film was declared an inflight anomaly (STS58-V-10).

Detailed Test Objective-312, photography of the external tank after separation, was performed this mission using Orbiter umbilical well cameras and a handheld Nikon camera. Thirty-eight frames of the external tank were acquired by the astronauts.

The lower left booster separation motor (BSM) aero heat shield cover was missing on the RSRB at the time of recovery. Post-recovery analysis of the booster rockets at Kennedy Space Center indicated that the cover was probably lost at the time of water impact.

1.2 On Orbit

No significant events were tracked on orbit.

1.3 Landing

STS-58 concluded with the landing on runway 22 at Edwards Air Force Base on Monday, November 1, 1993 (day 305). All of the landing sequence times were obtained from DTV-1. The right main gear touched down at 15:05:41.909 UTC and the left main gear touched down at 15:05:41.942 UTC. Nose wheel touchdown occurred at 15:05:53.087 UTC and wheel stop was at approximately 15:06:43.504 UTC.

No major anomalies were noted in any of the approach, landing and rollout video views.

During the post-landing walkdown, the following items were noted: damage was observed to the SSME #3 dome mounted heat shield (DMHS) at the nine o'clock position; the SSME #2 DMHS was lifted away from the surface at the three o'clock position; a large portion of one tile appeared to be missing from the upper surface of the body flap (in addition to several other small nicks); a divot was seen just beneath the forward starboard reaction control system ports; a white, putty-like substance (probably seal material) was noted on the LH2 umbilical outer rim; and thermal protection system damage was visible on both the left and right nose gear doors.

2.1.2 Debris near the Time of SRB Ignition

2.1.2.1 Dark Debris from RSRB HDP M-2 DCS
(Camera E-8)

Two small pieces of dark debris fell from the right SRB HDP M-2 DCS stud hole at liftoff. The objects did not appear to strike the vehicle. No follow-up action was requested.

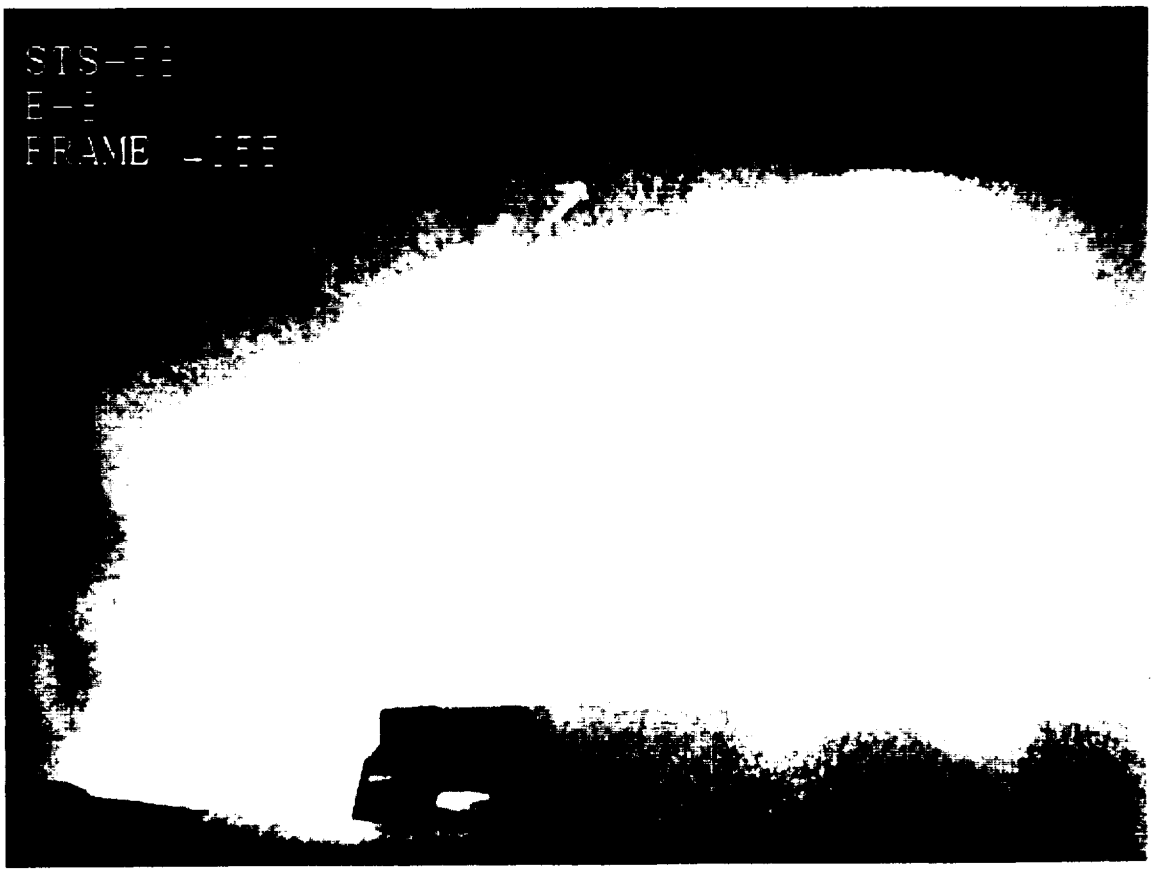


Figure 2.1.2.1 Debris falls from RSRB HDP M-2 DCS

A small piece of dark debris can be seen falling along the front of the RSRB aft skirt just after liftoff. This debris was one of two pieces seen exiting the DCS stud hole. Neither of the pieces appeared to strike the vehicle.

2.1.2.2 Debris from GH2 Vent Arm Carrier Plate
(Cameras E-31, E-33 and E-50)

Two small patches of intertank spray on foam insulation (SOFI) were stripped away from both sides of the ET intertank GH2 umbilical during the ground umbilical carrier plate (GUCP) retraction seen on Camera E-31. The bare metal substructure did not appear to be exposed. One of these pieces of debris was also seen on Camera E-50. The debris did not appear to strike the vehicle.

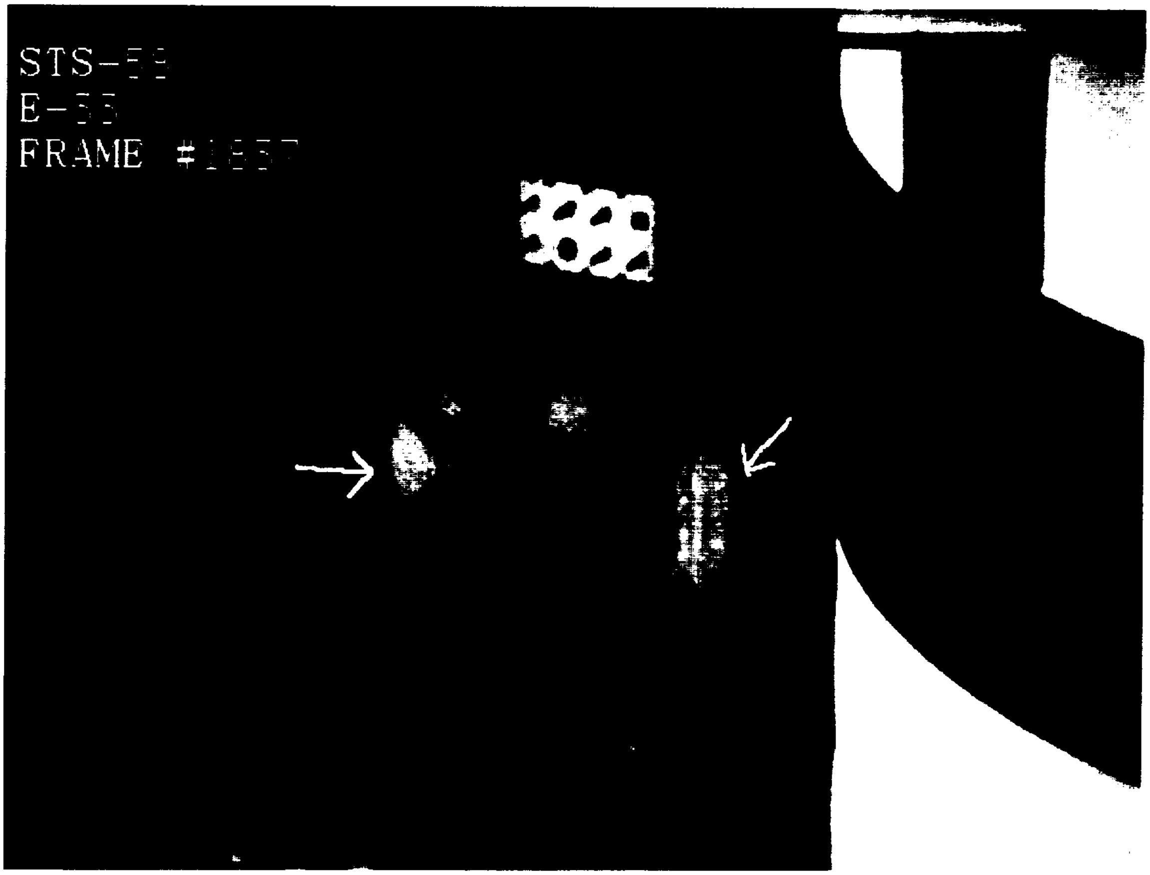


Figure 2.1.2.2 Stripped Foam Insulation on ET GH2 Intertank Area

Two pieces of foam insulation were stripped away, one on each side, from both sides of the GH2 intertank umbilical. This picture shows the vent arm pulling away at liftoff. Note that no bare metal is exposed on the ET.

2.1.2.3 Debris from above ET/Orbiter Bipod Area
(Camera E-65)

At least two very small, light-colored pieces of debris, first seen behind the LO2 feedline above the bipod, fell aft at liftoff. The debris did not appear to strike the vehicle.

2.1.2.4 SRB Flame Duct Debris *(Task #7)*
(Cameras E-1, E-7, E-9, E-12, E-13, E-15, E-16 and E-57)

As on previous missions, several pieces of debris were noted originating from the SRB flame duct area after SRB ignition. None of the flame duct debris was seen to strike the vehicle.

A fast moving rectangular piece of debris was seen exiting the LSRB flame duct at approximately 0.179 seconds MET on camera E-13. The debris moved up and then to the south, but did not appear to strike the vehicle. The size of the debris was approximately 2.9 sq. inches. (The 2" scale marker on the SRB was used for scale.) The three-dimensional velocity of this debris was calculated. The velocity of the debris in the image plane was generated by finding the distances in the x and y dimensions that the debris moved from its initial position. Because the scale changed as the debris moved closer to the camera, a new scale was applied for each position. The velocity in the direction of the camera (along the camera's optical axis) was determined by using the known size of the debris when it was near a 2" scale marker on the SRB and its subsequent apparent change in size as it moved closer to the camera. This variance in scale was then correlated with the change in distance using the formula: distance = focal length/scale. A 2nd order polynomial regression curve was then fit to the distance vs. time data in each dimension and the first derivative was used to find the velocities as a function of time. The maximum debris velocity was found to be approximately 58 feet/second which occurred at about 0.27 seconds MET.

A fast moving piece of debris was seen exiting the RSRB flame duct at approximately 1.7 seconds MET on cameras E-1 (see Figure 2.1.2.4) and E-57. The debris moved to the northwest and appeared to break into two pieces at approximately 1.716 seconds MET. The size of the debris could not be accurately determined because it was blurred and partially obscured by the SRB exhaust plume. The velocity of the debris in the image plane was found by finding the distances in the x and y dimensions that the debris moved from its initial position and applying a constant scale. (The width of the RSRB was used for scale.) A 2nd order polynomial regression curve was then fit to the distance vs. time data in each of the dimensions and the first derivative was used to find the velocities as a function of time. The maximum two-dimensional velocity was found to be approximately 152 feet/second using data from camera E-1 at about 1.7 seconds MET. The maximum 2-D velocity using data from camera E-57 was found to be only 60 feet/second which occurred at approximately 1.722 seconds MET. This large discrepancy between calculated debris velocities stems from the fact that a large component of the velocity vector using camera E-57 was in the direction of the camera and was not measured. (Since camera E-57 is on the perimeter northwest of the PAD the velocity discrepancy is also consistent with the movement of the debris to the northwest.)

A true three-dimensional velocity measurement for the debris seen on cameras E1 and E-57 using a phototheodolite solution was begun and will be completed as a general task.

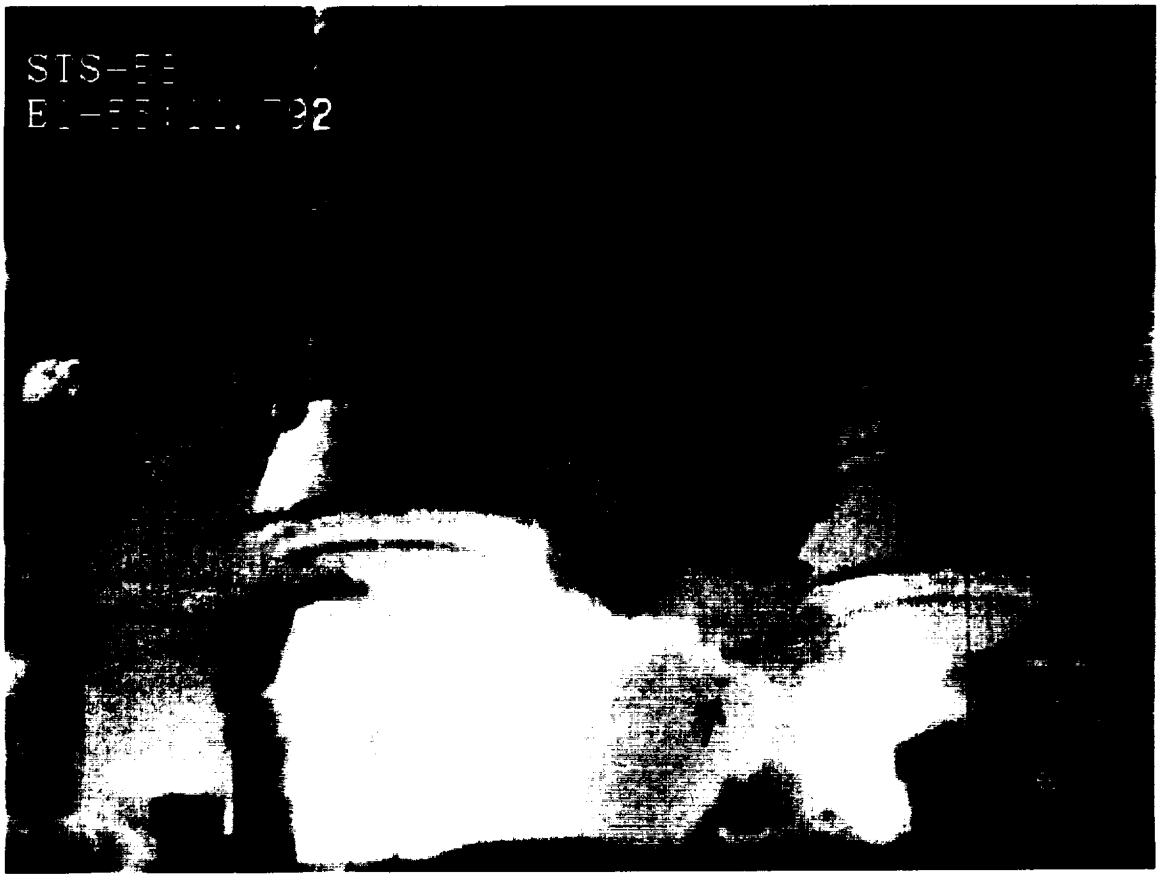


Figure 2.1.2.4 Debris from SRB Flame Duct at Liftoff

A fast-moving piece of dark debris was seen exiting the flame duct just after liftoff. The debris appeared to break into two pieces as it moved toward the northwest and away from the vehicle. The velocity of this debris is being calculated through the use of a multiple camera phototheodolite solution. The results of this analysis will be reported in a general task.

2.1.3 Debris after Liftoff

2.1.3.1 Large White Debris near SSMEs at 45 seconds MET*(Task #13) (Cameras E-208, E-212, E-220, E-222, ET-204, ET-208, ET-212 and KTV-4B)*

A single large piece of white debris, first seen between SSMEs #1 and #3, fell aft into the SSME plumes at 45.192 seconds MET. KSC personnel postulated that this debris might be the DMHS sacrificial panel. Measurements off the film indicated that the debris was about 14 by 15 inches when sighted near the SSMEs. See Figure 2.1.3.1(a). As the debris passed by the SSME #3 nozzle, a small flare was seen in the plume. The same debris was measured as 26 x 11 inches when seen further aft in the SSME plume (Figure 2.1.3.1(b)). A trajectory plot generated from a sequence of frames showed that the object originated from between SSME #1 and #3 (Figure 2.1.3.1(c)). Post-landing views of the aft end of the Orbiter seem to support the view that the debris originated from the SSME #3 DMHS. See Figure 2.1.3.1(d).

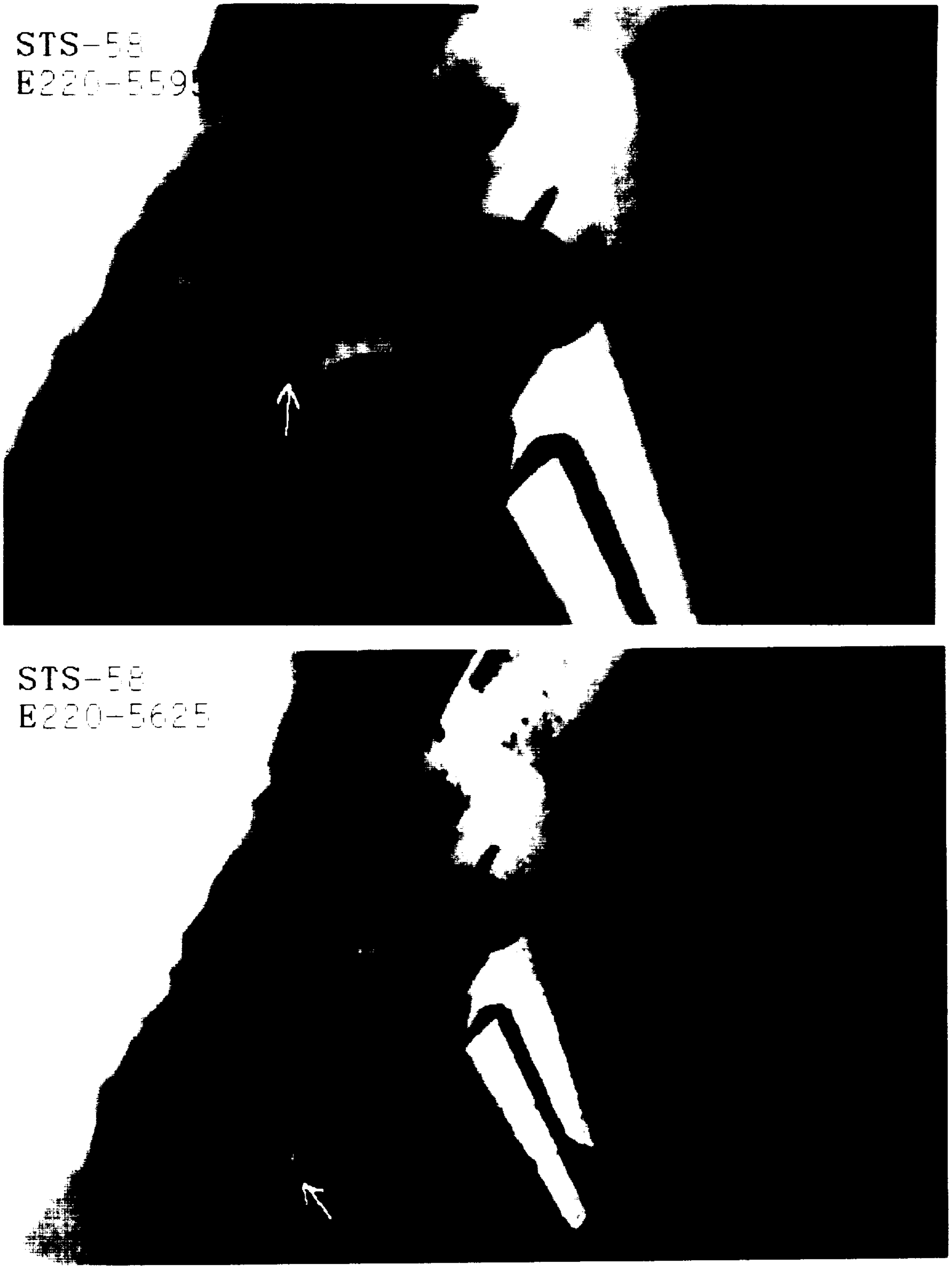
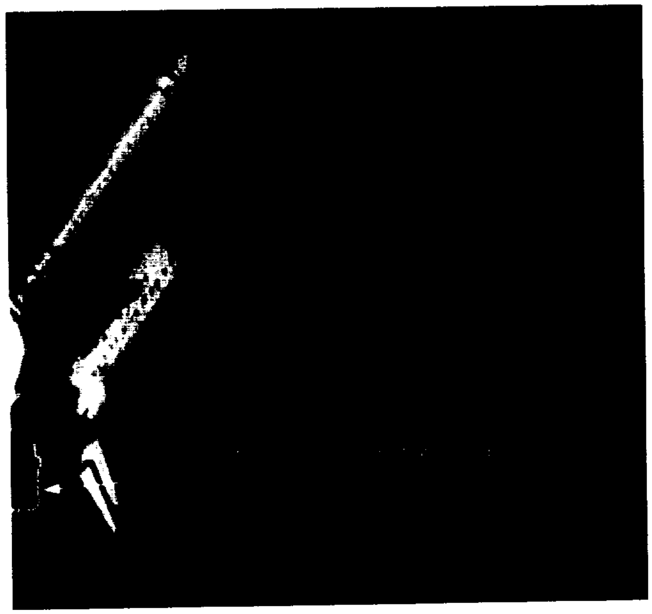


Figure 2.1.3.1(a) and (b) Debris in SSME Plume at 45 Seconds MET

A large piece of white debris, first observed between SSMEs #1 and #3, fell aft along the SSME plume.



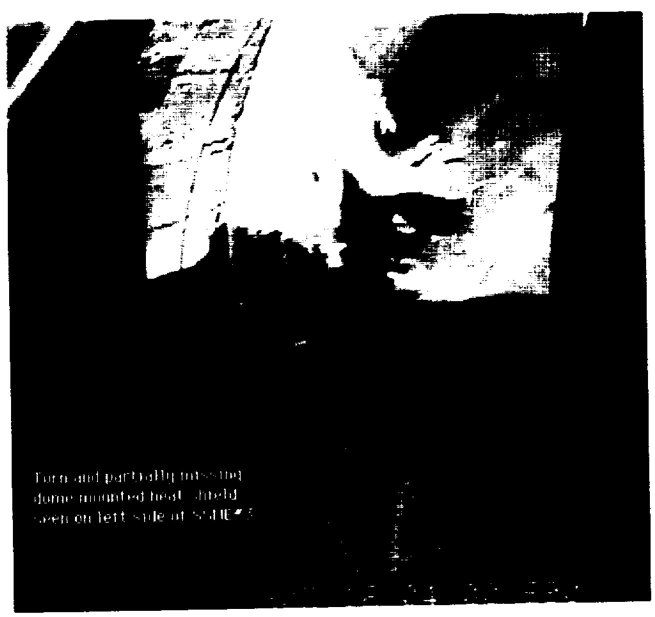


Figure 2.1.3.1(c) and (d) Analysis of Debris in SSME Plume at 45 Seconds MET

A trajectory analysis concluded that the white debris originated from between SSMEs #1 and #3 (c). Post-landing inspection of the vehicle revealed considerable damage to the SSME #3 DMHS at the nine o'clock position (d).

2.1.3.2 Light-Colored Debris at 70 Seconds MET
(Cameras E-220 and E-222)

Multiple pieces of light colored debris fell aft from the SRB exhaust plume at approximately 70 seconds MET. See Figure 2.1.3.2. No further analysis of this debris is expected.

Figure 2.1.3.2 Debris near SRB Plume at 70 Seconds MET

Two pieces of light-colored debris can be seen falling aft of the vehicle and along the SRB plume at 70 seconds MET. These are representative of the multiple pieces of debris seen during this time period. None of the debris appeared to strike the vehicle.

2.1.3.3 Large Orange Debris seen just prior to SRB Separation
(Camera E-208)

A single large piece of orange debris traveled away from the SRB exhaust plume just prior to SRB separation. (See Figure 2.1.3.3). The debris source could not be identified from the only available view. Since one of the forward RSRB BSM covers was missing at the time of SRB recovery, there was some speculation that this event may have been related. However, a later KSC report indicated that the cover came off at water impact. No further analysis is anticipated.

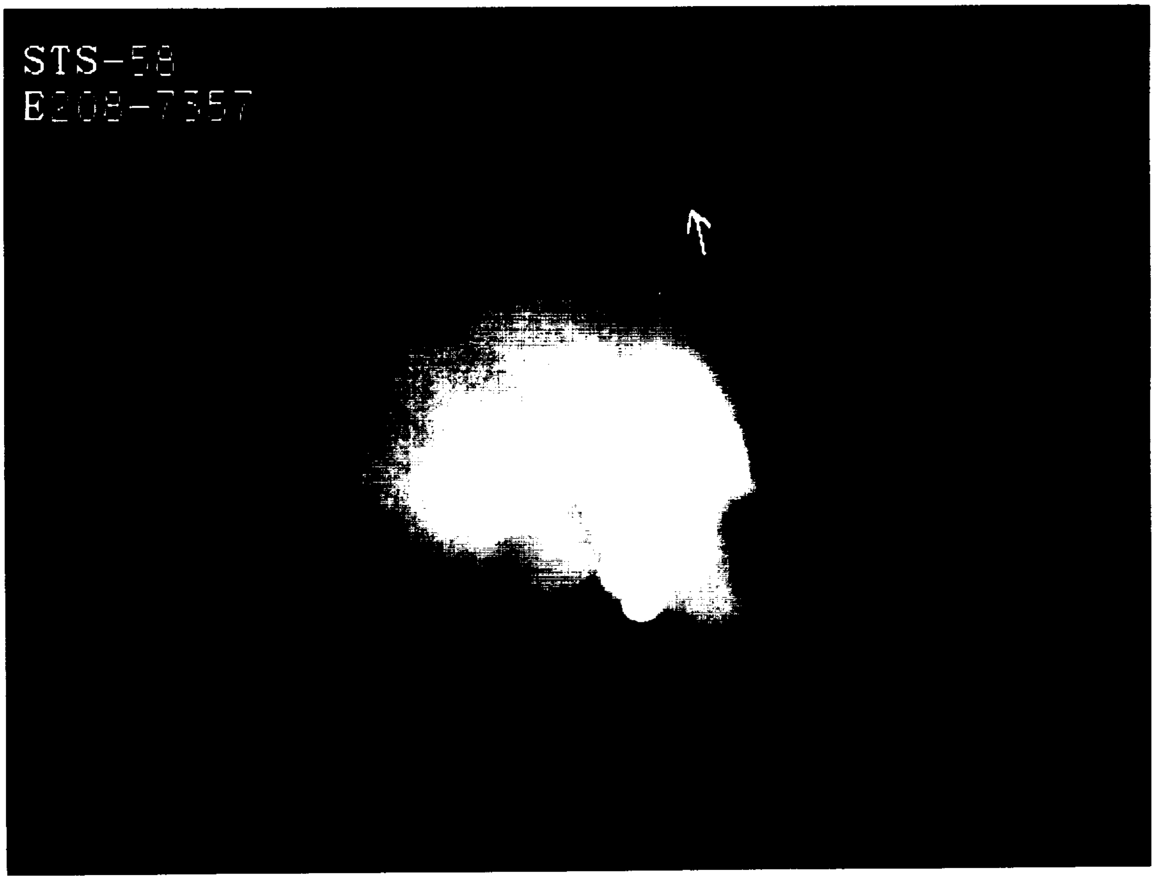


Figure 2.1.3.3 Large Orange Debris seen at SRB Separation

A single large piece of orange debris fell away from the SRB plume just before SRB separation. A debris source could not be identified. The object did not appear to strike the vehicle.

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

The commander reported that no unusual debris was visible from windows W1, W2 or W3 during launch and ascent.

2.2 MLP Events

2.2.1 Discoloration of RCS Cover
(Camera E-18)

A slight discoloration of the L4D RCS cover was noted prior to liftoff. Similar paper discoloration was seen on STS-43 and STS-56.

2.2.2 Orange Vapor (Possible Free-Burning Hydrogen)
(Cameras E-30, E-36 and OTV-163)

Orange vapor (possible free-burning hydrogen) was visible below the body flap at SSME startup. This event is monitored to verify that the vapor does not carry up toward the ET/Orbiter umbilicals (which might present a potential hazard). The vapor seen on this mission remained well below the umbilical area.

2.2.3 Rippling of the SSME #2 DMHS at SSME Startup
(Camera E-18)

Rippling of the DMHS on SSME #2 was noted at SSME startup. A narrow white line at the junction of the base of SSME #2 and the DMHS appeared intermittently. See Figures 2.2.3(a) and (b). KSC was consulted and they believed that the line indicated a slight flexing or brief unfolding of the DMHS blanket. A follow-up analysis of the same view from STS-51 did not reveal similar movement. This information has been passed on to both KSC and the MER.

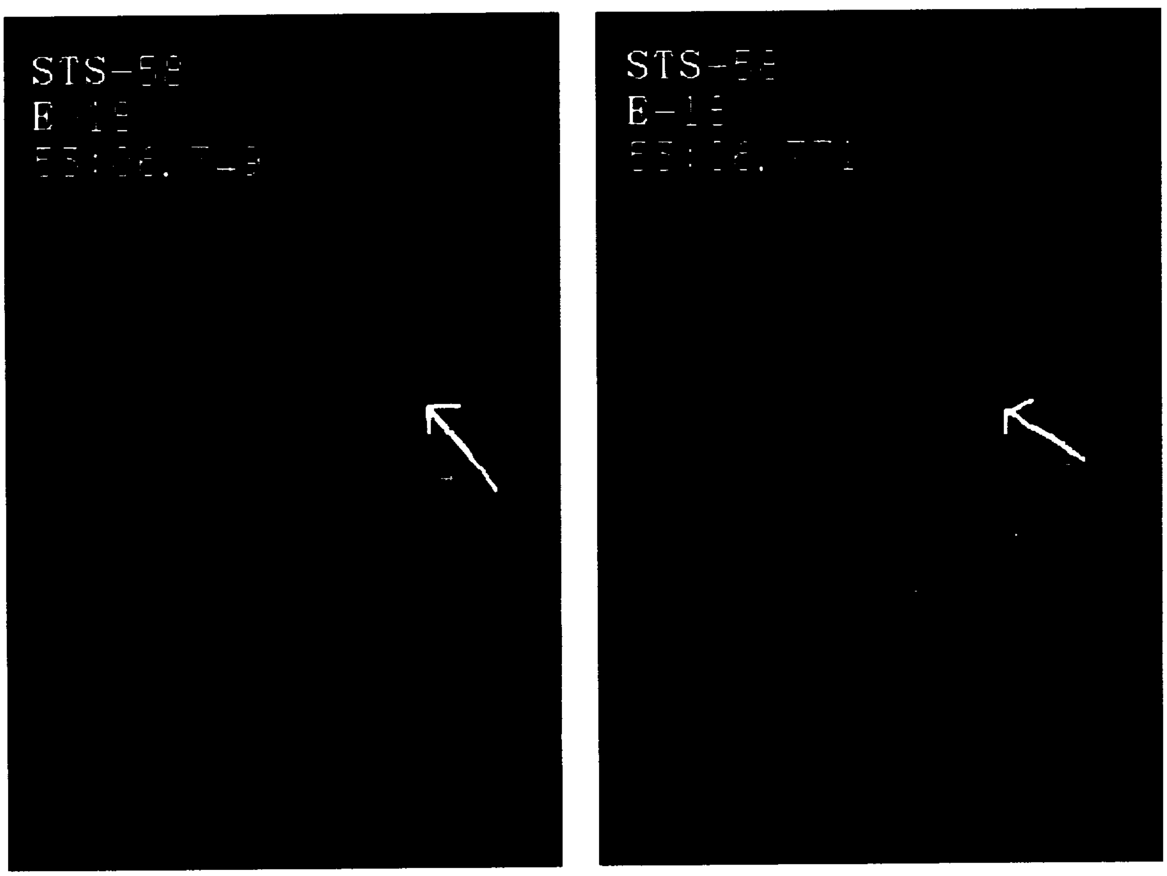


Figure 2.2.3(a) and (b) Rippling of the SSME #2 DMHS

These pictures show the rippling of the SSME #2 DMHS. Note the appearance of the white line in (b). This rippling continued intermittently from about T-3.355 seconds to T-3.193 seconds.

2.2.4 Flashes in SSME #3 Plume after SSME Ignition

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

Three flashes were noted in the SSME #3 plume at T-1.660 seconds, T-0.862 seconds and T-0.791 seconds. Flashes in the SSME exhaust plumes have been seen on fourteen missions since reflight. No follow-up analysis was requested.

2.2.5 Base Heat Shield Erosion

(Cameras E-18, E-19 and E-20)

Slight base heat shield erosion was noted near the -Y edge of SSME #2 during SSME startup. See Figure 2.2.5. TPS erosion was also noted at the base of both the right and left RCS stingers prior to liftoff. Some TPS erosion of the base heat shield has been seen on nearly all missions. No further analysis is expected.

Figure 2.2.5 TPS Erosion at the Base of the Right RCS Stinger

A small amount of TPS erosion can be seen at the base of the right RCS stinger just before liftoff. Minor base heat shield erosion has been seen on other missions and is not considered anomalous.

2.3 Ascent Events

2.3.1 Discoloration in SSME #3 at 35 Seconds MET

(Cameras E-213, E-220, E-222)

A white discoloration in the SSME #3 plume was visible at 35.083 seconds MET. Discoloration in the SSME plumes during ascent has previously been seen on STS-32. Discolorations in the SSME plumes before liftoff has been noted on STS-43, STS-48 and STS-46.

Figure 2.3.1 Discoloration in the SSME Plume At 35 Seconds MET

A white discoloration was seen in SSME plume #3 at 35.083 seconds MET. No further analysis is anticipated.

2.3.2 Large Flare in SSME #1 at 46 Seconds MET

(Cameras E-212, E-213, E-220, E-222)

A large bright flare was noted in the SSME #1 plume at 46.218 seconds MET. The event occurred about one second after the large white piece of debris was seen near the SSME plumes. Thirteen other small flares were visible during early ascent. No further analysis is expected.

Figure 2.3.2 Large Flare in SSME Plume at 46 Seconds MET

A large bright flare that lasted for less than one-fiftieth of a second was seen in the SSME #1 plume. While flares in the plume are not usually considered abnormal, the size and brightness of this particular event warranted closer study.

2.3.3 Body Flap Motion *(Task #4)*
(Cameras E-207, E-212 and E-222)

Slight body flap motion was noted during the time of maximum dynamic pressure (between 30 and 90 seconds MET). The magnitude of motion seen on this mission was not sufficient to warrant further analysis.

2.3.4 Linear Optical Distortions
(Cameras E-208, E-212, ET-208 and KTV-13)

At least five linear optical distortions were observed during ascent at 57.251, 60.357, 64.401, 69.873 and 71.008 seconds MET. Johnson Space Center engineers previously correlated this event with the propagation of shock waves through the atmosphere. No further analysis is anticipated.

2.3.5 Recirculation *(Task #1)*
(Cameras E-204 and ET-204)

The recirculation or expansion of burning gases at the aft end of the SLV prior to SRB separation was seen on nearly all previous missions. The sighting of this event is dependent upon launch inclination angle and cloud cover during ascent. For STS-58, the start of recirculation was observed at about 92 seconds MET and the end was noted at approximately 102 seconds MET on camera E-204. A compilation of recirculation start and stop times for all missions since reflight has been updated.

Cameras on which recirculation was observed for STS-58

CAMERA	START (seconds MET)	STOP (seconds MET)
ET-204	93	100
*E-204	92	102

*** BEST VIEW OF RECIRCULATION**

2.4 On Orbit

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

Thirty-eight photographs were analyzed from the STS-58 mission. The exposure was good for all frames and the focus was variable. Representative images are shown in Figures 2.4.1(a) and (b).

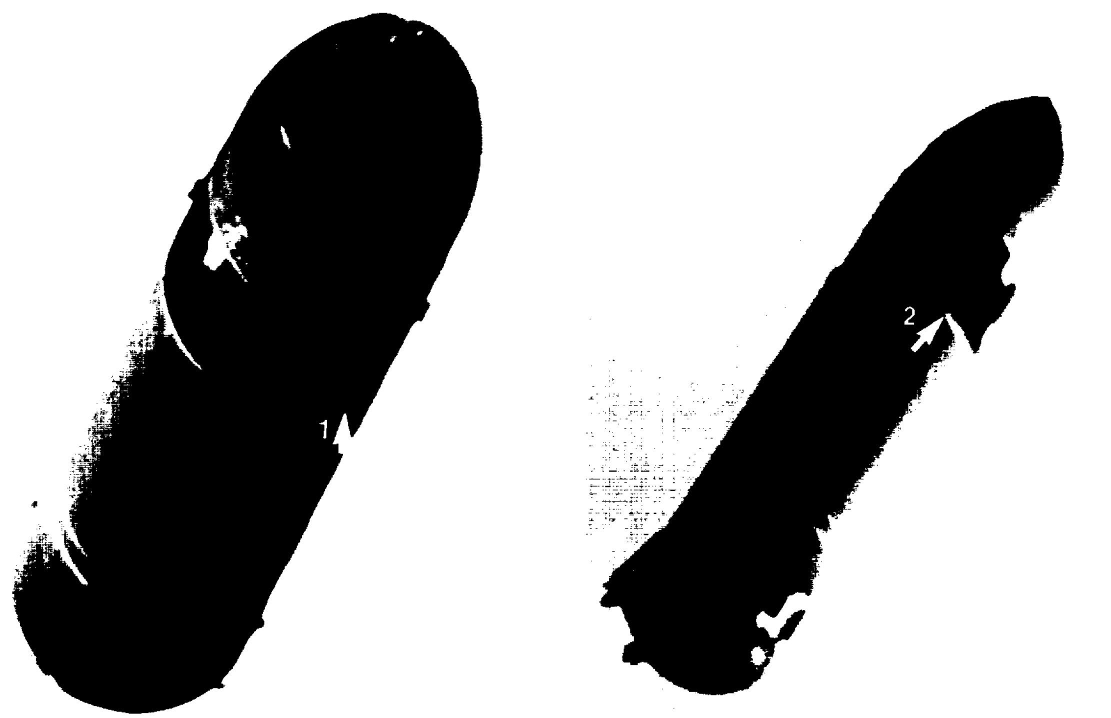


Figure 2.4.1(a) and (b) Handheld Camera Views of ET after Separation

Two apparent divots were noted on the LH2 tank-to-intertank interface on these photographs. These divots were linearly scaled from photographs STS-58-02-04 and STS-58-02-36. The divot observed in frame 4 measured 8 inches (arrow 1) and the divot noted on frame 36 measured 16 inches.

The separation velocity was calculated by determining the distance to the Orbiter on four photographs. The photographs had timing information. Separation velocity was determined by calculating the slope of the distance versus time line from the photographs. Separation velocity was calculated to be 5.7 meters per second.

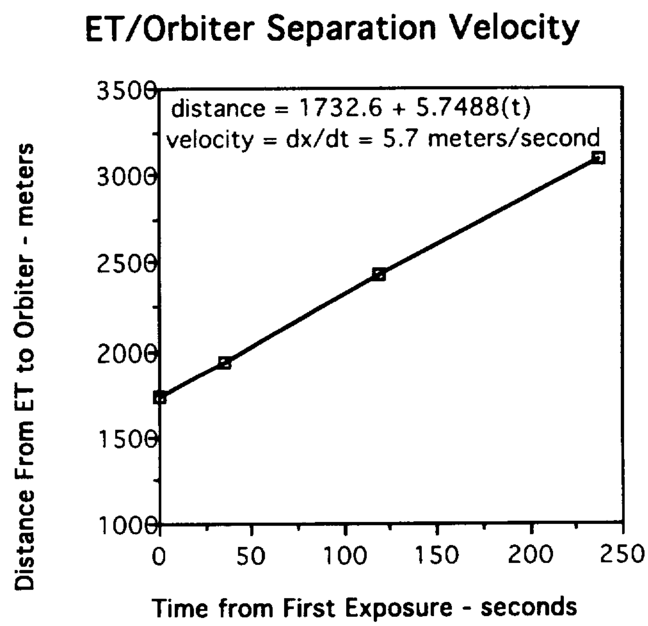


Figure 2.4.1(c) Graph Showing Orbiter/ET Separation as Function of Time

This graph shows the distance from the Orbiter to the ET as a function of time. The sequence of images used to produce this plot was acquired over a period of about four minutes. Note the linear correlation indicating a constant separation velocity.

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

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

Two 16 mm motion picture films (one with a 5 mm lens and one with a 10 mm lens) were acquired from the Orbiter LH2 umbilical cameras. The 16 mm motion picture films showed LSRB and ET separation along with the normal venting and debris associated with these events. The exposure and focus of the umbilical well films were good, however, the 16 mm with the 5 mm lens is degraded by the back lighting from the sun during the ET separation sequence. No timing data is available from OV-102.

Figure 2.4.2.1(a) 16 mm Camera with 5 mm Lens View of the LSRB at Separation

The LSRB separation appeared normal. Multiple pieces of light colored TPS debris of various shapes and sizes are visible before, during, and after the separation of the SRB (1). Chipping and erosion of the TPS on the base of the -Y electric cable tray (2) and the aft ET/Orbiter and ET/LSRB attach struts (3) are visible. The TPS on the -Y side of the LH2 umbilical has a blistered appearance(4).

Figure 2.4.2.1(b) 16 mm Camera with 10 mm Lens View of the ET LH2 Umbilical

A large horseshoe-shaped piece of white debris (frozen hydrogen) was seen in front of the LH2 umbilical after ET separation (1). This debris may have come from the flapper valve at the orifice of the LH2 17 inch line (2). A linear shaped piece of material was seen coming from near the cross beam between the LH2 and LO2 umbilicals (3). This debris has a thin edge and is light on one side and dark on the other. The movement is from the general direction of the LO2 umbilical. This debris might be the missing lightning contact strip from the LO2 umbilical (see Section 2.4.2.2 on the 35 mm umbilical well camera film analysis). A thin rectangular piece of debris was seen coming from behind the LH2 electrical cable tray prior to the separation of the external tank. A small dark piece of debris was seen just to the left of the LH2 electrical cable tray.

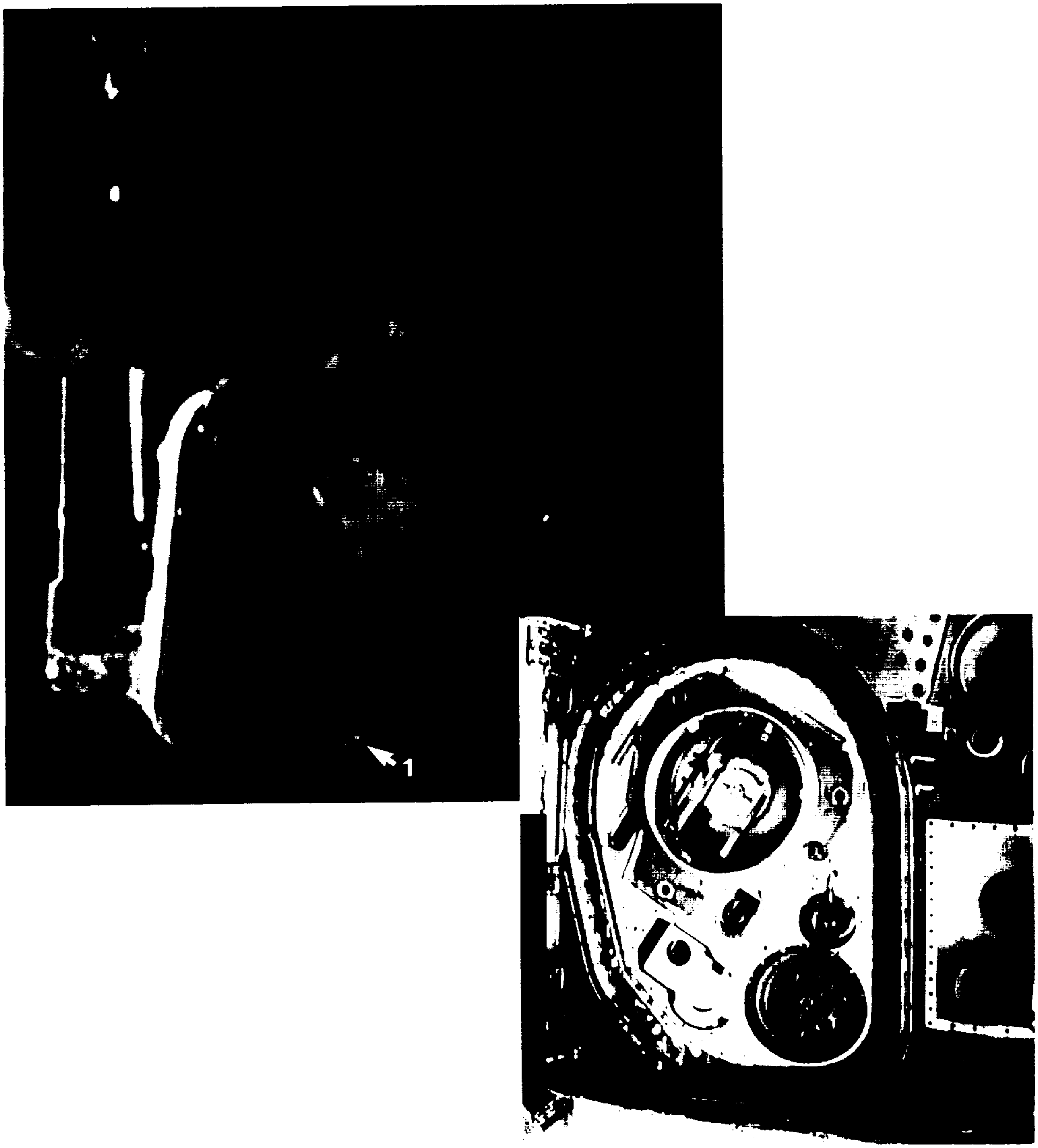


Figure 2.4.2.1(c) and (d) Comparison of the ET LH2 Umbilical (On Orbit View) and the Orbiter LH2 Umbilical (Post-Landing Inspection View)

A white substance (probably RTV) was seen on the lower rim of the ET LH2 umbilical (1) near the 4 inch disconnect. A picture taken by the debris team after the Orbiter landing indicated that loose material was present on the lower rim of the Orbiter LH2 umbilical near the four inch line disconnect (2).

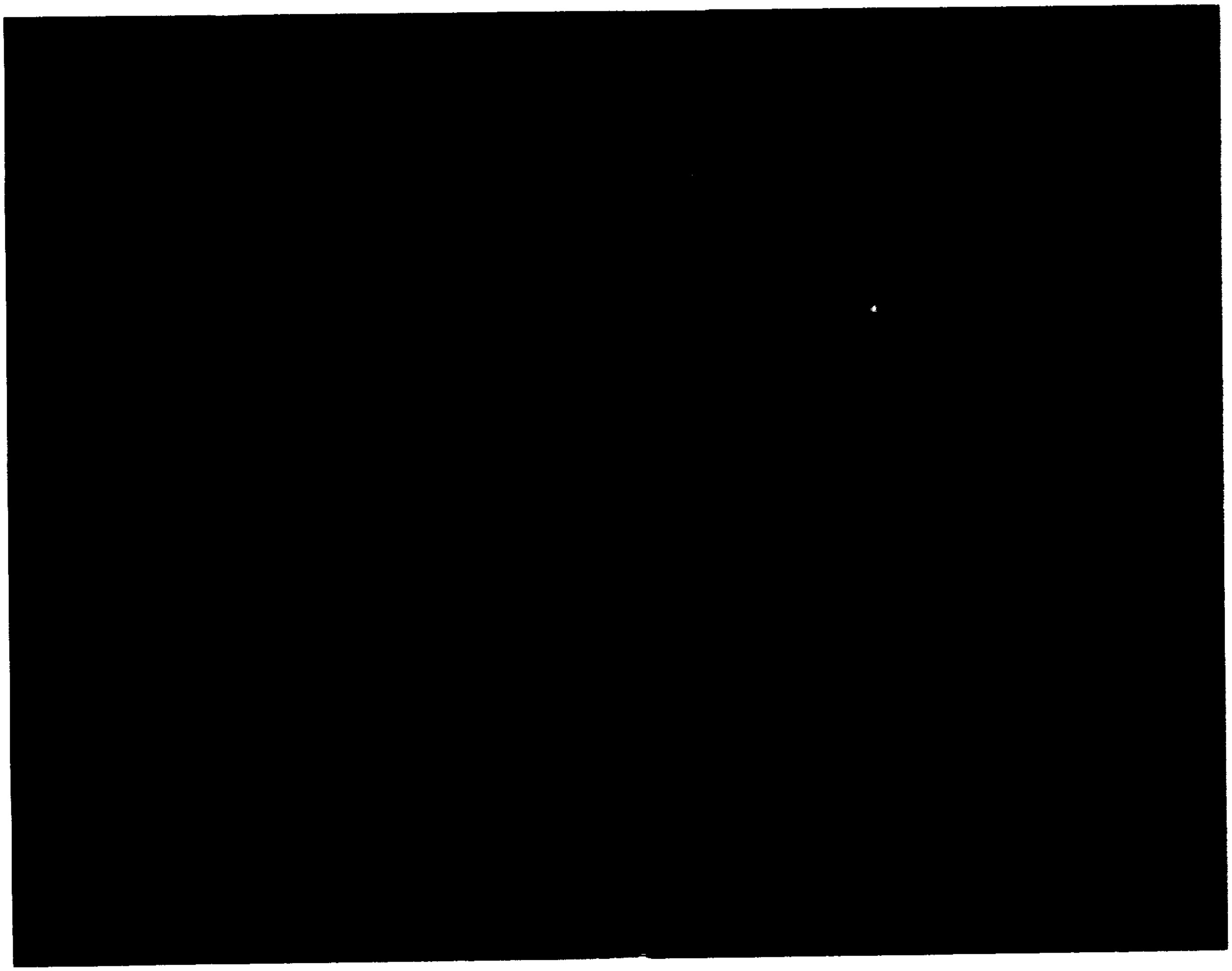


Figure 2.4.2.1(e) Debris falling along ET after separation

A piece of debris, light on one side, dark on the other, was seen tumbling aft in front of the hydrogen tank well after ET separation (1).

Pieces of white debris continued to move across the field of view until the end of the 16 mm films. The ET had a slight lean to the right by the end of the films. Multiple pieces of white debris (frozen hydrogen) and white vapors were in view throughout the ET separation sequence.

2.4.2.2 35 mm Umbilical Well Camera Views of ET Separation

Sixty well exposed and focused 35 mm frames were obtained of the external tank separation. The images are degraded slightly by what appears to be a smudge or smear on the camera window.

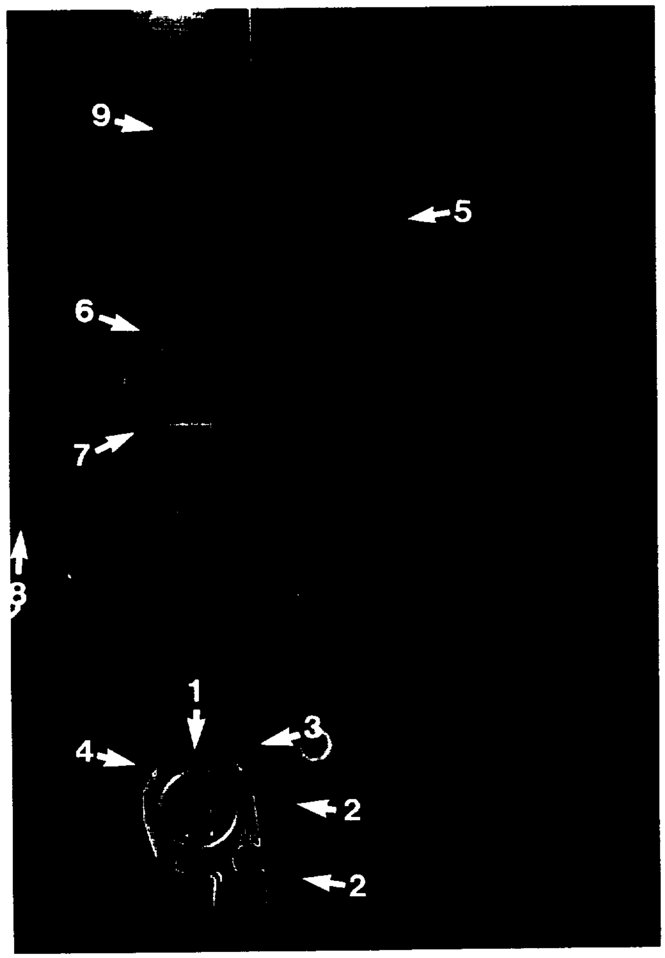


Figure 2.4.2.2(a) 35 mm Camera View of the ET LO2 Umbilical

The lightning contact strip across the forward portion of the LO2 umbilical appeared to be missing (1). TPS scarring was seen on the right side of the LO2 umbilical at the vertical section of the electric cable tray (2). A loose piece of material (insulation) was seen at the upper right corner of the LO2 umbilical (3). Missing or loose material (insulation) was seen at the upper left corner of the LO2 umbilical (4). TPS scarring was seen on the forward end of the +Y thrust strut (5). Chipping of the TPS on the aft LO2 feedline support bracket was noted (6). A thin white (frost appearing) line was visible on the aft LO2 feedline bellows (7). Small TPS blemishes were seen on the LH2 tank acreage forward of the cross beam near the LO2 umbilical (8). A dark circular mark was seen on the TPS of the aft portion of the LO2 feedline (9). A similar but less distinctive mark was visible at the same location on the pre-launch photography.

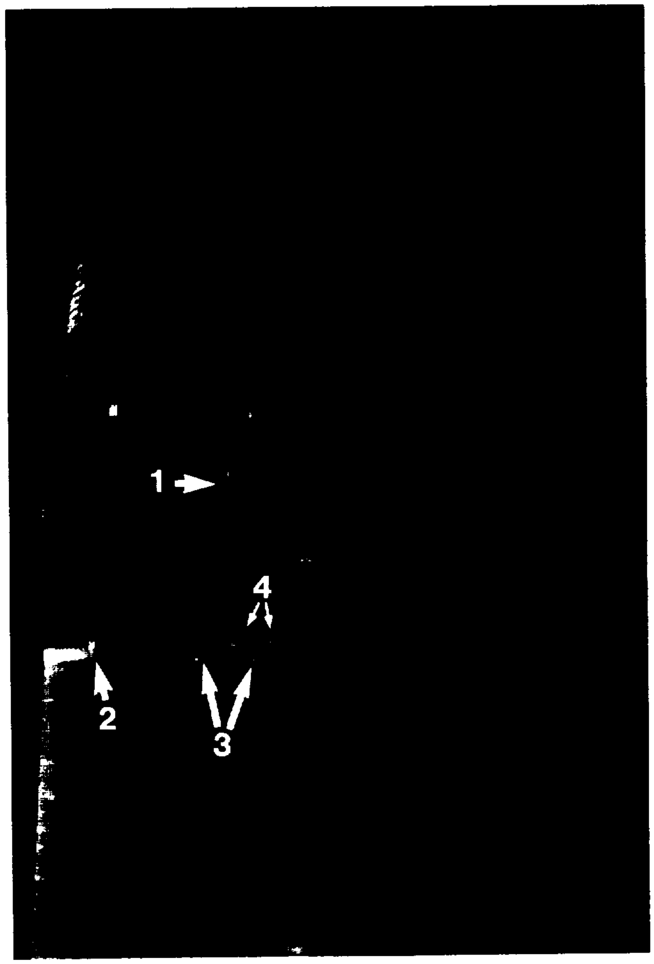


Figure 2.4.2.2(b) 35 mm View of Bipod and LH2 Tank/Intertank Region of ET

A linear white mark was seen on a intertank stringer (with dark substrate material visible in the center of the white mark) just below the +Z vent (1). The white mark was measured to be 29.1 inches long and 4.6 inches wide. The dark center of the mark measured 26 inches in length. A divot was seen on the intertank and the LH2 tank-to-intertank closeout flange in the -Y direction from the forward bipod (2). This divot was measured to be 19.7 inches in the longest dimension and 6 inches in width. Two white marks were seen under the forward bipod legs on the LH2 tank-to-intertank flange. These white marks may be missing bipod jackpad close-outs (3). Four small apparent divots were seen on the intertank TPS forward of the forward ET/Orbiter attach bipod (4).

2.0 Summary of Significant Events

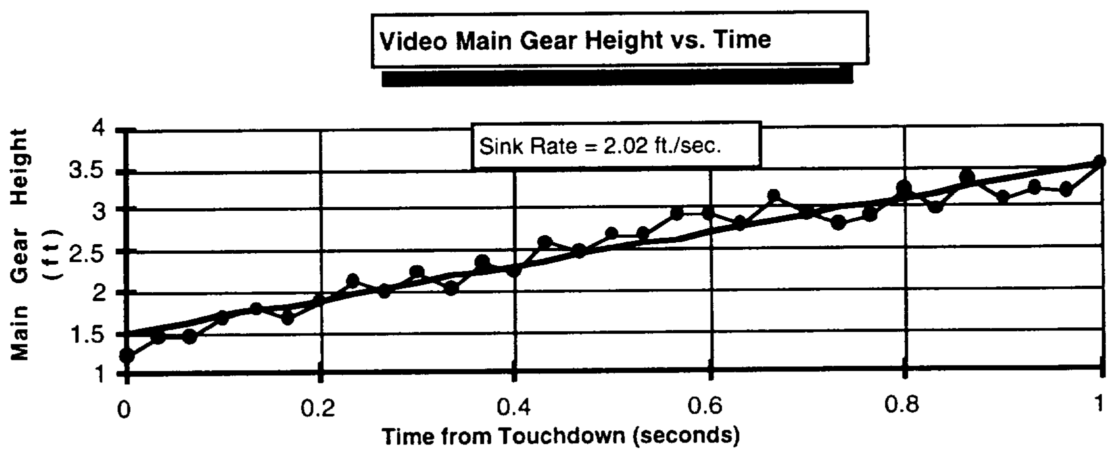
2.5 Landing Events

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

Landing sink rates are calculated from both film and video sources when available. On this mission, the best video view for generating sink rates was DTV-1; the best film views were seen from E-1002 and E-1008. In general, sink rates calculated from film are considerably more accurate than those obtained from video. However, the video results serve as a sanity check.

2.5.1.1 Sink Rate from Video *(Camera DTV-1)*

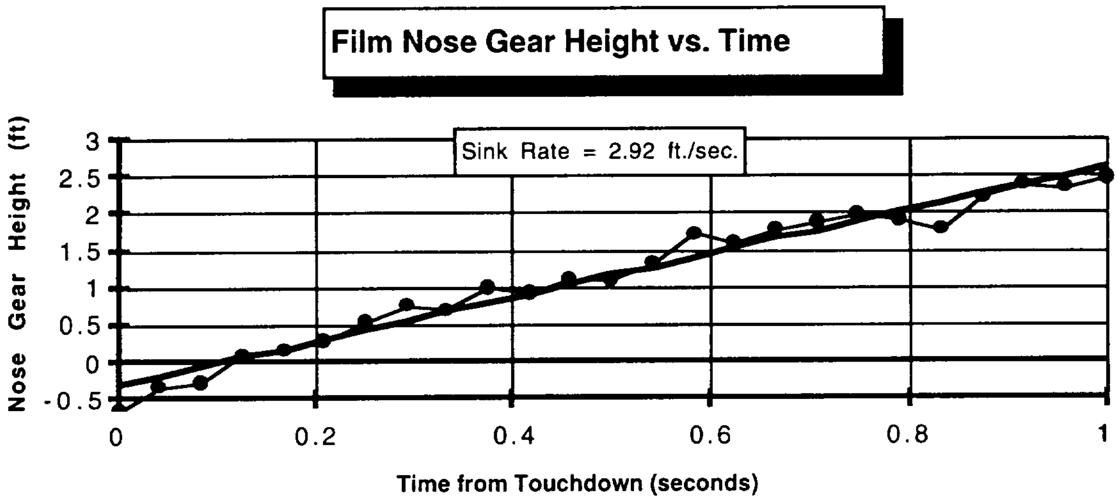
Camera TV-1 was used to determine the sink rate of the main gear. Scalar information was determined by a system of equations which took into account the orientation of the camera relative to the Orbiter. Data was gathered approximately 1 second prior to landing through touchdown at a rate of 30.0 frames per second. The equations were solved for each observation which took into account the change in perspective as well as change in size. The distance between the center of the main gear and a reference point 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 2.0 feet per second.



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

Camera TV-1 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 30.0 frames per second. The equations were solved for each observation which took into account the change in perspective as well as change in size. The distance between the center 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 3.3 feet per second.

perspective as well as change in size. The distance between the center 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 2.9 feet per second.



2.5.2 Drag Chute Performance*(Task #9)*

(Camera DTV-1, DTV-2, DTV-3 and DTV-4)

The landing of Columbia at the end of mission STS-58 marked the tenth deployment of the Orbiter drag chute. All components of the drag chute appeared to deploy as expected. The following event times were obtained from camera DTV-1 except for drag chute initiation which was acquired from DTV-4:

Drag chute initiation	15:05:51.299 UTC
Pilot chute inflation	15:05:52.386 UTC
Bag release	15:05:53.053 UTC
Drag chute inflation in reefed position	15:05:54.488 UTC
Drag chute inflation in disreefed configuration	15:05:58.025 UTC
Drag chute release	15:06:24.518 UTC

Standard analysis of the drag chute angles as a function of time was performed using views from film camera E-1008. This analysis is used to support the improvement of the aerodynamic math models currently in use. During the first twenty seconds of deployment, the maximum horizontal chute deflection was approximately 4.34 degrees.

2.6 Other Normal Events

Other normal events observed include: FSS deluge water; ice buildup on the SSME vent nozzles; ice debris and vapor from the ET/Mission umbilical disconnects at SSME startup through liftoff; slight vapor from the gaseous oxygen (GOX) vent on the ET, 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; water leak from MLP j-pipes; ice and vapor from the GUCP during SSME startup and arm retraction; ice and vapor from both Tail Service Mast (TSM) umbilicals at liftoff; debris in the exhaust cloud at the pad after liftoff; RCS paper debris

Appendix B. MSFC Photographic Analysis Summary

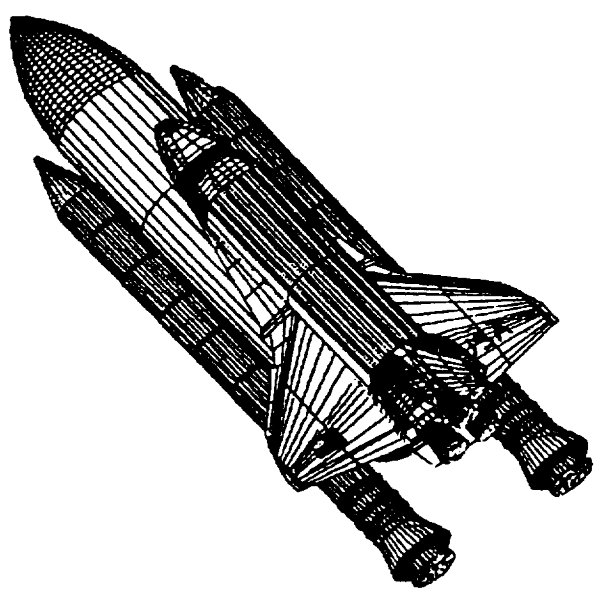
National Aeronautics and
Space Administration

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

SPACE SHUTTLE

ENGINEERING PHOTOGRAPHIC ANALYSIS REPORT

STS-58



MSFC - Form 454 (Rev. October 1978)

National Aeronautics and
Space Administration

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

NASA

Reply to Attn of: EP24 (93-27)

TO: Distribution

FROM: EP24/Thomas J. Rieckhoff

SUBJECT: Engineering Photographic Analysis Report for STS-58

Enclosed is the Engineering Photographic Analysis Report for the Space Shuttle Mission STS-58. 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

STS-58 ENGINEERING PHOTOGRAPHIC ANALYSIS REPORT

TABLE OF CONTENTS

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

Camera data received at MSFC
for STS-58

	16mm	35mm	70mm	Video
MLP	22	0	0	3
FSS	7	0	0	3
Perimeter	3	3	0	6
Tracking	0	15	0	11
Onboard	4	2	0	0
Totals	36	20	0	23

Total number of cameras received at MSFC	79

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-58 was considered good. Tracking coverage was limited due to cloud cover. Camera E-205 was not received because there was total cloud coverage at this site and the vehicle was not visible.

b. Onboard Camera Assessment:

A camera was flown on each SRB forward skirt to record the main parachute deployment. Both cameras operated properly. The astronauts carried a 35mm hand-held camera to record film for evaluating the ET TPS integrity after ET separation. Thirty-eight frames of the ET after separation were received and reviewed. Two 16mm motion picture cameras and one 35mm still camera were flown on this mission in the orbiter's umbilical well to record the SRB and ET separation.

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;

plume.

f. Slag from SRB Plume:

Figure 7 is a film frame from camera E-222 showing solid material exiting from the SRM plume. Twelve pieces of slag were observed exiting the plume between T+64 seconds and T+69 seconds.

g. ET divots

There was one large divot located on the intertank forward of the bipod and aft of the +Z aero vent. The size of this divot was estimated to be 24" x 3". The leading edge of this divot was measured to be at station 970 and -1 degree from the +Z axis. Figure 8 is a film frame from the 35mm umbilical well camera showing this divot. Also visible in figure 8 are three divots on the scarf joint in the bipod area. Figure 9 is another film frame from the 35mm umbilical well camera showing several small divots along the LH2 +Z tank acreage.

Several debris impacts greater than 1 inch were observed on the orbiter's belly after landing. The location of the large ET intertank divot was mapped onto the orbiter debris map as shown in figure 10.

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	291:14:53:10.019
M-2	E-8	291:14:53:10.017
M-5	E-12	291:14:53:10.018
M-6	E-13	291:14:53:10.018

b. ET Tip Deflection:

Maximum ET tip deflection for this mission was determined to be approximately 30 inches. Figure 11 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. Camera E-79 exhibited significant image jitter during operation.

c. SRB Separation Time:

SRB separation time for STS-56 was determined to be 291:14:55:13.69 UTC as recorded by camera E-207.

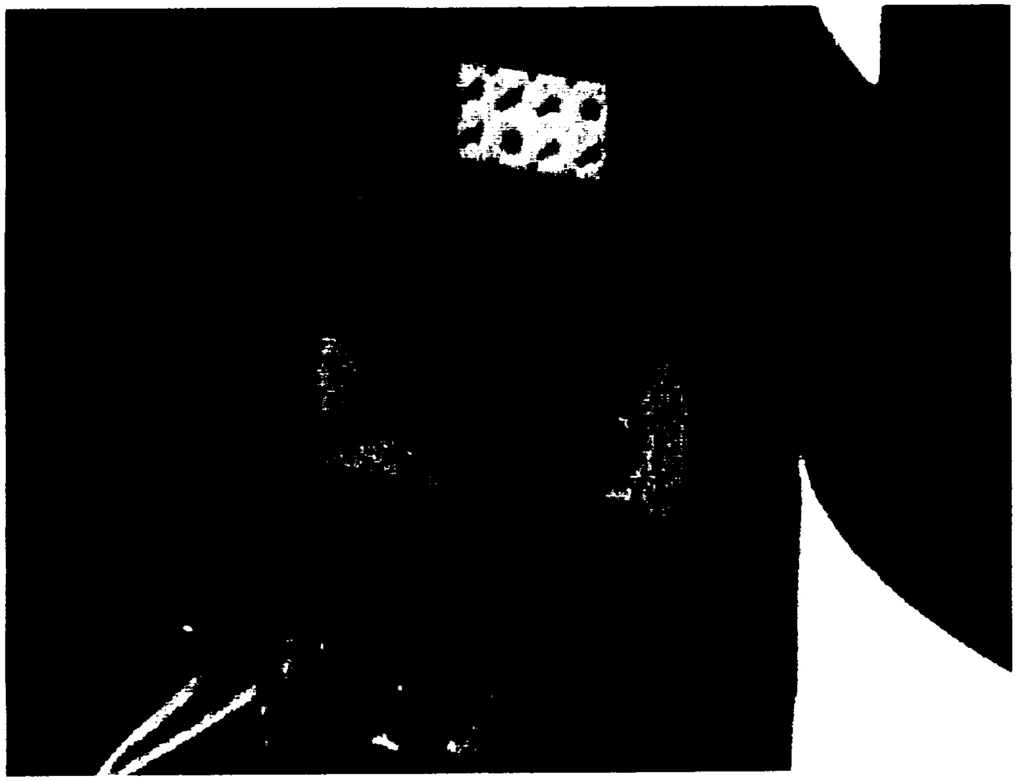


Figure 1.

Loose ET Instafoam at GUCP During Retraction

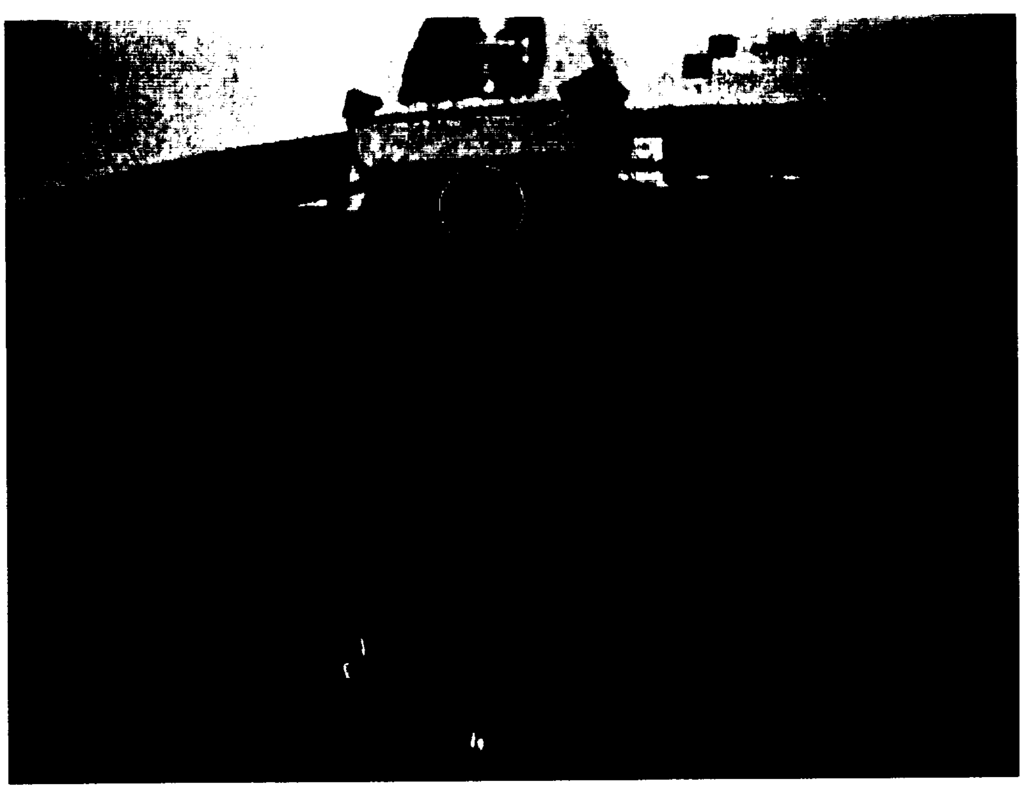


Figure 2.

Frangible Nut Material Falling from Holddown Post M-3

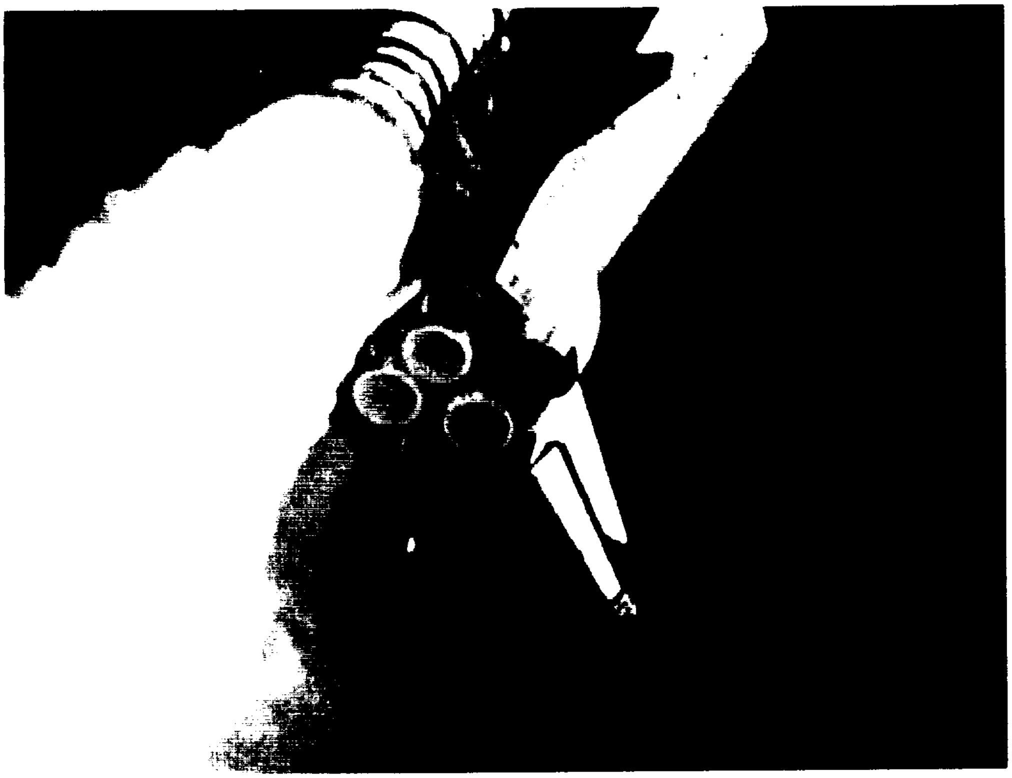


Figure 3.

Debris Falling from Boattail Region

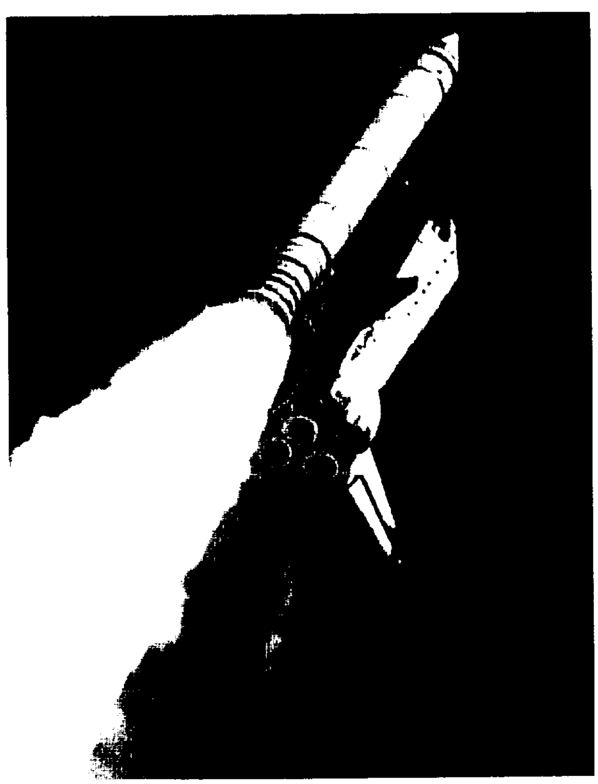


Figure 4.

Large Flash in SSME Plume

STS-58 FLASH IN SSME PLUME

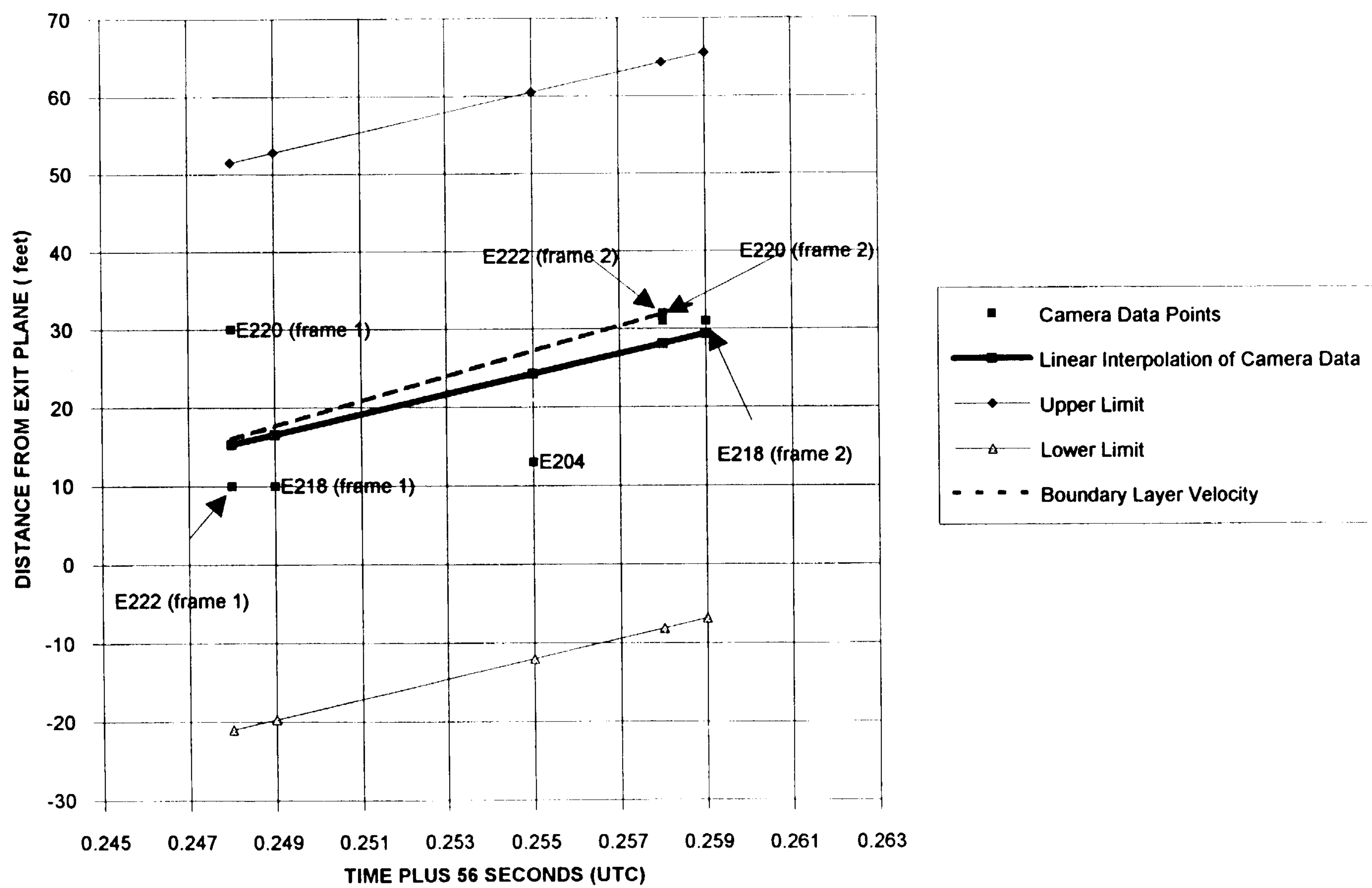


Figure 5

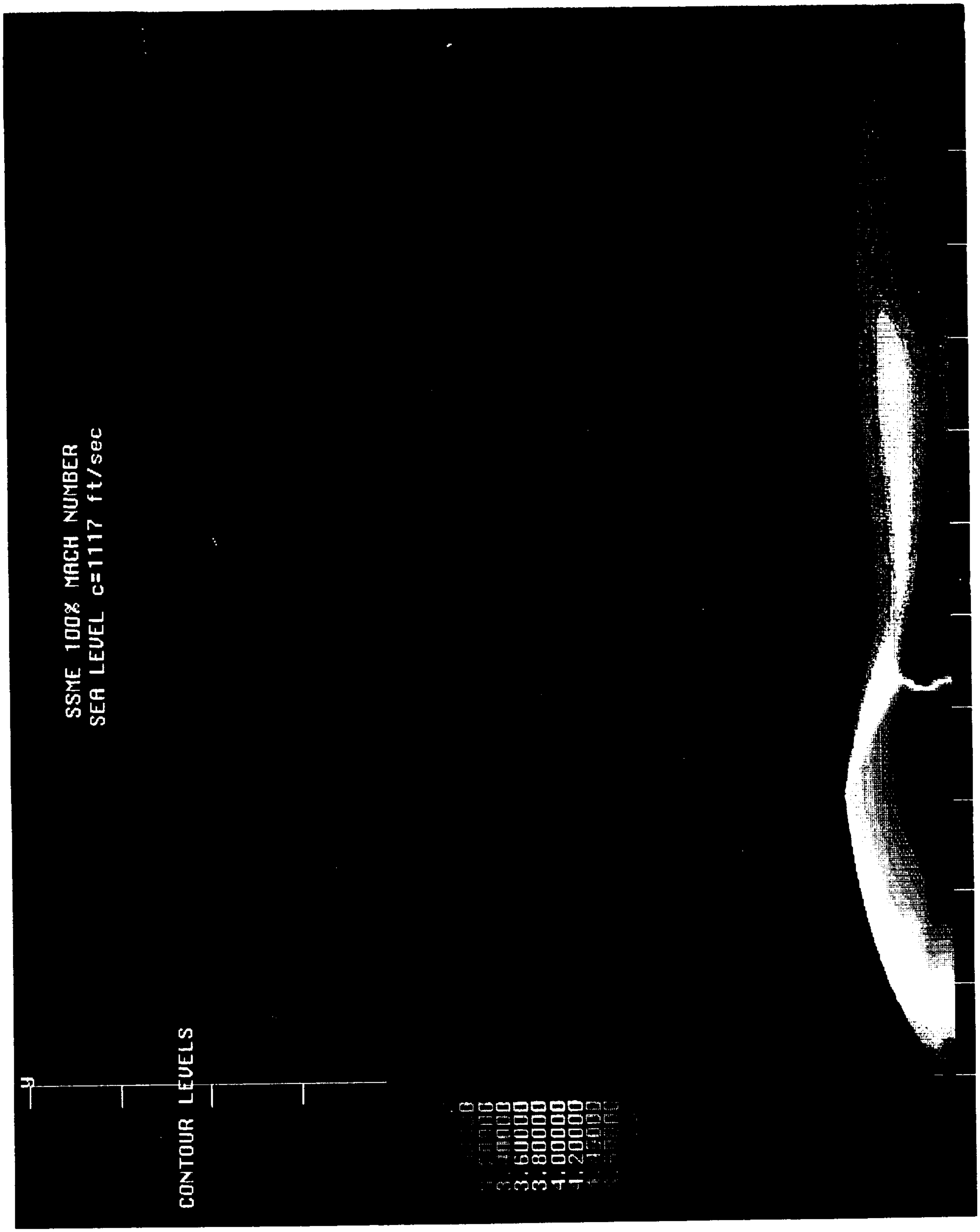

SSME 100% MACH NUMBER
SEA LEVEL c=1117 ft/sec
CONTOUR LEVELS
3.60000
3.80000
4.00000
4.20000

Figure 6

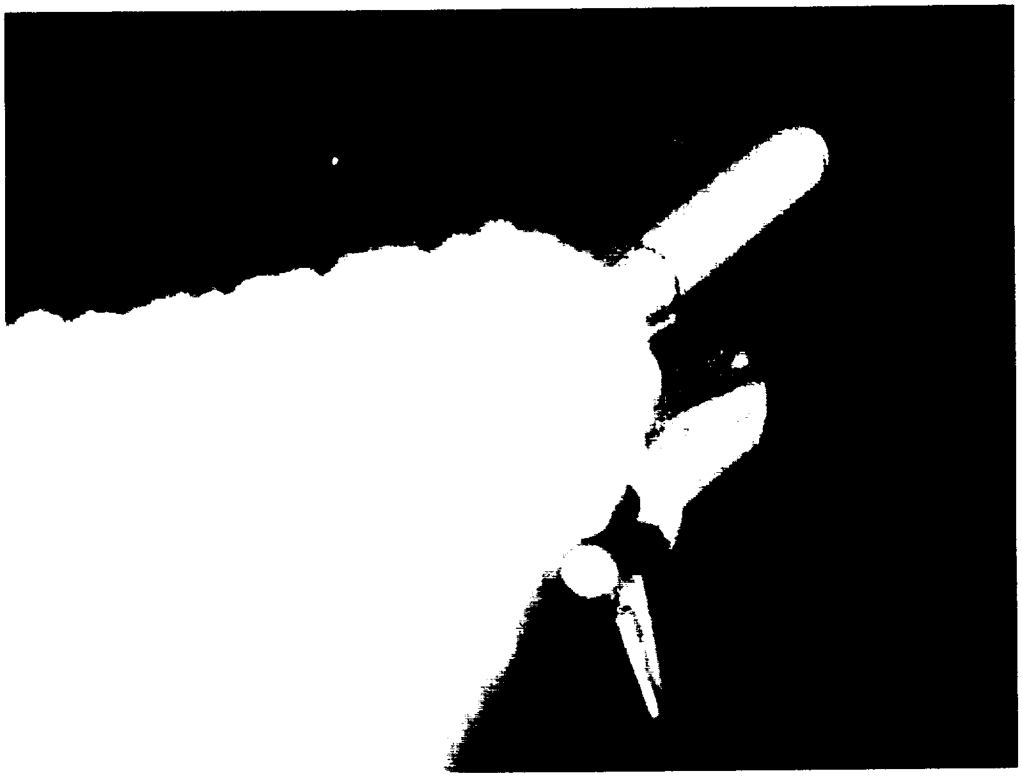


Figure 7.

Material Exiting SRM Plume

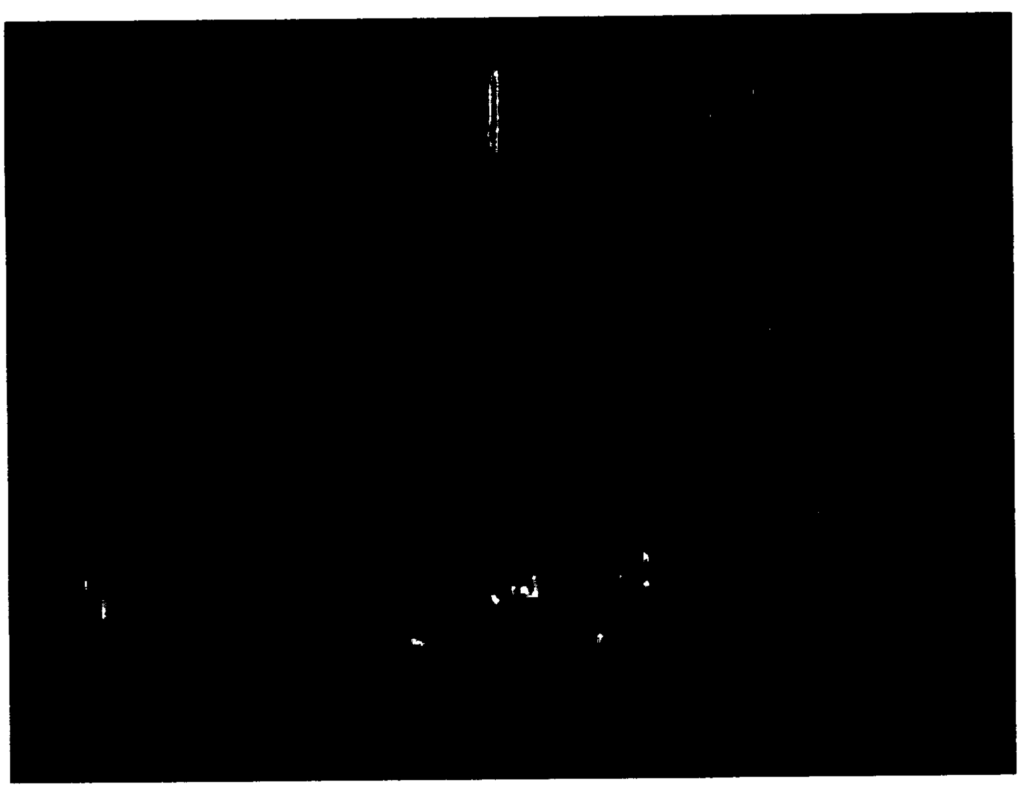


Figure 8.

Large TPS Divot on ET Intertank

Figure 9.

Several Small TPS Divots on LH2 Tank Acreage

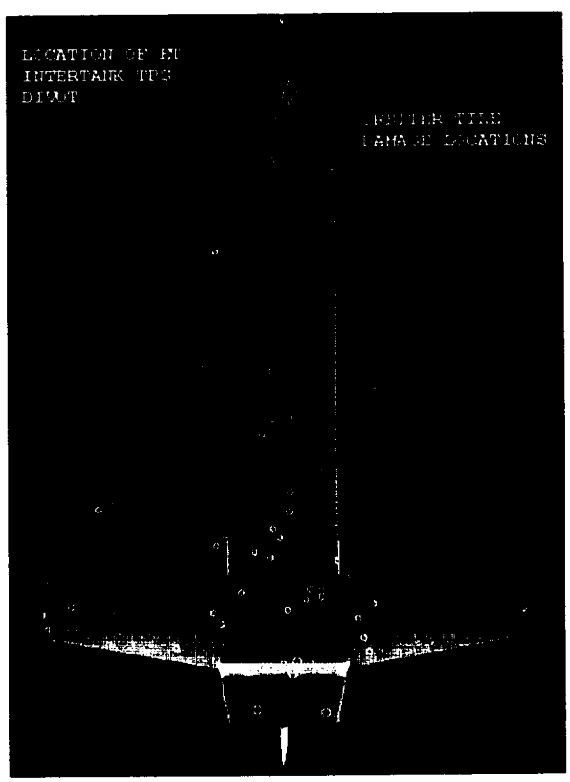


Figure 10.

Orbiter Belly Debris Map with ET Intertank Divot Location

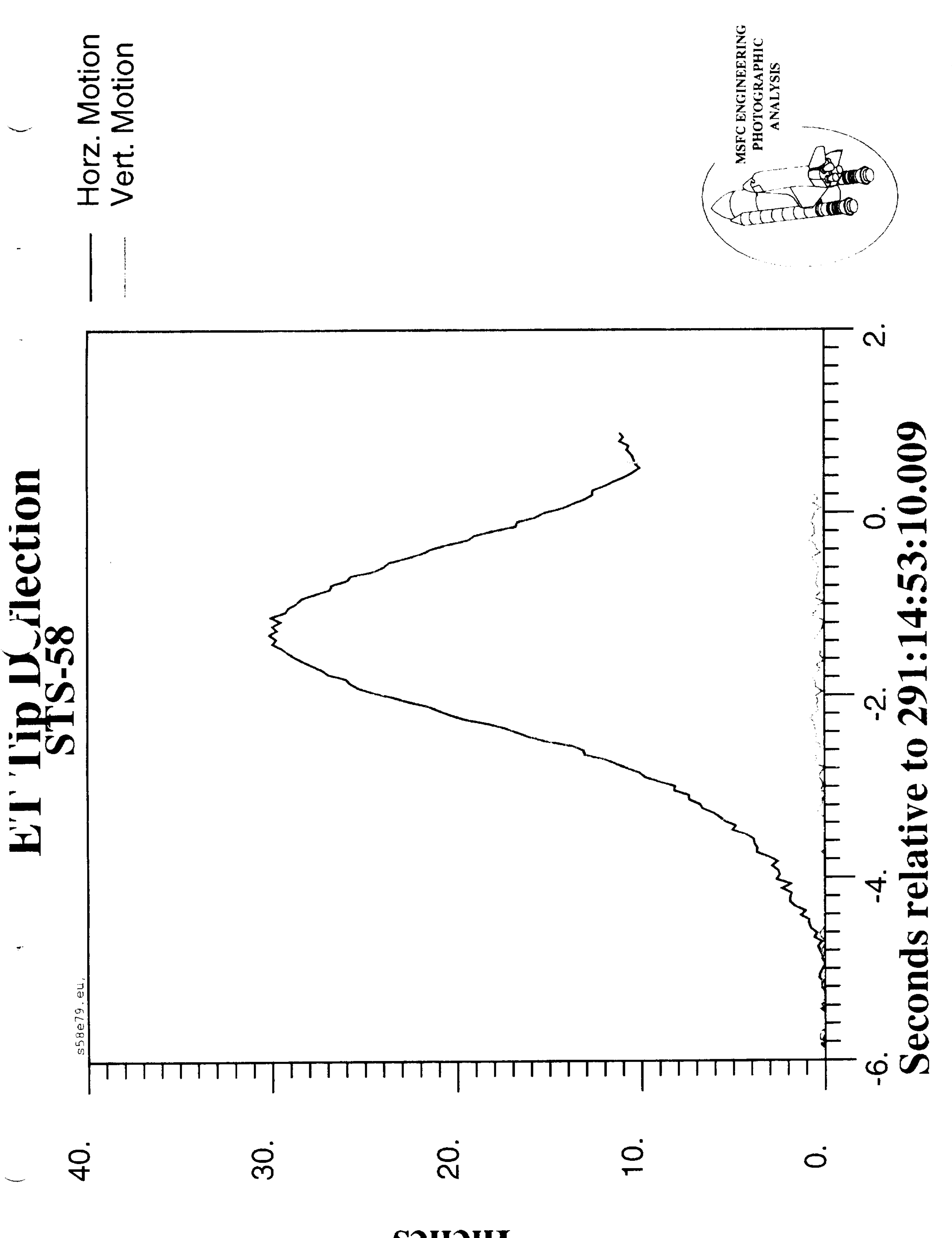

ET Tip Deflection
STS-58
s58e79.eu,
Horz. Motion
Vert. Motion
Inches
40.
30.
20.
10.
0.
-6.
-4.
-2.
0.
2.
Seconds relative to 291:14:53:10.009
MSFC ENGINEERING
PHOTOGRAPHIC
ANALYSIS
08:20:54 15-Nov-9

Figure 11

Appendix C. Rockwell Photographic Analysis Summary

Space Systems Division
Rockwell International Corporation
12214 Lakewood Boulevard
Downey, California 90241

Rockwell International

December 1, 1993

In Reply Refer to 93MA3669

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-58 (Scrub 1, Scrub 2) and STS-58 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 and second launch attempts of STS-58 on October 14 and 15, 1993 were scrubbed and no films were received for these launch attempts.

The third launch attempt of the STS-58 mission was successful and occurred on October 18, 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-58 launch conducted on October 18, 1993, at 7:53 a.m. PDT/GMT 291:14:53:10.009 from the Kennedy Space Center (KSC) and for the landing on November 1, 1993 at Edwards Air Force Base at 7:06 a.m. PST/GMT 305:15:05:42.

Rockwell received launch films from 81 cameras (57 cine, 24 video) and landing films from 17 cameras (10 cine, 7 video) to support the STS-58 photographic evaluation effort. Film E-205 was unavailable due to a camera malfunction.

(Packing Sheet No. DM93-19910)

During the post landing debris inspection of STS-58 (OV-102, Columbia) at the Edwards Air Force Base/Ames-Dryden Flight Research Center it was reported that a forty inch section of the DMHS closeout blanket was missing from the 9 o'clock position of SSME #3 exposing the inner blanket layer. The outer layer of the DMHS at the 3 o'clock position on SSME #2 was detached on three sides. All of the remaining DMHS blankets were in nominal condition. Analysis results will be documented in the KSC Ice/Debris/TPS Assessment and Integrated Photographic Analysis Report (NASA Technical Memorandum). No further action is planned at RI/Downey.

2. On cameras OTV-009, E-30, E-34, and E-65, multiple pieces of white debris (probably umbilical ice) were seen falling from the LH_2 and LO_2 ET/ Orbiter umbilical disconnect area at SSME ignition. Several of these particles contacted the LH2 umbilical sill, but no damage was detected. No follow-up analysis is planned.

3. On camera E-8 two pieces of ordnance debris was seen falling from the right SRB HDP M-2 DCS/stud hole during liftoff. No follow-up action is planned.

4. Orange vapor (possibly free burning hydrogen) was seen below the body flap at SSME startup on cameras OTV-163, 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.

5. A dark piece of debris (probably facility related) was seen falling along the left side of the vehicle prior to liftoff on cameras E-34 and E-35. This may be the same debris seen on camera E-31 entering the field of view and passing near the outboard elevon. Also, on camera E-31 a second piece of debris was seen falling between the Orbiter and the ET forward of the ET/Orbiter umbilicals at liftoff. No follow-up action is planned.

6. On Cameras E-31, E-33 and E-50 two small pieces of intertank spray on foam insulation (SOFI) were stripped away on either side of the ET GH2 umbilical connection during the ground umbilical carrier plate (GUCP) retraction. One piece of foam fell between the left SRB and the ET and did not appear to contact the vehicle. No follow-up action is planned.

7. On cameras E-2, E-3 and E-19 three flashes were noted in the SSME #3 plume before liftoff. Flashes in the SSME exhaust plumes have been seen on previous missions. No follow-up action has been requested.

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.

11. 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.

12. The landing of STS-58 occurred on the hard surface runway 22 at Edwards Air Force Base. Good video and film coverage was obtained and no anomalous events were observed. This flight marked the eleventh 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-58. Debris inspections of the flight elements and launch pad were performed before and after launch. Icing conditions on the External Tank were as[illegible] by the use of computer programs, nomographs, and infrared sc[illegible] during cryogenic loading of the vehicle followed by on-p[illegible] inspection. High speed photography of the launch was [illegible] ice/debris sources and evaluate potential vehicl[illegible] anomalies. This report documents the ice/debris, [illegible] integrated photographic analysis of Shuttle miss[illegible] resulting effect on the Space Shuttle Program.

14. SUBJECT TERMS
STS-58 Ice Frost Debris
Thermal Protection System (TPS) Photographic Analysis

15. NUMBER OF PAGES

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